Lower Athabasca Surface Water and Sediment Quality Criteria for Protection of Indigenous Use

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Disclaimer

This Report, and the findings, methodologies, data and information it contains, is based on the best information and evidence available to the authors at the time of preparation. Ecosystems and human communities are dynamic, and subject to change. While every effort has been made to incorporate the best information and evidence available, reliance on this Report is not a substitute for direct consultation and engagement with the Athabasca Chipewyan First Nation, Fort McKay First Nation, and Mikisew Cree First Nation regarding any proposed developments or activities that may affect water and sediment quality and Indigenous use within the Lower Athabasca Region. There are no warranties or representations in respect to any use of any of this Report, and any use or reliance on the Report is at the sole and absolute risk of the end user.

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Executive Summary

Surface water and sediment quality criteria were defined to protect Indigenous water use by Athabasca Chipewyan First Nation (ACFN), Fort McKay First Nation (FMFN) and Mikisew Cree First Nation (MCFN) members in the Lower Athabasca Region (LAR) using two approaches: current condition and risk-based. Current condition values were developed by collating and analyzing surface water and sediment quality monitoring data from multi-stakeholder, government and community-based programs and identifying representative values for three seasons (high flow, open water and under ice). Health risk criteria were defined by identifying valued components that reflect use of surface water by Indigenous community members; consumption of traditional foods, medicine and surface water, trapping furbearing mammals that consume aquatic biota, the health of wildlife (birds and mammals) from ingesting surface water and diet items, and aquatic ecosystem health. Available surface water and sediment quality guidelines were reviewed to identify level of protection for the traditional valued components. It was found that humans were more sensitive than aquatic biota and wildlife species for 50% of substances with published surface water quality guidelines. When unavailable, health risk criteria were derived using methods prescribed by regulatory agencies, using community specific ingestion rates of traditional foods (fish, and medicinal plants) estimated from a traditional food survey of 230 community members.

The study found goals reflecting current condition of surface water in the LAR indicated that, with a number of exceptions, water and sediment qualiuty is relatively good. Current conditions were generally lower than the calculated risk-based criteria, with some exceptions especially for metals and metalloids. For risk-based protection goals, surface water quality guidelines for the protection of human health were available but not from governments in Alberta or Canada. Adopting human health water quality criteria from the United States Environmental Protection Agency provided a good starting point for protection for of community members consuming fish and drinking water from surface water bodies. However, the traditional food consumption rates were higher than those used to derive US EPA criteria and therefore the adoption of this approach in the WQCIUs required modification to account for the higher consumption rates of ACFN, FMFN, and MCFN members. The collection of statistically representative community survey results enabled the risk assessor to analyze and calculate community members' ingestion rates of traditional foods and medicines for the three participating Indigenous communities.

The WQCIUs (for surface water and sediment) can be used by Indigenous communities, government and regulatory agencies and industry stakeholders to assess potential changes in

surface water and sediment conditions and risks to human and ecological receptors from releases of contaminants from oil sands to the Athabasca River and downstream within Lake Athabasca and the Athabasca Delta. The WQCIUs were developed for constituents characterized in oil sands mine water (OSMW), as well as for several additional common constituents and measures. As a result, the health risk criteria can be used to assess risks from the placement of tailings and OSMW in aquatic closure (reclamation) features such as constructed wetlands and End Pit Lakes (EPLs).

This report is structured as follows: Chapter 1 includes a summary of the study findings, and applies health risk criteria to the calculated current conditions in the Lower Athabasca River, the Athabasca River Delta and Lake Athabasca; Chapter 2 details the development of the current conditions, Chapters 3 and 4 detail the development of the health risk criteria; and Chapter 5 provides some detail about the community consumption surveys conducted with and by ACFN, MCFN and FMFN.

Keywords: Indigenous, protection, goals, Indigenous land use, traditional food, community survey, ingestion rate, monitoring, non-degradation, risk, health, human, wildlife, aquatic biota, ecosystem, oil sands, tailings, OSPW, wetlands, end pit lakes, Athabasca River, Athabasca River Delta, Lake Athabasca.

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Chapter 1

Summary and Application of Findings

This document outlines an approach for the development of health risk criteria and establishment of current conditions against which chemical parameters in surface water and sediment can be assessed to identify potential health risks as well as changes in conditions over time and space. These Water and Sediment Quality Criteria for the Protection of Indigenous Use (WQCIUs) were developed for the protection of water use by Athabasca Chipewyan First Nation (ACFN), Fort McKay First Nation (FMFN) and Mikisew Cree First Nation (MCFN) in the Lower Athabasca River region (LAR) of Alberta. This chapter describes key results from this study and provides a comparison of the current condition of the Athabasca River, Athabasca River Delta and Lake Athabasca to the health risk criteria.

The WQCIUs were developed to address gaps in existing government water, sediment and tissue guidelines and water quality management frameworks. ACFN, FMFN and MCFN expectations for establishment of current condiditons were that they would be season or flow-specific, and that they would be established for the entire Lower Athabasca Region (river, delta, lake). ACFN, FMFN and MCFN expectations for establishment of health risk criteria were that they would include all constituents of concern in the region, that they would account for bioaccumulation and biomagnification effects, that they would include humans, wildlife and plants as receptors, and that they would account for Indigenous community water uses.

The WQCIUs were developed to specifically consider the rights of Indigenous Peoples[1] and to support the evaluation of environmental conditions relative to tiers, triggers, limits, thresh-

[1] Indigenous peoples possess the same rights as all people, and specific rights as Indigenous people, such as Aboriginal and Treaty Rights enshrined in the Constitution Act, 1982, and through UNDRIP.

olds or other "limits of change" that ensure ecosystem components are sustainable, ecosystems are healthy, and effects to human health and well-being are avoided, minimized, or reduced as defined under the Oil Sands Monitoring Program (OSM)[2] Program.

More broadly, the health risk criteria and current conditions provide government and industry stakeholders with a framework and criteria for assessing performance of treatment technologies, produced effluents, and remediation and reclamation activities that reflect the values and interests of participating Indigenous communities. This includes risk tolerances and protection requirements for establishing and maintaining safe and usable environments to support exercising Aboriginal Rights, as defined by ACFN, FMFN and MCFN.

The WQCIUs reflect performance criteria which can be used to assess the health and safety of aquatic ecosystems to support Indigenous water uses. To be clear, any effort to adopt them as guidelines or objectives under provincial policy or legislative requirements [3] should only be undertaken with extensive consultation and engagement with the communities themselves.

1.1 Ecosystem Approach to Water Management

Health risk criteria and current conditions were developed for protection of ecosystem function which includes ecological and human receptors and their interactions with abiotic components of the environment (Keen et al., 2012) as described in Figure 1.1.

Environmental management decisions which consider the complex interactions within ecosystems more closely resemble the world views of Indigenous communities and traditional strategies for assessing and managing natural resources and minimizing health risks (Liboiron, 2021).

[2] Oil Sands Monitoring Program Operational Framework Agreement. 2018. Accessed at: https://open.alberta.ca/dataset/6db4cece-f936-40d6-bd9d-d8e5f2a60d3a/resource/1742d86f-e992-4af4-953f-032c0340a321/download/osm-ofa-signed-loa-including-citation-nov-15-2018.pdf

[3] Guidelines are science-based recommendations that form a cornerstone of water quality and aquatic ecosystem management. They are not legal instruments, however, guidelines and the site-specific objectives derived from them can be used in developing legally binding effluent limits under the Environmental Protection and Enhancement Act (EPEA). They can also be used in management frameworks as part of Regional Plans developed under the Land-use Framework (GoA, 2008) and the Alberta Land Stewardship Act, as well as other management tools. They are an integral component of the GOA Integrated Resource Management system that operates in accordance with the principle of cumulative effects management. The guidelines in this document support the Water Quality Based Effluent Limits Procedures Manual (AEP, 1995), the Alberta Tier 1 Soil and Groundwater Remediation Guidelines (Alberta Environment and Parks (AEP, 2016a), and the Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AEP, 2016b). The recreation and aesthetic guidelines also support those in use by Alberta Health under the Public Health Act.

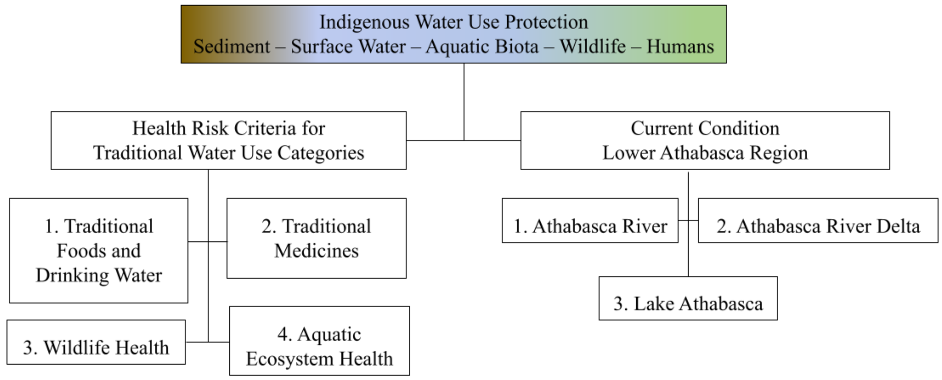

Figure 1.1: Ecosystem health approach to developing health risk criteria and current conditions for the protection of Indigenous water use and interactions with surface water and sediment.

1.2 Water Use by Indigenous Communities

Four water use categories, as presented in Table 1.1 were defined based on descriptions of water use described by community members from ACFN, FMFN and MCFN. The four categories were used to develop a conceptual model linking community members to the environment through exposure pathways, as well as identifying protection goals for surface water and sediment (see Section 3.4.1 of this report for more details of this process). In the development of Indigenous water use categories, water use by gender or age were not considered and further study may be necessary to understand exposure pathways by gender or age across the community. However, gender and age were considered in understanding community consumption patterns, barriers to consuming traditional foods and medicines and in the development of health risk criteria which considered consumption of traditional foods. Water is a core component of all aspects of life for ACFN, FMFN, and MCFN members. Each of the water use categories identified below should be understood as inextricably linked to ACFN, FMFN, and MCFN's cultural and spiritual value of water.

Table 1.1: Indigenous community water uses and health protection goals used to define water use criteria.

Indigenous water use	Protection Goal
Traditional foods and drinking water	Safe foods consumption
	Safe natural surface water consumption
Traditional medicines	Safe medicine consumption
Aquatic ecosystem health	Aquatic community consumption unchanged
	Robust populations
	Natural behaviours and patterns
Wildlife health	Healthy wildlife
	Robust populations
	Natural behaviours and patterns
	Good quality pelts

Exposure pathways, indicators and endpoints linked to water protection goals were then used to evaluate the level of protection offered by applying provincial and federal surface water quality guidelines. The results indicate that exposure pathways (ingestion of traditional foods, medicine, and surface water) and endpoints (e.g., carcinogenicity) for the protection of human health are not considered under environmental quality guidelines for the protection of surface water in Alberta or Canada (GoA, 2018; CCME, 2021). Protection goals linked to wildlife species are either less sensitive or not considered as frequently as aquatic biota, which was identified as the key protection endpoint. No reference to the protection of surface water for the spiritual and cultural needs of Indigenous communities were identified, as this was beyond the scope of this study. However, these are important components for inclusion in future work aimed at protecting all community water uses holistically.

Sediment is an integral component of aquatic ecosystems providing a substrate for fish and invertebrates to reproduce and live in and plants to grow but also a source of nutrients and energy supporting ecosystem production that supports the energy needs of food webs. Sediments act as sources and sinks for environmental contaminants, which can directly affect the health and diversity of benthos (plants and animals living at the bottom of a water body) interacting with the sediment and contribute to the biomagnification of persistent contaminants in aquatic and terrestrial food webs.

A review of sediment quality guidelines adopted in Alberta indicates a low level of protection both for benthic organisms and overlaying surface water due to limitations in available sediment toxicity test data and derivation methods.

1.3 Water and Sediment Quality Criteria for Indigenous Use Protection

Review of provincial water quality management tools under policy and regulations revealed that the following are not currently considered by Alberta when assessing the condition of surface water to support management decisions.

- Surface water is not assessed as a drinking water source (GoA, 2018)
- Assessing the partitioning of contaminants to sediments and subsequent deposition and downstream transport is not required (AEP, 1995)
- Persistence and biomagnification of contaminants within aquatic and semi-aquatic food webs is not assessed (AEP, 1995; GoA, 2018)
- Risk to human health from ingestion of surface water and aquatic biota do not need to be assessed beyond application of Alberta surface water guidelines for aquatic life and recreation use (GoA, 2018)
- Current guidance on releases allow for impacts to acute and chronic mixing zone areas within natural receiving water (AEP, 1995)
- Water, sediment and tissue quality guidelines have not been published for each contaminant identified as having intrinsically toxic properties and characterized in oil sands mine water (i.e. naphthenic acids, low and high molecular weight PAHs).

The identified limitations in the provincial system for assessing and managing environmental and human risks from contaminants in surface water and sediment were addressed by developing health risk criteria for those media which allows for an assessment of potential impacts to Indigenous water use pathways; traditional foods and drinking water, traditional medicines, aquatic ecosystem health, and wildlife health.

Figure 1.2 (below) summarizes findings from a review of federal, provincial and international water quality guidelines for the protection of freshwater life/ aquatic biota (US EPA, AEP, CCME), wildlife (AEP, CCME, Sample et al. (1996)) and humans (US EPA, Health Canada, WHO). The pie chart indicates the percentage of published water quality guidelines that were developed to protect the most sensitive receptor group from the contaminants of interest evaluated in this study. The results indicate that humans are the most sensitive receptor group from exposure to 50% of the contaminants for which published water quality guidelines are available. Aquatic biota are the next most sensitive receptor group (44%) and finally wildlife species are generally less sensitive than human and aquatic receptors (3% of available guidelines noted wildlife species as the most sensitive receptors). The three receptor groups were equally as sensitive for the remaining guidelines. It is important to note that there was a lack of wildlife watering guidelines available for several parameters and additional health risk criteria were not derived, only available guidelines for livestock were adopted.

This is an important finding which supports the inclusion of guidelines derived for the protection of human health (Health Canada, US EPA, WHO), specifically for carcinogenic substances, which are not an assessment endpoint considered in protection of aquatic life or wildlife/ livestock water quality guidelines (AEP, CCME).

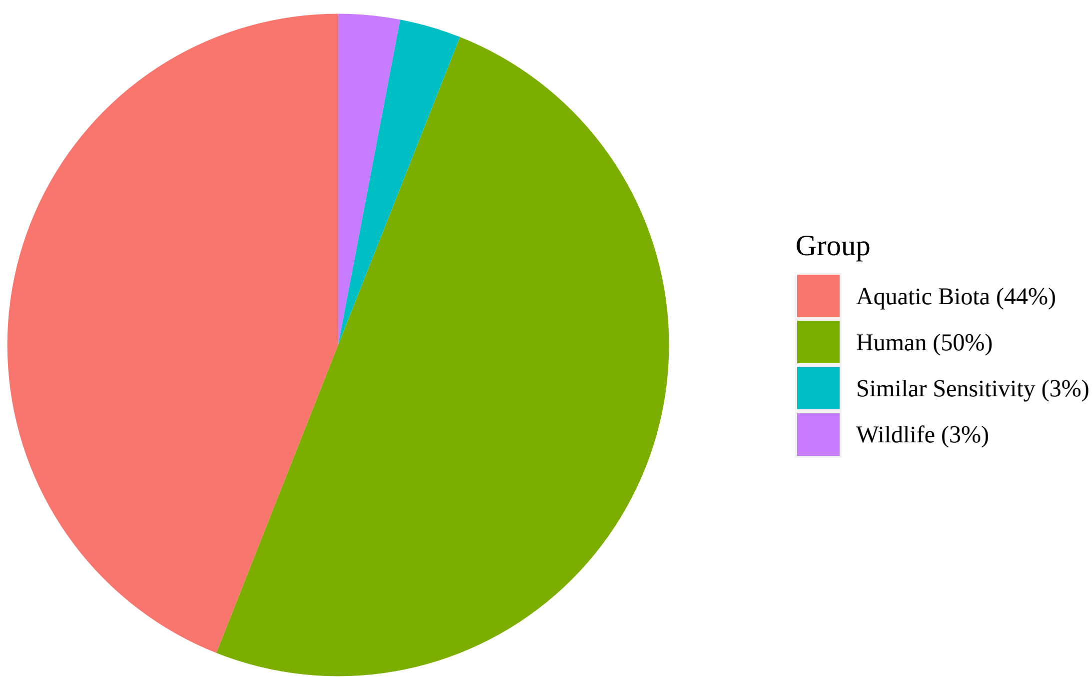

Figure 1.2: Comparison of the sensitivity between humans, aquatic biota, and wildlife species indicated by the percent of published surface water quality guidelines established to protect each receptor group (n = 317)

Modifications of the published guidelines were also used to achieve a higher degree of protection for consumers of traditional foods from the communities of ACFN, FMFN, and MCFN, as previously reported consumption rates representing the general population (22 g/d; (US EPA, 2015a) and Northern Alberta Indigenous communities (27.8 g/d; (Chan et al., 2016)) were lower than those reported through the community surveys for fish (388 g/d), and rat root (6.8 g/d).

A generic health risk criteria for surface water quality that identifies the most sensitive water use by contaminant is proposed as a conservative approach similar to that adopted for assessing soil and groundwater contamination (GoA, 2018). The generic health risk criteria should be applied unless a specific water use category is being assessed to answer community or research study questions and each water use category is not being assessed individually. A single health risk criteria for sediment quality (mg/kg) is proposed for the protection of sediment associated biota and biomagnification within aquatic food webs.

Importantly, the health risk criteria proposed here address gaps in published surface water and sediment quality guidelines that could underestimate potential effects in the ambient environment from mixtures of PAHs from varying modes of action. The WQCIUs were developed to assess surface water and sediment quality monitoring data by various groupings. The first, carcinogenicity (as BaP equivalents) is used to assess potential risks to human receptors from exposure to carcinogenic PAH congeners in the traditional foods and drinking water and medicines water use categories. The second are non-carcinogenic effect-based groups for high and low molecular PAH congeners and are used assess risks to ecological receptors in the aquatic ecosystem and wildlife health water use categories.

Together, the Indigenous criteria for water (generic) and sediment presented in Table 1.2 and Table 1.3, will allow ACFN, FMFN and MCFN to assess the ability for surface water bodies to meet their needs by ensuring water, animals, and plants are safe to consume and that populations are healthy and available to support Indigenous use.

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories.

			Generic (All water uses protected)		
Parameter	Sample Fraction	Units	Most Stringent	Sensitive Receptor	Source
.alpha.-Endosulfan		ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria
.beta.-Endosulfan		ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria
1,1,1-Trichloroethane*		ug/L	200	human	US EPA DWR
1,1,2,2-Tetrachloroethane*		ug/L	2	human	HH DW+Org (US EPA)
1,1,2-Trichloroethane		ug/L	3	human	US EPA DWR
1,1-Dichloroethylene		ug/L	7	human	US EPA DWR
1,2,3,4-Tetrachlorobenzene		ug/L	0.03	human	USEPA WQC HH Org HH DW+Org (US EPA)
1,2,3-Trichlorobenzene		ug/L	8	aquatic biota	AEP Water PAL CCME Water PAL
1,2,4-Trichlorobenzene		ug/L	0.071	human	HH DW+Org (US EPA)
1,2-Dibromo-3-chloropropane		ug/L	0.2	human	US EPA DWR

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected) Most Stringent	Sensitive Receptor	Source
1,2-Dibromoethane		ug/L	0.4	human	WHO DW
1,2-Dichlorobenzene		ug/L	0.7	aquatic biota	AEP Water PAL
1,2-Dichloroethane*		ug/L	5	human wildlife	Health Canada DW AEP Water Ag CCME Water Ag US EPA DWR
1,2-Dichloroethene		ug/L	50	human	WHO DW
1,2-Dichloropropane*		ug/L	5	human	US EPA DWR
1,2-Diphenylhydrazine*		ug/L	0.3	human	HH DW+Org (US EPA)
1,3-Dichlorobenzene		ug/L	7	human	HH DW+Org (US EPA)
1,3-Dichloropropene*		ug/L	2.7	human	HH DW+Org (US EPA)
1,4-Dichlorobenzene		ug/L	26	aquatic biota	AEP Water PAL
1,4-Dioxane		ug/L	50	human	WHO DW
2,3,4,6-Tetrachlorophenol		ug/L	1	human	USEPA WQC AO
2,3-Dichlorophenol		ug/L	0.04	human	USEPA WQC AO
2,4,5-Trichlorophenol		ug/L	1	human	USEPA WQC AO
2,4,6-Trichlorophenol*		ug/L	2	human	USEPA WQC AO
2,4-D		ug/L	4	aquatic biota	CCME Water PAL AEP Water PAL
2,4-DB		ug/L	25	aquatic biota	AEP Water PAL
2,4-Dichlorophenol		ug/L	0.3	human	USEPA WQC AO
2,4-Dimethylphenol		ug/L	100	human	HH DW+Org (US EPA)
2,4-Dinitrophenol		ug/L	10	human	HH DW+Org (US EPA)
2,4-Dinitrotoluene*		ug/L	0.49	human	HH DW+Org (US EPA)
2,5-Dichlorophenol		ug/L	0.5	human	USEPA WQC AO
2,6-Dichlorophenol		ug/L	0.2	human	USEPA WQC AO
2-Chloronaphthalene		ug/L	800	human	HH DW+Org (US EPA)
2-Chlorophenol		ug/L	0.1	human	USEPA WQC AO
2-Methyl-4,6-Dinitrophenol		ug/L	2	human	HH DW+Org (US EPA)
2-Methyl-4-Chlorophenol		ug/L	1800	human	USEPA WQC AO
3,3'-Dichlorobenzidine		ug/L	0.49	human	HH DW+Org (US EPA)
3,4-Dichlorophenol		ug/L	0.3	human	USEPA WQC AO
3-Chlorophenol		ug/L	0.1	human	USEPA WQC AO
3-Iodo-2-propynyl butyl carbamate		ug/L	1.9	aquatic biota	CCME Water PAL AEP Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
3-Methyl-4-Chlorophenol		ug/L	500	human	HH DW+Org (US EPA)
3-Methyl-6-Chlorophenol		ug/L	20	human	USEPA WQC AO
4-Chlorophenol		ug/L	0.1	human	USEPA WQC AO
Acenaphthene[§]		ug/L	4.79	human	HH DW+Org (derived)
Acridine		ug/L	4.4	aquatic biota	AEP Water PAL CCME Water PAL
Acrolein		ug/L	2.87	human	HH DW+Org (derived)
Acrylamide		ug/L	0.07	human	HH DW+Org (derived)
Acrylonitrile[*]		ug/L	0.53	human	HH DW+Org (derived)
Alachlor		ug/L	2	human	US EPA DWR
Alcohol ethoxylates		ug/L	70	aquatic biota	FEQG Water PAL
Aldicarb		ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL
Aldrin[*]		ug/L	0.0000077	human	USEPA WQC HH Org HH DW+Org (US EPA)
Aldrin and dieldrin		ug/L	0.03	human	WHO DW
Alkalinity, total		mg/L	20	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria
alpha-Endosulfan		ug/L	1.82	human	HH DW+Org (derived)
alpha-Hexachlorocyclohexane[*]		ug/L	0.0002	human	HH DW+Org (derived)
Aluminum	Total	ug/L	18	wildlife	US DOE Wildlife
Aluminum	Dissolved	ug/L	50	aquatic biota	AEP Water PAL
Ammonia		mg/L	0.67	human	HH DW+Org (derived)
Ammonia, unionized		mg/L	0.016	aquatic biota	AEP Water PAL
Aniline		ug/L	2.2	aquatic biota	AEP Water PAL CCME Water PAL
Anthracene		ug/L	0.012	aquatic biota	CCME Water PAL AEP Water PAL
Antimony	Total	ug/L	4.59	human	HH DW+Org (derived)
Arsenic[*]	Total	ug/L	0.03	human	HH DW+Org (derived)
Arsenic[*††]	Dissolved	ug/L	150	aquatic biota	US EPA Aquatic Life Criteria
Asbestos		ug/L	7	human	US EPA DWR HH DW+Org (US EPA)

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected) Most Stringent	Sensitive Receptor	Source
Atrazine		ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL
Atrazine and its chloro-s-triazine metabolites		ug/L	100	human	WHO DW
Azinphos-methyl		ug/L	0.01	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Barium	Total	ug/L	1000	human	HH DW+Org (US EPA) Health Canada DW
Benzene*		ug/L	2.11	human	HH DW+Org (derived)
Benzidine*		ug/L	0.001	human	HH DW+Org (derived)
Benzo(a)anthracene*†		ug/L	0.001	human	HH DW+Org (derived)
Benzo(a)pyrene*†		ug/L	0.0001	human	HH DW+Org (derived)
Benzo(b)fluoranthene*†		ug/L	0.001	human	HH DW+Org (derived)
Benzo(k)fluoranthene*†		ug/L	0.01	human	HH DW+Org (derived)
Beryllium	Total	ug/L	3.27	human	HH DW+Org (derived)
beta-Endosulfan		ug/L	2.87	human	HH DW+Org (derived)
beta-Hexachlorocyclohexane*		ug/L	0.01	human	HH DW+Org (derived)
Bis(2-Chloro-1-methylethyl) Ether		ug/L	127.99	human	HH DW+Org (derived)
Bis(2-Chloroethyl) Ether*		ug/L	0.25	human	HH DW+Org (derived)
Bis(2-Ethylhexyl) Phthalate		ug/L	0.21	human	HH DW+Org (derived)
Bis(Chloromethyl) Ether*		ug/L	0.001	human	HH DW+Org (derived)
Bisphenol A-d6		ug/L	3.5	aquatic biota	FEQG Water PAL
Boron	Total	ug/L	1333.33	human	HH DW+Org (derived)
Bromacil		ug/L	5	aquatic biota	AEP Water PAL CCME Water PAL
Bromate		ug/L	10	human	Health Canada DW US EPA DWR WHO DW
Bromodichloromethane		ug/L	6.33	human	HH DW+Org (derived)
Bromoform		ug/L	7	human	HH DW+Org (US EPA)

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
Bromoxynil		ug/L	5	aquatic biota human	AEP Water PAL CCME Water PAL Health Canada DW
Butylbenzyl Phthalate*		ug/L	0.06	human	HH DW+Org (derived)
Cadmium‡	Total	ug/L	0.002	human	HH DW+Org (derived)
Cadmium‡††	Dissolved	ug/L	0.824	aquatic biota	US EPA Aquatic Life Criteria
Calcium		mg/L	1000	wildlife	CCME Water Ag AEP Water Ag
Captan		ug/L	1.3	aquatic biota	CCME Water PAL AEP Water PAL
Carbamazepine		ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL
Carbaryl		ug/L	0.2	aquatic biota	AEP Water PAL CCME Water PAL
Carbofuran		ug/L	1.8	aquatic biota	CCME Water PAL AEP Water PAL
Carbon tetrachloride		ug/L	1.9	human	HH DW+Org (derived)
Chloramines		ug/L	0.5	aquatic biota	CCME Water PAL
Chlorate		ug/L	700	human	WHO DW
Chlordane		ug/L	0.001	human	HH DW+Org (derived)
Chloride		mg/L	120	aquatic biota	CCME Water PAL AEP Water PAL
Chlorinated paraffins, long-chain, C18-C20		ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL
Chlorinated paraffins, medium-chain, C14-C17		ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL
Chlorinated paraffins, short-chain, C10-C13		ug/L	2.4	aquatic biota	FEQG Water PAL AEP Water PAL
Chlorine		ug/L	0.5	aquatic biota	AEP Water PAL
Chlorine dioxide		ug/L	800	human	US EPA DWR
Chlorite		ug/L	700	human	WHO DW
Chlorobenzene		ug/L	1.3	aquatic biota	AEP Water PAL
Chlorodibromomethane		ug/L	8	human	HH DW+Org (US EPA)
Chloroform		ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL
Chlorophenol		ug/L	7	aquatic biota	AEP Water PAL CCME Water PAL
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]		ug/L	20.55	human	HH DW+Org (derived)
Chlorothalonil		ug/L	0.18	aquatic biota	CCME Water PAL AEP Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

			Generic (All water uses protected)		
Parameter	Sample Fraction	Units	Most Stringent	Sensitive Receptor	Source
Chlorotoluron		ug/L	30	human	WHO DW
Chlorpyrifos		ug/L	0.002	aquatic biota	AEP Water PAL CCME Water PAL
Chromium	Total	ug/L	50	human	WHO DW Health Canada DW
Chromium (III)‡	Total	ug/L	8.9	aquatic biota	CCME Water PAL AEP Water PAL
Chromium (III)‡††	Dissolved	ug/L	100.92	aquatic biota	US EPA Aquatic Life Criteria
Chromium (VI)	Total	ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL
Chromium (VI)	Dissolved	ug/L	5	aquatic biota	FEQG Water PAL
Chrysene*†		ug/L	0.07	human	HH DW+Org (derived)
cis-1,2-Dichloroethylene		ug/L	70	human	US EPA DWR
Cobalt‡	Total	ug/L	1.10	aquatic biota	FEQG Water PAL AEP Water PAL
Copper*‡	Total	ug/L	2.76	aquatic biota	CCME Water PAL
Copper	Dissolved	ug/L	0.53	aquatic biota	FEQG Water PAL
Cyanazine		ug/L	0.6	human	WHO DW
Cyanide		ug/L	3.62	human	HH DW+Org (derived)
Cyanobacterial toxins		ug/L	1.5	human	Health Canada DW
Dalapon		ug/L	200	human	US EPA DWR
DDT and metabolites*		ug/L	0.000004	wildlife	US DOE Wildlife
Deltamethrin		ug/L	0.0004	aquatic biota	AEP Water PAL CCME Water PAL
Demeton		ug/L	0.1	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Di(2-ethylhexyl) adipate		ug/L	400	human	US EPA DWR
Di(2-ethylhexyl) phthalate		ug/L	6	human	US EPA DWR
Di-n-Butyl Phthalate		ug/L	0.15	wildlife	US DOE Wildlife
Diazinon		ug/L	0.17	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria
Dibenzo(a,h)anthracene*		ug/L	0.0001	human	HH DW+Org (derived)
Dibromoacetonitrile		ug/L	70	human	WHO DW
Dibromochloromethane		ug/L	5.21	human	HH DW+Org (derived)
Dicamba		ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL
Dichloroacetate		ug/L	50	human	WHO DW
Dichloroacetonitrile*		ug/L	20	human	WHO DW

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
Dichlorobromomethane		ug/L	9.5	human	HH DW+Org (US EPA)
Dichloromethane*		ug/L	5	human	US EPA DWR
Dichlorophenol		ug/L	0.2	aquatic biota	CCME Water PAL AEP Water PAL
Dichlorprop		ug/L	100	human	WHO DW
Diclofop-methyl		ug/L	6.1	aquatic biota	AEP Water PAL CCME Water PAL
Didecyl dimethyl ammonium chloride		ug/L	1.5	aquatic biota	CCME Water PAL AEP Water PAL
Dieldrin*		ug/L	0.00001	human	HH DW+Org (derived) HH DW+Org (US EPA)
Diethanolamine		ug/L	450	aquatic biota	AEP Water PAL
Diethyl Phthalate		ug/L	35.61	human	HH DW+Org (derived)
Diethylene glycol		ug/L	150000	aquatic biota	AEP Water PAL
Diisopropanolamine		ug/L	1600	aquatic biota	AEP Water PAL CCME Water PAL
Dimethoate		ug/L	3	wildlife	CCME Water Ag AEP Water Ag
Dimethyl Phthalate		ug/L	102.91	human	HH DW+Org (derived)
Dinitrophenols		ug/L	10	human	HH DW+Org (US EPA)
Dinoseb		ug/L	0.05	aquatic biota	CCME Water PAL AEP Water PAL
Dioxin (2,3,7,8-TCDD)		ug/L	0.00000002134	wildlife	US DOE Wildlife
Diquat		ug/L	20	human	US EPA DWR
Diuron		ug/L	150	human	Health Canada DW
Edetic acid		ug/L	600	human	WHO DW
Endosulfan		ug/L	0.003	aquatic biota	AEP Water PAL CCME Water PAL
Endosulfan Sulfate		ug/L	2.63	human	HH DW+Org (derived)
Endothall		ug/L	100	human	US EPA DWR
Endrin		ug/L	0.001	wildlife	US DOE Wildlife
Endrin Aldehyde		ug/L	0.11	human	HH DW+Org (derived)
Epichlorohydrin		ug/L	0.4	human	WHO DW
Ethanol			123377	wildlife	US DOE Wildlife
Ethinyl estradiol		ng/L	0.5	aquatic biota	AEP Water PAL
Ethyl acetate			136465	wildlife	US DOE Wildlife
Ethylbenzene		ug/L	2.4	wildlife	AEP Water Ag CCME Water Ag
Ethylene dibromide		ug/L	0.05	human	US EPA DWR

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

			Generic (All water uses protected)		
Parameter	Sample Fraction	Units	Most Stringent	Sensitive Receptor	Source
Ethylene glycol		ug/L	192000	aquatic biota	AEP Water PAL CCME Water PAL
Fenoprop		ug/L	9	human	WHO DW
Fluoranthene§		ug/L	0.04	aquatic biota	AEP Water PAL CCME Water PAL
Fluorene§		ug/L	3	aquatic biota	AEP Water PAL CCME Water PAL
Fluoride		mg/L	0.12	aquatic biota	CCME Water PAL
Formaldehyde			73910	wildlife	US DOE Wildlife
gamma-Hexachlorocyclohexane [Lindane]		ug/L	0.01	aquatic biota	AEP Water PAL
Glyphosate		ug/L	280	human wildlife	AEP Water Ag Health Canada DW CCME Water Ag
Haloacetic acids		ug/L	60	human	US EPA DWR
heptaBDE		ng/L	14	aquatic biota	FEQG Water PAL
Heptachlor*		ug/L	0.00004	human	HH DW+Org (derived)
Heptachlor epoxide*		ug/L	0.0001	human	HH DW+Org (derived)
hexaBDE		ng/L	120	aquatic biota	FEQG Water PAL AEP Water PAL
Hexabromocyclododecane		ug/L	0.56	aquatic biota	FEQG Water PAL AEP Water PAL
Hexachlorobenzene*		ug/L	0.0001	human	HH DW+Org (derived)
Hexachlorobutadiene*		ug/L	0.001	human	HH DW+Org (derived)
Hexachlorocyclohexane*		ug/L	0.01	aquatic biota human	HH DW+Org (derived) CCME Water PAL
Hexachlorocyclopentadiene		ug/L	0.4	human	HH DW+Org (derived)
Hexachloroethane*		ug/L	0.02	human	HH DW+Org (derived)
Hydrazine		ug/L	2.6	aquatic biota	FEQG Water PAL AEP Water PAL
Hydrogen Sulfide		ug/L	2	aquatic biota	US EPA Aquatic Life Criteria
Hydroxyatrazine		ug/L	200	human	WHO DW
Imidacloprid		ug/L	0.23	aquatic biota	AEP Water PAL CCME Water PAL
Indeno(1,2,3-cd)pyrene*†		ug/L	0.001	human	HH DW+Org (derived)
Inorganic nitrogen (nitrate and nitrite)	Dissolved	mg/L	100	wildlife	CCME Water Ag AEP Water Ag
Iron	Total	ug/L	300	aquatic biota human	CCME Water PAL USEPA WQC AO

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
Iron	Dissolved	ug/L	300	aquatic biota	AEP Water PAL
Isophorone*		ug/L	268.41	human	HH DW+Org (derived)
Isoproturon		ug/L	9	human	WHO DW
Lead‡	Total	ug/L	4.01	aquatic biota	AEP Water PAL CCME Water PAL
Lead‡††	Dissolved	ug/L	3.07	aquatic biota	US EPA Aquatic Life Criteria
Linuron		ug/L	7	aquatic biota	CCME Water PAL AEP Water PAL
m-Dichlorobenzene		ug/L	150	aquatic biota	CCME Water PAL
Malathion		ug/L	0.1	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria
Manganese	Total	ug/L	50	human	HH DW+Org (US EPA)
MCPA		ug/L	2.6	aquatic biota	CCME Water PAL AEP Water PAL
Mecoprop		ug/L	10	human	WHO DW
Mercury	Total	ug/L	0.0016	wildlife	US DOE Wildlife
Mercury††	Dissolved	ug/L	0.77	aquatic biota	US EPA Aquatic Life Criteria
Mercury (methyl)	Total	ug/L	0.001	aquatic biota	AEP Water PAL
Mercury (methyl)	Dissolved	ug/L	0.004	aquatic biota	CCME Water PAL
Methanol		ug/L	1500	aquatic biota	AEP Water PAL
Methoprene		ug/L	0.09	aquatic biota	AEP Water PAL CCME Water PAL
Methoxychlor		ug/L	0.001	human	HH DW+Org (derived)
Methyl Bromide		ug/L	100	human	HH DW+Org (US EPA)
Methyl tert-butyl ether		ug/L	10	aquatic biota	AEP Water PAL
Methylene chloride*		ug/L	32.62	human	HH DW+Org (derived)
Metolachlor		ug/L	7.8	aquatic biota	AEP Water PAL CCME Water PAL
Metribuzin		ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL
Microcystin-LR		ug/L	1	human	WHO DW
Mirex		ug/L	0.001	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Molinate		ug/L	6	human	WHO DW
Molybdenum	Total	ug/L	33.33	human	HH DW+Org (derived)
Monochloramine		ug/L	3000	human	WHO DW
Monochloroacetate		ug/L	20	human	WHO DW

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

			Generic (All water uses protected)		
Parameter	Sample Fraction	Units	Most Stringent	Sensitive Receptor	Source
Monochlorobenzene		ug/L	1.3	aquatic biota	CCME Water PAL AEP Water PAL
Monoethanolamine		ug/L	75	aquatic biota	AEP Water PAL
N-Nitrosodi-n-Propylamine*		ug/L	0.05	human	HH DW+Org (US EPA) HH DW+Org (derived)
N-Nitrosodimethylamine*		ug/L	0.007	human	HH DW+Org (US EPA)
N-Nitrosodiphenylamine*		ug/L	33	human	HH DW+Org (US EPA)
Naphthalene§		ug/L	1	aquatic biota	AEP Water PAL
Naphthenic acids (Lower Athabasca River)	Total	ug/L	<50	Adopted current condition (Oil Sands Monitoring Program Reporting Limit)	
Naphthenic acids (Athabasca River Delta)	Total	ug/L	230	Adopted current condition (50th percentile, high flow)	
Naphthenic acids (Lake Athabasca)	Total	ug/L	140	Adopted current condition (50th percentile, open water)	
Nickel‡	Total	ug/L	7.35	human	HH DW+Org (derived)
Nickel‡††	Dissolved	ug/L	60.68	aquatic biota	US EPA Aquatic Life Criteria
Nitrate	Dissolved	mg/L	3	aquatic biota	CCME Water PAL AEP Water PAL
Nitrilotriacetic acid		ug/L	200	human	WHO DW
Nitrite	Dissolved	mg/L	0.06	aquatic biota	CCME Water PAL
Nitrobenzene		ug/L	9.72	human	HH DW+Org (derived)
Nitrosamines		ug/L	0.008	human	HH DW+Org (US EPA)
Nitrosodibutylamine		ug/L	0.05	human	HH DW+Org (derived)
Nitrosodiethylamine		ug/L	0.002	human	HH DW+Org (derived)
Nitrosopyrrolidine		ug/L	0.16	human	HH DW+Org (US EPA) HH DW+Org (derived)
Nonylphenol		ug/L	6.6	aquatic biota	US EPA Aquatic Life Criteria
Nonylphenol and its ethoxylates		ug/L	1	aquatic biota	CCME Water PAL
o-Dichlorobenzene		ug/L	0.7	aquatic biota	AEP Water PAL CCME Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected) Most Stringent	Sensitive Receptor	Source
octaBDE		ng/L	14	aquatic biota	FEQG Water PAL
Oxamyl (Vydate)		ug/L	200	human	US EPA DWR
p,p'-Dichlorodiphenyldichloroethane (DDD)*		ug/L	0.001	human	HH DW+Org (US EPA)
p,p'-Dichlorodiphenyldichlorc (DDE)*		ug/L	0.00018	human	USEPA WQC HH Org
p-Dichlorobenzene		ug/L	5	human	Health Canada DW
Paraquat		ug/L	10	human	Health Canada DW
Parathion		ug/L	0.013	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Pendimethalin		ug/L	20	human	WHO DW
pentaBDE		ng/L	0.2	aquatic biota	AEP Water PAL FEQG Water PAL
pentaBDE (BDE-100)		ng/L	0.2	aquatic biota	FEQG Water PAL AEP Water PAL
pentaBDE (BDE-99)		ng/L	4	aquatic biota	AEP Water PAL FEQG Water PAL
Pentachlorobenzene		ug/L	0.01	human	HH DW+Org (derived)
Pentachloronitrobenzene			4	wildlife	US DOE Wildlife
Pentachlorophenol		ug/L	0.1	human	HH DW+Org (derived)
Perchlorate		ug/L	70	human	WHO DW
Perfluorooctanesulfonate		ug/L	0.6	human	Health Canada DW
Perfluorooctanoic acid		ug/L	0.2	human	Health Canada DW
Permethrin		ug/L	0.004	aquatic biota	AEP Water PAL CCME Water PAL
pH		pH units	7-9	aquatic biota human human	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL CCME Water PAL Health Canada DW
Phenanthrene§		ug/L	0.4	aquatic biota	CCME Water PAL AEP Water PAL
Phenol		ug/L	2	wildlife	CCME Water Ag AEP Water Ag
Phorate		ug/L	2	human	Health Canada DW
Picloram		ug/L	29	aquatic biota	CCME Water PAL AEP Water PAL
Polychlorinated Biphenyls (PCBs)*		ug/L	0.00064	human	USEPA WQC HH Org
Propylene glycol		ug/L	500000	aquatic biota	CCME Water PAL AEP Water PAL
Pyrene§		ug/L	0.025	aquatic biota	CCME Water PAL AEP Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
Quinoline		ug/L	3.4	aquatic biota	AEP Water PAL CCME Water PAL
Selenium	Total	ug/L	0.24	wildlife	US DOE Wildlife
Silver	Total	ug/L	0.25	aquatic biota	AEP Water PAL CCME Water PAL
Simazine		ug/L	2	human	WHO DW
Sodium dichloroisocyanurate		ug/L	40000	human	WHO DW
Solids Dissolved and Salinity		ug/L	250000	human	HH DW+Org (US EPA)
Strontium	Total	ug/L	4000	human	HH DW+Org (derived)
Styrene		ug/L	20	human	WHO DW
Sulfate		mg/L	250	human	WHO DW
Sulfide		mg/L	0.0019	aquatic biota	AEP Water PAL
Sulfolane		ug/L	50	aquatic biota	AEP Water PAL
Tebuthiuron		ug/L	1.6	aquatic biota	CCME Water PAL
Terbufos		ug/L	1	human	Health Canada DW
Terbuthylazine		ug/L	7	human	WHO DW
tetraBDE		ng/L	24	aquatic biota	FEQG Water PAL AEP Water PAL
Tetrabromobisphenol A		ug/L	3.1	aquatic biota	FEQG Water PAL AEP Water PAL
Tetrachloroethane		ug/L	13.3	aquatic biota	CCME Water PAL
Tetrachloroethylene*		ug/L	4.48	human	HH DW+Org (derived)
Tetrachlorophenol		ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL
Thallium	Total	ug/L	0.02	human	HH DW+Org (derived)
Toluene		ug/L	0.5	aquatic biota	AEP Water PAL
Total dissolved solids§§		mg/L	3000	wildlife	AEP Water Ag CCME Water Ag
Toxaphene		ug/L	0.0002	aquatic biota	US EPA Aquatic Life Criteria
Toxicity (chronic)‡‡		Toxic Units (c)	1	aquatic biota	AEP Water PAL
trans-1,2-Dichloroethylene		ug/L	100	human	US EPA DWR
Triallate		ug/L	0.24	aquatic biota	CCME Water PAL AEP Water PAL
triBDE		ng/L	46	aquatic biota	AEP Water PAL FEQG Water PAL
Tribromomethane		ug/L	100	wildlife	CCME Water Ag
Tributyltin		ug/L	0.008	aquatic biota	CCME Water PAL
Trichlorfon		ug/L	0.009	aquatic biota	AEP Water PAL CCME Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected)		
			Most Stringent	Sensitive Receptor	Source
Trichloroacetate		ug/L	200	human	WHO DW
Trichloroethylene*		ug/L	1.38	human	HH DW+Org (derived)
Trichlorophenol		ug/L	18	aquatic biota	AEP Water PAL CCME Water PAL
Triclosan		ug/L	0.47	aquatic biota	FEQG Water PAL
Tricyclohexyltin		ug/L	250	wildlife	CCME Water Ag AEP Water Ag
Triethylene glycol		ug/L	350000	aquatic biota	AEP Water PAL
Trifluralin		ug/L	0.2	aquatic biota	AEP Water PAL CCME Water PAL
Trihalomethanes		ug/L	80	human	US EPA DWR
Triphenyltin		ug/L	0.022	aquatic biota	CCME Water PAL AEP Water PAL
Uranium	Total	ug/L	15	aquatic biota	CCME Water PAL AEP Water PAL
Vanadium	Total	ug/L	100	wildlife	AEP Water Ag CCME Water Ag
Vinyl chloride*		ug/L	0.18	human	HH DW+Org (derived)
Xylene		ug/L	28	wildlife	US DOE Wildlife
Xylenes (total)		ug/L	10000	human	US EPA DWR
Zinc‡	Total	ug/L	12.72	human	HH DW+Org (derived)
Zinc‡	Dissolved	ug/L	31.35	aquatic biota	CCME Water PAL
Low Moelcular Weight PAHs¶		ug/L	1	aquatic biota	AEP Water PAL

Table 1.2: Generic health risk criteria for the protection of all Indigenous water use categories. *(continued)*

Parameter	Sample Fraction	Units	Generic (All water uses protected) Most Stringent	Sensitive Receptor	Source
High Molecular Weight PAHs**		ug/L	0.0001	human	HH DW+Org (derived)

Note:
HH DW + Org and Org were adjusted to reflect carcinogenity of 1 in 1000,000 (1 x 10^{-5}) ILCR levels (Alberta Health (2019))
HH DW+Org: Human Health (HH) criteria from consuming surface water (SW) and aquatic organisms (O)
AO: Aesthetic Objectives; DW: Drinking Water; PAL: Protection of Aquatic Life; Ag: Agriculture
Aquatic biota: invertebrates, plants and fish
Wildlife: bird and mammalian species
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)
* Known human carcinogen via oral exposure route (Health Canada (2021))
† The following known human carcinogens and must be converted to Provisional Benzo[a]pyrene RPF and summed as per Health Canada (2021) then compared to the Benzo(a)pyrene and equivalents health risk criteria: Anthanthrene, Benzo[c]chrysene, Benzo[g]chrysene, Benzo[c]phenanthrene, Cyclopenta[c,d]pyrene, Dibenzo[a,e]fluoranthene Dibenzo[a,e]pyrene, Dibenzo[a,h]pyrene, Dibenzo[a,i]pyrene, Dibenzo[a,l]pyrene, 9,10- Dimethylanthracene, 7,12- Dimethylbenzo[a]anthracene, 1,2- Dimethylbenzo[a]pyrene, 1,6- Dimethylbenzo[a]pyrene, 3,6- Dimethylbenzo[a]pyrene, 4,5- Dimethylbenzo[a]pyrene, 5,6- Dimethylchrysene, 5,7- Dimethylchrysene, 5,11- Dimethylchrysene, 1,4- Dimethylphenanthrene, 4,10- Dimethylphenanthrene, 5- Ethylchrysene, Fluoranthene, 7- Methylbenzo[a]anthracene, Methylbenzo[a]anthracene, 9- Methylbenzo[a]anthracene, 12- Methylbenzo[a]anthracene, 11- Methylbenzo[b]fluorene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, 11- Methylbenzo[a]pyrene, 12- Methylbenzo[a]pyrene, 5- Methylchrysene, Methylchrysene, 2- Methylfluoranthene, Phenanthren,e 2,9,10- Trimethylanthracene, 2,3,9,10- Tetramethylanthracene .
‡ Calculated using modifying factors presented in Table 3.1.
§ Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) and compare to Naphthalene health risk criteria (adopted as surrogate) (CCME (2010))
¶ Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) (CCME (2010))
** Sum of identified HMW PAH congeners (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene) (CCME (2010))
†† Comparison of water quality data must be presented for both Dissolved and total fractions
‡‡ Toxic Unit-Chronic (TUc) is the reciprocal of the effluent concentration (e.g., TUc = 100/NOEC) that causes no observable effect (NOEC) on the test organisms by the end of a chronic toxicity test (US EPA (2000c)).
§§ Note the lower guideline for the related parameter ”Solids Dissolved and Salinity”

Table 1.3: Risk based sediment quality criteria for the protection of Indigenous use.

Parameter	Alberta ISQG (mg/kg)	SQC (mg/kg)	Source
Metals			
Arsenic*	5.9	4.1	Quebec (DSEE)-REL
Cadmium	—	0.33	Quebec (DSEE)-REL
Chromium (total)	37.3	25	Quebec (DSEE)-REL
Copper	35.7	8.6	SST Benchmark Approach (Derived)
Lead	35	25	Quebec (DSEE)-REL
Manganese	—	460	Ontario (OMOE) LEL
Mercury	0.17	0.094	Quebec (DSEE)-REL
Molybdenum	—	718	SST Benchmark Approach (Derived)
Nickel	—	16	Ontario (OMOEE) - LEL
Selenium	2	2	Alberta ISQG
Silver	—	0.57	Washington WSDOE
Thallium	—	0.86	Health Canada (2020)
Uranium	—	0.594	SST Benchmark Approach (Derived)
Vanadium	—	125	SST Benchmark Approach (Derived)
Zinc	123	7.4	SST Benchmark Approach (Derived)
Polycyclic Aromatic Hydrocarbons			
Low MW PAHs	—	0.552	US EPA (OSWER)-ER-L
High MW PAHs	—	0.655	US EPA (Region IV - FDEP)-TEL
Total PAHs	—	1.684	US EPA (Region IV - FDEP)-TEL
Acenaphthene	0.00671	0.0037	Quebec (DSEE)-REL
Acenaphthylene	0.00587	0.0033	Quebec (DSEE)-REL
Anthracene	0.0469	0.0087	US DOE-EqP secondary
Benz[a]anthracene*	0.0317	0.0079	Derived EqP fish tissue, carcinogenicity
Benzo[a]pyrene*	0.0319	6e-04	Derived EqP fish tissue, carcinogenicity
Chrysene*	0.0571	0.079	Derived EqP fish tissue, carcinogenicity
Dibenz[a,h]anthracene*	—	0.00062	Derived EqP fish tissue, carcinogenicity
Fluoranthene	0.111	0.047	Quebec (DSEE)-REL
Fluorene	0.0212	0.01	Quebec (DSEE)-OEL
2-Methylnaphthalene	—	0.016	Quebec (DSEE)-REL
Naphthalene	—	0.017	Quebec (DSEE)-REL
Phenanthrene	—	0.025	Quebec (DSEE)-REL
Pyrene	—	0.029	Quebec (DSEE)-REL
Naphthenic acids	—	3.3	Derived (US EPA EqPA method)

Table 1.3: Risk based sediment quality criteria for the protection of Indigenous use.
(continued)

Parameter	Alberta ISQG (mg/kg)	SQC (mg/kg)	Source
Phenols	—	0.23	Derived EqP fish tissue tainting

Note:
Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) (CCME (2010))
Sum of identified HMW PAH congeners (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene) (CCME (2010))
* Denotes carcinogenic substance

The following sections provide illustrations of how the health risk criteria and current conditions may be applied by users to assess potential health risks and changes in environmental conditions. Other applications, not discussed here, may include assessing risks to the environment and Indigenous land users from contaminants in treated tailings deposits used to create closure and reclamation landscapes, assessments of oil sands project applications (and amendments), and oilsands mine water effluent releases to the ambient environment.

1.4 Current Conditions

Existing, accessible water and sediment quality data collected through various monitoring and research programs in the lower Athabasca River, the Athabasca River Delta and Lake Athabasca were used to determine the current condition in monitored water and sediment quality parameters (see Chapter 2 of this report). Specifically, normal (i.e., median) and unusually low or high (i.e., 5th and 95th percentiles) values for these parameters were calculated for the high flow, open water and under ice seasons (water) and annually (sediment) in the River, Delta and Lake. The data used to define these current conditions were obtained between 2011 and 2020, except for sediment quality in the Delta where data obtained between 2000 and 2016.

1.4.1 Current State: Comparison of Current Conditions to Health Risk Criteria

The following section provides an overview of the state of the Lower Athabasca River, Athabasca Lake and Athabasca River Delta by comparing the current conditions to the health risk criteria established in Chapters 3 to 4 of this study.

Specific reference has been made to whether a chemical parameter exceeding the proposed health risk criteria is a known human carcinogen or not. This is an important component of the health risk criteria which addresses provincial gaps in the assessment of surface water and sediment quality (that do not currently include humans as a receptor and therefore have excluded an assessment of potential carcinogenicity) and directly addresses concerns around elevated cancer rates which ACFN, FMFN, and MCFN members have identified (McLachlan, 2014), and which led to the 2009 and 2014 investigations by researchers (Eggertson, 2009; Colquhoun et al., 2010) and Alberta Health (ACB, 2009; Chen, 2009; Services, 2014).

The comparison presented below is an illustration of how the health risk criteria are intended to be applied to surface water and sediment quality data and provides a preliminary assessment of the current condition of water and sediment quality in the LAR, ARD, and Lake Athabasca. Exceedances of the current condition 50th percentile values means that ambient conditions are exceeding the health risk criteria about half of the time in a given season. It is important to note that exceedances for other constituents may also be occurring, but less frequently, and the comprehensive current condition tables presented in Table 2 can be used together with the health risk criteria to, for example, determine whether exceedances are occurring but less frequently (compare to 95th percentile), or even more frequently than half of the time (compare to 5th percentile).

The results presented below are an indication of potential risk drivers but have not been assessed to understand health risks, sources of contaminants (i.e., oilsands development, natural), or changes over time.

The information therefore has limitations which must be addressed through follow up studies to understand potential health risks to community members, fish, and wildlife and to understand how oil sands development and other sources have contributed (or not) to contaminants in the LAR, ARD, and Lake Athabasca.

1.4.1.1 Athabasca River – Water Quality

The concentrations of most constituents of concern related to oil sands mining and natural oil sands deposits are lower than the generic health risk criteria identified for each parameter (see Table 1.4), with some exceptions discussed below.

Most of the current condition median values for PAHs with applicable health risk criteria were not measured above detection limit in the river, and none of these exceeded the calculated health risk criteria.

The toxicity and bioavailability of several metals is dependent on their oxidation state and form. Generally, dissolved metals are more bioavailable than metals bound to sediment or in complexes with other molecules. Increased bioavailability is directly and proportionately related to the toxicological response elicited in people, wildlife and fish exposed to chemicals (Canadian Council of Resource and Environment Ministers (CCREM), 1987). The majority of health risk criteria exceedances in Athbasca River water were related to metal concentrations with a higher frequency of exceedances noted for total fractions compared to dissolved, and during high flow time periods compared to periods of open water and under ice (see Table 1.4). Dissolved copper was an exception, with consistent exceedances of the health risk criteria in all seasons. In addition, it should be noted that all dissolved arsenic and cadmium concentrations exceed the health risk criteria for the corresponding total fraction, which results from the guideline development process discussed in Section 3.3.3 of this report. Importantly, for both arsenic and cadmium, median dissolved fraction concentrations represent approximately one third to one half of the median total fraction concentration. Similarly, median dissolved fractions of copper exceed generic health risk criteria under all flow conditions and represent a significant fraction of the median total fraction.

The median total arsenic, cadmium, iron and mercury concentrations exceed the generic health risk criteria in all seasons. The consistency of these exceedances indicates a year-round source(s) of these elements to the river, although all three have highest median concentrations in the high flow season.

Median concentrations of other metals in river water exceed the generic health risk criteria only during high flow conditions (i.e., total cobalt, copper, manganese, mercury, thallium, zinc), while total aluminum exceeds the generic health risk criteria during both the high flow and open water seasons.

These exceedances are likely related to the increased loads of trace elements that are bound to suspended sediments and particles that are carried in Athabasca River water during spring runoff and snow melt. Such particles can be contributed by erosion and sedimentation from catchments, including both undisturbed areas and areas impacted by human development. However, since dissolved arsenic and cadmium concentrations also consistently exceed the total fraction health risk criteria, it is unlikely that association with suspended particles are the only, or even dominant, control over the elevated concentrations of these two elements in the river.

Since current conditions indicate elevated concentrations (i.e., exceedances of health risk criteria) of some trace elements and historically members of ACFN, FMFN and MCFN consume untreated drinking water from the Lower Athabasca Region, additional studies are recommended to more comprehensively assess how the identified exceedances could affect human, aquatic biota and wildlife species health. Also, management of oil sands releases of these contaminants may be required to mitigate potential risks from the elevated condition currently identified in the Athabasca River.

Table 1.4: Comparison of health risk criteria to current conditions (Athabasca River).

		Generic health risk criteria (All water uses protected)			Current Condition		
Parameter	Unit	Helath Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Conventional Variables							
Alkalinity, total as CaCO3	mg/L	20.00	AEP Water PAL US EPA Aquatic Life Criteria	aquatic biota	**89.00**	**101.00**	**163.00**
Dissolved Metals							
Aluminum, Filtered	ug/L	50.00	AEP Water PAL	aquatic biota	32.35	16.00	13.20
Arsenic, Filtered *	ug/L	150.00	US EPA Aquatic Life Criteria	aquatic biota	0.55	0.49	0.46
Cadmium, Filtered *	ug/L	0.82	US EPA Aquatic Life Criteria	aquatic biota	0.011	0.010	0.015
Copper, Filtered	ug/L	0.53	FEQG Water PAL	aquatic biota	**1.28**	**0.66**	**0.58**
Iron, Filtered	ug/L	300.00	AEP Water PAL	aquatic biota	190.50	157.00	255.00
Lead, Filtered	ug/L	3.07	US EPA Aquatic Life Criteria	aquatic biota	0.089	0.039	0.032
Nickel, Filtered	ug/L	60.68	US EPA Aquatic Life Criteria	aquatic biota	1.38	0.91	0.94
Zinc, Filtered	ug/L	31.35	CCME Water PAL	aquatic biota	0.60	0.40	1.30
Field							
pH	pH units	7-9	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL CCME Water PAL Health Canada DW	aquatic biota human human	**7.97**	**8.20**	**7.52**
General Organics							
Toluene	ug/L	0.50	AEP Water PAL	aquatic biota	•	0.031	•
Nutrients and BOD							
Ammonia and ammonium, Unfiltered as N	mg/L	0.67	HH DW+Org (derived)	human	0.011	0.0080	0.048
PAHs							
Chrysene	ng/L	70.00	HH DW+Org (derived)	human	2.51	•	•
Fluoranthene	ng/L	40.00	AEP Water PAL CCME Water PAL	aquatic biota	2.14	•	•
Naphthalene	ng/L	1000.00	AEP Water PAL	aquatic biota	23.78	43.05	26.65
Phenanthrene	ng/L	400.00	CCME Water PAL AEP Water PAL	aquatic biota	10.64	•	•
Pyrene	ng/L	25.00	CCME Water PAL AEP Water PAL	aquatic biota	3.34	•	•
Total Metals							
Aluminum, Unfiltered	ug/L	18.00	US DOE Wildlife	wildlife	**2530.00**	**316.00**	**54.00**
Antimony, Unfiltered	ug/L	4.59	HH DW+Org (derived)	human	0.11	0.060	0.056
Arsenic, Unfiltered	ug/L	0.030	HH DW+Org (derived)	human	**1.98**	**0.71**	**0.56**
Barium, Unfiltered	ug/L	1000.00	HH DW+Org (US EPA) Health Canada DW	human	73.80	53.70	85.20

Table 1.4: Comparison of health risk criteria to current conditions (Athabasca River). *(continued)*

		Generic health risk criteria (All water uses protected)			Current Condition		
Parameter	Unit	Helath Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Beryllium, Unfiltered	ug/L	3.27	HH DW+Org (derived)	human	0.14	0.020	0.0070
Boron, Unfiltered	ug/L	1333.33	HH DW+Org (derived)	human	25.30	23.60	36.40
Cadmium, Unfiltered	ug/L	0.0020	HH DW+Org (derived)	human	**0.050**	**0.017**	**0.016**
Chromium, Unfiltered	ug/L	50.00	WHO DW Health Canada DW	human	3.56	0.45	0.18
Cobalt, Unfiltered	ug/L	1.10	FEQG Water PAL AEP Water PAL	aquatic biota	**1.65**	0.27	0.09
Copper, Unfiltered	ug/L	2.76	CCME Water PAL	aquatic biota	**4.40**	0.91	0.66
Iron, Unfiltered	ug/L	300.00	CCME Water PAL USEPA WQC AO	aquatic biota human	**4290.00**	**709.00**	**430.50**
Lead, Unfiltered	ug/L	4.01	AEP Water PAL CCME Water PAL	aquatic biota	2.15	0.27	0.09
Manganese, Unfiltered	ug/L	50.00	HH DW+Org (US EPA)	human	**114.00**	38.50	15.85
Mercury, Unfiltered	ng/L	1.58	US DOE Wildlife	wildlife	**10.00**	**1.90**	0.68
Methylmercury(1+), Unfiltered	ng/L	1.00	AEP Water PAL	aquatic biota	0.18	0.060	0.037
Molybdenum, Unfiltered	ug/L	33.33	HH DW+Org (derived)	human	0.75	0.73	0.90
Nickel, Unfiltered	ug/L	7.35	HH DW+Org (derived)	human	5.23	1.32	1.03
Selenium, Unfiltered	ug/L	0.24	US DOE Wildlife	wildlife	0.22	0.14	0.21
Silver, Unfiltered	ug/L	0.25	AEP Water PAL CCME Water PAL	aquatic biota	0.023	0.0040	0.0020
Strontium, Unfiltered	ug/L	4000.00	HH DW+Org (derived)	human	214.00	223.00	352.00
Thallium, Unfiltered	ug/L	0.020	HH DW+Org (derived)	human	**0.053**	0.010	0.0050
Uranium, Unfiltered	ug/L	15.00	CCME Water PAL AEP Water PAL	aquatic biota	0.45	0.37	0.57
Vanadium, Unfiltered	ug/L	100.00	AEP Water Ag CCME Water Ag	wildlife	6.92	1.07	0.36

Table 1.4: Comparison of health risk criteria to current conditions (Athabasca River). *(continued)*

		Generic health risk criteria (All water uses protected)			Current Condition		
Parameter	Unit	Helath Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Zinc, Unfiltered	ug/L	12.72	HH DW+Org (derived)	human	**13.10**	2.00	1.85

Note:
Refer to Tables 1.2 and 1.3 for health risk criteria calculation methods
Bolded values indicate exceedances of the corresponding water quality criteria for Indigenous use
Where under-ice conditions were calculated for individual sites (not merged), the maximum value across those sites is displayed
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)
* Dissolved current condition concentrations exceed health risk criteria for total fraction. See discussion in Section 3.3.3

Table 1.5: Comparison of health risk criteria for carcinogenic (BaP and equivalents) and non-carcinogenic (Naphthalene and equivalents) polycyclic aromatic hydrocarbon (PAH) congeners to current conditions (Athabasca River)

Parameter	Unit	Generic health risk criteria	Current Condition		
			High Flow 50th	Open Water 50th	Under Ice 50th
BaP (and equivalents)	ug/L	0.0001	0.00011	0.00000	0.00000
Naphthalene (and equivalents)	ug/L	1.0000	0.02078	0.02078	0.02078

* Known human carcinogens must be converted to provisional Benzo[a]pyrene RPF and summed (Health Canada (2021))

† Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluorene,Naphthalene, Phenanthrene, Pyrene) and compare to Naphthalene health risk criteria (adopted as surrogate) (CCME (2010))

1.4.1.2 Athabasca River – Sediment

The median current condition sediment concentrations in the River exceeded the generic health risk criteria for sediment (also referred to as the SQC) for manganese, uranium and zinc and the carcinogenic substances benzo(a)pyrene, dibenz[a,h]anthracene, and arsenic (see Table 1.6 below).

