Hatfield
CONSULTANTS
Environmental Specialist Since 1974

REGIONAL AQUATICS MONITORING

in support of the

JOINT OIL SANDS MONITORING PLAN

Final 2014 Program Report

April 2015

Prepared for:

Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA)
Edmonton, Alberta

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Prepared for:

ALBERTA ENVIRONMENTAL MONITORING, EVALUATION AND REPORTING AGENCY

Prepared by:

HATFIELD CONSULTANTS

KILGOUR AND ASSOCIATES LTD.

***and* WESTERN RESOURCE SOLUTIONS**

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EXECUTIVE SUMMARY

OVERVIEW

In 2012, the governments of Canada and Alberta developed a "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring" (Canada and Government of Alberta 2012) specific to the Athabasca oil sands region of northeastern Alberta. The implementation plan was to build and expand on existing environmental monitoring programs for the region, including the Regional Aquatics Monitoring Program (RAMP, www.ramp-alberta.org). RAMP was implemented in 1997 as a multi-stakeholder aquatics monitoring program that assessed the health of rivers and lakes within the oil sands region, and to assess potential cumulative effects of oil sands development. The intent of the new joint implementation plan was to enhance these monitoring activities and work to integrate environmental monitoring across all environmental components (i.e., air, water, land, and biodiversity), which were historically monitored independently through separate organizations or programs.

As a result of the implementation plan, the Joint Oil Sands Monitoring Plan (JOSMP, www.jointoilsandsmonitoring.ca) was initiated over three years (2012 to 2015) to characterize the state of the environment in the Athabasca oil sands region, understand the cumulative effects and changes, and develop recommendations for an integrated environmental monitoring program, with an adaptive management framework for implementation in the oil sands region. From 2012 to 2014, the RAMP Committees worked with the governments of Canada and Alberta to align aquatics monitoring activities historically undertaken by RAMP into the JOSMP, completing this process by April 1, 2014.

Established in 2014, the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA, www.aemera.org) is an arm's length organization responsible for collecting credible scientific data and other relevant information on the condition of Alberta's environment and providing the public with open and transparent reporting and access to the data and information. AEMERA is responsible for the coordination and implementation of the JOSMP in the oil sands region, as well as the integration of all environmental monitoring in the Province of Alberta. The intent of this agency is to provide timely collection and objective reporting of scientific data and information on air, land, water, and biodiversity, including information necessary to understand cumulative effects, in order to better inform the understanding of the public, policy makers, regulators, planners, researchers, communities, and industries (www.aemera.org).

This report presents the 2014 results for aquatics monitoring in the oil sands regions in support of the JOSMP that was historically conducted under the RAMP. Additional aquatics monitoring under the JOSMP was conducted by Alberta Environment and Sustainable Resource Development (AESRD) and Environment Canada; results from these monitoring activities are not provided in this report.

The study area that was used for this portion of aquatics monitoring under the JOSMP was defined as the major watersheds in the Athabasca oil sands region, where oil sands development has been approved or are active, while the geographic scope of the entire JOSMP encompasses a larger area, particularly to the north (Canada and Government of Alberta 2012). The watersheds where monitoring occurred in 2014 included:

- Lower Athabasca River;
- Major tributary watersheds/basins of the lower Athabasca River including the Clearwater River, Christina River, Hangingstone River, Gregoire River, Steepbank River, Muskeg River, MacKay River, Ells River, Tar River, Calumet River, High Hills River, and Firebag River;

- Select minor tributaries of the lower Athabasca River (McLean Creek, Mills Creek, Beaver River, Poplar Creek, Fort Creek, Pierre River, Eymundson Creek, Red Clay Creek, and Big Creek);
- Select minor tributaries to Christina Lake (Sunday Creek, Birch Creek, Jackfish River, Sawbones Creek, and two unnamed creeks);
- Specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- A selected group of 45 regional acid-sensitive lakes.

The study area also included the Athabasca River Delta as the receiving environment for any oil sands developments occurring in the Athabasca oil sands region.

The program incorporates both stressor- and effects-based monitoring approaches. Using impact predictions from the various oil sands environmental impact assessments, specific potential stressors have been identified that are monitored to document *baseline* conditions, as well as potential changes related to development. Examples include specific water quality variables and changes in water quantity. In addition, there is a strong emphasis on monitoring sensitive biological indicators that reflect the overall condition of the aquatic environment. By combining both monitoring approaches, the program strives to achieve a more holistic understanding of potential effects on the aquatic environment related to oil sands development.

