Summary of enhanced monitoring of the Lower Athabasca River 2018

A third party Science Report commissioned by the Office of the Chief Scientist

Alberta
Environment and Parks
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Summary of enhanced monitoring of the Lower Athabasca River, 2018

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Alberta’s Environmental Science Program

The Chief Scientist has a legislated responsibility for developing and implementing Alberta’s environmental science program for monitoring, evaluation and reporting on the condition of the environment in Alberta. The program seeks to meet the environmental information needs of multiple users in order to inform policy and decision-making processes. Two independent advisory panels, the Science Advisory Panel and the Indigenous Wisdom Advisory Panel, periodically review the integrity of the program and provide strategic advice on the respectful braiding of Indigenous Knowledge with conventional scientific knowledge.

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- *Scientific Integrity.* Standards, professional values, and practices of the scientific community are adopted to produce objective and reproducible investigations.
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The Chief Scientist, Alberta Environment and Parks, provides scientific oversight for the provincial environmental science program, which includes commissioning of scientific technical reports to inform Alberta Environment and Parks. Commissioning of third party technical reports is intended to fill gaps in current knowledge as part of building a credible and reliable body of knowledge which stands up to the scrutiny of the experts in a particular field of science and can be trusted to inform policy and management actions.

Upon request from the Minister, the Science Advisory Panel, the Department, or if the Chief Scientist deems it necessary, the Office of the Chief Scientist will engage independent expertise to undertake work to develop technical reports. The Office of the Chief Scientist acts as a neutral broker to bring together relevant experts from across scientific and Indigenous knowledge systems to evaluate, review and recommend improvements to the scientific foundations of ongoing science and monitoring programs or issue-focused applied research or monitoring activities. In upholding the principles of the environmental monitoring and science program, with the aim of building public trust in the credibility of scientific inputs to evidence-informed decision making processes, all third-party scientific reports will be publically available.

The Oil Sands Process Affected Water Science Team

Formation, role and structure

The Oil Sands Process Affected Water (OSPW) Science Team was formed in January 2018 by the Chief Scientist, Alberta Environment and Parks. The OSPW Science Team was established to provide independent, credible scientific information regarding the potential release of treated oil sands process water to the Lower Athabasca River by Syncrude Canada as part of its evaluation of a coke-slurry water treatment process. This information is intended to inform decision-making processes of government regulatory bodies (i.e., Alberta Energy Regulatory, Alberta Environment and Parks, Environment and Climate Change Canada). For the purpose of the Science Team work and the evaluation of the Syncrude proposal, OSPW is defined as water in tailings ponds that is recycled internally as a part of bitumen extraction process and for material transport including ore and tailings solids.

The OSPW Science Team is tasked with providing scientific information on **three focal areas** of work:

1. **Determining the toxicity of OSPW treated using Syncrude's coke-slurry treatment process.** This includes identifying relevant biological and ecological endpoints for toxicity testing as well as the specific details related to concentrations and exposure durations to quantify both acute and chronic toxicity. Endpoints used in toxicity testing includes those that reflect standardized testing plus those of value to Indigenous communities.
2. **Creating an enhanced environmental monitoring system for a focal reach of the Lower Athabasca River**. The design will build on Provincial and Federal designs and decision criteria, and incorporate culturally and locally relevant criteria based on Traditional Ecological Knowledge. The design will ensure a sufficient understanding and characterization of the baseline environmental conditions.
3. **Designing the requirements, parameters and conditions required for a quantitative modeling assessment of environmental impacts and a human ecological health risk assessment to evaluate and predict the effects of the release of treated OSPW to the Athabasca River**. The prediction system must address projections of the environmental fate and distribution of discharged compounds, potential cumulative effects on riverine water quality and ecosystem structure and function, and implications for human health.

For each of the three focal areas the OSPW Science Team will:

1. create study designs that will be integrated into work plans,
2. oversee the deployment of the work plans, and
3. provide and communicate findings to key stakeholders and government decision-makers.

The OSPW Science Team includes technical experts from academia, industry, Alberta Environment and Parks, the Alberta Energy Regulator (AER), Environment and Climate Change Canada (ECCC) and holders of Indigenous and local knowledge. The work of the OSPW Science team also supports efforts of the Integrated Water Management Working Group, a multi-stakeholder working group with representatives from industry, Indigenous Peoples, Environmental Non-Governmental Organizations, and Federal, Provincial and Municipal governments. The Integrated Water Management Working Group provides advice to Alberta Environment and Parks on water management issues for the oil sands sector, including the potential for the release of oil sands process affected water, as outlined in Alberta's Tailings Management Framework.

OSPW Science Report 3 – Summary of enhanced monitoring of the Lower Athabasca River 2018.

The following technical report summarizes enhanced monitoring of Lower Athabasca River in fall 2018. It describes monitoring of surface water quality, benthic sediments and algae, benthic macroinvertebrates, fish health and fish community structure, and efforts to support community based monitoring in the Peace Athabasca Delta. The sampling design builds on existing monitoring efforts by the Oil Sands Monitoring Program and includes sampling of new endpoints and approaches at several sites located downstream of Fort McMurray that had not previously been monitored. The report also identifies a few departures from the original sampling design and the rationale for these changes, and challenges and learnings from the first year of work. This work is foundational for the two additional focal areas related to quantifying the toxicity of coke-slurry treated OSPW and predictive modeling to assess potential effects on the environment and on human health, should a short-term trial release of treated OSPW be approved.

The sampling design deployed in 2018 was identified by the OSPW Science Team and are accompanied with the following context as requested by Mikisew Cree First Nation, Fort McKay First Nation and Fort McKay Metis Community Association.

NOTICE

This document and material is provided by the Oil Sands Process Water Science Team for general information purposes only. The Oil Sands Process Water Science Team (OSPWST) is comprised of representatives of the Government of Alberta, Government of Canada, industry, academia, Mikisew Cree First Nation, Fort McKay First Nation and Fort McKay Metis Community Association. The information contained in this document may include views, opinions and recommendations of representatives of the OSPWST for the sole purpose of facilitating the work of the OSPWST. The information is not intended to provide the views, opinions, recommendations, endorsement or approval by either Mikisew Cree First Nation, Fort McKay First Nation or Fort McKay Metis Community Association of the release of oil sands process water. Further, take note that Mikisew Cree First Nation is opposed to the untreated release of process affected water that furthers the risk to the Peace Athabasca Delta and the community of Fort Chipewyan. Partially treated OSPW like the stream in the Syncrude Pilot application is not considered treated by MCFN.

Summary of enhanced monitoring of the Lower Athabasca River 2018-2019

Prepared for:

Oil Sand Monitoring Secretariat and the

Oil Sands Process Affected Water Science Team

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EXECUTIVE SUMMARY

This document summarizes the work completed for the enhanced monitoring program for the 2018-2019 fiscal year. The objective of this program is to describe baseline environmental conditions prior to the potential release of coke-slurry-treated oil sands process affected water (OSPW) to the Lower Athabasca River. The enhanced monitoring study design was built through i) integration and augmentation of sampling at existing monitoring sites deployed through the Oil Sands Monitoring (OSM) program and ii) supplemental sampling at new monitoring sites. Existing and new monitoring sites are located at sites upstream and downstream of the proposed site where treated OSPW could be discharged to the Lower Athabasca River. Baseline environmental variables include surface water chemistry, benthic sediments, benthic algae, benthic macroinvertebrates, small-bodied fish health, and fish communities. Endpoints of relevance to Indigenous peoples were also addressed in the study design. The enhanced monitoring program also includes community-based monitoring activities in the Peace-Athabasca-Delta. The proposed study design was circulated to and approved by the OSPW Science Team in July 2018. The program was deployed between August and October 2018.

The full program was delivered with relatively few deviations from what was originally proposed. These deviations, which are detailed in this report, do not affect the outcome or quality of this work. Challenges and lessons learned are also addressed in this report. These were primarily related to sampling benthic macroinvertebrates in challenging habitats that are not routinely sampled in core OSM programs. Additional lessons learned address potential confounding factors that should be addressed in future study designs. Data that has been generated from this program to date includes surface water quality, sediment quality, fish health endpoints, and fish communities. These data are provided in appendices at the end of this report. All data generated through this program will be reviewed by the OSPW Science Team data analysis subgroup.

1 BACKGROUND AND CONTEXT

In support of wastewater reuse and fresh water conservation, the Government of Alberta has historically adhered to a zero discharge policy relating to the release of process-affected water from mineable oil sands operations to the receiving environment. However, current policy does allow for the possible release of process affected water if a treatment technology can be demonstrated, through pilot studies, to effectively treat water and thus if released would not result in adverse environmental effects. Pilot studies to inform a decision on the potential release of treated oil sands process affected water (OSPW) needs to be conducted in specific ways to achieve specific outcomes.

Syncrude Canada has developed a coke slurry technology that may be capable of treating OSPW (Zubot et al., 2012) such that it would not create unacceptable impacts if it were released into the Lower Athabasca River (LAR). Syncrude is establishing a medium-scale treatment facility (ca. 10 ha in size) to assess the efficacy of this OSPW treatment technology. Smaller scale assessments of the coke-slurry technology have shown that it is capable of reducing concentrations of several components of OSPW.

The application by Syncrude Canada to test the efficacy of its coke-slurry OSPW treatment technology resulted in the formation of the OSPW Science Team who were asked to fill key information gaps. These efforts support the larger OSPW Pilot Study that would inform a policy decision on the potential release of treated OSPW to the receiving environment (i.e., the Lower Athabasca River). The OSPW Pilot Study has been divided conceptually into three phases: Phase I – planning, Phase II- closed circuit testing of the toxicity of coke-slurry treated OSPW, and depending on the results of toxicity studies, Phase III –short- term open-circuit release of coke slurry treated OSPW to the Lower Athabasca River.

The decision by the Government of Alberta to allow a short-term release of treated OSPW to the Lower Athabasca River requires filling of key information gaps. The three key information gaps presented to the OSPW Science Team are:

1) Assessing the acute and chronic toxicity of treated OSPW
2) Predicting potential environmental effects under different release scenarios
3) Conducting enhanced monitoring in the Lower Athabasca River

The third component, enhanced monitoring of the Lower Athabasca River, establishes baseline environmental conditions prior to the potential release of treated OSPW and is one of three information needs that are required to inform the decision to transition from Phase II to Phase III. The remaining information needs are related to the toxicity studies and predictive modelling. The ability to detect an effect of the release of treated OSPW requires detailed information on the physical, chemical and biological characteristics of the river prior to possible release.

The primary objective of this program is to establish baseline conditions across multiple physical-chemical parameters and ecological indicators in the Lower Athabasca River prior to the possible release of treated OSPW. The specific objectives for year 1 of the program include i) design and deploy enhanced monitoring at multiple upstream and downstream sites of the possible discharge site and ii) identify chemical and biological endpoints of relevance from a classical science perspective and those of importance to Indigenous peoples. The information collected from the baseline data will be used to address these two key questions:

1) What is the spatial and temporal variation in water and sediment physio-chemistry, and aquatic life at sites upstream and downstream of the potential release site;
2) Giver inherent variance, what sampling intensities are required to be able to detect impacts should they occur

This work was reviewed and overseen by the Oil Sands Process Affected Water Science Team created by the Alberta Environment and Parks' Chief Scientist. This team is composed of multiple stakeholders including three Indigenous communities, federal and provincial government, industry, and consultants.

2 OVERVIEW OF THE PROGRAM STUDY DESIGN

The design of the enhanced monitoring program addressed the following gaps:

- Spatial sampling design elements (reference and potential exposure sites)
- Endpoint selection (e.g., surface water chemistry, benthic sediment chemistry, benthic invertebrates, fish, and endpoints of relevance to Indigenous communities)
- Temporal sampling design elements (seasons and frequency of monitoring)
- Standard operating procedures (sampling methodology, replication, QA/QC)

It is important to note, that the study design recognizes existing monitoring programs on the Lower Athabasca River, and these programs are considered to avoid redundancies, ensure consistency in protocols and methods, and to coordinate efforts. The following OSM programs were considered in the design of the enhanced monitoring program:

- Surface Water Quality Monitoring
- Biodiversity Monitoring of Benthic Macroinvertebrates
- Fish Health Monitoring
- Monitoring Fish Communities

These existing programs were integrated with the enhanced monitoring program including ongoing (or discontinued) sites and endpoints of interest. This program will also utilize historical data already available and new data being generated on baseline conditions. A summary of the available data is provided in Appendix A.

The general spatial design element of the study is a gradient design with relatively short distances between sampling sites located immediately upstream and downstream of the potential discharge site with increasing distances between sites at greater distances from the discharge site. The design established four sites upstream and 12 sites downstream, and is often a mix of new and existing sites from other OSM monitoring programs, depending on the endpoint. The study was deployed in August to October 2018, and includes the following main categories of endpoints selected for this study:

i) Surface water quality
ii) Structure of benthic macroinvertebrates combined with supporting environmental information (sediment quality, habitat, and benthic algae)
iii) Fish health and fish communities

The proposal for this study was circulated, presented, and approved by the OSPW Science Team in Calgary, July 4-5, 2018. This report presents the outcomes of year one of the study, including a breakdown of activities completed in 2018 for each of the major categories of endpoints and includes the spatial and temporal design elements and standard operating procedures. This is followed by any deviations from the original proposal and also what was learned in 2018, including any major challenges. Data that is currently available for any of the categories is provided in appendix B-D.

3 ACTIVITIES COMPLETED IN 2018

3.1 Surface Water Quality

Spatial Design

The enhanced monitoring design for surface water quality comprised of 12 new sites in the Lower Athabasca River. Four sites were located between 0.03 km and 12 km upstream of the proposed site where treated OSPW could be released and at eight sites located between 0.03 km and 12 km downstream of the proposed release site (Figure 1). Two existing sites that are part of the OSM surface water quality monitoring program are located 25 km upstream (M3) and 34 km downstream (M7) of the proposed treated OSPW discharge. These sites are long-term monitoring sites with multiple years of historical data and these data will be integrated into the full program.

The focus of sampling was in the thalweg (deepest part of the river channel) where effluent is expected to be fully mixed within river flow. The exception to this is the nearfield sites, which were sampled closer to the west or east banks (Figure 1). At 0.5 km and 1.5 km downstream, there is an island with a channel on the west side. Depending on seasonal/annual flows, water may or may not be flowing through this channel. As a result, water quality stations were installed on both the east side (main channel) and west side (side channels) at both the upstream end (0.5 km) and downstream end (1.5 km) of the island (Figure 1).

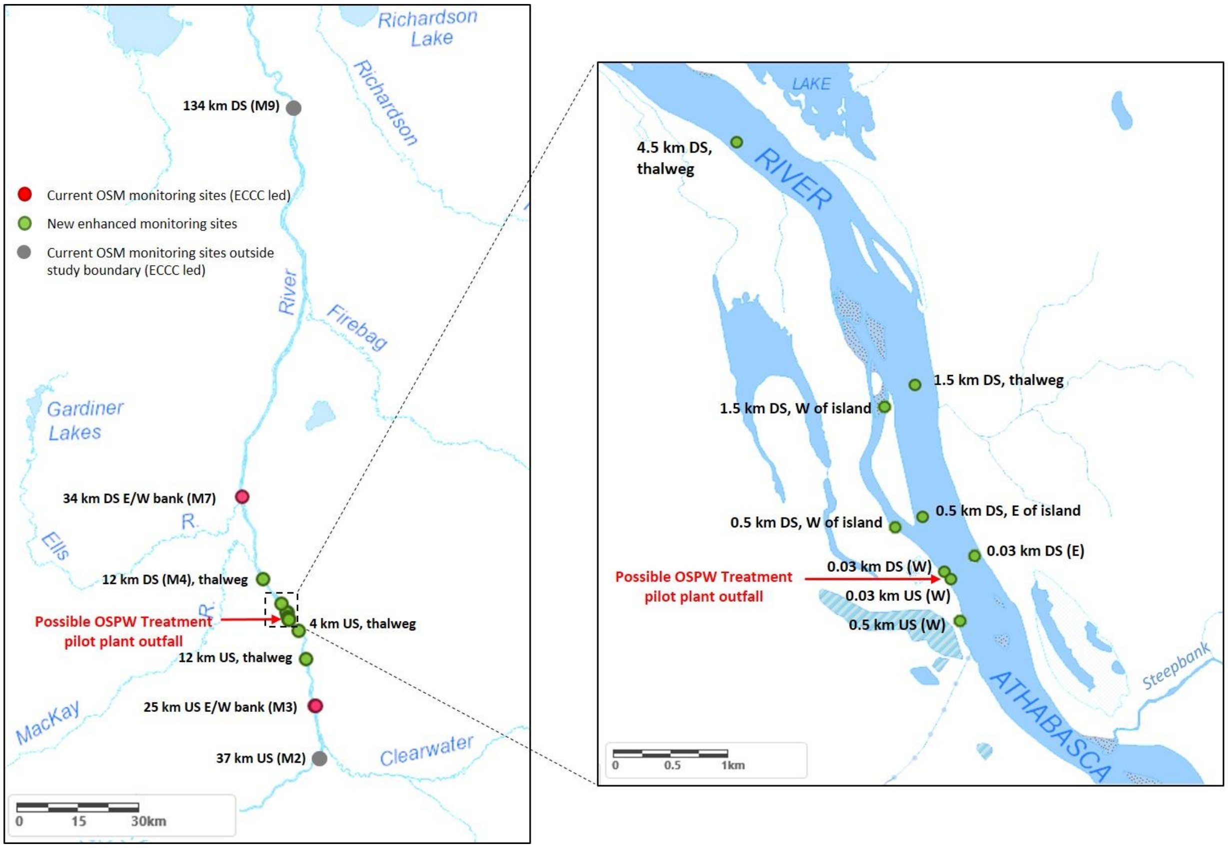

Figure 1. Enhanced monitoring of surface water in the Lower Athabasca River comprises new surface water quality sites (green) located upstream and downstream of the proposed treated OSPW discharge and existing OSM water quality monitoring sites (red). Grey sites are existing OSM water quality monitoring sites that are outside the study boundary. W = west, E = east.

Enhanced monitoring of benthic macroinvertebrates in the Lower Athabasca River. New enhanced sites (green) are all located on the west bank (both upstream and downstream of the proposed treated OSPW discharge) and make up habitats with either fine sediments or sand. Existing OSM benthic monitoring sites in red are located on the east bank in cobble habitats. Grey sites are existing OSM benthic monitoring sites that are outside the study boundary.

Endpoints

Surface water quality was assessed using three sampling methodologies including a single depth-integrated water quality grab samples, continuous monitoring (auto-monitoring) sondes, and passive sampling devices called semi-permeable membrane devices (SPMD). The parameters measured for each of these collection methods are provided in Table 1.

Water quality grab samples, using a single depth-integrated sample (Cooke et al., 2018), were collected at all 12 new enhanced monitoring sites (Table 2). Samples were analyzed for a series of inorganic, organic, and nutrient fractions (Table 1). Existing Oil Sand Monitoring (OSM) program sites (M3 and M7) also collected water quality grab samples measuring nearly all the same parameters as those in Table 1, with the exception of total phenols and naphthenic acids.

Sondes were deployed at a reduced number of sites due to limits on equipment availability. They were deployed at nine new sites that fall closest to the potential treated OSPW discharge (two upstream sites and seven downstream sites; Table 2). The sondes will provide semi-continuous measurements of pH, oxidizing or reducing potential, temperature, dissolved oxygen, conductivity, turbidity. Existing Oil Sand Monitoring (OSM) program sites (M3 and M7) did not have sondes for measuring continuous monitoring variables in 2018.

Semi-permeable membrane devices (SPMD's) were deployed at all sites during open water season to measure dissolved parent and alkylated PAHs (Table 2; Cooke et al., 2018). This includes the existing Oil Sand Monitoring (OSM) program sites (M3 and M7). SPMDs are passive sampling devices used to monitor trace levels of organic compounds with log KOW >3.

Table 1. Surface water quality parameters measured in the enhanced monitoring program

Collection Method	Major Category	Specific Parameters
Auto-monitoring variables		pH/ORP, temperature, dissolved oxygen, conductivity, turbidity
Depth integrated samples	Major ions	Hardness, ion balance, Ca[1], Cl, Fe[1], CO_3, OH, Mn[1], Mg[1], alkalinity, pH, K[1], Na[1], TDS, TSS, silica, true colour, sulphate
	Nutrients and carbon	DOC, TOC, total/dissolved P, NO_2, NO_3, dissolved/total KN, TN, ammonia
	Total and dissolved metals	Al, Sb, As, Ba, Be, Bi, B, Cd, Cl, Cr, Co, Cu, Fe, Pb, Li, Mg, Mo, Ni, Se, Ag, Sr, TI, Th, Sn, Ti, U, V, Zn
	Organics	Parent and alkylated PAHs, BTX, CCME fractions (F1-F4), naphthenic acids, total phenols, Hg/MeHg
Semi-permeable membrane device	Organics	Dissolved parent and alkylated PAHs

[1]dissolved

Table 2. Surface water quality sites and corresponding variables measured in August-October 2018 as part of the enhanced monitoring program for the Lower Athabasca River. Under the OSM surface water quality program (lead by ECCC) regular scheduled water quality sampling takes place at M3 and M7, these sites are shaded. The rest of the sites are new enhanced monitoring sites. Site distances denoted with negative and positive signs are located upstream and downstream of the potential treated OSPW discharge site, respectively. [1]Parameters sampled at M3 and M7 are similar to those measured at the new enhanced monitoring sites, but exclude total phenols and naphthenic acid. SPMD = semi-permeable membrane device, PAH = polycyclic aromatic hydrocarbons.