Table 1.6: Comparison of Indigenous use Sediment Quality Criteria to current conditions (Athabasca River).

Parameter	Unit	Health Risk Criteria	Annual 50th
General Organics			
Naphthenic acids	**ug/g**	**3.30**	**136.50**
PAHs			
2-Methylnaphthalene	ng/g	16.00	10.98
Acenaphthene	ng/g	3.70	0.70
Anthracene	ng/g	8.70	0.61
Benz[a]anthracene	ng/g	7.85	2.82
Benzo[a]pyrene	**ng/g**	**0.62**	**4.05**
Chrysene	ng/g	26.00	12.60
Dibenz[a,h]anthracene	**ng/g**	**0.62**	**1.69**
Fluoranthene	ng/g	47.00	3.43
Fluorene	ng/g	10.00	1.24
Naphthalene	ng/g	17.00	4.00
Phenanthrene	ng/g	25.00	11.10
Pyrene	ng/g	29.00	6.85
Total Metals			
Arsenic	**ug/g**	**4.10**	**4.21**
Cadmium	ug/g	0.33	0.14
Chromium	ug/g	25.00	10.90
Copper	ug/g	8.60	6.75
Lead	ug/g	11.00	5.34

Table 1.6: Comparison of Indigenous use Sediment Quality Criteria to current conditions (Athabasca River). *(continued)*

Parameter	Unit	Health Risk Criteria	Annual 50th
Manganese	**ug/g**	**28.00**	**289.00**
Molybdenum	ug/g	718.00	0.44
Nickel	ug/g	16.00	13.30
Silver	ug/g	0.57	0.05
Thallium	ug/g	0.86	0.10
Uranium	**ug/g**	**0.59**	**0.67**
Vanadium	ug/g	125.00	17.10
Zinc	**ug/g**	**7.40**	**39.90**

Note:
Refer to Tables 1.2 and 1.3 for health risk criteria calculation methods
Bolded rows indicate exceedances of the corresponding water quality criteria for Indigenous use

Comparison of the sum of median annual concentrations of low and high molecular weight and total PAH groupings to the respective SQC proposed for each group indicates that exceedances are unlikely using this "average" measure of sediment quality in the Athabasca River (see Table 1.7). The high MW group includes the known carcinogenic PAHs.

Table 1.7: Comparison of median concentrations (ng/g) of PAH groups (high and low molecular weight; total PAHs) measured in the Athabasca River to proposed sediment health risk criteria.

	High MW PAH	Low MW PAH	Total PAH
River	33	39	72
SQC - sediment	655	552	1,684

Note:
High MW PAHs and carcinogens Sum of 50%ile for Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene)
Low MW PAHs Sum of 50%ile for Acenaphthene, Acenaphthylene, Anthracene, Fluoranthene, Fluorene, 2-methylnapthalene, Naphthalene, Phenanthrene, Pyrene

The sediment health risk criteria (also referred to as SQCs) were developed to consider the protection of sediment associated biota from direct exposure and exposure through consuming diet items from the bioaccumulation of these contaminants within aquatic food webs. Comparison of these SQC with the current condition in the Athabasca River Table 1.6 indicate that there may be risks to sediment associated biota from exposure to PAHs and certain metals as well as risks of exposure through ingestion of aquatic biota, however, additional studies are required to better understand the risk potential and what management actions could be required.

1.4.1.3 Athabasca River Delta – Water

Concentrations of chemical parameters are elevated in the Athabasca River Delta surface water compared to the river and Lake Athabasca. Like the river, median trace element concentrations measured in total fractions in the delta exceeded health risk criteria more frequently compared to dissolved fractions (see Table 1.8). However, as noted for the river, dissolved arsenic and cadmium concentrations exceed the health risk criteria for the corresponding total fraction (see dicussion in Section 3.3.3 of this report). Seasonal conditions did not appear to vary to the same extent as in the river, becuase exceedances were more frequently identified in all seasons and for upper, median and lower values in each range (e.g., arsenic (carcinogenic substance), cadmium and total iron, as well as chlorine).

Median concentrations of total mercury, cobalt, copper and thallium exceeded generic health risk criteria in the delta during high flow only, while median total aluminum and manganese exceeded during both high flow and open water. Notably, and in contrast to conditions in the river, for many of these total metal parameters, the lower bound of their concentration range also exceeded the generic health risk criteria. These patterns were not present for most of the corresponding dissolved metals in delta water, indicating particle-associated fractions play a significant role in these consistent exceedances. However, median concentrations of dissolved copper in all seasons exceeded the generic health risk criteria, indicating that relevant copper, and arsenic and cadmium exceedances in water in the delta are not predominantly driven by particle-associated fractions.

The median concentration of the ion fluoride and the composite measure total dissolved solids also exceeded the generic health risk criteria during the under ice season in the Delta. This pattern generally indicates a lack of dilution power in these Delta channels during the winter, and the fluoride exceedance mirrors the elevated concentration in the River under ice.

The substantive number of chemical parameters exceeding the generic water quality health risk criteria indicates that there may be risks to community members, fish and wildlife consuming, interacting with, and ingesting aquatic biota within the ARD, however, a risk assessment to verify potential health risk was beyond the scope of this study.

Future studies to address monitoring gaps (see Chapter 2), assess potential risks to human and environmental health, and understand the contribution of oilsands development to the current state of the Athbasca River Delta are recommended.

Table 1.8: Comparison of health risk criteria to current conditions (Athabasca River Delta).

Parameter	Unit	Generic Health Risk Criteria: Health Risk Criteria	Source	Receptor	Current Condition: High Flow 50th	Open Water 50th	Under Ice 50th
Conventional Variables							
Alkalinity, total as CaCO3	mg/L	20.00	AEP Water PAL US EPA Aquatic Life Criteria	aquatic biota	**89.00**	**110.00**	**140.00**
Total dissolved solids, Filtered	mg/L	250.00	HH DW+Org (US EPA)	human	140.00	180.00	**250.00**
Dissolved Metals							
Aluminum, Filtered	ug/L	50.00	AEP Water PAL	aquatic biota	16.20	7.96	4.23
Arsenic, Filtered *	ug/L	150.00	US EPA Aquatic Life Criteria	aquatic biota	0.55	0.50	0.42
Cadmium, Filtered *	ug/L	0.82	US EPA Aquatic Life Criteria	aquatic biota	0.009	0.009	0.014
Copper, Filtered	ug/L	0.53	FEQG Water PAL	aquatic biota	**1.56**	**0.97**	**0.75**
Iron, Filtered	ug/L	300.00	AEP Water PAL	aquatic biota	121.50	95.00	178.00
Lead, Filtered	ug/L	3.07	US EPA Aquatic Life Criteria	aquatic biota	0.084	0.038	0.052
Mercury, Filtered	ng/L	770.00	US EPA Aquatic Life Criteria	aquatic biota	•	•	0.50
Methylmercury(1+), Filtered	ng/L	4.00	CCME Water PAL	aquatic biota	0.061	0.039	0.028
Nickel, Filtered	ug/L	60.68	US EPA Aquatic Life Criteria	aquatic biota	1.43	0.75	0.76
Zinc, Filtered	ug/L	31.35	CCME Water PAL	aquatic biota	0.62	0.53	1.58
Field							
pH	pH units	7-9	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL CCME Water PAL Health Canada DW	aquatic biota human human	**7.89**	**8.00**	**7.44**
Major Ions							
Chloride, Unfiltered	mg/L	120.00	CCME Water PAL AEP Water PAL	aquatic biota	6.00	12.00	25.00
Fluoride, Unfiltered	mg/L	0.12	CCME Water PAL	aquatic biota	0.10	0.10	**0.12**
Sulfate, Unfiltered as SO4	mg/L	250.00	WHO DW	human	23.00	28.00	36.00
Nutrients and BOD							
Ammonia and ammonium, Unfiltered as N	mg/L	0.67	HH DW+Org (derived)	human	•	0.022	0.052
Total Metals							
Mercury, Unfiltered	ng/L	1.58	US DOE Wildlife	wildlife	**8.90**	**2.99**	0.82
Methylmercury(1+), Unfiltered	ng/L	1.00	AEP Water PAL	aquatic biota	0.16	0.072	0.039
Total Recoverable Metals							
Aluminum, Unfiltered	ug/L	18.00	US DOE Wildlife	wildlife	**2770.00**	**792.00**	**97.50**
Antimony, Unfiltered	ug/L	4.59	HH DW+Org (derived)	human	0.10	0.065	0.052

Table 1.8: Comparison of health risk criteria to current conditions (Athabasca River Delta). *(continued)*

		Generic Health Risk Criteria			Current Condition		
Parameter	Unit	Health Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Arsenic, Unfiltered	ug/L	0.030	HH DW+Org (derived)	human	**1.75**	**0.86**	**0.57**
Barium, Unfiltered	ug/L	1000.00	HH DW+Org (US EPA) Health Canada DW	human	86.15	56.90	64.05
Beryllium, Unfiltered	ug/L	3.27	HH DW+Org (derived)	human	0.14	0.043	0.0080
Boron, Unfiltered	ug/L	1333.33	HH DW+Org (derived)	human	24.80	24.70	32.85
Cadmium, Unfiltered	ug/L	0.0020	HH DW+Org (derived)	human	**0.058**	**0.020**	**0.020**
Chlorine, Unfiltered	mg/L	0.00050	AEP Water PAL	aquatic biota	**4.13**	**8.40**	**20.80**
Chromium, Unfiltered	ug/L	50.00	WHO DW Health Canada DW	human	3.22	0.92	0.22
Cobalt, Unfiltered	ug/L	1.10	FEQG Water PAL AEP Water PAL	aquatic biota	**1.36**	0.41	0.12
Copper, Unfiltered	ug/L	2.76	CCME Water PAL	aquatic biota	**3.65**	1.42	0.91
Iron, Unfiltered	ug/L	300.00	CCME Water PAL USEPA WQC AO	aquatic biota human	**4240.00**	**1050.00**	**565.50**
Lead, Unfiltered	ug/L	4.01	AEP Water PAL CCME Water PAL	aquatic biota	2.13	0.47	0.16
Manganese, Unfiltered	ug/L	50.00	HH DW+Org (US EPA)	human	**104.40**	**54.70**	30.75
Molybdenum, Unfiltered	ug/L	33.33	HH DW+Org (derived)	human	0.52	0.60	0.65
Nickel, Unfiltered	ug/L	7.35	HH DW+Org (derived)	human	4.33	1.55	1.02
Selenium, Unfiltered	ug/L	0.24	US DOE Wildlife	wildlife	**0.26**	0.22	**0.30**
Silver, Unfiltered	ug/L	0.25	AEP Water PAL CCME Water PAL	aquatic biota	0.023	0.0060	0.0030
Strontium, Unfiltered	ug/L	4000.00	HH DW+Org (derived)	human	174.50	206.00	275.00
Thallium, Unfiltered	ug/L	0.020	HH DW+Org (derived)	human	**0.048**	0.016	0.0060
Uranium, Unfiltered	ug/L	15.00	CCME Water PAL AEP Water PAL	aquatic biota	0.49	0.41	0.44
Vanadium, Unfiltered	ug/L	100.00	AEP Water Ag CCME Water Ag	wildlife	6.73	2.04	0.43

Table 1.8: Comparison of health risk criteria to current conditions (Athabasca River Delta). *(continued)*

		Generic Health Risk Criteria			Current Condition		
Parameter	Unit	Health Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Zinc, Unfiltered	ug/L	12.72	HH DW+Org (derived)	human	10.36	3.10	2.58

Note:
Refer to Tables 1.2 and 1.3 for health risk criteria calculation methods
Bolded values indicate exceedances of the corresponding water quality criteria for Indigenous use
Where under-ice conditions were calculated for individual sites (not merged), the maximum value across those sites is displayed
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)
* Dissolved current condition concentrations exceed health risk criteria for total fraction. See discussion in Section 3.3.3

1.4.1.4 Athabasca River Delta – Sediment

In terms of sediment quality, the concentrations of trace elements, as well as PAHs in the Athabasca River Delta sediment were relatively high compared to the lower Athabasca River. This coincided with a higher median proportion of finer particles, specifically silt and clay, in the delta sediments compared to the river sediments (see Table 1.9). This makes sense, because these finer sediments are more likely to drop out of the water column in the relatively lower-energy environment of delta channels compared to the river. Finer sediments are also more likely to have these associated constituents compared to sand, which made up a larger proportion of river sediment.

Table 1.9: Comparison of median small sediment particle size distributions measured in the Athabasca River and Athabasca River Delta.

	% Clay*	% Silt†	% Sand‡
River	7	19	72
Delta	16	48	34

* < 2 um
† > or = 2 um to < 63 um
‡ > or = 63 um to < 2000 um

Median sediment concentrations of the carcinogenic substances benzo(a)pyrene and arsenic exceeded the calculated health risk criteria for Indigenous use. Several other non-carcinogenic parameters also exceeded the generic health risk criteria under median conditions, specifically copper, manganese, nickel and zinc.

Table 1.10: Comparison of Indigenous use Sediment Quality Criteria to current conditions (Athabasca River Delta).

Parameter	Unit	Health Risk Criteria	Annual 50th
PAHs			
Benzo[a]pyrene	**ng/g**	**0.62**	**5.88**
Chrysene	ng/g	26.00	17.75
Fluoranthene	ng/g	47.00	3.87
Fluorene	ng/g	10.00	2.30
Naphthalene	ng/g	17.00	7.75
Phenanthrene	ng/g	25.00	15.95
Pyrene	ng/g	29.00	10.45
Total Metals			
Arsenic	**ug/g**	**4.10**	**4.95**
Chromium	ug/g	25.00	14.95
Copper	**ug/g**	**8.60**	**13.10**
Lead	ug/g	11.00	7.90
Manganese	**ug/g**	**28.00**	**392.00**
Mercury	ug/g	0.09	0.04

Table 1.10: Comparison of Indigenous use Sediment Quality Criteria to current conditions (Athabasca River Delta). *(continued)*

Parameter	Unit	Health Risk Criteria	Annual 50th
Nickel	**ug/g**	**16.00**	**18.75**
Selenium	ug/g	0.63	0.41
Thallium	ug/g	0.86	0.16
Vanadium	ug/g	125.00	21.70
Zinc	**ug/g**	**7.40**	**59.35**

Note:
Refer to Tables 1.2 and 1.3 for health risk criteria calculation methods
Bolded rows indicate exceedances of the corresponding water quality criteria for Indigenous use

In addition, the PAH data available for the delta included far fewer parameters compared to PAH data from the river. Comparison of the sum of median annual concentrations of low and high molecular weight and total PAH groupings to the respective SQC proposed for each group indicates that exceedances are unlikely using this "average" measure of sediment quality in the Athabasca River Delta (see Table 1.11).

Table 1.11: Comparison of median concentrations (ng/g) of PAH groups (high and low molecular weight; total PAHs) measured in the Athabasca River Delta to proposed sediment health risk criteria.

	High MW PAH	Low MW PAH	Total PAH
River	30	40	70
SQC - sediment	655	552	1,684

Note:
High MW PAHs and carcinogens Sum of 50
Low MW PAHs Sum of 50

Given that several carcinogenic and noncarcinogenic parameters exceeded the most stringent (generic) health risk criteria for sediment using upper and lower ranges of the data, it is recommended that future studies on health risks and establishing contributions from oil sands development include an assessment and additional monitoring for chemical parameters in sediments (as recommended under the ARD water discussion).

1.4.1.5 Lake Athabasca - Water

The available water quality data for Lake Athabasca were more limited in terms of the number of parameters and the number of observations in under ice and high flow seasons. There were no sediment quality data available for Lake Athabasca.

Exceedances of health risk criteria in the lake were observed for total metal fractions under open water conditions (see Table 1.12). Aluminum, arsenic (carcinogenic substance), and iron exceeded under median conditions and may present the most likely risk potential although upper ranges of other total copper, manganese, nickel and zinc as well as total dissolved solids exceeded health risk criteria (refer to Chapter 3 for complete current condition tables). Dissolved metals data were not available for the lake.

It is important to recognize the community of Ft. Chipewyan has access to treated Athabasca Lake water as a drinking water source and the concentrations of the above noted parameters may be decreased through the municipal water treatment process. It is unclear to what degree ACFN, FMFN and MCFN members consume untreated water from Lake Athabasca and if there could be risks to community members, fish and wildlife from water quality conditions reported here. It is recommended that a focused study to better understand the results presented here be completed in the future.

Table 1.12: Comparison of health risk criteria to current conditions (Lake Athabasca).

		Generic health risk criteria			Current Condition		
Parameter	Unit	Health Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Conventional Variables							
Total dissolved solids, Filtered	mg/L	250.00	HH DW+Org (US EPA)	human	•	57.00	•
Field							
pH	pH units	7-9	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL CCME Water PAL Health Canada DW	aquatic biota human human	**8.22**	**8.13**	•
Major Ions							
Chloride, Unfiltered	mg/L	120.00	CCME Water PAL AEP Water PAL	aquatic biota	•	3.70	•
Sulfate, Unfiltered as SO4	mg/L	250.00	WHO DW	human	•	6.00	•
Total Metals							
Aluminum, Unfiltered	ug/L	18.00	US DOE Wildlife	wildlife	•	**591.00**	•
Arsenic, Unfiltered	ug/L	0.030	HH DW+Org (derived)	human	•	**0.70**	•
Barium, Unfiltered	ug/L	1000.00	HH DW+Org (US EPA) Health Canada DW	human	•	29.90	•
Beryllium, Unfiltered	ug/L	3.27	HH DW+Org (derived)	human	•	0.032	•
Chromium, Unfiltered	ug/L	50.00	WHO DW Health Canada DW	human	•	0.90	•
Copper, Unfiltered	ug/L	2.76	CCME Water PAL	aquatic biota	•	1.45	•
Iron, Unfiltered	ug/L	300.00	CCME Water PAL USEPA WQC AO	aquatic biota human	•	**953.00**	•
Lead, Unfiltered	ug/L	4.01	AEP Water PAL CCME Water PAL	aquatic biota	•	0.55	•
Manganese, Unfiltered	ug/L	50.00	HH DW+Org (US EPA)	human	•	21.10	•
Molybdenum, Unfiltered	ug/L	33.33	HH DW+Org (derived)	human	•	0.30	•
Nickel, Unfiltered	ug/L	7.35	HH DW+Org (derived)	human	•	1.50	•
Vanadium, Unfiltered	ug/L	100.00	AEP Water Ag CCME Water Ag	wildlife	•	1.90	•

Table 1.12: Comparison of health risk criteria to current conditions (Lake Athabasca). *(continued)*

		Generic health risk criteria			Current Condition		
Parameter	Unit	Health Risk Criteria	Source	Receptor	High Flow 50th	Open Water 50th	Under Ice 50th
Zinc, Unfiltered	ug/L	12.72	HH DW+Org (derived)	human	•	4.05	•

Note:
Refer to Tables 1.2 and 1.3 for health risk criteria calculation methods
Bolded values indicate exceedances of the corresponding water quality criteria for Indigenous use
Where under-ice conditions were calculated for individual sites (not merged), the maximum value across those sites is displayed
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)

1.4.2 Athabasca River Delta current condition - Comparison to LARP Surface Water Quality Management Framework (triggers)

There is another comparison that can be made with the Athabasca River Delta sites, which is with the current conditions calculated for the Lower Athabasca Regional Plan (LARP) Surface Water Quality Management Framework. Mean and peak (95th percentile) water quality triggers under LARP were calculated using data from the same sites used in this study. However, in the case of the development of LARP triggers, monitoring data from before 2009 were used whereas in this study, data from after 2011 were used to calculate current conditions. In addition, current conditions in this study were calculated seasonally instead of annually, and were calculated using different statistical approaches (see Chapter 2).

A comparison between these values is provided in Table 1.13 below. Comparison of the current conditions to the LARP triggers indicates that the LARP annual mean values are often lower in value – generally meaning more conservative – than the high flow median current condition values calculated here, but are often higher in value – generally meaning less conservative – for the open water and under ice seasons.

LARP trigger values for dissolved beryllium, total boron, dissolved and total cadmium, and dissolved thallium are very high in comparison to this study's current conditions. Specifically, neither the median or 95th percentile values calculated in this study exceed the LARP trigger for these parameters (see bolded values in Table 1.13). In addition, the LARP trigger for ammonia is high compared to the current condition for high flow and open water, and LARP triggers for total phosphosurs and total dissolved phosphorus are high compared to current conditions for open water and under ice. These differences may reflect a change in Delta water quality since the LARP values were released using data obtained before 2009, since the data used to calculate the current condition were obtained after 2011. Alternatively, these differences may be related to the different statistical methods used in the LARP and this study's current condition calculation. Whatever the cause, these LARP triggers should be re-examined.

The consequences of the lack of seasonal specificity in the calculated LARP triggers is particularly clear when comparing them to the seasonal current conditions, and it is recommended that LARP triggers are re-calculated using the seasonal approach. This would ensure that relevant and reasonable triggers are applied for the majority of the year (i.e., during open water and under ice) when concentrations are generally lower than the LARP triggers.

Table 1.13: Surface water quality triggers from the LARP Surface Water Quality Management Framework and seasonal current condition values calculated as part of this study for sites in the Athabasca River Delta. LARP values that appear to be an overestimate compared to the current condition values calculated in this study are bolded. Note that LARP central tendency measures are annual means, whereas this study used seasonal medians.

		LARP Water Quality Triggers		High flow		Open water		Under ice	
Parameter Name	Units	Mean	Peak (95th percentile)	Median	95%ile	Median	95%ile	Median	95%ile
Nutrients									
Total ammonia	mg/L	0.05	0.12	<	<	0.022	0.08	0.052	0.096
Nitrate	mg/L	0.09	0.26	0.046	0.11	-	-	0.17	0.27
Total nitrogen	mg/L	0.60	1.04	-	-	-	-	-	
Total dissolved phosphorus	mg/L	0.02	0.03	0.014	0.027	0.008	0.018	0.013	0.019
Total phosphorus	mg/L	0.07	0.26	0.11	0.228	0.041	0.192	0.024	0.046
Ions									
Calcium	mg/L	34.70	48.90	27.5	33.8	32.5	37.8	42	49.2
Chloride	mg/L	20.20	45.00	6	12..4	12	21.4	25	40
Magnesium	mg/L	9.50	13.70	7.9	9.7	9.4	11.8	12-13	14-15
Potassium	mg/L	1.40	2.10	1.3	2.6	1.2	1.5	1.8	2.3
Sodium	mg/L	21.50	43.70	9.4	15.8	16	20	29	40.2
Sulfate	mg/L	26.70	41.40	23	28.8	28	39	36	47.1
Metals and Metalloids									
Aluminum - dissolved	ug/L	16.00	49.00	16.2	104.85	7.96	39.06	4.23	18.39
Aluminum - total	ug/L	1533.00	6454.00	2770	13475	792	5480	97.5	1202.25
Antimony - dissolved	ug/L	0.11	0.20	0.087	0.129	<	<	<	<
Antimony - total	ug/L	0.15	0.39	0.1	0.152	0.065	0.285	0.051	0.125
Arsenic - dissolved	ug/L	0.50	0.70	0.546	0.787	0.504	0.799	0.424	0.596
Arsenic - total	ug/L	1.10	2.50	1.75	2.908	0.862	1.954	0.574	0.825
Barium - dissolved	ug/L	52.60	73.70	42.95	49.55	45.6	53.3	59.75	70.34

Table 1.13: Surface water quality triggers from the LARP Surface Water Quality Management Framework and seasonal current condition values calculated as part of this study for sites in the Athabasca River Delta. LARP values that appear to be an overestimate compared to the current condition values calculated in this study are bolded. Note that LARP central tendency measures are annual means, whereas this study used seasonal medians. *(continued)*

		LARP Water Quality Triggers		High flow		Open water		Under ice	
Parameter Name	Units	Mean	Peak (95th percentile)	Median	95%ile	Median	95%ile	Median	95%ile
Barium - total	ug/L	79.30	147.60	86.15	239.25	56.9	141.06	64.05	77.965
Beryllium - dissolved	**ug/L**	**0.08**	**0.27**	**0.006**	**0.022**	**0.001**	**0.043**	**0.003**	**0.046**
Bismuth - total	ug/L	0.02	0.06	0.017	0.06	0.009	0.023	0.002	0.021
Boron - dissolved	ug/L	26.00	40.00	22.2	30.925	22.6	29.2	31.75	37.77
Boron - total	**ug/L**	**48.00**	**69.00**	**24.8**	**41.775**	**24.7**	**40.54**	**32.85**	**39.78**
Cadmium – dissolved	**ug/L**	**0.10**	**0.52**	**0.009**	**0.022**	**0.009**	**0.109**	**0.014**	**0.033**
Cadmium – total	**ug/L**	**0.30**	**1.20**	**0.058**	**0.274**	**0.02**	**0.126**	**0.02**	**0.093**
Chromium - dissolved	ug/L	0.41	0.65	0.235	0.756	0.148	0.543	0.24	0.476
Chromium - total	ug/L	3.00	8.00	3.215	11.71	0.919	6.314	0.216	0.685
Cobalt - dissolved	ug/L	0.07	0.11	0.067	0.127	0.067	0.217	0.058-0.078	0.137-0.170
Cobalt - total	ug/L	0.80	2.20	1.355	4.942	0.414	1.874	0.124	0.426
Copper - dissolved	ug/L	1.60	3.60	1.555	2.46	0.97	2.184	0.75	1.353
Copper - total	ug/L	3.10	7.20	3.645	10.127	1.42	4.812	0.905	1.897
Iron - dissolved	ug/L	185.00	372.00	121.5	426.5	95	293.6	178	367.4
Iron - total	ug/L	1899.00	5821.00	4240	13625	1050	4414	565.5	1294.5
Lead – dissolved	ug/L	0.56	0.56	0.084	0.259	0.038	0.228	0.052	0.756
Lead - total	ug/L	3.30	7.00	2.125	10.55	0.466	2.806	1.16	2.564
Lithium - dissolved	ug/L	6.00	9.00	5.21	7.4	6.09	7.204	8.59	10.785
Lithium - total	ug/L	9.00	12.00	7.455	16.95	6.83	8.132	8.92	11.085
Manganese - dissolved	ug/L	12.00	36.00	1.725	6.015	1.4	8.228	18.8	35.095
Manganese - total	ug/L	65.00	141.00	104.4	320.5	54.7	113.8	30.75	51.665
Mercury - total	ug/L	0.01	0.02	0.0089	0.0238	0.00299	0.0137	0.00082	0.00425
Molybdenum - dissolved	ug/L	0.70	1.20	0.494	0.7	0.629	0.984	0.638	0.752

Table 1.13: Surface water quality triggers from the LARP Surface Water Quality Management Framework and seasonal current condition values calculated as part of this study for sites in the Athabasca River Delta. LARP values that appear to be an overestimate compared to the current condition values calculated in this study are bolded. Note that LARP central tendency measures are annual means, whereas this study used seasonal medians. *(continued)*

		LARP Water Quality Triggers		High flow		Open water		Under ice	
Parameter Name	Units	Mean	Peak (95th percentile)	Median	95%ile	Median	95%ile	Median	95%ile
Molybdenum - total	ug/L	0.90	1.60	0.516	0.73	0.602	0.985	0.649	0.769
Nickel - dissolved	ug/L	1.60	4.70	1.425	3.475	0.749	1.334	0.764	1.473
Nickel - total	ug/L	3.40	8.20	4.325	13.172	1.55	4.968	1.015	2.245
Selenium - dissolved	ug/L	0.23	0.41	0.114	0.259	0.239	0.3	0.247	0.454
Selenium - total	ug/L	0.33	0.58	0.26	0.467	0.22	0.3	0.3	0.5
Silver - total	ug/L	0.02	0.07	0.022	0.329	0.006	0.027	0.002-0.003	0.011-0.017
Strontium - dissolved	ug/L	215.00	361.00	162.5	213	206	253	266	339.4
Strontium - total	ug/L	225.00	361.00	174.5	227.5	206	256.6	275	343.4
Thallium - dissolved	**ug/L**	**0.02**	**0.11**	**0.006**	**0.008**	**0.005**	**0.014**	**0.005**	**0.019**
Thallium - total	ug/L	0.05	0.18	0.048	0.211	0.016	0.107	0.006	0.045
Thorium - dissolved	ug/L	0.03	0.09	0.026	0.131	0.014	0.058	0.007	0.05
Thorium - total	ug/L	0.35	1.44	0.415	2.51	0.135	0.882	0.024	0.204
Titanium - dissolved	ug/L	2.00	7.00	1.905	9.209	1.03	4.722	1.175	2.328
Titanium - total	ug/L	30.00	104.00	33.9	127	11.6	69.98	2.53	22.63
Uranium - dissolved	ug/L	0.31	0.38	0.344	0.385	0.353	0.434	0.39-0.42	0.48-0.49
Uranium - total	ug/L	0.40	0.70	0.487	1.274	0.414	0.646	0.4-0.44	0.53-0.52
Vanadium - dissolved	ug/L	0.45	0.70	0.435	0.673	0.306	0.649	0.171	0.329
Vanadium - total	ug/L	4.00	16.00	6.73	21.225	2.04	12.248	0.43	2.043
Zinc - dissolved	ug/L	4.50	12.40	0.615	1.73	0.531	1.109	1.03-1.58	3.51-7.75
Zinc - total	ug/L	12.30	25.60	10.355	32.95	3.1	15.626	1.65-2.58	6.98-13.22

Note:
- data insufficient
< too highly censored

1.5 Conclusions and Next Steps

Along with the current conditions, the health risk criteria for water and sediment quality address limitations in the provincial water quality assessment and management system. Addressing these limitations is critical to protect Indigenous community members who rely on the aquatic ecosystem to live and exercise their rights as Indigenous Peoples.

The comparison of current conditions established in this report to the health risk criteria for surface water and sediment indicate that there are conditions in each of the Athabasca River, Athabasca River Delta and Lake Athabasca which warrant further investigation. This may be accomplished through studies assessing health risks from consuming traditional foods and untreated surface water, and by ongoing efforts to better understand the contribution of oil sands development to the current condition.

While surface water quality criteria to protect consumers of fish were identified, there are uncertainties associated with the methods employed (United States Environmental Protection Agency (US EPA), 2021b; Sample et al., 1996) and there is an outstanding need to develop fish tissue specific criteria to ensure community members and wildlife consuming fish are sufficiently protected. Development of fish tissue residues for persistent and bioaccumulative substances would allow for an assessment of monitoring data currently available through various Community Based Monitoring (CBM) programs. Due to limited scope, this component was not integrated into the risk based criteria and future studies in this area are recommended.

The research presented here can be used by Indigenous communities, governments and regulatory agencies, and industry stakeholders to aid in answering community questions around how current and future oil sands development may affect the health of the environment and of Indigenous community members, as well as their ways of life, and cumulatively impact and further deteriorate conditions in the Athabasca River, Athabasca River Delta and Lake Athabasca. However, answering these questions requires implementation of this research and application of the WQCIUs in industry, community, and government led studies and assessments.

Specifically, the proposed health risk criteria and current conditions can be used assess potential changes in surface water and sediment conditions and risks to human and ecological receptors posed by releases of contaminants from oil sands developments to the Athabasca River and downstream within the Athabasca Delta and Lake Athabasca. The health risk criteria can also be used to guide decision making regarding the placement of tailings and OSMW in aquatic closure (reclamation) features such as constructed wetlands and end pit lakes (EPLs).

Chapter 2

Current Conditions

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2.1 Introduction

The following describes the development of current conditions for application as surface water and sediment quality criteria or limits of change. This reflects Indigenous communities' concerns that the condition of the Athabasca River, Athabasca River Delta and Lake Athabasca should not be degraded any further from current condition, recognizing that the communities have established that the current condition is already deteriorated from conditions prior to 1967. The objective of this study is to use existing, accessible water and sediment quality data collected through various monitoring and research programs in the lower Athabasca River, the Athabasca River Delta and Lake Athabasca to determine the range and variability in water and sediment quality parameters. This exercise will determine what normal (i.e., median) and unusually low or high (i.e., 5th and 95th percentiles) values for these parameters are in recent years at these locations. These values will be based on conditions during the period of record for the data used in this study. It is important to note that in the view of ACFN, FMFN and MCFN, the current conditions developed here are meant to serve as a current accumulated state and not an ideal state

2.2 Request from communities for current conditions

Athabasca Chipewyan First Nation (ACFN), Mikisew Cree First Nation (MCFN) and Fort McKay First Nation (FMFN), three First Nations with territories located along the lower

Athabasca River (LAR), at Lake Athabasca and in the Peace-Athabasca Delta are concerned about water quality in these surface water systems. Since the onset of oil sands mining along the LAR along with other stressors on water quality related to upstream effluent release and landscape change, water quality in the LAR and its downstream environment has changed (Glozier et al., 2009; Hebben, 2009; Tondu, 2017; Glozier et al., 2018). In some cases, these changes have been in step with the nature and magnitude of these stressors, while in others the causes have not been identified.

In the face of ongoing development and land disturbance in the Lower Athbasca Region, including oil sands extraction operations, there is a desire to understand the quality of water and sediment in the lower Athabasca River, the Athabasca River Delta and Lake Athabasca in its current state. The variability in constituent concentrations and other measures of water and sediment quality across years and locations can be characterized and described using relatively simple statistics, which is one way to establish "antidegradation" quality criteria. This type of approach involves establishing what normal water and sediment quality at these locations is so that future monitoring results can be compared against these normal conditions, in order to detect when measured environmental quality is different from normal.

As part of the WQCIU project, ACFN, MCFN and FMFN have requested that this benchmark approach be taken in order to create a mechanism to ensure that water and sediment quality in the lower Athabasca River, its delta and Lake Athabasca do not deteriorate from current conditions. However, these communities have established that water and sediment quality in these locations has already deteriorated compared to conditions before human development in the region expanded significantly after 1967. Establishment of a current condition in these surface water systems using monitoring data that were collected after anthropogenic impacts have occurred means that this accumulated state scenario does not represent natural or unimpacted conditions.

2.3 Long-term monitoring programs

The province of Alberta operates a long-term river network (LTRN) monitoring program which maintains four water quality monitoring sites on the lower Athabasca River and its delta, along with three upstream in the Athabasca Basin and many more throughout the province. Currently, this program involves approximately once-a-month sampling at the monitored sites, including the "Old Fort" station located in the Athabasca River Delta downstream of all oil sands development (historically, actually two stations - AB07DD0010 and AB07DD0105). The available water quality data record from this site runs from 1987 to present, although historically the program often missed certain months, especially during winter. Data from the Old Fort sites were used to establish current condition water quality triggers for the Surface Water Quality Management Framework of the Lower Athabasca Regional Plan (LARP)(Alberta Environment and Sustainable Resource Development (AESRD), 2012).

Similarly, there is one long term monitoring station maintained by Environment and Climate Change Canada on the lower Athabasca River, also located downstream of all current oil sands development. This site is known as Athabasca River at 27 Baseline (AL07DD0001, or site M9) and has an available record of water quality data from 1989 to present day, collected monthly. Data from this station were included in the most recent federal reporting on water quality in the major rivers around Wood Buffalo National Park, specifically the Peace, Slave and Athabasca Rivers (using data up to 2006, (Glozier et al., 2009).

Finally, since 2011, the Mikisew Cree First Nation (MCFN) and Athabasca Chipewyan First Nation (ACFN) have conducted a water quality monitoring program in the lower Athabasca River Delta and Lake Athabasca, as well as in the larger Peace-Athabasca Delta(PAD).

2.4 Regional monitoring programs targeting Oil Sands

2.4.1 Alberta Oil Sands Environmental Research Program (AOSERP)

The Alberta Oil Sands Environmental Research Program (AOSERP) was run by Alberta Environment and Parks between 1975 and 1985. The Program goal was to establish baseline conditions and assess terrestrial, aquatic, air and human impacts of oil sands developments, and numerous AOSERP reports[1] are available online. Unfortunately, the availability of AOSERP data, especially in an electronic format, is limited. Many of the data sets are available only in published reports.

2.4.2 Regional Aquatics Monitoring Program (RAMP)

The Regional Aquatics Monitoring Program (RAMP) was initiated in 1997 as a multi-stakeholder organization, with funding provided by oil sands industry members. On its website, the RAMP lists Fort McKay First Nation and Fort McKay Métis Local No. 63 as members of its Steering Committee[2], and in its organizational chart Fort McMurray First

[1] https://era.library.ualberta.ca/communities/e4fdd15f-c21d-4612-a2f7- bfec3fdfc1de/collections/d5685fd3-7ba5-4ee0-a4e8-f5d308d18efa

[2] http://www.ramp-alberta.org/ramp/terms+of+reference/membership/members.aspx

Nation is included as a member[3], however it isn't clear when these memberships were in effect. In addition, the Steering Committee membership list includes municipal, provincial and federal government agencies

The objectives of the RAMP program[4] were as follows:

- Monitor aquatic environments in the Athabasca oil sands region to detect and assess cumulative effects and regional trends;
- Collect baseline data to characterize natural variability in the aquatic environment in the Athabasca oil sands region;
- Collect and compare data against which predictions contained in Environmental Impact Assessments (EIAs) can be assessed;
- Collect data that satisfy the monitoring required by regulatory approvals of oil sands and other developments;
- Collect data that satisfy the monitoring requirements of company-specific community agreements;
- Recognize and incorporate traditional environmental knowledge into monitoring and assessment activities;
- Communicate monitoring and assessment activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies and other interested parties;
- Continuously review and adjust the program to incorporate monitoring results, technological advances, community concerns, and new or changed project approval conditions; and
- Conduct a periodic peer review of the program's results against its objectives, and recommend adjustments necessary for the program's continued success.

The RAMP was focused on monitoring both potential oil sands development stressors, such as water and sediment quality and hydrology, and potential oil sands development effects, such as in benthic invertebrate communities and fish populations. The RAMP program classified sampling sites as baseline or test, depending on their location relative to oil sands development, but also made extensive use of the idea of a regional baseline against which ongoing monitoring results were compared. The RAMP regional study area8 included the lower Athabasca River and the Athabasca River Delta, as well as Lake Athabasca (Figure 2.1). The water quality regional baseline for the Athabasca River mainstem and Delta sites was based on data collected

[3]http://www.ramp-alberta.org/ramp/terms+of+reference/membership/organization.aspx
[4]http://www.ramp-alberta.org/ramp/terms+of+reference/mandate+and+objectives.aspx

in the fall from the Athabasca River upstream Fort McMurray, downstream of Fort McMurray and its wastewater treatment plant outfall but upstream of oil sands activity, as well as from several tributaries of the lower Athabasca River (Hatfield Consultants, 2009). Unlike water quality, sediment quality data were not compared to a regional baseline, but were compared to data previously collected from the same stations.

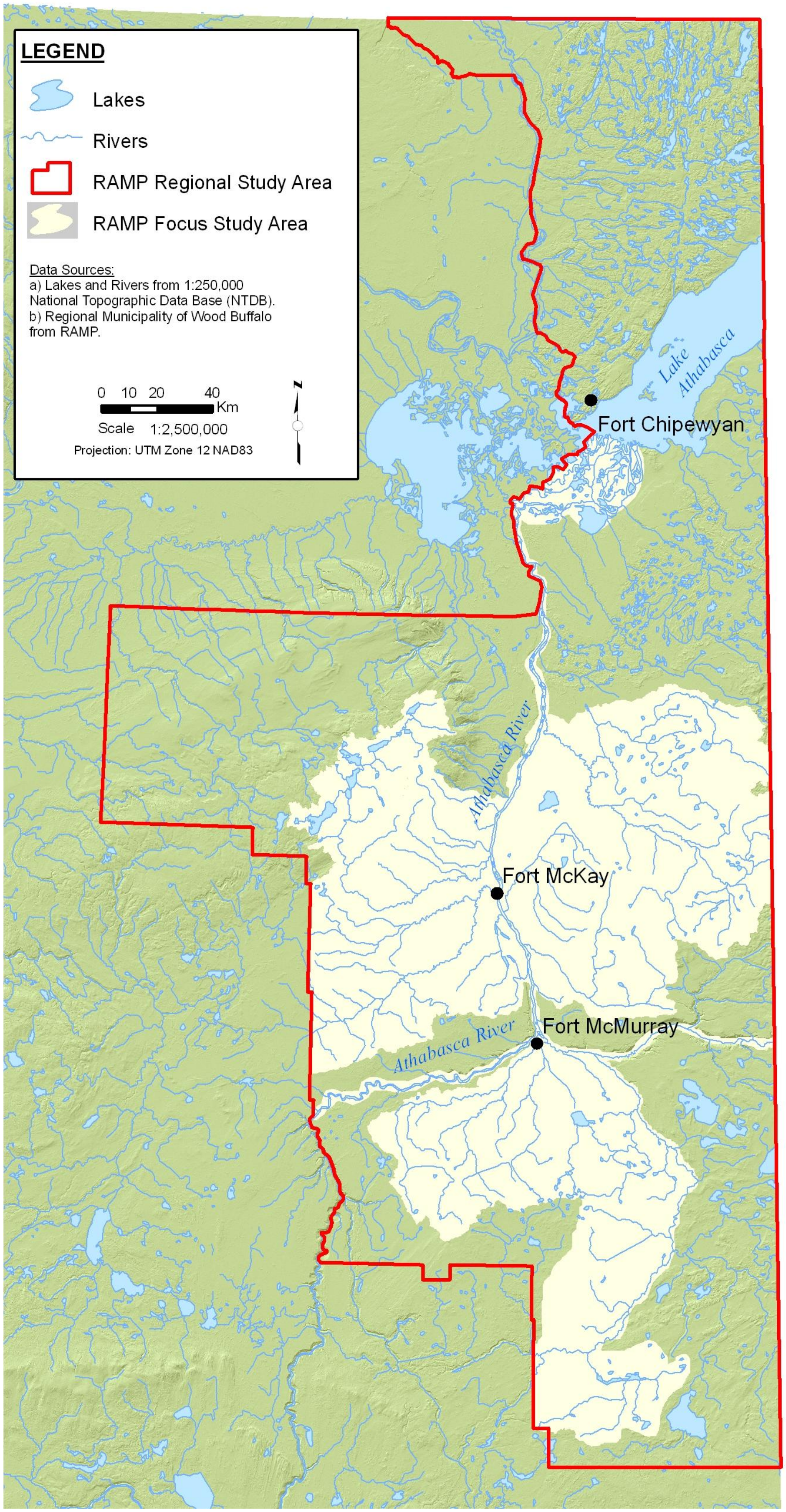

Figure 2.1: RAMP study area (reproduced from the RAMP website: http://www.rampalberta.org/ramp/design+and+monitoring/approach/study+areas.aspx)

Water and sediment quality monitoring was conducted at a maximum of 26 sites in the lower Athabasca River Mainstem, although sediment quality monitoring occurred only during certain time periods. In the Athabasca River Delta, sediment quality monitoring and limited water quality monitoring occurred in the Fletcher Channel, Goose Island Channel, Big Point Channel and the Embarras River. The RAMP did not include water or sediment quality monitoring of Lake Athabasca. A schematic diagram[5] produced by the RAMP of the relative water inflows from tributaries in the LAR is shown in Figure 2.2 below:

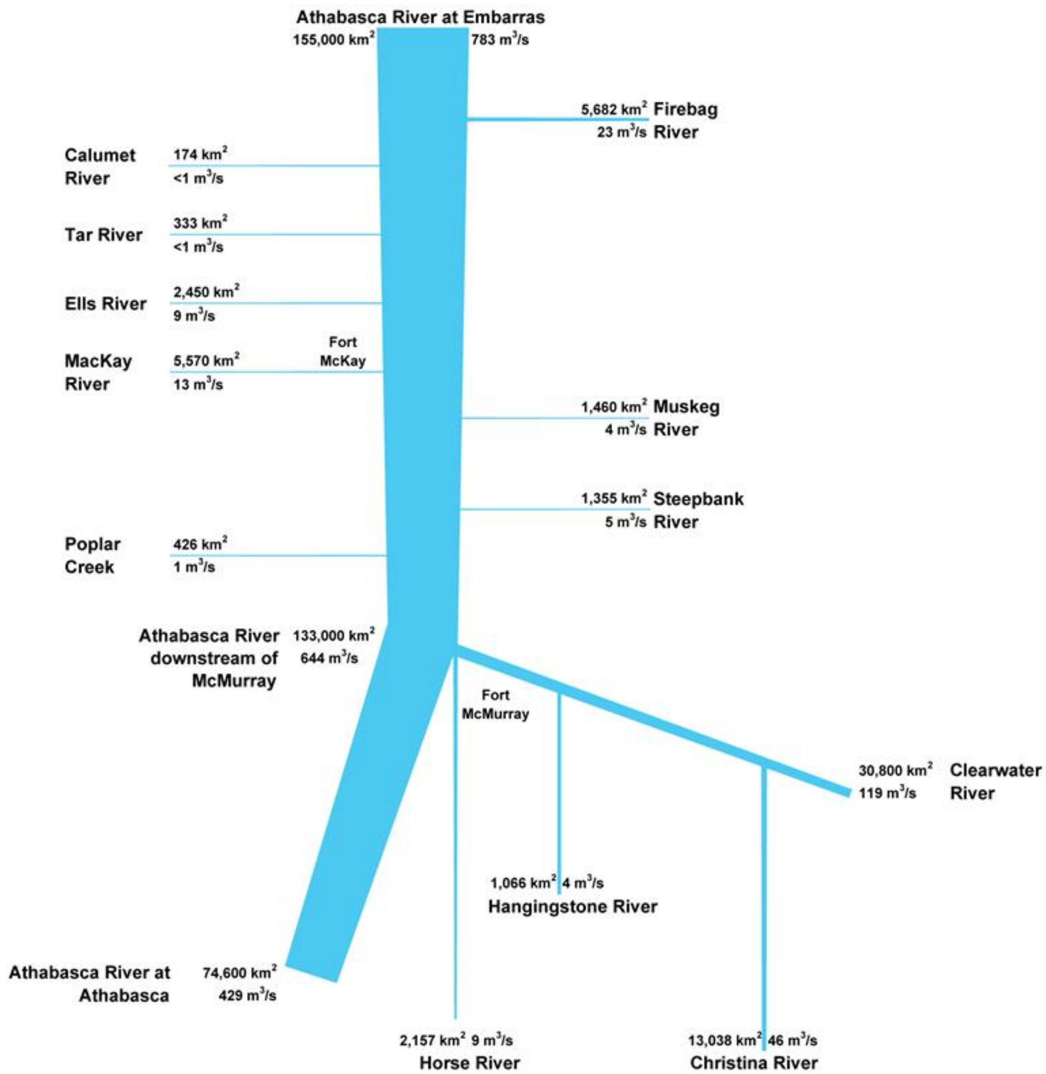

Figure 2.2: Relative water inflows from tributaries in the LAR (figure taken from the RAMP website: http://www.rampalberta.org/river/hydrology/river+hydrology.aspx).

The final standalone report from the RAMP was for the 2012 sampling year and was released in 2013. In 2010 and 2011, two scientific peer reviews of the RAMP program were conducted and identified several areas of concern in terms of the program's ability to detect change

[5] http://www.ramp-alberta.org/river/hydrology/river+hydrology.aspx

over time and space (e.g., lack of statistical confidence or power), and especially its ability to identify change as impacts of oil sands development activity (e.g., poorly or undefined baseline conditions) (Dowdeswell et al., 2010). The RAMP issued a response to the AITF peer review (Burn et al., 2011), outlining changes to its monitoring, reporting and communication practices and providing additional explanation and information (Regional Aquatics Monitoring Program (RAMP), 2011). RAMP data was also made publicly available on the program website.

2.4.3 Joint Oil Sands Monitoring Program/Oil Sands Monitoring Program (JOSM/OSM)

The Joint Oil Sands Monitoring Program (JOSM) was a cooperative effort between the governments of Canada and Alberta to monitor the environment in the lower Athabasca River/mineable oil sands region. The JOSM program was developed in response to criticisms of the RAMP program discussed above. The JOSM program officially operated between 2012 and 2015, working with many of the same consulting companies that had operated the RAMP program, and publishing collaborative annual reports. After 2015, the JOSM program transitioned to the Oil Sands Monitoring (OSM) Program, which retained some but not all of the RAMP water quality sampling sites.

The design of the JOSM program included several core elements, including an integrated monitoring program that would aim to measure “accumulated state,” or changes in the aquatic environment that are outside of both local and regional baseline. Measuring accumulated state requires the establishment of a baseline state, however the JOSM design document acknowledged that establishing baseline water quality condition in the mineable oil sands region (OSR) would be challenging due to the low number of long-term water quality monitoring stations in the OSR, the general lack of water or sediment quality data from the time before oil sands development, and the changing nature of oil sands development stressors (mines and other facilities being built and expanding over time) (Wrona et al., 2011). In order to better estimate baseline conditions, the JOSM water quality program design suggested using modeling exercises, data mining existing reports for historic data, and using sediment cores from surface waters to provide information about historical conditions. The water quality design document also indicated that the JOSM program should include establishment of additional baseline or unimpacted reference sites to the extent possible, as well as include efforts to monitor impacted areas before and after development occurs in the future.

Measuring accumulated state also requires monitoring of landscape change over space and time, including changes in point and non-point source loadings of substances to surface waters

(Wrona et al., 2011). The separate types of oil sands development compliance and performance (i.e., follow-up) monitoring were mentioned in the JOSM water quality program design. It was noted that this monitoring data must be integrated into a standardised and accessible electronic reporting system that is shared with the larger regional monitoring program. Performance monitoring in particular was included as a requirement to verify or validate predictions made in Environmental Impact Assessments (Wrona et al., 2011).

The core results proposed for the JOSM water quality monitoring program were:

- Assessment of accumulated environmental condition or state;
- Improved understanding of the relationships between system drivers and environmental response; and,
- Cumulative effects assessment. (Wrona et al., 2011)

According to the JOSM design document, in the absence of these core results, "cumulative change cannot be detected, predicted, managed or mitigated." (p. 9).

Ten monitoring locations were selected for the mainstem Athabasca River, from the inflowing "boundary condition" M0 site at the town of Athabasca downstream to M9 the downstream boundary condition, closest to the Athabasca River Delta at Lake Athabasca and downstream of all oil sands development (see Figure 2.3 below). These sites incorporated several existing provincial and federal long-term monitoring program locations.

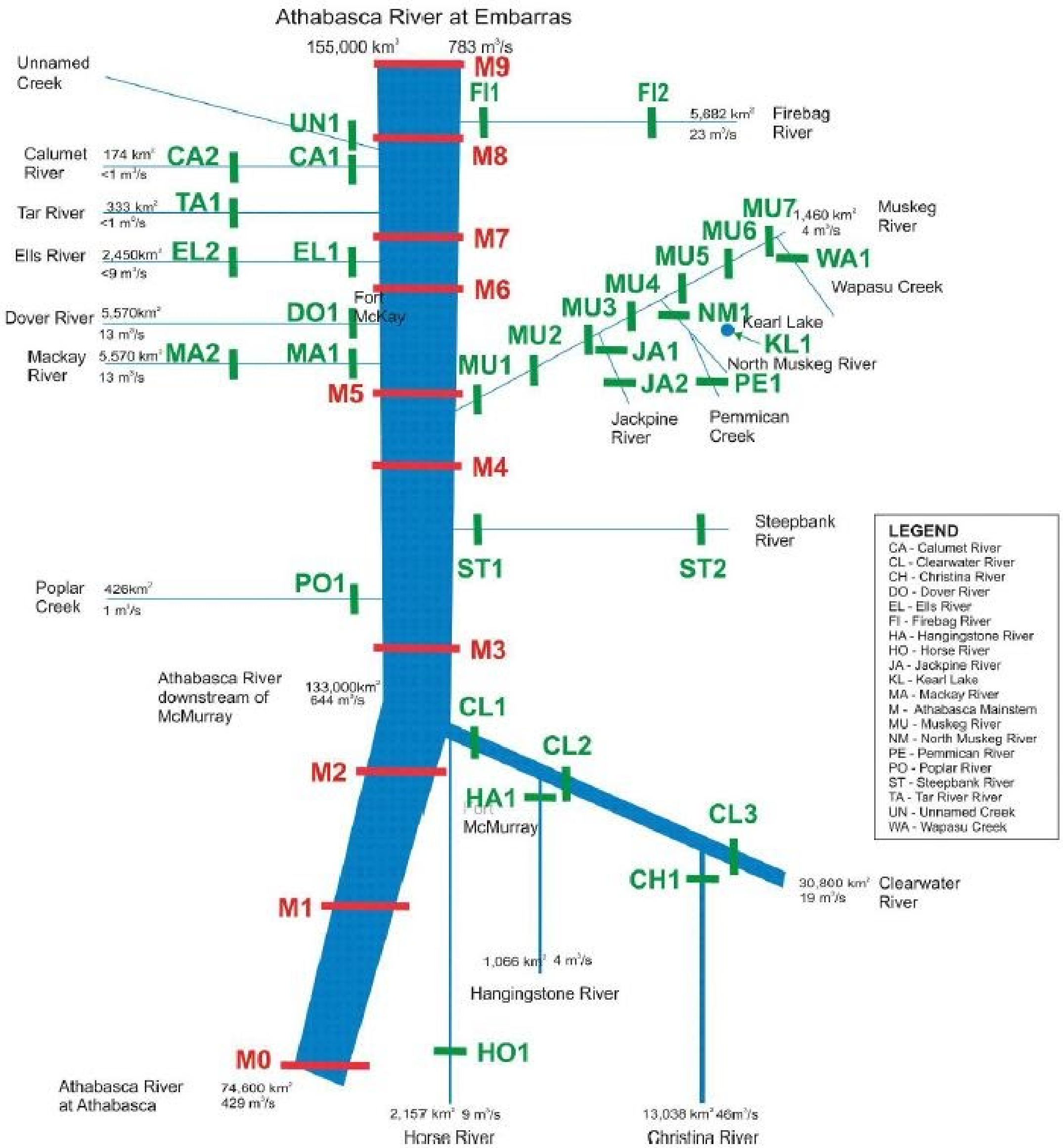

Figure 2.3: Schematic representation of proposed sampling sites on the Athabasca River mainstem and major tributaries (reproduced from Wrona et al. (2011), Figure 6).

The JOSM water quality program was designed to be integrated and coordinated with a hydrometric and sediment monitoring program, since it was recognized that sediment dynamics in the Athabasca River can be a significant driver of contaminant dynamics in the River and of contaminant loadings to downstream environments (Wrona et al., 2011). Groundwater quality monitoring was also meant to be coordinated with surface water quality monitoring as part of the program design, especially focused around oil sands mine tailings impoundments. Naphthenic acids, as a complex mixture of compounds that are a significant source of toxicity in oil sands process water, were targeted for further characterization, including by a fingerprinting research program conducted by Environment Canada (Wrona et al., 2011).

The JOSM program and its successor program, OSM, have been operating up to present day. In 2018, a series of summary reports were published for the JOSM aquatics program using data collected up to 2015. At that time, only one statistically significant longitudinal (upstream to downstream) trend in water quality was noted - a gradual increase in dissolved selenium between M3 and M6, after which concentrations stabilized downstream (Cooke et al., 2018). Those authors also noted a decreasing trend or stabilization of several nitrogen and phosphorus measures between the years 2000 and 2014 at the long-term monitoring site M9. These trends were linked by the authors to several changes in anthropogenic inputs, both upstream of Fort McMurray as well as at the Fort McMurray wastewater treatment plant, when the treatment process was improved significantly in 2010 (Cooke et al., 2018). Increasing trends between 2000 and 2014 in certain metal concentrations, including dissolved arsenic, aluminum and iron, as well as total selenium were also noted, as were decreasing and increasing trends for certain ions. After a water quality monitoring network rationalization exercise conducted in 2016, sampling at some of the mainstem Athabasca River monitoring sites was discontinued. The OSM program has not reported comprehensively on mainstem Athabasca River water quality since the 2018 reports. Recent program summaries have minimized the effect of existing effluent and water releases from oil sands developments (Culp et al., 2021)

2.4.4 Other Monitoring in the LAR, the PAD and Lake Athabasca

Several other large multi-year monitoring and research programs have been completed over the years, with support from provincial and federal government agencies and to varying extents the involvement of Indigenous communities. These include the Northern River Basins Study (1991-1996), the Peace-Athabasca Delta Technical Studies (1993-1996), and the Northern Rivers Ecosystem Initiative (1998-2004). Similar to the AOSERP program data, the availability of monitoring and sampling data generated by these programs is limited, with many of the data sets available only in published reports.

The province of Alberta has historically collected water quality data from Lake Athabasca, especially in the late 1980's and 1990's. This data is available from the province's surface water quality website under the "Lake Water Quality" program name, which includes data from lakes located across Alberta.

In addition to these long-term studies and monitoring programs, there have been many focused field programs and studies conducted by Indigenous communities, academic institutions, private industry and governments that encompassed water and sediment quality in the lower

Athabasca River region. The vast majority of these studies' data are not readily available in a digital format, and were not included in this study. However, digitizing these historical data sets for inclusion in an enhanced water and sediment quality characterization effort would be a worthwhile future project.

2.5 Methods

2.5.1 Data used in this Study

2.5.1.1 RAMP data

The RAMP water quality data is available for download from a dedicated website that is maintained by Alberta Environment and Parks. Both water and sediment quality data are available from the RAMP program for sites in the lower Athabasca River and the Athabasca River Delta channels. For all data used in this study, including RAMP data, it was assumed that data review and quality control was completed by the responsible program. Sediment quality samples were collected once per year in the fall. Water quality samples were collected from the Athabasca River and Delta in the fall, with one site sampled four times per year (ATR-DD). Water quality samples were also collected multiple times per year at two sites, upstream of Fort McMurray and at "Old Fort," but this actually reflects provincial long-term monitoring (Hatfield Consultants, 2009). Sediment quality was generally no longer sampled in the Athabasca River after 2004, and water quality was no longer sampled at most sites in the Athabasca River Delta channels after 2004.

Water samples were generally collected as near-surface grab samples, with the sample bottle uncapped and recapped at depth where possible (Hatfield Consultants, 2009). Field measures of water quality were obtained using a multiparameter sonde, a Winkler titration kit, a pH meter and a turbidity meter. Sediment samples were collected mainly with grab samplers or dredges (e.g., Ekman or Ponar grab), from depositional environments within river channels. At certain times, for example at some Athabasca Delta sites in 2005, a sediment corer was used to collect sediment samples for analysis (Hatfield Consultants, 2009).

The number of water quality parameters measured by RAMP also varied over time, but generally included basic chemical and physical properties, major ions, nutrients, metals, naphthenic acids and some polycyclic aromatic compounds (PACs). While the parameters analysed did not change substantially over the course of the program up until 2012, there were a few important changes to the analysed water quality parameters, including:

- addition of "ultra-trace" analysis of total mercury in water in 2002 (effectively lowers the detection limit, can detect lower concentrations)
- discontinuation of PAC analysis in water in 2005 due to non-detectable or very low concentrations in nearly all water samples
- discontinuation of chlorophyll analyses in water from streams and rivers in 2006 due to frequent non-detectable concentrations and a lack of correlation with nutrient parameters (chlorophyll continued to be measured in periphyton - or algae from the bottom of streams and rivers)
- a switch in the laboratory conducting metals analysis in 2002 (Hatfield Consultants, 2009)

In 2006, the RAMP sediment quality monitoring program was modified to better align with sampling of benthic invertebrates, and a one-time extensive sediment quality program was conducted in the Athabasca River Delta (Hatfield 2009). The parameters analysed in the RAMP sediment quality program generally included physical properties, carbon content, metals, various organic compounds, and 'parent' and alkylated polycyclic aromatic compounds (PACs). The analysed parameters changed over time as follows:

- addition of particle size distribution, total inorganic carbon, and total carbon in 1998
- addition of total volatile hydrocarbons (TVH) and total extractable hydrocarbons (TEH) in 2000
- switch to the Canadian Council of Ministers of the Environment (CCME) four-fraction hydrocarbon assay in 2005.

Analytical methods, and specifically VMV method codes, for RAMP water and sediment quality samples were taken from Table 1 and Table 2 of the Addenda to the RAMP Technical Design and Rationale Document (Hatfield Consultants, 2011), and verified through discussions with Hatfield Consultants personnel (M. Davies, pers. comm. October and September 2020) and staff of AXYS Analytical Services Ltd. (G. Brooks, pers. comm. December 2020).

2.5.1.2 LTRN and LWQ provincial data

The province of Alberta maintains two water quality sampling stations in the lower Athabasca River mainstem, as part of the provincial Long-Term River Network (LTRN) water quality monitoring program. The furthest upstream site is just upstream of Fort McMurray and the confluences of the Horse and Clearwater Rivers (AB07CC0030, also known in the JOSM/OSM program as site M2). Further downstream is the next site, which is upstream of the confluence with the Firebag River (AB07DA0980, also known in the JOSM/OSM program as site M8). Downstream in the Athabasca River Delta, two more LTRN sites together make up the station known as "Old Fort" (AB07DD0010, AB07DD0105). The annual water quality record for Old Fort from before 2016 is actually the combined monthly sampling at site AB07DD0010 during the open water season, and at AB07DD0105 during the ice-covered season (Kruk & Ballard, 2020). The two stations are separated by about 20 km and the confluence of the Richardson River. In 2016, year-round monthly sampling began at site AB07DD0010 ("Athabasca River at Old Fort - Right Bank") but site AB07DD0105 ("Athabasca River downstream of Devil's Elbow at Winter Road Crossing") remains a seasonal sampling site with data collected for the ice-covered season only.

Monthly sampling has been conducted either seasonally or year-round at the lower Athabasca River LTRN sites as early as 1987 upstream of Fort McMurray, since 1989 at Old Fort, and since 2008 at the site upstream of the Firebag River. LTRN water quality sampling has involved the analysis of hundreds of parameters, including basic chemical and physical properties, major ions, nutrients, metals, naphthenic acids, parent, alkylated and nitrogen-containing polycyclic aromatic compounds (PACs), pesticides, bacteriological measures, general organics, organohalides, phthalates, and phenolics. Not all of these parameters have been measured for the entire duration of the program, however. LTRN water samples in the lower Athabasca River were generally collected as near-surface grab samples or as vertically integrated samples (sample bottle on a sampling iron lowered through the water column) (GoA, 2019b).

LTRN water quality data are available for download via a dedicated website that is maintained by Alberta Environment and Parks10,11. However, for the purposes of this study, data were obtained directly via an email request to the Alberta Environment and Parks surface water data request email12, which provided a more comprehensive dataset with more measured parameters compared to what is available online.

The province of Alberta also maintains a website with water quality data obtained from lakes in the province, including from Lake Athabasca13, although provincial lake water quality (LWQ) data availability is not as consistent over time as the LTRN program. Water quality data from ten sites on Lake Athabasca were obtained by direct email request from Alberta Environment and Parks, and the majority of the data were collected in the late 1980's and early 1990's. There were dozens of water quality parameters measured, including basic chemical and physical properties, major ions, nutrients, chlorophyll a, metals, parent polycyclic aromatic compounds (PACs), bacteriological measures, general organics, organohalides, phthalates, phenolics and radium radiation. Vertical profile data for basic field measures were collected at some of the Lake Athabasca sites.