The scope of the program focuses on the following key components of boreal aquatic ecosystems:

1. Climate and hydrology are monitored to provide a description of changing climatic conditions in the oil sands region, as well as changes in the water level of selected lakes and in the quantity of water flowing through rivers and creeks.
2. Water quality in rivers and lakes is monitored to assess the potential exposure of fish and invertebrates to organic and inorganic chemicals.
3. Benthic invertebrate communities and sediment quality in rivers, lakes, and the Athabasca River Delta are monitored because they reflect habitat quality, serve as biological indicators, and are important components of fish habitat.
4. Fish populations in rivers and select lakes are monitored as they are biological indicators of ecosystem integrity and are a highly valued resource in the region.
5. Water quality in regional lakes sensitive to acidification is monitored as an early warning indicator of potential effects related to acid deposition.

A weight-of-evidence approach is used for the analysis of monitoring data by applying multiple analytical methods to interpret results and determine whether any changes have occurred due to oil sands developments. The analysis:

- is conducted at the watershed/river basin level, with an emphasis on watersheds in which development has already occurred, as well as the lower Athabasca River at the regional level;

- uses a set of measurement endpoints representing the health and integrity of valued environmental resources within the component; and
- uses specific criteria (criteria used in oil sands project EIAs, AESRD, and CCME water quality and sediment quality guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources. The magnitude of change in the values of measurement endpoints has been described as **Negligible-Low**, **Moderate**, or **High** relative to *baseline* conditions (see the tabular summary following the Executive Summary for details regarding these criteria).

The 2014 Program Report uses the following definitions for monitoring status:

- ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of oil sands development; data collected from these locations are designated as ***test*** for the purposes of analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2014) or were (prior to 2014) upstream of all oil sands development; data collected from these locations are to be designated as ***baseline*** for the purposes of data analysis, assessment, and reporting. The terms *test* and *baseline* depend solely on the location of the aquatic resource in relation to the location of the oil sands development to allow for long-term comparison of trends between *baseline* and *test* stations.

Satellite imagery was used in 2014 in conjunction with more detailed maps of Athabasca oil sands operations provided by a number of oil sands operators to estimate the type, location, and amount of land changed by oil sands development activities. As of 2014, it was estimated that approximately 123,990 ha (3.5%) of the Athabasca oil sands region had undergone land change from oil sands developments. The percentage of the area of watersheds with land change as of 2014 varied from less than 1% for many watersheds (MacKay, Horse, Pierre River, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, Ells, Christina, and Hangingstone watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

ASSESSMENT OF 2014 MONITORING RESULTS

A tabular summary of the 2014 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology For the 2014 water year (WY), the mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.7%, 1.6%, 0.6%, and 1.1% lower, respectively, in the observed *test* hydrograph for the Athabasca River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2014 at all three stations (east bank, centre of channel, and west bank) of the Athabasca River, downstream of oil sands development, were classified as **Negligible-Low** compared to regional *baseline* conditions (historical *baseline* data for the Athabasca River, upstream of development). Concentrations of water quality measurement endpoints were consistent with regional *baseline* conditions and generally consistent with previously-measured concentrations. Similarities of exceedances of guideline concentrations and regional *baseline* concentrations were generally observed across all three stations. Concentrations of total aluminum exceeded the guideline at all three stations in fall 2014 and total boron continued to show an increasing trend at the station on the west bank of the Athabasca River, downstream of development.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2014:

1. Differences in measurement endpoints for benthic invertebrate communities for Big Point Channel were classified as **Negligible-Low** because although there was a significant change in Correspondence Analysis (CA) Axis 1 scores over time, the change was not indicative of degradation. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variation for all previous sampling years at reaches of the ARD.