Site type		Placement of sample	Depth-integrated sample				Continuous monitoring variables (Sonde)	SPMDs[4]
	Distance (km) U/S or D/S of the proposed OSPW discharge		Major ions	Nutrients and carbon	Metals	Organics		Dissolved PAHs
U/S Sites	-25 (M3)[1]	Thalweg	✓	✓	✓	✓		✓
	-12	Thalweg	✓	✓	✓	✓		✓
	-4.0	Thalweg	✓	✓	✓	✓		✓
	-0.5[8]	Left Bank	✓	✓	✓	✓	✓	✓
	-0.03	Left Bank	✓	✓	✓	✓	✓	✓
D/S sites	+0.03 (E)	Right Bank	✓	✓	✓	✓	✓	✓
	+0.03 (W)	Left Bank	✓	✓	✓	✓	✓	✓
	+0.5 (WI)[7,8]	Left Bank	✓	✓	✓	✓	✓	✓
	+0.5 (EI)	Left Bank	✓	✓	✓	✓	✓	✓
	+1.5 (WI)	Left Bank	✓	✓	✓	✓	✓	✓
	+1.5 (EI)	Thalweg	✓	✓	✓	✓	✓	✓
	+4.5	Thalweg	✓	✓	✓	✓	✓	✓
	+12 (M4)[6]	Thalweg	✓	✓	✓	✓		✓
	+34 (M7)[1]	Thalweg	✓	✓	✓	✓		✓

Temporal Design

Water quality sampling for the enhanced monitoring program in 2018 occurred between August and October. This included the installation of auto-monitoring sondes at select sites in August which took measurements every 15 minutes of a suite of variables (Table 1). Auto-monitoring sondes were removed in mid-October. Two 28-day SPMD exposures commenced mid-August and again in mid-September. Depth-integrated samples for the analysis of inorganics, organics, and nutrients were sampled once in August, September, and October (three sampling events). Efforts were made to coordinate sampling events for water quality grab samples and SPMD exposures with the existing OSM water quality monitoring program sites (M3 and M7) currently led by Environment and Climate Change Canada (ECCC).

Sampling Methodology

Standard operating procedures (SOPs) remained consistent with existing protocols previously or currently used in Joint OSM/OSM for comparability among new and historical data sets. These methods have been rigorously tested, with robust and conservative quality assurance, quality control (QAQC) procedures. The rational for using these SOPs in the oil sands region are discussed in Cooke et al., (2018). The following SOPs were used for surface water quality sampling:

- ECCC (2018a): Standard operating procedures for the field collection of water quality samples
- ECCC (2018b): Standard operating procedures for auto-monitoring platforms and internally logging unattended samplers
- ECCC (2018c): Standard operating procedures for the deployment of anchoring arrays for water quality sampling devices in large rivers
- ECCC (2018e): Standard operating procedures for field water quality sampling using semi-permeable membrane devices (SPMD)

3.2 Benthic Macroinvertebrates

Spatial Design

The design required sampling of benthic macroinvertebrates (BMI) and select supporting environmental variables from sites located on the west bank of the Athabasca River. The west (left) bank is where the effluent will be released and where the plume is expected to occur prior to full mixing. The current long-term BMI OSM program does not include monitoring of BMI on the west side of river where sandy substratum are predominant, although historically they did (Culp et al., 2018). The spatial design of this study established five sites located between 0.03 km and 20 km upstream of the potential treated OSPW discharge and at eight sites located between 0.03 km and 34 km downstream of the potential treated OSPW discharge (Figure 2). These sites are all in close proximity to a water quality monitoring station (Figure 1). Sites were selected based on their distance from the propose OSPW discharge (similarly to water quality sites) and on available habitat. Sites were composed of fine sediments, sand, or a mix. We chose a gradient design with relatively short distances between sampling sites located immediately upstream and downstream of the potential discharge of treated OSPW with increasing distances between sites at greater distance from the discharge site. All 13 BMI sampling sites are 'new' to the OSM program. Data describing these sites are however augmented by regular annual sampling of BMI by ECCC on the east side of the river at sites M3, M3B, M4, and M6.

Endpoints

In addition to benthic macroinvertebrate communities, a series of supporting environmental data were collected at each of the sites. This includes the following:

- Particle size distribution (%clay, %silt, %sand)
- Current velocity and average water depth
- Chlorophyll *a* content of superficial sediment.
- Benthic (epipelic) algal communities
- Sediment Quality (Table 3)

Table 3. Sediment quality parameters measured in the enhanced monitoring program

Nutrients	Total organic carbon, total organic nitrogen, loss on ignition
Total metals	Al, Sb, As, Ba, Be, Bi, B, Cd, Cl, Cr, Co, Cu, Fe, Pb, Li, Mg, Mo, Ni, Se, Ag, Sr, Tl, Th, Sn, Ti, U, V, Zn, Hg,
Organics	Parent and alkylated PAHs; naphthenic acids; total phenols; MeHg

BMI were also collected from select sites for contaminant loadings (Hg/MeHg, trace metals) and stable isotopes ratios ($\delta^{15}N$ and $\delta^{13}C$). The select sites included two sites located upstream of the potential OSPW discharge (0.03 km and 0.5 km) and two sites located downstream of the potential OSPW discharge (0.03 km and 0.5 km). The site located at 0.5 km downstream was on the west side of the island only. The number of sites for body burdens was limited due to the difficulties in collecting enough tissue for the analysis. Therefore, the sites closest to the potential OSPW discharge were prioritized. Dragon fly nymphs were targeted for Hg/MeHg and trace metal analysis as they are large (higher body weight for the analysis) and are a secondary consumer. Chironomidae were targeted for stable isotopes ratios, as they are known to be part of the trout-perch diet, which is the small-bodied sentinel fish species assessed for fish health in this program. Mayfly larva were also collected and include the following families: Ametropodidae, Baetidae, Heptageniidae, Caenidae. The abundance of mayfly families present at the different sites were inconsistent among sites and therefore are not currently being considered for analysis. These samples are archived in case they are planned to be used in the future.

Temporal Design

The full spatial sampling program to describe the structure of BMI communities and the supporting environmental data was collected once in the fall (mid-September) to coincide with the normal sampling period for the main steam sampling sites on the Lower Athabasca River (Culp et al., 2018). BMI collected for contaminants loadings and stable isotope ratios ($\delta^{15}N$ and $\delta^{13}C$) were not collected mid-September due to timing constraints. They were collected at the end of August instead. High abundances of the mayfly Ametropodidae were observed in mid-October at predominantly sand sites. Since they were easy to capture in relatively high abundances, samples were collected at select sites and archived for potential future use in assessing contaminant loadings and/or stable isotope ratios ($\delta^{15}N$ and $\delta^{13}C$).

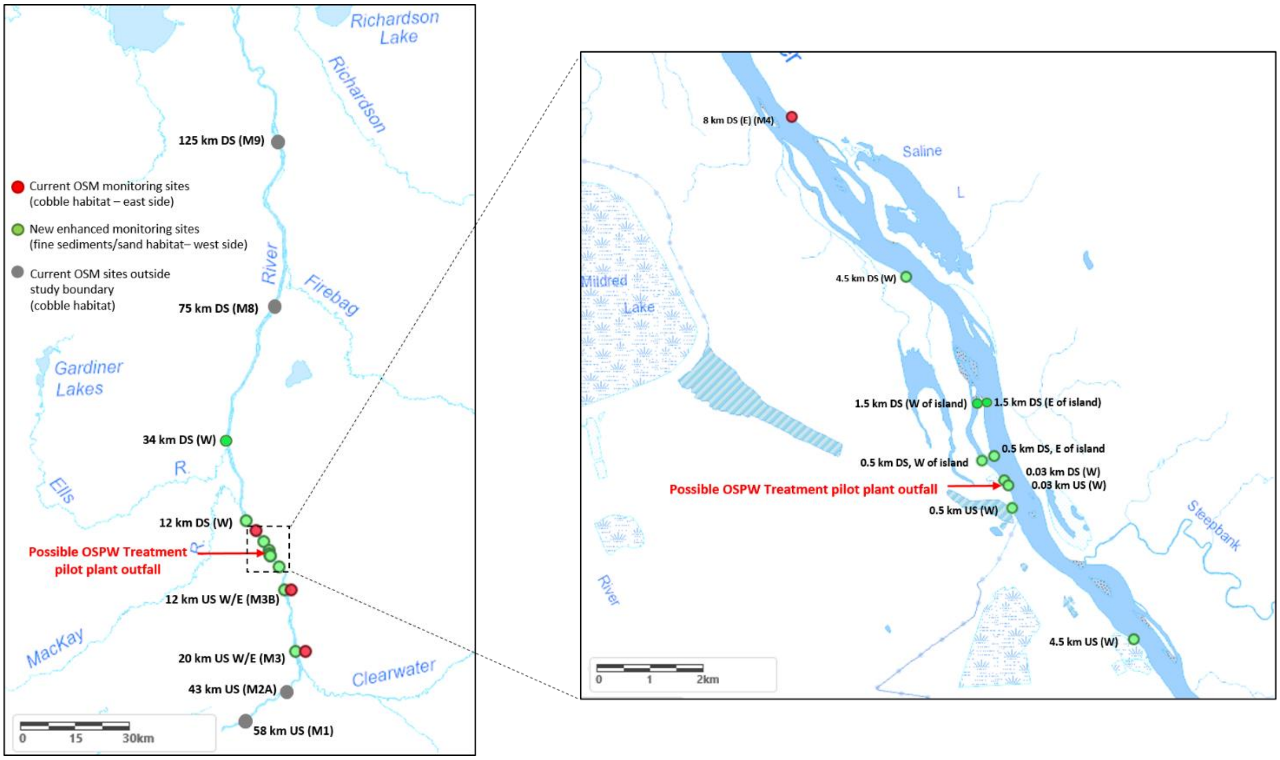

Figure 2. Enhanced monitoring of benthic macroinvertebrates in the Lower Athabasca River. New enhanced sites (green) are all located on the west bank (both upstream and downstream of the proposed treated OSPW discharge) and make up habitats with either fine sediments or sand. Existing OSM benthic monitoring sites in red are located on the east bank in cobble habitats. Grey sites are existing OSM benthic monitoring sites that are outside the study boundary. W = west, E = east

Table 4. Benthic invertebrate sampling endpoints and associated supporting environmental data collected in the Lower Athabasca River in 2018. [1]Three replicates taken for supporting environmental data, [2]five replicates taken for supporting environmental data, [3] Dragon fly nymph collected for mercury, methyl mercury, and trace metals, [4]Chironomidae collected for stable isotope ratios, [5]five replicate transects per site. BMI: benthic macroinvertebrate community structure collected using the CABIN protocol (ECCC 2018f). Site distances denoted with negative and positive signs are located upstream and downstream of the potential treated OSPW discharge site, respectively.

	Distance (km) U/S or D/S of the proposed discharge	BMI[5]	Distance between replicate kicks (m)	Body burdens[3]	Stable isotopes ($\delta^{15}N/\delta^{13}C$)[4]	Supporting environmental data				
						Algae biomass (Chl *a*)	Algae taxonomy	Sediment Quality	Substrate Particle size	Flow and depth
Upstream sites	-20 (M3)[2]	✓	50			✓	✓	✓	✓	✓
	-12 (M3B)[2]	✓	50			✓	✓	✓	✓	✓
	-4[2]	✓	50			✓	✓	✓	✓	✓
	-0.5[2]	✓	50	✓	✓	✓	✓	✓	✓	✓
	-0.03[1]	✓	10	✓	✓	✓	✓	✓	✓	✓
Downstream sites	+0.03[1]	✓	10	✓	✓	✓	✓	✓	✓	✓
	+0.5(WI)[2]	✓	50	✓	✓	✓	✓	✓	✓	✓
	+0.5 (EI)[2]	✓	50			✓	✓	✓	✓	✓
	+1.5(WI)[2]	✓	50			✓	✓	✓	✓	✓
	+1.5(WI)[2]	✓	50			✓	✓	✓	✓	✓
	+4.5[2]	✓	50			✓	✓	✓	✓	✓
	+12[2]	✓	50			✓	✓	✓	✓	✓
	+34 (M7)[2]	✓	50			✓	✓	✓	✓	✓

Sampling Methodology

Samples to describe the structure of BMI communities were collected using the Canadian Aquatic Biomonitoring Network (CABIN) methodology (ECCC 2018f) and supporting information provided by ECCC (Luiker et al., 2018; Culp et al., 2018). The sampling procedure consists of a time-limited sweeping of the substratum along transects. To ensure adequate statistical power, five kick samples were collected at each site, along with the associated habitat data (water velocity and depth). Replicate sites were separated by 50 m at most sites, except for some instances where habitat may have been limited, in which case the sites were separated by <50 m. Replicate sites at the two nearfield sites (0.03 km upstream and downstream of the potential OSPW discharge) were separated by 10 m, as proposed. These separation distances provide a level of spatial independence of samples. All other supporting environmental parameters were collected at three of the five replicate sites (beginning, middle and end of the sampling reach). The only exception to this was the first two nearfield sites (0.03 km upstream and downstream of the potential OSPW discharge), where supporting environmental data was collected at each of the five replicates. The procedures for collecting sediments, chlorophyll A, and benthic algae are provided in Luiker et al., (2018).

3.3 Fish health and fish communities

Spatial Design

The spatial sampling design incorporates existing long-term OSM fish health monitoring sites conducted on the Lower Athabasca River (McMaster et al., 2018). The OSM program utilizes both small-bodied fish health (trout-perch) and large-bodied fish health (white sucker) and Walleye for contaminant analysis only. These programs are currently on a three-year cycle, where trout-perch was already planned to be sampled in fall 2018. Large-bodied fish are planned for fall 2019. Because of this three-year cycle, only small-bodied fish were sampled in 2018 as part of the enhanced monitoring. Small-bodied fish species (e.g. trout-perch) have a small home range, which supports their use within the enhanced study area. In September 2018, 10 sites were sample. Four sites were part of the existing OSM monitoring program and include DSM4 (13 km downstream), M7 (33 km downstream), USM4 (4 km upstream), and M3 (20 km upstream). The remaining six sites were added as part of the enhanced monitoring program. Similar to BMI, sites were located in close proximity to water quality sample stations. Four sites were located upstream of the potential OSPW discharge (0.5 km – 20 km) and six sites were located downstream of the potential OSPW discharge (0.5 km – 33 km; Figure 3).

The additional OSM long-term monitoring fish health sites of M0, DS M0, M2, and M9 (outside of the boundaries of the enhanced study design) were also sampled in fall 2018 and will add to our understanding of trout-perch health in the main stem and potential impacts of the OSPW pilot discharge.

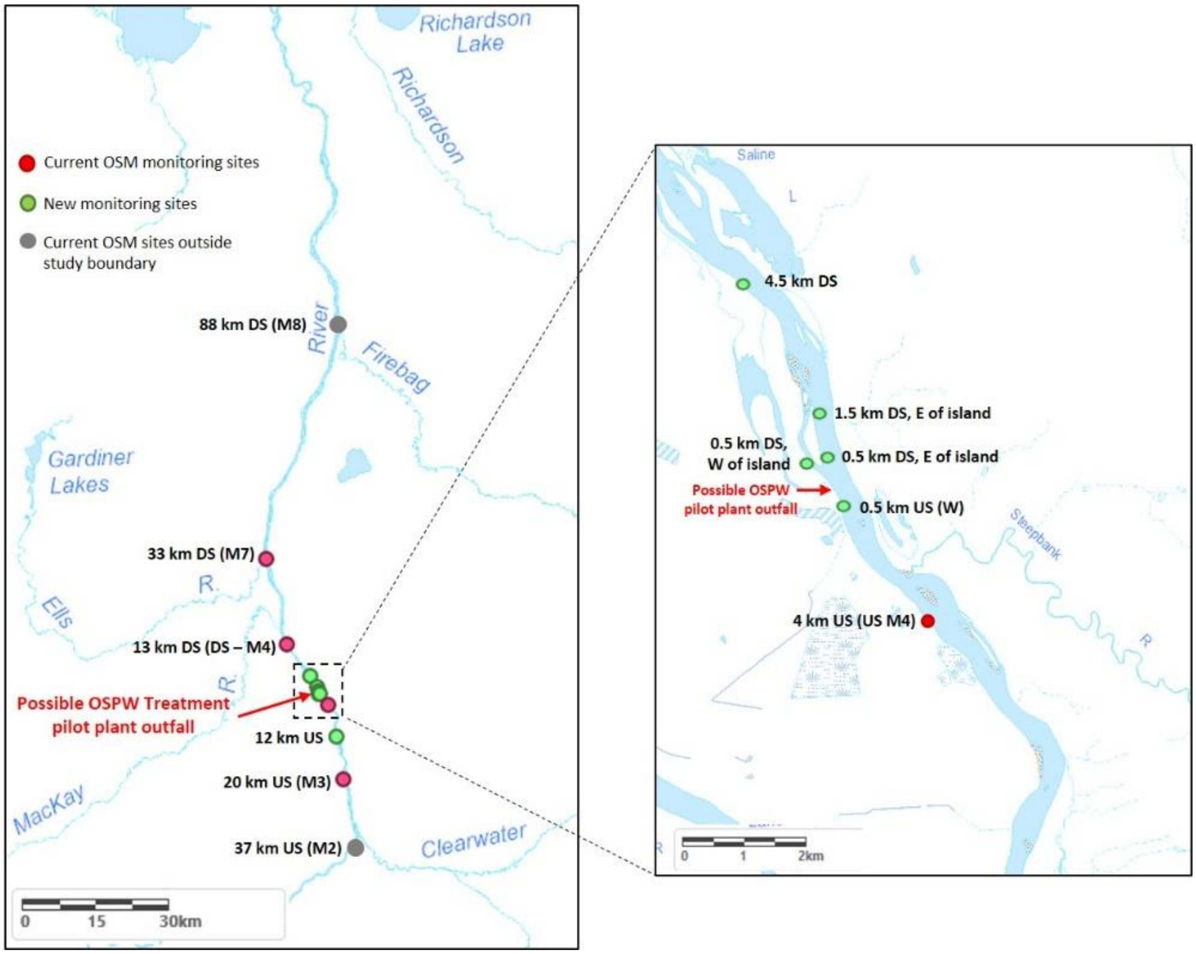

Figure 3. Enhanced monitoring of fish health in the Lower Athabasca River comprises new sites (green) located on the east bank both upstream and downstream of the proposed treated OSPW discharge and existing OSM fish health monitoring sites (red). Grey sites are existing OSM fish monitoring sites that are outside the study boundary.

Fish communities in the Lower Athabasca River, which identifies fish species that use the river at different times of the year, had been collected from 1997 to 2014 (RAMP 2016; Arciszewski et al., 2017). Some of the sites for this work where near the proposed OSPW pilot discharge location (Figure 4). Eight sites were sampled utilizing the same sites for data comparability over time. These sites included 01A, 04A, 04B, 05A, 05B, 06A, 10B, 11A (Figure 4). Table 5 compares the eight fish inventory collection sites with the location of the fish health monitoring sites.