2.5.1.3 ECCC long-term monitoring data

Environment and Climate Change Canada (ECCC) maintains a water quality monitoring site on the lower Athabasca River as part of its National Long-Term Water Quality Monitoring Program. The site (AL07DD0001) is located North of the confluence with the Firebag River in the south-western corner of Wood Buffalo National Park, and is referred to as Athabasca River at 27 Baseline. The monitoring site has been maintained since 1989, but the official data set available from the ECCC website includes data from the year 2000 to present. Water is sampled at the site monthly, except in November and December, for basic chemical and physical properties, major ions, nutrients, metals, parent and alkylated polycyclic aromatic compounds (PACs), and pesticides. This site was incorporated into the JOSM/OSM program as M9 (see below), and is considered to reflect improvement or "recovery" conditions from impacts of oil sands development and WWTP-related impacts to water quality and other aquatic ecosystems (Glozier et al., 2018).

2.5.1.4 JOSM/OSM data

The Joint Oil Sands Monitoring (JOSM) and Oil Sands Monitoring (OSM) Programs, now just OSM, involved sampling for water quality in the lower Athabasca River mainstream and its tributaries. There are over a dozen sites on the River that are referred to as OSM sites, however in actuality, several of these overlapped with AEP LTRN sites (M0, M1, M2, M8) and ECCC long-term monitoring sites (M9). There were therefore five water quality sites that were established specifically for the JOSM-OSM program (M3 through M7), and in some cases these sites are in the vicinity of former RAMP sites.

Water quality data generated by the JOSM-OSM program were obtained from the federal Oil Sands Monitoring website14. Data were downloaded from the "mainstem" lower Athabasca River water quality dataset, which was collected starting in 2011 and with data available up to 2018.

The JOSM mainstem water quality program began with a comprehensive investigation of sampling methods and data variability in the River, from 2011 to 2014 (Glozier et al., 2018). Different field sampling methods and data treatments were investigated using a 10-panel cross-channel approach at each sampling site (Figure 2.4).

West Shore	Panel										East Shore
	1	2	3	4	5	6	7	8	9	10	
A) Ten Panel Isokinetic Composite	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	Physically Pooled
B) Ten Panel Sampling Iron Composite	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	Physically Pooled
C) Ten Panel Sampling Iron Grab	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	Statistically Pooled
D) 3 Panel Sampling Iron Grab			⊗			⊗		⊗		⊗	Statistically Pooled
E) Thalweg Sampling Iron Grab						⊗					Individual Grab

Figure 2.4: Schematic of multi-panel sampling approaches, categories and data treatment for statistical analyses (reproduced from Glozier et al. (2018), Figure 18).

The results of the methods investigation indicated that cross-channel variability in water quality was significant at OSM sites M3 through M7 in the mainstem. For this reason, the JOSM researchers recommended that vertically integrated water samples (taken from the top of the River water column down to the River bed) at the deepest point of the River in each cross-section site (the thalweg) become the standard JOSM water quality sampling method for the lower Athabasca River. Importantly, the JOSM researchers determined that water quality samples taken from just below the River water surface, usually from shore or even from the middle of the River, are not comparable to samples collected according to the JOSM standard (Glozier et al., 2018). This difference is most likely associated with the larger amount of suspended sediment and other particles that are carried in the River due to the different hydrodynamic forces through the water column at the thalweg, compared with at the water surface and especially along the shoreline, where water flow energy is lower (N. Glozier, personal communication, January 22 2021; C. Cooke, personal communication, January 28 2021).

A water quality network rationalization workshop was attended by JOSM researchers and others in 2016, and as a result sampling at sites M4, M5 and M6 were suspended after March 2017 (Cooke et al., 2018; Glozier et al., 2018). Water quality at these three sites was determined to be essentially the same, apart from an increase in dissolved selenium concentrations with distance downstream (Glozier et al., 2018). Sites M4-M6 were originally intended to monitor flow and water quality including constituent loads up and downstream of major tributary rivers, and the recommendation to suspend monitoring at these sites noted that conditions at M7 capture all inputs from major tributary rivers (Glozier et al., 2018). Sampling at sites M1 was also suspended as part of the program rationalization (sampled from shore by Alberta Environment and Parks, AB07CC0100). The program rationalization confirmed that site M0 and the “Grand Rapids” site upstream of the McMurray oil sands geological formation and

Fort McMurray are necessary to characterize conditions upstream of the oil sands region. Both of these sites are sampled by Alberta Environment and Parks (site codes M0 = AB07BE0010, Grand Rapids = AB07CC0130). The rationalization also identified a step-change in water quality parameters between sites M2 and M3 (Glozier et al., 2018). Both M2 and M3 are located within the McMurray formation and upstream of oil sands development, but site M2 is upstream of the wastewater treatment plant (WWTP) effluent release location while M3 is downstream of that location and therefore influenced by this effluent release. Site M2 is sampled from the shore by Alberta Environment and Parks (AB07CC0030), while sampling at M3 is conducted using the OSM depth-integrated at the thalweg and shoreline panel method. Sampling at M7 in the OSM program continues and water quality at that site is characterized as capturing cumulative effects of all oil sands development as well as inputs from major LAR tributaries (Glozier et al., 2018). There is also water quality data for the lower Athabasca River mainstem available as part of the OSM benthic invertebrate monitoring program, however that data was not used in this study. This is because the sampling methods used were best suited for characterization of the local habitat conditions, specifically erosional habitats where benthic invertebrates could be effectively sampled, rather than for characterization of the River as a whole.

2.5.1.5 MCFN and ACFN CBM data

MCFN and ACFN began water quality collection in 2011 as part of community-based monitoring (CBM) programs. These programs have several sites located throughout the Peace-Athabasca Delta, as well as the Athabasca River and Lake Athabasca. Sampling is ongoing and generally occurs throughout the open water season. Water quality data from these programs were obtained from the program manager (B. Maclean and C. Bampfylde, pers. comm.), and are also available online (MCFN15 and ACFN16). Generally speaking, these programs have involved the approximately weekly collection of "field" water quality data using a multi-sensor sonde during the open water season, as well as more detailed near-surface grab water samples for laboratory analyses approximately four times a year, although this approach has varied over the years. Finalized data for this monitoring program were obtained directly from the program managers, for sampling between 2014 and 2019. Field-measured water quality data for both the ACFN and MCFN CBM programs are reported as water-column average values.

2.5.1.6 Enhanced Monitoring Program data

The Enhanced Monitoring Program is a focused study of water and sediment quality in the lower Athabasca that was initiated as part of the work of the Oil Sands Process Water (OSPW) Science Team and has been funded by the Oil Sands Monitoring (OSM) program. The Enhanced Monitoring program collected water and sediment quality samples during 2018 and 2019 in a localized area near a proposed mine water release site, in addition to sites further up- and downstream in the Athabasca River. Because bed sediment quality data for the lower Athabasca River in recent years is not otherwise readily available, data from this program was used in part to characterize sediment quality in the mainstem Athabasca River. Water quality data for this program are currently available through a publicly accessible website supported by the OSM program, however, sediment quality data were provided by the study's lead researcher (K. Hicks, pers. comm).

2.5.1.7 Compiled Sites – Water

Table 2.1 below lists all of the monitoring site locations by water quality monitoring program, for all data compiled in this study. The sites from which data were used to calculate current conditions are indicated in bold text in the table, and all data compiled from all programs are presented in Appendix A.1.

Table 2.1: Names and locations of monitoring sites that were included in the water quality data compilation. Bolded rows indicate locations used in the calculation of current conditions. The selection rationale for these locations is explained in the data selection methods sections below.

Section	Site Name	Program	Latitude	Longitude
Athabasca River	AB07CC0030	LTRN	56.720280	-111.40556
Athabasca River	AB07DA0980	LTRN	57.723610	-111.37917
Athabasca River	AL07DD0002	JOSM	56.720611	-111.40283
Athabasca River	**AL07DD0004 (M4)**	**JOSM**	**57.127639**	**-111.60003**
Athabasca River	**AL07DD0005 (M5)**	**JOSM**	**57.157583**	**-111.62394**
Athabasca River	**AL07DD0007 (M7)**	**JOSM**	**57.313950**	**-111.66737**
Athabasca River	**AL07DD0008 (M3)**	**JOSM**	**56.839910**	**-111.41164**
Athabasca River	**AL07DD0009 (M6)**	**JOSM**	**57.215300**	**-111.60727**
Athabasca River	Snowbirds	ACFN/MCFN	58.355402	-111.54556
Athabasca River Delta	**AB07DD0010**	**LTRN**	**58.382780**	**-111.51778**
Athabasca River Delta	**AB07DD0105**	**LTRN**	**58.447220**	**-111.18583**
Athabasca River Delta	Athabasca River	ACFN/MCFN	58.657433	-110.77628

Table 2.1: Names and locations of monitoring sites that were included in the water quality data compilation. Bolded rows indicate locations used in the calculation of current conditions. The selection rationale for these locations is explained in the data selection methods sections below. *(continued)*

Section	Site Name	Program	Latitude	Longitude
Athabasca River Delta	Athabasca River at Cutoff	ACFN/MCFN	58.397113	-111.52733
Athabasca River Delta	Athabasca at Embarras Portage	ACFN/MCFN	58.397113	-111.52733
Athabasca River Delta	Embarras Lowpoint	ACFN/MCFN	58.472286	-111.48958
Athabasca River Delta	Embarras River	ACFN/MCFN	58.685627	-111.05304
Athabasca River Delta	Fisherman's Channel	ACFN/MCFN	58.661893	-110.77168
Athabasca River Delta	Goose Island Channel	ACFN/MCFN	58.669596	-110.87028
Lake Athabasca	**Dock Site**	**ACFN/MCFN**	**58.690843**	**-111.15889**
Lake Athabasca	**Lake Athabasca**	**ACFN/MCFN**	**58.711461**	**-111.08976**
Lake Athabasca	**Water Intake**	**ACFN/MCFN**	**58.710816**	**-111.14499**

Note:
Bolded rows indicates that the site contributed to the current condition calculation.

2.6 Compiled Sites – Sediments

Table 2.2 below lists all of the monitoring site locations by sediment quality monitoring program, for all data compiled in this study. The sites from which data were used to calculate current conditions are indicated in bold text in the table, and all data compiled from all programs are presented in Appendix A.1.

Table 2.2: Names and locations of monitoring site that were included in the sediment quality data compilation. Bolded rows indicate locations used in the calculation of current conditions. The selection rationale for these locations is explained in the data selection methods sections below.

Section	Site Name	Program	Latitude	Longitude
Athabasca River	**AB07DA0062**	**OSPW**	**56.850200**	**-111.42064**
Athabasca River	**AB07DA0800**	**OSPW**	**57.330470**	**-111.67964**
Athabasca River	**AB07DA3008**	**OSPW**	**57.122941**	**-111.60156**
Athabasca River	**AB07DA3009**	**OSPW**	**57.070580**	**-111.53305**
Athabasca River	**AB07DA3015**	**OSPW**	**57.047184**	**-111.50941**
Athabasca River	**AB07DA3016**	**OSPW**	**57.047853**	**-111.51138**
Athabasca River	**AB07DA3017**	**OSPW**	**57.039101**	**-111.50832**
Athabasca River	**AB07DA3018**	**OSPW**	**57.037512**	**-111.50970**
Athabasca River	**AB07DA3020**	**OSPW**	**57.034986**	**-111.50558**
Athabasca River	**AB07DA3021**	**OSPW**	**57.033723**	**-111.50386**

Table 2.2: Names and locations of monitoring site that were included in the sediment quality data compilation. Bolded rows indicate locations used in the calculation of current conditions. The selection rationale for these locations is explained in the data selection methods sections below. *(continued)*

Section	Site Name	Program	Latitude	Longitude
Athabasca River	**AB07DA3022**	**OSPW**	**57.029219**	**-111.50218**
Athabasca River	**AB07DA3023**	**OSPW**	**57.009880**	**-111.47409**
Athabasca River	**AB07DA3024**	**OSPW**	**56.939911**	**-111.44329**
Athabasca River	ATR-DC-CC	RAMP	56.826557	-111.40931
Athabasca River	ATR-DC-E	RAMP	56.826562	-111.40767
Athabasca River	ATR-DC-M	RAMP	56.826538	-111.40839
Athabasca River	ATR-DC-W	RAMP	56.826540	-111.40796
Athabasca River	ATR-DD-CC	RAMP	57.453661	-111.60622
Athabasca River	ATR-DD-E	RAMP	57.452778	-111.60232
Athabasca River	ATR-DD-W	RAMP	57.455284	-111.60981
Athabasca River	**ATR-ER**	**RAMP**	**58.353316**	**-111.54185**
Athabasca River	ATR-FC-CC-D	RAMP	57.407729	-111.64489
Athabasca River	ATR-FC-E	RAMP	57.407625	-111.64035
Athabasca River	ATR-FC-E-D	RAMP	57.409593	-111.64048
Athabasca River	ATR-FC-M	RAMP	57.407759	-111.64527
Athabasca River	ATR-FC-W	RAMP	57.407621	-111.64987
Athabasca River	ATR-FC-W-D	RAMP	57.410182	-111.64984
Athabasca River	ATR-FR-CC	RAMP	57.740747	-111.36842
Athabasca River	ATR-FR-E	RAMP	57.744557	-111.36186
Athabasca River	ATR-FR-W	RAMP	57.746842	-111.36907
Athabasca River	ATR-MR-E	RAMP	57.131901	-111.60292
Athabasca River	ATR-MR-E-D	RAMP	57.133029	-111.60510
Athabasca River	ATR-MR-M	RAMP	57.131120	-111.60509
Athabasca River	ATR-MR-W	RAMP	57.130189	-111.60786
Athabasca River	ATR-MR-W-D	RAMP	57.132301	-111.60898
Athabasca River	ATR-SR-E	RAMP	57.019199	-111.47867
Athabasca River	ATR-SR-M	RAMP	57.017546	-111.48007
Athabasca River	ATR-SR-W	RAMP	57.015363	-111.48112
Athabasca River	ATR-UFM	RAMP	56.718330	-111.40307
Athabasca River Delta	**ARD-1**	**RAMP**	**58.590791**	**-110.79524**
Athabasca River Delta	**ARD-2**	**RAMP**	**58.439591**	**-111.29812**
Athabasca River Delta	**ATR-OF**	**RAMP**	**58.408734**	**-111.50990**
Athabasca River Delta	**BEC**	**RAMP**	**58.452500**	**-111.06111**
Athabasca River Delta	**BPC-1**	**RAMP**	**58.590791**	**-110.79524**
Athabasca River Delta	**BPC-2**	**RAMP**	**58.462714**	**-110.85983**

Table 2.2: Names and locations of monitoring site that were included in the sediment quality data compilation. Bolded rows indicate locations used in the calculation of current conditions. The selection rationale for these locations is explained in the data selection methods sections below. *(continued)*

Section	Site Name	Program	Latitude	Longitude
Athabasca River Delta	**EMR-1**	**RAMP**	**58.358268**	**-111.55015**
Athabasca River Delta	**EMR-2**	**RAMP**	**58.567500**	**-111.09222**
Athabasca River Delta	**FLB-1**	**RAMP**	**58.447996**	**-110.91532**
Athabasca River Delta	**FLC-1**	**RAMP**	**58.564539**	**-111.06220**
Athabasca River Delta	**GIC-1**	**RAMP**	**58.588101**	**-110.83525**

Note:
Bolded rows indicates that the site contributed to the current condition calculation.

2.7 Calculation of Current Conditions

2.7.1 Data standardization

One of the most significant challenges in assembling water and sediment quality data from multiple sources is to standardize the data descriptions to ensure that the same or similar measurement and analytical methods are used for the compiled parameter-specific data sets Sprague et al. (2017). This allows for a comparison of “apples to apples” in terms of each specific parameter across all programs.

The United States Environmental Protection Agency (US EPA) has created a data standard framework for discrete non-continuous water quality dataset reporting, known as WQX, or Water Quality Exchange[6]. This framework was adopted by the DataStream initiative in Canada, an open access platform for sharing surface water quality and sediment quality data developed and maintained by the non-profit Gordon Foundation[7]. As part of its program, DataStream produced an upload template [8] as well as nutrient data standardization guidance [9]. This template was used in this study to compile water and sediment quality data from all of the source data sets. The nutrient guidance document was also followed, specifically the separation of filtration status and extraction/sample preparation status, in order to avoid ambiguity and ensure comparability. According to that guidance, the terms “filtered,” “unfiltered” and “non-filterable” were assigned to account for the more conventional sample fraction descriptions “dissolved,” “total” and “particulate.” At the same time the term “total” was

[6]https://www.epa.gov/waterdata/water-quality-data
[7]https://gordonfoundation.ca/initiatives/datastream/
[8]https://datastream.cdn.prismic.io/datastream/8af9357f-b1aa-40dd-ba5c-59fa990c01f2_DataStream+Upload+Template+2.5_Jan2021.xlsb
[9]https://datastream.cdn.prismic.io/datastream%2F9d12bb3f-e456-4de0-9613-f8f7e50f221a_datastream+nutrient+data+best+practices+guide_march2019.pdf

assigned to encompass multiple forms including organic/inorganic, ionic/biological, etc. For example, the parameter "Total nitrogen, mixed forms" refers to multiple forms of nitrogen (i.e., organic nitrogen, ammonia, nitrate, nitrite) and is accompanied by an additional sample fraction qualifier, namely filtered, unfiltered or non-filterable. These combinations would therefore correspond to the more conventional terms total dissolved nitrogen, total nitrogen and total particulate nitrogen, respectively. Care was taken to ensure that reported method speciation aligned or were converted to equivalence (e.g., all forms of nitrogen reported 'as N,' and not separately as N, NO3, NH4, etc., when combining and comparing across data sets).

A similar approach was taken for trace elements and metals, where the filtration status was reported separately, as the sample fraction, while the characteristic name indicated the type of extraction methods used. Generally, little to no extraction was conducted for dissolved metals, acidification over time was used for extractable metals, acidification and heat were applied for total metals, and acidification, heat and increased pressure for total recoverable metals.

Detailed method descriptions were consulted to determine the preparation and analytical methods used for each parameter, and clarifications were made with the data holder. For almost all programs, valid method variable, or VMV codes, were provided for each observation. VMV codes are specific to several aspects of laboratory analysis, including sample preparation and analysis methods, and detection limits. VMV dictionary files were provided by both Alberta Environment and Parks and Environment and Climate Change Canada researchers (N. Glozier, pers comm.), to account for differences between VMV schemes in use by the two agencies. For certain data from the RAMP program, as well as for ACFN and MCFN CBM water data, VMV codes were not provided in the original data sets. Instead, other standardized methods contexts, including US EPA and American Public Health Association (APHA) method numbers, are provided wherever possible. Additional method information was obtained from the data holders and responsible laboratories where possible. Where it wasn't possible to determine aspects of the methods used, especially for sample fraction (filtration status), the label "unknown" was added to the parameter name instead. No outliers were removed from datasets, and only finalized data that had undergone program-specific quality control measures were used in this study (please refer to each program for details of these measures).

A purpose-built PostgreSQL database was created to house all of the compiled data sets, with native support for International System of Units (SI) units. This means that the original source data along with the respective unit and method speciation were imported as a complete observation, and were converted to a standard unit for analysis and display as required. Each parameter in the database was differentiated for analysis and reporting as a unique combination of basic parameter name, method speciation and sample fraction. The integrity of data in the database was controlled through automated data subset checks including unit conversion checks, before-and-after aggregate counts and value sum tests. This data flow is illustrated in Figure 2.5 below.

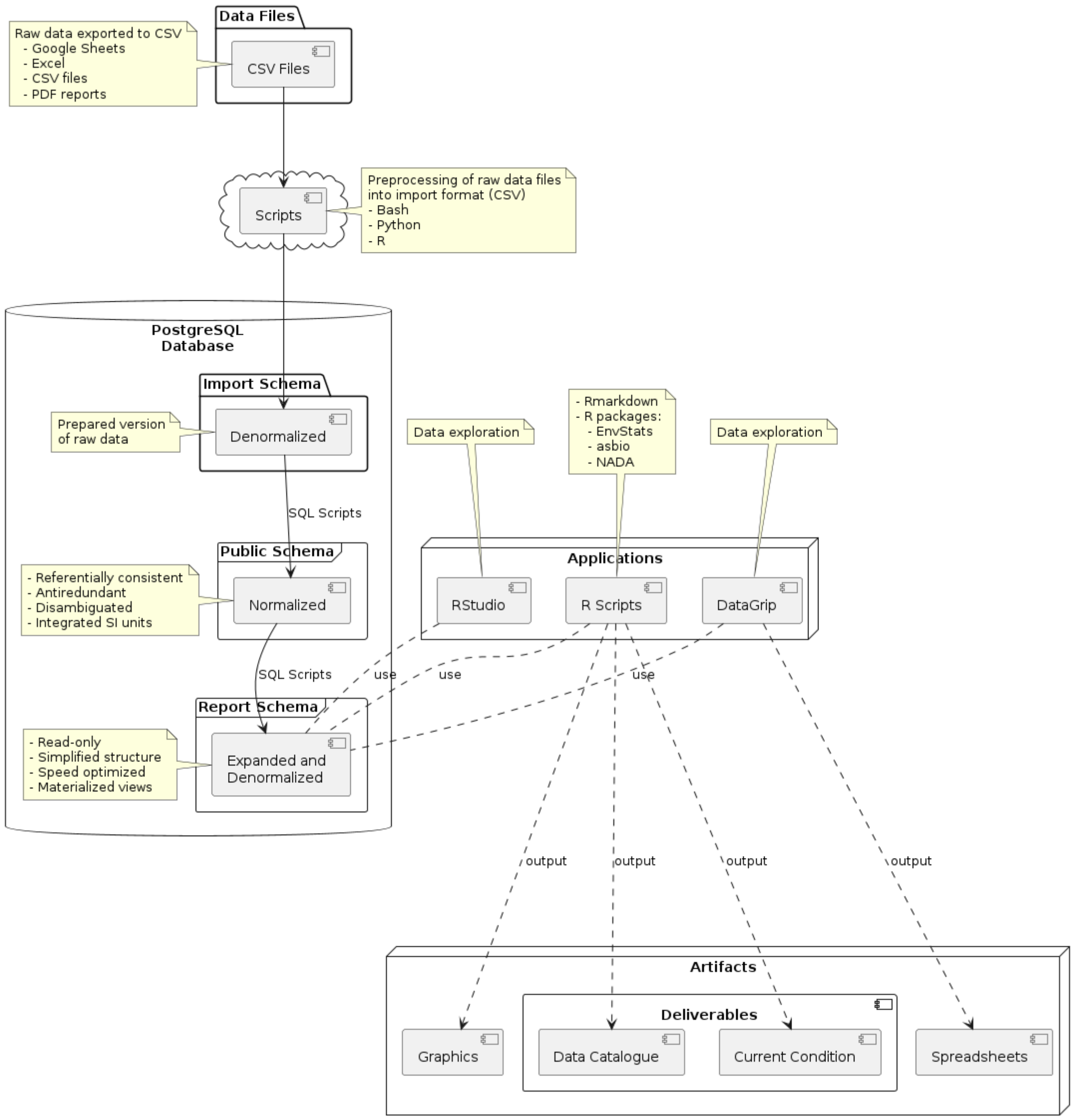

Figure 2.5: High-level data flow used to generate the current conditions.

While only a subset of the compiled water and sediment quality data were used to calculate current conditions (see selection criteria below), all of the compiled data are presented in Appendix A.1 using summary tables and figures.

2.7.2 Treatment of censored data

Water quality datasets often include what is referred to as “censored” data points or non-detects. Censored data are data that are reported as above or below some threshold value, without an actual specific value (Helsel et al., 2020). This usually occurs in water quality data that are reported as below or above a method detection limit. In general, detection limits, sometimes referred to as quantitation limits, refer to the lowest or highest constituent concentration that can be accurately measured. This can apply to measures collected using equipment or sensors in the field, or to laboratory analyses. If a sample is reported as having a concentration of a certain water quality constituent below a detection limit, then the actual concentration is somewhere between zero and the detection limit. However, the exact value is unknown. Dealing with censored data correctly is a very important step in water quality data analysis, especially when the goal is to characterize the range in values for a parameter from a dataset that includes censored data points. This is because the value of those censored data points is unknown, however data analysts will often assign a value to them in order to facilitate statistical analysis. This results in an estimated value that is usually an overestimate or underestimate of the real value and, especially where the detection limit is much higher or lower than the real values, the resulting findings and conclusions can be unacceptably inaccurate.

In this study, censored data are not removed from datasets and they are not substituted with another value before conducting statistical analyses. Instead, censored data points were replaced with the detection limit value or with the highest detection limit value in that compiled dataset (i.e., recensoring), depending on the input requirements of the statistical test conducted (after (Helsel, 2011)). Non-parametric rank-based analysis was used for censored data sets, which does not rely on estimating the actual value of censored data points. Non-parametric statistical analyses are often most appropriate because water and sediment quality data in general and censored data specifically often don't meet the requirements of parametric analysis.

2.7.3 Seasons (high flow, open water, under ice)

In this study, water quality data for the Athabasca River and its Delta as well as Lake Athabasca are considered in the context of the hydrological seasons outlined in Glozier et al. (2009). There is significant variation in water quality in the Athabasca River with variation in flow, especially during high flows in spring, in response to storm events during summer and fall, and in the winter under ice. Table 2.3 below outlines the months that are included in these seasons, along with the season names used by (2009) and in this study. Consultations with the program manager of the ACFN and MCFN CBM program confirmed that these seasons also reflect seasonal changes in Lake Athabasca, although the specific conditions may not be the same.

Table 2.3: Season names

Months	Season name in Glozier et al	Season name in this study
May-July	Spring/Summer	High Flow
August-October	Fall	Open Water
November-April	Winter	Under Ice

2.7.4 Monitoring Location Categories

Water and sediment quality data from the lower Athabasca River, its Delta and Lake Athabasca were assigned to overarching locations, based on these spatial designations. The focal length of the Athabasca River reaches from just upstream (south and west) of the city of Fort McMurray downstream (north) to the separation of the Embarras River from the Athabasca River. This separation also defined the beginning of the Athabasca River Delta, and the focus in this study was the Athabasca River Delta channels. Data from lakes and other rivers and tributaries in the Delta were not included in this study, despite the fact that those aquatic ecosystems have important connections to the channels and the River basin as a whole. Finally, data from Lake Athabasca defined the most downstream (northerly) location category used in this study.

2.7.5 Statistical Methods

In order to characterize water and sediment quality compiled for each study area, the data were first tested for differences across laboratory analysis methods and sampling sites, where more than one method per parameters and multiple sampling sites were included in the data set. Before analysis, censored data points were re-censored to the highest detection limit in the dataset. Then a non-parametric Brunner-Dette-Munk (BDM) test was performed for each water and sediment quality parameter (Helsel et al., 2020). The BDM tests for differences in cumulative distributions between parameter - specific data sets, and does not require that the tested data sets follow a normal distribution or that the compared datasets have equivalent variability (i.e., are 'homoscedastic'). In this case, a two-factor BDM test was conducted to test for differences in distributions between values of the two factors "analysis method" and "sampling site" (Aho 2015; Helsel et al. 2020). The BDM test compares distribution functions, and specifically the frequency of high vs. low values, between data subsets for each identified factor (Helsel et al. 2020). In this study a significant difference was determined where p values <0.05. If a significant difference in data distribution was found according to the analysis method factor, the smaller or less consistent over time data set(s) was removed from the analysis, so that only a single method remained. In practice, this situation only occurred in the LTRN water quality data for the Athabasca River Delta current condition calculations. Data for total dissolved solids (VMV 10451, n=6), manganese (VMV 102089, n=103, and iron (VMV 102090, n=103) were removed in favour of alternative method data with relatively more post-2011 observations. If a difference was found according to sampling site, then the data were separated into site-specific sets for further analysis and reporting. Where no differences were found, data were pooled across methods and/or sites for further analysis.

After data groupings were determined, parameter and season-specific quantiles were calculated and reported, specifically the 5th, 50th, and 95th percentile. These percentiles represent the parameter value at which 95%, 50% and 5% of the parameter data points have a greater value. Therefore, the 5th percentile value indicates a very low parameter value, the 50th percentile the middle or median parameter value, and the 95th percentile a very high parameter value. In other words, these percentiles indicate the lowest, middle and highest parameter values, or a range of 'normal' parameter values, for a given location. The 5th and 95th percentiles are used to define the end values instead of the minimum and maximum values because the latter can include very extreme values registered under exceptional circumstances, and may also include values that reflect errors such as sample contamination or equipment malfunction. Such extreme values will unavoidably be reported in the future, however, they should make up no more than the upper and lower 5% of a data set. Both the lower and upper bounds of parameter value ranges are important because impacts on aquatic ecosystems can occur both where concentrations of constituents are too high or too low (e.g., alkalinity, dissolved oxygen). In addition, the upper and lower bounds of certain parameter values are important in determining the extent to which they modify the toxicity of other constituents (e.g., pH, temperature, dissolved organic carbon). The use of percentiles in water and sediment quality data summaries is common in environmental impact assessments, and the 95th percentile is used to define water quality triggers in the Surface Water Quality Management Framework of the Lower Athabasca Regional Plan (Alberta Environment and Sustainable Resource Development (AESRD), 2012).

For non-censored data sets, a straightforward quantile method was used to determine these percentile values using a "weibull" plotting position approach ("quantile' function in R with type=6, formula (i)/(n+1), where i = rank of observation and n = sample size)(Helsel et al. 2020). For censored data, a robust regression on order statistics (robust ROS) method was used to estimate the 5th, 50th and 95th percentiles, except where the data set size (n) was greater than 50 and the level of data censoring was between 50% and 80%. In the latter case, a maximum likelihood estimate (MLE) method for censored data was used (after guidance in Bolks, DeWire, and Harcum (2014)). For datasets that were more than 80% censored, no estimation of quantiles was performed. Both the robust ROS and censored MLE methods involve interpolation approaches to estimate quantile values, including below the uncensored detection limit value. In other words, these methods estimate the frequency distribution below (or above, as applicable) the detected data values, usually including the 5th percentile value and, in some cases, the 50th percentile value.

In cases where the censored MLE method was used to estimate quantile values, grouped or non-grouped (as required) parameter data were tested to determine the best-fit distribution from the following possibilities; normal (Gaussian), lognormal, and gamma. This was done by calculating and maximizing a probability plot correlation coefficient (PPCC) for each distribution type after Helsel (2011). If the normal distribution was identified as the best fit, the dataset 5th percentile was examined to determine whether it was non-negative. If it was negative, then the normal distribution was discarded in favour of the next best fit distribution.

2.7.6 Lower Athabasca River Data Selection

This study uses the water quality data collected by the JOSM/OSM programs in the lower Athabasca River using the vertically-integrated-at-the-thalweg field sampling method to characterize current water quality in the River. While there was also extensive LTRN and RAMP program data available for water quality in the lower Athabasca River, the sampling method employed by those programs (generally nearshore via wading and often just below the water surface) meant that it was not suitable to be combined with the JOSM/OSM program data (C. Cooke and N. Glozier, pers. comms.). The JOSM/OSM data were favoured in this case because the sampling method used - vertically integrated sampling at the thalweg - was shown to best reflect and encompass the variability in lateral and vertical constituent concentrations, and therefore, to also best approximate and align with constituent loads in the River (Glozier et al., 2018).

The drawback of using the JOSM/OSM water quality data to characterize conditions in the lower Athabasca River is that the data are limited in terms of the period of record, which begins in 2012 and continues up to the most recently available data from 2019. In comparison, the period of record for the two LTRN sites in the lower Athabasca River begins much earlier, in 1987, and continues up to the most recently available data from 2019. The longer period of record for LTRN is a valuable record of conditions over that time period, and would be more amenable to an evaluation of trends over time (N. Glozier, pers. comm.). Therefore, the water quality conditions characterized using the JOSM/OSM data reflect recent and current conditions, and not historical conditions such as pre-development or during the increasing levels of anthropogenic and industrial development that occurred prior to 2012.

The analytical methods used in the JOSM/OSM program include two different methods for analysis of total metals or trace elements. These are a 34-element suite that is "in-bottle digest" as well as a 45-element suite referred to as "modified EPA 200.8 ICP-MS." Data from the two different methods are not combinable (N. Glozier, pers. comm.), and therefore data derived using the "in-bottle digest" 34-element suite methods were removed from this analysis.

Sediment data for the lower Athabasca mainstem consisted of RAMP and OSM-funded Enhanced Monitoring Program data. The RAMP sediment data were collected from the Athabasca mainstem in the fall over the years 1997 through 2005, with additional limited sampling between 2007 and 2013. The Enhanced Monitoring Program sediment data were collected in the fall of 2018 and 2019 as grab samples from sites along a roughly 60 km river length, centred around a potential future discharge location adjacent to the Syncrude Mildred Lake mine site. In order to align with the time span considered for the Athabasca River water quality analysis, post-2011 data were included in the sediment quality analysis. Where data were obtained using methods that were not appropriate for grouping, the methods with the shortest period of record and/or the smallest sample size were removed from the analysis. For the most part, this meant that the Enhanced Monitoring program data was favoured, due to the much higher number of samples collected in recent years.

2.7.7 Athabasca River Delta Data Selection

The longest water quality data set in the Athabasca River Delta channels is for the provincial LTRN sites AB07DD0010 and AB07DD0105, also known as Athabasca River at Old Fort and downstream of Devil's Elbow at Winter Road Crossing, respectively. These sites combined are the composite "Old Fort" provincial water quality site that serves as the focal point for the Lower Athabasca Regional Plan (LARP) Surface Water Quality Management Framework. Several of the methods used by the LTRN and by the MCFN and ACFN CBM programs to measure the same parameter were not compatible for grouping, and many of the multiple methods used over time within the LTRN program were also not combinable. Given the longer period of record, more frequent sampling, and larger number of parameters measured, the LTRN data was used for this analysis. The LTRN data set was truncated to include only post-2011 data in the analysis, since several analytical methods for multiple parameters were changed between the years 2008 and 2010 and were not combinable.

Sediment quality data were available from the RAMP program for the Athabasca River Delta. Those data were collected in the fall between 2000 and 2016, and the analytical methods used were consistent over time.

2.7.8 Lake Athabasca Data Selection

The longest water quality dataset in Lake Athabasca is for sites from the ACFN and MCFN CBM programs. Data from the two sites, near the Fort Chipewyan water intake and at the Dock site, have been collected about four times a year since 2011. The available provincial water quality data for Lake Athabasca didn't generally consist of long-term data sets, but did include data from eight locations on the lake. In addition, while the CBM data is relatively recent, the provincial LWQ data is strictly more historical, collected between the late 1980's and early 1990's. For both the ACFN and MCFN CBM programs, the sampling and analytical methods used were the same, and in particular the field-measured parameter data are average values from water column profile data taken at 1m intervals. Given that it is a long-term and recent dataset, the ACFN MCFN CBM data were used to calculate current conditions in Lake Athabasca.

There were no sediment quality data obtained for Lake Athabasca from the monitoring programs surveyed in this study.

2.8 Results

2.8.1 Lower Athabasca River Current Conditions

The current condition (5th, 50th, and 95th percentile values) for each water and sediment quality parameter and each season are presented for the lower Athabasca River in Table 2.4 (water) and Table 2.5 (sediment). Note that additional information, including sample size, analytical method codes, and quantile estimation method for each suite of current conditions are provided in Appendix A.2.

Table 2.4: Current Conditions, Athabasca River water.

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
Conventional Variables											
Alkalinity, Phenolphthalein (total hydroxide+1/2 carbonate) as CaCO3	mg/L	all sites	-	-	-	1.00	6.40	7.06	-	-	-
Alkalinity, total as CaCO3	mg/L	all sites	61.05	89.00	99.09	81.54	101.00	122.00	+	+	+
	mg/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0007	+	+	+	+	+	+	133.00	147.00	165.00
	mg/L	AL07DD0008	+	+	+	+	+	+	89.00	163.00	199.00
	mg/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Fixed suspended solids, Non-Filterable (Particle)	mg/L	all sites	30.50	166.00	661.80	3.95	20.40	125.70	<	<	<
Organic carbon, Filtered	mg/L	all sites	3.53	12.20	16.36	4.24	7.90	17.50	5.49	7.43	10.40
Organic carbon, Non-Filterable (Particle)	mg/L	all sites	1.23	4.01	13.17	0.39	0.98	5.07	0.09	0.23	0.47
Specific conductivity	uS/cm	all sites	160.90	216.00	263.10	213.20	266.00	322.20	318.85	409.50	484.75
Total suspended solids, Non-Filterable (Particle)	mg/L	all sites	37.04	183.00	719.90	9.64	24.00	141.50	<	<	<
True colour, Filtered	TCU	all sites	-	-	-	-	-	-	-	-	-
True colour, Supernate	rel units	all sites	5.00	60.00	98.25	6.00	25.00	88.00	5.00	15.00	35.00
Turbidity	NTU	all sites	18.49	69.00	219.00	5.28	12.20	95.20	1.84	3.65	6.63
pH, lab	pH units	all sites	7.79	8.09	8.32	7.94	8.22	8.38	7.65	7.84	8.12
Dissolved Metals											
Aluminum, Filtered	ug/L	all sites	7.68	32.35	117.90	5.06	16.00	56.68	3.83	13.20	28.20
Antimony, Filtered	ug/L	all sites	0.04	0.07	0.12	0.03	0.05	0.11	+	+	+

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.04	0.06	0.11
	ug/L	AL07DD0008	+	+	+	+	+	+	0.02	0.05	0.13
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Arsenic, Filtered	ug/L	all sites	0.37	0.55	0.81	0.36	0.49	0.73	0.32	0.46	0.66
Barium, Filtered	ug/L	all sites	24.52	43.75	55.41	27.22	49.10	63.38	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	62.30	71.90	79.90
	ug/L	AL07DD0008	+	+	+	+	+	+	24.90	86.65	109.00
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Beryllium, Filtered	ug/L	all sites	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.01
Bismuth, Filtered	ug/L	all sites	0.00	0.00	0.00	0.00	0.00	0.00	<	<	<
Boron, Filtered	ug/L	all sites	12.84	21.60	30.28	15.18	23.30	31.22	30.39	36.35	41.60
Cadmium, Filtered	ug/L	all sites	0.00	0.01	0.03	0.00	0.01	0.02	0.00	0.01	0.03
Cerium, Filtered	ug/L	all sites	0.04	0.18	0.60	0.02	0.07	0.27	0.02	0.06	0.08
Cesium, Filtered	ug/L	all sites	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.01
Chromium, Filtered	ug/L	all sites	0.05	0.10	0.25	0.03	0.06	0.14	0.06	0.08	0.13
Cobalt, Filtered	ug/L	all sites	0.04	0.07	0.17	0.04	0.08	0.12	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.04	0.06	0.09

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	ug/L	AL07DD0008	+	+	+	+	+	+	0.04	0.05	0.09
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Copper, Filtered	ug/L	all sites	0.62	1.28	2.41	0.42	0.66	1.56	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.28	0.58	0.96
	ug/L	AL07DD0008	+	+	+	+	+	+	0.31	0.56	1.26
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Gallium, Filtered	ug/L	all sites	0.01	0.02	0.04	0.00	0.01	0.06	0.00	0.01	0.06
Germanium, Filtered	ug/L	all sites	0.01	0.01	0.02	0.01	0.01	0.01	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.01	0.01	0.02
	ug/L	AL07DD0008	+	+	+	+	+	+	0.01	0.01	0.01
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Indium, Filtered	ug/L	all sites	<	<	<	<	<	<	<	<	<
Iron, Filtered	ug/L	all sites	22.64	190.50	572.75	37.76	157.00	445.60	72.11	255.00	563.50
Lanthanum, Filtered	ug/L	all sites	0.02	0.10	0.28	0.01	0.04	0.15	0.01	0.03	0.05
Lead, Filtered	ug/L	all sites	0.02	0.09	0.30	0.01	0.04	0.13	0.02	0.03	0.07
Lithium, Filtered	ug/L	all sites	3.98	5.39	7.37	4.80	6.03	8.58	7.96	9.98	11.37
Manganese, Filtered	ug/L	all sites	0.58	2.71	5.57	0.71	2.06	5.84	2.20	7.91	12.01
Molybdenum, Filtered	ug/L	all sites	+	+	+	0.33	0.69	0.91	+	+	+
	ug/L	AL07DD0004	0.40	0.59	2.88	+	+	+	-	-	-
	ug/L	AL07DD0005	0.50	0.63	0.73	+	+	+	-	-	-
	ug/L	AL07DD0007	0.63	0.74	0.96	+	+	+	0.64	0.79	0.88

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
	ug/L	AL07DD0008	0.26	0.53	0.81	+	+	+	0.23	0.89	1.14
	ug/L	AL07DD0009	-	-	-	+	+	+	-	-	-
Nickel, Filtered	ug/L	all sites	0.74	1.38	2.52	0.68	0.91	1.74	0.49	0.94	1.47
Niobium, Filtered	ug/L	all sites	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Palladium, Filtered	ug/L	all sites	<	<	<	<	<	<	<	<	<
Platinum, Filtered	ug/L	all sites	<	<	<	<	<	<	<	<	<
Rubidium, Filtered	ug/L	all sites	0.56	0.89	1.16	0.68	0.84	0.98	1.07	1.44	1.95
Scandium, Filtered	ug/L	all sites	0.00	0.01	0.14	0.00	0.01	0.06	0.00	0.01	0.04
Selenium, Filtered	ug/L	all sites	0.07	0.15	0.22	0.08	0.12	0.17	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.11	0.16	0.21
	ug/L	AL07DD0008	+	+	+	+	+	+	0.05	0.20	0.34
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Silver, Filtered	ug/L	all sites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Strontium, Filtered	ug/L	all sites	81.89	170.00	241.05	123.20	226.00	303.60	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	278.00	322.00	388.00
	ug/L	AL07DD0008	+	+	+	+	+	+	134.00	364.00	489.00
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Tellurium, Filtered	ug/L	all sites	0.01	0.01	0.01	<	<	<	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.01	0.01	0.02

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

				High Flow			Open Water			Under Ice	
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	ug/L	AL07DD0008	+	+	+	+	+	+	0.00	0.00	0.01
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Thallium, Filtered	ug/L	all sites	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01
Tin, Filtered	ug/L	all sites	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.01	0.02
Titanium, Filtered	ug/L	all sites	0.10	1.00	4.54	0.10	0.50	1.50	0.10	0.50	1.20
Tungsten, Filtered	ug/L	all sites	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
Uranium, Filtered	ug/L	all sites	0.13	0.34	0.48	0.14	0.36	0.48	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.40	0.45	0.53
	ug/L	AL07DD0008	+	+	+	+	+	+	0.10	0.57	0.81
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Vanadium, Filtered	ug/L	all sites	0.21	0.39	0.74	0.15	0.31	0.64	0.13	0.20	0.48
Yttrium, Filtered	ug/L	all sites	0.05	0.18	0.42	0.04	0.08	0.26	0.05	0.07	0.10
Zinc, Filtered	ug/L	all sites	0.27	0.60	2.15	0.16	0.40	1.20	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.60	1.30	3.60
	ug/L	AL07DD0008	+	+	+	+	+	+	0.60	1.30	3.20
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Zirconium, Filtered	ug/L	all sites	0.08	0.20	0.50	0.05	0.10	0.30	0.07	0.10	0.20
Field											
Dissolved oxygen (DO)	mg/L	all sites	8.15	8.72	10.75	8.07	9.86	13.01	11.54	12.39	13.05
Specific conductivity	uS/cm	all sites	153.70	222.00	269.35	225.20	268.00	319.40	+	+	+
	uS/cm	AL07DD0004	+	+	+	+	+	+	-	-	-

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	uS/cm	AL07DD0005	+	+	+	+	+	+	-	-	-
	uS/cm	AL07DD0007	+	+	+	+	+	+	373.00	417.00	484.00
	uS/cm	AL07DD0008	+	+	+	+	+	+	266.00	432.00	521.00
	uS/cm	AL07DD0009	+	+	+	+	+	+	-	-	-
Temperature, water	degC	all sites	10.46	18.79	22.14	2.44	12.68	22.62	+	+	+
	degC	AL07DD0004	+	+	+	+	+	+	-	-	-
	degC	AL07DD0005	+	+	+	+	+	+	-	-	-
	degC	AL07DD0007	+	+	+	+	+	+	-0.32	-0.13	-0.07
	degC	AL07DD0008	+	+	+	+	+	+	-0.80	-0.25	-0.08
	degC	AL07DD0009	+	+	+	+	+	+	-	-	-
Turbidity	NTU	all sites	20.25	64.65	321.95	2.43	12.15	71.75	0.00	1.50	101.50
pH	pH units	all sites	7.74	7.97	8.29	7.83	8.20	8.41	7.06	7.51	8.15
General Organics											
Benzene	ug/L	all sites	<	<	<	-	-	-	<	<	<
C10-C16 Hydrocarbons	ug/L	all sites	23.15	52.59	133.06	<	<	<	<	<	<
C16-C34 Hydrocarbons	ug/L	all sites	<	<	<	<	<	<	<	<	<
C34-C50 Hydrocarbons	ug/L	all sites	<	<	<	<	<	<	<	<	<
C6-C10 Hydrocarbons	ug/L	all sites	<	<	<	<	<	<	<	<	<
Cyanide	mg/L	all sites	<	<	<	<	<	<	<	<	<
Ethylbenzene	ug/L	all sites	<	<	<	-	-	-	<	<	<
Hydrocarbons, petroleum	mg/L	all sites	0.02	0.08	0.40	<	<	<	<	<	<
Naphthenic acids	mg/L	all sites	<	<	<	<	<	<	<	<	<
Toluene	ug/L	all sites	+	+	+	0.01	0.03	0.14	<	<	<
	ug/L	AL07DD0004	-	-	-	+	+	+	+	+	+
	ug/L	AL07DD0005	-	-	-	+	+	+	+	+	+

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

	Parameter	Unit	Site	High Flow			Open Water			Under Ice		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
		ug/L	AL07DD0007	-	-	-	+	+	+	+	+	+
		ug/L	AL07DD0008	<	<	<	+	+	+	+	+	+
		ug/L	AL07DD0009	-	-	-	+	+	+	+	+	+
	m,p-Xylene	ug/L	all sites	<	<	<	-	-	-	<	<	<
	o-Xylene	ug/L	all sites	<	<	<	<	<	<	<	<	<
Major Ions												
	Calcium, Filtered	mg/L	all sites	+	+	+	23.47	32.15	38.89	24.26	43.20	57.34
		mg/L	AL07DD0004	-	-	-	+	+	+	+	+	+
		mg/L	AL07DD0005	-	-	-	+	+	+	+	+	+
		mg/L	AL07DD0007	-	-	-	+	+	+	+	+	+
		mg/L	AL07DD0008	15.80	23.15	33.20	+	+	+	+	+	+
		mg/L	AL07DD0009	-	-	-	+	+	+	+	+	+
	Calcium, Unknown	mg/L	all sites	22.40	27.10	29.80	19.80	32.00	36.00	26.10	38.40	48.30
	Chloride, Filtered	mg/L	all sites	1.15	4.52	12.93	1.52	8.13	18.04	+	+	+
		mg/L	AL07DD0004	+	+	+	+	+	+	-	-	-
		mg/L	AL07DD0005	+	+	+	+	+	+	-	-	-
		mg/L	AL07DD0007	+	+	+	+	+	+	14.70	17.90	24.70
		mg/L	AL07DD0008	+	+	+	+	+	+	5.38	13.16	36.70
		mg/L	AL07DD0009	+	+	+	+	+	+	-	-	-
	Fluoride, Filtered	mg/L	all sites	+	+	+	0.06	0.09	0.11	+	+	+
		mg/L	AL07DD0004	0.07	0.09	0.09	+	+	+	-	-	-
		mg/L	AL07DD0005	0.06	0.09	0.09	+	+	+	-	-	-
		mg/L	AL07DD0007	0.08	0.09	0.10	+	+	+	0.10	0.11	0.15
		mg/L	AL07DD0008	0.07	0.08	0.09	+	+	+	0.09	0.11	0.13

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	mg/L	AL07DD0009	-	-	-	+	+	+	-	-	-
Magnesium, Filtered	mg/L	all sites	+	+	+	6.73	8.55	11.40	+	+	+
	mg/L	AL07DD0004	4.76	7.13	8.55	+	+	+	-	-	-
	mg/L	AL07DD0005	5.59	6.97	7.84	+	+	+	-	-	-
	mg/L	AL07DD0007	6.73	8.32	9.40	+	+	+	10.10	12.30	14.00
	mg/L	AL07DD0008	4.29	6.48	9.35	+	+	+	7.08	13.35	17.10
	mg/L	AL07DD0009	-	-	-	+	+	+	-	-	-
Potassium, Filtered	mg/L	all sites	0.79	1.03	1.75	0.95	1.11	1.41	1.27	2.03	2.55
Silica, Filtered as SiO2	mg/L	all sites	3.06	5.89	9.02	1.92	4.51	7.91	5.63	8.85	12.16
Silica, Unknown as SiO2	mg/L	all sites	4.63	5.39	6.62	3.71	5.74	8.40	7.88	9.17	11.20
Sodium, Filtered	mg/L	all sites	6.12	8.63	13.06	6.99	12.20	18.22	21.49	27.80	32.89
Sulfate, Filtered as SO4	mg/L	all sites	+	+	+	9.67	24.00	37.26	+	+	+
	mg/L	AL07DD0004	9.91	16.60	24.10	+	+	+	-	-	-
	mg/L	AL07DD0005	10.60	17.00	20.70	+	+	+	-	-	-
	mg/L	AL07DD0007	15.60	21.75	29.00	+	+	+	31.50	38.70	52.40
	mg/L	AL07DD0008	6.61	13.20	30.40	+	+	+	11.60	44.05	65.50
	mg/L	AL07DD0009	-	-	-	+	+	+	-	-	-
Nutrients and BOD											
Ammonia and ammonium, Unfiltered as N	mg/L	all sites	0.00	0.01	0.03	0.00	0.01	0.02	0.02	0.05	0.08
Inorganic nitrogen (nitrate and nitrite), Filtered	mg/L	all sites	0.01	0.03	0.07	0.00	0.01	0.03	+	+	+
	mg/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0007	+	+	+	+	+	+	0.21	0.26	0.31

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
	mg/L	AL07DD0008	+	+	+	+	+	+	0.18	0.22	0.31
	mg/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Organic Nitrogen, Non-Filterable (Particle) as N	mg/L	all sites	0.11	0.31	1.00	0.03	0.11	0.31	+	+	+
	mg/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0007	+	+	+	+	+	+	0.01	0.02	0.03
	mg/L	AL07DD0008	+	+	+	+	+	+	0.01	0.02	0.05
	mg/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Total Nitrogen, mixed forms, Filtered as N	mg/L	all sites	0.12	0.30	0.61	0.11	0.22	0.62	0.39	0.53	0.81
Total Nitrogen, mixed forms, Non-Filterable (Particle) as N	mg/L	all sites	-	-	-	0.07	0.10	0.47	-	-	-
Total Nitrogen, mixed forms, Unknown as N	mg/L	all sites	0.29	0.45	0.59	0.22	0.34	0.52	+	+	+
	mg/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0007	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0008	+	+	+	+	+	+	-	-	-
	mg/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Total Phosphorus, mixed forms, Filtered as P	mg/L	all sites	0.01	0.02	0.03	0.00	0.01	0.03	0.01	0.02	0.04
Total Phosphorus, mixed forms, Unfiltered as P	mg/L	all sites	0.05	0.19	0.58	0.02	0.05	0.19	0.02	0.04	0.05
Organohalides											
2-Chloronaphthalene	ng/L	AL07DD0004	<	<	<	-	-	-	-	-	-
	ng/L	AL07DD0005	-	-	-	-	-	-	-	-	-

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	ng/L	AL07DD0007	-	-	-	-	-	-	-	-	-
	ng/L	AL07DD0008	-	-	-	-	-	-	-	-	-
	ng/L	AL07DD0009	-	-	-	-	-	-	-	-	-
PAHs											
1,2,3,4-Tetrahydronaphthalene	ng/L	all sites	<	<	<	<	<	<	<	<	<
1,6,7-Trimethylnaphthalene	ng/L	all sites	0.46	1.64	4.15	0.35	1.00	3.11	0.11	0.43	2.11
1-Methylnaphthalene	ng/L	all sites	1.17	4.70	18.66	<	<	<	<	<	<
2-Isopropylnaphthalene	ng/L	all sites	<	<	<	<	<	<	-	-	-
2-Methylnaphthalene	ng/L	all sites	2.48	9.19	35.30	<	<	<	<	<	<
3-Methylcholanthrene	ng/L	all sites	1.24	4.26	13.78	0.13	0.52	2.49	<	<	<
7,10-Dimethylbenzo[a]pyrene	ng/L	all sites	<	<	<	<	<	<	-	-	-
7-Methylbenzo[a]pyrene	ng/L	all sites	<	<	<	<	<	<	-	-	-
9-Ethylfluorene	ng/L	all sites	<	<	<	<	<	<	-	-	-
9-Methylfluorene	ng/L	all sites	0.10	0.56	3.92	<	<	<	<	<	<
Acenaphthene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Acenaphthylene	ng/L	AL07DD0004	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0005	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0007	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0008	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0009	-	-	-	-	-	-	-	-	-
Anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Benz[a]anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Benzo(b)fluoranthene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Benzo[a]pyrene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Benzo[e]pyrene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Benzo[ghi]perylene	ng/L	AL07DD0004	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0005	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0007	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0008	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0009	-	-	-	-	-	-	-	-	-
Benzo[k]fluoranthene	ng/L	AL07DD0004	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0005	<	<	<	<	<	<	-	-	-
	ng/L	AL07DD0007	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0008	<	<	<	<	<	<	<	<	<
	ng/L	AL07DD0009	-	-	-	-	-	-	-	-	-
Biphenyl	ng/L	all sites	-	-	-	-	-	-	-	-	-
C1-Dibenzothiophenes	ng/L	all sites	-	-	-	-	-	-	-	-	-
C1-Fluoranthenes/pyrenes	ng/L	all sites	23.36	30.50	45.02	-	-	-	-	-	-
C2-1,6-Dimethylnaphthalene	ng/L	all sites	4.48	6.21	27.16	0.50	1.89	8.97	1.05	2.23	5.36
C2-1,9-Dimethylfluorene	ng/L	all sites	0.07	0.42	3.40	<	<	<	-	-	-
C2-3-Ethylfluoranthene	ng/L	all sites	<	<	<	<	<	<	-	-	-
C2-Benzopyrenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C2-Chrysenes	ng/L	all sites	4.13	7.42	14.61	<	<	<	<	<	<
C2-Dibenzothiophenes	ng/L	all sites	6.26	21.00	50.82	-	-	-	-	-	-
C2-Dimethyldibenzothiophenes	ng/L	all sites	3.95	16.56	60.42	0.32	1.70	26.69	0.39	0.75	2.90
C2-Fluoranthenes/pyrenes	ng/L	all sites	5.39	6.87	9.07	<	<	<	<	<	<
C2-Fluorenes	ng/L	all sites	14.00	21.90	50.10	-	-	-	-	-	-

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
C2-Naphthalenes	ng/L	all sites	-	-	-	-	-	-	-	-	-
C2-Phenanthrenes	ng/L	all sites	7.91	26.20	85.24	0.09	1.44	29.99	-	-	-
C3-2,4,7-Trimethyldibenzothiophene	ng/L	all sites	<	<	<	<	<	<	<	<	<
C3-4-Propyldibenzothiophene	ng/L	all sites	0.07	0.45	3.73	<	<	<	<	<	<
C3-Chrysenes	ng/L	all sites	9.57	10.60	11.90	-	-	-	-	-	-
C3-Dibenzothiophenes	ng/L	all sites	16.40	18.50	27.50	-	-	-	-	-	-
C3-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C3-Fluorenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C3-N-Propylfluorene	ng/L	all sites	<	<	<	<	<	<	<	<	<
C3-Naphthalenes	ng/L	all sites	5.53	15.23	50.65	<	<	<	<	<	<
C3-Phenanthrenes	ng/L	all sites	5.99	15.65	49.18	-	-	-	-	-	-
C4-Chrysenes	ng/L	all sites	11.58	12.65	13.84	-	-	-	-	-	-
C4-Dibenzothiophenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C4-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C4-Fluorenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C4-Naphthalenes	ng/L	all sites	11.51	22.00	39.20	-	-	-	-	-	-
C4-Phenanthrenes	ng/L	all sites	+	+	+	<	<	<	<	<	<
	ng/L	AL07DD0004	-	-	-	+	+	+	+	+	+
	ng/L	AL07DD0005	4.66	8.95	14.55	+	+	+	+	+	+
	ng/L	AL07DD0007	-	-	-	+	+	+	+	+	+
	ng/L	AL07DD0008	-	-	-	+	+	+	+	+	+
	ng/L	AL07DD0009	-	-	-	+	+	+	+	+	+
Chrysene	ng/L	all sites	0.36	2.51	23.46	-	-	-	-	-	-
Dibenz[a,h]anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Dibenzothiophene	ng/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

	Parameter	Unit	Site	High Flow			Open Water			Under Ice		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
	Fluoranthene	ng/L	all sites	0.67	2.14	7.11	<	<	<	<	<	<
	Fluorene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	Indene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Indeno[1,2,3-cd]fluoranthene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Indeno[1,2,3-cd]pyrene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Methylbenzopyrene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Methylchrysene	ng/L	all sites	37.07	59.20	91.20	<	<	<	-	-	-
	Methyldibenzothiophene	ng/L	all sites	1.52	3.55	17.76	0.24	0.93	4.47	0.30	0.82	2.60
	Methylfluoranthene	ng/L	all sites	4.24	7.70	30.77	0.18	1.17	7.91	<	<	<
	Methylfluorene	ng/L	all sites	14.61	30.30	57.48	-	-	-	-	-	-
	Methylnaphthalene	ng/L	all sites	19.11	48.03	148.13	-	-	-	-	-	-
	Methylphenanthrene	ng/L	all sites	6.21	30.20	110.19	<	<	<	-	-	-
	Naphthalene	ng/L	all sites	3.16	23.78	251.85	11.84	43.05	123.20	4.51	26.65	200.50
	Perylene	ng/L	all sites	1.59	9.09	71.88	<	<	<	<	<	<
	Phenanthrene	ng/L	all sites	2.95	10.64	34.80	<	<	<	-	-	-
	Pyrene	ng/L	all sites	0.67	3.34	24.60	<	<	<	<	<	<
	Retene	ng/L	all sites	1.86	10.25	67.50	<	<	<	<	<	<
Phenolics												
	Phenol	ug/L	all sites	<	<	<	<	<	<	<	<	<
Target PANHs												
	Acridine	ug/L	all sites	<	<	<	<	<	<	<	<	<
	Carbazole	ng/L	all sites	<	<	<	<	<	<	<	<	<
Total Metals												
	Aluminum, Unfiltered	ug/L	all sites	142.40	2530.00	8576.00	110.82	316.00	3154.00	15.18	54.00	127.85
	Antimony, Unfiltered	ug/L	all sites	0.05	0.11	0.20	0.02	0.06	0.15	0.01	0.06	0.09

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Arsenic, Unfiltered	ug/L	all sites	0.64	1.98	5.43	0.50	0.71	2.63	0.38	0.56	0.77
Barium, Unfiltered	ug/L	all sites	48.02	73.80	174.00	34.70	53.70	104.24	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	63.30	69.50	79.30
	ug/L	AL07DD0008	+	+	+	+	+	+	26.00	85.20	107.00
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Beryllium, Unfiltered	ug/L	all sites	0.03	0.14	0.46	0.01	0.02	0.17	0.00	0.01	0.02
Bismuth, Unfiltered	ug/L	all sites	0.01	0.03	0.14	0.00	0.00	0.04	0.00	0.00	0.00
Boron, Unfiltered	ug/L	all sites	13.96	25.30	34.60	16.26	23.60	31.56	31.14	36.40	43.05
Cadmium, Unfiltered	ug/L	all sites	0.02	0.05	0.17	0.01	0.02	0.07	0.01	0.02	0.04
Cerium, Unfiltered	ug/L	all sites	0.99	5.59	17.62	0.29	0.64	6.50	0.07	0.18	0.52
Cesium, Unfiltered	ug/L	all sites	0.07	0.49	1.67	0.02	0.06	0.58	0.01	0.01	0.03
Chromium, Unfiltered	ug/L	all sites	0.26	3.56	11.80	0.20	0.45	4.41	0.04	0.18	0.34
Cobalt, Unfiltered	ug/L	all sites	0.39	1.65	5.23	0.17	0.27	1.94	0.08	0.09	0.14
Copper, Unfiltered	ug/L	all sites	1.14	4.40	12.36	0.53	0.91	5.69	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.29	0.66	0.97
	ug/L	AL07DD0008	+	+	+	+	+	+	0.17	0.59	2.00
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Gallium, Unfiltered	ug/L	all sites	0.07	0.78	2.72	0.05	0.10	0.91	0.01	0.03	0.07
Germanium, Unfiltered	ug/L	all sites	0.02	0.07	0.22	0.01	0.02	0.06	0.01	0.01	0.02
Indium, Unfiltered	ug/L	all sites	0.00	0.01	0.02	0.00	0.00	0.01	<	<	<
Iron, Unfiltered	ug/L	all sites	631.40	4290.00	12800.00	308.00	709.00	5302.00	132.90	430.50	863.55

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Lanthanum, Unfiltered	ug/L	all sites	0.45	2.58	8.40	0.13	0.31	3.05	0.04	0.09	0.25
Lead, Unfiltered	ug/L	all sites	0.45	2.15	6.85	0.11	0.27	2.48	0.03	0.09	0.33
Lithium, Unfiltered	ug/L	all sites	5.47	7.88	13.52	5.75	6.91	9.95	8.32	9.97	11.11
Manganese, Unfiltered	ug/L	all sites	48.26	114.00	289.00	16.30	38.50	135.00	5.38	15.85	26.75
Mercury, Unfiltered	ng/L	all sites	2.85	10.00	28.90	0.98	1.90	12.63	0.47	0.68	0.98
Methylmercury(1+), Unfiltered	ng/L	all sites	0.07	0.18	0.33	0.02	0.06	0.22	0.03	0.04	0.04
Molybdenum, Unfiltered	ug/L	all sites	0.39	0.75	1.24	0.36	0.73	1.01	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.69	0.77	3.74
	ug/L	AL07DD0008	+	+	+	+	+	+	0.23	0.90	1.14
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Nickel, Unfiltered	ug/L	all sites	1.45	5.23	16.32	0.90	1.32	6.39	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.75	1.03	1.48
	ug/L	AL07DD0008	+	+	+	+	+	+	0.45	0.96	2.43
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Niobium, Unfiltered	ug/L	all sites	0.00	0.10	0.23	0.00	0.01	0.11	0.00	0.00	0.01
Palladium, Unfiltered	ug/L	all sites	<	<	<	<	<	<	<	<	<
Platinum, Unfiltered	ug/L	all sites	0.00	0.00	0.00	<	<	<	<	<	<
Rubidium, Unfiltered	ug/L	all sites	1.49	5.93	18.42	1.06	1.40	6.71	1.18	1.57	1.97
Scandium, Unfiltered	ug/L	all sites	0.02	0.44	2.52	0.00	0.05	0.66	0.00	0.02	0.09
Selenium, Unfiltered	ug/L	all sites	0.14	0.22	0.59	0.10	0.14	0.29	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.13	0.18	0.21
	ug/L	AL07DD0008	+	+	+	+	+	+	0.04	0.20	0.24
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Silver, Unfiltered	ug/L	all sites	0.00	0.02	0.07	0.00	0.00	0.04	0.00	0.00	0.01
Strontium, Unfiltered	ug/L	all sites	+	+	+	123.00	223.00	293.00	+	+	+
	ug/L	AL07DD0004	111.00	177.00	222.00	+	+	+	-	-	-
	ug/L	AL07DD0005	136.00	182.00	205.00	+	+	+	-	-	-
	ug/L	AL07DD0007	162.00	214.00	246.00	+	+	+	275.00	316.00	384.00
	ug/L	AL07DD0008	81.60	137.00	248.00	+	+	+	134.00	352.00	481.00
	ug/L	AL07DD0009	-	-	-	+	+	+	-	-	-
Tellurium, Unfiltered	ug/L	all sites	0.00	0.01	0.06	0.00	0.00	0.03	0.00	0.00	0.02
Thallium, Unfiltered	ug/L	all sites	0.01	0.05	0.18	0.01	0.01	0.05	0.00	0.01	0.01
Tin, Unfiltered	ug/L	all sites	0.03	0.09	0.39	0.00	0.02	0.14	0.00	0.01	0.06
Titanium, Unfiltered	ug/L	all sites	3.02	36.00	98.38	1.80	5.30	50.18	0.40	1.10	2.66
Tungsten, Unfiltered	ug/L	all sites	0.00	0.01	0.02	0.00	0.01	0.02	0.00	0.00	0.02
Uranium, Unfiltered	ug/L	all sites	0.27	0.45	1.03	0.18	0.37	0.57	+	+	+
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	0.38	0.45	0.52
	ug/L	AL07DD0008	+	+	+	+	+	+	0.10	0.57	0.77
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Vanadium, Unfiltered	ug/L	all sites	0.88	6.92	23.36	0.57	1.07	8.98	0.22	0.36	0.59
Yttrium, Unfiltered	ug/L	all sites	0.48	2.07	6.49	0.15	0.31	2.49	0.09	0.11	0.35
Zinc, Unfiltered	ug/L	all sites	2.52	13.10	41.38	0.98	2.00	14.64	+	+	+

Table 2.4: Current Conditions, Athabasca River water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
	ug/L	AL07DD0004	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0005	+	+	+	+	+	+	-	-	-
	ug/L	AL07DD0007	+	+	+	+	+	+	1.00	1.60	2.00
	ug/L	AL07DD0008	+	+	+	+	+	+	0.70	1.85	6.90
	ug/L	AL07DD0009	+	+	+	+	+	+	-	-	-
Zirconium, Unfiltered	ug/L	all sites	0.36	1.80	4.40	0.20	0.30	2.82	0.10	0.20	0.30

Note:
- data insufficient
< too highly censored;
+ grouped differently (merged sites vs individual site);

Table 2.5: Current Conditions, Athabasca River sediment.