2. Differences in measurement endpoints for benthic invertebrate communities of Goose Island Channel were classified as **High** because there were significant differences for all measurement endpoints. Abundance and richness were lower and equitability was higher in 2014 than any previous year of sampling, indicating potential negative changes to the benthic invertebrate community. The percentage of sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa was higher in 2014 and was increasing over time. CA Axis 1 scores were decreasing over time and were lower in 2014 than previous years and CA Axis 2 scores were increasing over time. Abundance and richness were below the tolerance limits of the 5^{th} percentile for the means of previous years of sampling in the ARD. Chironomids were nearly absent in 2014 and tubificids dominated the relative abundance of organisms at this reach, potentially reflecting the high silt content in sediments.

3. Differences in measurement endpoints for benthic invertebrate communities of Fletcher Channel were classified as **Moderate** because of the significant and large decreases in abundance and CA Axis 1 scores, and increase in equitability, over time. However, Fletcher Channel showed numerous indications of a stable community including a higher richness in 2014 and the presence of EPT taxa.

4. Differences in measurement endpoints of benthic invertebrate communities for the Embarras River were classified as **Negligible-Low** because although there were significant decreases in abundance, percentage of fauna as EPT taxa, and CA Axis 1 and 2 scores, the percentage of EPT taxa has actually remained stable over the past three years and abundance was higher in 2014 than 2013. There were no measurement endpoints that exceeded the tolerance limits for the normal range of variation for previous years of sampling in the ARD indicating that there was no concern that conditions were significantly degraded.

In 2014, all sediment stations of the ARD were dominated by silt. All sediment quality measurement endpoints at *test* stations on Big Point and Fletcher channels were within previously-measured concentrations. Concentrations of F2, F3, and F4 hydrocarbons at Goose Island Channel reached maximum values in fall 2014, while only F4 hydrocarbons exceeded the previously-measured maximum concentration at the Embarras River. Concentrations of retene, total dibenzothiophenes, total polycyclic aromatic hydrocarbons (PAHs), and total alkylated PAHs exceeded previously-measured maximum concentrations, while naphthalene was below the previously-measured minimum concentration at Goose Island Channel. At the Embarras River, concentrations of retene and total dibenzothiophenes also exceeded previously-measured maximum concentrations, while naphthalene and total parent PAHs were below previously-measured minimum results. Concentrations of PAHs at all stations in fall 2014 were dominated by alkylated species, indicating a petrogenic origin of these compounds. At all stations, with the exception of Fletcher Channel, the PAH Hazard Index value exceeded the potential chronic toxicity threshold of 1.0. The concentration of F3 hydrocarbons exceeded the CCME guideline at Goose Island Channel, while concentrations of total arsenic exceeded the CCME guideline at Fletcher Channel, Goose Island Channel, and the Embarras River. All toxicity test measurements were within the range of previously-measured results at all stations for the amphipod *Hyalella*. Because no *baseline* data were available for the ARD, it was not possible to calculate the Sediment Quality Index (SQI) for each station, nor compare concentrations to relative *baseline* conditions.

Fish Populations (fish inventory) The objective of the fish inventory program was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years were as follows:

- Total catch in summer and fall 2014 was much lower compared to 2013, although catch in spring was similar to 2013**.** The lower catch in fall was attributed primarily to the timing of sampling with respect to the migration of lake whitefish from Lake Athabasca to spawning grounds in the Athabasca River. Due to restrictions outlined in the Fish Research License issued by AESRD, sampling could not occur during the spawning period, as it has in previous years. Lower water levels were also observed in fall 2014, limiting habitat availability as well as boat access and fishing efficiency. These factors also may have contributed to the reduction in total catch and richness observed in 2014.

- A large change in species composition was observed in fall with a record low percentage of lake whitefish captured. In years where lake whitefish were the most abundant species in fall in the Athabasca River, sampling was generally conducted in the last ten days of September (compared to 2014 when sampling was conducted from September 10 to 15).

- There was a decrease in catch per unit effort (CPUE) of white sucker in 2014 compared to 2013 in spring. However, the highest CPUE of white sucker continued to be observed in the Muskeg area of the Athabasca River, which is a river that white sucker use for spawning.

- The dominant age class of northern pike in 2013 and 2014 was one and two years, respectively; dominance was most pronounced at five years in 2012 and from 1997 to 2011. The increased frequency of younger northern pike in the Athabasca River suggested higher levels of recruitment or increased selection of older individuals from fishing pressure. The limited catch of younger lake whitefish is typical as lake whitefish are only commonly caught in the Athabasca River in the fall as adults migrate from Lake Athabasca to spawning grounds upstream of Fort McMurray.