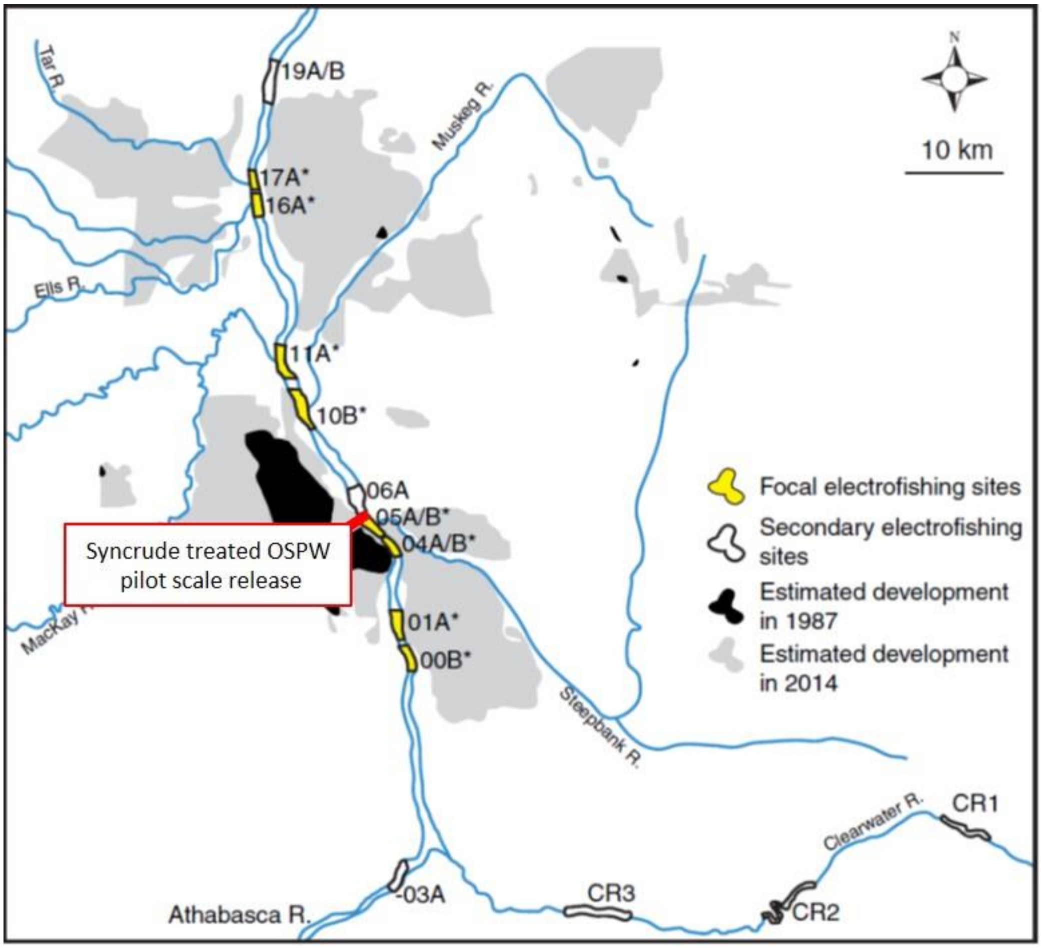

Figure 4. Existing fish community inventory monitoring reaches on the Lower Athabasca River and Clearwater River (Arciszewski et al., 2017) in relation to the possible release of treated OSPW. Eight of the focal electroshocking sites were sampled as part of the enhanced monitoring program design in 2018 (see Table 5).

Endpoints

Endpoints to assess trout-perch health were consistent with the OSM fish health program (McMaster et al., 2018). These include Environmental Effects Monitoring (EEM) endpoints, which include general indicators of growth, reproduction, and energy storage (Environment Canada, 1998). Additional endpoints collected include mixed function oxygenase (MFO) activity in liver measured as EROD (7-ethoxyresorufin O-demethylase activity), body burdens of contaminants (Hg/MeHg, parent and alkylated PAHs, and trace metals), and stable isotope ratios in dorsal muscle tissue ($\delta^{15}N$ and $\delta^{13}C$). Gills were collected, preserved, and archived for potential future histological analysis. A full description of endpoints selected for fish health are provided in Table 5.

The fish inventory data will be used to assess fish community composition as well as examining the frequency of external abnormalities (DELTS: deformities, erosions, lesions, and tumours).

Temporal Design

The full temporal sampling program is carried out annually in the fall to coincide with the normal sampling period for the Athabasca River fish sampling sites. Fish health (trout-perch) and fish communities were sampled once in September 2018. The three-year rotation will be discontinued and switched to annual sampling for fish communities, trout-perch, and large bodied fish (white sucker and walleye) in 2019.

Sampling Methodology

Standard operating procedures (SOPs) will remain consistent with existing protocols previously or currently used in oil sand monitoring programs (OSM/RAMP) to ensure data consistency and comparability among new and historical data sets. The following SOPs were used for the monitoring of fish health and fish communities:

- Environment Canada (1998): Pulp and paper technical guidance for aquatic environmental effects monitoring
- Regional Aquatic Monitoring Program (2016): Ramp fish inventory protocols

Table 5. Summary of endpoints for fish health monitoring in the Lower Athabasca River. Under OSM, regular scheduled fish sampling takes place at M3 (-20 km), uM4 (-4 km), dM4 (+13 km) and M7 (+33 km). These existing sites are shaded. [1] Length, weight, condition factor, liver and gonad size relative body weight, age relative to weight/length in small-bodied fish (trout-perch), [2] Gills, [3] mercury, methyl mercury, PAHs (parent and alkylated), [4] Collected in dorsal muscle tissue. Site distances denoted with negative and positive signs are located upstream and downstream of the potential treated OSPW discharge site, respectively. U/S = upstream of the potential Syncrude treated OSPW release site. D/S = downstream of the potential Syncrude treated OSPW release site. EROD = 7-ethoxyresorufin O-demethylase.

	Distance (km) U/S or D/S of the proposed release site	Fish community sites	EEM Endpoints[1]	EROD (liver)	Histology[2]	Body burdens[3]	Stable isotopes ($\delta^{15}N$ and $\delta\ ^{13}C$)[4]
U/S sites	-20 (M3)	01A	✓	✓	✓	✓	✓
	-12		✓	✓	✓	✓	✓
	-4 (uM4)	04A/B	✓	✓	✓	✓	✓
	-0.5	05A/B	✓	✓	✓	✓	✓
D/S Sites	+0.5 (EI)		✓	✓	✓	✓	✓
	+0.5 (WI)	06A	✓	✓	✓	✓	✓
	+1.5		✓	✓	✓	✓	✓
	+4.5		✓	✓	✓	✓	✓
	+13 M4 (dM4)	10B/11A	✓	✓	✓	✓	✓
	+33 (M7)		✓	✓	✓	✓	✓

3.4 Community-based monitoring in the Peace-Athabasca-Delta

In 2018, we participated in a week long Whitefish Camp, from September 10-14 (2018) with Mikisew Cree and Athabasca Chipewyan First Nations in the Peace-Athabasca-Delta on Lake Claire (PAD; Figure 5). Multiple scientists were invited including scientists from Environment and Climate Change Canada, Parks Canada, Alberta Environment and Parks, as well as those from academia and consulting companies. The purpose of the camp was to build relationships between First Nations communities and scientists. The camp provided a platform to exchange information between Scientists and Elders' Indigenous knowledge, with the goal of developing future monitoring programs in the PAD.

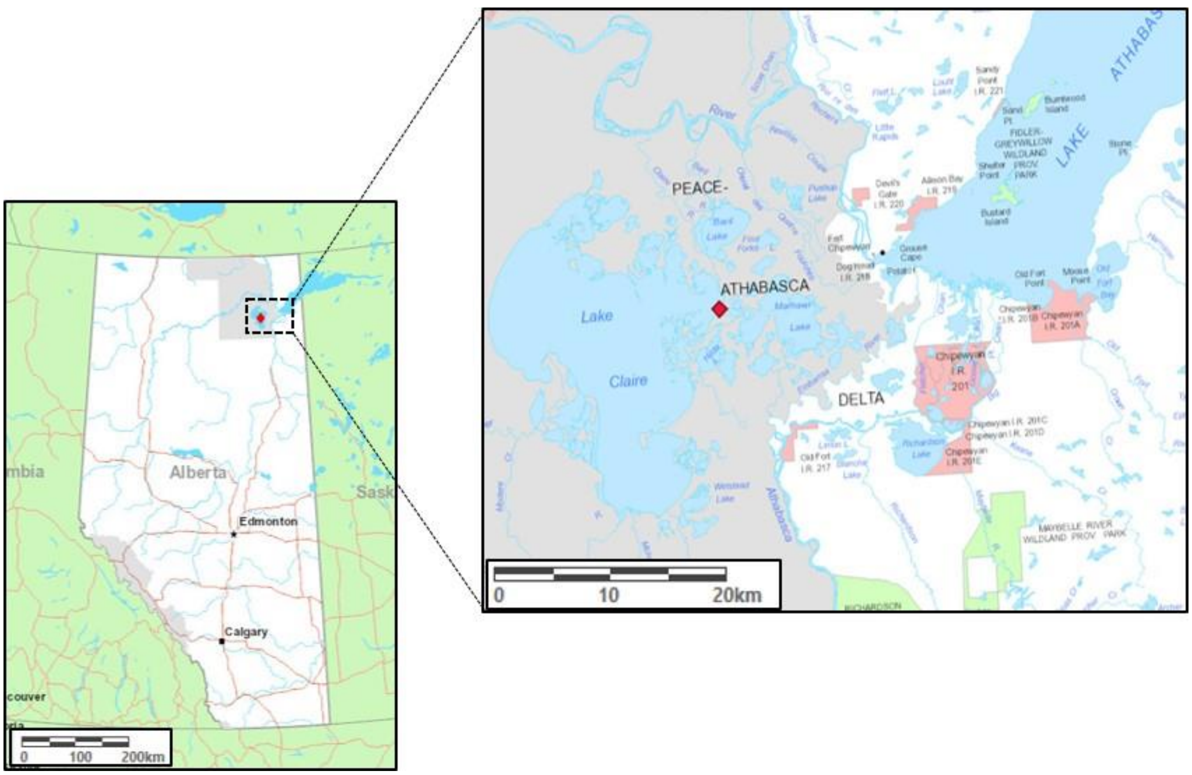

Figure 5. Map of the site in the Peace-Athabasca-Delta where the Whitefish Camp took place in September 2018.

During the camp, participates worked together to catch whitefish in the PAD, which are a traditional species consumed by the FN communities. The elders demonstrated the importance of this food source, and took the scientists through the procedure of smoking the fish (Figure 6). This was also an opportunity for the elders to demonstrate their traditional methods to

First Nation youth, who for some, was their first time seeing it done. There was also an exchange of information of other important food sources (e.g. trapping) in this region. They shared their knowledge of the land and the significant changes they observed since the last 50 or more years.

This camp also provided an opportunity for scientists to demonstrate the methods they use to assess fish health (Figure 6). Prior to the filleting and smoking the whitefish meat, scientists processed the fish how they would for typical monitoring program, such as the OSM fish health monitoring program. They demonstrated the general procedures such as taking a length, weight, and how they observe and record any abnormalities. We also demonstrated the different structures used for ageing the fish and why this is important. A few fish were dissected to examine different organs as well as how to properly sex the fish. In addition to sampling large-bodied fish, other methods were demonstrated for assessing ecological health, including the importance of small-bodied fish and benthic macroinvertebrates.

In addition to demonstrating the First Nations on methods used to assess fish health, tissues and other information were gathered by the scientists on the whitefish and bycatch species such as pike and walleye. Fish tissues were collected and preserved for the analysis of contaminants including mercury and polycyclic aromatic hydrocarbons. How to collect fish for these types of analyses was demonstrated, including potential sources of contamination. Fish ageing structures were collected and sent to a lab for ageing. The enhanced monitoring program supported all these analyses and the data will be available in a report that is being drafted by the organizers of the Whitefish Camp. This information will be shared with the First Nation communities and participants of the camp.

Figure 6. 2018 Whitefish camp photos (Sept 10-14) in the Peace-Athabasca-Delta with Mikiew Cree and Athabasca Chipewyan First Nations and invited scientists. A) Retrieving index gill nets for collecting whitefish and bycatch species, B) scientists demonstrating to a First Nation youth the procedures for collecting information on fish health, C) whitefish smoking chamber, D) whitefish camp participants, E) First Nations elder filleting whitefish prior to smoking.

The enhanced monitoring program is still in the early phases of understanding ways to continue supporting monitoring efforts in the Lower Athabasca River and the Peace Athabasca Delta in relation to community-based monitoring. Discussions are ongoing for efforts in 2019, which include the potential participation of Indigenous people in field collections on the Lower Athabasca River.

4 DEVIATIONS FROM PROPOSED WORK

Overall, there were no major deviations affecting the outcome or quality of the proposed work. Below is a list of deviations and a rational for those deviations for each of the major endpoint categories.

Surface Water Quality:

- The enhanced monitoring proposal originally included chloride ion selective electrodes (ISE) as part of the continuous monitoring variables, as chloride was identified as an important variable in treated OSPW. After investigating the use of Cl ISE in the Lower Athabasca River, it was concluded that they would not provide any valuable information as a result of their low accuracy (±15% of the reading or ± 5 mg/L, which is lower) in concentrations typically found in the Athabasca River (4-10 mg/L; at Appendix B, Table B-1). Dissolved chloride concentrations is still captured in the monthly depth-integrated water quality grab samples.
- Continuous monitoring variables were not collected at M3 or M7 (sites part of the OSM surface water quality program led by ECCC). These sites make up the most upstream (M3) and downstream (M7) boundaries of the enhanced monitoring study design. Monthly depth-integrated samples and SPMD (semi-permeable membrane devices) exposures are collected at M3/M7 consistent with the remaining enhanced monitoring sites.

Benthic macroinvertebrates communities:

- We increased the sampling effort from the originally proposed three replicates/site to five replicates per site to capture site variability. This was due to the unknown variance at sites with fine sediments, as this was not a habitat routinely sampled (using the CABIN kick protocol) in any current or historical oil sands monitoring program. This data will be evaluated to assess within site and between site variability to determine the proper sample size for future sampling events.
- Because of the increased sampling effort from three to five replicates, the proposed distance between replicates was not attainable. It was originally proposed to separate sample replicates by 100 m. However, due to the limit of consistent habitat, sample replicates were placed approximately 50 m apart instead. It was considered more important to standard habitat type over distance between replicate sites. A separation of 10 m at the nearfield sites (0.03 km U/S, 0.03 km D/S) did not change from the original proposal.

Fish health and fish communities

- Only 10 out of the proposed 12 sampling sites were sampled for the small-bodied fish health assessment using trout-perch. This was a result of the nearfield sites (0.03 km U/S and 0.03 km D/S) being too close in proximity. These nearfield sites were combined with the next nearfield site either in the upstream or downstream direction in order to get the appropriate sample size. Therefore, 0.03 km U/S was combined with 0.5 km U/S, and 0.03 km D/S was combined with 0.5 km D/S WI.
- The proper sample size for trout-perch (20 males and 20 females) was not attainable at all sites. Two sites did not collect enough females (20 km U/S and 0.5 D/S EI).

5 CHALLENGES AND LESSONS LEARNED

As this was the first year to deploy the enhanced monitoring, there were a series of challenges and lessons learned that arose throughout the field studies. Challenges were often associated with habitats that are not routinely sampled as part of the core OSM programs. In addition, there were a number of confounding factors identified that would need consideration for future monitoring and specifically in the event that treated OSPW is released into the Lower Athabasca River. Below is a list of challenges and lessons learned identified in the 2018 field season:

1) Benthic macroinvertebrates communities

- Sites to assess benthic macroinvertebrate communities were difficult to standardize for depth, velocity, and substrate type. This was in part due to the limitation on site location and distance from the potential OSPW discharge. For habitat type, sites were standardized for fine sediments to sandy substrates, or a mix of both, as this was the predominant habitat type in close proximity to the potential OSPW discharge. Therefore, cobble substrate (which is the habitat routinely measured in the core OSM BMI program) was avoided. Fine-sediments are challenging to kick in as the proponent doing the kicking can sink anywhere from ankles deep to knee deep, depending on the site. This resulted in inconsistencies in kicks between sites (or even between replicate sites) due to the restricted movement. The variable depth of fine-sediment between sites was not quantified, and may be something to consider quantifying in future sampling events.

- Because sampling took place in many depositional areas, the water velocity was often very low. As a result, standardization of water velocity was difficult. In addition, there were often large back-eddies (upwards of 500 m in length), particularly at the nearfield sites (0.03 km U/S and 0.5 km U/S), creating additional challenges in flow measurements and standardization. This will likely create challenges in the future, where in the event of a discharge, treated OSPW may enter these large back-eddies, resulting in effluent going upstream. This would be dependant on the season and low flow periods. This will need to be accounted for in future study designs.

- When performing the transect kick, wading was often restricted from 1-5 m from shore. This was because there was often a large drop-off at some sites, with variability in slope above and below the shoreline. For this reason, the distance from shore could not be standardized.

2) Body-burdens of contaminants in benthic macroinvertebrates

- Assessing burdens of contaminants (and stable isotopes ratios) in benthic macroinvertebrates was one of the endpoints identified in this study design. This is challenging in many ways, including the effort required in collecting the appropriate amounts of tissue and selecting a consistent species that is present at all sites. This challenge was identified in the study design prior to its deployment and to address it, only nearfield priority sites were selected including the following: 0.5 km U/S, 0.03 km U/S, 0.03 D/S, 0.5 km D/S WI, 0.5 km EI. Because of the time required to collect these invertebrates, samples were collected two-three weeks (end of August) prior to the collection of CABIN samples. In addition, only trace metals and mercury/methyl mercury (Hg/MeHg) were selected as parameters to measure, as they generally require smaller amounts of weight to perform the extraction and analysis. Only at four out of the five sites identified, did we collect enough tissues for the analysis, and the selected candidate species was the dragonfly nymph. The site 0.5 km EI, which is composed of sand substrate, lacked abundance of any invertebrate, including the dragonfly nymphs, who were more abundant in fine sediment locations. Specimens from the family Chironomidae was also collected for stable isotope ratios for carbon and nitrogen. In mid-October, there was an emergence of a mayfly family (Ametropodidae) is high numbers at the sandy site locations. Since they were relatively quick to collect in high numbers, we also collected and archived these samples from a series of sites.

- Although we successfully collected enough dragonfly nymphs, the amount of effort was extreme and we had to go in aggressively. From this experience, it was decided to collect invertebrates after the CABIN collections to avoid any disturbance of the sites. In future sampling events, invertebrates will be targeted in later September/October to target either i) dragonfly nymphs, or ii) the mayfly family, Ametropodidae, which ever is present in higher numbers and consistent across sites. Other invertebrate groups may be collected if present in high enough numbers.

3) Locations of water quality monitoring stations

- It was identified prior to deploying the full enhanced monitoring in 2018, that sites would include those in a side channel just downstream of the potential treated OSPW discharge (0.05 km D/S WI, and 1.5 km D/S WI). In the event of a discharge, and depending on flow conditions, the effluent would likely go through this channel. These sites get relatively shallow throughout the year as the flows drop (August-October), and pose challenges for collected surface water quality. These challenges primarily related to the installation of continuous monitoring sondes and SPMDs. This is something to be cognisant of in future monitoring activities.

- The placement of surface water quality monitoring stations is challenging, and it was identified by the OSPW Science Team that modelling of the potential plume would be helpful. Placement of the stations for the 2019 enhanced monitoring design will remain consistent with 2018.

4) Location of the Syncrude sewage outfall

- It was identified that the Syncrude sewage outfall is approximately 80 m downstream of the potential OSPW discharge. The sewage outfall releases continuously throughout the year. Data collected just downstream of the sewage outfall (at 0.5 km D/S WI) will be examined for evidence of enrichment. This outfall will need to be considered for future study designs.

6 RESULTS TO DATE

The results for this program will be assessed by the OSPW Science Team data analysis subgroup that was recently formed. The outcome of this assessment from the 2018 field season will be assessed by this subgroup and provided in a report in the 2019/2020 fiscal year. Below is a table summarizing the status of the results that are currently available from the 2018 field season.

Table 6. Status of the 2018 results for the enhanced monitoring program

Results completed	Results to be completed by end of Q4 2019	To be completed Q1/Q2 2019/2020[1]
• water quality[2]	• Stable isotope ratios	• Contaminant in fish/BMI
• SPMD[2]	• Chlorophyll A	• Algae taxonomy
• Sediment quality		• BMI communities
• Fish health		• EROD activity[3]
• Fish aging		
• Fish communities		

[1]Contracts are in the process of being set up for 2019/2020 fiscal year
[2]Sonde and SPMD data is still undergoing QA/QC
[3]EROD activity is being completed by Environment and Climate Change Canada

All the results that are available for this program are summarized in tabular format in the following appendices:

- Appendix B: Surface water quality (depth-integrated water samples)
- Appendix C: Sediment quality
- Appendix D: Fish health and fish communities

7 REPORTING AND COMMUNICATION

Date	Item/Meeting	Comment
July 4, 2018	Enhanced monitoring draft proposal circulated and presented to the OSPW Science Team	Approved under the conditions of recommended changes
July 16, 2018	Final enhanced monitoring proposal (with edits) circulated to OSPW Science Team	Recommended changes addressed in the final version
February 19, 2019	Status of project updates presented to the OSPW Science Team	Presented: • Work completed in the 2018 field season • Deviations from the proposal • Challenges/lessons learned
March 7, 2019	Presented the 2019/2020 enhanced monitoring study design for approval by the OSPW Science Team	• Conditionally approved, but still some decisions on parameters to be measured in fish tissue
Q4 2018/2019	Circulation of year end synopsis report to the OSPW Science Team	

8 ACKNOWLEDGEMENTS

We thank the OSPW Science Team for valuable guidance on many components of the study design for 2018. Many aspects of this document benefited from sharing of extensive knowledge, thoughtful advice and critique by Joseph Culp, Bruce Kilgour, Janice Linehan, Mark McMaster and Kelly Munkittrick. We'd like to thank also all those who helped in the field component of the program including those from Environment and Climate Change Canada including Mark McMaster, Gerald Tetreault, Bob Brua, Daryl Halliwell, and Jim Syrgiannis. We would also like to thank all the field crews from AEP and Hatfield Consultants. Finally, we appreciate the help from Kristin Hynes, Justin Hanisch, and Fred Noddin in processing the data.