	Parameter	Unit	Site	5th	50th	95th
Conventional Variables						
	Acid Neutralization Potential as %CaCO3	%	all sites	-	-	-
	Grain size, clay (<2 um)	%	all sites	0.99	7.00	15.48
	Grain size, sand (>=63 um to 2000 um)	%	all sites	30.50	72.00	98.80
	Grain size, silt (>=2 to 63 um)	%	all sites	1.48	19.40	48.44
	Inorganic carbon	%	all sites	-	-	-
	Loss on Ignition @ 375 C	%	all sites	0.64	1.50	3.23
	Moisture content	%	AB07DA0062	-	-	-
		%	AB07DA0800	-	-	-
		%	AB07DA3008	-	-	-
		%	AB07DA3009	-	-	-
		%	AB07DA3015	-	-	-
		%	AB07DA3016	-	-	-
		%	AB07DA3017	-	-	-
		%	AB07DA3018	-	-	-
		%	AB07DA3020	-	-	-
		%	AB07DA3021	-	-	-
		%	AB07DA3022	-	-	-
		%	AB07DA3023	-	-	-
		%	AB07DA3024	-	-	-
		%	ATR-ER	-	-	-
	Organic Matter	%	all sites	0.68	1.40	2.77
	Organic carbon	%	all sites	-	-	-
	Total carbon	%	all sites	-	-	-
Extractable Metals						
	Methylmercury(1+), Extractable	ng/g	all sites	0.02	0.31	1.19
General Organics						
	BTEX, Total	ug/g	all sites	-	-	-
	Benzene	ug/g	all sites	-	-	-
	C10-C16 Hydrocarbons	ug/g	all sites	-	-	-
	C10H16O2	%	all sites	0.00	0.01	0.04
	C10H18O2	%	all sites	0.01	0.04	0.14
	C10H20O2	%	all sites	0.07	0.39	1.68
	C11H14O2	%	all sites	0.01	0.03	0.07
	C11H16O2	%	all sites	0.00	0.00	0.04
	C11H18O2	%	all sites	0.00	0.01	0.04
	C11H20O2	%	all sites	0.01	0.06	0.19
	C11H22O2	%	all sites	0.21	0.45	0.78
	C12H16O2	%	all sites	0.00	0.01	0.06
	C12H18O2	%	all sites	0.00	0.00	0.02
	C12H20O2	%	all sites	0.01	0.06	0.28
	C12H22O2	%	all sites	0.11	0.31	0.62
	C12H24O2	%	all sites	0.43	1.00	1.60
	C13H16O2	%	all sites	0.00	0.00	0.05
	C13H18O2	%	all sites	0.00	0.01	0.04

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
C13H20O2	%	all sites	0.01	0.03	0.14
C13H22O2	%	all sites	0.00	0.03	0.20
C13H24O2	%	all sites	0.04	0.10	0.20
C13H26O2	%	all sites	0.38	0.77	0.94
C14H16O2	%	all sites	<	<	<
C14H18O2	%	all sites	0.00	0.01	0.08
C14H20O2	%	all sites	0.00	0.03	0.09
C14H22O2	%	all sites	0.05	0.10	1.61
C14H24O2	%	all sites	0.06	0.14	2.64
C14H26O2	%	all sites	0.42	0.79	1.31
C14H28O2	%	AB07DA0062	-	-	-
	%	AB07DA0800	-	-	-
	%	AB07DA3008	-	-	-
	%	AB07DA3009	-	-	-
	%	AB07DA3015	-	-	-
	%	AB07DA3016	-	-	-
	%	AB07DA3017	-	-	-
	%	AB07DA3018	-	-	-
	%	AB07DA3020	-	-	-
	%	AB07DA3021	-	-	-
	%	AB07DA3022	-	-	-
	%	AB07DA3023	-	-	-
	%	AB07DA3024	-	-	-
C15H14O2	%	all sites	0.00	0.01	0.02
C15H16O2	%	all sites	0.00	0.01	0.03
C15H18O2	%	all sites	0.00	0.00	0.03
C15H20O2	%	all sites	0.00	0.04	0.17
C15H22O2	%	all sites	0.02	0.10	1.44
C15H24O2	%	all sites	0.03	0.15	2.12
C15H26O2	%	all sites	0.07	0.18	1.90
C15H28O2	%	all sites	0.83	2.01	3.51
C15H30O2	%	all sites	2.61	4.24	6.84
C16-C34 Hydrocarbons	ug/g	all sites	-	-	-
C16H14O2	%	all sites	0.00	0.01	0.04
C16H16O2	%	all sites	<	<	<
C16H18O2	%	all sites	0.00	0.01	0.05
C16H20O2	%	all sites	0.00	0.03	0.14
C16H22O2	%	all sites	0.01	0.06	0.22
C16H24O2	%	all sites	0.33	2.17	3.93
C16H26O2	%	all sites	0.47	2.79	4.55
C16H28O2	%	all sites	0.76	3.03	4.71
C16H30O2	%	all sites	6.65	13.70	20.71
C16H32O2	%	all sites	0.09	4.52	25.45
C17H18O2	%	all sites	0.00	0.01	0.08
C17H20O2	%	all sites	0.00	0.02	0.08

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
C17H22O2	%	all sites	0.00	0.04	0.22
C17H24O2	%	all sites	0.01	0.07	0.26
C17H26O2	%	all sites	0.04	0.12	0.46
C17H28O2	%	all sites	0.08	0.27	0.69
C17H30O2	%	all sites	0.13	0.30	0.68
C17H32O2	%	all sites	1.66	2.94	7.08
C17H34O2	%	all sites	1.42	2.92	8.32
C18H20O2	%	all sites	0.00	0.01	0.10
C18H22O2	%	all sites	0.01	0.04	0.14
C18H24O2	%	all sites	0.03	0.09	0.17
C18H26O2	%	all sites	0.08	0.14	0.64
C18H28O2	%	all sites	0.32	1.77	5.47
C18H30O2	%	all sites	0.62	1.93	3.47
C18H32O2	%	all sites	1.47	2.78	6.48
C18H34O2	%	all sites	4.56	7.01	25.26
C18H36O2	%	all sites	0.12	0.61	24.95
C19H20O2	%	all sites	0.00	0.00	0.09
C19H22O2	%	all sites	0.03	0.14	0.48
C19H24O2	%	all sites	0.01	0.05	0.10
C19H26O2	%	all sites	0.02	0.08	0.33
C19H28O2	%	all sites	0.03	0.15	0.38
C19H30O2	%	all sites	0.05	0.16	0.35
C19H32O2	%	all sites	0.03	0.15	0.61
C19H34O2	%	all sites	0.07	0.32	1.09
C19H36O2	%	all sites	0.22	0.46	1.16
C19H38O2	%	all sites	0.20	0.32	0.56
C20H22O2	%	all sites	0.00	0.01	0.12
C20H24O2	%	all sites	0.01	0.03	0.11
C20H26O2	%	all sites	0.02	0.12	0.29
C20H28O2	%	all sites	0.45	1.06	4.85
C20H30O2	%	all sites	0.95	7.21	13.09
C20H32O2	%	all sites	0.39	1.19	2.14
C20H34O2	%	all sites	0.13	0.32	0.69
C20H36O2	%	all sites	0.22	0.41	1.42
C20H38O2	%	all sites	0.11	0.29	0.52
C20H40O2	%	all sites	0.30	0.85	1.25
C21H24O2	%	all sites	0.01	0.05	0.10
C21H26O2	%	all sites	0.00	0.01	0.05
C21H28O2	%	all sites	0.00	0.02	0.10
C21H30O2	%	all sites	0.01	0.06	0.12
C21H32O2	%	all sites	0.02	0.07	0.24
C21H34O2	%	all sites	0.03	0.11	0.40
C21H36O2	%	all sites	0.02	0.20	0.82
C21H38O2	%	all sites	0.04	0.29	1.37
C21H40O2	%	all sites	0.01	0.10	0.48

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
C21H42O2	%	all sites	0.21	0.39	0.96
C22H32O2	%	all sites	0.12	0.80	2.45
C22H34O2	%	all sites	0.08	0.24	0.81
C22H36O2	%	all sites	0.04	0.12	0.50
C22H38O2	%	all sites	0.03	0.10	0.30
C22H40O2	%	all sites	0.06	0.28	1.39
C22H42O2	%	all sites	0.12	0.34	1.11
C22H44O2	%	all sites	0.01	0.60	1.86
C23H32O2	%	all sites	0.00	0.02	0.07
C23H34O2	%	all sites	0.00	0.03	0.10
C23H36O2	%	all sites	0.00	0.04	0.12
C23H38O2	%	all sites	0.01	0.06	0.30
C23H40O2	%	all sites	0.02	0.15	0.85
C23H42O2	%	all sites	0.04	0.27	1.38
C23H44O2	%	all sites	0.05	0.19	0.85
C23H46O2	%	all sites	0.12	0.41	0.92
C24H36O2	%	all sites	0.00	0.02	0.10
C24H38O2	%	all sites	0.01	0.03	0.08
C24H40O2	%	all sites	0.01	0.04	0.12
C24H42O2	%	all sites	0.04	0.20	1.23
C24H44O2	%	all sites	0.06	0.24	1.34
C24H46O2	%	all sites	0.03	0.23	0.38
C24H48O2	%	all sites	0.01	0.75	2.04
C25H38O2	%	all sites	0.00	0.00	0.05
C25H40O2	%	all sites	0.01	0.04	0.08
C25H42O2	%	all sites	0.01	0.03	0.12
C25H44O2	%	all sites	0.01	0.08	0.28
C25H46O2	%	all sites	0.04	0.15	0.49
C25H48O2	%	all sites	0.04	0.09	0.38
C25H50O2	%	all sites	0.01	0.39	0.80
C34-C50 Hydrocarbons	ug/g	all sites	-	-	-
C5H10O2	%	all sites	0.00	0.03	0.12
C6H12O2	%	all sites	0.00	0.02	0.14
C7H12O2	%	all sites	0.00	0.01	0.03
C7H14O2	%	all sites	0.01	0.04	0.19
C8H14O2	%	all sites	0.01	0.02	0.07
C8H16O2	%	all sites	0.04	0.18	0.69
C9H14O2	%	all sites	0.00	0.01	0.06
C9H16O2	%	all sites	0.00	0.03	0.07
C9H18O2	%	all sites	0.13	0.47	1.38
Ethylbenzene	ug/g	all sites	-	-	-
Hydrocarbons	ug/g	all sites	-	-	-
Naphthenic acids	ug/g	all sites	52.91	136.50	458.90
Toluene	ug/g	all sites	-	-	-
Total xylenes	ug/g	all sites	-	-	-

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

	Parameter	Unit	Site	5th	50th	95th
	m,p-Xylene	ug/g	all sites	-	-	-
	o-Xylene	ug/g	all sites	-	-	-
Nutrients and BOD						
	Ammonium, Available as N	ng/g	all sites	819.46	6550.00	25800.00
	Kjeldahl nitrogen, Total	%	all sites	0.01	0.04	0.10
PAHs						
	1,2,6-Trimethylphenanthrene	ng/g	all sites	1.05	3.15	8.62
	1,2-Dimethylnaphthalene	ng/g	all sites	0.22	1.53	2.98
	1,4,6,7-Tetramethylnaphthalene	ng/g	all sites	1.65	4.55	8.09
	1,6,7-Trimethylnaphthalene	ng/g	all sites	1.41	6.21	10.20
	1,7-Dimethylfluorene	ng/g	all sites	0.53	1.62	4.68
	1,7-Dimethylphenanthrene	ng/g	all sites	2.05	6.92	22.40
	1,8-Dimethylphenanthrene	ng/g	all sites	0.51	1.75	4.98
	1-Methylchrysene	ng/g	all sites	1.55	4.68	29.00
	1-Methylnaphthalene	ng/g	all sites	1.40	6.79	16.60
	1-Methylphenanthrene	ng/g	all sites	1.70	6.16	21.40
	2,3,6-Trimethylnaphthalene	ng/g	all sites	1.71	7.29	14.20
	2,4-Dimethyldibenzothiophene	ng/g	all sites	1.59	4.05	26.10
	2,6-Dimethylnaphthalene	ng/g	all sites	1.56	6.96	18.30
	2,6-Dimethylphenanthrene	ng/g	all sites	1.08	3.13	17.50
	2-Methylanthracene	ng/g	all sites	0.47	1.19	19.60
	2-Methyldibenzothiophenes/3-Methyldibenzothiophenes	ng/g	all sites	1.12	3.58	45.00
	2-Methylfluorene	ng/g	all sites	0.46	1.09	3.07
	2-Methylnaphthalene	ng/g	all sites	2.15	10.98	32.00
	2-Methylphenanthrene	ng/g	all sites	2.50	9.30	48.60
	3,6-Dimethylphenanthrene	ng/g	all sites	1.34	3.92	12.30
	3-Methylfluoranthene/Benzo[a]fluorene	ng/g	all sites	3.29	8.38	31.80
	3-Methylphenanthrene	ng/g	all sites	2.07	6.86	29.40
	4,6-Dimethyldibenzothiophene	ng/g	all sites	-	-	-
	5,9-Dimethylchrysene	ng/g	all sites	4.84	11.90	56.30
	5-Methylchrysene/6-Methylchrysene	ng/g	all sites	1.00	2.84	11.90
	7-Methylbenzo[a]pyrene	ng/g	all sites	1.03	2.54	12.00
	9-Methylphenanthrene/4-Methylphenanthrene	ng/g	all sites	2.57	7.95	22.90
	Acenaphthene	ng/g	all sites	0.23	0.69	1.54
	Acenaphthylene	ng/g	all sites	-	-	-
	Anthracene	ng/g	all sites	0.07	0.61	4.53
	Benz[a]anthracene	ng/g	all sites	0.16	2.82	44.50
	Benzo(b)fluoranthene	ng/g	all sites	2.38	7.83	22.30
	Benzo(j+k)fluoranthene	ng/g	all sites	1.10	2.73	13.80
	Benzo[a]pyrene	ng/g	all sites	0.30	4.05	51.71
	Benzo[b,j,k]fluoranthene	ng/g	all sites	-	-	-
	Benzo[e]pyrene	ng/g	all sites	2.87	8.22	46.90
	Benzo[ghi]perylene	ng/g	all sites	0.72	7.17	35.81
	Biphenyl	ng/g	all sites	0.45	3.51	6.35

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

	Parameter	Unit	Site	5th	50th	95th
	C1-Acenaphthenes	ng/g	all sites	0.08	0.21	0.38
	C1-Benzo[a]anthracenes/chrysenes	ng/g	all sites	11.20	35.15	262.00
	C1-Benzofluoranthenes/benzopyrenes	ng/g	all sites	2.68	36.90	239.02
	C1-Biphenyls	ng/g	all sites	0.35	5.20	9.79
	C1-Dibenzothiophenes	ng/g	all sites	0.35	10.70	109.89
	C1-Fluoranthenes/pyrenes	ng/g	all sites	5.23	27.90	121.02
	C1-Fluorenes	ng/g	all sites	0.55	4.31	14.10
	C1-Naphthalenes	ng/g	all sites	0.71	15.30	46.77
	C1-Phenanthrenes/anthracenes	ng/g	all sites	1.18	20.10	133.91
	C2-Benzo[a]anthracenes/chrysenes	ng/g	all sites	4.07	39.70	209.56
	C2-Benzofluoranthenes/benzopyrenes	ng/g	all sites	1.46	19.40	129.09
	C2-Biphenyls	ng/g	all sites	1.06	4.44	7.91
	C2-Dibenzothiophenes	ng/g	all sites	2.30	54.40	321.20
	C2-Fluoranthenes/pyrenes	ng/g	all sites	10.37	48.20	159.05
	C2-Fluorenes	ng/g	all sites	0.51	19.40	48.36
	C2-Naphthalenes	ng/g	all sites	2.23	27.50	68.71
	C2-Phenanthrenes/anthracenes	ng/g	all sites	1.59	38.40	147.43
	C3-Benzo[a]anthracenes/chrysenes	ng/g	all sites	5.91	16.30	49.00
	C3-Dibenzothiophenes	ng/g	all sites	4.40	103.00	364.80
	C3-Fluoranthenes/pyrenes	ng/g	all sites	9.05	38.20	96.17
	C3-Fluorenes	ng/g	all sites	1.73	38.30	96.83
	C3-Naphthalenes	ng/g	all sites	1.55	26.20	53.82
	C3-Phenanthrenes/anthracenes	ng/g	all sites	2.67	50.00	127.10
	C4-Benzo[a]anthracenes/chrysenes	ng/g	all sites	2.43	8.35	17.00
	C4-Dibenzothiophenes	ng/g	all sites	6.23	82.00	274.90
	C4-Fluoranthenes/pyrenes	ng/g	all sites	7.32	22.05	47.40
	C4-Naphthalenes	ng/g	all sites	1.24	28.80	50.74
	C4-Phenanthrenes/anthracenes	ng/g	all sites	16.61	215.00	895.60
	Chrysene	ng/g	all sites	1.03	12.60	73.84
	Dibenz[a,h]anthracene	ng/g	all sites	0.33	1.69	5.85
	Dibenzothiophene	ng/g	all sites	0.14	1.76	23.99
	Fluoranthene	ng/g	all sites	0.19	3.43	10.25
	Fluorene	ng/g	all sites	0.06	1.24	3.59
	Indeno[1,2,3-cd]pyrene	ng/g	all sites	0.37	3.82	13.07
	Naphthalene	ng/g	all sites	0.51	4.00	14.03
	Perylene	ng/g	all sites	22.10	68.75	129.00
	Phenanthrene	ng/g	all sites	0.55	11.10	35.90
	Pyrene	ng/g	all sites	0.62	6.85	36.91
	Retene	ng/g	all sites	2.82	42.20	89.26
Phenolics						
	Phenols, Extractable	ng/g	all sites	<	<	<
Total Metals						
	Aluminum	ug/g	all sites	848.00	5340.00	9890.00
	Antimony	ug/g	all sites	0.09	0.20	0.30
	Arsenic	ug/g	all sites	1.96	4.21	6.67

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
Barium	ug/g	AB07DA0062	-	-	-
	ug/g	AB07DA0800	-	-	-
	ug/g	AB07DA3008	-	-	-
	ug/g	AB07DA3009	-	-	-
	ug/g	AB07DA3015	-	-	-
	ug/g	AB07DA3016	-	-	-
	ug/g	AB07DA3017	-	-	-
	ug/g	AB07DA3018	-	-	-
	ug/g	AB07DA3020	-	-	-
	ug/g	AB07DA3021	-	-	-
	ug/g	AB07DA3022	-	-	-
	ug/g	AB07DA3023	-	-	-
	ug/g	AB07DA3024	-	-	-
	ug/g	ATR-ER	-	-	-
Beryllium	ug/g	all sites	0.19	0.35	0.56
Bismuth	ug/g	all sites	<	<	<
Boron	ug/g	all sites	1.28	5.25	8.42
Cadmium	ug/g	all sites	0.06	0.13	0.23
Calcium	ug/g	AB07DA0062	-	-	-
	ug/g	AB07DA0800	-	-	-
	ug/g	AB07DA3008	-	-	-
	ug/g	AB07DA3009	-	-	-
	ug/g	AB07DA3015	-	-	-
	ug/g	AB07DA3016	-	-	-
	ug/g	AB07DA3017	-	-	-
	ug/g	AB07DA3018	-	-	-
	ug/g	AB07DA3020	-	-	-
	ug/g	AB07DA3021	-	-	-
	ug/g	AB07DA3022	-	-	-
	ug/g	AB07DA3023	-	-	-
	ug/g	AB07DA3024	-	-	-
Chromium	ug/g	all sites	2.29	10.90	17.35
Cobalt	ug/g	all sites	2.00	6.03	8.80
Copper	ug/g	all sites	1.02	6.75	15.65
Iron	ug/g	all sites	4000.00	13000.00	20300.00
Lead	ug/g	all sites	1.47	5.34	9.41
Lithium	ug/g	all sites	4.25	8.12	12.36
Magnesium	ug/g	AB07DA0062	-	-	-
	ug/g	AB07DA0800	-	-	-
	ug/g	AB07DA3008	-	-	-
	ug/g	AB07DA3009	-	-	-
	ug/g	AB07DA3015	-	-	-
	ug/g	AB07DA3016	-	-	-
	ug/g	AB07DA3017	-	-	-
	ug/g	AB07DA3018	-	-	-

Table 2.5: Current Conditions, Athabasca River sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
	ug/g	AB07DA3020	-	-	-
	ug/g	AB07DA3021	-	-	-
	ug/g	AB07DA3022	-	-	-
	ug/g	AB07DA3023	-	-	-
	ug/g	AB07DA3024	-	-	-
	ug/g	ATR-ER	-	-	-
Manganese	ug/g	all sites	78.35	289.00	555.50
Mercury	ug/g	all sites	<	<	<
Molybdenum	ug/g	all sites	0.15	0.44	0.82
Nickel	ug/g	all sites	3.37	13.30	21.15
Phosphorus	ug/g	AB07DA0062	-	-	-
	ug/g	AB07DA0800	-	-	-
	ug/g	AB07DA3008	-	-	-
	ug/g	AB07DA3009	-	-	-
	ug/g	AB07DA3015	-	-	-
	ug/g	AB07DA3016	-	-	-
	ug/g	AB07DA3017	-	-	-
	ug/g	AB07DA3018	-	-	-
	ug/g	AB07DA3020	-	-	-
	ug/g	AB07DA3021	-	-	-
	ug/g	AB07DA3022	-	-	-
	ug/g	AB07DA3023	-	-	-
	ug/g	AB07DA3024	-	-	-
Potassium	ug/g	all sites	222.10	767.50	1261.50
Silver	ug/g	all sites	0.03	0.05	0.09
Sodium	ug/g	all sites	<	<	<
Strontium	ug/g	all sites	7.95	46.70	75.55
Thallium	ug/g	all sites	0.04	0.10	0.16
Thorium	ug/g	all sites	0.89	3.33	5.25
Tin	ug/g	all sites	0.11	0.25	0.41
Titanium	ug/g	all sites	34.41	63.90	96.81
Tungsten	ug/g	all sites	<	<	<
Uranium	ug/g	all sites	0.12	0.67	1.00
Vanadium	ug/g	all sites	4.21	17.10	27.40
Zinc	ug/g	all sites	9.45	39.90	65.40
Zirconium	ug/g	all sites	1.32	3.95	5.95

Note:
- data insufficient
< too highly censored;

2.8.2 Athabasca River Delta Current Conditions

The current condition (5th, 50th, and 95th percentile values) for each water and sediment quality parameter and each season are presented for the Athabasca River Delta in Table 2.6

(water) and Table 2.7 (sediment). Note that additional information, including sample size, analytical method codes, and quantile estimation method for each suite of current conditions are provided in Appendix A.2.

Table 2.6: Current Conditions, Athabasca River Delta water.

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
Bacteria											
Escherichia coli	No/100 mL	all sites	1.37	5.48	30.00	<	<	<	<	<	<
Fecal Coliform	No/100 mL	all sites	1.24	6.50	39.80	0.09	1.53	29.00	<	<	<
Total Coliform	No/100 mL	all sites	-	-	-	-	-	-	-	-	-
Conventional Variables											
Alkalinity, Phenolphthalein (total hydroxide+1/2 carbonate) as CaCO3	mg/L	all sites	<	<	<	<	<	<	<	<	<
Alkalinity, total as CaCO3	mg/L	all sites	68.80	89.00	100.00	90.40	110.00	128.00	100.00	140.00	160.00
Deuterium/Hydrogen ratio	o/oo VSMOW	all sites	-152.40	-144.25	-135.60	-142.20	-139.30	-133.80	-144.57	-139.95	-136.68
Dissolved oxygen (DO)	mg/L	all sites	-	-	-	-	-	-	-	-	-
Organic carbon, Filtered	mg/L	all sites	4.60	12.00	19.60	5.42	7.90	16.80	4.48	7.50	13.00
Organic carbon, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Organic carbon, Unknown	mg/L	all sites	4.30	12.50	19.00	4.47	9.10	20.50	5.03	8.20	14.00
Oxidation reduction potential (ORP)	mV	all sites	162.30	288.50	547.90	107.00	208.50	421.25	+	+	+
	mV	AB07DD0010	+	+	+	+	+	+	105.20	193.00	426.86
	mV	AB07DD0105	+	+	+	+	+	+	104.30	227.50	553.20
Oxygen-18	o/oo VSMOW	all sites	-19.02	-18.18	-16.98	-17.76	-17.30	-16.70	-18.21	-17.32	-16.90
Specific conductivity	uS/cm	all sites	172.00	220.00	286.00	232.00	290.00	362.00	289.00	420.00	493.00
Temperature, air	degC	all sites	6.00	17.00	34.00	-4.00	8.00	22.00	-26.50	-7.00	6.25
Total dissolved solids, Filtered	mg/L	all sites	101.00	140.00	180.00	141.00	180.00	267.00	178.00	250.00	302.00
Total suspended solids, Non-Filterable (Particle)	mg/L	all sites	34.00	160.00	612.00	10.40	32.00	206.00	1.30	4.00	17.00
True colour, Filtered	rel units	all sites	15.60	66.00	126.00	16.20	32.00	97.80	17.80	28.00	57.90
Turbidity	NTU	all sites	4.12	65.00	246.00	4.20	13.00	77.80	2.88	3.70	14.90

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
pH, lab	pH units	all sites	7.63	8.02	8.17	7.60	8.04	8.20	+	+	+
	pH units	AB07DD0010	+	+	+	+	+	+	7.78	7.96	8.06
	pH units	AB07DD0105	+	+	+	+	+	+	7.64	7.88	8.02
Dissolved Metals											
Aluminum, Filtered	ug/L	all sites	3.55	16.20	104.85	1.84	7.96	39.06	1.92	4.23	18.39
Antimony, Filtered	ug/L	all sites	0.06	0.09	0.13	<	<	<	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	<	<	<
	ug/L	AB07DD0105	+	+	+	+	+	+	<	<	<
Arsenic, Filtered	ug/L	all sites	0.35	0.55	0.79	0.33	0.50	0.80	0.30	0.42	0.60
Barium, Filtered	ug/L	all sites	34.70	42.95	49.55	40.78	45.60	53.30	44.51	59.75	70.34
Beryllium, Filtered	ug/L	all sites	0.00	0.01	0.02	0.00	0.00	0.04	0.00	0.00	0.05
Bismuth, Filtered	ug/L	all sites	0.00	0.00	0.01	0.00	0.00	0.02	<	<	<
Boron, Filtered	ug/L	all sites	15.62	22.20	30.93	17.86	22.60	29.20	24.36	31.75	37.77
Cadmium, Filtered	ug/L	all sites	0.01	0.01	0.02	0.00	0.01	0.11	0.01	0.01	0.03
Calcium, Filtered	mg/L	all sites	17.65	25.75	31.07	25.12	31.40	36.80	29.55	40.20	48.64
Chlorine, Filtered	mg/L	all sites	1.56	4.09	7.83	4.03	8.22	16.48	10.29	20.80	37.09
Chromium, Filtered	ug/L	all sites	0.08	0.23	0.76	0.05	0.15	0.54	0.10	0.24	0.48
Cobalt, Filtered	ug/L	all sites	0.04	0.07	0.13	0.04	0.07	0.22	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	0.04	0.08	0.17
	ug/L	AB07DD0105	+	+	+	+	+	+	0.02	0.06	0.14
Copper, Filtered	ug/L	all sites	0.83	1.55	2.46	0.65	0.97	2.18	0.50	0.75	1.35
Iron, Filtered	ug/L	all sites	29.55	121.50	426.50	23.60	95.00	293.60	116.65	178.00	367.40
Lead, Filtered	ug/L	all sites	0.02	0.08	0.26	0.01	0.04	0.23	0.01	0.05	0.76
Lithium, Filtered	ug/L	all sites	3.75	5.21	7.40	4.73	6.09	7.20	6.78	8.59	10.79
Manganese, Filtered	ug/L	all sites	0.55	1.73	6.01	0.31	1.40	8.23	4.68	18.80	35.09

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Mercury, Filtered	ng/L	all sites	-	-	-	-	-	-	0.33	0.50	1.29
Methylmercury(1+), Filtered	ng/L	all sites	0.02	0.06	0.11	0.02	0.04	0.12	0.02	0.03	0.06
Molybdenum, Filtered	ug/L	all sites	0.15	0.49	0.70	0.38	0.63	0.98	0.52	0.64	0.75
Nickel, Filtered	ug/L	all sites	0.36	1.43	3.48	0.29	0.75	1.33	0.07	0.76	1.47
Selenium, Filtered	ug/L	all sites	0.05	0.11	0.26	0.18	0.24	0.30	0.14	0.25	0.45
Silver, Filtered	ug/L	all sites	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
Strontium, Filtered	ug/L	all sites	99.12	162.50	213.00	128.20	206.00	253.00	195.80	266.00	339.40
Thallium, Filtered	ug/L	all sites	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.02
Thorium, Filtered	ug/L	all sites	0.00	0.03	0.13	0.00	0.01	0.06	0.00	0.01	0.05
Tin, Filtered	ug/L	all sites	<	<	<	<	<	<	<	<	<
Titanium, Filtered	ug/L	all sites	0.64	1.91	9.21	0.44	1.03	4.72	0.81	1.18	2.33
Uranium, Filtered	ug/L	all sites	0.25	0.34	0.39	0.26	0.35	0.43	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	0.27	0.42	0.49
	ug/L	AB07DD0105	+	+	+	+	+	+	0.31	0.39	0.48
Vanadium, Filtered	ug/L	all sites	0.26	0.43	0.67	0.19	0.31	0.65	0.07	0.17	0.33
Zinc, Filtered	ug/L	all sites	0.23	0.61	1.73	0.22	0.53	1.11	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	0.75	1.02	3.51
	ug/L	AB07DD0105	+	+	+	+	+	+	0.59	1.58	7.75
Extractable Metals											
Aluminum, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Antimony, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Arsenic, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Barium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Beryllium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bismuth, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

	Parameter	Unit	Site	High Flow			Open Water			Under Ice		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
	Boron, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Cadmium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Calcium, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
	Chromium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Cobalt, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Copper, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Iron, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Lead, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Lithium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Manganese, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Molybdenum, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Nickel, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Selenium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Silver, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Strontium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Thallium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Thorium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Tin, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Titanium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Uranium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Vanadium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Zinc, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Field												
	Colour (visual)	1	all sites	0.20	1.00	2.00	0.20	1.00	1.80	0.00	1.00	1.00
	Depth, snow cover	m	all sites	-	-	-	-	-	-	0.03	0.16	0.45

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Dissolved oxygen (DO)	mg/L	all sites	7.64	9.05	11.28	7.88	10.40	13.16	+	+	+
	mg/L	AB07DD0010	+	+	+	+	+	+	9.87	11.32	13.47
	mg/L	AB07DD0105	+	+	+	+	+	+	8.79	10.78	12.93
Floating solids or foam	1	all sites	0.00	1.00	3.00	0.00	1.00	2.00	0.00	0.00	0.00
Ice cover	%	all sites	-	-	-	-	-	-	88.25	100.00	100.00
Ice thickness	m	AB07DD0010	+	+	+	+	+	+	0.10	0.50	0.79
	m	AB07DD0105	+	+	+	+	+	+	0.26	0.70	1.35
Odor	1	all sites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snow cover	%	all sites	-	-	-	-	-	-	80.00	100.00	100.00
Specific conductivity	uS/cm	all sites	150.06	228.60	287.38	217.25	286.20	362.00	+	+	+
	uS/cm	AB07DD0010	+	+	+	+	+	+	137.18	425.40	510.44
	uS/cm	AB07DD0105	+	+	+	+	+	+	271.09	401.20	486.53
Temperature, water	degC	all sites	7.40	17.27	21.82	1.59	10.95	21.91	-0.21	0.01	0.19
Turbidity, visual	1	all sites	1.00	2.00	3.00	0.00	1.00	2.00	0.00	1.00	1.15
pH	pH units	all sites	7.51	7.88	8.20	7.47	8.00	9.05	+	+	+
	pH units	AB07DD0010	+	+	+	+	+	+	6.97	7.43	8.23
	pH units	AB07DD0105	+	+	+	+	+	+	6.33	7.25	7.64
General Organics											
12-Chlorodehydroabietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
14-Chlorodehydroabietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,6-Dinitrotoluene	ug/L	all sites	-	-	-	-	-	-	-	-	-
2-Chloroethyl vinyl ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,4,5-Trichlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,4,5-Trichloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
3,4,6-Trichlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,4,6-Trichloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,4-Dichlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,4-Dichloroguaiacol	mg/L	all sites	-	-	-	-	-	-	-	-	-
3,5-Dichlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
3,6-Dichlorocatechol	mg/L	all sites	-	-	-	-	-	-	-	-	-
4,5,6-Trichloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4,5,6-Trichlorosyringol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4,5-Dichlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4,5-Dichloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4,5-Dichloroveratrole	ug/L	all sites	-	-	-	-	-	-	-	-	-
4,6-Dichloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4-Chlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4-Chloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Abietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Arachidic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
BTEX, Total	mg/L	all sites	-	-	-	-	-	-	<	<	<
Benzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Benzidine	ug/L	all sites	-	-	-	-	-	-	-	-	-
C10-C16 Hydrocarbons	ug/L	all sites	-	-	-	-	-	-	<	<	<
C16-C34 Hydrocarbons	ug/L	all sites	<	<	<	<	<	<	<	<	<
C34-C50 Hydrocarbons	ug/L	all sites	-	-	-	-	-	-	<	<	<
C6-C10 Hydrocarbons	ug/L	all sites	-	-	-	-	-	-	<	<	<
Cumene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Cyanide, Unknown	mg/L	all sites	<	<	<	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Dehydroabietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Ethylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Isophorone	ug/L	all sites	-	-	-	-	-	-	-	-	-
Isopimaric acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Levopimaric acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Linoleic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Methyl tert-butyl ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
Myristic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
N-Nitrosodi-n-propylamine	ug/L	all sites	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	ug/L	all sites	-	-	-	-	-	-	-	-	-
Naphthenic acids	mg/L	all sites	0.07	0.23	0.41	0.07	0.14	0.27	0.05	0.19	0.52
Neoabietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Nitrobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Oilsands extractable organics	mg/L	all sites	0.28	0.66	6.95	0.15	0.40	2.93	0.14	0.50	1.66
Oleic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Palmitic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Palustric acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Pimaric acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
S-Ethyl dipropylthiocarbamate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Sandaracopimaric acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Stearic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Styrene	ug/L	all sites	-	-	-	-	-	-	<	<	<
Tetrachlorocatechol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Tetrachloroguaiacol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Tetrachloroveratrole	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Toluene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Vinyl chloride	ug/L	all sites	-	-	-	-	-	-	-	-	-
Xylene	ug/L	all sites	-	-	-	-	-	-	<	<	<
m,p-Xylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
n-Butylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
n-Propylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
o-Xylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Cymene	ug/L	all sites	-	-	-	-	-	-	-	-	-
sec-Butylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
tert-Butylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Major Ions											
Calcium, Filtered	mg/L	all sites	20.40	27.00	33.80	26.00	33.00	37.80	32.00	42.00	49.20
Chlorate, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Chloride, Unfiltered	mg/L	all sites	3.70	6.00	12.40	6.04	12.00	21.40	13.90	25.00	40.00
Fluoride, Unfiltered	mg/L	all sites	0.08	0.10	0.12	0.09	0.10	0.13	0.10	0.12	0.14
Magnesium, Filtered	mg/L	all sites	4.84	7.90	9.74	8.32	9.40	11.80	+	+	+
	mg/L	AB07DD0010	+	+	+	+	+	+	9.42	13.00	15.00
	mg/L	AB07DD0105	+	+	+	+	+	+	9.65	12.00	14.00
Potassium, Filtered	mg/L	all sites	0.74	1.30	2.60	0.96	1.20	1.48	1.29	1.80	2.31
Sodium, Filtered	mg/L	all sites	8.20	9.40	15.80	10.20	16.00	20.00	20.70	29.00	40.20
Sulfate, Unfiltered as SO4	mg/L	all sites	14.00	23.00	28.80	19.40	28.00	39.00	27.80	36.00	47.10
Sulfide, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Nutrients and BOD											
Ammonia and ammonium, Unfiltered as N	mg/L	all sites	<	<	<	0.01	0.02	0.08	0.02	0.05	0.10

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Biochemical oxygen demand, standard conditions, Filtered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Carbonaceous biochemical oxygen demand, non-standard conditions	mg/L	all sites	-	-	-	-	-	-	-	-	-
Chlorophyll a	ug/L	all sites	1.32	6.21	11.22	4.02	6.40	13.02	0.26	0.40	4.22
Inorganic nitrogen (nitrate and nitrite), Unfiltered as N	mg/L	all sites	0.02	0.05	0.11	-	-	-	0.03	0.17	0.27
Kjeldahl nitrogen, Unfiltered as N	mg/L	all sites	0.33	0.70	1.70	0.18	0.45	0.86	0.26	0.41	0.67
Nitrate, Unfiltered as N	mg/L	all sites	0.02	0.05	0.11	-	-	-	0.03	0.17	0.27
Nitrite, Unfiltered as N	mg/L	all sites	-	-	-	-	-	-	<	<	<
Orthophosphate, Filtered as P	mg/L	all sites	0.00	0.00	0.01	<	<	<	0.00	0.00	0.00
Silica, reactive, Unknown	mg/L	all sites	3.20	5.80	6.40	-	-	-	-	-	-
Total Phosphorus, mixed forms, Filtered as P	mg/L	all sites	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.01	0.02
Total Phosphorus, mixed forms, Unfiltered as P	mg/L	all sites	0.04	0.11	0.23	0.01	0.04	0.19	0.02	0.02	0.05
Organohalides											
1,1,1,2-Tetrachloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,1,2-Trichloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,1-Dichloroethylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2,3-Trichlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2,3-Trichloropropane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
1,2-Dibromo-3-chloropropane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2-Dichloropropane	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,2-Diphenylhydrazine	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,3,5-Trimethylbenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,3-DICHLOROPROPANE	ug/L	all sites	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
1-Propene, 1,1-dichloro-	ug/L	all sites	-	-	-	-	-	-	-	-	-
12,14-Dichlorodehydroabietic acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,2-Dichloropropane	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4,6-Trichloroanisole	mg/L	all sites	-	-	-	-	-	-	-	-	-
2,6-Dichlorosyringaldehyde	mg/L	all sites	-	-	-	-	-	-	-	-	-
2-Chloronaphthalene	ng/L	all sites	-	-	-	-	-	-	-	-	-
2-Chlorosyringaldehyde	mg/L	all sites	-	-	-	-	-	-	-	-	-
4-Bromophenyl phenyl ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
5,6-Dichlorovanillin	mg/L	all sites	-	-	-	-	-	-	-	-	-
5-Chlorovanillin	mg/L	all sites	-	-	-	-	-	-	-	-	-
6-Chlorovanillin	mg/L	all sites	-	-	-	-	-	-	-	-	-
9,10-Dichlorostearic Acid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Adsorbable Organic Halide	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bis(2-chloroethoxy)methane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bis(2-chloroethyl) ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bis(2-chloroisopropyl) ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bromobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
CFC-11	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Carbon tetrachloride	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chlorodibromomethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chloroform	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chloromethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dibromomethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dichlorobromomethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Ethylene dibromide	ug/L	all sites	-	-	-	-	-	-	-	-	-
Hexachlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Hexachlorobutadiene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Hexachlorocyclopentadiene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Hexachloroethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Methyl bromide	ug/L	all sites	-	-	-	-	-	-	-	-	-
Methylene chloride	ug/L	all sites	-	-	-	-	-	-	-	-	-
Tetrachloroethylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Tribromomethane	ug/L	all sites	-	-	-	-	-	-	-	-	-
Trichloroethylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethylene	ug/L	all sites	-	-	-	-	-	-	-	-	-
cis-1,3-Dichloropropene	ug/L	all sites	-	-	-	-	-	-	-	-	-
o-Chlorotoluene	ug/L	all sites	-	-	-	-	-	-	-	-	-
o-Dichlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Chlorophenyl phenyl ether	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Chlorotoluene	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Dichlorobenzene	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

	Parameter	Unit	Site	High Flow			Open Water			Under Ice		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
	trans-1,2-Dichloroethene	ug/L	all sites	-	-	-	-	-	-	-	-	-
	trans-1,3-Dichloropropene	ug/L	all sites	-	-	-	-	-	-	-	-	-
PAHs												
	1-Methylnaphthalene	ng/L	all sites	-	-	-	-	-	-	<	<	<
	2-Methylnaphthalene	ng/L	all sites	-	-	-	-	-	-	<	<	<
	3-Methylcholanthrene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	7,12-Dimethylbenz[a]anthracene	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Acenaphthene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Acenaphthylene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Benz[a]anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<
	Benzo(b)fluoranthene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	Benzo[a]pyrene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	Benzo[b,j,k]fluoranthene	ug/L	all sites	-	-	-	-	-	-	<	<	<
	Benzo[c]phenanthrene	ug/L	all sites	-	-	-	-	-	-	-	-	-
	Benzo[e]pyrene	ng/L	all sites	-	-	-	-	-	-	<	<	<
	Benzo[ghi]perylene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	Benzo[k]fluoranthene	ng/L	all sites	-	-	-	-	-	-	-	-	-
	C1-Dibenzothiophenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C1-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C2-Chrysenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C2-Dibenzothiophenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C2-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C2-Fluorenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
	C2-Naphthalenes	ng/L	all sites	<	<	<	-	-	-	<	<	<

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
C2-Phenanthrenes/anthracenes	ug/L	all sites	<	<	<	-	-	-	<	<	<
C3-Chrysenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C3-Dibenzothiophenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C3-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C3-Fluorenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C3-Naphthalenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C3-Phenanthrenes/anthracenes	ug/L	all sites	<	<	<	-	-	-	<	<	<
C4-Chrysenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C4-Dibenzothiophenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C4-Fluoranthenes/pyrenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C4-Fluorenes	ng/L	all sites	<	<	<	-	-	-	<	<	<
C4-Naphthalenes	ng/L	all sites	<	<	<	<	<	<	<	<	<
C4-Phenanthrenes/anthracenes	ug/L	all sites	<	<	<	-	-	-	<	<	<
Chrysene	ng/L	all sites	-	-	-	-	-	-	-	-	-
Dibenz[a,h]anthracene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Dibenzo[a,h]pyrene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dibenzo[a,i]pyrene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dibenzo[a,l]pyrene	ug/L	all sites	-	-	-	-	-	-	-	-	-
Fluoranthene	ng/L	all sites	-	-	-	-	-	-	-	-	-
Fluorene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Indeno[1,2,3-cd]pyrene	ng/L	all sites	<	<	<	<	<	<	<	<	<
Methylchrysene	ng/L	all sites	<	<	<	-	-	-	<	<	<
Methylfluorene	ng/L	all sites	<	<	<	-	-	-	<	<	<
Methylphenanthrene	ng/L	all sites	<	<	<	-	-	-	<	<	<
Naphthalene	ng/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
Perylene	ng/L	all sites	-	-	-	-	-	-	<	<	<
Phenanthrene	ng/L	all sites	-	-	-	-	-	-	-	-	-
Pyrene	ng/L	all sites	-	-	-	-	-	-	-	-	-
Retene	ng/L	all sites	-	-	-	-	-	-	<	<	<
Pesticide											
.alpha.-Endosulfan	ug/L	all sites	<	<	<	<	<	<	-	-	-
.lambda.-Cyhalothrin	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4-D	ug/L	all sites	<	<	<	<	<	<	-	-	-
2,4-DB	ug/L	all sites	<	<	<	<	<	<	-	-	-
2-Chloro-4-isopropylamino-6-amino-s-triazine	ug/L	all sites	<	<	<	<	<	<	-	-	-
2-Choro-6-ethylamino-4-amino-s-triazine	ug/L	all sites	<	<	<	<	<	<	-	-	-
Aldicarb	ug/L	all sites	<	<	<	<	<	<	-	-	-
Aldicarb sulfone	ug/L	all sites	-	-	-	-	-	-	-	-	-
Aldicarb sulfoxide	ug/L	all sites	-	-	-	-	-	-	-	-	-
Aldrin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Aminocarb	ug/L	all sites	-	-	-	-	-	-	-	-	-
Aminopyralid	ug/L	all sites	<	<	<	<	<	<	-	-	-
Atrazine	ug/L	all sites	<	<	<	<	<	<	-	-	-
Atrazine de-ethylated	ug/L	all sites	-	-	-	-	-	-	-	-	-
Azinphos-methyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Azoxystrobin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Benomyl	ug/L	all sites	-	-	-	-	-	-	-	-	-
Bentazon	ug/L	all sites	<	<	<	<	<	<	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Benzene Hexachloride, Alpha (BHC)	ug/L	all sites	<	<	<	<	<	<	-	-	-
Bromacil	ug/L	all sites	<	<	<	<	<	<	-	-	-
Bromoxynil	ug/L	all sites	<	<	<	<	<	<	-	-	-
Carbaryl	ug/L	all sites	-	-	-	-	-	-	-	-	-
Carbofuran	ug/L	all sites	-	-	-	-	-	-	-	-	-
Carboxin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Chlorothalonil	ug/L	all sites	<	<	<	<	<	<	-	-	-
Chlorpyrifos	ug/L	all sites	<	<	<	<	<	<	-	-	-
Clodinafop acid metabolite	ug/L	all sites	<	<	<	<	<	<	-	-	-
Clodinafop-propargyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Clopyralid	ug/L	all sites	<	<	<	<	<	<	-	-	-
Clothianidin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Cyanazine	ug/L	all sites	<	<	<	<	<	<	-	-	-
Deltamethrin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Diazinon	ug/L	all sites	<	<	<	<	<	<	-	-	-
Dicamba	ug/L	all sites	<	<	<	<	<	<	-	-	-
Dichlorprop	ug/L	all sites	<	<	<	<	<	<	-	-	-
Diclofop methyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Dieldrin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Difenoconazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dimethoate	ug/L	all sites	<	<	<	<	<	<	-	-	-
Disulfoton	ug/L	all sites	<	<	<	<	<	<	-	-	-
Diuron	ug/L	all sites	<	<	<	<	<	<	-	-	-
Ethalfluralin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Ethion	ug/L	all sites	<	<	<	<	<	<	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Ethofumesate	ug/L	all sites	<	<	<	<	<	<	-	-	-
Fenoxaprop-p-ethyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Fenoxaprop-p-methyl	ug/L	all sites	-	-	-	-	-	-	-	-	-
Fluazifop-P-butyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Fluroxypyr	ug/L	all sites	<	<	<	<	<	<	-	-	-
Hexaconazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Imazamethabenz-methyl	ug/L	all sites	<	<	<	<	<	<	-	-	-
Imazamox	ug/L	all sites	-	-	-	-	-	-	-	-	-
Imazethapyr	ug/L	all sites	<	<	<	<	<	<	-	-	-
Imidacloprid	ug/L	all sites	-	-	-	-	-	-	-	-	-
Iprodione	ug/L	all sites	<	<	<	<	<	<	-	-	-
Lindane	ug/L	all sites	<	<	<	<	<	<	-	-	-
Linuron	ug/L	all sites	<	<	<	<	<	<	-	-	-
MCPA	ug/L	all sites	<	<	<	<	<	<	-	-	-
MCPB	ug/L	all sites	<	<	<	<	<	<	-	-	-
Malathion	ug/L	all sites	<	<	<	<	<	<	-	-	-
Mecoprop	ug/L	all sites	<	<	<	<	<	<	-	-	-
Metalaxyl-M	ug/L	all sites	<	<	<	<	<	<	-	-	-
Metconazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Methomyl	ug/L	all sites	<	<	<	-	-	-	-	-	-
Methoxychlor	ug/L	all sites	<	<	<	<	<	<	-	-	-
Metolachlor	ug/L	all sites	<	<	<	<	<	<	-	-	-
Metribuzin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Monuron	ug/L	all sites	-	-	-	-	-	-	-	-	-
Napropamide	ug/L	all sites	<	<	<	<	<	<	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
OH-Carbofuran	ug/L	all sites	-	-	-	-	-	-	-	-	-
Oxycarboxin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Parathion	ug/L	all sites	<	<	<	<	<	<	-	-	-
Permethrin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Phorate	ug/L	all sites	<	<	<	<	<	<	-	-	-
Picloram	ug/L	all sites	<	<	<	<	<	<	-	-	-
Picoxystrobin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Propiconazole	ug/L	all sites	<	<	<	<	<	<	-	-	-
Prothioconazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Pyraclostrobin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Pyridaben	ug/L	all sites	<	<	<	<	<	<	-	-	-
Quinclorac	ug/L	all sites	<	<	<	<	<	<	-	-	-
Quizalofop	ug/L	all sites	<	<	<	<	<	<	-	-	-
Simazine	ug/L	all sites	<	<	<	<	<	<	-	-	-
Tebuconazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Terbufos	ug/L	all sites	<	<	<	<	<	<	-	-	-
Thiamethoxam	ug/L	all sites	<	<	<	<	<	<	-	-	-
Triallate	ug/L	all sites	<	<	<	<	<	<	-	-	-
Triclopyr	ug/L	all sites	<	<	<	<	<	<	-	-	-
Trifloxystrobin	ug/L	all sites	-	-	-	-	-	-	-	-	-
Trifluralin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Triticonazole	ug/L	all sites	-	-	-	-	-	-	-	-	-
Vinclozolin	ug/L	all sites	<	<	<	<	<	<	-	-	-
Phenolics											
2,3,4,6-Tetrachlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow			Open Water			Under Ice		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
2,4,5-Trichlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4,6-Trichlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4-Dichlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4-Dichlorophenol/2,5-Dichlorophenol	mg/L	all sites	-	-	-	-	-	-	-	-	-
2,4-Dimethylphenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,4-Dinitrophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
2,6-Dichlorophenol	mg/L	all sites	-	-	-	-	-	-	-	-	-
4,6-Dinitro-o-cresol	ug/L	all sites	-	-	-	-	-	-	-	-	-
4-Chloro-2-methylphenol	ug/L	all sites	<	<	<	<	<	<	-	-	-
4-Chlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Pentachlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Phenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Phenolics	mg/L	all sites	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01
o-Chlorophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
o-Nitrophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Chloro-m-cresol	ug/L	all sites	-	-	-	-	-	-	-	-	-
p-Nitrophenol	ug/L	all sites	-	-	-	-	-	-	-	-	-
Phthalates											
Butyl benzyl phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Di(2-ethoxylhexyl) phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Di-n-octyl phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dibutyl phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Diethyl phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-
Dimethyl phthalate	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
Target PANHs											
Acridine	ug/L	all sites	-	-	-	-	-	-	-	-	-
Total Metals											
Chromium(VI), Unknown	mg/L	all sites	<	<	<	-	-	-	-	-	-
Mercury, Unfiltered	ng/L	all sites	3.42	8.90	23.80	0.80	2.99	13.70	0.46	0.82	4.25
Methylmercury(1+), Unfiltered	ng/L	all sites	0.03	0.16	0.25	0.04	0.07	0.19	0.03	0.04	0.10
Total Recoverable Metals											
Aluminum, Unfiltered	ug/L	all sites	396.75	2770.00	13475.00	142.40	792.00	5480.00	26.60	97.50	1202.25
Antimony, Unfiltered	ug/L	all sites	0.07	0.10	0.15	0.03	0.07	0.28	0.04	0.05	0.12
Arsenic, Unfiltered	ug/L	all sites	0.72	1.75	2.91	0.50	0.86	1.95	0.42	0.57	0.83
Barium, Unfiltered	ug/L	all sites	55.85	86.15	239.25	46.06	56.90	141.06	49.84	64.05	77.97
Beryllium, Unfiltered	ug/L	all sites	0.03	0.14	0.47	0.01	0.04	0.23	0.00	0.01	0.11
Bismuth, Unfiltered	ug/L	all sites	0.01	0.02	0.06	0.00	0.01	0.02	0.00	0.00	0.02
Boron, Unfiltered	ug/L	all sites	17.00	24.80	41.77	20.70	24.70	40.54	24.30	32.85	39.78
Cadmium, Unfiltered	ug/L	all sites	0.02	0.06	0.27	0.01	0.02	0.13	0.01	0.02	0.09
Calcium, Unfiltered	mg/L	all sites	19.57	27.85	35.48	25.82	32.40	38.18	29.82	40.50	50.23
Chlorine, Unfiltered	mg/L	all sites	1.58	4.12	7.88	4.06	8.40	16.74	10.89	20.80	38.17
Chromium, Unfiltered	ug/L	all sites	0.69	3.21	11.71	0.15	0.92	6.31	0.05	0.22	0.68
Cobalt, Unfiltered	ug/L	all sites	0.39	1.35	4.94	0.17	0.41	1.87	0.06	0.12	0.43
Copper, Unfiltered	ug/L	all sites	1.63	3.65	10.13	0.94	1.42	4.81	0.54	0.91	1.90
Iron, Unfiltered	ug/L	all sites	1292.50	4240.00	13625.00	454.20	1050.00	4414.00	412.75	565.50	1294.50
Lead, Unfiltered	ug/L	all sites	0.54	2.12	10.55	0.17	0.47	2.81	0.07	0.16	2.56
Lithium, Unfiltered	ug/L	all sites	5.16	7.46	16.95	5.83	6.83	8.13	7.04	8.92	11.09
Manganese, Unfiltered	ug/L	all sites	44.25	104.40	320.50	19.80	54.70	113.80	16.82	30.75	51.66
Molybdenum, Unfiltered	ug/L	all sites	0.15	0.52	0.73	0.38	0.60	0.98	0.54	0.65	0.77

Table 2.6: Current Conditions, Athabasca River Delta water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Nickel, Unfiltered	ug/L	all sites	1.50	4.33	13.17	0.60	1.55	4.97	0.10	1.01	2.25
Selenium, Unfiltered	ug/L	all sites	0.15	0.26	0.47	0.15	0.22	0.30	0.19	0.30	0.50
Silver, Unfiltered	ug/L	all sites	0.01	0.02	0.33	0.00	0.01	0.03	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	0.00	0.00	0.01
	ug/L	AB07DD0105	+	+	+	+	+	+	0.00	0.00	0.02
Strontium, Unfiltered	ug/L	all sites	111.00	174.50	227.50	129.40	206.00	256.60	197.10	275.00	343.40
Thallium, Unfiltered	ug/L	all sites	0.02	0.05	0.21	0.01	0.02	0.11	0.00	0.01	0.05
Thorium, Unfiltered	ug/L	all sites	0.09	0.42	2.51	0.03	0.14	0.88	0.01	0.02	0.20
Tin, Unfiltered	ug/L	all sites	0.02	0.05	0.11	<	<	<	0.01	0.04	0.10
Titanium, Unfiltered	ug/L	all sites	6.74	33.90	127.00	2.78	11.60	69.98	1.73	2.53	22.63
Uranium, Unfiltered	ug/L	all sites	0.36	0.49	1.27	0.32	0.41	0.65	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	0.28	0.44	0.52
	ug/L	AB07DD0105	+	+	+	+	+	+	0.31	0.40	0.52
Vanadium, Unfiltered	ug/L	all sites	1.58	6.73	21.23	0.64	2.04	12.25	0.25	0.43	2.04
Zinc, Unfiltered	ug/L	all sites	3.27	10.36	32.95	1.40	3.10	15.63	+	+	+
	ug/L	AB07DD0010	+	+	+	+	+	+	1.02	1.65	6.98
	ug/L	AB07DD0105	+	+	+	+	+	+	1.05	2.58	13.22

Note:
- data insufficient
< too highly censored;
+ grouped differently (merged sites vs individual site);

Table 2.7: Current Conditions, Athabasca River Delta sediment.