- Overall, the 2014 fish health assessment indicated that abnormalities observed among all species were within the historical range (1987 to 2013), despite the higher than average incidence of abnormalities observed in northern pike (14.8%) related primarily to fin erosion. These findings were also consistent with previously cited studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Fish Populations (fish tissue) Measurement endpoints used in the assessment for the Athabasca River fish tissue program included concentrations of metals and tainting compounds in muscle tissue of both individual and composite samples of lake whitefish and walleye. Potential human health risks from contaminated fish tissue were predicted from both individual and composite samples. In 2014, the mean concentration of mercury in lake whitefish was slightly higher than 2011, but within the range of concentrations observed in previous sampling years. The mean mercury concentration across all size classes of lake whitefish were below the Health Canada guideline for subsistence fishers indicating a **Negligible-Low** risk to human health. The mean concentration of mercury in walleye was higher in 2014 compared to previous years. The mean mercury concentration in size classes of walleye greater than 300 mm exceeded the subsistence fishers guideline for consumption indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

Fish Populations (fish assemblages) Results of the fish assemblage monitoring in the ARD indicated a decrease in abundance across all reaches relative to 2013. All other measurement endpoints were generally consistent across channels, with high values of the Assemblage Tolerance Index (ATI) reflecting the tolerant nature of fish species in the delta. Water temperatures during the 2013 fish assemblage monitoring program in the ARD ranged from 19.5˚C to 20.4˚C with a mean of 19.8˚C, whereas water temperatures during the 2014 monitoring program were higher ranging from 20.4˚C to 23.4˚C, with a mean of 22.1˚C. The higher temperatures in 2014 could have resulted in fish being in deeper, cooler waters, where boat electrofishing was not effective. The most abundant large-bodied species were goldeye and northern pike; goldeye was dominant at reaches of Big Point, Goose Island, and Fletcher channels, while northern pike was dominant at the Embarras River.

Muskeg River Watershed

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -4.9%, -5.5%, -8.3%, and 35.6%, respectively, in the observed *test* hydrograph for the Muskeg River compared to the estimated *baseline* hydrograph. The difference in mean open-water discharge was classified as **Negligible-Low.** The difference in annual maximum daily discharge and mean winter discharge were classified as **Moderate**, and the difference in open-water minimum daily discharge was classified as **High**. The results of the longitudinal assessment of the Muskeg River suggested that the extent of the **High** hydrologic changes was limited to a length of the Muskeg River between Stanley Creek and Muskeg Creek.

In the 2014 WY, the water level of Kearl Lake declined from November until mid-April and then increased from early April to early June and then decreased steadily until early September. The maximum level was 0.05 m higher than the historical mean annual maximum daily lake level. From early September until the end of the water year, the lake level remained relatively stable. The lake level was within the historical interquartile range for most of the WY, and did not exceed or drop below historical maxima or minima.

Water Quality In fall 2014, concentrations of most water quality measurement endpoints at stations of the Muskeg River watershed were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2014 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most water quality measurement endpoints at the lower *test* station of the Muskeg River (sampled monthly) were within the range of regional *baseline* fall concentrations in each month of 2014, with monthly variability generally showing higher concentrations of ions and metals in winter and early spring when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at the lower *test* station of the Muskeg River remained consistent.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2014:

1. Differences in values of measurement endpoints at the lower *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant changes in CA Axis 1 and 2 scores were a result of higher relative abundances of benthic invertebrates at this reach. Higher relative abundances of chironomids, mayflies, and caddisflies, and the presence of stoneflies were indicative of good water quality and habitat conditions and higher habitat quality relative to 2013. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. The percentage of EPT taxa was slightly higher than the inner tolerance limit for the 95th percentile, indicating a positive change at this reach.

2. Differences in values of measurement endpoints for benthic invertebrate communities at the middle *test* reach of the Muskeg River were classified as **Negligible-Low** because there were no significant changes detected at this reach, with high diversity and a high percentage of EPT taxa in 2014, and habitat quality was higher relative to 2013.