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10 APPENDICES

APPENDIX A A summary of existing and current monitoring of surface water and biota in the Lower Athabasca River through the Oil sands Monitoring Program)

The enhanced monitoring of the Lower Athabasca results from augmenting existing monitoring programs on the main stem of the Athabasca River involve the monitoring of various ecosystem components including water quality, benthic macroinvertebrates, fish health, and fish communities. Existing environmental monitoring programs, as well as historic data will be an important component of the enhanced monitoring program. Existing programs that will be utilized in the enhanced monitoring are described in Table 1A.

Table A1. Summary of existing environmental monitoring programs (oil sand monitoring funded programs) on the main stem of the lower Athabasca River (LAR) that contribute to the enhanced monitoring design. [1] Environmental Effects Monitoring (EEM) endpoints: Length, weight, body condition, relative weight of gonad and liver to body weight, relative weight/length at age, DELTs (i.e., deformities, erosions, lesions, tumors). Abbreviations: ECCC = Environment and Climate Change Canada; SPMD = semi-permeable membrane device; EROD = 7-ethoxyresorufin O-demethylase activity; SOP: standard operating procedure. BMI= benthic macroinvertebrates.

Existing program	Current lead	Season/months	Matrix	Parameters	Frequency	SOP	Sites
Water quality monitoring	ECCC (Nancy Glozier)	Open water (May-Oct)	Grab samples	• Nutrients, trace metals, major ions, PAHs	Bi-weekly	ECCC 2018a	M2, M3, M7, M9 (Figure 1A.A)
			SPMD	• Dissolved PAHs	6 X 28d	ECCC 2018e	
Benthic macroinvertebrate monitoring (BMI)	ECCC (Joseph Culp)	Aug/Sept	BMI	• Community composition	1 per year	ECCC 2018f	MO, M1A, M2, M2A, M3, M3B, M4, M6, M8, M9 (plus one of: M1, M7, M7C every 3 years). Cobble sites only (East bank (Figure 1A.B)
			Water quality grab samples	• Nutrients, trace metals, major ions, PAHs, YSI (temp, conductivity, pH, dissolved oxygen (DO)	1 per year	ECCC 2018a	
			SPMD	• Dissolved PAHs	1 X 28d	ECCC 2018e	
			Sediments quality	• Total organic carbon, total dissolved nitrogen, total metals, total Hg/MeHg, PAHs	1 per year	ECCC 2018g	
			Algae	• Chl a	1 per year	ECCC 2018g	
Fish health monitoring	ECCC (Mark McMaster)	Fall	Small-bodied (Trout-perch)	• Body burdens (PAH/Hg) • Biomarkers (EROD) • EEM endpoints[1]	2018 (Sept/Oct)	ECCC/EEM	M0, ARDS M0, AR DS M0, M2, AR DS M3, AR US M4, AR DS M4, M7, M8, M9 (Figure 1A.C)
			Large-bodied (white sucker)	• Body burdens (PAH/Hg) • Biomarkers (EROD) • EEM endpoints[1]	2019 (Sept/Oct)	ECCC/EEM	M0, AR DS M0, AR DS M3, AR US M4, AR DS M4, (Figure 1.C)
			Large-bodied (Walleye)	• Body burdens (PAH/Hg)	2019 (Sept/Oct)	ECCC/EEM	
Fish communities (inventory)	AEP	Spring	Fish assemblages	• Community composition • DELTs, Condition Factor	May (2018)	RAMP 2016	Multiple 2 km stretches along LAR/Clear water (Figure 4)

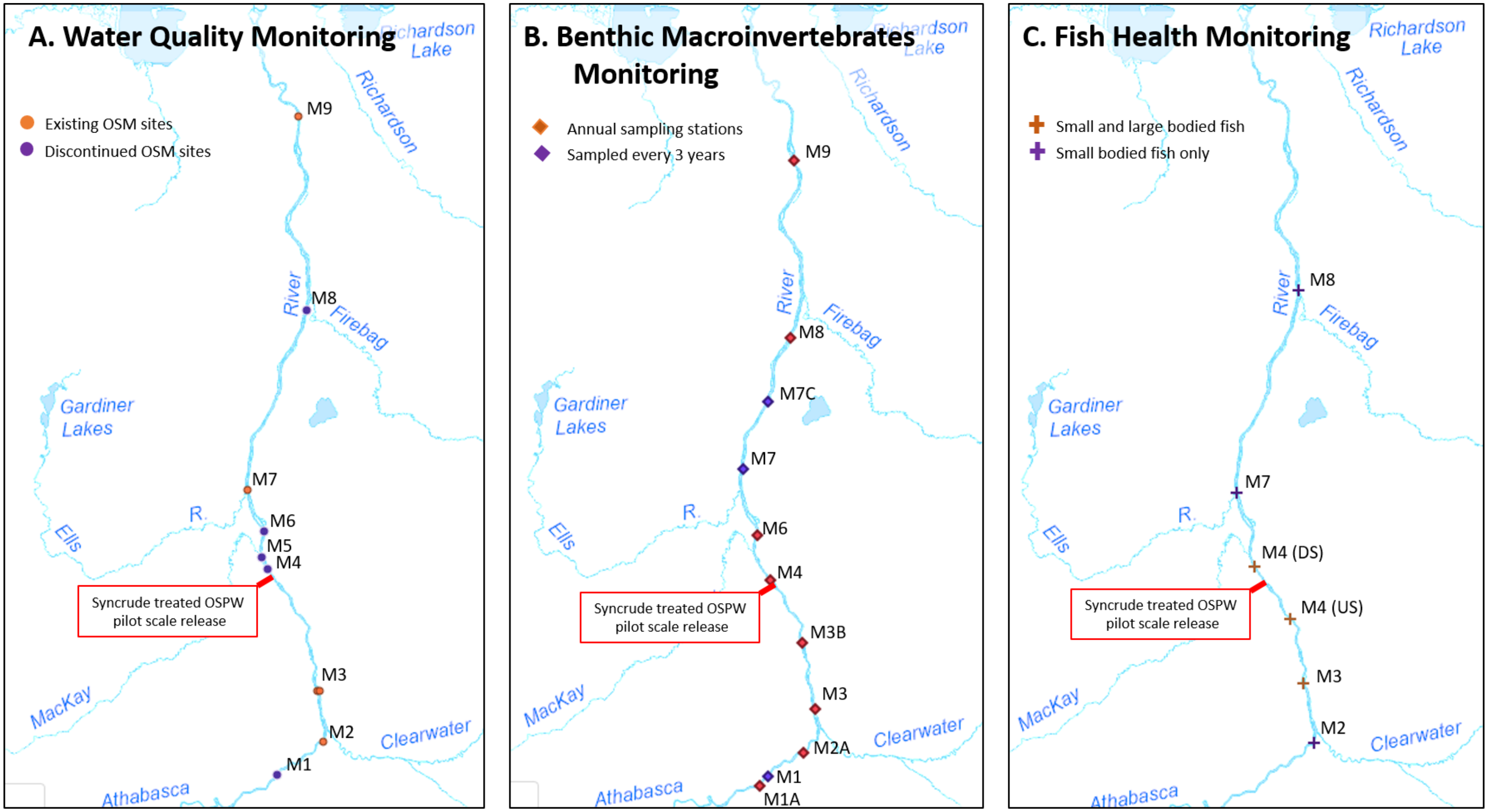

Figure A1. Existing environmental monitoring (A, water quality; B, benthic macroinvertebrates; C, fish health) are currently led by ECCC on the Lower Athabasca River in relation to the discharge of the potential Syncrude treated OSPW pilot scale facility.

Description existing baseline data available

Water quality:

Historical water quality monitoring data collected under the Regional Aquatic Monitoring Program (RAMP) is available for sites along the Lower Athabasca River. Under JOSM (2012-2014), main stem sites included M1, M2, M3, M4, M5, M6, M7, M8, and M9. In the more recent OSM program (2015-present), water quality is being collected at M2, M3, M7 and M9. All available water quality data from the OSM program, including data collected through the duration of this enhanced program will be used to support the interpretation of the data from this program. The regional data collected annually will be used to more fully characterize natural background variations.

Benthic Macroinvertebrates:

Despite that there are no existing OSM sampling sites within the anticipated plume, or on the west side upstream of the return point, the OSM program has produced BMI community samples from sand environments from other areas (2012-2014; Culp et al., 2018). All available BMI data from the OSM program, including data collected through the duration of this enhanced program will be used to support the interpretation of the data from this program enhancement. The regional data collected annually will be used to more fully characterize natural background variations, and to put into context any observed effluent-related changes.

Fish Health:

Trout-perch

Baseline data are available from 2009 to 2015 at some of the sites on the Lower Athabasca River. Fish sampling under OSM entered into a 3 year rotation after 2015, and those that overlap with the enhanced monitoring sites will return to annual sampling.

In 2015, ECCC conducted initial baseline sampling in areas where potential future discharges may take place. Sampling occurred at 6 sites in the Lower Athabasca River [in square brackets are the distances from the potential Syncrude pilot discharge]:

- Upstream and downstream of Suncor intake (UUM4 [5 km U/S], UM4 [3 km U/S))
- Upstream and downstream of CNRL (DS1 M7[35 km D/S], DS2 M7 [36 km D/S])
- Upstream and downstream of Fort Hills (US1 M8 [38 km U/S], US2 M8 [39 km U/S]

Fish communities

Fish community sampling was conducted under RAMP in spring, summer and fall, and are comparable from 1997 to 2014. Spring sampling was conducted again in 2018, but was scheduled to occur on a 3 year rotation. The enhanced monitoring program will continue sampling at the same sites in the fall, including five upstream sites (between 0.5 to 20 km upstream) and three downstream sites ranging from 0.03 to 20 km downstream of the site where treated OSPW may be discharged.

APPENDIX B Summary statistics for surface water quality parameters (depth-integrated sample) collected August-October 2018

Table B1. Summary of Major ions, nutrients and physical parameters (mean ± standard deviation, n=3)

Parameter	DL	Unit	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Major Ions														
Hardness (CaCO3)	0.5	mg/L	120.00±0.00	110.00±0.00	130.00±10.00	136.67±5.77	130.00±10.00	116.67±5.77	136.67±5.77	126.67±5.77	136.67±5.77	110.00±0.00	126.67±5.77	116.67±5.77
Calculated Total Dissolved Solids	10	mg/L	156.67±5.77	156.67±5.77	173.33±11.55	173.33±11.55	170.00±17.32	160.00±10.00	176.67±15.28	166.67±15.28	176.67±15.28	153.33±5.77	163.33±11.55	160.00±10.00
Reactive Silica	0.05	mg/L	5.60±1.01	5.77±0.78	4.70±0.96	4.67±0.46	4.83±0.58	5.80±0.50	4.70±0.52	5.03±0.42	4.60±0.53	5.97±0.45	5.03±0.58	5.47±0.38
Alkalinity (PP as CaCO3)	1	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity (Total as CaCO3)	1	mg/L	106.67±5.77	99.00±1.73	116.67±5.77	116.67±5.77	116.67±5.77	103.33±5.77	116.67±5.77	113.33±11.55	116.67±5.77	103.33±5.77	116.67±5.77	106.67±5.77
Bicarbonate (HCO3)	1	mg/L	130.00±0.00	123.33±5.77	140.00±10.00	140.00±10.00	140.00±10.00	123.33±5.77	143.33±11.55	140.00±10.00	140.00±10.00	126.67±5.77	136.67±5.77	130.00±10.00
Carbonate (CO3)	1	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Hydroxide (OH)	1	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Sulphate (SO4)	1	mg/L	27.67±2.08	25.00±1.73	33.33±3.21	34.33±4.51	33.00±5.00	24.67±1.53	36.00±6.24	29.67±2.52	34.33±3.51	23.67±1.15	30.67±3.06	27.33±3.21
Dissolved Chloride (Cl)	1	mg/L	8.23±3.33	9.83±1.88	4.40±1.30	4.63±1.31	4.67±1.40	9.63±1.52	5.10±1.40	6.17±1.26	6.00±3.44	10.33±2.31	5.83±1.56	9.17±2.47
Dissolved Calcium (Ca)	0.3	mg/L	32.33±0.58	30.67±1.15	36.00±2.00	36.00±2.00	36.00±2.00	31.33±1.53	36.33±2.08	34.33±1.15	36.33±2.08	30.67±0.58	34.33±1.15	32.00±1.00
Dissolved Iron (Fe)	0.06	mg/L	0.06±0.06	0.07±0.08	0.05±0.03	0.05±0.03	0.04±0.02	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060
Dissolved Magnesium (Mg)	0.2	mg/L	9.30±0.44	8.87±0.15	10.30±0.61	10.33±0.58	10.30±0.61	9.10±0.17	10.67±0.58	9.83±0.29	10.67±0.58	8.97±0.25	10.00±0.95	9.27±0.42
Dissolved Manganese (Mn)	0.004	mg/L	0.010±0.014	0.005±0.004	0.004±0.004	0.005±0.003	0.004±0.004	0.006±0.005	0.004±0.004	0.004±0.003	0.005±0.005	0.006±0.005	0.004±0.003	0.004±0.004
Dissolved Potassium (K)	0.3	mg/L	1.20±0.00	1.10±0.10	1.27±0.06	1.23±0.12	1.27±0.06	1.13±0.06	1.33±0.15	1.20±0.10	1.33±0.12	1.10±0.00	1.20±0.10	1.13±0.06
Dissolved Sodium (Na)	0.5	mg/L	12.33±2.52	13.67±1.15	10.63±1.58	10.83±1.26	11.10±1.85	13.67±1.15	11.47±1.86	12.33±1.53	11.07±1.90	14.00±1.73	11.90±2.15	13.00±1.73
Ion Balance (% Difference)	N/A	%	1.02±0.93	1.19±0.80	0.91±0.16	1.12±0.52	1.00±0.52	1.54±2.05	1.20±0.78	1.06±1.00	0.69±0.27	0.53±0.40	0.29±0.12	1.09±0.38
Nutrients														
Dissolved Organic Carbon (C)	0.5	mg/L	8.23±1.62	8.70±1.35	7.73±2.39	7.43±2.06	7.63±1.78	8.80±1.49	7.27±0.93	7.33±1.75	6.73±0.78	8.97±0.67	7.43±1.25	8.57±1.27
Orthophosphate (P)	0.003	mg/L	0.003±0.002	0.003±0.002	0.002±0.000	0.002±0.000	0.002±0.000	0.003±0.001	0.022±0.030	0.002±0.002	0.010±0.014	0.002±0.001	0.002±0.001	0.003±0.001
Dissolved Phosphorus (P)	0.003	mg/L	0.007±0.001	0.008±0.001	0.006±0.000	0.006±0.000	0.012±0.011	0.009±0.001	0.027±0.031	0.007±0.001	0.015±0.013	0.008±0.001	0.008±0.004	0.008±0.001
Dissolved Total Kjeldahl Nitrogen	0.05	mg/L	0.32±0.03	0.33±0.03	0.27±0.04	0.29±0.04	0.29±0.01	0.31±0.04	0.33±0.05	0.28±0.01	0.32±0.09	0.35±0.05	0.34±0.06	0.33±0.04
Nitrate plus Nitrite (N)	0.0042	mg/L	<0.0042	<0.0042	0.01±0.01	0.01±0.01	0.01±0.01	<0.0042	0.17±0.21	0.00±0.00	0.08±0.10	<0.0042	0.00±0.00	<0.0042
Total Nitrogen (N)	0.055	mg/L	0.35±0.04	0.36±0.01	0.33±0.03	0.34±0.03	0.34±0.04	0.37±0.04	0.56±0.26	0.34±0.04	0.45±0.17	0.38±0.04	0.35±0.05	0.38±0.04
Dissolved Nitrite (N)	0.003	mg/L	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.01±0.01	<0.0030	0.00±0.00	<0.0030	<0.0030	<0.0030
Dissolved Nitrate (N)	0.003	mg/L	<0.0030	0.00±0.00	0.01±0.01	0.01±0.01	0.01±0.01	<0.0030	0.16±0.21	0.00±0.00	0.08±0.09	<0.0030	0.00±0.00	<0.0030
Total Organic Carbon (C)	0.5	mg/L	8.33±1.72	9.00±1.00	7.33±1.93	7.40±2.17	8.10±1.40	8.80±1.08	7.20±1.45	7.77±1.23	6.17±1.08	9.33±0.72	7.27±1.19	8.20±1.57
Total Ammonia (N)	0.015	mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.03±0.04	<0.015	0.03±0.04	<0.015	<0.015	<0.015
Total Phosphorus (P)	0.003	mg/L	0.040±0.020	0.039±0.018	0.028±0.015	0.030±0.016	0.029±0.014	0.036±0.015	0.061±0.036	0.034±0.018	0.035±0.009	0.032±0.014	0.031±0.014	0.036±0.012
Total Kjeldahl Nitrogen	0.05	mg/L	0.35±0.04	0.36±0.01	0.31±0.03	0.33±0.03	0.33±0.04	0.37±0.04	0.39±0.06	0.34±0.04	0.37±0.08	0.38±0.04	0.34±0.05	0.38±0.04
Physical														
Conductivity		uS/cm	270.00±10.00	266.67±11.55	290.00±17.32	296.67±23.09	293.33±20.82	270.00±10.00	300.00±26.46	286.67±23.09	296.67±23.09	273.33±5.77	286.67±15.28	280.00±17.32
pH	N/A	pH	8.02±0.02	8.02±0.03	8.05±0.04	8.08±0.04	8.10±0.05	8.08±0.06	8.17±0.06	8.14±0.05	8.22±0.10	8.13±0.07	8.17±0.04	8.14±0.04
True Colour	2	PtCo units	36.00±4.00	42.67±4.16	28.33±2.52	27.33±3.21	38.67±12.22	40.33±3.51	28.00±2.65	31.33±1.53	29.00±2.65	43.33±7.64	32.67±2.31	38.00±3.46
Total Dissolved Solids	10	mg/L	170.00±10.00	180.00±10.00	190.00±10.00	183.33±20.82	183.33±20.82	176.67±20.82	193.33±11.55	186.67±15.28	186.67±23.09	173.33±11.55	186.67±5.77	170.00±17.32
Total Suspended Solids	1	mg/L	23.33±14.64	20.10±15.27	20.67±17.79	19.33±17.10	22.00±18.25	19.43±12.93	36.77±52.17	24.00±17.06	13.90±13.18	16.43±8.61	18.67±9.29	19.67±9.50

Table B2. Summary of total and dissolved metals (mean ± standard deviation, n=3)