Parameter	Unit	Site	5th	50th	95th
Conventional Variables					
Acid Neutralization Potential as %CaCO3	%	all sites	1.61	5.51	8.35
Grain size, clay (<2 um)	%	all sites	3.07	16.10	33.23
Grain size, sand (>=63 um to 2000 um)	%	all sites	3.39	34.50	92.03
Grain size, silt (>=2 to 63 um)	%	all sites	4.57	48.20	72.33
Inorganic carbon	%	all sites	0.24	0.74	1.02
Moisture content	%	all sites	22.25	34.20	56.30
Organic carbon	%	all sites	0.53	1.44	2.50
Total carbon	%	all sites	0.77	2.10	3.33
General Organics					
AEP Total recoverable hydrocarbons	ug/g	all sites	600.00	700.00	1400.00
BTEX, Total	ug/g	all sites	-	-	-
Benzene	ug/g	all sites	<	<	<
C10-C16 Hydrocarbons	ug/g	all sites	15.48	26.65	48.60
C11-C30 AEP Total extractable hydrocarbons	ug/g	all sites	54.00	200.00	500.00
C16-C34 Hydrocarbons	ug/g	all sites	33.42	216.00	394.50
C34-C50 Hydrocarbons	ug/g	all sites	33.45	172.00	424.50
C5-C10 AEP Total volatile hydrocarbons	ug/g	all sites	0.79	2.35	8.50
Ethylbenzene	ug/g	all sites	<	<	<
Hydrocarbons	ug/g	all sites	85.25	405.50	715.15
Styrene	ug/g	all sites	-	-	-
Toluene	ug/g	all sites	<	<	<
Total xylenes	ug/g	all sites	-	-	-
m,p-Xylene	ug/g	all sites	<	<	<
o-Xylene	ug/g	all sites	<	<	<
PAHs					
1,2,6-Trimethylphenanthrene	ng/g	all sites	-	-	-
1,2-Dimethylnaphthalene	ng/g	all sites	-	-	-
1,4,6,7-Tetramethylnaphthalene	ng/g	all sites	-	-	-
1,6,7-Trimethylnaphthalene	ng/g	all sites	-	-	-
1,7-Dimethylfluorene	ng/g	all sites	-	-	-
1,7-Dimethylphenanthrene	ng/g	all sites	-	-	-
1,8-Dimethylphenanthrene	ng/g	all sites	-	-	-
1-Methylchrysene	ng/g	all sites	-	-	-
1-Methylnaphthalene	ng/g	all sites	-	-	-
1-Methylphenanthrene	ng/g	all sites	-	-	-
2,3,6-Trimethylnaphthalene	ng/g	all sites	-	-	-
2,4-Dimethyldibenzothiophene	ng/g	all sites	-	-	-
2,6-Dimethylnaphthalene	ng/g	all sites	-	-	-
2,6-Dimethylphenanthrene	ng/g	all sites	-	-	-
2-Methylanthracene	ng/g	all sites	-	-	-
2-Methyldibenzothiophenes/3-Methyldibenzothiophenes	ng/g	all sites	-	-	-
2-Methylfluorene	ng/g	all sites	-	-	-
2-Methylnaphthalene	ng/g	all sites	-	-	-

Table 2.7: Current Conditions, Athabasca River Delta sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
2-Methylphenanthrene	ng/g	all sites	-	-	-
3,6-Dimethylphenanthrene	ng/g	all sites	-	-	-
3-Methylfluoranthene/Benzo[a]fluorene	ng/g	all sites	-	-	-
3-Methylphenanthrene	ng/g	all sites	-	-	-
5,9-Dimethylchrysene	ng/g	all sites	-	-	-
5-Methylchrysene/6-Methylchrysene	ng/g	all sites	-	-	-
7-Methylbenzo[a]pyrene	ng/g	all sites	-	-	-
9-Methylphenanthrene/4-Methylphenanthrene	ng/g	all sites	-	-	-
Acenaphthene	ng/g	all sites	$<$	$<$	$<$
Acenaphthylene	ng/g	all sites	$<$	$<$	$<$
Anthracene	ng/g	all sites	$<$	$<$	$<$
Benz[a]anthracene	ng/g	all sites	$<$	$<$	$<$
Benzo(b)fluoranthene	ng/g	all sites	-	-	-
Benzo(j+k)fluoranthene	ng/g	all sites	-	-	-
Benzo[a]pyrene	ng/g	all sites	3.39	5.88	10.20
Benzo[b,j,k]fluoranthene	ng/g	all sites	3.30	15.65	27.77
Benzo[e]pyrene	ng/g	all sites	-	-	-
Benzo[ghi]perylene	ng/g	all sites	3.44	10.45	18.43
Biphenyl	ng/g	all sites	1.69	5.87	10.68
C1-Acenaphthenes	ng/g	all sites	$<$	$<$	$<$
C1-Benzo[a]anthracenes/chrysenes	ng/g	all sites	7.73	67.95	256.75
C1-Benzofluoranthenes/benzopyrenes	ng/g	all sites	17.39	47.45	87.61
C1-Biphenyls	ng/g	all sites	3.30	6.80	14.43
C1-Dibenzothiophenes	ng/g	all sites	3.46	11.35	22.95
C1-Fluoranthenes/pyrenes	ng/g	all sites	17.90	46.25	135.50
C1-Fluorenes	ng/g	all sites	3.26	8.54	25.59
C1-Naphthalenes	ng/g	all sites	5.87	26.25	48.42
C1-Phenanthrenes/anthracenes	ng/g	all sites	7.01	37.80	77.25
C2-Benzo[a]anthracenes/chrysenes	ng/g	all sites	$<$	$<$	$<$
C2-Benzofluoranthenes/benzopyrenes	ng/g	all sites	9.50	21.15	39.20
C2-Biphenyls	ng/g	all sites	2.97	8.62	25.80
C2-Dibenzothiophenes	ng/g	all sites	15.80	49.45	108.80
C2-Fluoranthenes/pyrenes	ng/g	all sites	31.49	80.80	243.70
C2-Fluorenes	ng/g	all sites	8.81	26.50	55.42
C2-Naphthalenes	ng/g	all sites	11.60	43.00	78.95
C2-Phenanthrenes/anthracenes	ng/g	all sites	5.43	52.25	96.10
C3-Benzo[a]anthracenes/chrysenes	ng/g	all sites	-	-	-
C3-Dibenzothiophenes	ng/g	all sites	27.12	92.50	253.50
C3-Fluoranthenes/pyrenes	ng/g	all sites	28.47	78.20	198.90
C3-Fluorenes	ng/g	all sites	12.00	37.75	104.23
C3-Naphthalenes	ng/g	all sites	10.54	37.35	61.75
C3-Phenanthrenes/anthracenes	ng/g	all sites	19.91	59.00	144.75
C4-Benzo[a]anthracenes/chrysenes	ng/g	all sites	-	-	-
C4-Dibenzothiophenes	ng/g	all sites	33.26	113.50	267.35

Table 2.7: Current Conditions, Athabasca River Delta sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
C4-Fluoranthenes/pyrenes	ng/g	all sites	-	-	-
C4-Naphthalenes	ng/g	all sites	10.15	27.80	55.88
C4-Phenanthrenes/anthracenes	ng/g	all sites	24.50	248.00	543.75
Chrysene	ng/g	all sites	3.43	17.75	30.38
Dibenz[a,h]anthracene	ng/g	all sites	<	<	<
Dibenzothiophene	ng/g	all sites	<	<	<
Fluoranthene	ng/g	all sites	1.14	3.87	7.12
Fluorene	ng/g	all sites	0.38	2.30	4.53
Indeno[1,2,3-cd]pyrene	ng/g	all sites	2.25	6.22	11.50
Naphthalene	ng/g	all sites	2.17	7.75	20.20
Perylene	ng/g	all sites	-	-	-
Phenanthrene	ng/g	all sites	3.72	15.95	27.25
Pyrene	ng/g	all sites	3.22	10.45	18.55
Retene	ng/g	all sites	12.88	52.10	132.70
Total Metals					
Aluminum	ug/g	all sites	3314.00	7800.00	14340.00
Antimony	ug/g	all sites	0.13	0.22	0.35
Arsenic	ug/g	all sites	2.97	4.95	8.19
Barium	ug/g	all sites	66.33	149.50	213.50
Beryllium	ug/g	all sites	<	<	<
Bismuth	ug/g	all sites	<	<	<
Boron	ug/g	all sites	4.00	10.00	23.40
Cadmium	ug/g	all sites	<	<	<
Calcium	ug/g	all sites	9030.00	21100.00	27880.00
Chromium	ug/g	all sites	7.65	14.95	32.88
Cobalt	ug/g	all sites	5.03	7.70	11.22
Copper	ug/g	all sites	4.54	13.10	22.23
Iron	ug/g	all sites	8956.00	17500.00	26380.00
Lead	ug/g	all sites	3.85	7.91	12.10
Lithium	ug/g	all sites	2.19	10.70	20.10
Magnesium	ug/g	all sites	3518.00	7340.00	9310.00
Manganese	ug/g	all sites	172.80	392.00	632.60
Mercury	ug/g	all sites	0.02	0.04	0.07
Molybdenum	ug/g	all sites	<	<	<
Nickel	ug/g	all sites	10.19	18.75	29.40
Phosphorus	ug/g	all sites	185.50	610.50	767.50
Potassium	ug/g	all sites	525.50	1200.00	2100.00
Selenium	ug/g	all sites	0.19	0.41	1.01
Silver	ug/g	all sites	-	-	-
Sodium	ug/g	all sites	72.89	140.00	277.50
Strontium	ug/g	all sites	26.70	60.50	80.50
Thallium	ug/g	all sites	0.09	0.16	0.25
Tin	ug/g	all sites	<	<	<
Titanium	ug/g	all sites	25.44	56.00	82.72
Uranium	ug/g	all sites	<	<	<

Table 2.7: Current Conditions, Athabasca River Delta sediment. *(continued)*

Parameter	Unit	Site	5th	50th	95th
Vanadium	ug/g	all sites	12.82	21.70	36.10
Zinc	ug/g	all sites	29.82	59.35	83.53
Zirconium	ug/g	all sites	-	-	-

Note:
- data insufficient
< too highly censored;

2.8.3 Lake Athabasca Current Conditions

The current condition (5th, 50th, and 95th percentile values) for each water quality parameter and each season are presented for Lake Athabasca in Table 2.8 (water). Note that additional information, including sample size, analytical method codes, and quantile estimation method for each suite of current conditions are provided in Appendix A.2.

Table 2.8: Current Conditions, Lake Athabasca water.

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Conventional Variables											
Alkalinity, total	mg/L	all sites	-	-	-	30.20	35.20	99.30	-	-	-
Hardness as CaCO3	mg/L	all sites	-	-	-	31.20	38.54	104.00	-	-	-
Organic carbon, Filtered	mg/L	all sites	-	-	-	3.30	4.35	13.50	-	-	-
Organic carbon, Unfiltered	mg/L	all sites	-	-	-	3.50	4.15	13.10	-	-	-
Specific conductivity	uS/cm	all sites	-	-	-	79.70	92.35	234.00	-	-	-
Total dissolved solids, Filtered	mg/L	all sites	-	-	-	22.00	57.00	268.00	-	-	-
Total suspended solids, Non-Filterable (Particle)	mg/L	all sites	-	-	-	1.11	20.00	212.85	-	-	-
Turbidity, Unfiltered	NTU	all sites	-	-	-	6.08	25.95	158.00	-	-	-
pH, lab	pH units	all sites	-	-	-	7.58	7.72	8.11	-	-	-
Field											
Conductivity	uS/cm	all sites	73.19	170.52	248.91	45.57	136.13	226.60	-	-	-
Depth, Secchi disk depth	cm	all sites	1.50	10.12	55.50	10.03	21.59	81.10	-	-	-
Dissolved oxygen (DO)	mg/L	all sites	6.24	9.04	12.67	7.96	9.80	13.92	-	-	-
Dissolved oxygen saturation	%	all sites	62.93	94.62	113.90	84.33	95.27	117.30	-	-	-
Oxidation reduction potential (ORP)	mV	all sites	-286.94	135.50	319.68	-447.32	108.72	286.20	-	-	-
Salinity	ppt	all sites	0.04	0.09	0.17	0.03	0.10	0.14	-	-	-
Temperature, water	degC	all sites	7.79	17.55	22.28	1.17	14.00	21.50	-	-	-
Turbidity	NTU	all sites	9.70	48.80	198.70	7.54	24.70	80.70	-	-	-
pH	pH units	all sites	7.75	8.22	9.39	7.67	8.13	8.55	-	-	-
General Organics											
Silica gel treated n-hexane extractable material	mg/L	all sites	-	-	-	<	<	<	-	-	-
Major Ions											
Calcium, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.8: Current Conditions, Lake Athabasca water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Chloride, Unfiltered	mg/L	all sites	-	-	-	3.30	3.70	4.70	-	-	-
Fluoride, Unfiltered	mg/L	all sites	-	-	-	<	<	<	-	-	-
Magnesium, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Potassium, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Sodium, Unfiltered	mg/L	all sites	-	-	-	-	-	-	-	-	-
Sulfate, Unfiltered as SO4	mg/L	all sites	-	-	-	3.00	6.00	20.00	-	-	-
Nutrients and BOD											
Ammonia and ammonium, Unfiltered as N	mg/L	all sites	-	-	-	<	<	<	-	-	-
Inorganic nitrogen (nitrate and nitrite), Unfiltered as N	mg/L	all sites	-	-	-	0.02	0.10	0.22	-	-	-
Nitrate, Unfiltered as N	mg/L	all sites	-	-	-	0.01	0.10	0.22	-	-	-
Nitrite, Unfiltered as N	mg/L	all sites	-	-	-	0.00	0.00	0.04	-	-	-
Orthophosphate, Unfiltered as P	mg/L	all sites	-	-	-	0.00	0.00	0.00	-	-	-
Total Nitrogen, mixed forms, Filtered as N	mg/L	all sites	-	-	-	0.17	0.20	0.47	-	-	-
Total Nitrogen, mixed forms, Unfiltered as N	mg/L	all sites	-	-	-	0.20	0.25	0.65	-	-	-
Total Phosphorus, mixed forms, Filtered as P	mg/L	all sites	-	-	-	0.00	0.00	0.01	-	-	-
Total Phosphorus, mixed forms, Unfiltered as P	mg/L	all sites	-	-	-	0.01	0.04	0.27	-	-	-
Total Metals											
Aluminum, Unfiltered	ug/L	all sites	-	-	-	137.00	591.00	3100.00	-	-	-
Antimony, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Arsenic, Unfiltered	ug/L	all sites	-	-	-	0.30	0.70	2.40	-	-	-
Barium, Unfiltered	ug/L	all sites	-	-	-	19.10	29.90	92.60	-	-	-

Table 2.8: Current Conditions, Lake Athabasca water. *(continued)*

Parameter	Unit	Site	High Flow 5th	High Flow 50th	High Flow 95th	Open Water 5th	Open Water 50th	Open Water 95th	Under Ice 5th	Under Ice 50th	Under Ice 95th
Beryllium, Unfiltered	ug/L	all sites	-	-	-	0.01	0.03	0.14	-	-	-
Bismuth, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Boron, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Cadmium, Unfiltered	ug/L	all sites	-	-	-	<	<	<	-	-	-
Cesium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Chromium, Filtered	ug/L	all sites	-	-	-	<	<	<	-	-	-
Chromium, Unfiltered	ug/L	all sites	-	-	-	0.30	0.90	4.90	-	-	-
Chromium(VI), Unfiltered	mg/L	all sites	-	-	-	<	<	<	-	-	-
Cobalt, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Copper, Unfiltered	ug/L	all sites	-	-	-	0.90	1.45	7.20	-	-	-
Iron, Unfiltered	ug/L	all sites	-	-	-	236.00	953.00	6700.00	-	-	-
Lead, Unfiltered	ug/L	all sites	-	-	-	0.10	0.55	3.60	-	-	-
Lithium, Unfiltered	ug/L	all sites	-	-	-	3.00	3.85	8.00	-	-	-
Manganese, Unfiltered	ug/L	all sites	-	-	-	6.70	21.10	162.00	-	-	-
Mercury, Unfiltered	ng/L	all sites	-	-	-	-	-	-	-	-	-
Methylmercury(1+), Unfiltered	ng/L	all sites	-	-	-	-	-	-	-	-	-
Molybdenum, Unfiltered	ug/L	all sites	-	-	-	0.10	0.30	0.70	-	-	-
Nickel, Unfiltered	ug/L	all sites	-	-	-	0.60	1.50	8.70	-	-	-
Rubidium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Selenium, Unfiltered	ug/L	all sites	-	-	-	<	<	<	-	-	-
Silver, Unfiltered	ug/L	all sites	-	-	-	<	<	<	-	-	-
Strontium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Thallium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Tin, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Titanium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-

Table 2.8: Current Conditions, Lake Athabasca water. *(continued)*

			High Flow			Open Water			Under Ice		
Parameter	Unit	Site	5th	50th	95th	5th	50th	95th	5th	50th	95th
Uranium, Unfiltered	ug/L	all sites	-	-	-	-	-	-	-	-	-
Vanadium, Unfiltered	ug/L	all sites	-	-	-	0.50	1.90	9.20	-	-	-
Zinc, Unfiltered	ug/L	all sites	-	-	-	1.02	4.05	20.70	-	-	-

Note:
- data insufficient
< too highly censored;
+ grouped differently (merged sites vs individual site);

2.9 Discussion

2.9.1 Water and Sediment Quality

This section provides a high-level discussion of the results of the calculated current conditions for water and sediment quality. This includes a comparison with the Alberta water and sediment quality guidelines for the protection of aquatic life. However, please refer to Chapter 1 of this report for a discussion of the current conditions compared to the more comprehensive WQCIUs.

In the lower Athabasca River, the Athabasca River Delta and Lake Athabasca, median concentrations of nitrogen species, including ammonia and nitrate, are generally below guidelines for the protection of aquatic life. Median total phosphorus measures are mostly below the level at which eutrophication becomes a concern, however, high flow median and other peak values (i.e., 95th percentile) are above that level, up to 0.59 mg/L in the lower Athabasca River. However, similarly high peak concentrations of total phosphorus in the Athabasca River Delta do not correspond to high concentrations of chlorophyll a, which is an indicator of algal biomass in the water column. Instead, median and peak chlorophyll a measures in the Athabasca River Delta during the high flow and open water seasons indicate mesotrophic conditions. No measures of benthic or epiphytic chlorophyll were available for any of the locations in this study.

Field and laboratory measures of pH indicate that the River, Delta and Lake water is neutral to moderately basic, with moderate to high hardness levels, moderate conductivity measures including significant contributions from sodium, calcium and sulfate ions. An exception to this is in the Delta and Lake during the under ice season, where some 5th percentile values were slightly acidic. Dissolved oxygen concentrations are above the required concentration to support aquatic life, although it can be relatively low during the high flow season in Lake Athabasca, presumably in early winter after the ice cover has been in place for many months. In general, Lake Athabasca water is slightly less alkaline with lower concentrations of chloride and sulfate compared to River and Delta water.

Certain median metals and trace element concentrations in water are above provincial guidelines for the protection of aquatic life. This includes total cobalt, total and dissolved copper, total lead, total manganese, total selenium, total thallium and total zinc in the Athabasca River and Delta, especially in the high flow seasons but also in others. Total mercury exceeds these guidelines in the River, but insufficient data are available for the Delta. In Lake Athabasca, where total metals and trace elements data were available for the open water season only, fewer guideline exceedances were noted. Those exceedances included total copper and lead (peak values only). For many trace elements and metals, data for Lake Athabasca were insufficient to calculate summary statistics.

The pattern of trace element exceedances in water in the Athabasca River and Delta occurring especially in the high flow season, indicates that these constituents are likely associated with suspended particles that are transported in the water column predominantly during high flows. The majority of total trace elements measured in the Athabasca River follow this pattern, including total lead, total mercury, total nickel, total selenium, total uranium, and total vanadium. Measures of total suspended solids in these locations are highest in the high flow season, lower in the open water season, and lowest in the under ice season, coinciding with these exceedances and supporting the importance of the association of particles and certain trace elements. In addition, in the Athabasca River, there are examples of non-particle associated, or dissolved, trace element concentrations that peak during the high flow season, including dissolved aluminum, dissolved chromium, dissolved copper, dissolved lead, and dissolved nickel. Not all trace element concentrations peak during the high flow season, however, for example, in the Athabasca River, dissolved barium, dissolved boron, dissolved lithium, dissolved manganese, dissolved strontium, dissolved uranium, total boron and total strontium concentrations peak in the under ice season. Other trace elements, both dissolved and total, do not exhibit distinct peaks in any season. In some cases in the Athabasca River, the seasonal pattern of trace element concentrations is site-specific, indicating the importance of local conditions. The seasonal patterns of trace element and other constituent concentrations can help to understand the sources and delivery pathways of these constituents to the Athabasca River, Athabasca River Delta and Lake Athabasca when paired with information about water and sediment delivery to these systems. For example, the proportion of water inflows made up by groundwater, snow melt, overland runoff generated during storms and from upstream flow generally changes predictably through the seasons.

Pesticides and organohalides were generally not measured in water above the relevant detection limits in the Athabasca River and the Delta. This was also true for the vast majority of measured PAHs and general organic measures in the River, with the exception of certain hydrocarbon measures, toluene, and certain mainly alkylated PAHs (the latter mainly during high flows). In the Delta, PAHs and general organic constituents were not measured above the relevant detection limits, with the exception of naphthenic acids and the related measure, oil sands extractable organics, which were consistently detected. Pesticides were not measured in Lake Athabasca water, and organohalide data were minimal.

Certain trace elements and metals were detected at elevated levels in sediment in the River and Delta, however most median concentrations did not exceed the provincial guidelines for the protection of aquatic life, with the exception of nickel in the Delta. For those PAHs with provincial sediment quality guidelines for the protection of aquatic life, no exceedances in the current conditions were noted. It is important to keep in mind however, that most of the measured metals, trace elements and PAHs do not have applicable sediment quality guidelines. For example, in the Athabasca River Delta, 20 non-alkylated PAHs, 27 alkylated PAHs, 27 alkylated PAH groups and dibenzothiphene were measured in sediments, however Alberta sediment quality guidelines for the protection of aquatic life apply to only 11 non-alkylated PAHs (GoA, 2018).

2.9.2 The Effect of Location

It should be kept in mind that in many cases, different detection limits were in effect for water quality measures from the Athabasca River, the Delta and the Lake. The lack of detection in one system does not necessarily mean that it is a lower concentration than in the other system, where it may have been detected. In addition, no statistical tests were conducted to test for differences between these locations, but it should also be remembered that not all available data for each location were used to create current conditions due to incompatible sampling and analytical methods.

Notwithstanding the above, some trace elements have higher median concentrations in water in the Athabasca River compared to the Athabasca River Delta (e.g., dissolved aluminum, dissolved iron), while for others the reverse is true (e.g., dissolved chromium, dissolved copper, dissolved thallium, dissolved titanium). For other trace elements, there is no consistent difference apparent between these locations. Other than these general observations, little in the way of differences between the Athabasca River, Delta and Lake water quality were noted. There are insufficient data currently available for Lake Athabasca to establish high flow and under ice current conditions for most measured parameters. For the open water season, median concentrations for most trace elements in Lake Athabasca were similar to those in the River and Delta, with some exceptions such as somewhat higher chromium, copper and zinc compared to the River and lower aluminum, molybdenum and zinc compared to the Delta.

In terms of sediment quality, the River and Delta locations are distinguished by particle size, with a relatively greater proportion of silt and clay in the Delta and a greater proportion of sand in the River. Most measured trace element concentrations in the Delta are also higher than in the River sediment, including aluminum, boron, chromium, cobalt, copper, iron, lead, lithium, manganese, nickel, strontium, thallium, vanadium and zinc, while the reverse was true for titanium. Many PAHs were also present in higher concentrations in the Delta sediment compared to the River, especially for alkylated PAHs that were consistently measured in both locations. The smaller sediment particle size in the Delta compared to the River are likely related to this increased concentrations of trace elements and PAHs in the Delta, since PAHs are preferentially associated with smaller sediment particles (CCME, 1999), although other influences may also be present.

2.9.3 The Effect of Season

Generally, major ions concentrations and related measures such as alkalinity and specific conductivity are highest in the River and Delta in the under ice season. This is a common phenomenon, given the lower water flows and lower dilution potential. There may also be an increased proportion of high-solute groundwater inflows during the winter, when surface water inputs are lowest.

Ammonia and nitrogen are also highest in the under ice season, with most total nutrient measures highest in the high flow season. The latter is quite common where total nitrogen and phosphorus are associated with particles in the water, which are generally at their highest concentration during high flow.

Surprisingly, in both the River and Delta, field measured dissolved oxygen concentrations are highest during the ice covered season. This is counter-intuitive, given that ice covers generally reduce the potential for oxygen to be entrained in the water column and that algae are not usually as photosynthetically active during winter months. However, colder water can accommodate more dissolved oxygen and the ice covered season as defined in this report may very well include ice free periods, both of which can contribute to higher dissolved oxygen concentrations. Dissolved oxygen data for the under ice season were not available for Lake Athabasca.

Dissolved and total metals and trace element concentrations are variable across seasons. Notably, in the Athabasca River, concentrations values for these parameters are most often significantly different across sampling sites during the high flow season and especially the under ice season. In the Delta, site-specific percentile values were calculated for the under ice season. This suggests that local differences or influences are most consequential during the under ice season, at least in terms of metals and trace elements concentrations. Otherwise, most total measures (more associated with particles) are at their highest concentrations during high flow, while dissolved measures were more variable across seasons.

Sediment data were not collected seasonally and are not included in this discussion.

2.10 Application

The current conditions calculated in this study serve as an accumulated state range for water and sediment quality in the Athabasca River, the Athabasca River Delta and Lake Athabasca. They characterize water and sediment quality for the specific sampling sites or the reaches across which the sampling sites span, using data collected by the selected monitoring programs between 2011 and 2020, as available. This study has not identified change in or impacts to water or sediment quality in these locations, nor has it inferred sources of the measured constituents. The intended application of these current conditions is to serve as "no change" criteria in the absence of risk-based guideline values formulated in other sections of this report. The current conditions can serve as a benchmark against which past or future conditions can be compared, with relevance to impact prediction and assessment projects, water and sediment quality monitoring, or risk assessment, for example.

2.11 Limitations

2.11.1 Potential to Rehabilitate Long-term Datasets

As has already been discussed, this study was limited by the incompatibility of sampling and analytical methods used to collect water and sediment quality data by different programs and even within programs at different times over the period of record. The setting of current conditions according to the methods used in this study would benefit from additional data points, many of which could be included in such an analysis if the differences introduced by variations in methods could be reconciled.

In addition to this additional potential improvement, further monitoring in Lake Athabasca would greatly contribute to establishing additional current conditions for water and sediment quality in that location, especially during the high flow and under ice seasons.

Chapter 3

Health Risk Criteria for the Protection of Surface Water to Support Indigenous Use

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3.1 Introduction

Community members from ACFN, MCFN, and FMFN have observed changes in the health and condition of surface water, aquatic biota, wildlife (birds and mammals) and community members since development of the oil sands began in the 1960s (Personal communications; Pinto, A. et., al., 2019; Droitsch, D. and Simieritsch, T., 2010)

Health concerns expressed by community members include changes in the behavior and health of fish (i.e., soft/mushy muscle, increased parasites and tumors, increased and malformations of gills and body parts), fewer and small and unhealthy furbearers, absence of invertebrate species used by fish and birds as food sources, decreased potency of medicinal plants and increased prevalence of human health morbidities such as cancer and skin disorders.

ACFN, FMFN, and MCFN community members are concerned that the changes in health condition of humans, wildlife and aquatic biota are linked to the release of contaminants by oil sands mining operations (Personal communications; McLachlan (2014); Droitsch & Simieritsch (2010)).

The health concerns described above have been observed and recorded by Indigenous community members during their time on the land while participating in activities, such as; trapping fur bearing semi-aquatic mammals (i.e., beaver, mink, otter, muskrat), drinking from lakes, rivers and muskeg, fishing and hunting for food (i.e., walleye, pickerel, whitefish, moose, ducks) and harvesting medicines to treat various conditions (i.e., rat root). Through this connection with the land, members of ACFN, FMFN, and MCFN are guided by their knowledge that the health of the "land" is directly related to their ability to sustain their way of life and their overall sense of wellbeing (Personal communications; Baker & Westman (2018); Cunningham & Stanley (2003)).

In Alberta, risks to aquatic environments from exposure to chemical substances are assessed by comparing ambient monitoring data to environmental quality guidelines derived for the protection of aquatic life (GoA (2018); CCME (2021)). Surface water quality guidelines are also available to assess potential risks to livestock (GoA, 2018) and human health from the consumption of drinking water (Health Canada, 2021). However, the latter guidelines are rarely applied to surface water in Alberta (GoA, 2018) resulting in a disconnect between the provincial process for assessing risks posed by the quality of surface waters and the exposure of Indigenous community members to chemical substances during Indigenous land use activities.

Previous research by Olsgard & Thompson (2020) identified several surface water quality guidelines (GoA, 2018) which do not consider bioaccumulation and persistence of chemical substances which could limit the protection of higher trophic level species. Specifically beaver, northern pintail ducks, lesser scaup, muskrat, river otter and bald eagles could be at risk from biomagnification of methyl mercury, selenium, and thallium in aquatic food webs.

Due to limitations in the comprehensiveness of the existing surface water quality guidelines in Alberta and Canada, a need to develop water quality criteria that protect the ways in which Indigenous people interact with and rely on surface water was identified.

The following describes the development of health risk criteria to assess potential risks to Indigenous community members and the environment on which they rely for exercising Aboriginal Rights. The health risk criteria can also be applied as limits of change which reflect Indigenous ways of life and health risk concerns related to the condition of the Athabasca River, Athabasca River Delta, and Lake Athabasca.

3.2 Objective

To address gaps in surface water quality guidelines which may limit the protection of Indigenous community members, aquatic receptors and wildlife by identifying and/ or deriving health risk criteria which explicitly consider Indigenous use of water for constituents of concern that may be naturally occurring, related to releases from non-oilsands industrial sectors, and present in oil sands mine water (OSMW) which may seep or be actively released to surface water bodies historically and currently used by ACFN, FMFN, and MCFN members while exercising their Aboriginal Rights.

3.3 Methods

The following stages, described in detail below, were used to identify and/ or modify existing surface water quality guidelines and derive health risk criteria that consider protection of the aquatic environment to support Indigenous land use.

- Develop a Indigenous water use conceptual model and identify protection goals,
- Identify constituents of potential concern (COPCs),
- Identify available surface water guidelines by protection endpoint,
- Adopt available guidelines as Indigenous water use protection criteria in those cases where protection goals are met, and
- Derive criteria, when Indigenous water use protection was not considered.

3.3.1 Indigenous Water Use Conceptual Model

Indigenous water use protection goals for health risks were identified by developing a conceptual model based on Indigenous knowledge shared by community members and staff from ACFN, FMFN and MCFN. The conceptual model identifies indicators (i.e., culturally important ecosystem components), exposure pathways for human and ecological indicators, and the protection criteria and endpoints for each Indigenous water use protection goal.

3.3.2 Identification of Chemical Substances

Chapter 2 provides a detailed description of monitoring data collected in ambient surface water in the Lower Athabasca Region. Surface water quality guidelines are not available for each of these parameters, nor may they be required in all cases (i.e., inherent toxicity of the compound is negligible, not associated with natural or anthropogenic sources). Rather, the approach herein is to identify indicators of change and effect related to oil sands development pressures and compare concentrations of those indicator parameters to guidelines appropriate for Indigenous water use.

For the purposes of this study OSMW refers to any water produced and/ or accumulated by oil sands mining activities, including oil sands process water (OSPW), expressed water from tailings impoundments, collected surface water runoff, industrial wastewater, sewage water, etc.

Classes and species of chemical substances, which have been characterized in air emissions, tailings and OSMW were identified as indicator parameters and used to focus the development of health risk criteria. The following information sources were consulted:

- Peer reviewed literature,
- Ambient monitoring data, and
- Industry regulatory reporting.

Additionally, measured parameters, which may not be identified in oil sands specific data sets, identified in the monitoring networks described in Chapter 2 were also considered. These parameters provide an indication of other sources of contaminants (i.e., naturally occurring; agriculture and municipal sectors) in the Athabasca River watershed which may cumulatively contribute to potential risks to human and environmental health.

3.3.3 Inventory of Surface Water Quality Guidelines

Available surface water quality guidelines were identified through a jurisdictional scan of the regulatory agencies described below. Previous work completed by Olsgard & Thompson (2020) was also considered during this exercise.

Identified guidelines (and supporting technical documents) were reviewed and an inventory of existing surface water quality guidelines used by regulatory agencies was developed.

Environmental Quality Guidelines for Alberta Surface Waters

These guidelines are for application to surface water quality (to protect aquatic life (PAL), agricultural, and recreational uses), sediment quality, and tissue residue (to protect wildlife consumers and fish from direct toxicity)(GoA, 2018). The surface water quality guidelines do not apply to drinking water and the user is directed to Health Canada guidelines. The majority of guidelines have been adopted or modified from CCME, US EPA and British Columbia Canadian Environmental Quality Guideline for Water (CEQGs; CCME (2021)).

Canadian Environmental Quality Guidelines (CEQG)

The CEQGs provide science-based goals for water quality through published fact sheets and scientific criteria documents which describe the development of guidelines for the majority of substances with available surface water quality guidelines (to protect aquatic life, agricultural, and recreational uses), sediment quality, and tissue residue (to protect wildlife consumers and fish from direct toxicity. Guidelines are developed using CCME (2007) protocol which updates to the previous development in 1987, which closely aligned with development of the National Water Quality Standards by the US EPA and adopted widely throughout Canada.

Federal Environmental Quality Guidelines (FEQG)

The FEQGs were developed to support federal initiatives and provide thresholds below which direct adverse effects from the chemical on aquatic life exposed via water or sediment, or bioaccumulative effects in wildlife (birds and mammals) that consume aquatic life should be unlikely. The federal government identifies that FEQGs are not effluent limits nor are they “never to be exceeded” values. Seventeen FEQCs and scientific criteria documents have been developed to meet requirements of the federal environment Minister under Section 54 of CEPA, which goes beyond factors which were considered in development of the CCME CEQGs (of Canada, 2021).

Guidelines for Canadian Drinking Water Quality (CDWQG)

The CDWQGs were established by Health Canada (2020a) in collaboration with the Federal Provincial-Territorial Committee on Drinking Water based on current, published scientific research related to health effects (defined as Maximum Acceptable Concentrations (MACs), aesthetic effects (i.e., taste, odour, colour), and operational (i.e., treatment) considerations). The CDWQGs are developed for substances which could result in toxicological effects in exposed humans, have the potential to be present in drinking water supplies and have available methods of quantification (i.e., lab analysis). Scientific criteria documents have been published for each substance with a Maximum Acceptable Concentration (MAC).

National Drinking Water Regulations (DWR)

The US EPA DWRs (US EPA, 2021a) are legal limits for more than 90 chemical and microbial contaminants in United States drinking water. The legal limit for each substance reflects both human health protection and concentrations that are achievable using the best available technology.

National Recommended Water Quality Criteria (WQCs)

The US EPA provides three Criteria under the National Recommended Water Quality Program (WQCs); aquatic life, human health, and organoleptic (i.e., aesthetic) (US EPA, 2021b).

The Aquatic Life Criteria published in the National Recommended WQCs vary from those prescribed in Canada and Alberta as the data from freshwater species toxicity tests reported as total recoverable fractions have been converted to a dissolved fraction using Conversion Factors (CFs) (US EPA, 1993, 1996). The US EPA determined that dissolved guidelines are more appropriate as they represent the fraction of metals which is bioavailable to aquatic biota (as adsorption at gill surfaces required dissolved forms of metals) compared to particulate forms of metals which cannot be taken up as easily within biological organisms (US EPA, 1993).

The US EPA (1993) referenced studies which report that the toxicity of particulate metals is less compared to dissolved metals. To derive dissolved metal criteria the US EPA calculated CFs from toxicity tests in which both the total recoverable and dissolved fractions of the metal of interest was measured. The US EPA (1993) also states that the CF derived dissolved guidelines should be applied to conditions where pH ranges from 6.5-9 and total organic carbon and total suspended solids are less than 5 mg/L. Table 3.1 indicates that the median values for open water season in the Lower Athabasca River are within the prescribed range for pH (8.2) but well above for total suspended solids (24 mg/L) and total organic carbon (8.9 mg/L).

Aquatic Life (AL WQCs) describe criteria which are the highest contaminant specific concentrations that are not expected to pose a significant risk to most aquatic species. The AL WQCs are reported in total concentrations. Conversion factors are available for estimating total metals when dissolved metals were measured.

Human Health Ambient Water Quality Criteria (HH AWQCs) developed under United States legislation (Section 304(a) of the Clean Water Act) represent substance specific concentrations that are not expected to cause adverse effects to human health from the consumption of drinking water alone or in combination with consuming organisms (i.e., fish). The HH AWQCs consider both carcinogenic and non-carcinogenic effects from exposure of humans to chemical substances in untreated surface water and wild organisms. Notably, the HH WQCs are recommended for consideration by "authorized tribes", comparable to First Nations in Canada when adopting criteria into their water quality standards. Methodology for deriving the HH AWQCs is also available (US EPA, 2000b).

Organoleptic Effect (OE WQCs), similar to Health Canada Aesthetic Objectives (Health

Canada, 2020a), protect water against tainting and fouling from offensive odours, colour, and taste (World Health Organization (WHO), 2017).

Guidelines for Drinking Water Quality (GDWQs; WHO, 2017 4th Ed)

The GDWQs for chemical, microbial, radiological and acceptability (i.e., aesthetics) aspects are based on over 50 years of WHO guidance on identifying safe drinking water quality and recognized internationally as formative regulations and standards for water safety in support of public health. In addition to health-based guidelines, the WHO provides guidance on developing a conceptual framework for implementation, water safety plans, and monitoring (World Health Organization (WHO), 2017).

Toxicological Benchmarks for Wildlife (US Department of Energy, 1996)

The Oak Ridge National Laboratory (ORNL) reported No Observable Adverse Effect Levels (NOAELs) for 9 representative mammalian wildlife species or 11 avian wildlife which were then used to derive species-based toxicological benchmarks that represent concentrations of chemicals in environmental media (water, sediment, soil, food, etc.) that are presumed to nonhazardous for the listed wildlife species. The piscivore benchmarks reported as surface water quality concentrations (mg/L) can be used to assess the potential risks to mammals (i.e., mink and otter) and birds (i.e., kingfisher, mallard, great blue heron, osprey) from ingesting chemicals in surface water and fish (Sample et al., 1996).

The combined food and water benchmarks for wildlife species primarily consuming aquatic organisms (piscivores) as reported in Sample et. al., (1996) were calculated using the following equation:

Equation (3.1)

$$C_w = \frac{NOAEL_w \times bw_w}{W + (F \times BAF)} \tag{3.1}$$

Where:

C_w = Concentration of the contaminant in the drinking water of an animal (mg/L)

$NOAEL_w$ = No Observable adverse Effects Level in wildlife species (mg/kg bw/d)

bw_w = body weight of wildlife species

W = Water ingestion rate (L/d)

F = Food ingestion rate (kg/d)

BAF = ratio of concentration of a contaminant in tissue (mg/kg) over water (mg/L)

3.3.4 Adopting Existing Guidelines as Water Quality Criteria for the Protection of Indigenous Use

To determine whether available guidelines consider Indigenous water use protection goals, the inventory of guidelines for COPCs was compared to the protection goals for each Indigenous water use category described in the Indigenous water use conceptual model as described in Section 3.4.1.

If a currently available surface water quality guideline considered protection of Indigenous water use goals (indicators, exposure pathways and endpoints), the regulatory guideline was adopted as the health risk criteria for Indigenous use protection for that substance.

If the review exercise indicated that there were no available guidelines for a COPC or that currently available surface water quality guidelines did not consider Indigenous water use protection goals it was not adopted, and health risk criteria were developed using the methods discussed below.

3.3.5 Deriving Water Quality Criteria for the Protection of Indigenous Use

Health risk criteria for the protection of humans consuming surface water and traditional foods were derived using guidance from the US EPA (2000b) *"Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health"*.

Health risk criteria for Indigenous use protection were derived through modifications of the US EPA (2000b) Equation (3.2) to account for consumption of locally caught fish and river/lake/muskeg water as drinking water and the ingestion of medicinal plants Equation (3.2).

The US EPA (2015c) values for body weight (80 kg) and drinking water intake (2.4 L) were considered representative of ACFN, FMFN, and MCFN adult community members.

Chemical-specific inputs used to develop the HH AWQC were adopted when available/published (US EPA, 2015b). When not available, values were sourced from resources specified in US EPA (2000b).

References doses for non-cancer effects (RfD, mg/kg-d) and Risk-specific doses for carcinogens (RsD, mg/kg-d) were adopted from the current US EPA Integrated Risk Information System (US EPA IRIS).

Bioaccumulation factors (BAFs), bioconcentration factors (BCFs), food chain multipliers (FCM), and lipid fractions for organic substances were adopted from US EPA (2015b) and inorganic substances were adopted from several US EPA ecological risk assessment documents; BAFs (Sample et al., 1996), BCFs and FCMs (US EPA, 1999).

As per Alberta Health (2019) the dose associated with an incremental lifetime cancer risk (ILCR) of 1 in 100,000 (1 x 10-5) is considered to be “essentially negligible” and was adopted rather than the acceptable risk level for cancer (1 x 10-6) used by the US EPA (2000b; 2015a).

Equation (3.2): Consumption of traditional foods and drinking water to derive health risk criteria (modified from US EPA US EPA (2000b)).

$$HRC\ TF + DW(ug/L) = \frac{toxicity\ value(\frac{mg}{kg} - d)xRSC \times BW(kg)x1,000(\mu\frac{g}{mg})}{DI(\frac{L}{d}) + \sum_{i=2}^{4}(FCRi(kg/d) \times BAFi(L/kg))} \tag{3.2}$$

Where:

$HRCTF + DW$	=	health risk criteria for traditional foods and
		drinking water consumption toxicity value = RfD x RSC (mg/kg-d)
		for noncarcinogenic effects or 10-5/CSF (kg-d/mg)
		for carcinogenic effects
RSC	=	relative source contribution (applicable to only noncarcinogenic)
		(0.2, unless otherwise stated)
BW	=	body weight (80 kg)
DI	=	drinking water intake (2.4 L/d) = summation of values for
		aquatic trophic levels (TLs), where the letter i stands for the
		TLs to be considered,
		starting with TL2 and proceeding to TL4
FCR	=	Fish Consumption Rate (0.388 kg/d)
$BAFi$	=	bioaccumulation factor for aquatic TLs 2, 3, and 4

Equation (3.3): Equation to derive water quality criteria for human health protection from consumption of medicinal plants (modified from US EPA (2000b)).

$$HRC\ medicinal\ plants(ug/L) = \frac{toxicity\ value(\frac{mg}{kg} - d)xRSC \times BW(kg)x1,000(\frac{\mu g}{mg})}{PCRxBCF_{eS-P}} \quad (3.3)$$

Where:

$HRC\ medicinal\ plants$	=	health risk criteria for protection of health risks from exposure to contaminants in medicinal plants
$toxicity\ value$	=	RfD x RSC (mg/kg-d) for noncarcinogenic effects or 10-5/CSF (kg-d/mg) for carcinogenic effects
RSC	=	relative source contribution (applicable to only noncarcinogenic effects), (0.2, unless otherwise stated)
BW	=	body weight (80 kg)
PCR	=	medicinal plant consumption rate (0.007 kg/d)
$BCFS - P$	=	bioconcentration factor sediment to plant

3.4 Results

3.4.1 Indigenous Water Use Conceptual Model

Indigenous water uses and exposure pathways for community members (human receptors) were identified through personal communications with community members and staff from ACFN, FMFN and MCFN.

The community identified Indigenous water uses, cultural practices and species of importance were integrated into a conceptual model with western science measures (quality focused criteria and endpoints) to define Indigenous water uses and protection goals. Each use and protection goal are discussed below to provide context for why each Indigenous water use must be considered in developing surface water quality criteria to achieve protection goals. A visual depiction of the detailed conceptual model is provided in Figure 3.1 and each of the Indigenous water uses and protection goals described further below.

Traditional foods

Community members (human receptors) are exposed to contaminants through ingestion of culturally important wildlife and fish species. Fish are directly exposed to and take up contaminants from the surface water but can also accumulate toxic substances through ingestion of prey items (invertebrates and smaller fish). Therefore, consideration of the trophic level from which fish are consumed is important in developing surface water quality criteria that protect humans from consumption of fish. This is a well-recognized exposure pathway and human health risk regulated for certain substances in Canada (Health Canada, 2020b) and used to set maximum consumption levels/advisories by GoA (2019a) and the US EPA (2000a).

An often-overlooked exposure pathway is the uptake of contaminants by wildlife from consuming surface water. This pathway was identified by community members as a potential cause of decreased health being observed in herbivorous mammals and waterfowl species (moose, mallard, scaup) relied on for traditional diets (as discussed under the wildlife health water use) but is also an exposure pathway for community members ingesting wildlife tissues.

Exposure of human receptors to contaminants through ingestion of wildlife species (as traditional foods) is considered in human health risk assessment methods (Alberta Health (2019); Health Canada (2021); Health Canada (2019); Health Canada (2018)) but not mirrored in surface water quality guidelines applied in Alberta.

To ensure protection of community members (human receptors) from exposure to contaminants in wildlife and fish water quality, guidelines must consider biomagnification of contaminants in food webs and carcinogenicity, which is a human health endpoint not considered in the derivation of environmental quality guidelines, such as those developed by the US EPA US EPA (2015c).

Surface water quality guidelines against which monitoring data can be compared when collected under risk-based surveillance programs must consider Indigenous community health exposure pathways and endpoints to understand impacts to Indigenous water use and protection goals.

Natural waterbodies as drinking water sources

Regardless of Health Canada and Alberta Health guidance on sources of drinking water, members of ACFN, FMFN and MCFN have traditionally and continue to consume untreated drinking water from surface water bodies in the Lower Athabasca Region (i.e., lakes, rivers, muskeg). As such, ambient water quality guidelines such as the (US EPA, 2015c) which consider ingestion of raw surface water must be applied to understand impacts to Indigenous water use.

Traditional medicines

Through traditional knowledge guided practices Indigenous communities rely on the medicinal properties of several aquatic plant species for treating health maladies (i.e., cardiovascular health, kidney infections, respiratory problems). Aquatic plants such as wild mint and rat root may absorb and translocate chemical substances from surface water and sediments resulting in potential exposure of community members relying on these species for preparations of medicinal teas, powders, and poultices (Clemens (2006)).

Community members have also noted that the potency of medicinal plants is decreasing as is availability. Both of these concerns are thought to be linked to chemical emissions from industrial development and the changes to the land (personal communications).

The accumulation of contaminants from surface water and sediment in medical plants and exposure of community members must be considered in developing surface water quality criteria however, no guidelines which considered bioaccumulation in plant species were identified through publications from US EPA (1999; 2000b). This pathway is rarely assessed in human health risk assessments and may require further investigation.

Aquatic ecosystem health

Members of ACFN, FMFN and MCFN have shared that their health is experiential and relational from an Indigenous world view and directly related to their sense of personal health and wellbeing. As such, water cannot be managed as a single component broken off from the environment or communities. Water is the giver of life and must be protected using traditional knowledge and now due to industrial development, western science methods. But western science water management was unnecessary prior to industrial development in the Lower Athabasca Region (personal communications).

While several of the identified guidelines (GoA (2018); CCME (2021); US EPA (2021b)) consider protection of aquatic life through four main receptor groups (fish, amphibians, invertebrates, plants/ algae) it is really the integration of these components that establishes and maintains a functional and healthy ecosystem from an indigenous perspective (Greenwood & Leeuw (2007); Arsenault et al. (2018)).

Wildlife health

Wildlife health, like water health described above, is a community health indicator upon which members of ACFN, FMFN and MCFN view their personal sense of wellbeing. The quality of moose and duck meat, abundance, and presence of wildlife species for trapping and hunting and population dynamics between predators and prey have been noted by community members as changing and as being of poorer quality overall since industrial development began.

Community members are concerned that wildlife species are being exposed to contaminants though their drinking water and diet (aquatic plants, invertebrates, algae) and that these contaminants are directly affecting wildlife health but also human health through ingestion of traditional foods (personal communications) (Baker & Westman, 2018).

Eccles et al. (2020) validated the community observation that contaminant concentrations are changing (increasing) in water in the oil sands region, and this could be impacting wildlife health.

Exposure of wildlife to contaminants is a well described exposure pathway in the oil sands region (Rodríguez-Estival & Smits, 2016) and the requirement to assess potential risks to wildlife species from exposure to contaminants is well defined in ecological risk assessment guidance (CCME, 2020) and subsequent exposure in humans consuming wildlife as traditional foods (Health Canada (2021); Health Canada (2012); Health Canada (2010)). However, water quality guidelines are limited to the protection of livestock for agricultural purposes again disconnecting the regulatory practice of risk assessment from the realities of Indigenous water use.

Environmental and human health impacts from persistent and bioaccumulative substances which can biomagnify in aquatic ecosystems is well described (Arnot & Gobas (2004); Ali et al. (2019)) and exposure pathways linked to the contamination of traditional foods is described above.

However, wildlife support Indigenous community traditional lifestyles beyond provision of traditional foods. Trapping semi-aquatic furbearing species such as muskrat, beaver and otter are recognized Aboriginal Rights (Collins & Murtha (2009); Passelac-Ross (2005)) and the sale of pelts has long been an economic staple in Athabasca Region First Nation Communities (Baker & Westman, 2018).

Semi-aquatic mammals' diets are sustained by aquatic biota (invertebrates, plants, fish) and members from ACFN, FMFN and MCFN have noted that the health, quality of pelts, and abundance of muskrats has been declining over time. Members have attributed the decline in condition and quality of pelts to poor water quality and the decreasing populations to lower water levels in the PAD (Personal communications).

While not a common factor considered in the development of water quality guidelines, the health of aquatic fur-bearing mammals is directly linked to aquatic ecosystems and water quality criteria are required to protect this water use.

Primary Use			Secondary Use		Protection	
Receptor	**Water use**	**Exposure pathway (human receptor)**	**Environmental Indicator**	**Exposure pathway (ecological receptor)**	**Goal**	**Endpoints**
Indigenous community member (Human)	1. Traditional foods and drinking water	Direct exposure - Ingestion	Fish Plants Wildlife Water	Direct contact/ uptake Ingestion aquatic biota Direct contact/ uptake Ingestion aquatic biota Water ingestion	Safe food consumption Safe natural surface water consumption	Carcinogenic Non-carcinogenic Aesthetic
	2. Traditional medicines	Direct exposure - Ingestion	Plants	Direct contact and uptake	Safe medicine consumption Potency of medicinal plants	
	3. Aquatic ecosystem health	Indirect health determinant	Invertebrates Fish Plants Algae	Direct contact/ uptake Direct contact/ uptake Direct contact/ uptake Direct contact/ uptake	Aquatic community composition unchanged, healthy, and robust biota populations	Non-carcinogenic Aesthetic
	4. Wildlife health	Indirect health determinant	Mammals Birds	Water ingestion Fish Ingestion	Healthy wildlife, robust populations, natural behaviours, good quality pelts	

Figure 3.1: Indigenous Water Use Conceptual Model

3.4.2 Inventory of Contaminants

The inventory of contaminants for which health risk criteria were developed include constituents of concern that may be naturally occurring, related to releases from non-oilsands industrial sectors, and present in oil sands mine water (OSMW).

There are several sources of OSMW associated with mining activities. Tailings waste streams are comprised of sand, silt, clay, processed water, and residual bitumen which is a complex mixture of a multitude of chemicals (Allen, 2008). Mine water that accumulates from muskeg dewatering and collection of surface water runoff from mine sites has a different chemical signature than surface water bodies such as lakes and contains elevated trace elements and polycyclic aromatic hydrocarbons, both dissolved and bound to suspended solids and organic matter, which elicit toxicological responses in exposed receptors (Alexander, A.C. and Chambers, P. 2016; Kelly, E. et., al., 2009). Naturally saline basal groundwater is also accumulated in OSMW inventories during depressurization (Sawatsky et al., 2004) and the toxicity associated with exposing surface water biota to saline groundwater has been documented for decades (Giles & Klaverkamp (1979); Rogers & Lake (1979)).

The contaminants associated with the various sources of OSMW have also been identified as contributing to acute and chronic toxicity in biological organisms (Li et al. (2017); Mahaffey & Dubé (2017); Hughes et al. (2017)).

In addition to mine water, contaminants released from point and area source emissions from oil sands mines contribute deposition of acids (from transformation of gaseous compounds), and PAHs and trace elements (from particulate matter) (Lynam et al. (2015); Brook et al. (2019))

Through this review the following classes of substances were identified in oil sands mine water, tailings, and air emissions (deposited in the ambient environment). The concentrations and types of chemical substances varies by oil sands operation as extraction, processing and treatment technologies differ by mine. Variability in composition of OSMW was indiscernible using externally available information sources, therefore, all identified contaminated classes were included for identifying Indigenous water use protection goals.

- Inorganic ions (such as salts, ammonia and nutrients),
- Trace elements and heavy metals,
- Volatile organic hydrocarbons (VOCs) including Benzene (B), Toluene (T), Ethylbenzene (E) and Xylene (X),
- Polycyclic aromatic hydrocarbons (PAHs),
- Petroleum hydrocarbon fractions (PHC F1-F4),
- Sulfates, sulfites, and sulfides,
- Nitrate and nitrites, and
- Organic compounds (such as phenols and naphthenic acids).

3.4.3 Available Surface Water Quality Guidelines

As identified in the Indigenous water use conceptual model, water quality guidelines are required for both human and ecological (aquatic, wildlife) receptors to meet community identified protection goals for four traditional water use categories; consumption of traditional foods and drinking water, consumption of traditional medicines, wildlife health, and aquatic ecosystem health (Figure 3.1).

Chronic surface water quality guidelines for the protection of aquatic biota, wildlife and human receptors were identified from multiple jurisdictions. Available guidelines, by jurisdiction, are briefly described below.

Certain parameters (cadmium, copper, lead, nickel and zinc) require the guideline to be calculated using modifying factors for total hardness or alkalinity (as CaCO3 mg/L), pH, water temperature (C), chloride (mg/L) and/ or dissolved organic carbon (mg/L) from the area where guidelines are being applied. Modifying factors were adopted from 50th percentile values in open water season from multiple locations in the Athabasca River (see Chapter 2), summarized in Table 3.1 below.

Table 3.1: Modifying Factors calculated from median values measured during open water season at "Old Fort" from 2011-2019.

Modifying Factor	Unit	Median
Alkalinity	as CaCO3 mg/L	110.0
Field pH	pH units	8.0
Water Temperature	°C	10.9
Total suspended solids	mg/L	24.0
Chloride	mg/L	12.0
Total hardness	as CaCO3 mg/L	120.0
Dissolved organic carbon	mg/L	7.9
Total organic carbon	mg/L	8.9

Generally, ambient water quality and drinking water quality guidelines for the protection of human health endpoints, including carcinogenicity, were prescribed by the US EPA, Health Canada and the WHO while those available from the GOA and CCME were limited to the protection of aquatic biota, livestock (agricultural uses) and wildlife consuming aquatic biota (for a single OSMW contaminant (mercury)).

A detailed comparison of available guidelines for each substance by jurisdiction and water use is provided in Appendix A.3.

Chronic surface water quality guidelines could not be identified for naphthenic acids, BTEX compounds, or petroleum hydrocarbons. For these substances, water use protection criteria are defined by the current conditions described in Chapter 2.

A comparison of available guidelines was used to identify the most sensitive use and/ or receptor group (i.e. aquatic biota, humans, livestock, wildlife) for surface water as shown in Table 3.2. Appendix A.3 should be consulted to determine which guidelines were available for each use.

Table 3.2 indicates that aquatic biota were the most sensitive receptor group for 44% of substances related to oil sands wastes and emissions currently monitored in the Lower Athabasca River. As commonly practiced in Alberta, adopting the protection of aquatic life (PAL) guidelines to assess risks from exposure to chemicals in OSMW would limit the protection of humans and wildlife (birds and mammals) which are the most sensitive receptors for exposure to 53% of the substances with available surface water quality guidelines. As shown in Table 3.2, approximately 50% of chemicals which have been detected in the ambient environment and characterized in OSMW present a higher potential for health risks to humans, which are not currently considered under provincial guidelines (GoA, 2018).

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies.

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
.alpha.-Endosulfan			ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria
.beta.-Endosulfan			ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria
1,1,1-Trichloroethane			ug/L	200	human	US EPA DWR
1,1,2,2-Tetrachloroethane			ug/L	2	human	HH DW+Org (US EPA)
1,1,2-Trichloroethane			ug/L	3	human	US EPA DWR
1,1-Dichloroethylene			ug/L	7	human	US EPA DWR
1,2,3,4-Tetrachlorobenzene			ug/L	0.03	human	HH DW+Org (US EPA) USEPA WQC HH Org
1,2,3-Trichlorobenzene			ug/L	8	aquatic biota	AEP Water PAL CCME Water PAL
1,2,4-Trichlorobenzene			ug/L	0.071	human	HH DW+Org (US EPA)
1,2-Dibromo-3-chloropropane			ug/L	0.2	human	US EPA DWR
1,2-Dibromoethane			ug/L	0.4	human	WHO DW
1,2-Dichlorobenzene			ug/L	0.7	aquatic biota	AEP Water PAL
1,2-Dichloroethane			ug/L	5	human wildlife	CCME Water Ag AEP Water Ag US EPA DWR Health Canada DW
1,2-Dichloroethene			ug/L	50	human	WHO DW
1,2-Dichloropropane			ug/L	5	human	US EPA DWR
1,2-Diphenylhydrazine			ug/L	0.3	human	HH DW+Org (US EPA)
1,3-Dichlorobenzene			ug/L	7	human	HH DW+Org (US EPA)
1,3-Dichloropropene			ug/L	2.7	human	HH DW+Org (US EPA)
1,4-Dichlorobenzene			ug/L	26	aquatic biota	AEP Water PAL
1,4-Dioxane			ug/L	50	human	WHO DW

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
2,3,4,6-Tetrachlorophenol			ug/L	1	human	USEPA WQC AO
2,3-Dichlorophenol			ug/L	0.04	human	USEPA WQC AO
2,4,5-Trichlorophenol			ug/L	1	human	USEPA WQC AO
2,4,6-Trichlorophenol			ug/L	2	human	USEPA WQC AO
2,4-D			ug/L	4	aquatic biota	AEP Water PAL CCME Water PAL
2,4-DB			ug/L	25	aquatic biota	AEP Water PAL
2,4-Dichlorophenol			ug/L	0.3	human	USEPA WQC AO
2,4-Dimethylphenol			ug/L	100	human	HH DW+Org (US EPA)
2,4-Dinitrophenol			ug/L	10	human	HH DW+Org (US EPA)
2,4-Dinitrotoluene			ug/L	0.49	human	HH DW+Org (US EPA)
2,5-Dichlorophenol			ug/L	0.5	human	USEPA WQC AO
2,6-Dichlorophenol			ug/L	0.2	human	USEPA WQC AO
2-Chloronaphthalene			ug/L	800	human	HH DW+Org (US EPA)
2-Chlorophenol			ug/L	0.1	human	USEPA WQC AO
2-Methyl-4,6-Dinitrophenol			ug/L	2	human	HH DW+Org (US EPA)
2-Methyl-4-Chlorophenol			ug/L	1800	human	USEPA WQC AO
3,3'-Dichlorobenzidine			ug/L	0.49	human	HH DW+Org (US EPA)
3,4-Dichlorophenol			ug/L	0.3	human	USEPA WQC AO
3-Chlorophenol			ug/L	0.1	human	USEPA WQC AO
3-Iodo-2-propynyl butyl carbamate			ug/L	1.9	aquatic biota	AEP Water PAL CCME Water PAL
3-Methyl-4-Chlorophenol			ug/L	500	human	HH DW+Org (US EPA)
3-Methyl-6-Chlorophenol			ug/L	20	human	USEPA WQC AO

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
4-Chlorophenol			ug/L	0.1	human	USEPA WQC AO
Acenaphthene			ug/L	5.8	aquatic biota	CCME Water PAL AEP Water PAL
Acridine			ug/L	4.4	aquatic biota	AEP Water PAL CCME Water PAL
Acrolein			ug/L	3	aquatic biota human	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL
Acrylamide			ug/L	0.5	human	WHO DW US EPA DWR
Acrylonitrile			ug/L	0.61	human	HH DW+Org (US EPA)
Alachlor			ug/L	2	human	US EPA DWR
Alcohol ethoxylates			ug/L	70	aquatic biota	FEQG Water PAL
Aldicarb			ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL
Aldrin			ug/L	0.0000077	human	USEPA WQC HH Org HH DW+Org (US EPA)
Aldrin and dieldrin			ug/L	0.03	human	WHO DW
Alkalinity, total	as CaCO3		mg/L	20	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
alpha-Endosulfan			ug/L	20	human	HH DW+Org (US EPA)
alpha-Hexachlorocyclohexane			ug/L	0.0036	human	HH DW+Org (US EPA)
Aluminum		Total	ug/L	100	aquatic biota	CCME Water PAL
Aluminum		Dissolved	ug/L	50	aquatic biota	AEP Water PAL
Ammonia			mg/L	0.794	aquatic biota	AEP Water PAL
Ammonia, unionized			mg/L	0.016	aquatic biota	AEP Water PAL

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Aniline			ug/L	2.2	aquatic biota	AEP Water PAL CCME Water PAL
Anthracene			ug/L	0.012	aquatic biota	AEP Water PAL CCME Water PAL
Antimony		Total	ug/L	5.6	human	HH DW+Org (US EPA)
Arsenic		Total	ug/L	0.18	human	HH DW+Org (US EPA)
Arsenic		Dissolved	ug/L	150	aquatic biota	US EPA Aquatic Life Criteria
Asbestos			ug/L	7	human	US EPA DWR HH DW+Org (US EPA)
Atrazine			ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL
Atrazine and its chloro-s-triazine metabolites			ug/L	100	human	WHO DW
Azinphos-methyl			ug/L	0.01	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria
Barium		Total	ug/L	1000	human	HH DW+Org (US EPA) Health Canada DW
Benzene			ug/L	5	human	US EPA DWR Health Canada DW
Benzidine			ug/L	0.0014	human	HH DW+Org (US EPA)
Benzo(a)anthracene			ug/L	0.012	human	HH DW+Org (US EPA)
Benzo(a)pyrene			ug/L	0.001	human	HH DW+Org (US EPA)
Benzo(b)fluoranthene			ug/L	0.012	human	HH DW+Org (US EPA)
Benzo(k)fluoranthene			ug/L	0.12	human	HH DW+Org (US EPA)
Beryllium		Total	ug/L	4	human	US EPA DWR
beta-Endosulfan			ug/L	20	human	HH DW+Org (US EPA)

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
beta-Hexachlorocyclohexane			ug/L	0.08	human	HH DW+Org (US EPA)
Bis(2-Chloro-1-methylethyl) Ether			ug/L	200	human	HH DW+Org (US EPA)
Bis(2-Chloroethyl) Ether			ug/L	0.3	human	HH DW+Org (US EPA)
Bis(2-Ethylhexyl) Phthalate			ug/L	0.32	human	HH DW+Org (US EPA)
Bis(Chloromethyl) Ether			ug/L	0.002	human	HH DW+Org (US EPA)
Bisphenol A-d6			ug/L	3.5	aquatic biota	FEQG Water PAL
Blue-green algae (Cyanobacteria)			1			
Boron		Total	ug/L	1500	aquatic biota	AEP Water PAL CCME Water PAL
Bromacil			ug/L	5	aquatic biota	CCME Water PAL AEP Water PAL
Bromate			ug/L	10	human	WHO DW Health Canada DW US EPA DWR
Bromodichloromethane			ug/L	60	human	WHO DW
Bromoform			ug/L	7	human	HH DW+Org (US EPA)
Bromoxynil			ug/L	5	aquatic biota human	Health Canada DW AEP Water PAL CCME Water PAL
Butylbenzyl Phthalate			ug/L	1	human	USEPA WQC HH Org HH DW+Org (US EPA)
Cadmium		Total	ug/L	0.1843828121	aquatic biota	CCME Water PAL AEP Water PAL
Cadmium		Dissolved	ug/L	0.8237781279	aquatic biota	US EPA Aquatic Life Criteria
Calcium			mg/L	1000	wildlife	AEP Water Ag CCME Water Ag

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Captan			ug/L	1.3	aquatic biota	AEP Water PAL CCME Water PAL
Carbamazepine			ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL
Carbaryl			ug/L	0.2	aquatic biota	CCME Water PAL AEP Water PAL
Carbofuran			ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL
Carbon tetrachloride			ug/L	2	human	Health Canada DW
Chloramines			ug/L	0.5	aquatic biota	CCME Water PAL
Chlorate			ug/L	700	human	WHO DW
Chlordane			ug/L	0.003	human	HH DW+Org (US EPA)
Chloride			mg/L	120	aquatic biota	CCME Water PAL AEP Water PAL
Chlorinated paraffins, long-chain, C18-C20			ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL
Chlorinated paraffins, medium-chain, C14-C17			ug/L	2.4	aquatic biota	FEQG Water PAL AEP Water PAL
Chlorinated paraffins, short-chain, C10-C13			ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL
Chlorine			ug/L	0.5	aquatic biota	AEP Water PAL
Chlorine dioxide			ug/L	800	human	US EPA DWR
Chlorite			ug/L	700	human	WHO DW
Chlorobenzene			ug/L	1.3	aquatic biota	AEP Water PAL
Chlorodibromomethane			ug/L	8	human	HH DW+Org (US EPA)

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Chloroform			ug/L	1.8	aquatic biota	CCME Water PAL AEP Water PAL
Chlorophenol			ug/L	7	aquatic biota	CCME Water PAL AEP Water PAL
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]			ug/L	50	human	US EPA DWR
Chlorothalonil			ug/L	0.18	aquatic biota	CCME Water PAL AEP Water PAL
Chlorotoluron			ug/L	30	human	WHO DW
Chlorpyrifos			ug/L	0.002	aquatic biota	CCME Water PAL AEP Water PAL
Chromium		Total	ug/L	50	human	WHO DW Health Canada DW
Chromium (III)		Total	ug/L	8.9	aquatic biota	CCME Water PAL AEP Water PAL
Chromium (III)		Dissolved	ug/L	100.9185723	aquatic biota	US EPA Aquatic Life Criteria
Chromium (VI)		Total	ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL
Chromium (VI)		Dissolved	ug/L	5	aquatic biota	FEQG Water PAL
Chrysene			ug/L	1.2	human	HH DW+Org (US EPA)
cis-1,2-Dichloroethylene			ug/L	70	human	US EPA DWR
Cobalt		Total	ug/L	1.099682588	aquatic biota	FEQG Water PAL AEP Water PAL
Copper		Total	ug/L	2.763433095	aquatic biota	CCME Water PAL
Copper		Dissolved	ug/L	0.53	aquatic biota	FEQG Water PAL
Cyanazine			ug/L	0.6	human	WHO DW

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Cyanide	as free CN		ug/L	4	human	HH DW+Org (US EPA)
Cyanobacterial toxins			ug/L	1.5	human	Health Canada DW
Dalapon			ug/L	200	human	US EPA DWR
DDT and metabolites			ug/L	0.0003	human	USEPA WQC HH Org HH DW+Org (US EPA)
Dehydroabietic acid			ug/L			
Deltamethrin			ug/L	0.0004	aquatic biota	CCME Water PAL AEP Water PAL
Demeton			ug/L	0.1	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Di(2-ethylhexyl) adipate			ug/L	400	human	US EPA DWR
Di(2-ethylhexyl) phthalate			ug/L	6	human	US EPA DWR
Di-n-Butyl Phthalate			ug/L	19	aquatic biota	CCME Water PAL AEP Water PAL
Diazinon			ug/L	0.17	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Dibenzo(a,h)anthracene			ug/L	0.001	human	HH DW+Org (US EPA)
Dibromoacetonitrile			ug/L	70	human	WHO DW
Dibromochloromethane			ug/L	100	human wildlife	CCME Water Ag WHO DW AEP Water Ag
Dicamba			ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL
Dichloroacetate			ug/L	50	human	WHO DW
Dichloroacetonitrile			ug/L	20	human	WHO DW
Dichlorobromomethane			ug/L	9.5	human	HH DW+Org (US EPA)