3. Differences in values of measurement endpoints for benthic invertebrate communities at the upper *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase over time in the percentage of EPT taxa and the higher percentage of EPT taxa in 2014 compared to the mean of *baseline* years or the mean of all years combined were indicative of a positive change in the benthic invertebrate community. Four measurement endpoints were outside of the tolerance limits for the historical range of variation, but were also indicative of improving water quality and benthic community health. The relative abundance of tubificid worms was high in 2014, but consistent with previous years, and habitat quality was higher relative to 2013.

4. Differences in measurement endpoints for benthic invertebrate communities at the *test* reach of Jackpine Creek were classified as **Negligible-Low** because equitability was lower than previous years, indicating improving conditions, and the benthic community was diverse, including clams, snails, mayflies, and stoneflies.

5. Differences in measurement endpoints of benthic invertebrate communities of Kearl Lake were classified as **Negligible-Low** because the statistically large changes observed for richness, equitability, and CA Axis 1 and 2 scores were not indicative of degraded conditions. Additionally, the benthic invertebrate community of Kearl Lake contained a diverse fauna and included several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves).

Concentrations of sediment quality measurement endpoints at all Muskeg River watershed stations sampled in fall 2014 were within previously-measured concentrations, with the exception of naphthalene at the *baseline* station of upper Jackpine Creek, and the *test* stations of the upper Muskeg River and Kearl Lake, and total dibenzothiophenes, total PAHs, and total alkylated PAHs at Kearl Lake, which were below previously-measured minimum concentrations. Concentrations of F3 hydrocarbons exceeded the relevant CCME guideline at the *test* stations of lower Jackpine Creek and the middle Muskeg River, and F1, F2, and F3 hydrocarbons exceeded guidelines at Kearl Lake. Concentrations of metals in 2014 were below CCME guidelines at all stations. Differences in sediment quality in fall 2014 at all applicable stations of the Muskeg River watershed were classified as **Negligible-Low** relative to regional *baseline* conditions. Sediment quality monitoring was not conducted at the lower station of the Muskeg River given it is erosional habitat.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the Muskeg River were classified as **Moderate**. Although values of all measurement endpoints were within the range of regional *baseline* variability, there were significant decreases in abundance and catch per unit effort (CPUE), which were indicative of a potential negative change in the fish assemblage over time. Differences in measurement endpoints for fish assemblages between the middle *test* reach of the Muskeg River and regional *baseline* conditions were classified as **Negligible-Low** given there were no significant differences implying a negative change in the fish assemblage and only abundance and diversity were at the outer tolerance limit of the 5^{th} percentile of variation of *baseline* conditions. Differences in measurement endpoints for the upper *test* reach of the Muskeg River were classified as **High** because although there were no significant differences over time, abundance, diversity, and CPUE have been below the range of *baseline* variability for three consecutive years.

Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Jackpine Creek were classified as **High** because abundance and CPUE were low and near the outer tolerance limit of the 5^{th} percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints that were indicative of a negative change in the fish assemblage over time. It should be noted; however, that although there has been decreases in measurement endpoints since 2009, abundance, CPUE, richness, and diversity were higher in 2014 compared to 2013, which could indicate improving conditions.

Steepbank River Watershed

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.33%, 0.34%, 0.34%, and 0.01% higher, respectively, in the observed *test* hydrograph for the Steepbank River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of most water quality measurement endpoints in the Steepbank River watershed in fall 2014 were within previously-measured concentrations, with the exception of many ions at the middle *test* station (downstream of the confluence of the North Steepbank River), which showed concentrations higher than previously measured in fall 2014. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2014 was similar to previous years. Concentrations of water quality measurement endpoints were also generally within the range of regional *baseline* conditions. Differences in water quality in fall 2014 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed, with the exception of the lower *test* station of the Steepbank River (near the mouth), which was classified as **Moderate** due to exceedances of concentrations of total metals, ions, and physical variables from the 95th percentile of regional *baseline* conditions.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at the middle *test* station of the Steepbank River, which was sampled on a monthly basis in 2014. Typically the maximum concentration of ions were reached in April, while the minimum concentrations were reached in June. Despite the observed changes in ion concentrations from previous years in fall, the ionic composition remained consistent throughout the year.