Parameter	DL	Unit	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Aluminum, Dissolved	0.4	ug/L	6.40±1.25	5.64±1.16	5.13±1.62	5.20±0.44	4.82±1.46	4.52±1.18	4.67±1.27	5.30±1.47	4.47±1.52	4.87±1.10	4.80±1.35	5.03±0.80
Aluminum, Total	0.4	ug/L	232.3±124.6	256.2±124.7	192.0±110.5	207.6±192.7	175.0±160.6	155.1±140.1	267.2±315.5	208.2±205.2	169.5±182.9	225.7±133.1	193.3±219.8	263.3±181.8
Antimony, Dissolved	0.09	ug/L	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Antimony, Total	0.008	ug/L	0.054±0.009	0.051±0.007	0.062±0.006	0.062±0.005	0.062±0.006	0.046±0.007	0.067±0.009	0.059±0.005	0.061±0.007	0.049±0.010	0.056±0.008	0.052±0.007
Arsenic, Dissolved	0.01	ug/L	0.420±0.056	0.462±0.056	0.407±0.031	0.420±0.046	0.416±0.034	0.406±0.084	0.487±0.045	0.443±0.049	0.500±0.053	0.490±0.017	0.433±0.029	0.443±0.006
Arsenic, Total	0.01	ug/L	0.637±0.165	0.740±0.130	0.600±0.095	0.650±0.148	0.616±0.098	0.616±0.151	0.703±0.224	0.650±0.154	0.620±0.113	0.680±0.060	0.623±0.090	0.657±0.081
Barium, Dissolved	0.05	ug/L	46.3±2.1	42.4±1.7	52.6±1.6	53.0±1.6	53.4±1.4	43.9±0.4	52.4±1.0	49.6±1.0	53.0±1.5	41.7±1.7	51.0±3.1	45.1±0.8
Barium, Total	0.05	ug/L	54.1±5.1	50.7±3.5	59.8±1.4	61.3±1.4	59.9±2.6	48.7±3.8	61.8±7.8	56.8±3.8	58.1±3.8	48.0±5.2	56.3±5.4	51.7±4.9
Beryllium, Dissolved	0.004	ug/L	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Beryllium, Total	0.003	ug/L	0.019±0.010	0.024±0.010	0.019±0.010	0.018±0.013	0.018±0.011	0.014±0.009	0.022±0.020	0.019±0.010	0.015±0.011	0.019±0.009	0.017±0.014	0.023±0.014
Bismuth, Dissolved	0.003	ug/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004±0.004	<0.003	<0.003	<0.003
Bismuth, Total	0.003	ug/L	0.004±0.002	0.005±0.002	0.005±0.001	0.006±0.006	0.005±0.003	0.004±0.003	0.006±0.004	0.004±0.003	0.003±0.003	0.005±0.004	0.005±0.004	0.007±0.004
Boron, Dissolved	0.2	ug/L	20.9±4.7	20.9±1.1	18.9±2.5	19.4±2.2	19.8±1.8	22.5±1.7	20.3±2.7	19.0±2.0	19.7±2.3	24.1±1.0	19.3±2.3	21.4±1.9
Boron, Total	0.2	ug/L	21.8±4.8	21.5±1.2	19.9±2.8	20.3±2.6	20.6±2.0	23.0±1.4	21.2±2.5	19.9±1.7	20.3±2.4	24.8±0.7	19.6±2.0	21.5±1.6
Cadmium, Dissolved	0.002	ug/L	0.010±0.001	0.007±0.001	0.011±0.001	0.012±0.002	0.011±0.001	0.008±0.000	0.010±0.001	0.009±0.001	0.011±0.002	0.007±0.002	0.011±0.001	0.009±0.000
Cadmium, Total	0.01	ug/L	0.020±0.010	0.016±0.005	0.020±0.000	0.020±0.000	0.020±0.000	0.012±0.004	0.020±0.010	0.017±0.006	0.013±0.006	0.020±0.010	0.020±0.010	0.020±0.000
Calcium, Dissolved	0.03	mg/L	30.6±1.0	28.5±0.6	33.8±1.5	33.9±2.0	34.4±1.7	29.5±1.3	34.9±2.5	32.3±2.1	34.9±2.5	29.0±0.9	33.1±2.9	30.5±1.8
Calcium, Total	0.01	mg/L	32.2±1.8	29.8±0.2	35.6±1.6	36.1±1.7	36.1±1.1	30.4±1.0	36.8±1.5	34.1±1.4	36.3±2.0	30.2±0.6	34.4±1.8	31.3±0.3
Chlorine, Dissolved	0.2	mg/L	7.933±4.786	8.580±1.481	4.400±1.670	4.367±1.650	4.300±1.257	9.600±2.151	5.000±1.562	5.333±1.115	4.400±1.510	9.800±1.664	5.867±0.862	8.467±1.305
Chlorine, Total	0.03	mg/L	8.160±4.713	8.740±1.395	4.660±1.796	4.547±1.746	4.460±1.185	9.822±2.071	5.080±1.595	5.513±1.111	4.440±1.465	9.907±1.468	5.870±0.996	8.497±1.392
Chromium, Dissolved	0.3	ug/L	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chromium, Total	0.1	ug/L	0.367±0.115	0.460±0.195	0.433±0.321	0.333±0.231	0.340±0.207	0.290±0.213	0.500±0.520	0.367±0.306	0.300±0.265	0.400±0.173	0.300±0.346	0.433±0.231
Cobalt, Dissolved	0.006	ug/L	0.082±0.017	0.077±0.008	0.085±0.009	0.078±0.018	0.083±0.017	0.078±0.011	0.084±0.004	0.079±0.024	0.088±0.023	0.073±0.004	0.077±0.008	0.074±0.009
Cobalt, Total	0.002	ug/L	0.303±0.111	0.352±0.128	0.259±0.113	0.290±0.153	0.280±0.120	0.214±0.131	0.383±0.331	0.295±0.160	0.253±0.164	0.293±0.106	0.269±0.259	0.338±0.183
Copper, Dissolved	0.08	ug/L	0.620±0.069	0.596±0.059	0.667±0.064	0.673±0.070	0.668±0.088	0.570±0.122	0.720±0.061	0.667±0.121	0.673±0.055	0.563±0.104	0.637±0.072	0.620±0.104
Copper, Total	0.08	ug/L	1.23±0.64	1.23±0.54	2.20±2.12	1.11±0.26	1.35±0.99	0.84±0.28	1.36±0.62	0.97±0.27	0.97±0.31	0.94±0.30	0.95±0.40	1.08±0.34
Iron, Dissolved	2	ug/L	107.7±30.9	153.2±14.1	63.7±15.8	61.3±21.2	58.2±17.2	147.2±10.9	57.0±19.2	82.7±9.1	55.0±13.9	159.7±5.0	83.0±18.2	120.3±14.3
Iron, Total	0.6	ug/L	745.7±214.9	930.8±281.0	567.3±219.2	584.7±334.5	560.6±272.1	628.4±345.2	744.3±629.2	657.0±369.7	469.7±339.8	840.3±264.0	540.7±501.9	826.3±393.1
Lead, Dissolved	0.02	ug/L	0.027±0.006	0.023±0.012	0.027±0.006	<0.02	0.020±0.010	0.020±0.010	0.026±0.009	0.028±0.015	<0.02	<0.02	0.026±0.011	<0.02
Lead, Total	0.004	ug/L	0.322±0.194	0.371±0.167	0.356±0.289	0.311±0.237	0.267±0.180	0.244±0.148	0.404±0.397	0.289±0.207	0.230±0.216	0.292±0.171	0.306±0.267	0.351±0.240
Lithium, Dissolved	0.02	ug/L	6.29±1.19	5.69±0.47	6.12±0.90	6.06±0.76	6.24±0.61	6.46±0.65	6.27±0.97	6.14±0.91	6.17±0.83	6.42±0.47	6.15±0.72	6.25±0.65
Lithium, Total	0.007	ug/L	6.74±0.97	6.16±0.44	6.68±0.89	6.58±0.66	6.73±0.51	6.72±0.44	6.88±0.53	6.68±0.67	6.45±0.64	6.81±0.30	6.41±0.27	6.57±0.20
Manganese, Dissolved	0.01	ug/L	6.39±8.87	2.09±2.11	2.22±2.30	2.19±2.20	2.03±1.56	3.69±2.54	1.95±1.94	1.52±1.53	1.28±1.19	1.87±1.24	0.97±0.45	1.03±0.71
Manganese, Total	0.04	ug/L	39.5±8.3	42.5±14.4	28.1±8.6	28.1±11.9	28.1±9.8	28.0±15.3	37.3±27.0	29.9±14.7	23.6±15.6	35.2±13.3	21.8±22.0	35.0±18.4
Molybdenum, Dissolved	0.005	ug/L	0.589±0.072	0.557±0.030	0.802±0.037	0.911±0.065	0.876±0.045	0.555±0.045	1.223±0.206	0.665±0.041	1.027±0.041	0.514±0.040	0.666±0.099	0.591±0.094
Molybdenum, Total	0.002	ug/L	0.609±0.090	0.576±0.046	0.845±0.053	0.930±0.038	0.897±0.064	0.584±0.064	1.247±0.234	0.675±0.044	1.050±0.035	0.527±0.054	0.702±0.115	0.623±0.118
Nickel, Dissolved	0.03	ug/L	0.863±0.107	0.942±0.325	0.903±0.067	0.900±0.046	1.042±0.228	0.852±0.080	1.020±0.089	0.960±0.180	0.963±0.083	0.833±0.068	0.767±0.188	0.877±0.015
Nickel, Total	0.03	ug/L	2.91±1.76	2.06±0.82	1.63±0.20	1.71±0.30	1.66±0.32	1.46±0.32	3.58±2.75	3.49±3.31	1.52±0.32	1.56±0.16	1.37±0.68	1.90±0.56
Selenium, Dissolved	0.2	ug/L	0.133±0.058	0.120±0.045	0.167±0.115	0.200±0.100	0.220±0.084	0.140±0.055	0.300±0.000	0.167±0.115	0.167±0.058	0.233±0.115	0.233±0.058	0.167±0.058
Selenium, Total	0.2	ug/L	0.200±0.100	0.200±0.100	0.167±0.115	0.267±0.058	0.300±0.000	0.200±0.071	0.300±0.000	0.300±0.000	0.233±0.058	0.233±0.058	0.267±0.058	0.233±0.058
Silver, Dissolved	0.003	ug/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Silver, Total	0.001	ug/L	0.005±0.001	0.004±0.002	0.003±0.001	0.007±0.009	0.004±0.003	0.003±0.002	0.005±0.005	0.004±0.003	0.003±0.002	0.004±0.001	0.003±0.001	0.004±0.002
Strontium, Dissolved	0.07	ug/L	218.3±13.6	200.4±5.3	246.0±11.4	246.3±17.2	254.4±15.4	205.8±12.0	249.0±17.4	239.0±13.5	251.7±20.2	199.3±7.6	240.0±31.2	217.0±7.0
Strontium, Total	0.07	ug/L	230.0±19.3	207.2±4.8	257.3±17.9	258.0±12.3	266.2±16.4	212.0±16.2	264.0±21.6	252.0±14.0	259.0±24.4	209.0±13.9	250.0±30.0	221.3±10.7
Thallium, Dissolved	0.002	ug/L	0.004±0.001	0.004±0.001	0.004±0.001	0.005±0.001	0.005±0.000	0.004±0.000	0.005±0.001	0.004±0.001	0.005±0.001	0.004±0.001	0.006±0.001	0.006±0.002
Thallium, Total	0.002	ug/L	0.009±0.003	0.009±0.003	0.009±0.003	0.009±0.004	0.009±0.003	0.007±0.004	0.011±0.008	0.009±0.005	0.009±0.004	0.009±0.003	0.010±0.004	0.010±0.003
Thorium, Dissolved	0.002	ug/L	0.005±0.002	0.008±0.001	0.005±0.001	0.007±0.003	0.005±0.002	0.008±0.001	0.006±0.001	0.006±0.001	0.006±0.002	0.008±0.001	0.006±0.002	0.006±0.001
Thorium, Total	0.002	ug/L	0.051±0.016	0.060±0.021	0.042±0.018	0.051±0.045	0.045±0.036	0.041±0.027	0.067±0.071	0.051±0.045	0.040±0.039	0.060±0.024	0.050±0.046	0.061±0.035
Tin, Dissolved	0.06	ug/L	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Tin, Total	0.06	ug/L	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Titanium, Dissolved	0.03	ug/L	0.697±0.051	0.814±0.013	0.610±0.056	0.677±0.107	0.618±0.076	0.796±0.025	0.800±0.085	0.690±0.053	0.667±0.130	0.853±0.051	0.733±0.119	0.703±0.090
Titanium, Total	0.03	ug/L	4.29±1.49	5.00±1.54	3.58±1.17	3.610±1.70	3.48±1.26	3.44±1.71	4.48±2.83	3.80±1.88	2.96±1.80	4.61±1.01	3.71±2.27	4.53±1.58
Uranium, Dissolved	0.002	ug/L	0.353±0.028	0.318±0.008	0.425±0.021	0.429±0.021	0.438±0.025	0.327±0.014	0.438±0.020	0.402±0.028	0.437±0.035	0.313±0.009	0.399±0.032	0.366±0.038
Uranium, Total	0.002	ug/L	0.388±0.051	0.355±0.019	0.460±0.039	0.465±0.016	0.474±0.028	0.341±0.023	0.477±0.028	0.435±0.026	0.460±0.041	0.343±0.024	0.418±0.032	0.386±0.028
Vanadium, Dissolved	0.006	ug/L	0.200±0.023	0.201±0.026	0.236±0.031	0.187±0.004	0.208±0.021	0.201±0.023	0.272±0.061	0.178±0.010	0.229±0.027	0.183±0.042	0.222±0.017	0.191±0.038
Vanadium, Total	0.007	ug/L	0.892±0.284	0.930±0.240	0.710±0.177	0.788±0.349	0.775±0.299	0.616±0.359	0.975±0.749	0.805±0.340	0.683±0.387	0.846±0.226	0.624±0.413	0.885±0.377
Zinc, Dissolved	0.3	ug/L	0.667±0.058	0.860±0.422	0.733±0.321	0.617±0.407	0.680±0.239	0.490±0.270	0.717±0.530	0.500±0.200	0.700±0.100	0.733±0.416	0.600±0.173	0.767±0.379
Zinc, Total	0.2	ug/L	4.10±3.73	2.44±0.73	2.43±1.10	2.30±0.79	2.02±0.89	1.92±0.51	3.133±1.834	2.200±0.755	1.733±1.185	2.033±0.945	2.167±1.250	2.433±1.447

Table B3. Summary of parent and alkylated PAHs (batch 1; mean ± standard deviation, n=3)

Parameter	Reporting Limit (Min - Max)[1]	Unit	% Nondetects	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Naphthalene	0.028 - 0.245	ng/L	0	1.767±0.235	2.057±0.323	1.673±0.310	1.683±0.198	1.743±0.180	2.383±0.185	9.510±13.593	2.087±0.167	2.347±0.768	2.173±0.508	1.923±0.287	2.407±0.514
Acenaphthylene	0.020 - 0.131	ng/L	25	0.070±0.034	0.093±0.038	0.067±0.040	0.061±0.034	0.068±0.042	0.111±0.019	0.148±0.173	0.106±0.016	0.083±0.046	0.115±0.043	0.088±0.029	0.095±0.064
Acenaphthene	0.035 - 0.146	ng/L	0	0.149±0.031	0.152±0.022	0.130±0.010	0.140±0.011	0.149±0.022	0.142±0.015	0.187±0.056	0.171±0.024	0.154±0.043	0.168±0.012	0.165±0.031	0.189±0.009
2-Methylfluorene	0.039 - 0.194	ng/L	22	0.132±0.026	0.083±0.023	0.105±0.046	0.076±0.033	0.119±0.064	0.089±0.053	0.159±0.127	0.112±0.074	0.131±0.037	0.086±0.004	0.133±0.014	0.134±0.012
C2 Phenanthrenes/Anthracenes	0.018 - 0.182	ng/L	0	3.243±1.056	2.110±0.208	2.123±0.926	2.093±0.486	2.390±1.106	2.323±0.235	3.653±2.569	2.793±1.581	1.979±0.929	2.307±0.644	2.580±1.236	2.690±0.876
Fluorene	0.020 - 0.178	ng/L	0	0.266±0.097	0.209±0.021	0.227±0.034	0.233±0.075	0.218±0.044	0.181±0.030	0.273±0.143	0.270±0.141	0.173±0.042	0.216±0.080	0.260±0.136	0.268±0.102
Phenanthrene	0.033 - 0.186	ng/L	0	1.573±0.382	1.340±0.061	1.390±0.221	1.300±0.223	1.323±0.248	1.091±0.124	1.462±0.769	1.293±0.413	1.088±0.359	1.193±0.325	1.330±0.431	1.317±0.375
Anthracene	0.032 - 0.184	ng/L	58	0.073±0.058	0.061±0.031	0.049±0.022	0.082±0.010	0.057±0.008	0.060±0.006	0.096±0.085	0.054±0.023	0.061±0.041	0.064±0.008	0.057±0.018	0.056±0.012
C1 Phenanthrenes/Anthracenes	0.049 - 0.223	ng/L	0	1.864±1.039	1.453±0.365	1.747±0.628	1.376±0.702	1.767±0.737	1.577±0.235	2.518±1.538	1.557±0.439	1.753±0.742	1.733±0.726	1.850±0.871	1.840±0.548
Fluoranthene	0.021 - 0.134	ng/L	0	0.743±0.116	0.659±0.031	0.606±0.036	0.504±0.152	0.526±0.144	0.498±0.112	0.491±0.189	0.569±0.244	0.413±0.123	0.474±0.067	0.519±0.132	0.511±0.096
Pyrene	0.021 - 0.131	ng/L	0	1.054±0.253	1.069±0.234	0.829±0.237	0.780±0.363	0.878±0.373	0.895±0.249	0.885±0.524	0.964±0.622	0.691±0.430	0.834±0.256	0.827±0.273	0.862±0.249
Benz[a]anthracene	0.031 - 0.135	ng/L	8	0.167±0.108	0.140±0.038	0.209±0.071	0.131±0.028	0.166±0.073	0.140±0.031	0.316±0.269	0.139±0.021	0.169±0.172	0.139±0.019	0.119±0.046	0.123±0.041
Chrysene	0.033 - 0.152	ng/L	0	1.085±0.182	0.876±0.186	0.802±0.295	0.734±0.255	0.831±0.432	0.902±0.262	1.087±0.681	0.832±0.348	0.636±0.299	0.866±0.364	0.908±0.464	0.930±0.355
Benzo[b]fluoranthene	0.024 - 0.182	ng/L	0	0.451±0.052	0.323±0.114	0.313±0.098	0.237±0.083	0.280±0.164	0.335±0.119	0.339±0.275	0.273±0.092	0.178±0.112	0.273±0.094	0.333±0.098	0.282±0.035
Benzo[j,k]fluoranthenes	0.027 - 0.203	ng/L	19	0.227±0.036	0.149±0.019	0.150±0.035	0.072±0.023	0.135±0.064	0.136±0.039	0.155±0.121	0.121±0.085	0.094±0.058	0.108±0.030	0.116±0.077	0.098±0.044
Benzo[e]pyrene	0.035 - 0.264	ng/L	0	0.643±0.112	0.504±0.096	0.433±0.151	0.389±0.088	0.431±0.248	0.442±0.068	0.520±0.350	0.376±0.120	0.310±0.174	0.363±0.081	0.465±0.174	0.442±0.095
Benzo[a]pyrene	0.038 - 0.287	ng/L	22	0.212±0.111	0.152±0.057	0.226±0.068	0.127±0.066	0.181±0.091	0.184±0.035	0.345±0.294	0.156±0.072	0.170±0.142	0.171±0.034	0.173±0.035	0.191±0.013
Perylene	0.038 - 0.286	ng/L	0	2.437±0.431	1.987±0.573	1.677±0.782	1.590±0.633	1.753±0.935	1.867±0.589	2.222±2.085	1.853±0.700	1.122±0.901	1.587±0.460	2.437±0.872	2.350±1.097
Dibenz[a,h]anthracene	0.064 - 0.298	ng/L	78	< RL	0.090±0.009	< RL	0.073±0.021	< RL	0.094±0.045	0.137±0.102	< RL	0.084±0.046	0.071±0.039	0.097±0.042	0.101±0.042
Indeno[1,2,3-cd]pyrene	0.059 - 0.232	ng/L	8	0.319±0.063	0.215±0.014	0.194±0.039	0.182±0.050	0.159±0.081	0.215±0.030	0.188±0.107	0.195±0.074	0.128±0.079	0.209±0.022	0.262±0.113	0.283±0.126
Benzo[ghi]perylene	0.048 - 0.203	ng/L	0	0.467±0.086	0.358±0.053	0.306±0.078	0.270±0.056	0.316±0.149	0.359±0.049	0.403±0.256	0.346±0.077	0.229±0.135	0.317±0.046	0.407±0.077	0.404±0.125
2-Methylnaphthalene	0.030 - 0.101	ng/L	0	1.044±0.315	1.075±0.208	0.930±0.212	0.956±0.163	0.914±0.142	1.114±0.157	8.134±12.275	1.112±0.286	1.100±0.481	1.074±0.273	0.990±0.079	1.148±0.194
1-Methylnaphthalene	0.032 - 0.107	ng/L	0	0.637±0.157	0.668±0.074	0.573±0.126	0.600±0.098	0.585±0.088	0.729±0.019	3.967±5.664	0.725±0.199	0.778±0.319	0.704±0.132	0.629±0.083	0.739±0.118
C1-Naphthalenes	0.030 - 0.101	ng/L	0	1.680±0.469	1.743±0.280	1.500±0.334	1.553±0.257	1.497±0.226	1.847±0.172	12.103±17.936	1.837±0.490	1.877±0.793	1.777±0.401	1.617±0.160	1.883±0.311
Biphenyl	0.013 - 0.088	ng/L	0	0.543±0.350	0.476±0.196	0.501±0.344	0.504±0.308	0.542±0.330	0.508±0.243	0.642±0.426	0.543±0.336	0.549±0.363	0.456±0.197	0.543±0.335	0.544±0.238
C1-Biphenyls	0.020 - 0.103	ng/L	0	0.717±0.065	0.670±0.168	0.749±0.271	0.705±0.179	0.832±0.354	0.899±0.574	0.738±0.247	0.827±0.313	0.810±0.390	0.866±0.421	0.753±0.289	0.951±0.382
C2-Biphenyls	0.024 - 0.211	ng/L	0	1.593±0.508	1.477±0.920	1.770±1.325	1.574±1.310	2.192±2.141	2.966±3.259	1.483±0.350	2.208±2.054	2.302±2.523	2.627±2.376	1.812±1.045	2.533±2.177
C2-Naphthalenes	0.062 - 0.236	ng/L	0	1.483±0.440	1.227±0.156	1.424±0.478	1.407±0.441	1.403±0.457	1.230±0.202	3.938±3.460	1.753±0.993	1.456±0.511	1.480±0.543	1.683±0.751	1.773±0.733
1,2-Dimethylnaphthalene	0.062 - 0.236	ng/L	92	< RL	< RL	< RL	< RL	< RL	< RL	0.109±0.107	< RL	< RL	< RL	0.118±0.116	0.129±0.106
2,6-Dimethylnaphthalene	0.050 - 0.192	ng/L	0	0.407±0.129	0.325±0.047	0.378±0.158	0.370±0.101	0.372±0.123	0.346±0.066	1.055±0.911	0.447±0.260	0.349±0.150	0.360±0.051	0.404±0.132	0.390±0.110
C3-Naphthalenes	0.045 - 0.195	ng/L	0	2.090±0.533	1.637±0.206	1.530±0.282	1.683±0.025	1.587±0.384	1.447±0.194	1.864±1.119	1.850±0.814	1.539±0.480	1.114±0.667	1.593±0.554	1.733±0.199
2,3,6-Trimethylnaphthalene	0.043 - 0.189	ng/L	0	0.404±0.102	0.324±0.036	0.370±0.139	0.352±0.078	0.356±0.101	0.360±0.054	0.486±0.262	0.423±0.172	0.343±0.109	0.336±0.033	0.350±0.062	0.383±0.049
2,3,5-Trimethylnaphthalene	0.046 - 0.201	ng/L	0	0.319±0.089	0.242±0.053	0.245±0.070	0.265±0.078	0.278±0.077	0.278±0.028	0.381±0.211	0.319±0.148	0.263±0.095	0.288±0.069	0.277±0.141	0.314±0.072
C4-Naphthalenes	0.054 - 0.217	ng/L	0	2.020±0.173	1.257±0.241	1.162±0.622	1.201±0.601	1.310±0.885	1.567±0.356	1.810±1.399	1.622±0.750	1.269±0.491	1.707±0.090	1.362±0.567	1.633±0.218
C1-Acenaphthenes	0.032 - 0.148	ng/L	97	< RL	< RL	< RL	< RL	< RL	< RL	< RL	< RL	< RL	0.054±0.018	< RL	< RL
C1-Fluorenes	0.039 - 0.194	ng/L	0	0.664±0.161	0.497±0.089	0.507±0.068	0.524±0.103	0.566±0.139	0.471±0.065	0.683±0.319	1.752±2.198	0.570±0.191	0.580±0.140	0.634±0.255	0.636±0.138
1,7-Dimethylfluorene	0.075 - 0.300	ng/L	92	0.115±0.105	< RL	< RL	< RL	< RL	0.110±0.036	0.115±0.097	< RL	< RL	< RL	< RL	< RL
C2-Fluorenes	0.075 - 0.300	ng/L	0	1.773±0.380	1.333±0.291	1.104±0.215	1.090±0.104	1.376±0.569	1.074±0.119	1.674±1.183	1.462±0.921	1.141±0.399	1.168±0.252	1.241±0.480	1.477±0.310
C3-Fluorenes	0.094 - 0.448	ng/L	0	4.547±0.166	3.373±1.606	2.462±1.461	2.320±1.182	2.823±1.891	2.763±0.893	3.105±3.471	2.790±2.366	2.243±1.080	2.617±1.419	3.057±1.520	2.230±0.888
Dibenzothiophene	0.026 - 0.139	ng/L	0	0.183±0.077	0.154±0.031	0.216±0.046	0.188±0.025	0.175±0.033	0.165±0.053	0.305±0.183	0.174±0.060	0.214±0.142	0.169±0.036	0.174±0.018	0.152±0.029