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Dichloromethane			ug/L	5	human	US EPA DWR
Dichlorophenol			ug/L	0.2	aquatic biota	AEP Water PAL CCME Water PAL
Dichlorprop			ug/L	100	human	WHO DW
Diclofop-methyl			ug/L	6.1	aquatic biota	AEP Water PAL CCME Water PAL
Didecyl dimethyl ammonium chloride			ug/L	1.5	aquatic biota	AEP Water PAL CCME Water PAL
Dieldrin			ug/L	0.00001	human	HH DW+Org (US EPA)
Diethanolamine			ug/L	450	aquatic biota	AEP Water PAL
Diethyl Phthalate			ug/L	600	human	USEPA WQC HH Org HH DW+Org (US EPA)
Diethylene glycol			ug/L	150000	aquatic biota	AEP Water PAL
Diisopropanolamine			ug/L	1600	aquatic biota	CCME Water PAL AEP Water PAL
Dimethoate			ug/L	3	wildlife	AEP Water Ag CCME Water Ag
Dimethyl Phthalate			ug/L	2000	human	USEPA WQC HH Org HH DW+Org (US EPA)
Dinitrophenols			ug/L	10	human	HH DW+Org (US EPA)
Dinoseb			ug/L	0.05	aquatic biota	CCME Water PAL AEP Water PAL
Dioxin (2,3,7,8-TCDD)			ug/L	0.00000005	human	HH DW+Org (US EPA)
Diquat			ug/L	20	human	US EPA DWR
Diuron			ug/L	150	human	Health Canada DW
Edetic acid			ug/L	600	human	WHO DW

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Endosulfan			ug/L	0.003	aquatic biota	AEP Water PAL CCME Water PAL
Endosulfan Sulfate			ug/L	20	human	HH DW+Org (US EPA)
Endothall			ug/L	100	human	US EPA DWR
Endrin			ug/L	0.0023	aquatic biota	AEP Water PAL CCME Water PAL
Endrin Aldehyde			ug/L	1	human	USEPA WQC HH Org HH DW+Org (US EPA)
Epichlorohydrin			ug/L	0.4	human	WHO DW
Ethinyl estradiol			ng/L	0.5	aquatic biota	AEP Water PAL
Ethylbenzene			ug/L	2.4	wildlife	AEP Water Ag CCME Water Ag
Ethylene dibromide			ug/L	0.05	human	US EPA DWR
Ethylene glycol			ug/L	192000	aquatic biota	CCME Water PAL AEP Water PAL
Fenoprop			ug/L	9	human	WHO DW
Fluoranthene			ug/L	0.04	aquatic biota	AEP Water PAL CCME Water PAL
Fluorene			ug/L	3	aquatic biota	AEP Water PAL CCME Water PAL
Fluoride			mg/L	0.12	aquatic biota	CCME Water PAL
gamma-Hexachlorocyclohexane [Lindane]			ug/L	0.01	aquatic biota	AEP Water PAL
Glyphosate			ug/L	280	human wildlife	CCME Water Ag Health Canada DW AEP Water Ag

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Haloacetic acids			ug/L	60	human	US EPA DWR
heptaBDE			ng/L	14	aquatic biota	FEQG Water PAL
Heptachlor			ug/L	0.000059	human	USEPA WQC HH Org
Heptachlor epoxide			ug/L	0.00032	human	HH DW+Org (US EPA) USEPA WQC HH Org
hexaBDE			ng/L	120	aquatic biota	FEQG Water PAL AEP Water PAL
Hexabromocyclododecane			ug/L	0.56	aquatic biota	FEQG Water PAL AEP Water PAL
Hexachlorobenzene			ug/L	0.00079	human	USEPA WQC HH Org
Hexachlorobutadiene			ug/L	0.1	human	USEPA WQC HH Org HH DW+Org (US EPA)
Hexachlorocyclohexane			ug/L	0.01	aquatic biota	CCME Water PAL
Hexachlorocyclopentadiene			ug/L	1	human	USEPA WQC AO
Hexachloroethane			ug/L	1	human	USEPA WQC HH Org HH DW+Org (US EPA)
Hydrazine			ug/L	2.6	aquatic biota	FEQG Water PAL AEP Water PAL
Hydrogen Sulfide			ug/L	2	aquatic biota	US EPA Aquatic Life Criteria
Hydroxyatrazine			ug/L	200	human	WHO DW
Imidacloprid			ug/L	0.23	aquatic biota	CCME Water PAL AEP Water PAL
Indeno(1,2,3-cd)pyrene			ug/L	0.012	human	HH DW+Org (US EPA)
Inorganic nitrogen (nitrate and nitrite)	as N	Dissolved	mg/L	100	wildlife	AEP Water Ag CCME Water Ag

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Iron		Total	ug/L	300	aquatic biota human	USEPA WQC AO CCME Water PAL
Iron		Dissolved	ug/L	300	aquatic biota	AEP Water PAL
Isophorone			ug/L	340	human	HH DW+Org (US EPA)
Isoproturon			ug/L	9	human	WHO DW
Lead		Total	ug/L	4.01275079	aquatic biota	CCME Water PAL AEP Water PAL
Lead		Dissolved	ug/L	3.067487163	aquatic biota	US EPA Aquatic Life Criteria
Linuron			ug/L	7	aquatic biota	CCME Water PAL AEP Water PAL
m-Dichlorobenzene			ug/L	150	aquatic biota	CCME Water PAL
Malathion			ug/L	0.1	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria
Manganese		Total	ug/L	50	human	HH DW+Org (US EPA)
MCPA			ug/L	2.6	aquatic biota	AEP Water PAL CCME Water PAL
Mecoprop			ug/L	10	human	WHO DW
Mercury		Total	ug/L	0.005	aquatic biota	AEP Water PAL
Mercury		Dissolved	ug/L	0.77	aquatic biota	US EPA Aquatic Life Criteria
Mercury (methyl)		Total	ug/L	0.001	aquatic biota	AEP Water PAL
Mercury (methyl)		Dissolved	ug/L	0.004	aquatic biota	CCME Water PAL
Methanol			ug/L	1500	aquatic biota	AEP Water PAL
Methoprene			ug/L	0.09	aquatic biota	AEP Water PAL CCME Water PAL
Methoxychlor			ug/L	0.02	human	HH DW+Org (US EPA) USEPA WQC HH Org

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Methyl Bromide			ug/L	100	human	HH DW+Org (US EPA)
Methyl tert-butyl ether			ug/L	10	aquatic biota	AEP Water PAL
Methylene chloride			ug/L	98.1	aquatic biota	CCME Water PAL AEP Water PAL
Metolachlor			ug/L	7.8	aquatic biota	CCME Water PAL AEP Water PAL
Metribuzin			ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL
Microcystin-LR			ug/L	1	human	WHO DW
Mirex			ug/L	0.001	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL
Molinate			ug/L	6	human	WHO DW
Molybdenum		Total	ug/L	73	aquatic biota	AEP Water PAL CCME Water PAL
Monochloramine			ug/L	3000	human	WHO DW
Monochloroacetate			ug/L	20	human	WHO DW
Monochlorobenzene			ug/L	1.3	aquatic biota	AEP Water PAL CCME Water PAL
Monoethanolamine			ug/L	75	aquatic biota	AEP Water PAL
N-Nitrosodi-n-Propylamine			ug/L	0.05	human	HH DW+Org (US EPA)
N-Nitrosodimethylamine			ug/L	0.007	human	HH DW+Org (US EPA)
N-Nitrosodiphenylamine			ug/L	33	human	HH DW+Org (US EPA)
Naphthalene			ug/L	1	aquatic biota	AEP Water PAL
Nickel		Total	ug/L	60.86254826	aquatic biota	AEP Water PAL
Nickel		Dissolved	ug/L	60.67996061	aquatic biota	US EPA Aquatic Life Criteria

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Nitrate	as N		mg/L	3	aquatic biota	CCME Water PAL AEP Water PAL
Nitrilotriacetic acid			ug/L	200	human	WHO DW
Nitrite	as N		mg/L	0.06	aquatic biota	CCME Water PAL
Nitrobenzene			ug/L	10	human	HH DW+Org (US EPA)
Nitrosamines			ug/L	0.008	human	HH DW+Org (US EPA)
Nitrosodibutylamine			ug/L	0.063	human	HH DW+Org (US EPA)
Nitrosodiethylamine			ug/L	0.008	human	HH DW+Org (US EPA)
Nitrosopyrrolidine			ug/L	0.16	human	HH DW+Org (US EPA)
Nonylphenol			ug/L	6.6	aquatic biota	US EPA Aquatic Life Criteria
Nonylphenol and its ethoxylates			ug/L	1	aquatic biota	CCME Water PAL
o-Dichlorobenzene			ug/L	0.7	aquatic biota	CCME Water PAL AEP Water PAL
octaBDE			ng/L	14	aquatic biota	FEQG Water PAL
Oxamyl (Vydate)			ug/L	200	human	US EPA DWR
p,p'-Dichlorodiphenyldichloroethane (DDD)			ug/L	0.001	human	HH DW+Org (US EPA)
p,p'-Dichlorodiphenyldichloroethylene (DDE)			ug/L	0.00018	human	USEPA WQC HH Org
p-Dichlorobenzene			ug/L	5	human	Health Canada DW
Paraquat	as paraquat dichloride		ug/L	10	human	Health Canada DW
Parathion			ug/L	0.013	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Pendimethalin			ug/L	20	human	WHO DW
pentaBDE			ng/L	0.2	aquatic biota	AEP Water PAL FEQG Water PAL
pentaBDE (BDE-100)			ng/L	0.2	aquatic biota	FEQG Water PAL AEP Water PAL
pentaBDE (BDE-99)			ng/L	4	aquatic biota	AEP Water PAL FEQG Water PAL
Pentachlorobenzene			ug/L	0.1	human	USEPA WQC HH Org HH DW+Org (US EPA)
Pentachlorophenol			ug/L	0.3	human	HH DW+Org (US EPA)
Perchlorate			ug/L	70	human	WHO DW
Perfluorooctanesulfonate			ug/L	0.6	human	Health Canada DW
Perfluorooctanoic acid			ug/L	0.2	human	Health Canada DW
Permethrin			ug/L	0.004	aquatic biota	AEP Water PAL CCME Water PAL
pH			pH units	6.5-9.0	aquatic biota human human	HH DW+Org (US EPA) US EPA Aquatic Life Criteria CCME Water PAL AEP Water PAL Health Canada DW
Phenanthrene			ug/L	0.4	aquatic biota	AEP Water PAL CCME Water PAL
Phenol			ug/L	2	wildlife	AEP Water Ag CCME Water Ag
Phorate			ug/L	2	human	Health Canada DW
Picloram			ug/L	29	aquatic biota	AEP Water PAL CCME Water PAL

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Polychlorinated Biphenyls (PCBs)			ug/L	0.00064	human	USEPA WQC HH Org
Propylene glycol			ug/L	500000	aquatic biota	AEP Water PAL CCME Water PAL
Pyrene			ug/L	0.025	aquatic biota	AEP Water PAL CCME Water PAL
Quinoline			ug/L	3.4	aquatic biota	AEP Water PAL CCME Water PAL
Selenium		Total	ug/L	1	aquatic biota	CCME Water PAL
Silver		Total	ug/L	0.25	aquatic biota	CCME Water PAL AEP Water PAL
Simazine			ug/L	2	human	WHO DW
Sodium dichloroisocyanurate			ug/L	40000	human	WHO DW
Solids Dissolved and Salinity			ug/L	250000	human	HH DW+Org (US EPA)
Strontium		Total	ug/L	7000	human	Health Canada DW
Styrene			ug/L	20	human	WHO DW
Sulfate	as SO4		mg/L	250	human	WHO DW
Sulfide			mg/L	0.0019	aquatic biota	AEP Water PAL
Sulfolane			ug/L	50	aquatic biota	AEP Water PAL
Tebuthiuron			ug/L	1.6	aquatic biota	CCME Water PAL
Terbufos			ug/L	1	human	Health Canada DW
Terbuthylazine			ug/L	7	human	WHO DW
tetraBDE			ng/L	24	aquatic biota	AEP Water PAL FEQG Water PAL
Tetrabromobisphenol A			ug/L	3.1	aquatic biota	FEQG Water PAL AEP Water PAL

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Tetrachloroethane			ug/L	13.3	aquatic biota	CCME Water PAL
Tetrachloroethylene			ug/L	5	human	US EPA DWR
Tetrachlorophenol			ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL
Thallium		Total	ug/L	0.24	human	HH DW+Org (US EPA)
Toluene			ug/L	0.5	aquatic biota	AEP Water PAL
Total dissolved solids (TDS)			mg/L	3000	wildlife	AEP Water Ag CCME Water Ag
Toxaphene			ug/L	0.0002	aquatic biota	US EPA Aquatic Life Criteria
Toxicity (chronic)			Toxic units	1	aquatic biota	AEP Water PAL
Trans-1,2-Dichloroethylene			ug/L	100	human	HH DW+Org (US EPA)
Triallate			ug/L	0.24	aquatic biota	CCME Water PAL AEP Water PAL
triBDE			ng/L	46	aquatic biota	AEP Water PAL FEQG Water PAL
Tribromomethane			ug/L	100	wildlife	CCME Water Ag
Tributyltin			ug/L	0.008	aquatic biota	CCME Water PAL
Trichlorfon			ug/L	0.009	aquatic biota	CCME Water PAL AEP Water PAL
Trichloroacetate			ug/L	200	human	WHO DW
Trichloroethylene			ug/L	5	human	Health Canada DW US EPA DWR
Trichlorophenol			ug/L	18	aquatic biota	AEP Water PAL CCME Water PAL
Triclosan			ug/L	0.47	aquatic biota	FEQG Water PAL

Table 3.2: Identification of most stringent surface water quality guidelines and sensitive receptor as published by provincial, federal and international regulatory agencies. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Value	Sensitive Receptor	Source
Tricyclohexyltin			ug/L	250	wildlife	AEP Water Ag CCME Water Ag
Triethylene glycol			ug/L	350000	aquatic biota	AEP Water PAL
Trifluralin			ug/L	0.2	aquatic biota	CCME Water PAL AEP Water PAL
Trihalomethanes			ug/L	80	human	US EPA DWR
Triphenyltin			ug/L	0.022	aquatic biota	AEP Water PAL CCME Water PAL
Uranium		Total	ug/L	15	aquatic biota	AEP Water PAL CCME Water PAL
Vanadium		Total	ug/L	100	wildlife	AEP Water Ag CCME Water Ag
Vinyl chloride			ug/L	0.22	human	HH DW+Org (US EPA)
Xylene			ug/L	30	aquatic biota	AEP Water PAL
Xylenes (total)			ug/L	10000	human	US EPA DWR
Zinc		Total	ug/L	30	aquatic biota	AEP Water PAL
Zinc		Dissolved	ug/L	31.34535401	aquatic biota	CCME Water PAL

Note:
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)

3.4.4 Water Quality Criteria for the Protection of Indigenous Use (adopted)

Based on review of available guidelines described in Section 3.4.3 existing guidelines can offer a degree of protection for the goals, and endpoints identified for Indigenous water uses (Figure 3.1) and were adopted as health risk criteria when appropriate. As discussed above, the degree of health protection varies by agency and substance and available guidelines could only be adopted for two two Indigenous water use categories; wildlife health and aquatic ecosystem health (Figure 3.1), as described below.

For wildlife health and aquatic ecosystem health water use categories, individual PAH congeners should be compared to indicated criteria, when available. However, criteria could not be established for all PAH congeners. In these cases, the sum of low and high molecular weight (MW) congeners should be compared to the criteria for naphthalene and BaP, respectively. The equations below can be used to estimate concentrations of low and high MW PAH mixtures which exert toxicity through the same mechanism of action (CCME, 2010).

Low MW PAHs = (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, Pyrene)

High MW PAHs = (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene)

Wildlife Health

Surface water concentrations for the protection of piscivorous wildlife species consuming surface water and fish were identified in Sample et al. (1996).

Additionally, in Alberta, Tier 1 soil and groundwater remediation guidelines consider the protection of surface water for wildlife watering (via hydraulically connected groundwater) by modifying the livestock/ agriculture guidelines to account for contaminant migration from groundwater to surface water (AEP, 2019).

Aligning with Alberta guidance, livestock watering guidelines for agricultural water uses were also considered applicable to wildlife species to assess potential risks to wildlife health from ingestion of contaminants in water sources. Review of the protocol for deriving livestock watering guidelines for agricultural uses indicates that livestock watering guidelines were developed, where possible, for both agricultural bird (i.e. poultry) and large mammal (i.e. cattle) species (CCME, 2021). The agricultural species are similar to wildlife species of cultural importance to Indigenous communities (i.e., mallard, lesser scaup, moose) further supporting the application of livestock watering guidelines to avian and mammalian wildlife.

As the development of new livestock water guidelines is a complex process (CCME, 2021), the surface water quality protection goals for wildlife consuming surface water are limited to those defined by AEP (GoA, 2018) and CCME and the surface water benchmarks published by Sample et al. (1996) which is not representative of all identified substances, but it is a first step in protecting wildlife health more broadly. The health risk criteria for the protection of wildlife health from consuming drinking water and fish are provided in Table 3.3.

It is important to note, concentrations of substances required for the protection of wildlife species may be greater than (meaning less conservative than) concentrations associated with toxicological responses in more sensitive receptors (i.e., humans or aquatic biota).

Finally, the health risk criteria for wildlife, should not be adopted unless all other water use categories described in Figure 3.1 have been assessed and identified as not applicable or non-operational (i.e., the surface water being assessed is not used by humans or aquatic biota).

Table 3.3: Health risk criteria for the protection of wildlife species

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
1,1-Dichloroethylene			ug/L			929	929	US DOE Wildlife
1,2-Dichloroethane			ug/L	5	5	4284	5	AEP Water Ag CCME Water Ag
Aldicarb			ug/L	11	11		11	AEP Water Ag CCME Water Ag
Aldrin			ug/L			0.001	0.001	US DOE Wildlife
Aluminum		Total	ug/L	5000	5000	18	18	US DOE Wildlife
Antimony		Total	ug/L			161	161	US DOE Wildlife
Arsenic		Total	ug/L	25	25	16	16	US DOE Wildlife
Atrazine			ug/L	5	5		5	AEP Water Ag CCME Water Ag
Benzene			ug/L			2293	2293	US DOE Wildlife
Benzo(a)pyrene and equivalents			ug/L			0.006722	0.006722	US DOE Wildlife
Beryllium		Total	ug/L	100	100	136	100	AEP Water Ag CCME Water Ag
Boron		Total	ug/L	5000	5000		5000	AEP Water Ag CCME Water Ag
Bromacil			ug/L	1100	1100		1100	AEP Water Ag CCME Water Ag
Bromodichloromethane			ug/L	100			100	AEP Water Ag
Bromoform			ug/L	100			100	AEP Water Ag
Bromoxynil			ug/L	11	11		11	AEP Water Ag CCME Water Ag
Cadmium		Total	ug/L	80	80	0.2307	0.2307	US DOE Wildlife
Calcium			mg/L	1000	1000		1000	AEP Water Ag CCME Water Ag
Captan			ug/L	13			13	AEP Water Ag
Carbaryl			ug/L	1100	110		110	CCME Water Ag

Table 3.3: Health risk criteria for the protection of wildlife species *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
Carbofuran			ug/L	45	45		45	AEP Water Ag CCME Water Ag
Carbon tetrachloride			ug/L	5	5	913	5	AEP Water Ag CCME Water Ag
Chlordane			ug/L	7	7	0.00889	0.00889	US DOE Wildlife
Chloroform			ug/L	100	100	3439	100	AEP Water Ag CCME Water Ag
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]			ug/L	100	100		100	AEP Water Ag CCME Water Ag
Chlorothalonil			ug/L	170	170		170	AEP Water Ag CCME Water Ag
Chlorpyrifos			ug/L	24	24		24	AEP Water Ag CCME Water Ag
Chromium (III)		Total	ug/L	50	50		50	AEP Water Ag CCME Water Ag
Chromium (VI)		Total	ug/L	50	50	3593	50	AEP Water Ag CCME Water Ag
Cobalt		Total	ug/L	1000	1000		1000	AEP Water Ag CCME Water Ag
Copper		Total	ug/L	500	500		500	AEP Water Ag CCME Water Ag
Cyanazine			ug/L	10	10		10	AEP Water Ag CCME Water Ag
Cyanide	as free CN		ug/L			369092	369092	US DOE Wildlife
DDT and metabolites			ug/L	30		4.136e-06	4.136e-06	US DOE Wildlife
Deltamethrin			ug/L	2.5	2.5		2.5	AEP Water Ag CCME Water Ag
Di-n-Butyl Phthalate			ug/L			0.15	0.15	US DOE Wildlife

Table 3.3: Health risk criteria for the protection of wildlife species *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
Dibromochloromethane			ug/L	100	100		100	AEP Water Ag CCME Water Ag
Dicamba			ug/L	122	122		122	AEP Water Ag CCME Water Ag
Dichlorobromomethane			ug/L		100		100	CCME Water Ag
Dichloromethane			ug/L	50	50		50	AEP Water Ag CCME Water Ag
Diclofop-methyl			ug/L	9	9		9	AEP Water Ag CCME Water Ag
Dieldrin			ug/L			0.001362	0.001362	US DOE Wildlife
Diethyl Phthalate			ug/L			210561	210561	US DOE Wildlife
Dimethoate			ug/L	3	3		3	AEP Water Ag CCME Water Ag
Dinoseb			ug/L	150	150		150	AEP Water Ag CCME Water Ag
Dioxin (2,3,7,8-TCDD)			ug/L			2.13e-08	2.134e-08	US DOE Wildlife
Endosulfan			ug/L			1	1	US DOE Wildlife
Endrin			ug/L	0.2	0.2	0.001313	0.001313	US DOE Wildlife
Ethanol			ug/L			123377	123377	US DOE Wildlife
Ethyl acetate			ug/L			136465	136465	US DOE Wildlife
Ethylbenzene			ug/L	2.4	2.4		2.4	AEP Water Ag CCME Water Ag
Fluoride			mg/L	1	1		1	AEP Water Ag CCME Water Ag
Formaldehyde			ug/L			73910	73910	US DOE Wildlife
Glyphosate			ug/L	280	280		280	AEP Water Ag CCME Water Ag
Heptachlor			ug/L	3	3	0.001083	0.001083	US DOE Wildlife

Table 3.3: Health risk criteria for the protection of wildlife species *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
Hexachlorobenzene			ug/L	0.52	0.52		0.52	AEP Water Ag CCME Water Ag
Inorganic nitrogen (nitrate and nitrite)	as N	dissolved	mg/L	100	100		100	AEP Water Ag CCME Water Ag
Lead		Total	ug/L	100	100	168	100	AEP Water Ag CCME Water Ag
MCPA			ug/L	25	25		25	AEP Water Ag CCME Water Ag
Mercury		Total	ug/L	3	3	0.001576	0.001576	US DOE Wildlife
Methanol			ug/L			230691	230691	US DOE Wildlife
Methoxychlor			ug/L			1	1	US DOE Wildlife
Methylene chloride			ug/L			3990	3990	US DOE Wildlife
Metolachlor			ug/L	50	50		50	AEP Water Ag CCME Water Ag
Metribuzin			ug/L	80	80		80	AEP Water Ag CCME Water Ag
Molybdenum		Total	ug/L	500	500		500	AEP Water Ag CCME Water Ag
Nickel		Total	ug/L	1000	1000	1438	1000	AEP Water Ag CCME Water Ag
Nitrite	as N	dissolved	mg/L	10	10		10	AEP Water Ag CCME Water Ag
Pentachloronitrobenzene			ug/L			4	4	US DOE Wildlife
Pentachlorophenol			ug/L			0.275	0.275	US DOE Wildlife
Phenol			ug/L	2	2		2	AEP Water Ag CCME Water Ag
Picloram			ug/L	190	190		190	AEP Water Ag CCME Water Ag

Table 3.3: Health risk criteria for the protection of wildlife species *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
Selenium		Total	ug/L	50	50	0.2363	0.2363	US DOE Wildlife
Simazine			ug/L	10	10		10	AEP Water Ag CCME Water Ag
Sulfate	as SO4		mg/L	1000	1000		1000	AEP Water Ag CCME Water Ag
Tebuthiuron			ug/L	130	130		130	AEP Water Ag CCME Water Ag
Tetrachloroethylene			ug/L			48	48	US DOE Wildlife
Thallium		Total	ug/L			1	1	US DOE Wildlife
Toluene			ug/L	24	24	764	24	AEP Water Ag CCME Water Ag
Total dissolved solids			mg/L	3000	3000		3000	AEP Water Ag CCME Water Ag
Toxaphene			ug/L	5	5	1	1	US DOE Wildlife
Triallate			ug/L	230	230		230	AEP Water Ag CCME Water Ag
Tribromomethane			ug/L		100		100	CCME Water Ag
Tributyltin			ug/L	250	250		250	AEP Water Ag CCME Water Ag
Trichloroethylene			ug/L	50	50	49419	22	US DOE Wildlife
Tricyclohexyltin			ug/L	250	250		250	AEP Water Ag CCME Water Ag
Trifluralin			ug/L	45	45		45	AEP Water Ag CCME Water Ag
Triphenyltin			ug/L	820	820		820	AEP Water Ag CCME Water Ag
Uranium		Total	ug/L	200	200		200	AEP Water Ag CCME Water Ag

Table 3.3: Health risk criteria for the protection of wildlife species *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP Water Ag	CCME Water Ag	US DOE Wildlife	Wildlife Health Risk Criteria	Source
Vanadium		Total	ug/L	100	100		100	AEP Water Ag CCME Water Ag
Vinyl chloride			ug/L			78	78	US DOE Wildlife
Xylene			ug/L			28	28	US DOE Wildlife
Zinc		Total	ug/L	50	50000	30	30	US DOE Wildlife
gamma-Hexachlorocyclohexane [Lindane]			ug/L	4		9	4	AEP Water Ag

Note:
AG: Agriculture

Aquatic Ecosystem Health

Indigenous communities identified the health of ecosystems as an indicator of their physical and mental health. Indicators of ecosystem health were identified as the presence and abundance of each of the following groups: invertebrates, fish, amphibians, plants, algae, and wildlife species (birds and mammals).

To evaluate which aquatic biota were considered in development of the CCME PALs (and the majority of GOA 2018 PALs) and understand the level of protection for various aquatic biota within an ecosystem, the technical information sheets for each substance were reviewed. Table 3.4 describes available toxicity data and relative sensitivity for fish, amphibian, invertebrate, plant, and algae species (1 = most sensitive, 4 = least sensitive).

The CCME PALs most frequently included toxicity test species from fish (90%) and invertebrates (76%) classes and less frequently included toxicity data from algae (49%), plant (41%), amphibian (31) species in development of PALs.

Sensitivity is indicated by the number of times (count) a class of species was the most sensitive from exposure to a specific contaminant in comparison to the other species with available toxicity data. If two classes showed similar sensitivity, they were not included in the count (see example for benzene where neither fish nor amphibian were counted). Comparatively, invertebrates were the most sensitive to chemical exposures followed by fish and then primary producers (plants and algae).

Table 3.4: Availability and sensitivity of fish, amphibian, invertebrate, plant and algae species in toxicity data used to derive CCME PAL guidelines (1 = most sensitive, 4 = least sensitive).

	Sensitivity rank*				
Parameter (n = 29)	Fish (n = 26)	Amphibians (n = 9)	Invertebrates (n = 22)	Plants (n = 12)	Algae (n = 14)
Acenaphthene	1				2
Ammonia, unionized	1		2	3	
Anthracene	2		1		3
Benz(a)anthracene	2				1
Benz(a)pyrene	1				2
Benzene	1	1			
Boron	2	4	3	1	
Cadmium	2	4	1	3	3
Chloride	2	3	1	4	4
Chromium, hexavalent	3		1	2	

Table 3.4: Availability and sensitivity of fish, amphibian, invertebrate, plant and algae species in toxicity data used to derive CCME PAL guidelines (1 = most sensitive, 4 = least sensitive). *(continued)*

	Sensitivity rank*				
Parameter (n = 29)	Fish (n = 26)	Amphibians (n = 9)	Invertebrates (n = 22)	Plants (n = 12)	Algae (n = 14)
Chromium, trivalent	1		3	2	
Ethylbenzene			1		2
Fluoranthene					
Fluorene			1		2
Fluoride	1		1		
Manganese	1	3	2		
Mercury	1		2	2	
Molybdenum	1		3		2
Naphthalene					
Nitrate	1	2	3		
Phenanthrene	1		1		
Phenol	1	1		2	
Pyrene	3	3	1		2
Silver	3		1		2
Thallium	2		3	1	
Toluene	1		2		
Ammonia (un-ionized)	1		1	1	
Uranium	3		1	2	1
Zinc	2	3	2	1	1
Most sensitive class (frequency)	35%	-	42%	27%	23%

* 1 = most sensitive, 4 = least sensitive

Protection of aquatic life guidelines were not available for acrylamide, PHC F1 and F2, naphthenic acids, antimony, barium, lithium, silver, strontium, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene.

The protocol for derivation of surface water quality for the protection of aquatic life is complex and beyond the scope of this project. Recognizing this limitation, health risk criteria for the protection of aquatic ecosystems are proposed in Table 3.5.

While new criteria were not derived guidance is provided on assessment of complex mixtures which may be acting through similar modes of action to elicit toxicological responses (high and low MW PAH groups) and overall toxicity (as toxic units).

To assess potential toxicity, results from whole effluent toxicity tests (WET) must be used and predicted toxicity from water quality modelling is not recommended as toxicity is not a "conserved substance". If the practitioner is attempting to predict toxicity in ambient environments complex models such as the Biotic Ligand Models (BLMs) for metals or Quantitative Structure Activity Relationships (QSARs) for organics are required

The health risk criteria presented in Table 3.5 apply to the assessment of aquatic ecosystem health only and risks to aquatic species may be less than those associated with toxicological responses in more sensitive receptors (i.e., humans, wildlife species) and other water uses.

As discussed in Section 3.3.3, the US EPA prescribes aquatic life criteria for dissolved fractions which were developed by applying CFs to total recoverable metal concentrations used for toxicity testing. Comparison of the CFs estimated from laboratory conditions during toxicity tests differ from conditions in the Athabasca River, therefore the health risk criteria were developed by adopting published guidelines for total recoverable fractions, until site specific CFs can be developed for the Lower Athabasca River.

However, to better understand the condition of the LAR and potential health risks, the US EPA aquatic life criteria for dissolved metals may be applied, in addition to the health risk criteria for total fractions, when dissolved monitoring data is available. Comparison of trace element monitoring data must be presented for total health risk criteria. If the US EPA aquatic life criteria (dissolved) identified in Table 3.5 are applied to monitoring data, they must be presented alongside comparison with total health risk criteria.

The health risk criteria for aquatic health should not be applied singularly unless all other exposure pathways described in Figure 3.1. have been assessed and identified as not applicable or non-operational (i.e., the surface water being assessed is not used by humans or wildlife).

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion).

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
.alpha.-Endosulfan			ug/L				0.06	0.056	US EPA Aquatic Life Criteria
.beta.-Endosulfan			ug/L				0.06	0.056	US EPA Aquatic Life Criteria
1,1,2-Trichloroethane			ug/L		21.00			21	CCME Water PAL
1,2,3,4-Tetrachlorobenzene			ug/L	1.80	1.80			1.8	AEP Water PAL CCME Water PAL
1,2,3-Trichlorobenzene			ug/L	8.00	8.00			8	AEP Water PAL CCME Water PAL
1,2,4-Trichlorobenzene			ug/L	24.00	24.00			24	AEP Water PAL CCME Water PAL
1,2-Dichlorobenzene			ug/L	0.70				0.7	AEP Water PAL
1,2-Dichloroethane			ug/L	100.00	100.00			100	AEP Water PAL CCME Water PAL
1,3-Dichlorobenzene			ug/L	150.00				150	AEP Water PAL
1,4-Dichlorobenzene			ug/L	26.00				26	AEP Water PAL
2,4-D			ug/L	4.00	4.00			4	AEP Water PAL CCME Water PAL
2,4-DB			ug/L	25.00				25	AEP Water PAL
3-Iodo-2-propynyl butyl carbamate			ug/L	1.90	1.90			1.9	AEP Water PAL CCME Water PAL
Acenaphthene†			ug/L	5.80	5.80			5.8	AEP Water PAL CCME Water PAL
Acridine			ug/L	4.40	4.40			4.4	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Acrolein			ug/L	3.00			3.00	3	AEP Water PAL US EPA Aquatic Life Criteria
Alcohol ethoxylates			ug/L			70.00		70	FEQG Water PAL
Aldicarb			ug/L	1.00	1.00			1	AEP Water PAL CCME Water PAL
Aldrin			ug/L	0.00	0.00			0.004	AEP Water PAL CCME Water PAL
Alkalinity, total	as CaCO3		mg/L	20.00			20.00	20	AEP Water PAL US EPA Aquatic Life Criteria
Aluminum		Total	ug/L		100.00			100	CCME Water PAL
Aluminum		dissolved	ug/L	50.00				50	AEP Water PAL
Ammonia			mg/L	0.79				0.794	AEP Water PAL
Ammonia, unionized			mg/L	0.02	0.02			0.016	AEP Water PAL
Aniline			ug/L	2.20	2.20			2.2	AEP Water PAL CCME Water PAL
Anthracene†			ug/L	0.01	0.01			0.012	AEP Water PAL CCME Water PAL
Arsenic		Total	ug/L	5.00	5.00			5	AEP Water PAL CCME Water PAL
Arsenic		dissolved	ug/L				150.00	150	US EPA Aquatic Life Criteria
Atrazine			ug/L	1.80	1.80			1.8	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Azinphos-methyl			ug/L	0.01			0.01	0.01	AEP Water PAL US EPA Aquatic Life Criteria
Benzene			ug/L	40.00	370.00			40	AEP Water PAL
Benzo(a)anthracene[‡]			ug/L	0.02	0.02			0.018	AEP Water PAL CCME Water PAL
Benzo(a)pyrene[‡]			ug/L	0.01	0.01			0.015	AEP Water PAL CCME Water PAL
Bisphenol A-d6			ug/L			3.50		3.5	FEQG Water PAL
Boron		Total	ug/L	1,500.00	1,500.00			1500	AEP Water PAL CCME Water PAL
Bromacil			ug/L	5.00	5.00			5	AEP Water PAL CCME Water PAL
Bromoxynil			ug/L	5.00	5.00			5	AEP Water PAL CCME Water PAL
Cadmium[*]		Total	ug/L	0.18	0.18			0.1843828121	AEP Water PAL CCME Water PAL
Cadmium[*]		dissolved	ug/L				0.82	0.8237781279	US EPA Aquatic Life Criteria
Captan			ug/L	1.30	1.30			1.3	AEP Water PAL CCME Water PAL
Carbamazepine			ug/L	10.00	10.00			10	AEP Water PAL CCME Water PAL
Carbaryl			ug/L	0.20	0.20		2.10	0.2	AEP Water PAL CCME Water PAL
Carbofuran			ug/L	1.80	1.80			1.8	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Carbon tetrachloride			ug/L	13.30	13.30			13.3	AEP Water PAL CCME Water PAL
Chloramines			ug/L		0.50			0.5	CCME Water PAL
Chlordane			ug/L	0.01	0.01		0.00	0.0043	US EPA Aquatic Life Criteria
Chloride			mg/L	120.00	120.00		230.00	120	AEP Water PAL CCME Water PAL
Chlorinated paraffins, long-chain, C18-C20			ug/L	2.40		2.40		2.4	AEP Water PAL FEQG Water PAL
Chlorinated paraffins, medium-chain, C14-C17			ug/L	2.40		2.40		2.4	AEP Water PAL FEQG Water PAL
Chlorinated paraffins, short-chain, C10-C13			ug/L	2.40		2.40		2.4	AEP Water PAL FEQG Water PAL
Chlorine			ug/L	0.50			11.00	0.5	AEP Water PAL
Chlorobenzene			ug/L	1.30				1.3	AEP Water PAL
Chloroform			ug/L	1.80	1.80			1.8	AEP Water PAL CCME Water PAL
Chlorophenol			ug/L	7.00	7.00			7	AEP Water PAL CCME Water PAL
Chlorothalonil			ug/L	0.18	0.18			0.18	AEP Water PAL CCME Water PAL
Chlorpyrifos			ug/L	0.00	0.00		0.04	0.002	AEP Water PAL CCME Water PAL
Chromium (III)*		Total	ug/L	8.90	8.90			8.9	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Chromium (III)*§		dissolved	ug/L				100.92	100.9185723	US EPA Aquatic Life Criteria
Chromium (VI)		Total	ug/L	1.00	1.00			1	AEP Water PAL CCME Water PAL
Chromium (VI)		dissolved	ug/L			5.00	11.00	5	FEQG Water PAL
Cobalt*		Total	ug/L	1.10		1.10		1.099682588	AEP Water PAL FEQG Water PAL
Copper*		Total	ug/L	7.00	2.76			2.763433095	CCME Water PAL
Copper		dissolved	ug/L			0.53		0.53	FEQG Water PAL
Cyanazine			ug/L	2.00	2.00			2	AEP Water PAL CCME Water PAL
Cyanide	as free CN		ug/L	5.20	5.00		5.20	5	CCME Water PAL
DDT and metabolites			ug/L	0.00	0.00		0.00	0.001	AEP Water PAL CCME Water PAL US EPA Aquatic Life Criteria
Deltamethrin			ug/L	0.00	0.00			0.0004	AEP Water PAL CCME Water PAL
Demeton			ug/L	0.10			0.10	0.1	AEP Water PAL US EPA Aquatic Life Criteria
Di(2-ethylhexyl) phthalate			ug/L	16.00	16.00			16	AEP Water PAL CCME Water PAL
Di-n-Butyl Phthalate			ug/L	19.00	19.00			19	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Diazinon			ug/L	0.17			0.17	0.17	AEP Water PAL US EPA Aquatic Life Criteria
Dicamba			ug/L	10.00	10.00			10	AEP Water PAL CCME Water PAL
Dichlorophenol			ug/L	0.20	0.20			0.2	AEP Water PAL CCME Water PAL
Diclofop-methyl			ug/L	6.10	6.10			6.1	AEP Water PAL CCME Water PAL
Didecyl dimethyl ammonium chloride			ug/L	1.50	1.50			1.5	AEP Water PAL CCME Water PAL
Dieldrin			ug/L	0.00	0.00		0.06	0.004	AEP Water PAL CCME Water PAL
Diethanolamine			ug/L	450.00				450	AEP Water PAL
Diethylene glycol			ug/L	150,000.00				150000	AEP Water PAL
Diisopropanolamine			ug/L	1,600.00	1,600.00			1600	AEP Water PAL CCME Water PAL
Dimethoate			ug/L	6.20	6.20			6.2	AEP Water PAL CCME Water PAL
Dinoseb			ug/L	0.05	0.05			0.05	AEP Water PAL CCME Water PAL
Endosulfan			ug/L	0.00	0.00			0.003	AEP Water PAL CCME Water PAL
Endrin			ug/L	0.00	0.00		0.04	0.0023	AEP Water PAL CCME Water PAL
Ethinyl estradiol			ng/L	0.50				0.5	AEP Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Ethylbenzene			ug/L	90.00	90.00			90	AEP Water PAL CCME Water PAL
Ethylene glycol			ug/L	192,000.00	192,000.00			192000	AEP Water PAL CCME Water PAL
Fluoranthene†			ug/L	0.04	0.04			0.04	AEP Water PAL CCME Water PAL
Fluorene†			ug/L	3.00	3.00			3	AEP Water PAL CCME Water PAL
Fluoride			mg/L		0.12			0.12	CCME Water PAL
Glyphosate			ug/L	800.00	800.00			800	AEP Water PAL CCME Water PAL
Heptachlor			ug/L		0.01		0.00	0.0038	US EPA Aquatic Life Criteria
Heptachlor epoxide			ug/L	0.01			0.00	0.0038	US EPA Aquatic Life Criteria
Hexabromocyclododecan			ug/L	0.56		0.56		0.56	AEP Water PAL FEQG Water PAL
Hexachlorobutadiene			ug/L	1.30	1.30			1.3	AEP Water PAL CCME Water PAL
Hexachlorocyclohexane			ug/L		0.01			0.01	CCME Water PAL
Hydrazine			ug/L	2.60		2.60		2.6	AEP Water PAL FEQG Water PAL
Hydrogen Sulfide			ug/L				2.00	2	US EPA Aquatic Life Criteria
Imidacloprid			ug/L	0.23	0.23			0.23	AEP Water PAL CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Iron		Total	ug/L		300.00	4,206.07		300	CCME Water PAL
Iron		dissolved	ug/L	300.00			1,000.00	300	AEP Water PAL
Lead*		Total	ug/L	4.01	4.01			4.01275079	AEP Water PAL CCME Water PAL
Lead*		dissolved	ug/L				3.07	3.067487163	US EPA Aquatic Life Criteria
Linuron			ug/L	7.00	7.00			7	AEP Water PAL CCME Water PAL
MCPA			ug/L	2.60	2.60			2.6	AEP Water PAL CCME Water PAL
Malathion			ug/L	0.10			0.10	0.1	AEP Water PAL US EPA Aquatic Life Criteria
Manganese		Total	ug/L		470.00			470	CCME Water PAL
Mecoprop			ug/L	13.00				13	AEP Water PAL
Mercury (methyl)		Total	ug/L	0.00				0.001	AEP Water PAL
Mercury (methyl)		dissolved	ug/L		0.00			0.004	CCME Water PAL
Mercury		Total	ug/L	0.00	0.03			0.005	AEP Water PAL
Mercury§		dissolved	ug/L				0.77	0.77	US EPA Aquatic Life Criteria
Methanol			ug/L	1,500.00				1500	AEP Water PAL
Methoprene			ug/L	0.09	0.09			0.09	AEP Water PAL CCME Water PAL
Methoxychlor			ug/L	0.03			0.03	0.03	AEP Water PAL US EPA Aquatic Life Criteria

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Methyl tert-butyl ether			ug/L	10.00	10,000.00			10	AEP Water PAL
Methylene chloride			ug/L	98.10	98.10			98.1	AEP Water PAL CCME Water PAL
Metolachlor			ug/L	7.80	7.80			7.8	AEP Water PAL CCME Water PAL
Metribuzin			ug/L	1.00	1.00			1	AEP Water PAL CCME Water PAL
Mirex			ug/L	0.00			0.00	0.001	AEP Water PAL US EPA Aquatic Life Criteria
Molybdenum		Total	ug/L	73.00	73.00			73	AEP Water PAL CCME Water PAL
Monochlorobenzene			ug/L	1.30	1.30			1.3	AEP Water PAL CCME Water PAL
Monoethanolamine			ug/L	75.00				75	AEP Water PAL
Naphthalene[†]			ug/L	1.00	1.10			1	AEP Water PAL
Nickel[*]		Total	ug/L	60.86	109.78			60.86254826	AEP Water PAL
Nickel[*§]		dissolved	ug/L				60.68	60.67996061	US EPA Aquatic Life Criteria
Nitrate	as N	dissolved	mg/L	3.00	3.00			3	AEP Water PAL CCME Water PAL
Nitrite	as N	dissolved	mg/L	0.20	0.06			0.06	CCME Water PAL
Nonylphenol			ug/L				6.60	6.6	US EPA Aquatic Life Criteria

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Nonylphenol and its ethoxylates			ug/L	6.60	1.00			1	CCME Water PAL
Parathion			ug/L	0.01			0.01	0.013	AEP Water PAL US EPA Aquatic Life Criteria
Pentachlorobenzene			ug/L	6.00	6.00			6	AEP Water PAL CCME Water PAL
Pentachlorophenol			ug/L	0.50	0.50		15.00	0.5	AEP Water PAL CCME Water PAL
Perfluorooctanesulfonate			ug/L			6.80		6.8	FEQG Water PAL
Permethrin			ug/L	0.00	0.00			0.004	AEP Water PAL CCME Water PAL
Phenanthrene†			ug/L	0.40	0.40			0.4	AEP Water PAL CCME Water PAL
Phenol			ug/L	4.00	4.00			4	AEP Water PAL CCME Water PAL
Picloram			ug/L	29.00	29.00			29	AEP Water PAL CCME Water PAL
Polychlorinated Biphenyls (PCBs)			ug/L	0.00	0.00		0.01	0.001	AEP Water PAL CCME Water PAL
Propylene glycol			ug/L	500,000.00	500,000.00			500000	AEP Water PAL CCME Water PAL
Pyrene†			ug/L	0.03	0.03			0.025	AEP Water PAL CCME Water PAL
Quinoline			ug/L	3.40	3.40			3.4	AEP Water PAL CCME Water PAL
Selenium		Total	ug/L	2.00	1.00			1	CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Silver		Total	ug/L	0.25	0.25			0.25	AEP Water PAL CCME Water PAL
Simazine			ug/L	10.00	10.00			10	AEP Water PAL CCME Water PAL
Styrene			ug/L	72.00	72.00			72	AEP Water PAL CCME Water PAL
Sulfate	as SO4		mg/L	309.00				309	AEP Water PAL
Sulfide			mg/L	0.00				0.0019	AEP Water PAL
Sulfolane			ug/L	50.00	50,000.00			50	AEP Water PAL
Tebuthiuron			ug/L	1,600.00	1.60			1.6	CCME Water PAL
Tetrabromobisphenol A			ug/L	3.10		3.10		3.1	AEP Water PAL FEQG Water PAL
Tetrachloroethane			ug/L		13.30			13.3	CCME Water PAL
Tetrachloroethylene			ug/L	110.00	110.00			110	AEP Water PAL CCME Water PAL
Tetrachlorophenol			ug/L	1.00	1.00			1	AEP Water PAL CCME Water PAL
Thallium		Total	ug/L	0.80	0.80			0.8	AEP Water PAL CCME Water PAL
Toluene			ug/L	0.50	2.00			0.5	AEP Water PAL
Toxaphene			ug/L	0.01	0.01		0.00	0.0002	US EPA Aquatic Life Criteria
Toxicity (acute)¶			Toxic Units (TUa)	0.30					AEP Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
Toxicity (chronic)**			Toxic Units (TUc)	1.00					AEP Water PAL
Triallate			ug/L	0.24	0.24			0.24	AEP Water PAL CCME Water PAL
Tributyltin			ug/L	0.07	0.01		0.07	0.008	CCME Water PAL
Trichlorfon			ug/L	0.01	0.01			0.009	AEP Water PAL CCME Water PAL
Trichloroethylene			ug/L	21.00	21.00			21	AEP Water PAL CCME Water PAL
Trichlorophenol			ug/L	18.00	18.00			18	AEP Water PAL CCME Water PAL
Triclosan			ug/L			0.47		0.47	FEQG Water PAL
Triethylene glycol			ug/L	350,000.00				350000	AEP Water PAL
Trifluralin			ug/L	0.20	0.20			0.2	AEP Water PAL CCME Water PAL
Triphenyltin			ug/L	0.02	0.02			0.022	AEP Water PAL CCME Water PAL
Uranium		Total	ug/L	15.00	15.00			15	AEP Water PAL CCME Water PAL
Vanadium		Total	ug/L			120.00		120	FEQG Water PAL
Xylene			ug/L	30.00				30	AEP Water PAL
Zinc		Total	ug/L	30.00				30	AEP Water PAL
Zinc*		dissolved	ug/L		31.35		137.87	31.34535401	CCME Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
gamma-Hexachlorocyclohexane [Lindane]			ug/L	0.01				0.01	AEP Water PAL
heptaBDE			ng/L	17.00		14.00		14	FEQG Water PAL
hexaBDE			ng/L	120.00		120.00		120	AEP Water PAL FEQG Water PAL
m-Dichlorobenzene			ug/L		150.00			150	CCME Water PAL
o-Dichlorobenzene			ug/L	0.70	0.70			0.7	AEP Water PAL CCME Water PAL
octaBDE			ng/L	17.00		14.00		14	FEQG Water PAL
p-Dichlorobenzene			ug/L	26.00	26.00			26	AEP Water PAL CCME Water PAL
pH			pH units	9.00	9.00		6.50	6.5-9	AEP Water PAL CCME Water PAL US EPA Aquatic Life Criteria
pentaBDE (BDE-100)			ng/L	0.20		0.20		0.2	AEP Water PAL FEQG Water PAL
pentaBDE (BDE-99)			ng/L	4.00		4.00		4	AEP Water PAL FEQG Water PAL
pentaBDE			ng/L	0.20		0.20		0.2	AEP Water PAL FEQG Water PAL
tetraBDE			ng/L	24.00		24.00		24	AEP Water PAL FEQG Water PAL

Table 3.5: Health risk criteria for the protection of aquatic ecosystem health (adopted from GoA (2018); CCME PAL guidelines, Federal Environmental quality Guidelines; US EPA Aquatic Life Criterion). *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	AEP	CCME	FEQG	US EPA	Aquatic Ecosystem Health Criteria value	Source
triBDE			ng/L	46.00		46.00		46	AEP Water PAL FEQG Water PAL

Note:
PAL: Protection of Aquatic Life
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)

* Calculated using modifying factors presented in Table 3.1.

† Naphthalene applied as surrogate to sum of low molecular weight PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) and compare to Naphthalene health risk criteria (adopted as surrogate) (CCME (2010))

‡ BaP and equivalents applied as surrogate to sum of high molecular weight PAH congeners (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene) should be used for comparison to identified health risk criteria (CCME (2010))

§ Comparison of water quality data must be presented for both dissolved and total fractions

¶ Toxic Unit-Acute (TUa) is the reciprocal of the effluent concentration (i.e., TUa = 100/LC50) that causes 50 percent of the organisms to die by the end of an acute toxicity test (US EPA (2000c))

** Toxic Unit-Chronic (TUc) is the reciprocal of the effluent concentration (e.g., TUc = 100/NOEC) that causes no observable effect (NOEC) on the test organisms by the end of a chronic toxicity test (US EPA (2000c)).

3.4.5 Water Quality Criteria for the Protection of Indigenous Use (derived)

The following water use categories are specific to protection of human health. As such, the potential for carcinogenic effects from exposure to chemicals must be considered. Known human carcinogens are identified in each table presenting health risk criteria. For PAHs, a comparison to the BaP health risk criteria requires the practitioner to calculate the BaP equivalent concentration by applying the health Canada (2021) RPFs to measured concentrations of PAH congeners as follows:

Equation (3.4)

$$\text{BaP equivalent (ug/L)} = \sum[\text{PAH congener} \times \text{BaP RPF}] \tag{3.4}$$

Once estimated, the BaP equivalent concentrations should be compared to the risk criteria for BaP in both the traditional foods and surface water and traditional medicine tables.

Local Indigenous Community Food and Medicine Ingestion Rates

Derived health risk criteria for the remaining two water use categories (traditional foods and drinking water and medicinal plants are described below.

Traditional food consumption surveys were used to identify ingestion rates of culturally important fish and plant species required to develop health risk criteria protective of ACFN, FMFN and MCFN members. Details of the survey methodology and results are provided in Chapter 5. Consumption rates (g/d) for fish and medicinal plants were estimated using methods described in Chan et al. (2016) by multiplying the frequency (servings per year) by serving size (g per serving) and normalizing over the year. The highest calculated ingestion rate for each of fish (as a surrogate for traditional foods) and medicinal plants was adopted to derive the respective health risk criteria.

Modifications were required to address differences in the assumed fish consumption rate (22 g/d) between for the general population that was used to develop the US EPA Ambient Water Quality Criteria for Human Health (US EPA, 2015c) and the fish consumption rates developed in this work for the community members from ACFN, FMFN and MCFN who are consumers of traditional foods as described below.

For each ingestion rate, the upper range (95th percentile) was selected as a representative estimate of the higher range of exposure for members as compared to the 95th percentile upper confidence limit of the mean, which is commonly adopted in risk assessment. This decision was guided by members from each of the three participating communities. The 95th percentile represents a higher estimate therefore a calorie check was undertaken. The fish consumption rate results in a 1400 kcal/day contribution, as compared to a reference adult value of 2800 kcal/day total, so was deemed possible and appropriate. For reference each of the upper range and mean values are presented in the figures below.

The US EPA HH AWQC for drinking water and fish consumption would protect community members consuming average quantities of fish (up to 22 g/d). However, the community survey data indicates that ACFN, MCFN and FMFN members consume greater quantities of fish than considered in the HH AWQCs. Based on the survey results, community 1 had the highest fish ingestion rate of 0.388 kg/day (Figure 3.2) and this value was adopted to calculate the health risk criteria for fish and water ingestion using Equation (3.2)

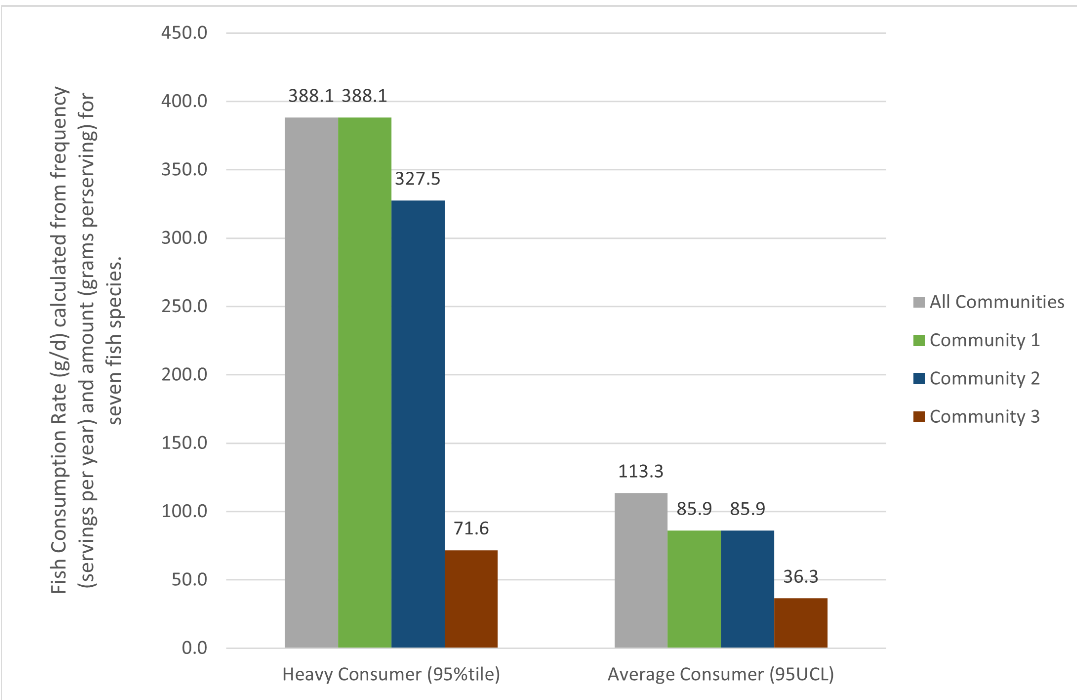

Figure 3.2: Comparison of pooled and individual Indigenous community member plant consumption rates (kg/d) calculated from survey responses for seven traditionally consumed fish species.

Plant Consumption Rates were estimated from the community survey data for wild mint and rat root species. The survey data indicates that rat root consumption (Figure 3.4) was greater than wild mint (Figure 3.3). The rat root consumption rate estimated from the pooled community data (0.0068 kg/d) was adopted as the plant consumption rate in Equation 2 to calculate the medicinal plant health risk criteria which is considered protective of members ingesting either mint or rat root.

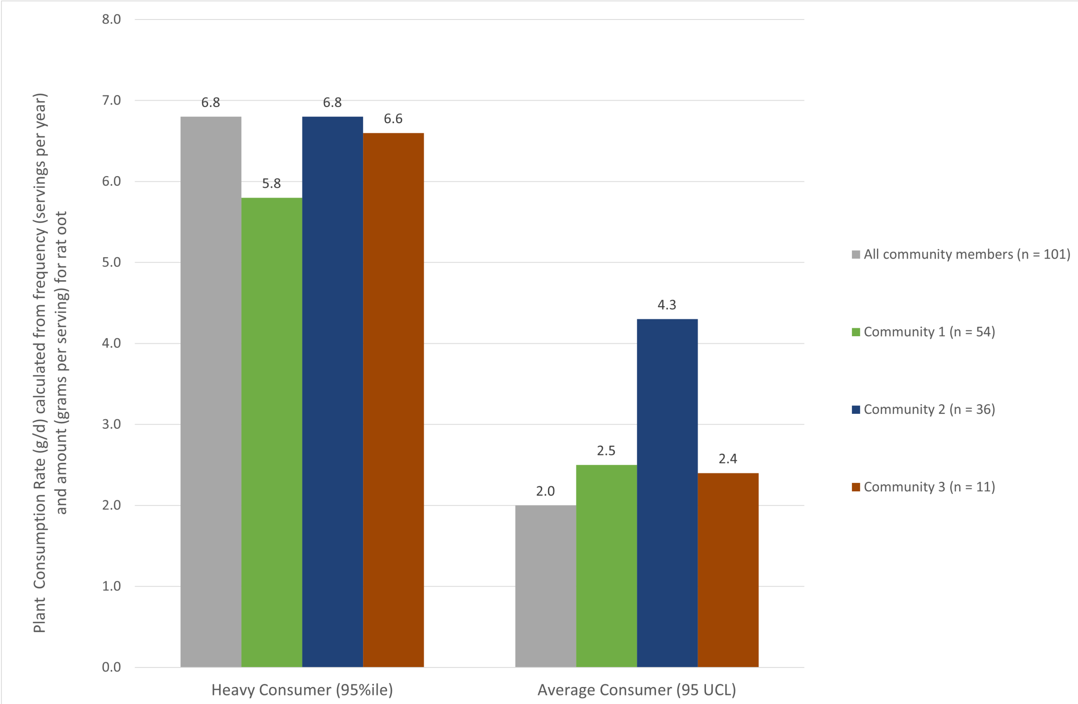

Figure 3.3: Comparison of pooled and individual Indigenous community member plant consumption rates (kg/d) calculated from survey responses for rat root.

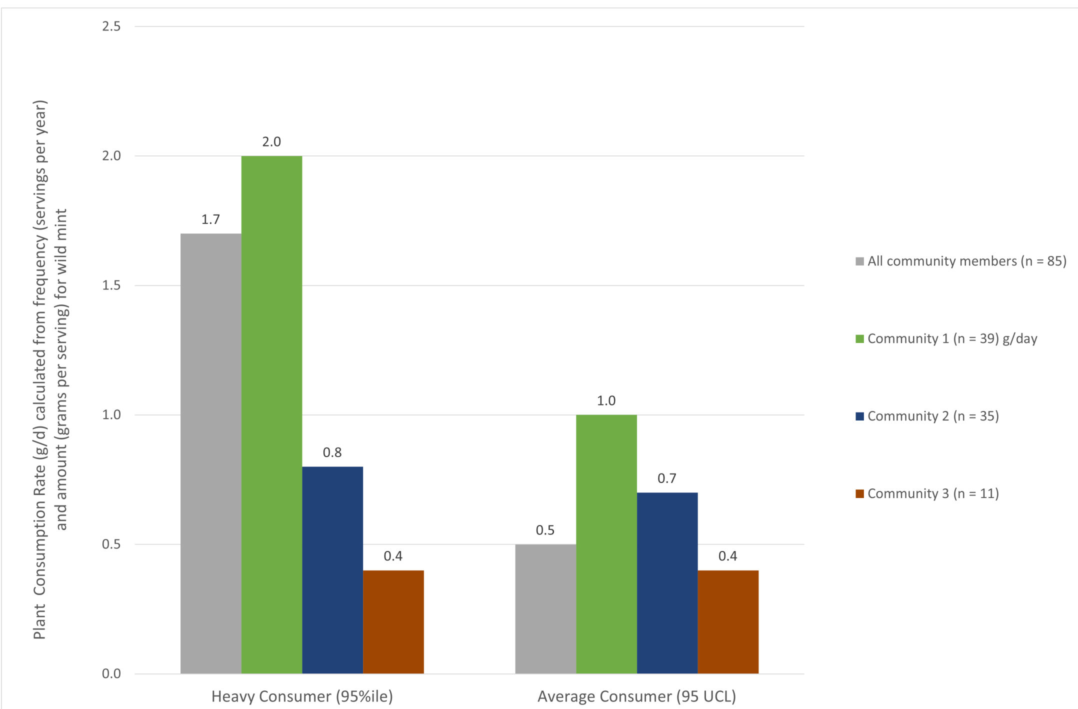

Figure 3.4: Comparison of pooled and individual Indigenous community member plant consumption rates (g/d) calculated from survey responses for wild mint.

Traditional Foods and Drinking Water (adopted and derived)

The health risk criteria for the protection of human health from consuming fish and untreated surface water were derived using fish consumption rates for seven species (0.388 kg/d) and a drinking water ingestion rate of 2.4 L/d. Additional input parameters and calculations are provided in Appendix A.4.

The US EPA HH AWQCs (US EPA, 2015c) are the only ambient water quality criteria which were developed for the protection of human health from consuming surface water (raw) and fish and consider carcinogenicity. As discussed above, the applicability of the HH AWQCs is limited for ACFN, FMFN and MCFN members which consume more fish (Figure 3.2) and more stringent guidelines are required to protect community members as compared to the US population. For certain substances, the guidelines prescribed by Health Canada and the WHO, which not only consider drinking water ingestion but also carcinogenicity, were more protective than the HH ACWR (US EPA) or derived health risk criteria. In these cases, the most stringent guideline was adopted.

The health risk criteria presented in Table 3.6 can be applied to surface water quality data to understand potential risks to human health from consumption of fish and natural/untreated surface water such as lakes, rivers and muskeg.

It is important to note that concentrations of substances required for the protection of humans consuming surface water and traditional foods may be different than concentrations associated with toxicological responses in more sensitive receptors (i.e., wildlife, aquatic biota, ecosystem function) and other water uses.

The health risk criteria for human consumption alone, should not be adopted unless all other exposure pathways described in Table 3.6 have been assessed and identified as not applicable or non-operational (i.e., the surface water being assessed is not used by humans or aquatic biota). The health risk criteria for traditional foods and drinking water may not always be the lowest value so it is important to review the health risk criteria for each water use category to understand risks to humans and ecological receptors.

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water.