Benthic Invertebrate Communities Differences in measurement endpoints of the benthic invertebrate community at the lower *test* reach of the Steepbank River were classified as **Moderate** because abundance, richness, CA Axis 1 and 2 scores, and the percentage of EPT taxa were significantly lower than the upstream *baseline* reach. The benthic invertebrate community at the lower *test* reach; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach and generally good water quality conditions. Sediment quality monitoring was not conducted on the Steepbank River given it is an erosional river.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the Steepbank River were classified as **High** because three of the five measurement endpoints (abundance, richness, and catch per unit effort) significantly decreased over time and catch per unit effort and abundance were lower than the range of regional *baseline* variability, indicating a potential negative change to the fish assemblage.

Tar River Watershed

Hydrology The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 28.8% lower in the observed *test* hydrograph for the Tar River than in the estimated *baseline* hydrograph. These differences were classified as **High**. While the overall classification of watershed changes was classified as **High**, the results from the longitudinal assessment suggested that the extent of **High** hydrologic changes was limited to the lowest 7 km of the Tar River, which were approved changes as part of the development of the Canadian Natural Horizon project.

Water Quality In fall 2014, water quality at stations of the Tar River indicated **Negligible-Low** differences from regional *baseline* conditions. Most water quality measurement endpoints at the lower *test* and upper *baseline* stations were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities at the lower *test* reach of the Tar River were classified as **High** because of the significant decreases in abundance and richness, and increase in equitability (i.e., lower diversity) from the *baseline* period at this reach. A significant time trend was noted for CA Axis 1 scores suggesting a change in taxa composition over time with fewer water mites and mayflies found in more recent years at the lower *test* reach. Abundance and richness were below the normal range of variation for regional *baseline* depositional reaches. Overall diversity and the percentage of EPT taxa has been steadily decreasing since 2009 and mayflies and caddisflies, which were present during the *baseline* period and in previous *test* years, were absent in both 2013 and 2014.

Concentrations of all sediment quality measurement endpoints at the lower *test* station of the Tar River in fall 2014 were within previously-measured concentrations except naphthalene, which was below historical observations. The concentration of F3 hydrocarbons and the predicted PAH toxicity exceeded relevant thresholds, but were within the range of historical observations. Differences in sediment quality observed in fall 2014 between the lower *test* station and regional *baseline* conditions were classified as **Negligible-Low.** Sediment quality monitoring was not conducted at the upper station of the Tar River given it is erosional habitat.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower *test* reach of the Tar River and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the *baseline* range of variability and there were no significant changes in measurement endpoints over time.

MacKay River Watershed

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, and open-water minimum daily discharge were 0.004%, 0.069%, 0.045% lower, respectively, and the annual maximum daily discharge was 0.007% higher in the observed *test* hydrograph for the MacKay River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints for stations of the MacKay River watershed were within the range of previously-measured concentrations and within the range of regional *baseline* concentrations in fall 2014. Differences between water quality at the lower and middle *test* stations, and the upper *baseline* station and regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at the upper *baseline* station, which was sampled on a monthly basis in 2014. Typically, the maximum concentration of ions occurred in March and the minimum concentrations occurred in May, consistent with expected seasonal influences of surface-water runoff (i.e., greatest during freshet and weakest during winter low-flow conditions). The decrease in alkalinity in spring likely resulted from base-cation dilution by snowmelt rather than consumption of alkalinity by acidic compounds in snow, given consistent seasonal trends also were observed in other ions. Despite the observed changes in ion concentrations, the ionic composition remained relatively consistent throughout the year but was slightly less dominated by calcium in winter months.

Benthic Invertebrate Communities Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the MacKay River were classified as **Negligible-Low** because, although richness was significantly lower than the upper *baseline* reach, richness was higher in 2014 than the mean of all *baseline* years for the lower and upper reaches. Differences in CA Axis 2 scores were due to slight differences in taxa composition between the lower *test* and upper *baseline* reaches. Additionally, the taxa composition at the lower *test* reach has remained stable and diverse over the past two years with the presence of EPT taxa and a low overall abundance of worms. Differences in measurement endpoints for the benthic invertebrate community at the middle *test* reach of the MacKay River were classified as **Negligible-Low** because the only significant change was an increasing trend over time in the percentage of the fauna as EPT taxa and differences in CA Axis 2 scores, which did not imply a negative change in the benthic invertebrate community. The benthic fauna at the middle *test* reach was representative of good overall water quality with a high percentage of EPT taxa and a low relative abundance of worms. Sediment quality monitoring was not conducted on the MacKay River given it is an erosional river.