Table B4. Summary of parent and alkylated PAHs (batch 2; mean ± standard deviation, n=3)

Parameter	Reporting Limit (Min - Max)[1]	Unit	% Nondetects	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
C1-Dibenzothiophenes	0.046 - 0.205	ng/L	6	0.590±0.460	0.472±0.298	0.740±0.254	0.604±0.247	0.522±0.300	0.493±0.276	1.413±0.892	0.761±0.623	0.895±0.533	0.747±0.220	0.274±0.088	0.406±0.265
2/3-Methyldibenzothiophenes	0.046 - 0.205	ng/L	11	0.210±0.123	0.206±0.069	0.240±0.101	0.203±0.045	0.222±0.108	0.245±0.057	0.483±0.333	0.267±0.215	0.303±0.178	0.227±0.082	0.178±0.122	0.125±0.049
C2-Dibenzothiophenes	0.032 - 0.296	ng/L	0	5.063±2.072	3.523±0.464	3.407±0.774	2.910±0.419	4.247±2.033	4.463±1.306	6.447±4.401	4.547±3.245	3.827±1.778	3.997±0.867	3.540±0.849	4.463±0.819
2,4-Dimethyldibenzothiophene	0.032 - 0.296	ng/L	17	0.273±0.185	0.155±0.035	0.247±0.072	0.197±0.037	0.261±0.112	0.225±0.114	0.411±0.310	0.309±0.262	0.224±0.144	0.223±0.111	0.148±0.043	0.273±0.093
C3-Dibenzothiophenes	0.062 - 0.275	ng/L	0	11.383±3.363	6.320±0.285	5.140±1.799	4.413±1.142	7.280±5.452	7.907±1.340	8.610±7.009	7.767±5.572	5.037±2.465	6.450±1.457	7.130±3.322	7.763±0.761
C4-Dibenzothiophenes	0.045 - 0.282	ng/L	0	13.407±5.215	7.263±0.846	4.687±1.480	4.250±0.978	7.653±6.023	8.167±2.191	6.300±5.686	8.397±4.867	3.770±2.128	5.640±1.054	8.670±4.407	8.763±1.443
3-Methylphenanthrene	0.050 - 0.224	ng/L	0	0.458±0.149	0.361±0.032	0.388±0.130	0.379±0.136	0.380±0.152	0.333±0.055	0.568±0.364	0.393±0.196	0.403±0.187	0.373±0.171	0.408±0.194	0.413±0.112
2-Methylphenanthrene	0.049 - 0.221	ng/L	0	0.575±0.183	0.451±0.061	0.516±0.233	0.454±0.119	0.506±0.289	0.470±0.110	0.779±0.477	0.493±0.278	0.546±0.253	0.471±0.229	0.529±0.273	0.532±0.191
2-Methylanthracene	0.051 - 0.230	ng/L	36	0.143±0.064	0.188±0.160	0.238±0.259	0.185±0.136	0.147±0.066	0.232±0.258	0.419±0.600	0.221±0.237	0.576±0.416	0.390±0.349	0.451±0.310	0.733±0.617
9/4-Methylphenanthrene	0.050 - 0.224	ng/L	0	0.623±0.198	0.443±0.008	0.456±0.112	0.422±0.065	0.476±0.152	0.441±0.024	0.644±0.356	0.488±0.182	0.429±0.141	0.536±0.189	0.521±0.213	0.538±0.134
1-Methylphenanthrene	0.049 - 0.223	ng/L	0	0.451±0.131	0.346±0.036	0.385±0.154	0.356±0.114	0.405±0.148	0.329±0.064	0.526±0.349	0.365±0.160	0.375±0.167	0.353±0.140	0.392±0.188	0.360±0.120
3,6-Dimethylphenanthrene	0.018 - 0.183	ng/L	0	0.291±0.072	0.209±0.018	0.194±0.060	0.175±0.061	0.216±0.080	0.214±0.014	0.311±0.222	0.250±0.163	0.183±0.090	0.232±0.072	0.270±0.198	0.235±0.062
2,6-Dimethylphenanthrene	0.018 - 0.182	ng/L	0	0.206±0.051	0.154±0.021	0.174±0.054	0.165±0.042	0.189±0.053	0.186±0.048	0.293±0.176	0.227±0.093	0.185±0.056	0.166±0.082	0.216±0.144	0.194±0.065
1,7-Dimethylphenanthrene	0.018 - 0.181	ng/L	0	0.450±0.148	0.334±0.019	0.349±0.152	0.296±0.052	0.361±0.121	0.308±0.029	0.503±0.335	0.428±0.154	0.284±0.128	0.433±0.142	0.382±0.212	0.427±0.132
1,8-Dimethylphenanthrene	0.018 - 0.182	ng/L	17	0.148±0.056	0.076±0.017	0.068±0.030	0.081±0.035	0.080±0.053	0.087±0.025	0.129±0.127	0.116±0.096	0.071±0.050	0.062±0.022	0.106±0.082	0.096±0.013
C3-Phenanthrenes/Anthracenes	0.055 - 0.270	ng/L	0	5.110±1.490	2.803±0.110	2.260±0.850	2.110±0.700	2.843±1.462	3.120±0.062	3.690±3.133	3.740±2.313	2.050±1.002	3.220±1.300	3.847±2.417	3.453±0.955
1,2,6-Trimethylphenanthrene	0.055 - 0.270	ng/L	17	0.237±0.073	0.145±0.004	0.114±0.022	0.105±0.042	0.140±0.088	0.126±0.029	0.171±0.157	0.184±0.089	0.076±0.046	0.149±0.043	0.193±0.099	0.185±0.028
Retene	0.146 - 0.610	ng/L	0	2.600±0.702	2.033±0.883	1.890±0.815	1.572±0.702	3.367±1.996	2.297±0.757	2.356±1.910	2.580±1.457	1.300±0.925	2.407±1.177	2.493±1.829	2.480±0.898
C4-Phenanthrenes/Anthracenes	0.146 - 0.610	ng/L	0	20.333±4.148	12.133±0.751	9.377±2.969	8.413±2.001	14.707±8.619	14.267±3.723	14.260±10.914	13.983±7.204	8.153±4.418	11.400±3.655	13.823±6.628	12.733±1.877
C1-Fluoranthenes/Pyrenes	0.026 - 0.165	ng/L	0	2.723±0.380	2.267±0.483	1.803±0.591	1.580±0.493	1.920±1.076	2.313±0.833	2.260±1.417	2.097±0.886	1.404±0.662	2.147±0.782	2.190±1.178	2.253±0.504
3-Methylfluoranthene/Benzo[a]fluorene	0.026 - 0.165	ng/L	0	0.656±0.171	0.480±0.089	0.461±0.154	0.411±0.105	0.463±0.162	0.478±0.150	0.618±0.440	0.478±0.204	0.350±0.161	0.460±0.166	0.446±0.180	0.516±0.165
C2-Fluoranthenes/Pyrenes	0.023 - 0.140	ng/L	0	5.143±0.935	3.800±0.666	2.750±0.740	2.347±0.482	3.513±2.095	3.857±0.938	3.183±2.036	3.477±1.539	2.073±0.937	3.533±1.142	4.147±1.884	4.330±0.720
C3-Fluoranthenes/Pyrenes	0.033 - 0.170	ng/L	0	4.130±1.124	2.903±0.777	1.883±0.486	1.750±0.601	2.757±2.293	2.957±1.145	1.969±1.556	2.963±1.340	1.197±0.730	2.163±0.281	3.100±1.566	3.120±0.465
C4-Fluoranthenes/Pyrenes	0.047 - 0.207	ng/L	0	1.827±0.412	1.184±0.378	0.836±0.273	0.669±0.277	1.194±0.929	1.224±0.460	0.817±0.652	1.156±0.561	0.567±0.238	1.175±0.572	1.479±1.071	1.590±0.645
C1-Benzo[a]anthracenes/Chrysenes	0.030 - 0.126	ng/L	0	2.360±0.208	1.717±0.222	1.527±0.583	1.303±0.290	1.743±1.089	1.773±0.361	2.364±1.591	1.587±0.554	1.240±0.738	1.590±0.529	2.060±0.944	1.783±0.801
5/6-Methylchrysene	0.030 - 0.128	ng/L	3	0.222±0.028	0.122±0.016	0.107±0.031	0.102±0.021	0.139±0.087	0.144±0.022	0.149±0.123	0.148±0.030	0.085±0.038	0.150±0.038	0.235±0.126	0.170±0.069
1-Methylchrysene	0.029 - 0.125	ng/L	0	0.313±0.053	0.217±0.017	0.197±0.081	0.167±0.046	0.213±0.127	0.231±0.022	0.290±0.195	0.208±0.059	0.157±0.084	0.211±0.047	0.279±0.115	0.219±0.074
C2-Benzo[a]anthracenes/Chrysenes	0.032 - 0.168	ng/L	0	3.650±0.733	2.363±0.499	1.830±0.677	1.547±0.352	2.523±1.909	2.473±0.709	2.450±1.660	2.220±0.818	1.289±0.739	2.100±0.554	2.930±1.209	2.797±0.901
5,9-Dimethylchrysene	0.032 - 0.168	ng/L	0	0.922±0.197	0.560±0.067	0.416±0.117	0.414±0.047	0.608±0.448	0.639±0.253	0.619±0.486	0.535±0.262	0.304±0.145	0.423±0.086	0.836±0.507	0.650±0.205
C3-Benzo[a]anthracenes/Chrysenes	0.031 - 0.192	ng/L	3	1.750±0.621	1.065±0.343	0.626±0.179	0.693±0.308	1.012±0.695	1.155±0.229	0.896±0.774	1.057±0.331	0.190±0.173	0.882±0.148	1.221±0.588	1.350±0.195
C4-Benzo[a]anthracenes/Chrysenes	0.047 - 0.248	ng/L	81	0.560±0.498	0.274±0.252	< RL	< RL	< RL	0.192±0.128	< RL	< RL	< RL	0.107±0.099	< RL	< RL
C1-Benzofluoranthenes/Benzopyrenes	0.064 - 0.513	ng/L	0	2.173±0.025	1.673±0.490	1.343±0.570	1.067±0.115	1.676±1.343	1.603±0.443	2.123±1.596	1.527±0.639	0.935±0.633	1.317±0.150	2.143±0.971	1.870±0.408
7-Methylbenzo[a]pyrene	0.064 - 0.513	ng/L	92	0.138±0.050	0.113±0.060	< RL	< RL	< RL	< RL	< RL	< RL	< RL	0.096±0.019	< RL	< RL
C2-Benzofluoranthenes/Benzopyrenes	0.086 - 0.361	ng/L	6	1.177±0.154	0.834±0.251	0.579±0.251	0.369±0.174	0.855±0.576	0.770±0.247	0.972±0.785	0.712±0.416	0.441±0.299	0.557±0.101	0.752±0.195	0.841±0.134
1,4,6,7-Tetramethylnaphthalene	0.054 - 0.217	ng/L	0	0.359±0.083	0.240±0.034	0.212±0.068	0.216±0.069	0.253±0.139	0.342±0.050	0.382±0.301	0.318±0.116	0.217±0.073	0.473±0.148	0.343±0.270	0.338±0.171

Table B5. Summary of petroleum hydrocarbons (mean ± standard deviation, n=3)

Parameter	DL	Unit	% Nondetects	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Benzene	0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
EthylBenzene	0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
F1(C6-C10)	0.1	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
F1-BTEX	0.1	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
F2 (>C10-C16)	0.1	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
F3 (C16-C34)	0.25	mg/L	97.9	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.33±0.57	<DL	<DL	<DL	<DL
F4 (C34-C50)	0.25	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
m+p-Xylene	0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
o-Xylene	0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Styrene	0.001 or 0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	No data	<DL	No data	No data
Toluene	0.0005	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Xylenes	0.00071	mg/L	100	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL

Table B6. Summary of total phenols (mean ± standard deviation, n=3)

Parameter	DL	Unit	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Phenol	0.001	mg/L	<DL	<DL	<DL	0.0011±0.0007	<DL	<DL	0.0011±0.0005	0.0011±0.0007	0.0012±0.0007	<DL	<DL	<DL

Table B7. Summary of mercury and methyl mercury (mean ± standard deviation, n=3)

Parameter	Detection Limit	Unit	12 km U/S	4.0 km U/S	0.5 km U/S	0.03 km U/S	0.03 km D/S W	0.03 km D/S E	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S	4.5 km D/S	12 km D/S
Total Mercury	0.06	ng/L	2.50±0.69	1.83±0.56	1.79±0.68	1.82±0.62	1.72±0.60	1.76±0.52	1.75±0.99	1.97±0.49	1.39±0.54	1.73±0.52	2.14±0.70	2.01±0.58
Dissolved Mercury	0.08	ng/L	0.70±0.05	0.74±0.06	0.68±0.13	0.70±0.22	0.67±0.16	0.73±0.04	0.67±0.16	0.69±0.13	0.67±0.14	0.76±0.07	0.71±0.13	0.74±0.08
Methyl Mercury	0.01	ng/L	0.06±0.01	0.06±0.01	0.07±0.03	0.05±0.00	0.06±0.01	0.06±0.01	0.05±0.00	0.05±0.00	0.04±0.01	0.05±0.01	0.06±0.01	0.06±0.02
Dissolved Methyl Mercur	0.01	ng/L	0.04±0.01	0.04±0.01	0.03±0.01	0.03±0.01	0.03±0.01	0.04±0.01	0.02±0.02	0.03±0.01	0.02±0.02	0.04±0.01	0.03±0.00	0.03±0.01

APPENDIX C Summary statistics for sediment quality parameters collected in the Lower Athabasca River in September, 2018

Table C1. Summary of nutrients in sediment (mean ± standard deviation, n=3-5)

Parameter	DL	Unit	20 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Available Ammonium-N	1-5	mg/kg	11.60±10.80	7.63±3.42	8.73±3.18	13.80±9.42	15.26±6.84	21.90±3.30	17.57±14.09	1.57±1.44	4.90±2.50	4.40±4.28	3.80±2.31	11.50±7.46	41.93±26.64
Total Kjeldahl Nitrogen	0.02	%	0.02±0.02	0.04±0.02	0.06±0.01	0.06±0.03	0.07±0.03	0.10±0.01	0.06±0.04	0.01±0.00	0.02±0.01	0.03±0.03	0.02±0.01	0.06±0.05	0.05±0.03
Total Organic Carbon	0.05-0.51	%	0.48±0.25	0.98±0.19	1.32±0.40	1.40±0.50	1.24±0.40	1.64±0.15	1.06±0.74	0.21±0.09	0.55±0.24	0.61±0.57	0.48±0.24	1.28±0.79	1.26±0.49
Total Organic Nitrogen	0.02	%	0.02±0.02	0.04±0.02	0.05±0.01	0.06±0.03	0.06±0.03	0.09±0.01	0.05±0.04	0.01±0.00	0.02±0.01	0.03±0.03	0.02±0.01	0.06±0.05	0.05±0.02
Loss on Ignition @ 375 C	1	%	0.87±0.64	1.87±0.60	2.00±0.46	2.37±0.95	2.10±0.74	3.18±0.24	1.83±1.16	0.50±0.00	0.70±0.35	1.03±0.92	0.77±0.46	2.07±1.37	2.07±0.90

Table C2. Summary of particle size distribution (mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	20 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Clay	1	%	4.40±2.43	11.30±2.39	11.73±3.71	11.92±4.85	13.84±1.28	8.40±6.10	1.17±0.76	3.27±2.41	3.47±4.27	3.17±2.75	10.67±2.41	13.47±8.20	11.03±4.84
Sand	1	%	86.47±13.51	51.67±12.58	50.00±19.08	52.20±22.43	36.32±5.03	58.40±33.62	95.93±4.62	88.07±11.13	83.27±23.09	86.60±12.00	59.67±7.64	53.07±33.98	60.00±16.12
Silt	1	%	9.13±11.09	37.03±10.32	38.27±15.56	35.88±17.59	49.84±4.28	33.20±27.54	2.80±3.98	8.67±8.77	13.27±18.82	10.10±9.45	29.67±5.37	33.47±25.78	28.97±11.40
Texture			Sand, sandy loam	Sandy loam	Loam, sandy loam	Loam, sandy loam	Sandy loam, silt loam	Silt loam, loam	Loam, sand	Sand	Sand, sandy loam / loamy sand	Sand, sandy loam	Sand, sandy loam	Silt loam, loam, sand	Sandy loam, loam