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
1,1,1-Trichloroethane			ug/L			200		10000	2e+05		200	US EPA DWR
1,1,2,2-Tetrachloroethane*			ug/L					2	30		2	HH DW+Org (US EPA)
1,1,2-Trichloroethane*			ug/L			3		5.5	89		3	US EPA DWR
1,1-Dichloroethylene			ug/L		14	7		300	20000		7	US EPA DWR
1,2,3,4-Tetrachlorobenze			ug/L					0.03	0.03		0.03	HH DW+Org (US EPA) USEPA WQC HH Org
1,2,4-Trichlorobenzene			ug/L			70		0.071	0.76		0.071	HH DW+Org (US EPA)
1,2-Dibromo-3-chloropropane			ug/L			0.2				1	0.2	US EPA DWR
1,2-Dibromoethane			ug/L							0.4	0.4	WHO DW
1,2-Dichlorobenzene			ug/L					1000	3000	1000	1000	HH DW+Org (US EPA) WHO DW
1,2-Dichloroethane*			ug/L		5	5		99	6500	30	5	Health Canada DW US EPA DWR
1,2-Dichloroethene			ug/L							50	50	WHO DW
1,2-Dichloropropane*			ug/L			5		9	310	40	5	US EPA DWR

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
1,2-Diphenylhydrazi			ug/L					0.3	2		0.3	HH DW+Org (US EPA)
1,3-Dichlorobenzene			ug/L	13.33				7	10		7	HH DW+Org (US EPA)
1,3-Dichloropropene*			ug/L					2.7	120	20	2.7	HH DW+Org (US EPA)
1,4-Dichlorobenzene			ug/L					300	900	300	300	HH DW+Org (US EPA) WHO DW
1,4-Dioxane			ug/L							50	50	WHO DW
2,3,4,6-Tetrachlorophenol			ug/L		100		1				1	USEPA WQC AO
2,3-Dichlorophenol			ug/L				0.04				0.04	USEPA WQC AO
2,4,5-Trichlorophenol			ug/L				1	300	600	9	1	USEPA WQC AO
2,4,6-Trichlorophenol*			ug/L		5		2	15	28	200	2	USEPA WQC AO
2,4-D			ug/L	451.29	100	70		1300	12000	30	30	WHO DW
2,4-DB			ug/L							90	90	WHO DW
2,4-Dichlorophenol			ug/L		900		0.3	10	60		0.3	USEPA WQC AO
2,4-Dimethylphenol			ug/L				400	100	3000		100	HH DW+Org (US EPA)
2,4-Dinitrophenol			ug/L	12.82				10	300		10	HH DW+Org (US EPA)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
2,4-Dinitrotoluene*			ug/L					0.49	17		0.49	HH DW+Org (US EPA)
2,5-Dichlorophenol			ug/L				0.5				0.5	USEPA WQC AO
2,6-Dichlorophenol			ug/L				0.2				0.2	USEPA WQC AO
2-Chloronaphthalene			ug/L					800	1000		800	HH DW+Org (US EPA)
2-Chlorophenol			ug/L				0.1	30	800		0.1	USEPA WQC AO
2-Methyl-4,6-Dinitrophenol			ug/L					2	30		2	HH DW+Org (US EPA)
2-Methyl-4-Chlorophenol			ug/L				1800				1800	USEPA WQC AO
3,3'-Dichlorobenzidine*			ug/L					0.49	1.5		0.49	HH DW+Org (US EPA)
3,4-Dichlorophenol			ug/L				0.3				0.3	USEPA WQC AO
3-Chlorophenol			ug/L				0.1				0.1	USEPA WQC AO
3-Methyl-4-Chlorophenol			ug/L				3000	500	2000		500	HH DW+Org (US EPA)
3-Methyl-6-Chlorophenol			ug/L				20				20	USEPA WQC AO
4-Chlorophenol			ug/L				0.1				0.1	USEPA WQC AO

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Acenaphthene[‡]			ug/L	4.79			20	70	90		4.79	HH DW+Org (derived)
Acrolein			ug/L	2.87				3	400		2.87	HH DW+Org (derived)
Acrylamide			ug/L	0.07		0.5				0.5	0.07	HH DW+Org (derived)
Acrylonitrile[*]			ug/L	0.53				0.61	70		0.53	HH DW+Org (derived)
Alachlor			ug/L			2				20	2	US EPA DWR
Aldicarb			ug/L							10	10	WHO DW
Aldrin[*]			ug/L	1e-05				7.7e-06	7.7e-06		7.7e-06	HH DW+Org (US EPA) USEPA WQC HH Org
Aldrin and dieldrin			ug/L							0.03	0.03	WHO DW
Aluminum		Total	ug/L							200	200	WHO DW
Ammonia			mg/L	0.67						35	0.67	HH DW+Org (derived)
Anthracene[‡]			ug/L	20.07				300	400		20.07	HH DW+Org (derived)
Antimony		Total	ug/L	4.59	6	6		5.6	640	20	4.59	HH DW+Org (derived)
Arsenic[*]		Total	ug/L	0.03	10	10		0.18	1.4	10	0.03	HH DW+Org (derived)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Asbestos			ug/L			7		7			7	US EPA DWR HH DW+Org (US EPA)
Atrazine			ug/L		5	3					3	US EPA DWR
Atrazine and its chloro-s-triazine metabolites			ug/L							100	100	WHO DW
Azinphos-methyl			ug/L		20						20	Health Canada DW
Barium		Total	ug/L	1147.74	1000	2000		1000		1300	1000	Health Canada DW HH DW+Org (US EPA)
Benzene*			ug/L	2.11	5	5		5.8	160	10	2.11	HH DW+Org (derived)
Benzidine*			ug/L	0.001				0.0014	0.11		0.001	HH DW+Org (derived)
Benzo(a)anthracene*†			ug/L	0.001				0.012	0.013		0.001	HH DW+Org (derived)
Benzo(a)pyrene and equivalents*†			ug/L	1e-04	0.04	0.2		0.001	0.0013	0.7	1e-04	HH DW+Org (derived)
Benzo(b)fluoranthene*†			ug/L	0.001				0.012	0.013		0.001	HH DW+Org (derived)
Benzo(k)fluorant			ug/L	0.01				0.12	0.13		0.01	HH DW+Org (derived)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Beryllium		Total	ug/L	3.27		4					3.27	HH DW+Org (derived)
Bis(2-Chloro-1-methylethyl) Ether			ug/L	127.99				200	4000		127.99	HH DW+Org (derived)
Bis(2-Chloroethyl) Ether*			ug/L	0.25				0.3	22		0.25	HH DW+Org (derived)
Bis(2-Ethylhexyl) Phthalate			ug/L	0.21				0.32	0.37		0.21	HH DW+Org (derived)
Bis(Chloromethyl) Ether*			ug/L	0.001				0.002	0.17		0.001	HH DW+Org (derived)
Boron		Total	ug/L	1333.33	5000					2400	1333.33	HH DW+Org (derived)
Bromate			ug/L		10	10				10	10	Health Canada DW US EPA DWR WHO DW
Bromodichlorom			ug/L	6.33						60	6.33	HH DW+Org (derived)
Bromoform			ug/L	38.22				7	120	100	7	HH DW+Org (US EPA)
Bromoxynil			ug/L		5						5	Health Canada DW
Butylbenzyl Phthalate*			ug/L	0.06				1	1		0.06	HH DW+Org (derived)
Cadmium		Total	ug/L	0.002		5				3	0.002	HH DW+Org (derived)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Carbaryl			ug/L		90						90	Health Canada DW
Carbofuran			ug/L		90	40				7	7	WHO DW
Carbon tetrachloride			ug/L	1.9	2	5		4	50	4	1.9	HH DW+Org (derived)
Chloramines			ug/L		3000	4000					3000	Health Canada DW
Chlorate			ug/L		1000					700	700	WHO DW
Chlordane			ug/L	0.001		2		0.003	0.0032	0.2	0.001	HH DW+Org (derived)
Chloride			mg/L		250					250	250	Health Canada DW WHO DW
Chlorine dioxide			ug/L			800					800	US EPA DWR
Chlorite			ug/L		1000	800				700	700	WHO DW
Chlorobenzene			ug/L	40.85	80	100		100	800		40.85	HH DW+Org (derived)
Chlorodibromomethane			ug/L					8	210		8	HH DW+Org (US EPA)
Chloroform			ug/L	45.89				60	2000	300	45.89	HH DW+Org (derived)
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]			ug/L	20.55		50		100	400		20.55	HH DW+Org (derived)
Chlorotoluron			ug/L							30	30	WHO DW

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Chlorpyrifos			ug/L		90					30	30	WHO DW
Chromium (III)		Total	ug/L	10000				100	100		100	HH DW+Org (US EPA) USEPA WQC HH Org
Chromium (VI)		Total	ug/L	13.47				100	100		13.47	HH DW+Org (derived)
Chromium		Total	ug/L		50	100				50	50	Health Canada DW WHO DW
Chrysene[*†]			ug/L	0.07				1.2	1.3		0.07	HH DW+Org (derived)
Copper[*]		Total	ug/L		2000	1300	1000	13000		2000	1000	USEPA WQC AO
Cyanazine			ug/L							0.6	0.6	WHO DW
Cyanide	as free CN		ug/L	3.62	200	200		4	400		3.62	HH DW+Org (derived)
Cyanobacterial toxins			ug/L		1.5						1.5	Health Canada DW
DDT and metabolites[*]			ug/L					3e-04	3e-04	1	3e-04	HH DW+Org (US EPA) USEPA WQC HH Org
Dalapon			ug/L			200					200	US EPA DWR
Di(2-ethylhexyl) adipate			ug/L			400					400	US EPA DWR

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Di(2-ethylhexyl) phthalate			ug/L			6				8	6	US EPA DWR
Di-n-Butyl Phthalate			ug/L	1.42				20	30		1.42	HH DW+Org (derived)
Diazinon			ug/L		20						20	Health Canada DW
Dibenzo(a,h)antl			ug/L	1e-04				0.001	0.0013		1e-04	HH DW+Org (derived)
Dibromoacetonitrile*			ug/L							70	70	WHO DW
Dibromochlorom			ug/L	5.21						100	5.21	HH DW+Org (derived)
Dicamba			ug/L		120						120	Health Canada DW
Dichloroacetate			ug/L							50	50	WHO DW
Dichloroacetonitrile			ug/L							20	20	WHO DW
Dichlorobromom			ug/L					9.5	270		9.5	HH DW+Org (US EPA)
Dichloromethane*			ug/L		50	5				20	50	Health Canada DW
Dichlorprop			ug/L							100	100	WHO DW
Diclofop-methyl			ug/L		9						9	Health Canada DW
Dieldrin*			ug/L	1e-05				1e-05	1.2e-05		1e-05	HH DW+Org (derived) HH DW+Org (US EPA)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Diethyl Phthalate			ug/L	35.61				600	600		35.61	HH DW+Org (derived)
Dimethoate			ug/L		20					6	6	WHO DW
Dimethyl Phthalate			ug/L	102.91				2000	2000		102.91	HH DW+Org (derived)
Dinitrophenols			ug/L	10.72				10	1000		10	HH DW+Org (US EPA)
Dinoseb			ug/L			7					7	US EPA DWR
Dioxin (2,3,7,8-TCDD)			ug/L			3e-05		5e-08	5.1e-08		5e-08	HH DW+Org (US EPA)
Diquat			ug/L		70	20					20	US EPA DWR
Diuron			ug/L		150						150	Health Canada DW
Edetic acid			ug/L							600	600	WHO DW
Endosulfan Sulfate			ug/L	2.63				20	40		2.63	HH DW+Org (derived)
Endothall			ug/L			100					100	US EPA DWR
Endrin			ug/L	0.01		2		0.03	0.03	0.6	0.01	HH DW+Org (derived)
Endrin Aldehyde			ug/L	0.11				1	1		0.11	HH DW+Org (derived)
Epichlorohydrin			ug/L			200				0.4	0.4	WHO DW
Ethylbenzene			ug/L	8.54	140	700		68	130	300	8.54	HH DW+Org (derived)
Ethylene dibromide			ug/L			0.05					0.05	US EPA DWR

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Fenoprop			ug/L							9	9	WHO DW
Fluoranthene[‡]			ug/L	1.09				20	20		1.09	HH DW+Org (derived)
Fluorene[‡]			ug/L	6.98				50	70		6.98	HH DW+Org (derived)
Fluoride			mg/L	0.4	1.5	4				1.5	0.4	HH DW+Org (derived)
Glyphosate			ug/L		280	700					280	Health Canada DW
Haloacetic acids			ug/L		80	60					60	US EPA DWR
Heptachlor[*]			ug/L	4e-05		0.4		6e-05	5.9e-05		4e-05	HH DW+Org (derived)
Heptachlor epoxide[*]			ug/L	1e-04		0.2		0.00032	0.00032		1e-04	HH DW+Org (derived)
Hexachlorobenzene[*]			ug/L	1e-04		1		0.001	0.00079		1e-04	HH DW+Org (derived)
Hexachlorobutad			ug/L	0.001				0.1	0.1	0.6	0.001	HH DW+Org (derived)
Hexachlorocyclohexane[*]			ug/L	0.01				0.066	0.1		0.01	HH DW+Org (derived)
Hexachlorocyclop			ug/L	0.4		50	1	4	4		0.4	HH DW+Org (derived)
Hexachloroethane[*]			ug/L	0.02				1	1		0.02	HH DW+Org (derived)
Hydroxyatrazine			ug/L							200	200	WHO DW

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Indeno(1,2,3-cd)pyrene			ug/L	0.001				0.012	0.013		0.001	HH DW+Org (derived)
Iron		Total	ug/L				300				300	USEPA WQC AO
Isophorone*			ug/L	268.41				340	18000		268.41	HH DW+Org (derived)
Isoproturon			ug/L							9	9	WHO DW
Lead		Total	ug/L		5	15				10	5	Health Canada DW
MCPA			ug/L		100						100	Health Canada DW
Malathion			ug/L		190						190	Health Canada DW
Manganese		Total	ug/L	933.33	120			50	100		50	HH DW+Org (US EPA)
Mecoprop			ug/L							10	10	WHO DW
Mercury (methyl)		Total	ug/L	0.67							0.67	HH DW+Org (derived)
Mercury		Total	ug/L		1	2				6	1	Health Canada DW
Methoxychlor			ug/L	0.001		40		0.02	0.02	20	0.001	HH DW+Org (derived)
Methyl Bromide			ug/L	111.66				100	10000		100	HH DW+Org (US EPA)
Methylene chloride*			ug/L	32.62				200	10000		32.62	HH DW+Org (derived)
Metolachlor			ug/L		50					10	10	WHO DW

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Metribuzin			ug/L		80						80	Health Canada DW
Microcystin-LR			ug/L							1	1	WHO DW
Molinate			ug/L							6	6	WHO DW
Molybdenum		Total	ug/L	33.33							33.33	HH DW+Org (derived)
Monochloramine			ug/L							3000	3000	WHO DW
Monochloroacetate			ug/L							20	20	WHO DW
Monochlorobenze			ug/L				20				20	USEPA WQC AO
N-Nitrosodi-n-Propylamine[*]			ug/L	0.05				0.05	5.1		0.05	HH DW+Org (derived) HH DW+Org (US EPA)
N-Nitrosodimethyla			ug/L	0.01	0.04			0.007	30	0.1	0.007	HH DW+Org (US EPA)
N-Nitrosodiphenylamine[*]			ug/L	68.03				33	60		33	HH DW+Org (US EPA)
Naphthalene[‡]			ug/L	133.33							133.33	HH DW+Org (derived)
Nickel		Total	ug/L	7.35				610	4600	70	7.35	HH DW+Org (derived)
Nitrate	as N	dissolved	mg/L	10.1	10	10		10		11.3	10	Health Canada DW US EPA DWR HH DW+Org (US EPA)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Nitrilotriacetic acid			ug/L		400					200	200	WHO DW
Nitrite	as N	dissolved	mg/L		1	1				0.912	0.912	WHO DW
Nitrobenzene			ug/L	9.72			30	10	600		9.72	HH DW+Org (derived)
Nitrosamines			ug/L					0.008	12.4		0.008	HH DW+Org (US EPA)
Nitrosodibutylamine			ug/L	0.05				0.063	2.2		0.05	HH DW+Org (derived)
Nitrosodiethylam			ug/L	0.002				0.008	12.4		0.002	HH DW+Org (derived)
Nitrosopyrrolidine			ug/L	0.16				0.16	340		0.16	HH DW+Org (derived) HH DW+Org (US EPA)
Oxamyl (Vydate)			ug/L			200					200	US EPA DWR
Paraquat	as paraquat dichloride		ug/L		10						10	Health Canada DW
Pendimethalin			ug/L							20	20	WHO DW
Pentachlorobenzene*			ug/L	0.01				0.1	0.1		0.01	HH DW+Org (derived)
Pentachlorophen			ug/L	0.1	60	1	30	0.3	0.4	9	0.1	HH DW+Org (derived)
Perchlorate			ug/L							70	70	WHO DW

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Perfluorooctanes			ug/L		0.6						0.6	Health Canada DW
Perfluorooctanoic acid			ug/L		0.2						0.2	Health Canada DW
Phenanthrene			ug/L	200							200	HH DW+Org (derived)
Phenol			ug/L	1609.58			300	4000	3e+05		300	USEPA WQC AO
Phorate‡			ug/L		2						2	Health Canada DW
Picloram			ug/L		190	500					190	Health Canada DW
Polychlorinated Biphenyls (PCBs)			ug/L			0.5		0.001	0.00064		0.00064	USEPA WQC HH Org
Pyrene			ug/L	1.43				20	30		1.43	HH DW+Org (derived)
Selenium		Total	ug/L	18.77	50	50		170	4200	40	18.77	HH DW+Org (derived)
Silver‡		Total	ug/L	33.33							33.33	HH DW+Org (derived)
Simazine			ug/L		10	4				2	2	WHO DW
Sodium dichloroisocya-nurate			ug/L							40000	40000	WHO DW
Solids Dissolved and Salinity			ug/L					250000			250000	HH DW+Org (US EPA)

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Strontium		Total	ug/L	4000	7000						4000	HH DW+Org (derived)
Styrene			ug/L			100				20	20	WHO DW
Sulfate	as SO4		mg/L							250	250	WHO DW
Terbufos			ug/L		1						1	Health Canada DW
Terbuthylazine			ug/L							7	7	WHO DW
Tetrachloroethyle			ug/L	4.48	10	5		100	290	40	4.48	HH DW+Org (derived)
Thallium		Total	ug/L	0.02		0.5		0.24	0.47		0.02	HH DW+Org (derived)
Toluene			ug/L	191.93	60	1000		57	520	700	57	HH DW+Org (US EPA)
Toxaphene			ug/L	0.001		3		0.007	0.0071		0.001	HH DW+Org (derived)
Trans-1,2-Dichloroethylene			ug/L					100	4000		100	HH DW+Org (US EPA)
Trichloroacetate			ug/L							200	200	WHO DW
Trichloroethylene			ug/L	1.38	5	5		6	70	20	1.38	HH DW+Org (derived)
Trifluralin			ug/L		45					20	20	WHO DW
Trihalomethanes			ug/L		100	80					80	US EPA DWR
Uranium*		Total	ug/L	20	20	30				30	20	HH DW+Org (derived) Health Canada DW

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
Vinyl chloride			ug/L	0.18	2	2		0.22	16	0.3	0.18	HH DW+Org (derived)
Xylene			ug/L	114.15	90					500	90	Health Canada DW
Xylenes (total)			ug/L			10000					10000	US EPA DWR
Zinc*		Total	ug/L	12.72			5000	7400	26000		12.72	HH DW+Org (derived)
alpha-Endosulfan			ug/L	1.82				20	30		1.82	HH DW+Org (derived)
alpha-Hexachlorocyclohexane			ug/L	2e-04				0.0036	0.0039		2e-04	HH DW+Org (derived)
beta-Endosulfan			ug/L	2.87				20	40		2.87	HH DW+Org (derived)
beta-Hexachlorocyclohexane			ug/L	0.01				0.08	0.14		0.01	HH DW+Org (derived)
cis-1,2-Dichloroethylene			ug/L			70					70	US EPA DWR
gamma-Hexachlorocyclohexane [Lindane]			ug/L	0.4		0.2		4.2	4.4	2	0.2	US EPA DWR
o-Dichlorobenzene			ug/L		200	600					200	Health Canada DW
p,p'-Dichlorodiphenyldichloroethane (DDD)*			ug/L					0.001	0.0012		0.001	HH DW+Org (US EPA)
p,p'-Dichlorodiphenyl (DDE)*			ug/L					2e-04	0.00018		0.00018	USEPA WQC HH Org

Table 3.6: Health risk criteria for the protection of community consumers of fish and drinking water. *(continued)*

Parameter	Method Speciation	Sample Fraction	Units	Derived	Health Canada	DWR US EPA	WQC AO US EPA	HH Org US EPA	HH DW Org US EPA	WHO	Traditional Foods and Drinking Water Criteria Value	Source
p-Dichlorobenzene			ug/L		5	75					5	Health Canada DW
pH			pH units		7			5			44751	Health Canada DW HH DW+Org (US EPA)
trans-1,2-Dichloroethylene			ug/L			100					100	US EPA DWR

Note:
Known carcinogens, US EPA HH ACWR (DW+C) were adjusted to reflect 10^{-5} ILCR levels (Alberta Health (2019))

* Known human carcinogen via oral exposure route (Health Canada (2021))

† The following known human carcinogens and must be converted to Provisional Benzo[a]pyrene RPF and summed as per Health Canada (2021) then compared to the Benzo(a)pyrene and equivalents health risk criteria: Anthanthrene, Benzo[c]chrysene, Benzo[g]chrysene, Benzo[c]phenanthrene, Cyclopenta[c,d]pyrene, Dibenzo[a,e]fluoranthene Dibenzo[a,e]pyrene, Dibenzo[a,h]pyrene, Dibenzo[a,i]pyrene, Dibenzo[a,l]pyrene, 9,10- Dimethylanthracene, 7,12- Dimethylbenzo[a]anthracene, 1,2- Dimethylbenzo[a]pyrene, 1,6- Dimethylbenzo[a]pyrene, 3,6- Dimethylbenzo[a]pyrene, 4,5- Dimethylbenzo[a]pyrene, 5,6- Dimethylchrysene, 5,7- Dimethylchrysene, 5,11- Dimethylchrysene, 1,4- Dimethylphenanthrene, 4,10- Dimethylphenanthrene, 5- Ethylchrysene, Fluoranthene, 7- Methylbenzo[a]anthracene, Methylbenzo[a]anthracene, 9- Methylbenzo[a]anthracene, 12- Methylbenzo[a]anthracene, 11- Methylbenzo[b]fluorene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, 11- Methylbenzo[a]pyrene, 12- Methylbenzo[a]pyrene, 5- Methylchrysene, Methylchrysene, 2- Methylfluoranthene, Phenanthren,e 2,9,10- Trimethylanthracene, 2,3,9,10- Tetramethylanthracene .

‡ Naphthalene applied as surrogate to sum of low molecular weight PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) and compare to Naphthalene health risk criteria (adopted as surrogate) (CCME (2010))

Traditional Medicines (derived)

The health risk criteria for the protection of human health from consuming traditional medicines were derived using consumption rates for rat root (0.0068 kg/d) and are provided in Table 3.7. Additional input parameters and calculations are provided in Appendix A.4.

These criteria were developed using modifications to the (US EPA, 2000b) methodology aligning with human health risk assessment protocols where BCFs for sediment to plants are adopted to predict the uptake of contaminants by aquatic plants.

Due to this uncertainty and lack of BCF data for culturally important aquatic plant species (i.e. fresh rat root), the health risk criteria identified in Table 3.7 should be considered interim until discussions with health agencies can confirm modifications and BCFs for rat root and wild mint should be applied to medicinal plants.

Table 3.7: Health risk criteria for the protection of community consumers of medicinal plants.

Parameter Name	Units	Value
Acenaphthene	mg/L	0
Anthracene	mg/L	0
Antimony	mg/L	9
Arsenic*	mg/L	2
Barium	mg/L	3137
Benzene	mg/L	0
Benzo(a)anthracene*	mg/L	8
Benzo(a)pyrene*	mg/L	0
Benzo(b)fluoranthene*	mg/L	16
Benzo(k)fluoranthene*	mg/L	160
Cadmium	mg/L	3
Chrysene*	mg/L	862
Copper	mg/L	0
Chromium (VI)	mg/L	941
Chromium (III)	mg/L	0
Cyanide	mg/L	0
Dibenzo(a,h)anthracene*	mg/L	3
Ethylbenzene	mg/L	0
Fluoranthene	mg/L	0
Fluorene	mg/L	0
Indeno(1,2,3-cd)pyrene*	mg/L	41
Lead	mg/L	7320
Manganese	mg/L	0

Table 3.7: Health risk criteria for the protection of community consumers of medicinal plants. *(continued)*

Parameter Name	Units	Value
Mercury	mg/L	19
Nickel	mg/L	1471
Phenol	mg/L	0
Pyrene	mg/L	0
Selenium	mg/L	735
Thallium	mg/L	4
Toluene	mg/L	0
Zinc	mg/L	> 10,000

* Substances are known carcinogens in humans and cannot be assessed using non-carcinogenic thresholds.

3.5 Discussion

The health risk criteria which were developed in this project recognize both western science environmental assessment methods and Indigenous community world views and knowledge systems.

The conceptual model identified Indigenous water uses and exposure pathways that are not explicitly considered or protected through application of provincial or federal surface water quality guidelines.

A key finding of this project which informed method development was the consideration that water use protection goals (described in 3.8) of ACFN, FMFN and MCFN community members are holistic, require protection of human receptors, and include more water uses than considered under the provincial and federal processes for defining surface water quality guidelines.

Members shared that understanding the health of water (and all-connected components) is experiential, relational, and directly informs their sense of personal health and wellbeing. As such, water cannot be managed as a single component broken off from the environment or communities. Members shared that water is the giver of life and must be protected using traditional knowledge and now due to industrial development, western science methods must also be relied on. Members also communicated that western science water management practices were unnecessary prior to industrial development in the Lower Athabasca Region (personal communications).

Table 3.8: Indigenous community water uses and health protection goals used to define health risk criteria.

Indigenous water use	Protection Goal
Traditional foods and drinking water	Safe foods consumption
	Safe natural surface water consumption
Traditional medicines	Safe medicine consumption
Aquatic ecosystem health	Aquatic community consumption unchanged
	Robust populations
	Natural behaviours and patterns
Wildlife health	Healthy wildlife
	Robust populations
	Natural behaviours and patterns
	Good quality pelts

The review of water quality guidelines prescribed across North American and internationally indicate that ambient surface water guidelines have been derived for the protection of ecological and human receptors. Adaptation of the identified water guidelines used in Alberta (GoA, 2018) to consider the protection of human health can be achieved by supplementing the current protection of aquatic life focused regime with human health guidelines specifically developed for consumption of ambient water and organisms (US EPA, 2015a) and integrated available drinking water quality standards (Health Canada (2020a); World Health Organization (WHO) (2017); US EPA DWRs).

The consumption rates used to develop the regulatory guidelines are generally representative of the average consumption rates of fish and surface water reported for ACFN, FMFN and MCFN members but would not protect members who are heavier consumers of fish.

Modifications of the existing guidelines were used to achieve a higher degree of protection for by deriving health risk criteria that will protect consumers of traditional foods based on the upper range of fish (388 g/d) and medicinal plant (6.8 g/d) consumption.

Further integrating water quality benchmarks to protect piscivorous wildlife species (Sample et al., 1996) and water use pathways developed for agricultural purposes (GoA, 2018), specifically, livestock watering, would offer a degree of protection to wildlife species consuming surface water and being consumed used as traditional foods.

A comparison of the health risk criteria developed for various water uses and protection goals aligns with the multi-use system developed by GOA and CCME in that some water uses require a higher degree of protection than other uses. This is due to the sensitivity of receptors being exposed, toxicological, chemical, and physical properties of the contaminants and likelihood of exposure. Similar to the application of existing guidelines the various use specific criteria can be selectively applied based on how Indigenous communities are interacting with a specific waterbody or the most protective criteria (i.e. lowest value) can be selected to ensure all other uses are protected.

In general terms, the two most sensitive water uses identified in this research were traditional foods/drinking water supply and aquatic ecosystem health protection.

The toxicity, persistence, and bioaccumulation of contaminants drives risk potential of contaminants in aquatic ecosystems and each substance should be evaluated rather than assessing water quality by use, as is common practice in Alberta (i.e. PAL guidelines to screen surface water quality data regardless of contaminants).

Risk is also driven by the sensitivity of the receptor and chemical, physical and toxicological properties of each substance, therefore a single use protection category cannot meet each of the Indigenous water protection goals for human and ecological receptors. Application of criteria for a single water use will limit protection and underestimate potential risks particularly for carcinogens (i.e., arsenic, high MW PAHs).

Recognizing that human and ecological health risks are a function of exposure and inherent toxicity of the contaminants, it is recommended that the health risk criteria shown in Table 3.9 be used to assess the quality of water in surface water that is being developed for Indigenous use purposes or currently being used by Indigenous communities. The generic use protection category is equivalent to the Tier 1 category within the tiered system used by Alberta (AEP, 2019) for assessing contamination and developing remediation/ treatment programs of soils and groundwater.

For parameters that did not have published guidelines, it is recommended that the current condition for open water season at the Athabasca River location be adopted (see Chapter 2).

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use.

Parameter	Sample Fraction	Units	Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
			Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
.alpha.-Endosulfan		ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria	0.056			
.beta.-Endosulfan		ug/L	0.056	aquatic biota	US EPA Aquatic Life Criteria	0.056			
1,1,1-Trichloroethane*		ug/L	200	human	US EPA DWR			200	
1,1,2,2-Tetrachloroethane*		ug/L	2	human	HH DW+Org (US EPA)			2	
1,1,2-Trichloroethane		ug/L	3	human	US EPA DWR	21		3	
1,1-Dichloroethylene		ug/L	7	human	US EPA DWR		929.00	7	
1,2,3,4-Tetrachlorobenzene		ug/L	0.03	human	USEPA WQC HH Org HH DW+Org (US EPA)	1.8		0.03	
1,2,3-Trichlorobenzene		ug/L	8	aquatic biota	AEP Water PAL CCME Water PAL	8			
1,2,4-Trichlorobenzene		ug/L	0.071	human	HH DW+Org (US EPA)	24		0.071	
1,2-Dibromo-3-chloropropane		ug/L	0.2	human	US EPA DWR			0.2	
1,2-Dibromoethane		ug/L	0.4	human	WHO DW			0.4	
1,2-Dichlorobenzene		ug/L	0.7	aquatic biota	AEP Water PAL	0.7		1000	
1,2-Dichloroethane*		ug/L	5	human wildlife	Health Canada DW AEP Water Ag CCME Water Ag US EPA DWR	100	5.00	5	
1,2-Dichloroethene		ug/L	50	human	WHO DW			50	
1,2-Dichloropropane*		ug/L	5	human	US EPA DWR			5	
1,2-Diphenylhydrazine*		ug/L	0.3	human	HH DW+Org (US EPA)			0.3	
1,3-Dichlorobenzene		ug/L	7	human	HH DW+Org (US EPA)	150		7	
1,3-Dichloropropene*		ug/L	2.7	human	HH DW+Org (US EPA)			2.7	
1,4-Dichlorobenzene		ug/L	26	aquatic biota	AEP Water PAL	26		300	
1,4-Dioxane		ug/L	50	human	WHO DW			50	
2,3,4,6-Tetrachlorophenol		ug/L	1	human	USEPA WQC AO			1	
2,3-Dichlorophenol		ug/L	0.04	human	USEPA WQC AO			0.04	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

Parameter	Sample Fraction	Units	Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
			Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
2,4,5-Trichlorophenol		ug/L	1	human	USEPA WQC AO			1	
2,4,6-Trichlorophenol*		ug/L	2	human	USEPA WQC AO			2	
2,4-D		ug/L	4	aquatic biota	CCME Water PAL AEP Water PAL	4		30	
2,4-DB		ug/L	25	aquatic biota	AEP Water PAL	25		90	
2,4-Dichlorophenol		ug/L	0.3	human	USEPA WQC AO			0.3	
2,4-Dimethylphenol		ug/L	100	human	HH DW+Org (US EPA)			100	
2,4-Dinitrophenol		ug/L	10	human	HH DW+Org (US EPA)			10	
2,4-Dinitrotoluene*		ug/L	0.49	human	HH DW+Org (US EPA)			0.49	
2,5-Dichlorophenol		ug/L	0.5	human	USEPA WQC AO			0.5	
2,6-Dichlorophenol		ug/L	0.2	human	USEPA WQC AO			0.2	
2-Chloronaphthalene		ug/L	800	human	HH DW+Org (US EPA)			800	
2-Chlorophenol		ug/L	0.1	human	USEPA WQC AO			0.1	
2-Methyl-4,6-Dinitrophenol		ug/L	2	human	HH DW+Org (US EPA)			2	
2-Methyl-4-Chlorophenol		ug/L	1800	human	USEPA WQC AO			1800	
3,3'-Dichlorobenzidine		ug/L	0.49	human	HH DW+Org (US EPA)			0.49	
3,4-Dichlorophenol		ug/L	0.3	human	USEPA WQC AO			0.3	
3-Chlorophenol		ug/L	0.1	human	USEPA WQC AO			0.1	
3-Iodo-2-propynyl butyl carbamate		ug/L	1.9	aquatic biota	CCME Water PAL AEP Water PAL	1.9			
3-Methyl-4-Chlorophenol		ug/L	500	human	HH DW+Org (US EPA)			500	
3-Methyl-6-Chlorophenol		ug/L	20	human	USEPA WQC AO			20	
4-Chlorophenol		ug/L	0.1	human	USEPA WQC AO			0.1	
Acenaphthene§		ug/L	4.79	human	HH DW+Org (derived)	5.8		4.79	
Acridine		ug/L	4.4	aquatic biota	AEP Water PAL CCME Water PAL	4.4			
Acrolein		ug/L	2.87	human	HH DW+Org (derived)	3		2.87	
Acrylamide		ug/L	0.07	human	HH DW+Org (derived)			0.07	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

Parameter	Sample Fraction	Units	Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
			Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Acrylonitrile*		ug/L	0.53	human	HH DW+Org (derived)			0.53	
Alachlor		ug/L	2	human	US EPA DWR			2	
Alcohol ethoxylates		ug/L	70	aquatic biota	FEQG Water PAL	70			
Aldicarb		ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL	1	11.00	10	
Aldrin*		ug/L	0.0000077	human	USEPA WQC HH Org HH DW+Org (US EPA)	0.004	0.00	0.0000077	
Aldrin and dieldrin		ug/L	0.03	human	WHO DW			0.03	
Alkalinity, total		mg/L	20	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria	20			
alpha-Endosulfan		ug/L	1.82	human	HH DW+Org (derived)			1.82	
alpha-Hexachlorocyclohexane*		ug/L	0.0002	human	HH DW+Org (derived)			0.0002	
Aluminum	Total	ug/L	18	wildlife	US DOE Wildlife	100	18.00	200	
Aluminum	Dissolved	ug/L	50	aquatic biota	AEP Water PAL	50			
Ammonia		mg/L	0.67	human	HH DW+Org (derived)	0.794		0.67	
Ammonia, unionized		mg/L	0.016	aquatic biota	AEP Water PAL	0.016			
Aniline		ug/L	2.2	aquatic biota	AEP Water PAL CCME Water PAL	2.2			
Anthracene		ug/L	0.012	aquatic biota	CCME Water PAL AEP Water PAL	0.012		20.07	
Antimony	Total	ug/L	4.59	human	HH DW+Org (derived)		161.00	4.59	please refer to Table 3.7
Arsenic*	Total	ug/L	0.03	human	HH DW+Org (derived)	5	16.00	0.03	please refer to Table 3.7
Arsenic*††	Dissolved	ug/L	150	aquatic biota	US EPA Aquatic Life Criteria	150			
Asbestos		ug/L	7	human	US EPA DWR HH DW+Org (US EPA)			7	
Atrazine		ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL	1.8	5.00	3	
Atrazine and its chloro-s-triazine metabolites		ug/L	100	human	WHO DW			100	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Azinphos-methyl		ug/L	0.01	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL	0.01		20	
Barium	Total	ug/L	1000	human	HH DW+Org (US EPA) Health Canada DW			1000	please refer to Table 3.7
Benzene*		ug/L	2.11	human	HH DW+Org (derived)	40	2,293.00	2.11	
Benzidine*		ug/L	0.001	human	HH DW+Org (derived)			0.001	
Benzo(a)anthracene*†		ug/L	0.001	human	HH DW+Org (derived)	0.018		0.001	please refer to Table 3.7
Benzo(a)pyrene*†		ug/L	0.0001	human	HH DW+Org (derived)	0.015	0.01	0.0001	
Benzo(b)fluoranthene*†		ug/L	0.001	human	HH DW+Org (derived)			0.001	please refer to Table 3.7
Benzo(k)fluoranthene*†		ug/L	0.01	human	HH DW+Org (derived)			0.01	please refer to Table 3.7
Beryllium	Total	ug/L	3.27	human	HH DW+Org (derived)		100.00	3.27	
beta-Endosulfan		ug/L	2.87	human	HH DW+Org (derived)			2.87	
beta-Hexachlorocyclohexane		ug/L	0.01	human	HH DW+Org (derived)			0.01	
Bis(2-Chloro-1-methylethyl) Ether		ug/L	127.99	human	HH DW+Org (derived)			127.99	
Bis(2-Chloroethyl) Ether*		ug/L	0.25	human	HH DW+Org (derived)			0.25	
Bis(2-Ethylhexyl) Phthalate		ug/L	0.21	human	HH DW+Org (derived)			0.21	
Bis(Chloromethyl) Ether*		ug/L	0.001	human	HH DW+Org (derived)			0.001	
Bisphenol A-d6		ug/L	3.5	aquatic biota	FEQG Water PAL	3.5			
Boron	Total	ug/L	1333.33	human	HH DW+Org (derived)	1500	5,000.00	1333.33	
Bromacil		ug/L	5	aquatic biota	AEP Water PAL CCME Water PAL	5	1,100.00		
Bromate		ug/L	10	human	Health Canada DW US EPA DWR WHO DW			10	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Bromodichloromethane		ug/L	6.33	human	HH DW+Org (derived)		100.00	6.33	
Bromoform		ug/L	7	human	HH DW+Org (US EPA)		100.00	7	
Bromoxynil		ug/L	5	aquatic biota human	AEP Water PAL CCME Water PAL Health Canada DW	5	11.00	5	
Butylbenzyl Phthalate[*]		ug/L	0.06	human	HH DW+Org (derived)			0.06	
Cadmium[‡]	Total	ug/L	0.002	human	HH DW+Org (derived)	0.18	0.23	0.002	please refer to Table 3.7
Cadmium[‡††]	Dissolved	ug/L	0.824	aquatic biota	US EPA Aquatic Life Criteria	0.824			
Calcium		mg/L	1000	wildlife	CCME Water Ag AEP Water Ag		1,000.00		
Captan		ug/L	1.3	aquatic biota	CCME Water PAL AEP Water PAL	1.3	13.00		
Carbamazepine		ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL	10			
Carbaryl		ug/L	0.2	aquatic biota	AEP Water PAL CCME Water PAL	0.2	110.00	90	
Carbofuran		ug/L	1.8	aquatic biota	CCME Water PAL AEP Water PAL	1.8	45.00	7	
Carbon tetrachloride		ug/L	1.9	human	HH DW+Org (derived)	13.3	5.00	1.9	
Chloramines		ug/L	0.5	aquatic biota	CCME Water PAL	0.5		3000	
Chlorate		ug/L	700	human	WHO DW			700	
Chlordane		ug/L	0.001	human	HH DW+Org (derived)	0.004	0.01	0.001	
Chloride		mg/L	120	aquatic biota	CCME Water PAL AEP Water PAL	120		250	
Chlorinated paraffins, long-chain, C18-C20		ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL	2.4			
Chlorinated paraffins, medium-chain, C14-C17		ug/L	2.4	aquatic biota	AEP Water PAL FEQG Water PAL	2.4			
Chlorinated paraffins, short-chain, C10-C13		ug/L	2.4	aquatic biota	FEQG Water PAL AEP Water PAL	2.4			
Chlorine		ug/L	0.5	aquatic biota	AEP Water PAL	0.5		4000	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Chlorine dioxide		ug/L	800	human	US EPA DWR			800	
Chlorite		ug/L	700	human	WHO DW			700	
Chlorobenzene		ug/L	1.3	aquatic biota	AEP Water PAL	1.3		40.85	
Chlorodibromomethane		ug/L	8	human	HH DW+Org (US EPA)			8	
Chloroform		ug/L	1.8	aquatic biota	AEP Water PAL CCME Water PAL	1.8	100.00	45.89	
Chlorophenol		ug/L	7	aquatic biota	AEP Water PAL CCME Water PAL	7			
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]		ug/L	20.55	human	HH DW+Org (derived)		100.00	20.55	
Chlorothalonil		ug/L	0.18	aquatic biota	CCME Water PAL AEP Water PAL	0.18	170.00		
Chlorotoluron		ug/L	30	human	WHO DW			30	
Chlorpyrifos		ug/L	0.002	aquatic biota	AEP Water PAL CCME Water PAL	0.002	24.00	30	
Chromium	Total	ug/L	50	human	WHO DW Health Canada DW			50	
Chromium (III)‡	Total	ug/L	8.9	aquatic biota	CCME Water PAL AEP Water PAL	8.9	50.00	100	
Chromium (III)‡††	Dissolved	ug/L	100.92	aquatic biota	US EPA Aquatic Life Criteria	100.92			
Chromium (VI)	Total	ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL	1	50.00	13.47	please refer to Table 3.7
Chromium (VI)	Dissolved	ug/L	5	aquatic biota	FEQG Water PAL	5			
Chrysene*†		ug/L	0.07	human	HH DW+Org (derived)			0.07	please refer to Table 3.7
cis-1,2-Dichloroethylene		ug/L	70	human	US EPA DWR			70	
Cobalt‡	Total	ug/L	1.10	aquatic biota	FEQG Water PAL AEP Water PAL	1.10	1,000.00		
Copper*‡	Total	ug/L	2.76	aquatic biota	CCME Water PAL	2.76	500.00	1000	
Copper	Dissolved	ug/L	0.53	aquatic biota	FEQG Water PAL	0.53			
Cyanazine		ug/L	0.6	human	WHO DW	2	10.00	0.6	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Cyanide		ug/L	3.62	human	HH DW+Org (derived)	5	369,092.00	3.62	
Cyanobacterial toxins		ug/L	1.5	human	Health Canada DW			1.5	
Dalapon		ug/L	200	human	US EPA DWR			200	
DDT and metabolites*		ug/L	0.000004	wildlife	US DOE Wildlife	0.001	0.00	0.0003	
Deltamethrin		ug/L	0.0004	aquatic biota	AEP Water PAL CCME Water PAL	0.0004	2.50		
Demeton		ug/L	0.1	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL	0.1			
Di(2-ethylhexyl) adipate		ug/L	400	human	US EPA DWR			400	
Di(2-ethylhexyl) phthalate		ug/L	6	human	US EPA DWR	16		6	
Di-n-Butyl Phthalate		ug/L	0.15	wildlife	US DOE Wildlife	19	0.15	1.42	
Diazinon		ug/L	0.17	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria	0.17		20	
Dibenzo(a,h)anthracene		ug/L	0.0001	human	HH DW+Org (derived)			0.0001	please refer to Table 3.7
Dibromoacetonitrile		ug/L	70	human	WHO DW			70	
Dibromochloromethane		ug/L	5.21	human	HH DW+Org (derived)		100.00	5.21	
Dicamba		ug/L	10	aquatic biota	CCME Water PAL AEP Water PAL	10	122.00	120	
Dichloroacetate		ug/L	50	human	WHO DW			50	
Dichloroacetonitrile*		ug/L	20	human	WHO DW			20	
Dichlorobromomethane		ug/L	9.5	human	HH DW+Org (US EPA)		100.00	9.5	
Dichloromethane*		ug/L	5	human	US EPA DWR		50.00	5	
Dichlorophenol		ug/L	0.2	aquatic biota	CCME Water PAL AEP Water PAL	0.2			
Dichlorprop		ug/L	100	human	WHO DW			100	
Diclofop-methyl		ug/L	6.1	aquatic biota	AEP Water PAL CCME Water PAL	6.1	9.00	9	
Didecyl dimethyl ammonium chloride		ug/L	1.5	aquatic biota	CCME Water PAL AEP Water PAL	1.5			

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Dieldrin		ug/L	0.00001	human	HH DW+Org (derived) HH DW+Org (US EPA)	0.004	0.00	0.00001	
Diethanolamine		ug/L	450	aquatic biota	AEP Water PAL	450			
Diethyl Phthalate		ug/L	35.61	human	HH DW+Org (derived)		210,561.00	35.61	
Diethylene glycol		ug/L	150000	aquatic biota	AEP Water PAL	150000			
Diisopropanolamine		ug/L	1600	aquatic biota	AEP Water PAL CCME Water PAL	1600			
Dimethoate		ug/L	3	wildlife	CCME Water Ag AEP Water Ag	6.2	3.00	6	
Dimethyl Phthalate		ug/L	102.91	human	HH DW+Org (derived)			102.91	
Dinitrophenols		ug/L	10	human	HH DW+Org (US EPA)			10	
Dinoseb		ug/L	0.05	aquatic biota	CCME Water PAL AEP Water PAL	0.05	150.00	7	
Dioxin (2,3,7,8-TCDD)		ug/L	0.00000002134	wildlife	US DOE Wildlife		0.00	0.00000005	
Diquat		ug/L	20	human	US EPA DWR			20	
Diuron		ug/L	150	human	Health Canada DW			150	
Edetic acid		ug/L	600	human	WHO DW			600	
Endosulfan		ug/L	0.003	aquatic biota	AEP Water PAL CCME Water PAL	0.003	1.00		
Endosulfan Sulfate		ug/L	2.63	human	HH DW+Org (derived)			2.63	
Endothall		ug/L	100	human	US EPA DWR			100	
Endrin		ug/L	0.001	wildlife	US DOE Wildlife	0.002	0.00	0.01	
Endrin Aldehyde		ug/L	0.11	human	HH DW+Org (derived)			0.11	
Epichlorohydrin		ug/L	0.4	human	WHO DW			0.4	
Ethanol		ug/L	123377	wildlife	US DOE Wildlife		123,377.00		
Ethinyl estradiol		ng/L	0.5	aquatic biota	AEP Water PAL	0.5			
Ethyl acetate			136465	wildlife	US DOE Wildlife		136,465.00		
Ethylbenzene		ug/L	2.4	wildlife	AEP Water Ag CCME Water Ag	90	2.40	8.54	
Ethylene dibromide		ug/L	0.05	human	US EPA DWR			0.05	
Ethylene glycol		ug/L	192000	aquatic biota	AEP Water PAL CCME Water PAL	192000			
Fenoprop		ug/L	9	human	WHO DW			9	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

Parameter	Sample Fraction	Units	Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
			Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Fluoranthene§		ug/L	0.04	aquatic biota	AEP Water PAL CCME Water PAL	0.04		1.09	
Fluorene§		ug/L	3	aquatic biota	AEP Water PAL CCME Water PAL	3		6.98	
Fluoride		mg/L	0.12	aquatic biota	CCME Water PAL	0.12	1.00	0.4	
Formaldehyde		ug/L	73910	wildlife	US DOE Wildlife		73,910.00		
gamma-Hexachlorocyclohexane [Lindane]		ug/L	0.01	aquatic biota	AEP Water PAL	0.01	4.00	0.2	
Glyphosate		ug/L	280	human wildlife	AEP Water Ag Health Canada DW CCME Water Ag	800	280.00	280	
Haloacetic acids		ug/L	60	human	US EPA DWR			60	
heptaBDE		ng/L	14	aquatic biota	FEQG Water PAL	14			
Heptachlor*		ug/L	0.00004	human	HH DW+Org (derived)	0.0038	0.00	0.00004	
Heptachlor epoxide*		ug/L	0.0001	human	HH DW+Org (derived)	0.0038		0.0001	
hexaBDE		ng/L	120	aquatic biota	FEQG Water PAL AEP Water PAL	120			
Hexabromocyclododecane		ug/L	0.56	aquatic biota	FEQG Water PAL AEP Water PAL	0.56			
Hexachlorobenzene*		ug/L	0.0001	human	HH DW+Org (derived)		0.52	0.0001	
Hexachlorobutadiene*		ug/L	0.001	human	HH DW+Org (derived)	1.3		0.001	
Hexachlorocyclohexane:		ug/L	0.01	aquatic biota human	HH DW+Org (derived) CCME Water PAL	0.01		0.01	
Hexachlorocyclopentadiene		ug/L	0.4	human	HH DW+Org (derived)			0.4	
Hexachloroethane*		ug/L	0.02	human	HH DW+Org (derived)			0.02	
Hydrazine		ug/L	2.6	aquatic biota	FEQG Water PAL AEP Water PAL	2.6			
Hydrogen Sulfide		ug/L	2	aquatic biota	US EPA Aquatic Life Criteria	2			
Hydroxyatrazine		ug/L	200	human	WHO DW			200	
Imidacloprid		ug/L	0.23	aquatic biota	AEP Water PAL CCME Water PAL	0.23			
Indeno(1,2,3-cd)pyrene*†		ug/L	0.001	human	HH DW+Org (derived)			0.001	please refer to Table 3.7

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Inorganic nitrogen (nitrate and nitrite)	Dissolved	mg/L	100	wildlife	CCME Water Ag AEP Water Ag		100.00		
Iron	Total	ug/L	300	aquatic biota human	CCME Water PAL USEPA WQC AO	300		300	
Iron	Dissolved	ug/L	300	aquatic biota	AEP Water PAL	300			
Isophorone[*]		ug/L	268.41	human	HH DW+Org (derived)			268.41	
Isoproturon		ug/L	9	human	WHO DW			9	
Lead[‡]	Total	ug/L	4.01	aquatic biota	AEP Water PAL CCME Water PAL	4.01	100.00	5	please refer to Table 3.7
Lead[‡††]	Dissolved	ug/L	3.07	aquatic biota	US EPA Aquatic Life Criteria	3.07			
Linuron		ug/L	7	aquatic biota	CCME Water PAL AEP Water PAL	7			
m-Dichlorobenzene		ug/L	150	aquatic biota	CCME Water PAL	150			
Malathion		ug/L	0.1	aquatic biota	AEP Water PAL US EPA Aquatic Life Criteria	0.1		190	
Manganese	Total	ug/L	50	human	HH DW+Org (US EPA)	470		50	
MCPA		ug/L	2.6	aquatic biota	CCME Water PAL AEP Water PAL	2.6	25.00	100	
Mecoprop		ug/L	10	human	WHO DW	13		10	
Mercury	Total	ug/L	0.0016	wildlife	US DOE Wildlife	0.005	0.00	1	please refer to Table 3.7
Mercury[††]	Dissolved	ug/L	0.77	aquatic biota	US EPA Aquatic Life Criteria	0.77			
Mercury (methyl)	Total	ug/L	0.001	aquatic biota	AEP Water PAL	0.001		0.67	
Mercury (methyl)	Dissolved	ug/L	0.004	aquatic biota	CCME Water PAL	0.004			
Methanol		ug/L	1500	aquatic biota	AEP Water PAL	1500	230,691.00		
Methoprene		ug/L	0.09	aquatic biota	AEP Water PAL CCME Water PAL	0.09			
Methoxychlor		ug/L	0.001	human	HH DW+Org (derived)	0.03	1.00	0.001	
Methyl Bromide		ug/L	100	human	HH DW+Org (US EPA)			100	
Methyl tert-butyl ether		ug/L	10	aquatic biota	AEP Water PAL	10			

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Methylene chloride*		ug/L	32.62	human	HH DW+Org (derived)	98.1	3,990.00	32.62	
Metolachlor		ug/L	7.8	aquatic biota	AEP Water PAL CCME Water PAL	7.8	50.00	10	
Metribuzin		ug/L	1	aquatic biota	AEP Water PAL CCME Water PAL	1	80.00	80	
Microcystin-LR		ug/L	1	human	WHO DW			1	
Mirex		ug/L	0.001	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL	0.001			
Molinate		ug/L	6	human	WHO DW			6	
Molybdenum	Total	ug/L	33.33	human	HH DW+Org (derived)	73	500.00	33.33	
Monochloramine		ug/L	3000	human	WHO DW			3000	
Monochloroacetate		ug/L	20	human	WHO DW			20	
Monochlorobenzene		ug/L	1.3	aquatic biota	CCME Water PAL AEP Water PAL	1.3		20	
Monoethanolamine		ug/L	75	aquatic biota	AEP Water PAL	75			
N-Nitrosodi-n-Propylamine*		ug/L	0.05	human	HH DW+Org (US EPA) HH DW+Org (derived)			0.05	
N-Nitrosodimethylamine*		ug/L	0.007	human	HH DW+Org (US EPA)			0.007	
N-Nitrosodiphenylamine*		ug/L	33	human	HH DW+Org (US EPA)			33	
Naphthalene§		ug/L	1	aquatic biota	AEP Water PAL	1		133.33	
Naphthenic acids (Lower Athabasca River)	Total	ug/L	<50		Adopted current condition (OSM Reporting Limit)				
Naphthenic acids (Athabasca River Delta)	Total	ug/L	230		Adopted current condition (50th percentile, high flow)				
Naphthenic acids (Lake Athabasca)	Total	ug/L	140		Adopted current condition (50th percentile, open water)				
Nickel‡	Total	ug/L	7.35	human	HH DW+Org (derived)	60.86	1,000.00	7.35	please refer to Table 3.7
Nickel‡††	Dissolved	ug/L	60.68	aquatic biota	US EPA Aquatic Life Criteria	60.68			

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Nitrate	Dissolved	mg/L	3	aquatic biota	CCME Water PAL AEP Water PAL	3		10	
Nitrilotriacetic acid		ug/L	200	human	WHO DW			200	
Nitrite	Dissolved	mg/L	0.06	aquatic biota	CCME Water PAL	0.06	10.00	0.912	
Nitrobenzene		ug/L	9.72	human	HH DW+Org (derived)			9.72	
Nitrosamines		ug/L	0.008	human	HH DW+Org (US EPA)			0.008	
Nitrosodibutylamine		ug/L	0.05	human	HH DW+Org (derived)			0.05	
Nitrosodiethylamine		ug/L	0.002	human	HH DW+Org (derived)			0.002	
Nitrosopyrrolidine		ug/L	0.16	human	HH DW+Org (US EPA) HH DW+Org (derived)			0.16	
Nonylphenol		ug/L	6.6	aquatic biota	US EPA Aquatic Life Criteria	6.6			
Nonylphenol and its ethoxylates		ug/L	1	aquatic biota	CCME Water PAL	1			
o-Dichlorobenzene		ug/L	0.7	aquatic biota	AEP Water PAL CCME Water PAL	0.7		200	
octaBDE		ng/L	14	aquatic biota	FEQG Water PAL	14			
Oxamyl (Vydate)		ug/L	200	human	US EPA DWR			200	
p,p’-Dichlorodiphenyldichloroethane (DDD)*		ug/L	0.001	human	HH DW+Org (US EPA)			0.001	
p,p’-Dichlorodiphenyldichlo (DDE)*		ug/L	0.00018	human	USEPA WQC HH Org			0.00018	
p-Dichlorobenzene		ug/L	5	human	Health Canada DW	26		5	
Paraquat		ug/L	10	human	Health Canada DW			10	
Parathion		ug/L	0.013	aquatic biota	US EPA Aquatic Life Criteria AEP Water PAL	0.013			
Pendimethalin		ug/L	20	human	WHO DW			20	
pentaBDE		ng/L	0.2	aquatic biota	AEP Water PAL FEQG Water PAL	0.2			
pentaBDE (BDE-100)		ng/L	0.2	aquatic biota	FEQG Water PAL AEP Water PAL	0.2			
pentaBDE (BDE-99)		ng/L	4	aquatic biota	AEP Water PAL FEQG Water PAL	4			

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Pentachlorobenzene		ug/L	0.01	human	HH DW+Org (derived)	6		0.01	
Pentachloronitrobenzene			4	wildlife	US DOE Wildlife		4.00		
Pentachlorophenol		ug/L	0.1	human	HH DW+Org (derived)	0.5	0.28	0.1	
Perchlorate		ug/L	70	human	WHO DW			70	
Perfluorooctanesulfonat		ug/L	0.6	human	Health Canada DW	6.8		0.6	
Perfluorooctanoic acid		ug/L	0.2	human	Health Canada DW			0.2	
Permethrin		ug/L	0.004	aquatic biota	AEP Water PAL CCME Water PAL	0.004			
pH		pH units	7-9	aquatic biota human human	US EPA Aquatic Life Criteria HH DW+Org (US EPA) AEP Water PAL CCME Water PAL Health Canada DW	6.5-9		7-9	
Phenanthrene[§]		ug/L	0.4	aquatic biota	CCME Water PAL AEP Water PAL	0.4		200	
Phenol		ug/L	2	wildlife	CCME Water Ag AEP Water Ag	4	2.00	300	
Phorate		ug/L	2	human	Health Canada DW			2	
Picloram		ug/L	29	aquatic biota	CCME Water PAL AEP Water PAL	29	190.00	190	
Polychlorinated Biphenyls (PCBs)[*]		ug/L	0.00064	human	USEPA WQC HH Org	0.001		0.00064	
Propylene glycol		ug/L	500000	aquatic biota	CCME Water PAL AEP Water PAL	500000			
Pyrene[§]		ug/L	0.025	aquatic biota	CCME Water PAL AEP Water PAL	0.025		1.43	
Quinoline		ug/L	3.4	aquatic biota	AEP Water PAL CCME Water PAL	3.4			
Selenium	Total	ug/L	0.24	wildlife	US DOE Wildlife	1	0.24	18.77	please refer to Table 3.7
Silver	Total	ug/L	0.25	aquatic biota	AEP Water PAL CCME Water PAL	0.25		33.33	
Simazine		ug/L	2	human	WHO DW	10	10.00	2	
Sodium dichloroisocyanurate		ug/L	40000	human	WHO DW			40000	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Solids Dissolved and Salinity		ug/L	250000	human	HH DW+Org (US EPA)			250000	
Strontium	Total	ug/L	4000	human	HH DW+Org (derived)			4000	
Styrene		ug/L	20	human	WHO DW	72		20	
Sulfate		mg/L	250	human	WHO DW	309	1,000.00	250	
Sulfide		mg/L	0.0019	aquatic biota	AEP Water PAL	0.0019			
Sulfolane		ug/L	50	aquatic biota	AEP Water PAL	50			
Tebuthiuron		ug/L	1.6	aquatic biota	CCME Water PAL	1.6	130.00		
Terbufos		ug/L	1	human	Health Canada DW			1	
Terbuthylazine		ug/L	7	human	WHO DW			7	
tetraBDE		ng/L	24	aquatic biota	FEQG Water PAL AEP Water PAL	24			
Tetrabromobisphenol A		ug/L	3.1	aquatic biota	FEQG Water PAL AEP Water PAL	3.1			
Tetrachloroethane		ug/L	13.3	aquatic biota	CCME Water PAL	13.3			
Tetrachloroethylene*		ug/L	4.48	human	HH DW+Org (derived)	110	48.00	4.48	
Tetrachlorophenol		ug/L	1	aquatic biota	CCME Water PAL AEP Water PAL	1			
Thallium	Total	ug/L	0.02	human	HH DW+Org (derived)	0.8	1.00	0.02	please refer to Table 3.7
Toluene		ug/L	0.5	aquatic biota	AEP Water PAL	0.5	24.00	57	
Total dissolved solids		mg/L	3000	wildlife	AEP Water Ag CCME Water Ag		3,000.00		
Toxaphene		ug/L	0.0002	aquatic biota	US EPA Aquatic Life Criteria	0.0002	1.00	0.001	
Toxicity (chronic)‡‡		Toxic Units (TUc)	1	aquatic biota	AEP Water PAL	1			
trans-1,2-Dichloroethylene		ug/L	100	human	US EPA DWR			100	
Triallate		ug/L	0.24	aquatic biota	CCME Water PAL AEP Water PAL	0.24	230.00		
triBDE		ng/L	46	aquatic biota	AEP Water PAL FEQG Water PAL	46			
Tribromomethane		ug/L	100	wildlife	CCME Water Ag		100.00		

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
Tributyltin		ug/L	0.008	aquatic biota	CCME Water PAL	0.008	250.00		
Trichlorfon		ug/L	0.009	aquatic biota	AEP Water PAL CCME Water PAL	0.009			
Trichloroacetate		ug/L	200	human	WHO DW			200	
Trichloroethylene[*]		ug/L	1.38	human	HH DW+Org (derived)	21	22.00	1.38	
Trichlorophenol		ug/L	18	aquatic biota	AEP Water PAL CCME Water PAL	18			
Triclosan		ug/L	0.47	aquatic biota	FEQG Water PAL	0.47			
Tricyclohexyltin		ug/L	250	wildlife	CCME Water Ag AEP Water Ag		250.00		
Triethylene glycol		ug/L	350000	aquatic biota	AEP Water PAL	350000			
Trifluralin		ug/L	0.2	aquatic biota	AEP Water PAL CCME Water PAL	0.2	45.00	20	
Trihalomethanes		ug/L	80	human	US EPA DWR			80	
Triphenyltin		ug/L	0.022	aquatic biota	CCME Water PAL AEP Water PAL	0.022	820.00		
Uranium	Total	ug/L	15	aquatic biota	CCME Water PAL AEP Water PAL	15	200.00	20	
Vanadium	Total	ug/L	100	wildlife	AEP Water Ag CCME Water Ag	120	100.00		
Vinyl chloride[*]		ug/L	0.18	human	HH DW+Org (derived)		78.00	0.18	
Xylene		ug/L	28	wildlife	US DOE Wildlife	30	28.00	90	
Xylenes (total)		ug/L	10000	human	US EPA DWR			10000	
Zinc[‡]	Total	ug/L	12.72	human	HH DW+Org (derived)	30	30.00	12.72	please refer to Table 3.7
Zinc[‡]	Dissolved	ug/L	31.35	aquatic biota	CCME Water PAL	31.35			
Low Moelcular Weight PAHs[¶]		ug/L	1	aquatic biota	AEP Water PAL	1		133.33	

Table 3.9: Summary of Generic and Use Specific Health Risk Criteria for protection of Indigenous water use. *(continued)*

			Generic health Risk Criteria			Specific Water Use Category Health Risk Criteria			
Parameter	Sample Fraction	Units	Value	Sensitive Receptor	Source	Aquatic Ecosytem Health	Wildlife Health	Traditional Foods and Drinking Water	Traditional Medicines
High Molecular Weight PAHs**		ug/L	0.0001	human	HH DW+Org (derived)	0.015	0.01	0.0001	

Note:
HH DW + Org and Org were adjusted to reflect carcinogenity of 1 in 1000,000 (1 x 10^{-5}) ILCR levels (Alberta Health (2019))
HH DW+Org: Human Health (HH) criteria from consuming surface water (SW) and aquatic organisms (O)
AO: Aesthetic Objectives; DW: Drinking Water; PAL: Protection of Aquatic Life; Ag: Agriculture
Aquatic biota: invertebrates, plants and fish
Wildlife; bird and mammalian species
WHO DW taken from World Health Organization (WHO) (2017)
AEP Water PAL taken from GoA (2018)
Health Canada DW taken from Health Canada (2020a)
CCME Water Ag taken from CCME (2021)
US EPA DWR taken from United States Environmental Protection Agency (US EPA) (2021a)
HH DW+Org (US EPA) taken from US EPA (2015a)
FEQG Water PAL taken from of Canada (2021)
US DOE Wildlife taken from Sample et al. (1996)

* Known human carcinogen via oral exposure route (Health Canada (2021))

† The following known human carcinogens and must be converted to Provisional Benzo[a]pyrene RPF and summed as per Health Canada (2021) then compared to the Benzo(a)pyrene and equivalents health risk criteria: Anthanthrene, Benzo[c]chrysene, Benzo[g]chrysene, Benzo[c]phenanthrene, Cyclopenta[c,d]pyrene, Dibenzo[a,e]fluoranthene Dibenzo[a,e]pyrene, Dibenzo[a,h]pyrene, Dibenzo[a,i]pyrene, Dibenzo[a,l]pyrene, 9,10- Dimethylanthracene, 7,12- Dimethylbenzo[a]anthracene, 1,2- Dimethylbenzo[a]pyrene, 1,6- Dimethylbenzo[a]pyrene, 3,6- Dimethylbenzo[a]pyrene, 4,5- Dimethylbenzo[a]pyrene, 5,6- Dimethylchrysene, 5,7- Dimethylchrysene, 5,11- Dimethylchrysene, 1,4- Dimethylphenanthrene, 4,10- Dimethylphenanthrene, 5- Ethylchrysene, Fluoranthene, 7- Methylbenzo[a]anthracene, Methylbenzo[a]anthracene, 9- Methylbenzo[a]anthracene, 12- Methylbenzo[a]anthracene, 11- Methylbenzo[b]fluorene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, Methylbenzo[a]pyrene, 11- Methylbenzo[a]pyrene, 12- Methylbenzo[a]pyrene, 5- Methylchrysene, Methylchrysene, 2- Methylfluoranthene, Phenanthren,e 2,9,10- Trimethylanthracene, 2,3,9,10- Tetramethylanthracene .