Fish Populations Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the MacKay River were classified as **Moderate** because of significant decreases in abundance and catch per unit effort over time and differences compared to the upper *baseline* reach. In addition, abundance and catch per unit effort were also lower than regional *baseline* conditions. Differences in measurement endpoints for the fish assemblage at the middle *test* reach of the MacKay River were classified as **Negligible-Low** given there was only a significant decrease in abundance over time and all measurement endpoints were within regional *baseline* variability.

Calumet River Watershed

Hydrology The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were 0.26% lower in the observed *test* hydrograph for the Calumet River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2014, water quality at the lower *test* station and upper *baseline* station of the Calumet River indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured concentrations for both stations, with the exception of concentrations of many hydrocarbons (CCME fractions and PAHs) in 2014 at the lower *test* station, which had concentrations substantially greater than historically observed at this station and compared to the upper *baseline* station in 2014. Significantly higher flows in 2014 in the Calumet River in May and June 2014 contributed to bank erosion near the lower water quality station, which may have caused the increase in total suspended solids and PAHs and hydrocarbons from bank sediments. The ionic composition of water at the lower *test* station was consistent with previous years, while the ionic composition of water at the upper *baseline* station was less dominated by bicarbonate ions in 2014 than most previous sampling years.

Firebag River Watershed

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.23% lower in the observed *test* hydrograph for the Firebag River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.** The water level of McClelland Lake, in winter of the 2014 WY was generally near the upper quartile and reached a peak in early June due to rainfall events. The lake level from June to October was above the historical median values.

Water Quality In fall 2014, water quality at the lower *test* station and upper *baseline* station of the Firebag River showed **Negligible-Low** differences from regional *baseline* water quality conditions. Concentrations of most water quality measurement endpoints at both stations were within the range of regional *baseline* concentrations and within the range of previously-measured concentrations in fall 2014. The ionic composition of water in fall 2014 at both Firebag River stations and Johnson Lake were consistent with previous sampling years and dominated by calcium and bicarbonate ions. The ionic composition of McClelland Lake was dominated by magnesium and bicarbonate and consistent with previous sampling years. Concentrations of water quality measurement endpoints for McClelland Lake and Johnson Lake were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers and the lack of *baseline*-lake data for the region.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities of McClelland Lake were classified as **Negligible-Low** because although there was a significant increase in the percentage of fauna as EPT taxa and lower equitability in 2014 compared to previous years, these changes were indicative of good lake conditions. The general composition of the community in terms of relative abundances, presence of fully aquatic forms, and presence of generally sensitive taxa such as the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent to *baseline* conditions.

The benthic invertebrate community of Johnson Lake showed some improvement in 2014 compared to 2013, with the presence of sensitive EPT taxa, which were not observed in 2013. The abundance of worms (Tubificidae and Naididae) were lower in 2014 compared to 2013 and there were amphipods and gastropods present, indicating that Johnson Lake was generally in good condition.

Sediment of McClelland Lake and Johnson Lake was predominantly composed of silt. The percentage of silt and the total organic carbon content exceeded previously-measured maximum values at McClelland Lake, while the percentage of sand was below the previously-measured minimum value. All physical sediment variables for Johnson Lake were within the range of previously-measured values. Concentrations of naphthalene, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs at Johnson Lake were below previously-measured minimum concentrations. All sediment quality measurement endpoints were below the relevant sediment quality guidelines, with the exception F3 hydrocarbons, which exceeded the CCME guideline at both lakes. SQI values were not calculated for McClelland and Johnson lakes given the absence of regional *baseline* concentrations for lakes.