Table C3. Summary of mercury and methyl mercury in sediment (mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	25 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Mercury	1.60	ng/g	12.41±6.87	27.57±5.77	33.20±7.53	35.84±14.12	34.21±10.08	45.30±3.51	30.25±21.54	5.35±2.43	12.83±5.34	17.38±17.08	14.97±10.14	35.56±19.97	31.14±12.44
Methyl Mercury	0.010	ng/g	0.20±0.21	0.38±0.11	0.50±0.19	0.76±0.49	0.65±0.32	1.16±0.10	0.53±0.45	0.04±0.05	0.17±0.10	0.31±0.48	0.09±0.08	0.75±0.57	0.48±0.29

Table C4. Summary of total phenols in sediment (mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	20 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Extractable (Water) Phenols	0.02	mg/kg	<DL	0.03±0.01	<DL	<DL	<DL	0.02±0.01	<DL	<DL	<DL	<DL	<DL	<DL	<DL

Table C5. Summary of trace metals in sediment (mean ± standard deviation, n=3-5)

Parameter	DL	Unit	25 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Total Aluminum (Al)	100	mg/kg	3,453±2,122	5,713±1,284	7,406±1,022	7,370±2,046	8,032±2,638	9,718±912	6,343±3,819	1,470±554	3,353±686	4,236±3,009	4,130±2,185	7,106±3,305	5,993±1,657
Total Antimony (Sb)	0.1	mg/kg	0.15±0.06	0.19±0.06	0.23±0.03	0.25±0.08	0.26±0.08	0.30±0.01	0.20±0.13	0.05±0.00	0.13±0.02	0.13±0.10	0.12±0.07	0.22±0.09	0.21±0.06
Total Arsenic (As)	0.5	mg/kg	3.91±0.83	4.48±0.82	5.13±0.58	5.98±1.20	5.44±0.90	6.42±0.40	4.70±1.41	2.76±0.36	3.85±0.40	3.74±1.55	3.95±0.95	5.10±1.78	4.96±1.20
Total Barium (Ba)	0.1	mg/kg	78.73±39.21	130.00±24.27	168.00±25.53	165.33±32.59	170.60±35.68	183.80±7.33	134.33±72.22	33.73±14.46	80.37±7.59	89.10±59.67	87.63±36.95	136.10±37.07	135.67±24.01
Total Beryllium (Be)	0.2	mg/kg	0.19±0.15	0.37±0.07	0.47±0.04	0.43±0.09	0.48±0.15	0.56±0.07	0.38±0.24	0.10±0.00	0.21±0.10	0.21±0.18	0.24±0.15	0.44±0.19	0.37±0.05
Total Bismuth (Bi)	0.1	mg/kg	0.05±0.00	0.05±0.00	0.07±0.03	0.10±0.04	0.09±0.05	0.13±0.01	0.09±0.04	0.05±0.00	0.05±0.00	0.05±0.00	0.05±0.00	0.09±0.04	0.07±0.03
Total Boron (B)	1	mg/kg	3.17±1.59	5.23±0.65	7.10±0.35	5.87±0.91	6.66±1.78	8.04±1.10	4.87±2.80	1.43±0.59	3.07±0.99	3.53±2.59	3.93±2.38	6.63±3.17	5.60±0.72
Total Cadmium (Cd)	0.05	mg/kg	0.07±0.05	0.13±0.03	0.18±0.02	0.19±0.06	0.19±0.06	0.22±0.02	0.16±0.11	0.03±0.00	0.07±0.02	0.10±0.06	0.08±0.05	0.16±0.08	0.15±0.07
Total Calcium (Ca)	100	mg/kg	11,520±6,233	19,566±3,879	25,333±702	25,866±5,958	27,580±8,500	26,420±676	18,530±9,314	4,260±1,396	13,033±1,501	15,200±6,609	13,716±5,944	20,500±5,230	18,633±1,604
Total Chromium (Cr)	1	mg/kg	6.67±3.41	11.00±2.02	13.77±1.82	13.80±2.26	14.68±3.60	16.86±1.40	11.77±6.57	3.37±0.71	7.27±1.00	8.27±4.88	8.07±3.91	12.77±4.56	11.73±2.03
Total Cobalt (Co)	0.3	mg/kg	4.56±1.56	6.02±1.16	7.10±0.56	7.41±1.42	7.59±1.58	8.60±0.50	6.60±2.55	2.77±0.44	4.77±0.40	5.14±2.14	5.15±1.49	6.60±1.86	6.35±1.15
Total Copper (Cu)	0.5	mg/kg	4.28±2.54	7.66±1.97	9.77±2.16	10.78±4.03	11.20±4.34	14.28±1.35	9.08±6.47	1.66±0.71	3.59±1.20	5.02±4.76	4.18±2.51	9.50±5.38	8.57±3.41
Total Iron (Fe)	100	mg/kg	9,713±3,109	13,000±2,605	15,766±1,497	16,700±3,364	16,740±3,874	19,920±1,257	14,300±6,248	5,990±1,022	9,920±975	10,380±4,643	10,446±3,480	14,713±4,915	14,433±2,746
Total Lead (Pb)	0.1	mg/kg	3.87±1.58	5.77±1.29	6.79±0.87	7.37±1.87	8.23±2.42	9.08±0.56	6.39±3.29	2.06±0.47	3.90±0.46	4.40±2.58	4.37±1.56	6.89±2.69	6.23±1.68
Total Lithium (Li)	5	mg/kg	4.43±3.35	8.67±1.50	11.20±1.30	9.97±2.00	11.30±3.52	13.56±1.63	8.73±5.40	2.50±0.00	4.87±2.26	5.00±4.33	5.60±3.32	10.40±4.11	8.03±0.99
Total Magnesium (Mg)	100	mg/kg	3,156±1,806	6,030±1,056	7,480±636	7,463±1,411	7,716±1,979	8,000±466	5,963±3,191	1,393±490	3,780±400	4,473±2,376	4,080±1,869	6,393±1,911	6,453±808
Total Manganese (Mn)	0.2	mg/kg	276.33±83.01	329.00±114.33	375.00±43.86	400.67±121.51	431.20±143.73	542.80±36.46	328.00±128.93	148.67±33.25	257.00±22.72	263.00±114.94	256.00±61.55	374.67±139.79	317.33±92.54
Total Mercury (Hg)	0.05	mg/kg	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.01	0.03±0.01	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00
Total Molybdenum (Mo)	0.1	mg/kg	0.43±0.11	0.53±0.11	0.70±0.05	0.69±0.21	0.73±0.23	0.79±0.05	0.55±0.31	0.18±0.03	0.33±0.06	0.38±0.27	0.35±0.12	0.62±0.28	0.57±0.15
Total Nickel (Ni)	0.8	mg/kg	9.28±3.57	13.70±2.52	16.57±1.67	17.37±3.97	17.76±4.41	20.58±1.31	14.77±7.12	5.09±1.02	9.72±1.31	10.94±5.77	10.22±3.72	15.18±5.15	14.37±2.97
Total Phosphorus (P)	10	mg/kg	377.67±99.88	555.33±108.55	674.33±35.28	681.33±84.89	648.80±95.78	687.60±36.57	597.00±287.52	239.33±59.47	418.33±11.59	477.00±156.00	415.33±123.93	564.33±107.38	604.67±52.60
Total Potassium (K)	100	mg/kg	477.00±252.29	733.67±121.40	948.00±112.28	935.33±258.37	1,031.00±318.15	1,276.00±145.02	739.67±411.42	246.00±78.46	471.67±111.55	544.33±341.88	545.67±256.94	921.33±423.49	820.67±216.68
Total Selenium (Se)	0.5	mg/kg	0.25±0.00	0.25±0.00	0.25±0.00	0.33±0.14	0.32±0.15	0.30±0.11	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00
Total Silver (Ag)	0.05	mg/kg	0.03±0.01	0.04±0.02	0.05±0.02	0.06±0.03	0.07±0.03	0.08±0.01	0.06±0.03	0.03±0.00	0.03±0.00	0.04±0.02	0.03±0.00	0.06±0.03	0.05±0.03
Total Sodium (Na)	100	mg/kg	50.00±0.00	50.00±0.00	166.00±97.12	97.00±40.73	77.60±37.96	116.80±9.81	50.00±0.00	50.00±0.00	50.00±0.00	50.00±0.00	50.00±0.00	91.33±36.47	69.67±34.06
Total Strontium (Sr)	0.1	mg/kg	31.50±15.90	49.80±10.28	60.27±6.57	64.80±14.91	68.34±19.53	73.54±4.64	50.50±27.14	15.00±5.12	31.70±3.80	36.33±19.81	35.10±14.43	55.40±20.45	50.97±11.22
Total Thallium (Tl)	0.05	mg/kg	0.05±0.04	0.09±0.02	0.13±0.02	0.13±0.04	0.14±0.04	0.16±0.01	0.10±0.07	0.03±0.00	0.06±0.01	0.07±0.05	0.06±0.04	0.11±0.05	0.10±0.03
Total Thorium (Th)	0.1	mg/kg	2.82±0.32	3.56±0.77	4.47±0.54	4.22±0.69	4.75±1.15	5.16±0.55	3.59±2.13	1.01±0.22	2.82±0.46	2.58±1.61	2.36±1.10	3.93±1.08	3.91±0.64
Total Tin (Sn)	0.1	mg/kg	0.13±0.09	0.23±0.04	0.30±0.05	0.35±0.09	0.35±0.12	0.42±0.05	0.25±0.18	0.05±0.00	0.14±0.04	0.23±0.10	0.15±0.10	0.35±0.09	0.28±0.10
Total Titanium (Ti)	1	mg/kg	54.40±12.78	48.83±8.43	69.53±12.39	72.20±16.54	69.42±5.79	67.32±9.91	61.77±7.22	37.97±7.18	74.87±18.37	65.10±18.42	57.20±14.55	59.30±2.15	55.23±11.06
Total Tungsten (W)	0.5	mg/kg	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00	0.25±0.00
Total Uranium (U)	0.05	mg/kg	0.46±0.18	0.68±0.11	0.88±0.08	0.84±0.15	0.90±0.19	0.93±0.08	0.71±0.42	0.19±0.05	0.48±0.04	0.53±0.30	0.49±0.20	0.74±0.22	0.75±0.13
Total Vanadium (V)	2	mg/kg	11.23±4.99	16.17±2.74	20.60±2.11	20.67±3.54	22.10±5.13	25.96±2.67	18.13±9.23	5.57±1.25	11.80±1.39	13.20±7.53	13.17±5.35	19.43±6.87	18.13±3.40
Total Zinc (Zn)	1	mg/kg	26.33±11.67	41.63±9.13	51.37±4.77	53.00±12.43	55.56±14.12	63.18±4.63	47.03±25.32	12.77±3.26	26.20±3.28	31.13±17.73	30.80±13.20	46.67±17.42	44.60±8.92
Total Zirconium (Zr)	0.5	mg/kg	2.87±1.11	3.75±0.60	5.35±0.56	5.22±1.17	5.22±0.86	5.45±0.50	3.95±2.11	1.52±0.40	3.11±0.15	3.38±1.77	3.32±1.24	4.51±1.23	4.73±1.04

Table C6. Summary of PAHs in sediment (Batch 1; mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	% ND	% NDR	25 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Naphthalene	0.05-0.18	ng/g	0	14	1.84±1.15	3.42±0.60	8.31±5.79	6.24±3.60	6.16±2.18	6.67±1.39	4.57±3.78	0.52±0.53	1.44±1.18	2.05±2.72	1.25±0.82	5.63±4.10	4.16±2.34
Acenaphthylene	0.02-0.09	ng/g	72	26	0.02±0.00	0.04±0.01	0.06±0.04	0.04±0.02	0.05±0.02	0.06±0.03	0.05±0.03	0.02±0.01	0.02±0.01	0.02±0.01	0.02±0.01	0.03±0.02	0.04±0.01
Acenaphthene	0.04-0.15	ng/g	14	0	0.29±0.19	0.78±0.10	1.17±0.49	0.89±0.41	0.82±0.31	1.22±0.20	0.69±0.56	0.09±0.10	0.20±0.18	0.30±0.45	0.27±0.19	0.93±0.61	1.12±0.62
2-Methylfluorene	0.06-0.54	ng/g	12	5	0.27±0.22	0.84±0.21	1.72±1.05	1.03±0.34	1.15±0.48	1.53±0.32	0.94±0.78	0.17±0.24	0.31±0.23	0.43±0.42	0.38±0.17	1.27±0.68	1.66±0.85
C2 Phenanthrenes/Anthracenes	0.06-0.83	ng/g	0	0	17.22±10.52	55.60±17.24	92.30±57.32	53.50±25.43	48.80±16.30	61.66±9.18	33.60±26.87	5.95±6.89	11.27±8.19	16.14±19.38	21.19±15.57	55.10±36.73	121.83±74.59
Fluorene	0.03-0.20	ng/g	2	9	0.53±0.38	1.45±0.31	2.48±1.23	1.98±0.81	2.27±0.90	2.41±0.32	1.74±1.48	0.16±0.20	0.45±0.38	0.58±0.75	0.46±0.32	1.73±1.18	1.29±0.47
Phenanthrene	0.04-0.84	ng/g	0	0	4.90±2.98	11.06±2.08	23.20±13.31	16.07±7.70	16.89±6.68	19.46±2.71	12.00±9.72	1.60±1.89	3.92±3.02	5.30±6.84	4.32±3.11	15.18±10.23	13.24±6.62
Anthracene	0.03-0.83	ng/g	16	77	0.18±0.09	0.48±0.09	5.88±5.04	1.67±0.89	2.53±1.57	2.00±0.61	1.09±0.92	0.12±0.13	0.37±0.40	0.36±0.46	0.32±0.33	0.73±0.46	0.33±0.07
C1 Phenanthrenes/Anthracenes	0.11-1.72	ng/g	0	0	10.53±6.20	23.03±3.85	80.17±57.54	36.30±19.30	40.84±16.90	49.18±8.20	28.32±23.18	3.69±4.37	9.02±7.95	12.41±16.11	9.08±6.16	34.54±24.41	50.13±32.49
Fluoranthene	0.05-0.75	ng/g	0	0	1.83±0.70	3.23±0.77	7.40±2.78	4.80±2.06	4.63±1.51	6.10±0.80	3.84±3.03	0.70±0.70	1.29±0.65	1.87±2.21	1.69±1.03	4.07±2.50	3.65±1.86
Pyrene	0.05-0.73	ng/g	0	0	3.04±0.93	5.69±1.27	22.32±15.37	9.58±4.53	9.99±3.67	11.94±2.28	7.03±5.40	1.53±1.50	2.63±1.51	3.60±3.97	3.83±2.50	7.61±4.44	9.08±5.00
Benz[a]anthracene	0.09-1.13	ng/g	0	44	0.98±0.43	2.00±0.72	24.14±22.07	6.81±3.96	7.31±3.70	7.83±2.27	3.85±3.13	0.52±0.57	1.36±1.25	1.62±1.95	1.75±1.57	3.44±2.16	3.55±2.15
Chrysene	0.09-1.25	ng/g	0	5	5.51±2.39	13.80±4.33	42.90±33.10	18.63±8.98	19.00±7.95	22.30±4.30	12.24±9.39	2.38±2.24	4.61±3.05	5.61±5.85	7.05±5.04	15.40±9.54	22.13±12.42
Benzo[b]fluoranthene	0.08-1.27	ng/g	0	28	3.53±1.28	6.39±1.49	13.55±8.05	9.04±3.85	8.97±3.00	11.08±1.36	6.99±5.30	1.47±1.38	2.66±1.28	3.63±3.96	3.82±2.37	8.33±5.20	8.63±4.13
Benzo[j,k]fluoranthenes	0.08-1.34	ng/g	0	70	1.29±0.54	2.10±0.44	7.82±5.42	3.85±1.75	3.69±1.16	4.82±0.79	2.67±2.06	0.64±0.64	1.13±0.56	1.43±1.54	1.58±1.09	3.43±2.04	3.14±1.74
Benzo[e]pyrene	0.11-1.67	ng/g	0	2	3.33±1.29	7.92±2.09	24.89±20.08	11.31±5.02	11.85±4.99	13.84±2.63	8.13±6.08	1.70±1.24	3.02±1.79	3.76±3.74	4.51±3.07	9.39±5.66	11.31±4.92
Benzo[a]pyrene	0.12-1.82	ng/g	0	19	1.71±0.70	3.20±0.76	27.99±25.22	8.82±4.82	9.30±4.41	10.95±3.17	5.35±4.27	0.88±0.90	2.03±1.41	2.69±3.20	2.66±2.31	5.09±3.13	4.75±1.98
Perylene	0.12-1.82	ng/g	0	0	31.90±14.80	57.13±13.50	68.80±18.76	76.70±31.44	75.06±20.51	105.32±14.60	65.74±51.36	11.25±10.89	22.27±10.66	32.42±39.03	30.07±17.85	74.87±46.19	63.43±26.70
Dibenz[a,h]anthracene	0.17-0.89	ng/g	2	81	0.57±0.23	1.43±0.24	8.49±7.60	2.90±1.51	3.11±1.51	3.55±0.94	1.80±1.46	0.40±0.29	0.79±0.53	0.88±0.81	1.04±0.76	1.84±0.99	1.96±0.77
Indeno[1,2,3-cd]pyrene	0.16-1.94	ng/g	0	26	1.83±0.72	3.40±0.80	8.21±4.93	5.17±1.87	4.91±1.53	6.20±1.01	3.97±2.86	0.96±0.75	1.62±0.65	2.07±1.92	2.40±1.49	4.62±2.47	4.94±1.99
Benzo[ghi]perylene	0.14-5.32	ng/g	0	2	2.96±1.25	7.64±1.92	20.72±15.73	10.25±4.18	10.47±4.03	12.45±2.07	7.25±5.37	1.51±1.18	3.06±1.56	3.64±3.53	4.19±2.73	8.61±4.94	9.43±3.43
2-Methylnaphthalene	0.05-0.14	ng/g	0	0	3.96±2.57	7.74±1.67	18.43±12.64	13.79±7.73	14.43±5.71	15.80±2.90	10.04±8.37	1.02±1.21	3.29±2.89	4.32±6.05	2.80±2.06	12.98±9.50	9.01±4.67
1-Methylnaphthalene	0.06-0.15	ng/g	0	0	2.62±1.46	4.84±1.06	10.03±6.17	8.44±4.73	8.45±3.04	9.58±1.70	6.56±5.43	0.70±0.81	2.04±1.67	2.77±3.86	1.78±1.24	8.17±5.92	5.78±3.07
C1-Naphthalenes	0.05-0.14	ng/g	0	0	6.58±4.02	12.60±2.75	28.50±18.84	22.21±12.46	22.88±8.74	25.42±4.60	16.60±13.81	1.72±2.02	5.33±4.57	7.08±9.90	4.58±3.30	21.15±15.42	14.81±7.75
Biphenyl	0.03-0.09	ng/g	0	0	1.60±1.06	3.44±0.84	3.98±1.34	4.74±2.19	5.31±2.06	5.69±0.66	3.67±2.97	0.44±0.46	1.27±0.99	1.68±2.12	1.25±0.79	4.85±3.27	3.32±1.43
C1-Biphenyls	0.03-0.09	ng/g	0	0	2.28±1.46	4.67±0.96	6.20±2.54	6.67±2.95	7.81±3.21	8.46±0.74	5.25±4.25	0.74±0.70	2.08±1.72	2.61±3.08	1.99±1.23	7.23±4.64	5.08±2.30
C2-Biphenyls	0.02-0.15	ng/g	0	0	1.96±0.97	3.82±0.53	5.45±2.47	5.35±2.23	6.09±2.30	6.92±0.59	4.22±3.31	0.90±0.47	1.97±1.26	2.64±2.33	2.00±0.93	5.90±3.43	4.69±2.27
C2-Naphthalenes	0.08-0.33	ng/g	0	0	11.86±6.84	23.13±5.19	43.57±25.56	36.87±19.37	38.08±13.77	43.66±6.63	28.93±24.00	3.22±3.89	8.85±7.29	12.35±17.37	8.22±5.81	35.82±25.60	27.30±13.31
1,2-Dimethylnaphthalene	0.08-0.33	ng/g	16	12	0.49±0.30	1.09±0.14	1.85±1.03	1.60±0.94	1.63±0.51	2.01±0.24	1.33±1.10	0.16±0.16	0.29±0.26	0.56±0.83	0.29±0.25	1.61±1.22	1.72±0.86
2,6-Dimethylnaphthalene	0.06-0.27	ng/g	0	0	2.58±1.81	5.39±1.28	11.01±6.88	8.69±4.46	9.47±3.89	10.61±1.64	6.85±5.68	0.75±0.84	2.32±2.07	2.78±3.78	1.93±1.43	8.59±6.15	5.80±2.88
C3-Naphthalenes	0.05-0.53	ng/g	0	0	10.54±4.54	23.93±2.05	35.57±17.79	31.30±16.65	29.76±9.23	37.38±4.02	25.05±20.19	4.16±5.04	8.52±5.61	11.89±15.87	9.59±5.76	33.02±22.25	51.53±29.31
2,3,6-Trimethylnaphthalene	0.05-0.51	ng/g	0	0	2.43±1.20	5.60±0.69	8.97±4.82	7.43±3.83	7.40±2.40	9.30±1.03	5.90±4.79	0.92±1.05	2.00±1.49	2.83±3.72	2.28±1.40	8.00±5.53	13.41±7.75
2,3,5-Trimethylnaphthalene	0.05-0.54	ng/g	0	0	2.07±0.97	4.45±0.42	6.74±3.18	5.94±3.12	5.63±1.74	7.18±0.82	4.89±3.97	0.76±0.86	1.63±1.13	2.23±2.96	1.80±1.10	6.29±4.31	9.40±5.44
C4-Naphthalenes	0.06-0.90	ng/g	0	0	11.45±3.41	39.37±11.68	38.20±11.61	31.43±15.37	24.66±5.58	33.62±3.06	21.39±16.85	4.25±4.96	7.02±3.22	10.37±12.94	11.63±7.33	36.18±23.48	113.50±67.97
C1-Acenaphthenes	0.03-0.22	ng/g	28	2	0.06±0.04	0.24±0.04	0.27±0.09	0.22±0.10	0.19±0.06	0.28±0.04	0.17±0.11	0.03±0.00	0.03±0.00	0.08±0.08	0.06±0.05	0.22±0.13	0.50±0.27
C1-Fluorenes	0.06-0.54	ng/g	0	0	1.76±1.11	5.30±0.86	9.09±5.26	6.15±2.83	6.50±2.66	7.69±0.92	4.54±3.81	0.65±0.76	1.45±1.18	2.00±2.45	1.83±1.29	6.55±4.56	9.54±4.82
1,7-Dimethylfluorene	0.07-0.63	ng/g	9	65	0.62±0.40	2.22±0.59	2.85±1.63	1.84±0.93	1.67±0.48	2.14±0.28	1.43±1.22	0.18±0.20	0.39±0.23	0.54±0.68	0.68±0.47	2.13±1.42	5.73±4.03
C2-Fluorenes	0.07-0.63	ng/g	0	0	6.98±4.24	29.43±8.46	33.60±14.68	25.90±12.91	21.80±7.10	29.62±4.55	16.68±13.82	2.58±2.97	5.00±3.27	8.44±10.36	8.48±6.45	27.81±18.22	60.30±33.69
C3-Fluorenes	0.16-2.95	ng/g	0	0	15.15±7.16	66.70±23.56	65.37±28.99	51.87±22.01	37.74±8.28	55.54±3.56	28.67±22.37	5.92±6.57	11.62±5.12	17.57±19.61	23.78±16.50	58.17±34.99	143.00±91.99
Dibenzothiophene	0.04-0.85	ng/g	0	91	0.54±0.33	1.47±0.25	13.36±11.53	3.97±2.12	4.37±2.22	4.62±1.23	2.37±1.94	0.28±0.30	0.86±0.81	0.99±1.22	0.87±0.79	2.38±1.58	2.25±0.96