‡ Calculated using modifying factors presented in Table reftab:table4.

§ Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) and compare to Naphthalene health risk criteria (adopted as surrogate) (CCME (2010))

¶ Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) (CCME (2010))

** Sum of identified HMW PAH congeners (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene) (CCME (2010))

†† Comparison of water quality data must be presented for both Dissolved and total fractions

‡‡ Toxic Unit-Chronic (TUc) is the reciprocal of the effluent concentration (e.g., TUc = 100/NOEC) that causes no observable effect (NOEC) on the test organisms by the end of a chronic toxicity test (US EPA (2000c)).

Chapter 4

Health Risk Criteria for the Protection of Sediment to Support Indigenous Use

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4.1 Introduction

Traditional knowledge of Indigenous communities and modern science both recognize sediment as a critical and sustaining component within aquatic ecosystems. Sediments provide substrates for aquatic plants and animals to live and reproduce in, nutrients and minerals that maintain local and downstream ecosystems, and through physicochemical processes act as sinks and sources for chemical substances (Palmer, 1997). More recently the role of sediment in supporting ecosystem function has been considered in assessments of ecosystem services (Apitz, 2012).

The Peace Athabasca Delta (PAD), a culturally important area upon which ACFN and MCFN cultures and livelihoods depend, was formed through the deposition of sediments, and is sustained by this natural cycle (McLachlan, 2014; Candler et al., 2010).

Chemicals which enter the aquatic ecosystem (either through natural or human activity) may partition into the particulate phase depositing into bed sediments and potentially accumulating over time (CCME, 2001). As a result, these aquatic systems may act as both a long-term sink exposing those organisms living in or having direct contact to potentially harmful levels of contamination and act as a continued source of contamination into the water column.

As sediments are a crucial component of the aquatic ecosystem, effective assessment of sediment quality is necessary to evaluate the potential for adverse effects. Sediment quality guidelines provide one such method of evaluating the relationship between chemical concentrations in sediment and the potential for adverse effects in exposed benthic organisms and plants and contamination of overlaying water.

In Alberta, sediment quality guidelines were primarily adopted from the Canadian Council of Ministers of the Environment (CCME), Ontario Ministry of the Environment and Energy (OMOEE) with select values sourced from Environment Canada (GoA, 2018).

Derivation of the CCME Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PELs) was limited by availability of toxicity data and available methodology which could consider bioaccumulation of contaminants within food webs.

These limitations in conjunction with the lack of a recent review and modification to incorporate scientific advancements in sediment toxicity testing may limit the protectiveness of GOA and CCME sediment quality guidelines (ISQGs and PELs) for Indigenous water use as described in Chapter 3.

Similar to the water quality criteria developed for Indigenous uses (Table 3.9), Health risk sediment quality criteria (SQCs) are required to assess risks to benthic and aquatic invertebrates from contaminants which partition to and may accumulate in sediments from natural sources and in surface water receiving OSMW seepage and releases.

The proposed SQCs are applicable to aquatic environments receiving oil sands mine water releases and closure features on oil sands mines (i.e., wetlands, end pit lakes) and can also be used to assess the performance of tailings treatment technologies if the treated tailings are to be placed in contact with sediments or used to create tailings substrates within aquatic closure features.

The SQC provides a mechanism by which Indigenous communities, government, regulatory and industry stakeholders can gauge the potential for adverse effects and through a weight of evidence approach, determine logical next steps in addressing the contaminant situation.

The identified SQCs supplement the Indigenous water use category health risk criteria identified in Chapter 3 and application of both criteria form an ecosystem management system which considers the protection of Indigenous water use.

4.2 Objective

Review published regulatory guidelines, sediment toxicity data, and guideline derivation methods to identify and when required, derive new, health risk criteria that consider risks to benthic and aquatic biota from partitioning and accumulation of chemicals in sediments and uptake through the aquatic food web.

4.3 Methods

The following stages were used to identify and/ or modify existing sediment quality guidelines and when required derive SQCs.

- Identify benthic and aquatic biota - sediment exposure pathways for contaminants and community protection goals,
- Identify substances of concern in oil sands mine water and tailings which may partition to and accumulate in receiving water body sediments,
- Review and evaluate available sediment quality guidelines by applying criteria that consider protection of benthic and aquatic biota (biodiversity and toxicity) and biomagnification in aquatic food webs,
- Adopt available sediment quality guidelines as SQCs, when health risks were considered, or
- Identify sediment toxicity data and derive SQCs when health risks were not considered.

4.3.1 Sediment Quality Protection Goals

Community members did not identify specific Indigenous uses for sediment, therefore use categories have not been developed for sediment. Rather, sediment protection goals were identified for benthic and aquatic biota and humans which can be exposed to chemicals that partition from surface water to sediments or are naturally occurring.

The following protection goals for SQCs were identified:

- Concentrations of chemicals in sediment do not result in toxicological effects to survival, health, reproduction, or biodiversity in benthic invertebrate, emergent macrophyte and fish populations.
- Concentrations of chemicals in sediment do not result in bioaccumulation of chemicals in diet items which are over safe daily intake levels for consumers of benthic invertebrates, emergent macrophytes, and fish.

4.3.2 Identification of Chemical Substances Related to Oil sands Development and Database of Sediment Toxicity Data

Chemical substances identified in Section 3.4.2 and 3.9 were carried forward and screened against available sediment quality guidelines and bioaccumulation data to identify substances which require SQCs.

To support the derivation of SQCs, when required, spiked sediment toxicity study data and values were obtained from the Society of Environmental Toxicology and Chemistry (SETAC) Sediment Advisory Group (SEDAG) database (Society of Environmental Toxicology and Chemistry Sediment Advisory Group (SETAC SEDAG), 2016).

4.3.3 Inventory of Regulatory Sediment Quality Guidelines

Available sediment quality guidelines developed using various approaches were identified through a jurisdictional scan of the following agencies.

- Federal
  - Canadian Council of Ministers of the Environment [CCME (2001); and updates]
- Provincial
  - Government of Alberta (GoA, 2018)
  - Nova Scotia Environment (Nova Scotia Environment (NSE), 2014)
  - Ontario Ministry of Environment and Energy (Ontario Ministry of Environment (OMOE), 2008)
  - Quebec (Direction du suivi de l'état de l'environment (Environment Canada and Ministère du Développement durable de l'Environnement et des Parcs du Québec (DSEE), 2007))
  - BC Ministry of Water, Land and Air Protection (MWLAP, 2003)
- United States Environmental Protection Agency
  - US EPA Assessment and Remediation of Contaminated Sediments Program (ARCS) (United States Department of Energy (US DOE), 1997)
  - US EPA Office of Solid Waste and Emergency Response (OSWER) (United States Department of Energy (US DOE), 1997)
  - US EPA (Region III) Biological Technical Assistance Group (BTAG) (Environmental Protection Agency Biological Technical Assistance Group (EPA BTAG), 2006)
  - US EPA (Region IV) (United States Department of Energy (US DOE), 1996)

- United States (State)
  - Minnesota Pollution Control Agency (Minnesota Pollution Control Agency (MPCA), 2007)
  - New York State Department of Environmental Conservation of Fish, Wildlife and Marine Resources Bureau of Habitat (New York State Department of Environmental Conservation (NYSDEC), 2014)
  - United States Department of Energy (US DOE) Office of Environmental Management (United States Department of Energy (US DOE), 1997)
  - FDEP - Florida Department of Environmental Protection (Florida Department of Environmental Protection (FDOEP), 2003)
  - Washington State Department of Environment (Washington State Department of Ecology (WS DOE), 2019)

Jurisdictions throughout North America have developed numerical and objective based standards for the protection of freshwater ecosystems. The approaches, listed below, vary widely, and may include an empirical and/or theoretical based sediment quality guideline (MWLAP, 2003; Florida Department of Environmental Protection (FDOEP), 2003). A description of each method is provided in Appendix A.6.

- Screening Level Concentration Approach (SLCA)
- Effects Range and Effects Level Approach (ERA, ELA)
- Apparent Effects Threshold Approach (AETA)
- Equilibrium Partitioning Approach (EqPA)
- Logistic Regression Modeling Approach (LRMA)
- Consensus Approach (CA)
- Tissue Residue Approach (TRA)

4.3.4 Evaluation of Regulatory Agency Sediment Quality Guidelines.

Numerical and objective based sediment guidelines published by jurisdictions throughout North America were evaluated against Indigenous water use protection goals established in the conceptual model to determine if published regulatory sediment quality guidelines could be adopted as SQCs.

4.3.5 Developing Sediment Quality Criteria for the Protection of Indigenous Water Use

The approach presented below, adapted from the OMOE (2008) weight of evidence (WoE) methodology, considers overall toxicity, benthos alteration, and biomagnification potential.

The weight of evidence approach recognizes limitations in published sediment quality guideline derivation methods and toxicity data and can be used to evaluate potential risks and support decision making regarding sediment contamination and health risks.

The selected SQC was identified as the concentration at which limited to no adverse effects would be anticipated to occur and was typically selected from the following published guidelines or derived using toxicity data and prescribed methods.

- Rare Effect Level (REL)
- Spiked-Sediment Toxicity Test Values (Sediment Advisory Group (SEDAG) database)
- Bioaccumulation Sediment Guidance Values (BSGV) and Partitioning Theory Guideline Derivations (i.e., higher trophic human and ecological receptors protection)
- Potential for fish-tissue tainting (i.e., adverse taste).

Sediment Quality Criteria (Adopted)

The following criteria were used to evaluate published sediment quality guidelines and determine if they could be adopted as SQCs. If an available guideline did not meet the most stringent criteria, an SQC was derived, as described in the following section.

Overall Toxicity

Overall toxicity is defined as being negligible, minor or major. The following decision criteria were taken directly from the OMOE (2008) guidance document. To adopt the OMOE sediment guideline the sediment guideline must meet negligible or minor criteria

Negligible

Reduction of 20% or less in all toxicological test endpoints with only minor effects having been observed in no more than one endpoint.

Minor

Statistically significant reduction of more than 20% in one or more toxicological endpoints with multiple tests/endpoints exhibiting minor toxicological effects and no more than one exhibiting a major effect.

Major

Statistically significant reduction of more than 50% in one or more toxicological endpoints with multiple tests/endpoints exhibiting major toxicological effects.

Benthos Alteration

Although not explicitly stated within the OMOE guidance document measures of community structure could employ either the Shannon-Wiener or Simpson's index. These approaches are based on the number of species present (the functional group richness of the sample) and their relative abundance (the dominance or evenness of the sample population). One difficulty that may occur during interpretation of the Shannon-Weiner and Simpsons diversity indices is that they do not account for the comparisons of actual species present between reference and sample sites. Instead, the Jaccards similarity index (which acts as a measure of the fraction of shared species between sample sites) can also be calculated. As described by the OMOE (2008) other approaches can also be used (such as multivariate analysis) and description of change in consideration of the diversity, abundance and dominance of species living within the sediment is strongly recommended.

Biomagnification Potential

To address the potential risks to both humans and higher trophic aquatic receptors (i.e., fish, mammals, and aquatic birds) an evaluation of the potential for biomagnification is required. Biomagnification is the uptake of one or more contaminants through the food-web resulting in increasing concentrations through three or more trophic levels (Fisheries & Canada, 2019).

Negligible

Chemical is not presently known to have bioaccumulating properties or sufficient scientific literature has been established to indicate that the chemical does not readily bioaccumulate (i.e., it is readily metabolized and/or excreted by the body).

Consistent with the Canadian Environmental Protection Act (CEPA) (of Canada, 1999), a substance is not considered bioaccumulative under the following considerations:

- Bioaccumulation Factor (BAF) is less than 5,000; or,
- Bioconcentration Factor (BCF) is less than 5,000 (if a BAF cannot be defined); or,
- LogKow is less than 5 (if neither a BAF nor a BCF can be defined)

Possible

Chemical is known to bioaccumulate and/or bioconcentrate within the food web. It is presently unknown whether concentrations measured in sediment presents a confirmed health risk, but conservative modeling assumptions indicate that the potential exists. Non-ionizable, non-polar organic chemicals with one or more of the following characteristics (BAF 5,000 and/or, BCF 5,000 and/or, Log Kow 5) would fit within this category so long as measured concentrations do not exceed known sediment guidelines that are protective of higher trophic receptor effect.

Significant

Concentrations in sediment exceeds known bioaccumulation-based guidance value and/or there is clear evidence of risk to higher trophic organisms. Chemicals within this category meet one or more of the CEPA (of Canada, 1999) considerations for bioaccumulation and/or have a proven impact to higher trophic receptors at concentrations presently exhibited in the sediment chemistry.

4.3.5.1 Sediment Quality Criteria (Derived)

When available guidelines could not be adopted, SQCs were derived as follows.

US EPA equilibrium partitioning (EqP)

The US EPA equilibrium partitioning (EqP) method was used to derive SQCs for non-carcinogenic organic contaminants using the published water quality objective/guideline (US EPA, 2018):

Equation (4.1): Equation to derive the sediment quality criteria using the equilibrium partitioning method for non carcinogenic organic contaminants (modified US EPA (2018)):

$$SQC = WQO/G \times (K_{oc} \times f_{oc} + (\frac{\theta m}{pw})) \tag{4.1}$$

Where:

$$\begin{aligned} SQC &= \text{sediment quality criteria (g/kg)} \\ WQO/G &= \text{Water Quality Objective/Guideline (g/L)} \\ K_{oc} &= \text{Organic carbon partitioning coefficient (L/kg)} \\ F_{oc} &= \text{fraction organic carbon (\%OC/kg sediment (e.g., 2\% = 20 g} \bullet \text{OC/kg))} \\ pw &= \text{0.9982 density of water at 20°C} \\ \theta &= \text{0.3 (assumed as 30\% moisture of sediment by mass)} \end{aligned}$$

Spiked Sediment Toxicity Test Approach

The spiked-sediment toxicity test (SSTT) approach uses information on the responses of test organisms to specific sediment associated chemicals under controlled laboratory conditions (Chapman and Long 1983; Ingersoll 1991; Lamberson and Swartz 1992). Sediments are spiked with known concentrations of chemicals, either alone or in combination, to establish definitive cause-and-effect relationships between chemicals and biological responses. At the end of the test period, the response of the test organism is examined in relation to a biological end point (e.g., mortality, reproduction, growth). As in the development of water quality guidelines in Canada (Canadian Council of Resource and Environment Ministers (CCREM), 1987) or water quality criteria in the United States (US EPA, 1986), acute and chronic effect data generated from sediment toxicity tests can be used to identify concentrations of chemicals in sediment below which aquatic life would not be adversely affected.

The Spiked Sediment Toxicity Test (SSTT) approach requires a minimum of 4 studies on 2 or more sediment-resident invertebrate species, one of which must be a benthic crustacean, and one a benthic arthropod and at least 2 of these studies must be partial or full lifecycle tests of ecologically relevant endpoints (i.e., survival, growth, reproduction) (CCME, 1995).

If the minimum data set requirements are met for the SSTT approach, an SQC can be derived, preferentially from the lowest-observed-effect level/Concentration (LOEL/C) from a chronic study using a nonlethal end point. The most sensitive LOEL/C is multiplied by an appropriate safety factor to derive the SQCs.

Applying Safety factors (SFs) to LOECs is a common approach to deriving risk-based guidelines using published toxicity data when data quality requirements are met. If toxicity data for a substance met minimum criteria, the LOEC) was multiplied by a SF of 0.2 to derive the SQC.

The conservative SF (0.2) published by CCME (1995) was derived from published SFs previously used to develop sediment quality guidelines from toxicity data.

Bioaccumulation Based Sediment Guideline Values (BBSGVs)

The approach presented herein is an abbreviation of the work of (Newell et al., 1987) as updated by the works of NYSDEC (1999) and as described in NYSDEC (2014) and the Technical Operational Guidance Series (TOGS) as prepared by the NYSDEC Division of Water.

The first step in derivation of the BBSGV is to identify the Acceptable Daily Intake (ADI) of the receptor (human or wildlife) under consideration. The NYSDEC defines the ADI as the maximum concentration of a chemical in food that the receptor (i.e., bird, animal or human) can consume without exceeding a dietary exposure risk. This varies from the traditional definition of ADIs in risk assessment where DI is usually defined as exposure dose (mg/kgBW/d), also known as Tolerable Daily Intake.

The dietary risk value might be the no observed effect level (NOEL) the lowest observed effect level (LOEL) or another toxicological endpoint. In Canada, typical endpoints associated with wildlife exposures are the daily threshold effect dose (DTED) whereas for humans it is typically referred to as either the oral Tolerable Daily Intake (TDI) (for non-carcinogenic chemicals) or the oral Slope Factor (SF) (for cancer causing chemicals). Note that the slope factor must be converted to a risk specific dose (RsD) utilizing the following equation:

Equation (4.2): Equation to derive the risk specific dose (RsD) using the slope factor (SF) for cancer causing chemicals, and acceptable risk level (ARL).

$$RsD = \frac{ARL}{SF} \tag{4.2}$$

Where:

RsD	=	reference dose (mg/kg body-weight/day)
ARL	=	acceptable risk level (10-5)
SF	=	slope factor

Once the ADI is defined the exposure concentration is derived as follows:

Equation (4.3): Equation to derive the baseline bioaccumulation factor (BAF Baseline) using the octanol-water partitioning coefficient and food chain multiplier.

$$BAF_{Baseline} = K_{ow} \times FCM \tag{4.3}$$

Where:

$BAF_{Baseline}$	=	Baseline Bioaccumulation Factor assuming 100% lipid content (trophic level specific)
Kow	=	n-Octanol/Water portioning coefficient
FCM	=	Food Chain Multiplier (as defined in literature based on trophic level)

Once the baseline is established, the wildlife BAF can now be calculated from the baseline BAF. The wildlife BAF is derived from the concentration of the contaminant freely dissolved in pore-water. This concentration is calculated as follows:

Equation (4.4): Equation to derive the concentration of the contaminant freely dissolved in pore-water (f fd) using the concentration of dissolved organic carbon (DOC) and particulate organic carbon (POC) in water.

$$f_{fd} = \frac{1}{1 + \frac{DOC)(K_{ow})}{10} + (POC)(K_{ow})} \tag{4.4}$$

Where:

f_{fd}	=	freely dissolved fraction of a chemical in water
DOC	=	concentration of dissolved organic carbon in water (kg DOC/L)
POC	=	concentration of particulate organic carbon in water (kg POC/L)

The value recommended by NYSDEC and applied for DOC is 0.000002 kg/L, and the POC is typically set as 0 (New York State Department of Environmental Conservation (NYSDEC), 2014). Wildlife BAFs must also be adjusted for the lipid content of fish. The values are often set based on literature derived studies and specified based on trophic level (e.g., 6.46% for trophic level 3 and 10.31 % for trophic level 4 (New York State Department of Environmental Conservation (NYSDEC), 2014)). Hence, the wildlife BAF for a specific trophic level can be calculated as follows:

Equation (4.5): Equation to derive the wildlife baseline bioaccumulation factor (BAF receptor/trophic level) for a specific trophic level using the BAF Baseline, (f fd) and % lipid in fish for a given trophic level (%Lipid Trophic Level x Fish).

$$BAF^{Receptor}_{TrophLevel_x} = [(BAF_{Baseline}) \times (\%Lipid_{Trophic\ Level_x\ Fish}) + 1](f_{fd}) \tag{4.5}$$

Where:

$BAF^{Receptor}_{Troph\ Level_x}$ = BAF for consumption of fish from a specified trophic level

$BAF_{Baseline}$ = Baseline Bioaccumulation Factor (trophic level specific) (L/kg)

$\%Lipid_{Trophic\ Level_x\ Fish}$ = %lipid in fish for a given trophic level

f_{fd} = freely dissolved fraction of a chemical in water

Once each of the required trophic level BAFs has been derived determination of a bioaccumulation-based pore-water quality value can be conducted. There are several ways in which this value can be derived and consideration of the various media in which the receptor can be exposed requires consideration.

The NYSCDEC (2014) defines the fish-flesh criterion (CFF) for protection of wildlife as the maximum concentration of a chemical that can be present in fish-flesh and not be harmful to birds and animals that consume the fish. The NYSCDEC (2014) thus consider the CFF and ADIwildlife as synonymous. A departure presented herein maintains the assumptions presented in both CCME (2007) and AEP (2019) whereby an allocation factor (AF) is incorporated such that protection to the receptor is maintained as the relative proportion of exposure should include consideration of the various environmental pathways (air, soil, food, water, and consumer products) by which the receptor may likewise be exposed. As per the prescribed method, the AF applied incorporates a safety factor, assuming that a substantial portion of threshold intake will come from sources unrelated to water and sediment. The ADI also includes an uncertainty factor (UF). When multiplied together, the resulting SQC may be very conservative.

For simplicity, it is assumed herein that wildlife receptors will have an applied AF of 75% (0.75) and humans an AF of 20% (0.2) (AEP, 2019; CCME, 2007) in derivation of the SQCOC.

The SQC normalized to organic content of the soil was calculated as:

Equation (4.6): Equation to derive the sediment quality criteria normalized to organic content of soil (SQC OC) using an applied allocation factor (AF) (AEP, 2019; CCME, 2007).

$$SQC_{OC} = \frac{ADI_{receptor} \times AF}{\sum(BAF^{Receptor}_{Trophic\ Level_x} \times \%diet)} \times 1,000 \times K_{OC} \times \frac{1kg}{1,000gOC} \tag{4.6}$$

Where:

SQC_{OC} = sediment quality criteria normalized to total organic carbon content (g • gOC)

$ADI_{receptor}$ = Acceptable Daily Intake for receptor (mg/kg)

AF = Allocation Factor (unitless)

$BAF^{Receptor}_{Trophic\ Level_x}$ = BAF for fish of specified trophic level (L/kg)

$\%diet$ = percent of fish from specified trophic level contribute to diet

$1,000$ = convert mg/L to g/L

K_{OC} = Organic carbon partitioning coefficient (L/kg)

Note, an AF does not apply when calculating a human based SQC for a carcinogenic chemical as the RsD already accounts for background exposure. Once the SQCOC has been calculated it can be adjusted (the SQC can be calculated) based on a site-specific TOC using standard equilibrium partitioning assumptions.

4.4 Results

4.4.1 Summary of North America Sediment Quality Guidelines

A summary table of available guidelines from regulatory agencies within North America is provided in Appendix A.5.

In Alberta, sediment quality guidelines were primarily adopted from the CCME (ISQG and PEL values) and the Ontario Ministry of the Environment and Energy (OMOEE). A select few chemicals were also sourced from Environment Canada (GoA, 2018). Values obtained from the OMOEE are listed separately and caution is recommended in their application as these values were derived over a limited geographic area (AEP 2018). The select few chemicals adopted from Environment Canada were calculated based on fish tissue guideline levels and the ratio of the contaminant in fish tissue compared to the concentrations found in sediment (i.e., biota-sediment accumulation factor (BSAF)) (Environment Canada, 2013).

The effects range approach (ERA), adopted by CCME and GOA (2018) in derivation of both the ISQG and PEL guidelines, was formulated to derive SQCs based on assessing the potential for various COPCs (as analyzed as part of National Status and Trends Program (NSTP)) to illicit adverse effects on sediment-dwelling organisms (CCME, 1995). This process involves numerous steps including the acquisition of co-occurrence data. This co-occurrence data (i.e., field-collected sediments that contain chemical mixtures) is maintained within Biological Effects Database for Sediment-associated contaminants (BEDS) [Long & Morgan (1990); Long (1992); Long & MacDonald (1992); MacDonald (1994); CCME (1995); Long et al. (1995)). Notably the CCME utilizes this methodology.

The BEDs is separated based on measured chemical concentration, location, analysis type (or approach), test duration, end point measured, species and life-stage tested, whether associated biological effects or no biological effects were observed, and the study reference. The data is separated into two specific datasets, one is created for effect data and the other is no effect. The effect dataset (E) relates to studies where an observed biological effect was associated with a measured chemical concentration. The no effects dataset (NE) comprises studies where there were nontoxic, without gradient, small gradient, or no-concordance. Only the effects data studies are used to generate SQCs.

Chemical concentrations between effects and no effects datasets overlap as different species and varying site conditions contribute to a range of concentrations where effects and no effects data are reported. For these reasons, the effects dataset is sorted in ascending order and specific percentiles are selected as an indicator of the likelihood for observation of an adverse effect.

Limitations in the CCME approach to developing sediment guidelines (adopted by GOA) are like those addressed under the OMOE (2008) approach which include lack of ability to establish dose-response relationships, absence of community structure consideration and limitations due to the geographical diversity of the studies used in matching chemistry and benthic invertebrate community structure for freshwater ecosystems.

Based on the paucity of data for chemical dose-response relationships, the fact that the BEDs database has not been revisited since the early 1990s, and a general lack of human health consideration, it was determined that derivation of sediment quality criteria for application in the Lower Athabasca Region would need to be developed.

In general, the CCME and GOA (2018) ISQGs and PELs do not meet the criteria for Indigenous water use protection from sediment associated contaminants.

4.4.2 Sediment Quality Criteria

A summary of adopted and derived SQCs for the protection of Indigenous water use protection goals including human health and carcinogenicity from exposure to bioaccumulative and persistent substances is provided in Table 3.9 along with a comparison to the provincial ISQGs [GoA (2018); CCME].

Detailed results of the WoE analysis are provided in Appendix A.5. An example of the results for arsenic are presented following Table 4.1, below.

Table 4.1: Risk based sediment quality criteria for the protection of Indigenous use.

Parameter	Alberta ISQG (mg/kg)	SQC (mg/kg)	Source
Metals			
Arsenic*	5.9	4.1	Quebec (DSEE)-REL
Cadmium	—	0.33	Quebec (DSEE)-REL
Chromium (total)	37.3	25	Quebec (DSEE)-REL
Copper	35.7	8.6	SST Benchmark Approach (Derived)
Lead	35	25	Quebec (DSEE)-REL
Manganese	—	460	Ontario (OMOE) LEL
Mercury	0.17	0.094	Quebec (DSEE)-REL
Molybdenum	—	718	SST Benchmark Approach (Derived)
Nickel	—	16	Ontario (OMOEE) - LEL
Selenium	2	2	Alberta ISQG
Silver	—	0.57	Washington WSDOE
Thallium	—	0.86	Health Canada (2020)
Uranium	—	0.594	SST Benchmark Approach (Derived)
Vanadium	—	125	SST Benchmark Approach (Derived)
Zinc	123	7.4	SST Benchmark Approach (Derived)
Polycyclic Aromatic Hydrocarbons			
Low MW PAHs	—	0.552	US EPA (OSWER)-ER-L
High MW PAHs	—	0.655	US EPA (Region IV - FDEP)-TEL
Total PAHs	—	1.684	US EPA (Region IV - FDEP)-TEL
Acenaphthene	0.00671	0.0037	Quebec (DSEE)-REL
Acenaphthylene	0.00587	0.0033	Quebec (DSEE)-REL
Anthracene	0.0469	0.0087	US DOE-EqP secondary
Benz[a]anthracene*	0.0317	0.0079	Derived EqP fish tissue, carcinogenicity
Benzo[a]pyrene*	0.0319	6e-04	Derived EqP fish tissue, carcinogenicity
Chrysene*	0.0571	0.079	Derived EqP fish tissue, carcinogenicity
Dibenz[a,h]anthracene*	—	0.00062	Derived EqP fish tissue, carcinogenicity
Fluoranthene	0.111	0.047	Quebec (DSEE)-REL
Fluorene	0.0212	0.01	Quebec (DSEE)-OEL
2-Methylnaphthalene	—	0.016	Quebec (DSEE)-REL
Naphthalene	—	0.017	Quebec (DSEE)-REL
Phenanthrene	—	0.025	Quebec (DSEE)-REL
Pyrene	—	0.029	Quebec (DSEE)-REL
Naphthenic acids	—	3.3	Derived (US EPA EqPA method)

Table 4.1: Risk based sediment quality criteria for the protection of Indigenous use.
(continued)

Parameter	Alberta ISQG (mg/kg)	SQC (mg/kg)	Source
Phenols	—	0.23	Derived EqP fish tissue tainting

Note:
Sum identified LMW PAH congeners (Anthracene, Acenapthene, Acenaphthylene, Fluoranthene, Fluorene,Naphthalene, Phenanthrene, Pyrene) (CCME (2010))
Sum of identified HMW PAH congeners (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene) (CCME (2010))
* Denotes carcinogenic substance

Arsenic

The SQC value of 4.1 mg/kg was adopted from Quebec (DSEE) REL for Arsenic.

Guideline Review

The literature review indicated that sediment guideline values for this chemical range from a low of 4.1 mg/kg (Quebec DSEE) to a high of 120 mg/kg (Washington DSE)).

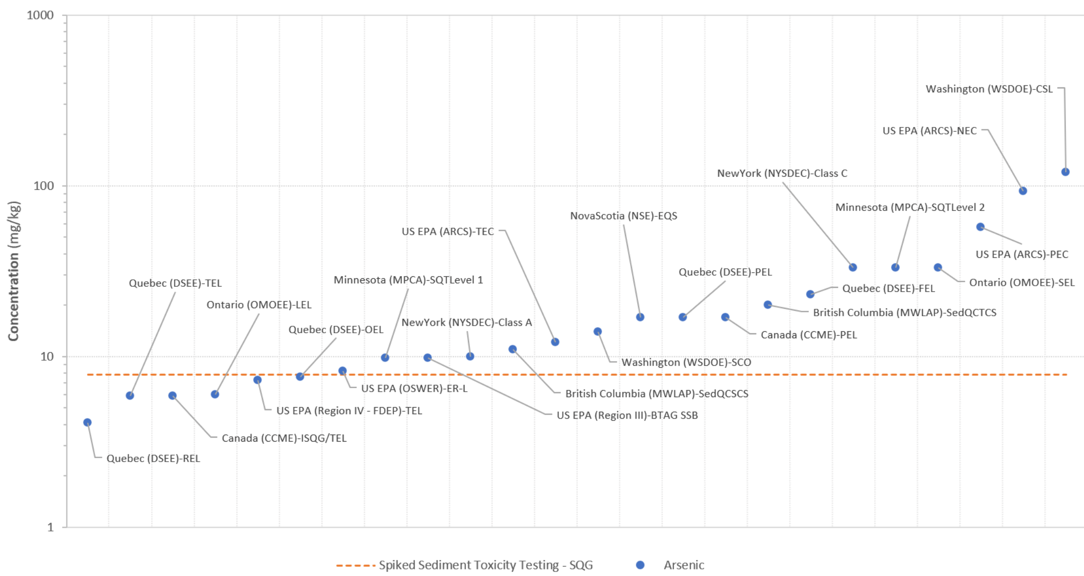

Figure 4.1: Distribution of sediment guideline values based on jurisdiction and associated guideline concentration (blue dots). The orange dashed line indicates a calculated value based on the CCME SST approach (7.8 mg/kg).

SSTT Derivation

Spiked sediment toxicity values obtained from the Society of Environmental Toxicology and Chemistry (SETAC) Sediment Advisory Group (SEDAG) database (Society of Environmental Toxicology and Chemistry Sediment Advisory Group (SETAC SEDAG), 2016) were used to estimate a SQC based on CCME guidance (1995). The lowest of the lowest observed effect concentration (LOEC) values (39 mg/kg; C. dilutes; survival and growth) was multiplied by an Uncertainty Factor (UF) of 0.2. The calculated value of 7.8 mg/kg is in close agreement with the OEL value (7.6 mg/kg) provided by DSEE (DSEE). However, the data used to derive this

SQC does not meet the minimum data-set requirements for derivation of a freshwater SQC for arsenic and confidence in this value is low.

Table 4.2: Spiked sediment toxicity testing results – Arsenic.

Test Species	Lifestage	Duration (Days)	Endpoint	Effect	Concentration	Units	OCNorm (g/g-OC)	TOC (%)	Citation
Chironomus dilutus	juvenile	10	survival	NOEC	39.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	NOEC	39.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LOEC	39.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LOEC	116.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC25	174.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	growth	LC50	342.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	NOEC	462.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	NOEC	462.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LC25	462.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LC50	462.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC25	521.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LC50	532.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC50	642.0	mg/kg		7.4	Liber et al. 2011
Chironomus dilutus	juvenile	10	survival	LC25	675.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	survival	LOEC	724.0	mg/kg		7.4	Liber et al. 2011
Hyalella azteca	juvenile	10	growth	LOEC	724.0	mg/kg		7.4	Liber et al. 2011
Derived guideline (LOEC*UF 0.2)					**7.8**	**mg/kg**			

Note:
NA - not applicable
NOEC - no observed effect concentration
LOEC - lowest observed effect concentration
LC25 - concentration lethal to 25
LC50 - concentration lethal to 50

Biomagnification Check

There were no biomagnification-based sediment quality guidelines identified. Sediment-to-benthic invertebrate bioconcentration factor reported by the US EPA (1999) is 0.9 (mg COPC / kg wet tissue per mg COPC / kg dry sediment). Arsenic appears to be bioaccumulated, through the ingestion of food, but is not biomagnified through food webs (Hepp et al., 2017).

A comparative check in consideration of the potential to cause adverse effect to either human or ecological (mammalian and avian) receptors was also conducted. An arbitrary screening concentration of 21 mg/kg for humans and 43 mg/kg for ecological receptors was identified. It is understood that these values are reflective of terrestrial receptors and terrestrial exposure scenarios (for which these guidelines were originally intended) but they are presented here as a simplified check function in an effort to evaluate whether further consideration of these exposure pathways is warranted. It is considered likely that protection of the aquatic receptors (benthic invertebrates) would inherently be protective of higher trophic organisms as well.

Derivation Summary

The results of screening existing guidelines, toxicity data and proposed SQC value (mg/kg against Toxicity and Benthos Alteration and Biomagnification Potential criteria are provided in Table 4.3, below.

Table 4.3: Arsenic WoE Evaluation

Screening Criteria	Proposed SQC value screening results
Toxicity Endpoints	Negligible: Reduction of 20% or less in all toxicological endpoints.
Overall Toxicity	Negligible: Minor toxicological effects observed in no more than one endpoint.
Benthos Alteration	“equivalent” to reference stations
Biomagnification Potential	Negligible: Chemical is unlikely to biomagnify

4.5 Discussion

Sediments provide substrates in which aquatic macrophytes root and grow and essential habitats for many sediment-dwelling invertebrates and benthic fish. The nutrients and contaminants in sediments nourish and are accumulated to varying degrees by aquatic macrophytes and benthic invertebrates. Importantly, sediments can also provide habitats for many wildlife species during portions of their life cycle and a variety of fish species utilize sediments for spawning and incubation of their eggs and larvae. The importance of sediment in the aquatic ecosystem is substantive and so must the assessment of potential risks from contamination of this substrate (MacDonald et al., 2003).

It has been reported that the use of the CCME ISQG values in establishing sediment benchmark concentrations are highly conservative, and their exceedance does not correlate with sediment toxicity (Nova Scotia Environment (NSE), 2014). For these reasons, a WoE approach to based on benthos alteration, toxicity, and bioaccumulation/ persistence potential was used to propose SQCs to meet sediment protection goals.

When regulatory sediment quality guidelines were not available, spiked sediment toxicity test data was used to derive a SQCs using CCME (1995) methods by applying a safety factor of 0.2 to the LOEC for that particular substance.

Within this WoE approach, available guidelines which offered the greatest level of protection were adopted as the SQC and proposed as the criteria for assessing sediment contamination and protection of Indigenous water use.

Generally, CCME and GOA (2018) ISQG and PEL values were higher than all other regulatory agencies with published sediment quality guidelines and could not be adopted as SQCs as they did not meet Indigenous protection goals for sediment quality (see Appendices 6 and 7).

Table 4.1 provides a summary of the SQCs which together with the Indigenous water use category specific criteria provide an ecosystem approach to assessing the quality of surface water bodies in the Lower Athabasca Region. The SQCs are intended for application to any substrate (i.e. treated tailings in contact with or used to create sediments) that is being used to construct a surface water closure feature including EPLs and wetlands.

Chapter 5

Community Traditional Food Survey

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5.1 Introduction

Consumption of traditional foods and medicines is essential for the health and wellbeing of Indigenous communities. These resources provide important nutrients and health benefits and offer a culturally-relevant way for community members to treat specific health conditions and maintain all aspects of their physical, mental and spiritual health (Kuhnlein & Turner, 1991). Consumption of traditional resources is essential for Indigenous communities to maintain a connection to the land and helps maintain community cohesion. Traditional foods and medicines are often shared with other family members and elders, promoting stronger social relationships within the community. Hunting, fishing, and gathering plants are also important practices for communities to exercise their rights as Indigenous peoples.

Chapter 5 describes the methods used for the Community Traditional Foods Consumption Survey with a discussion of demographic results, consumption preferences, and barriers to harvesting. The survey's primary role was to gather information from each of the participating Indigenous communities regarding the consumption patterns and ingestion rates for traditional foods and medicines.[1] The information collected was used to inform the risk-based analysis and modelling exercise, which was conducted to determine whether surface water and sediment quality thresholds for the protection of aquatic life (chronic and acute) are protective of

[1] Including medicines applied externally to the body (i.e., poultice).

receptors connected through feeding guild interactions or exposures to environmental media.

5.2 Objective

The survey objectives are to:

1. Develop a list of community-relevant receptors connected through feeding guild interactions or exposures to environmental media;
2. Identify representative community ingestion rates for traditional foods and medicines;
3. Identify community consumption preferences and barriers related to consumption of traditional foods and medicines.

5.3 Methods

The primary method for this component of the project focused on the design and delivery of a community survey. A survey is a "systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors (statistics) of the attributes of the larger population of which the entities are members," (Groves et al., 2009).

For this project, using a survey offers three key advantages. First, a survey offers versatility in its design and format and enables researchers to gather information directly from community members. Second, a survey involves the collection of responses from a representative portion of the community's population, meaning that findings can be generalized and applied to the broader population (i.e., the results are considered statistically representative of the population) (Palys, 1997). In this project, the collection of statistically representative results enabled the environmental scientist to analyze and calculate community members' ingestion rates of traditional foods and medicines for the three participating Indigenous communities and for different age groups and sex within each community. Third, a survey is an efficient way to collect detailed information from community members about traditional food consumption, and enabled the project team to compare and evaluate the survey findings against the Health Canada document Guidance for Evaluating Human Health Impacts in Environmental Assessment: Country Foods (Health Canada, 2018).

5.3.0.1 Survey design and implementation

Survey design and implementation consisted of four key elements, summarized below:

1. identify and prioritize receptors,

2. survey design,
3. planning and preparation, and
4. pilot and implementation.

The following sub-sections provide details of each element.

5.3.0.2 Identifying and prioritizing receptors

As noted above, information collected in the survey was used to inform the risk-based analysis and modelling exercise. This exercise was used to determine whether surface water and sediment quality thresholds for the protection of aquatic life (chronic and acute) are protective of receptors connected through feeding guild interactions or exposures to environmental media. Receptors are living organisms that could be adversely affected by environmental contaminations released and/or dispersed into the environment from an industrial site.

The first step in developing the survey was to identify and prioritize community relevant receptors, namely, plants and animals that are consumed as food or medicines by members of each community. To identify these receptors, a literature review regarding the consumption of traditional foods and medicines was conducted. Document searches were conducted within internal community databases and online using key words (e.g., Indigenous, ingestion, country foods, traditional foods, rates, consumption) to recover materials from government and organizational sources. Internal sources consisted of a traditional plants book, Indigenous knowledge interview transcripts, and community reports. During this step, a master list of 115 terrestrial and aquatic receptors known to be used by the communities for consumption and medicinal purposes was compiled.

Representatives from each community, along with support from the project technical team (social scientists [Integral Ecology Group Ltd.] and environmental scientists [Integrated Toxicology Solutions Ltd.]), reviewed the master list of receptors and underwent a process to group and prioritize the list of 115 receptors down to 35 receptors and receptor groups. Grouping and prioritizing was necessary to ensure the survey could be completed within each community with a reasonable amount of effort and time. Key steps for grouping and prioritizing the receptors included the following:

Ranking the receptors

The receptors were ranked in two ways to help prioritize receptors for including in the survey:

1. A frequency table depicting how many times a receptor was mentioned in the community

documents was compiled to understand how often a particular species was discussed in community documents. Receptors with more mentions ranked higher than receptors with ower mentions. Recognizing that concerns or community importance of a species cannot be fully assumed based on frequency information alone, we used the information as only a guide to estimate concerns and/or importance.

2. Available ingestion rates for receptors were reviewed in reports including the First Nations Food, Nutrition, and Environment Study by (Chan et al., 2016), and other internal community traditional foods studies. Receptors were prioritized if they were mentioned in more than three community documents, or if they were reported to be highly consumed in the region as traditional foods (i.e., with a high ingestion rate).

The results from these two ranking steps were compared and contrasted to develop a single prioritized list of receptors.

Removing terrestrial species

The technical team reviewed the list of priority receptors identified in the ranking exercise and removed a total of 31 terrestrial receptors, or plants and animals that are land-based and/or rely on water primarily for dietary purposes only. Some terrestrial receptors were not removed due to their importance in the community (e.g., moose). Examples of the terrestrial receptors removed at this stage include prickly rose/rose hip, blueberry, high-bush cranberry, pin cherry, and lynx.

Grouping closely related species into receptor groups

The technical team organized the list of priority receptors into individual receptors and receptor groups (i.e., groups of closely related species with similar diets). For example, two receptor groups were created for duck species, based on the differences in their diets. Grouping similar species with similar diets helped to reduce the overall number receptors included in the survey.

The prioritized list of receptors was reviewed by each community for feedback and verification. Community feedback resulted in the inclusion of new receptors (e.g., lily pads; *Nuphar variegata*) on the list and discussion about other receptors potentially less critical for the study. No receptors were removed at this stage. Following community review, we finalized a list of 35 aquatic receptors, capturing a total of approximately 79 species of mammals, fish, birds, and plants. This list was used as the basis for developing the community survey (see Table 5.1).

Table 5.1: List of the 35 community relevant receptors (including 79 species) for the survey. Note that this is not a comprehensive list of all of the receptors or species that are important to the MCFN, ACFN, or FMFN.

Receptor	List of species included in receptor
Fish and freshwater clams	
Ling cod (ling, maria, mariah, burbot, loche) or inconnu	Ling cod (ling, maria, mariah, burbot, loche) (*Lota lota*), inconnu (*Stenodus leucichthys*)
Whitefish or cisco	Mountain whitefish (*Prosopium williamsoni*), lake whitefish (*Coregonus clupeaformis*), cisco (*Coregonus zenithicus*)
Arctic grayling	Arctic grayling (*Thymallus arcticus*)
Trout	Rainbow trout (*Oncorhynchus mykiss*), lake (*char*) trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*), bull trout (*Salvelinus confluentus*), cutthroat trout (*Oncorhynchus clarki*), brown trout (*Salmo trutta*)
Sucker	White sucker (*Catostomus commersonii*), longnose sucker (*Catostomus catostomus*)
Goldeye	Goldeye (*Hiodon alosoides*)
Walleye (pickerel)	Walleye (pickerel) (*Sander vitreus*)
Great northern pike (jackfish)	Great northern pike (jackfish) (*Esox lucius*)
Freshwater clams[1]	May include[2] giant floater (*Anodonta grandis*), western floater (*Anodonta kennerlyi*), creek/brook heelsplitter (*Lasmigona compressa*), white heelsplitter (*Lasmigona complanate*), fat mucket (*Lampsilis siliquoidea*)
Mammals	
Caribou	Woodland caribou (*Rangifer tarandus*), barren caribou (*Rangifer tarandus groenlandicus*)
Moose	Moose (*Alces alces*)
Deer	White-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*)
Elk	Elk (*Cervus canadensis*)
Buffalo or wood bison	Buffalo or wood bison (*Bison bison*)
Bear	Black bear (*Ursus americanus*), grizzly bear (*Ursus arctos horribilis*)
Beaver	Beaver (*Castor canadensis*)
Muskrat	Muskrat (*Ondatra zibethicus*)
Rabbit or snowshoe hare	Rabbit or snowshoe hare (*Lepus americanus*)
Birds	
Duck, group 1	Mallard (*Anas platyrhynchos*), green-winged teal (*Anas carolinensis*), redhead (*Aythya americana*), ring-necked duck (*Aythya collaris*)
Duck, group 2	Lesser scaup (*Aythya affinis*), greater scaup (*Aythya marila*), canvasback (*Aythya valisineria*), goldeneye (*Bucephala clangula*), surf scoter (*Melanitta perspicillata*), white-winged scoter (*Melanitta fusca deglandi*), mud hen (*Fulica americana*), blue-winged teal (*Anis discors*), northern shoveler (*Anas clypeata*), northern pintail (*Anas acuta*), long-tailed (*Clangula hyemalis*), ruddy (*Oxyura jamaicensis*), Gadwall duck (*Mareca strepera*)
Goose	Greater white fronted goose (*Anser albifrons*), snow goose (wavy) (*Anser caerulescens*), Canada goose (*Branta canadensis*)
Swan	May include trumpeter swan (*Cygnus buccinator*), tundra swan (*Cygnus columbianus*)
Grouse	Blue grouse (*Dendragapus obscurus*), ruffed grouse (*Bonasa umbellus*), spruce grouse (*Falcipennis canadensis*), sharp-tailed grouse (*Tympanuchus phasianellus*), willow grouse (unknown)
Ptarmigan	May include willow ptarmigan (*Lagopus lagopus*), rock ptarmigan (*Lagopus mutus*)
Prairie chicken	Greater prairie chicken (*Tympanuchus cupido pinnatus*)
Plants	
Labrador tea	Labrador tea (*Rhododendron groenlandicum*)
Wild mint	Wild mint (*Mentha arvensis*)
Rat root	Rat root (*Acorus americanus*)
Black spruce	Black spruce (*Picea mariana*)
Bog cranberry	May include bog cranberry (*Vaccinium vitis-idaea*), small bog cranberry (*Vaccinium oxycoccos*)
Duckweed	Duckweed (*Lemna turionifera*)
Willow	May include red willow (*Cornus stolonifera*), sandbar willow (*Salix exigua*), Pacific willow (*Salix lucida ssp. lasiandra*)

Table 5.1: List of the 35 community relevant receptors (including 79 species) for the survey. Note that this is not a comprehensive list of all of the receptors or species that are important to the MCFN, ACFN, or FMFN. *(continued)*

Receptor	List of species included in receptor
Cattail	Cattail (*Typha latifolia*)
Fiddleheads	May include ostrich fern (*Metteuccia struthiopteris*), lady fern (*Athyrium filix-femina*), spinulose shield fern (*Dryopteris carthusiana*)
Lily pads (wild pineapple)	Lily pads (wild pineapple) (*Nuphar variegata*)

[1] Freshwater mussels are known locally by Indigenous communities in the Lower Athabasca region as freshwater clams Hopkins et al. (2019). The term "clams" was used in the survey as this is the preferred term among the participating communities.
[2] "May include" is used in the table to refer to species that were not listed in the survey questions. These species are thought to be consumed as traditional foods or medicines by community members.

5.3.0.3 Survey design

The project technical team worked closely with the communities to co-develop the survey questions. The majority of the survey consisted of questions about individual consumption patterns for the 35 receptors, including the frequency of consumption, which parts of the receptor are consumed (e.g. fat, meat/tissue, organs, leaves, flowers, stem, root, eggs), serving or portion size, and preparation methods (e.g., boiled/tea, fried, fresh/raw, baked, dried/smoked, put on skin). An optional set of questions focused on children's consumption patterns, intended for those participants responsible for providing traditional foods and medicines to children (ages 0- 18). The survey also covered other topics with relevance to the research questions, including: demographic characteristics, gender, age, changes in the availability of plants and wildlife, barriers to consuming traditional foods, consumption preferences, and the specific waterbodies where traditional foods are harvested within the lower Athabasca region. To achieve the objectives of this study, only demographic results, consumption preferences, and barriers to consumption are discussed (see Section 5.4).

The survey was designed using SoGo Survey[2], a secure online survey platform that offers survey design tools, multi-channel distribution, and analytics tools. The platform allows potential participants to complete the survey online via computer, tablet or smart phone. The survey included the full survey and once completed and submitted by the participant, responses are saved to an online database. The data collected is always owned by the respective communities. After the survey has been completed and it has been confirmed that all analysis is complete, the results of the survey have been removed from online servers and transferred to respective community servers to be stored and accessed by the community for future use.

Participant consent is an important component of ensuring participants are informed about

[2] https://www.sogosurvey.com/

the survey's purpose and how their information will be used. A consent letter and a community handout with information about the survey were developed to accompany the survey (see Appendix A.7). The community handout summarizes the purpose of the survey and reviews the approach for obtaining participant consent. A list of the survey receptors with pictures of key species was also included in the handout as a visual guide for participants completing the survey. The handout and consent letter were tailored for each community and shared with all participants prior to administering the survey. Before finalizing the survey and the accompanying materials (e.g., consent forms and community handouts) a final review was conducted by representatives of each community to ensure the survey questions aligned with community interests and protocols.

5.3.0.4 Planning and preparation

Survey planning and preparation was led by each community according to community-specific protocols for engaging their membership, guided by community leads, community researchers, and input from technical support. With COVID-19 restrictions making it difficult for researchers to meet face-to-face with participants, the research team planned that participants would either selected randomly by the community leads and community researchers or allowed to self-select to participate. Some of the communities identified that identifying participants was necessary due to facilitate access to members that might otherwise not have access to the survey especially with ongoing community and provincial COVID-19 restrictions. A selection criteria was developed to ensure the sample was randomized to the extent possible and that a broad sample of the community was selected. The selection criteria included the following:

- participant is a member of either ACFN, MCFN, or FMFN;
- participant is part of a diverse range of age groups and sexes; and
- participants are from different family groups represented within the community.

All community members had the opportunity to self-select and choose to participate in the survey online via a link provided through local community outlets (e.g. band office Facebook pages, local radio advertisements) or over the telephone via community researcher.

It was important for each community that participants were compensated for taking the time to complete the survey. Honoraria is provided for sharing knowledge and information and is a gift in a show of reciprocity. Honoraria were distributed to survey participants in accordance with protocols within each community. Two of the communities opted to distribute the honoraria as gift cards, while the other community issued payments to survey participants.

A target of approximately 100 surveys per community was set by the project team. This number was determined by communities to be reasonable given the scope of the project and anticipated efforts required by community leads and community researchers to implement the survey. To verify whether the three samples were representative of each community's population, an analysis of demographic results compared to community available profiles were calculated and allowed the researchers to make inferences about the community population.

To support implementation, community researchers were identified and selected by each community. These individuals were members of the participating Indigenous communities and actively participated in the project by attending planning meetings, delivering survey information materials, assisting with survey implementation, and making other planning and implementation related contributions. Remote training sessions with the community researchers were administered by the technical team and focused on interview protocols and survey delivery. The technical team also provided additional support to community researchers throughout the implementation of the survey.

5.3.0.5 Pilot and implementation

A pilot test of the survey was undertaken in late November and early December, 2020 as a first step in survey implementation. The survey pilot was completed by community leads and community researchers, and helped the project team identify inconsistencies, typographical errors, or technical glitches in the survey. Testing the survey with community researchers also helped these individuals gain a sense of familiarity with the online SoGo Survey platform and the flow of questions. Based on the feedback received, the survey was finalized by the research team.

Due to COVID-19 protocols and restrictions at the time when the surveys were being conducted and other restrictions (e.g., poor cellular data service, lack of computer connection or technological support), the research team determined that remote engagement with members was the best approach in order to keep everyone safe and reduce survey access barriers. The surveys were conducted using telephone and online survey methods (Fielding et al., 2008; Hayward et al., 2021; Wolf et al., 2016).

Most members have access to a telephone, and so one-on-one telephone interviews were conducted by the community researchers using a pre-selected randomized list of potential participants developed by the community. Prior to any one-on-one telephone survey, participants were provided with a paper copy of the community handout which included information about the survey and a consent letter to review and confirm within the survey or verbally with the interviewee. Using a computer, the community researchers accessed a web-based link to the survey and recorded responses via telephone on behalf of participating individual. The survey was implemented between mid-December, 2020 and mid-February, 2021.

Participants could also choose to complete the survey via an online link provided through local community outlets. We estimate that approximately 60 surveys were self-conducted via the online link distributed through community outlets.

To track survey progress, community researchers and community leads accessed a secure link to a Sogo Survey webpage with community-specific survey statistics. This link enabled these individuals to track participation rates within their community in real time for two primary purposes: (i) preparing progress updates about the survey for their department or band office, and (ii) creating a list of honoraria/gift card recipients.

5.3.1 Data Review and management

The raw survey data was compiled into a spreadsheet, stored on researcher computers, and reviewed for quality assurance and quality control by the technical support team. In some cases, narrative responses were converted into numerical values to assist with data analysis. For example, if a survey participant indicated they consumed whitefish "every two months in a year," this response was converted to the value of 6 (12/2=6). In addition, community researchers worked with their membership to develop a list of the approximate average weights for the certain traditional foods noted by participants in the survey (e.g., moose heart, burbot liver, duck gizzard). Again, these descriptive responses were replaced with numerical average weight values where possible. When the data review was complete.

5.3.1.1 Limitations

While the data was being reviewed, the social scientists noticed inconsistencies in the responses to the sub-set questions regarding children's consumption of traditional foods. It was determined that a technical glitch with the Sogo Survey platform was incorrectly recording responses on children consumption questions. This ultimately led to the loss of children consumption data. Once the technical glitch was resolved, the team was able to collect responses for a total of 18 children.

5.3.1.2 Analysis

Data collected by the survey resulted in detailed information about community ingestion rates of traditional foods and medicines, demographic information, and community context that inform community consumption. Ingestion data was analyzed to inform the risk-based analysis and modelling exercise to determine whether surface water and sediment quality thresholds for the protection of aquatic life (chronic and acute) are protective of receptors connected through feeding guild interactions or exposures to environmental media.

Analysis of demographic data and community context information was conducted to better understand the demographic characteristics of survey participants (such as community, age and sex), and to examine key traditional food consumption patterns, including whether members consumed traditional foods in the past year; community preferences for consuming traditional foods; how many members provide traditional foods and medicines to children; and identified barriers to harvesting more traditional foods and medicines.

5.4 Results and Discussion

5.4.1 Demographic results

The survey was implemented between mid-December 2020 and mid-February 2021 and a total of 247 surveys (n=247) were completed by members of the three communities. Approximately 43% of the surveys were completed by members of Athabasca Chipewyan First Nation, 33% were completed by Mikisew Cree First Nation members, and 23% were completed by members of Fort McKay First Nation (see Table 5.2).

Table 5.2: Community survey participation by percentage (n=247).

Indigenous community	Percent
Athabasca Chipewyan First Nation	43%
Fort McKay First Nation	23%
Mikisew Cree First Nation	33%

The survey was completed by community members representing different sexes. In total, 58% of the participants were female, 42% were male, and 0.4% identified as “other” (n=247). Compared to community profiles available for each community, there is a possible gender bias in responses. The reported proportion of female and male across all three communities is 50% compared to 58% female participants surveyed (Indigenous and Northern Affairs Canada, 2016).

The survey was completed by community members within four age groups (see Table 5.3). Participants in the 51 and over age group represent the largest sub-set of survey participants (48%), followed by participants between 31 and 50 years (29%), and participants between 18 and 30 years (13%). The fewest number of surveys (9%) were completed for children under 18 years (see Section 5.3). Compared to community profiles available for each community, there is a possible bias to persons over 51 years old. The reported proportion of persons 0-19 is 36%, persons 20-64 years old is 56%, and over 65 years old is 9%. (Indigenous and Northern Affairs Canada, 2016). Survey participation by sex and age group was as follows: participants in the 51 and over age group were comprised of 29% female, 19% male, and 0.4% other; participants between 31 and 50 years were comprised of 15% female and 14% male; participants between 18 and 30 years were comprised of 8% female and 5% male; and children under 18 were comprised of 5% female and 5% male individuals.

Table 5.3: Survey participation by age group and sex.

Sex	Under 18 years	18 - 30 years	31 - 50 years	51 years and over
Female	4.9%	8.1%	15.4%	29.1%
Male	4.5%	5.3%	13.8%	18.6%
Other	0.0%	0.0%	0.0%	0.4%
Total	9.3%	13.4%	29.1%	48.2%

5.4.2 Results overview: Community context

The following sub-sections summarize results of the survey regarding consumption of traditional foods and medicines, current and desired future consumption of traditional foods and medicines, providing traditional foods and medicines to children, and barriers to consuming traditional foods and medicines. It is important to note that the findings are presented across the three participating communities and therefore may not align with community-specific results. The results should also not be considered representative of a specific community, the results are representative of all three communities' perspectives and concerns combined.

5.4.2.1 Consumption of traditional foods in the past year

In the past year, 88% of survey participants have eaten or used traditional foods or medicines from the Athabasca River, Peace-Athabasca Delta, Lake Athabasca, or other waterbodies in the surrounding region (n=247; see Table 5.4).

Participants in the 51 years and over and under 18 years age groups represent the largest percentage of individuals who have consumed traditional foods or medicines from within the Athabasca River area (92%, n=119 and 91%, n=23), followed by participants between 31 and 50 years (86%, n=72), and participants between 18 and 30 years (76%, n=33). However, due to the reduced number of survey responses collected for children (n=23), this value (91%) may not be representative of the under 18 years age group. Ultimately, these results highlight that traditional foods and medicines are important and widely consumed by survey participants within the study area in the past year.

Table 5.4: Percentage of participants who have consumed traditional foods or used traditional medicines in the past year from the Athabasca River, Peace-Athabasca Delta, Lake Athabasca, or other waterbodies in the surrounding region, by age group and sex.

	Under 18 years (n = 23)		18 - 30 years (n = 33)		31 - 50 years (n = 72)		51 years and over (n = 119)	
Sex	Yes	No	Yes	No	Yes	No	Yes	No
Female	48%	4%	45%	15%	43%	10%	54%	7%
Male	43%	4%	30%	9%	43%	4%	37%	2%
Other	0%	0%	0%	0%	0%	0%	1%	0%
Total	91%	9%	76%	24%	86%	14%	92%	9%

5.4.2.2 Preferences for consuming traditional foods

The majority of participants would like to consume more traditional foods than they currently do across most receptor groups (see Table 5.5). The results suggest that 63% of participants would like to consume more mammals, 54% would like to consume more birds, and 51% of participants indicated they would like to consume more fish and freshwater clams. A slightly smaller percentage of participants (49%) indicated they would like to consume more traditional plants than they currently do. Overall, these results suggest there is a high level of interest among survey participants to consume more traditional foods than they did in the past year.

Table 5.5: Percentage of participants who would like to consume more traditional foods than they currently do, by receptor group

	Fish and freshwater clams (n = 220)	Mammals (n = 225)	Birds (n = 219)	Plants (n = 217)
Yes	51%	63%	54%	49%
No	49%	37%	46%	51%

5.4.2.3 Providing traditional foods and medicines to children

A total of 26% of survey participants indicated they are responsible for providing traditional foods or medicines to children under the age of 18 (n=199). Given that just over one quarter of survey participants are responsible for providing traditional foods and medicines to children, this suggests the importance of capturing younger demographics consumption information to ensure their consumption patterns are reflected in determining water quality thresholds for the protection of exposures to environmental media.

5.4.2.4 Barriers to harvesting more traditional foods and medicines

Participants identified numerous barriers that prevent them from harvesting more traditional foods and medicines than they currently do (Table 5.6). Fear that a resource may be contaminated was the most commonly identified barrier, which was reported by participants 224 times or an average of 24% across the four primary receptor groups (i.e., fish, mammals, birds, plants). The barrier that traditional resources are located too far away was indicated by participants 122 times or an average of 13% across the four primary receptor groups, and a lack of tools or equipment was indicated as a major barrier a total of 119 times or reported an average of 13% across the four primary receptor groups. Additional barriers frequently expressed by participants included (average percentage across receptor groups): changes to water levels (13%),[3] restricted access to harvesting areas (11%), lack of connection to a harvester (11%), lack of knowledge of where or how to harvest (11%), lack of transportation (10%), lack of time (8%), concerns that traditional resources are diseased or unhealthy (7%), cost (3%), decreases in plant or animal populations (2%), lack of experience (1%), medical conditions (1%), being an elder or too old to harvest (1%), as well as several others (10%).[4]

These results may not be comprehensive and likely do not capture all of barriers that prevent community members from harvesting traditional foods. However, they do suggest that survey participants want to consume more traditional foods and medicines and as a result estimated consumption patterns of traditional foods may be an underestimate if barriers are reduced.

[3] Participants indicated to community researchers that flooding this past year was particularly prohibitive for harvesting traditional foods and medicines.

[4] The 'other' category includes additional barriers identified to a lesser extent (indicated less than 10 times or 1%) by participants included: impacts of wildfires; changes in weather patterns; species migrating to different areas; difficulty finding traditional resources; changes in the taste of traditional resources; impacts of invasive plants; COVID-19-related restrictions; that it is unsafe to travel; that traditional foods are not being provided by the community; being a new member of the community.

Table 5.6: Percentage of participants that identified barriers to harvesting more traditional foods or medicines than they currently do.

Barrier to harvesting more traditional foods and medicines	Fish and freshwater clams	Mammals	Traditional birds	Traditional plants	Average percentage across primary receptor groups
Cost	3%	4%	4%	1%	3%
Lack of tools or equipment	12%	18%	14%	8%	13%
Lack of knowledge of where or how to harvest	10%	10%	8%	14%	11%
Too far away	11%	16%	15%	10%	13%
Fear of contamination	30%	28%	22%	18%	24%
Species appear diseased or unhealthy	8%	9%	5%	5%	7%
Lack of connection to a harvester	10%	14%	10%	10%	11%
Medical condition	2%	1%	1%	1%	1%
Lack of transportation	10%	13%	10%	7%	10%
Restricted access to harvesting areas	8%	15%	14%	9%	11%
Lack of time	7%	8%	7%	8%	8%
Changes to water levels	14%	14%	11%	11%	13%
Lack of experience	1%	1%	2%	2%	1%
Decrease in plant or animal populations	0%	5%	3%	1%	2%
Age related limitations	1%	1%	1%	0%	1%
Other	9%	12%	8%	12%	10%

Appendix A

Linked Appendices

A.1 Data Catalogue

Data Catalogue – Water and sediment quality data compilation

https://purl.archive.org/wqciu/wqciu_c2a1.pdf

A.2 Current condition target supplemental information

Current conditions – Additional information

https://purl.archive.org/wqciu/wqciu_c2a2.pdf

A.3 Summary of Available Surface Water Quality Guidelines

Summary of Available Surface Water Quality Guidelines

https://purl.archive.org/wqciu/wqciu_c3a1.pdf

A.4 Input Parameters for Derivation of Water Quality Criteria for Indigenous Use Protection

Input Parameters for Derivation of Water Quality Criteria

https://purl.archive.org/wqciu/wqciu_c3a2.pdf

A.5 Summary of Sediment Quality Guidelines from North America

Summary of Sediment Quality Guidelines from North America

https://purl.archive.org/wqciu/wqciu_c4a1.pdf

A.6 Derivation of Sediment Quality Criteria for Indigenous Use Protection

Derivation of Sediment Quality Criteria for Proteciton of Indigenous Water Use

https://purl.archive.org/wqciu/wqciu_c4a2.pdf

A.7 Consumptive Use Survey Handout

Consumptive Use Survey Handout

https://purl.archive.org/wqciu/wqciu_c5a1.pdf

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