Table C7. Summary of PAHs in sediment (Batch 2; mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	% ND	% NDR	25 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
C1-Dibenzothiophenes	0.11-0.86	ng/g	2	0	2.37±1.94	13.49±4.84	60.67±53.13	17.31±9.74	18.01±8.71	21.54±5.55	9.83±8.35	1.12±1.58	3.51±3.49	4.59±5.56	4.47±5.54	14.52±9.99	36.70±21.41
2/3-Methyldibenzothiophenes	0.11-0.86	ng/g	9	5	0.85±0.53	4.26±1.39	23.16±20.44	5.83±3.34	6.12±3.22	7.27±1.92	3.30±2.79	0.36±0.52	1.12±1.20	1.51±1.88	1.71±1.60	4.72±3.27	11.29±6.58
C2-Dibenzothiophenes	0.07-1.26	ng/g	0	0	19.15±9.53	99.40±44.34	188.47±138.80	75.47±38.97	65.34±21.91	88.62±16.45	42.13±33.53	7.89±8.41	14.76±10.04	21.72±22.29	34.72±26.23	85.53±54.86	284.90±178.29
2,4-Dimethyldibenzothiophene	0.07-1.26	ng/g	2	98	1.25±0.83	6.87±2.84	14.14±10.67	5.59±2.88	4.65±1.65	6.43±1.31	3.21±2.68	0.45±0.58	0.94±0.86	1.44±1.64	2.24±1.75	5.90±3.85	18.45±11.46
C3-Dibenzothiophenes	0.09-1.79	ng/g	0	0	39.70±20.62	191.73±87.25	223.00±134.32	126.60±67.41	95.06±21.15	146.20±19.83	66.65±52.53	15.83±16.52	23.70±13.19	40.23±38.61	71.57±52.54	163.33±104.14	531.33±354.34
C4-Dibenzothiophenes	0.14-3.95	ng/g	0	0	50.93±17.56	190.10±85.92	174.00±88.36	124.63±60.94	93.38±15.46	148.60±13.67	66.85±51.08	19.50±20.52	26.57±14.15	42.23±36.77	83.33±60.90	170.27±107.08	500.33±325.91
3-Methylphenanthrene	0.11-1.74	ng/g	0	21	2.26±1.53	6.64±1.01	16.76±11.71	8.82±4.48	9.10±3.76	10.71±1.68	6.07±4.99	0.75±0.91	2.02±1.75	2.59±3.41	2.50±1.95	8.59±5.74	10.78±6.14
2-Methylphenanthrene	0.11-1.71	ng/g	0	0	2.98±1.95	7.96±1.31	26.79±20.52	11.96±6.10	13.10±5.90	15.14±2.75	8.62±7.08	1.04±1.23	2.97±2.59	3.78±5.00	3.27±2.56	11.30±7.75	12.62±7.23
2-Methylanthracene	0.11-1.78	ng/g	35	16	0.15±0.07	0.24±0.07	9.59±9.32	1.83±1.17	2.25±1.28	2.52±0.96	1.09±0.89	0.46±0.25	0.38±0.45	0.58±0.38	0.45±0.50	0.81±0.29	0.57±0.34
9/4-Methylphenanthrene	0.11-1.74	ng/g	0	0	3.00±1.55	8.76±1.52	14.48±7.75	9.61±4.64	9.14±3.21	11.95±1.69	7.17±5.78	1.16±1.25	2.25±1.61	3.29±4.11	3.30±2.35	10.52±7.07	16.40±9.80
1-Methylphenanthrene	0.11-1.72	ng/g	0	2	2.30±1.20	6.32±1.28	12.53±8.18	7.47±3.78	7.21±2.70	8.84±1.26	5.42±4.42	0.81±0.92	1.69±1.24	2.39±2.98	2.28±1.58	7.33±4.99	11.89±6.98
3,6-Dimethylphenanthrene	0.06-0.83	ng/g	0	100	1.63±0.96	5.27±1.57	7.69±4.14	4.82±2.23	4.40±1.37	5.46±0.70	3.05±2.43	0.50±0.58	1.02±0.69	1.41±1.63	1.92±1.40	5.04±3.25	10.04±5.81
2,6-Dimethylphenanthrene	0.06-0.83	ng/g	0	2	1.19±0.79	3.37±0.87	9.54±7.29	4.04±1.95	4.30±1.82	5.40±0.97	2.69±2.21	0.40±0.49	0.98±0.80	1.22±1.47	1.40±1.07	4.17±2.77	7.49±4.79
1,7-Dimethylphenanthrene	0.06-0.82	ng/g	0	2	2.85±1.57	8.17±2.44	13.31±8.24	8.46±4.18	7.57±2.35	9.62±1.32	5.58±4.42	1.10±1.35	1.79±1.21	2.51±3.06	3.09±2.12	8.28±5.49	18.38±10.65
1,8-Dimethylphenanthrene	0.06-0.83	ng/g	9	7	0.66±0.44	2.05±0.79	2.98±1.77	1.80±0.90	1.63±0.53	2.12±0.24	1.16±0.91	0.19±0.28	0.33±0.28	0.58±0.73	0.82±0.56	2.11±1.39	5.25±3.43
C3-Phenanthrenes/Anthracenes	0.11-2.23	ng/g	0	0	24.13±13.18	81.93±34.30	84.40±38.74	62.47±29.89	50.20±11.15	64.72±7.60	36.25±27.69	7.55±8.36	11.77±6.43	17.67±17.48	29.77±21.04	67.30±42.47	188.17±115.78
1,2,6-Trimethylphenanthrene	0.11-2.23	ng/g	5	95	1.25±0.64	4.28±1.77	5.09±3.10	3.20±1.46	2.62±0.52	3.83±0.65	1.85±1.38	0.39±0.48	0.71±0.44	0.98±0.93	1.72±1.19	3.75±2.37	9.52±5.97
Retene	0.44-9.33	ng/g	0	0	25.47±10.65	41.60±13.80	63.30±21.04	61.07±29.58	58.00±20.00	76.20±7.34	37.60±29.45	12.03±15.05	14.63±6.27	20.89±25.42	22.97±13.11	53.17±34.83	62.80±40.22
C4-Phenanthrenes/Anthracenes	0.44-9.33	ng/g	0	0	108.27±41.95	271.67±104.27	547.67±369.99	282.00±135.37	254.20±77.44	346.60±40.76	166.40±128.36	47.67±47.95	71.13±38.58	96.70±93.31	143.97±102.41	291.40±179.78	588.33±365.16
C1-Fluoranthenes/Pyrenes	0.07-1.75	ng/g	0	0	13.69±5.24	31.23±9.32	72.63±50.60	37.40±17.07	36.74±12.66	50.28±6.67	25.92±19.74	6.62±5.97	10.73±6.07	14.97±15.93	17.57±11.01	38.23±23.23	61.33±36.64
3-Methylfluoranthene/Benzo[a]fluorene	0.07-1.75	ng/g	0	0	4.13±1.72	9.87±2.58	19.10±11.72	11.23±5.00	10.96±3.58	14.04±1.91	7.86±6.23	1.68±1.59	3.07±1.79	4.30±4.82	4.71±3.15	11.06±6.81	17.18±9.71
C2-Fluoranthenes/Pyrenes	0.09-2.09	ng/g	0	0	23.77±7.51	62.07±20.01	97.47±62.13	59.63±25.52	54.06±14.32	76.76±9.76	39.03±28.45	11.45±9.02	18.37±8.63	23.65±20.81	33.27±20.15	66.97±39.06	120.20±68.78
C3-Fluoranthenes/Pyrenes	0.11-1.89	ng/g	0	0	18.90±4.90	51.23±16.60	58.63±35.63	40.63±15.09	33.04±7.09	61.96±5.90	24.83±16.79	11.24±7.46	15.27±5.42	21.12±14.71	30.40±18.74	56.73±32.17	111.53±66.20
C4-Fluoranthenes/Pyrenes	0.11-1.54	ng/g	0	0	7.73±2.45	23.53±8.62	27.57±17.25	18.13±5.45	14.30±2.86	24.94±1.92	11.38±7.80	5.25±3.34	7.01±3.20	9.48±6.43	13.52±7.64	24.35±13.66	45.13±24.23
C1-Benzo[a]anthracenes/Chrysenes	0.10-0.73	ng/g	0	0	13.05±5.84	36.23±12.76	136.73±114.91	52.27±26.83	52.64±23.19	60.20±13.26	31.26±24.40	5.79±5.39	12.28±7.76	14.32±15.04	18.97±14.87	39.27±24.43	61.57±32.35
5/6-Methylchrysene	0.10-0.73	ng/g	0	0	1.24±0.48	3.47±1.21	6.77±4.63	3.64±1.67	3.31±1.13	4.30±0.67	2.25±1.71	0.42±0.36	0.87±0.44	1.13±1.12	1.66±1.23	3.50±2.18	6.31±3.54
1-Methylchrysene	0.10-0.72	ng/g	0	0	1.78±0.91	5.14±1.54	15.46±12.42	6.73±3.29	6.67±2.65	8.52±1.53	4.32±3.42	0.69±0.77	1.62±0.91	2.10±2.28	2.48±1.87	5.47±3.42	8.44±4.36
C2-Benzo[a]anthracenes/Chrysenes	0.11-1.30	ng/g	0	0	19.47±7.26	53.00±17.63	121.27±93.18	58.20±25.85	54.46±18.61	66.10±10.58	34.05±24.63	8.70±6.48	15.02±7.64	19.43±16.24	28.50±19.67	53.87±31.31	103.23±59.15
5,9-Dimethylchrysene	0.11-1.30	ng/g	0	0	4.95±1.45	12.75±4.49	29.45±24.06	12.98±5.80	11.75±4.15	18.14±3.07	7.93±5.83	2.20±1.81	4.05±2.00	4.97±4.20	7.56±5.44	14.41±8.35	26.93±15.65
C3-Benzo[a]anthracenes/Chrysenes	0.12-1.20	ng/g	0	0	9.13±1.23	30.87±12.62	32.80±15.42	26.40±9.61	22.42±5.47	22.58±3.03	15.94±10.30	4.69±2.58	5.98±1.88	8.33±4.80	13.77±8.43	21.28±10.87	48.83±19.41
C4-Benzo[a]anthracenes/Chrysenes	0.11-0.84	ng/g	0	0	3.57±0.91	12.50±4.35	10.53±4.62	8.60±2.62	7.31±1.85	9.22±0.90	5.63±3.88	2.26±1.32	2.81±0.59	3.32±1.72	5.62±3.16	8.94±4.95	20.70±8.07
C1-Benzofluoranthenes/Benzopyrenes	0.14-1.32	ng/g	0	0	14.59±6.52	36.73±9.60	130.10±113.40	53.33±23.20	54.66±21.92	70.78±12.68	34.71±26.50	8.25±6.62	16.15±8.46	20.28±20.32	24.67±17.79	46.13±27.43	61.00±29.30
7-Methylbenzo[a]pyrene	0.14-1.32	ng/g	0	0	1.01±0.09	2.72±0.92	6.32±5.15	2.72±1.14	2.62±0.95	3.36±0.50	1.79±1.22	0.60±0.39	0.90±0.41	1.40±1.33	1.55±0.86	2.51±1.28	4.70±2.03
C2-Benzofluoranthenes/Benzopyrenes	0.18-1.52	ng/g	0	0	7.18±2.67	23.47±6.23	71.90±61.28	27.33±12.16	28.30±10.83	30.84±6.45	16.47±11.94	4.10±2.72	7.03±3.37	9.08±7.50	11.44±7.57	20.74±11.68	32.73±14.52
1,4,6,7-Tetramethylnaphthalene	0.06-0.90	ng/g	0	98	1.60±0.53	7.05±2.87	5.78±2.02	4.64±2.35	3.47±0.75	4.88±0.38	3.16±2.50	0.58±0.64	0.96±0.58	1.56±1.91	1.95±1.25	5.74±3.70	22.20±14.06

Table C8. Summary of total naphthenic acids in sediment (mean ± standard deviation, n=3-5)

Parameter	Detection Limit	Unit	25 km U/S W	12 km U/S W	4.5 km U/S W	0.5 km U/S W	0.03 km U/S W	0.03 km D/S W	0.5 km D/S WI	0.5 km D/S EI	1.5 km D/S WI	1.5 km D/S W	4.5 km D/S W	12 km D/S W	34 km D/S W
Naphthenic acids	1.00	µg/g	127.67±82.31	199.93±155.30	165.50±107.97	193.33±47.17	210.40±55.05	542.40±27.01	174.00±56.45	249.00±113.86	264.50±284.49	174.33±92.36	120.67±25.89	217.67±82.04	111.73±32.40

APPENDIX D Summary of trout-perch fish health and fish communities collected in September 2018

Table D1. Summary of female trout-perch health somatic indices and age (mean ± standard error)

Site	N	Age	Length (cm)	Weight (g)	GSI	LSI	k
20 km U/S (M3)	14	5.1±0.2	71.64±2.03	4.39±0.36	4.29±0.22	1.49±0.08	1.16±0.03
12km U/S	20	4.1±0.2	67.50±0.97	3.51±0.17	4.53±0.19	1.73±0.07	1.12±0.02
4 km U/S (uM4)	20	4.8±0.2	67.50±1.29	3.61±0.19	4.10±0.24	1.89±0.11	1.16±0.02
0.5 km U/S	20	4.2±0.2	69.00±0.97	3.87±0.17	4.43±0.16	1.70±0.09	1.17±0.02
0.5 km D/S WI	20	4.5±0.2	65.91±0.83	3.43±0.15	4.51±0.14	1.88±0.07	1.19±0.02
0.5 km D/S EI	10	3.1±0.5	58.40±2.88	2.50±0.36	3.06±0.51	1.55±0.07	1.18±0.03
1.5 km D/S EI	20	4.4±0.2	70.10±1.54	4.22±0.29	4.44±0.30	1.90±0.06	1.19±0.02
4.5 km D/S	20	4.2±0.2	70.05±1.31	4.00±0.23	4.83±0.17	1.85±0.07	1.14±0.02
12 km D/S (dM4)	20	4.0±0.1	66.55±0.99	3.37±0.16	4.59±0.14	1.68±0.05	1.13±0.02
33 km DS (M7)	21	3.9±0.2	66.05±1.10	3.30±0.14	4.23±0.13	1.61±0.05	1.14±0.02

Table D2. Summary of male trout-perch health somatic indices and age (mean ± standard error)

Site	N	Age	Length (cm)	Weight (g)	GSI	LSI	k
20 km U/S (M3)	20	4.6±0.2	67.60 ± 1.93	3.63 ± 0.32	2.82 ± 0.39	1.34 ± 0.08	1.12 ± 0.01
12km U/S	20	4.0±0.2	65.90 ± 0.66	3.21 ± 0.11	1.99 ± 0.09	1.32 ± 0.06	1.11 ± 0.01
4 km U/S (uM4)	20	4.5±0.2	64.85 ± 0.83	3.11 ± 0.12	1.80 ± 0.06	1.39 ± 0.04	1.13 ± 0.01
0.5 km U/S	20	4.3±0.1	65.05 ± 0.97	3.17 ± 0.16	1.65 ± 0.08	1.38 ± 0.05	1.13 ± 0.02
0.5 km D/S WI	20	4.2±0.2	64.35 ± 1.16	3.05 ± 0.15	1.76 ± 0.08	1.36 ± 0.07	1.13 ± 0.01
0.5 km D/S EI	20	3.4±0.3	59.40 ± 1.42	2.40 ± 0.15	1.42 ± 0.10	1.36 ± 0.06	1.12 ± 0.02
1.5 km D/S EI	20	3.9±0.2	66.45 ± 1.17	3.27 ± 0.15	2.08 ± 0.20	1.38 ± 0.05	1.11 ± 0.02
4.5 km D/S	20	3.6±0.2	64.40 ± 0.91	2.99 ± 0.11	1.79 ± 0.09	1.29 ± 0.05	1.12 ± 0.03
12 km D/S (dM4)	20	3.4±0.2	62.45 ± 0.85	2.75 ± 0.11	1.52 ± 0.07	1.27 ± 0.05	1.12 ± 0.01
33 km DS (M7)	20	3.9±0.2	62.60 ± 0.88	2.74 ± 0.07	1.80 ± 0.15	1.39 ± 0.05	1.12 ± 0.02

GSI = Gonadosomatic index

LSI = Liversomatic index

K = condition factor

Table D3. Summary of fish community data collected in Fall 2018

RAMP Site ID	01A	04A	04B	05A	05B	06A	10B	11A
Enhanced Monitoring Site	12 km U/S	4 km U/S		0.5 km U/S		0.5-1.5 km D/S	12 km D/S	
Species abundance								
Burbot		1		1				
Cisco	7	4	4	2	7	1	8	3
Emerald Shiner	9	8		11	4	7	5	1
Flathead Chub	6	14	4	20	7	2	3	12
Goldeye	35	13	3	14	3	7	7	6
Lake Chub		1		2	3			
Lake Whitefish		5	1		6	2	6	2
Longnose Sucker	7	7	4	7	1	3	5	6
Northern Pike		2	1	1	1		1	2
Spoonhead Sculpin						1		
Spottail Shiner		1						
Trout-perch	17	11	1	18	8		22	37
Walleye	2	12	1	2	3	2	5	7
White Sucker		2	1	3	1	1	6	2
Yellow Perch								2
Community indices								
CPUE (#fish/300sec)	10.30	8.43	2.56	11.09	6.10	4.79	10.39	7.64
Total Number fish	83	81	20	81	44	26	68	80
Species Richness	7	13	9	11	11	9	10	11
Eveness	0.836	0.880	0.910	0.822	0.914	0.876	0.892	0.746
Shannon diversity	1.627	2.257	1.999	1.970	2.192	1.924	2.055	1.790