Ells River Watershed

Hydrology The 2014 WY mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph for the Ells River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2014 between the Ells River and regional *baseline* conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at the lower *test* station of the Ells River and were typically within the range of previously-measured concentrations and regional *baseline* conditions. The upper *baseline* station, initiated in 2013, showed similar water quality to the lower *test* station, and was within regional *baseline* conditions in fall 2014 for all measurement endpoints with the exception of lower concentrations of total mercury (ultra-trace). Concentrations of water quality measurement endpoints for Gardiner and Namur lakes were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. The ionic composition of water in Namur and Gardiner lakes was similar to stations of the Ells River but showed a slightly lower and greater dominance of calcium and bicarbonate, respectively, compared to the stations on the Ells River. There were no water quality guideline exceedances at Namur Lake and very few at Gardiner Lake in 2014.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at the lower *test* reach of the Ells River were classified as **Moderate** because significant decreases in abundance, EPT taxa, richness, and CA Axis 2 scores over time were indicative of potentially degrading conditions. Abundance in fall 2014 (111 organisms per sample) was higher than fall 2013 (48 organisms per sample), but still lower than previous years. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) were sparse in 2014 and EPT taxa were absent. All of the smaller and previously-abundant organisms remained abundant in 2014 and a decrease in tubificid worms has been occurring over time. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Similar to 2013, water velocity at the lower Ells River in 2014 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and could be an explanation for the absence of larger forms of benthic invertebrates at the lower *test* reach in recent years.

The benthic invertebrate communities of Gardiner and Namur lakes were sampled for the first time in 2014. The benthic invertebrate communities of both lakes were evident of good water quality conditions, with the presence of EPT taxa and permanent aquatic forms (e.g., bivalves, gastropods). The relative abundance of worms were high in both lakes in 2014.

Sediment quality in fall 2014 at the lower *test* station of the Ells River indicated **Negligible-Low** differences from regional *baseline* conditions, and most sediment quality measurement endpoints were within the range of the regional *baseline* concentrations, with the exception of total PAHs. Concentrations of F2 and F3 hydrocarbons, and chrysene exceeded CCME guidelines and the predicted PAH toxicity exceeded the potential chronic effect level at the lower *test* station. Sediment quality monitoring was not conducted at the upper station of the Ells River given it is erosional habitat. SQI values were not calculated for Namur and Gardiner lakes because lakes were not included in the regional *baseline* calculations. Sampling at Namur and Gardiner lakes was initiated in 2014; therefore, no historical data were available for comparison. No sediment guidelines or threshold values were exceeded at either lake in 2014.

Fish Populations Differences in measurement endpoints for the fish assemblage at the lower *test* reach of the Ells River were classified as **Moderate** given that abundance and catch per unit effort (CPUE) have decreased over time and all measurement endpoints were lower compared to the upper *baseline* reach. It is noted; however, that there was a decrease in the assemblage tolerance index (ATI) value, indicating a greater proportion of sensitive species in the assemblage, and all measurement endpoints were within regional *baseline* conditions.

Clearwater River Watershed

Hydrology Flows of the Clearwater River, downstream of the Christina River confluence, decreased from November 2013 to January 2014 and then remained relatively constant until early April. Flows then increased in mid-April in response to spring thaw, and reached the annual peak flow on June 12 shortly after rainfall accumulations starting in late May. Flows then receded until the minimum open-water daily flow on September 25. Flows from early July until the end of October were within the historical interquartile range. There was no effect in the Clearwater River watershed related to oil sands development in 2014, with the exception of development in the Christina River watershed. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

Water Quality In fall 2014, water quality at all stations of the Clearwater River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. Concentrations that exceeded previously-measured concentrations most frequently occurred at the *baseline* station on the High Hills River (tributary to the Clearwater River), due to the limited historical data available for comparison. All stations showed similar ionic composition to previous years of sampling, with the ionic composition at the *baseline* station of the High Hills River continuing to be more dominated by calcium and bicarbonate ions than the stations of the Clearwater River mainstem. No trends in measurement endpoints were observed over time, with the exception of a decreasing trend in potassium at the lower *test* station of the Clearwater River. Concentrations of many water quality variables fluctuated across months in 2014 at the upper *baseline* station of the Clearwater River, which was sampled on a monthly basis in 2014. Despite these fluctuations, the ionic composition of the Clearwater River remained fairly consistent across the year, with only slight differences in May and June. Concentrations of many water quality variables (e.g., metals) in May, June, and July exceeded guidelines and frequently exceeded fall regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Clearwater River were classified as **Negligible-Low** because the observed differences in equitability and CA axis scores were not related to oil sands development given similar trends were observed at both the *test* and *baseline* reaches. Equitability was higher at the *test* reach generally across all years of sampling but the reach had a relatively diverse community, and contained a number of taxa considered sensitive to degrading habitat such as the chironomid *Lopesocladius* and the mayfly *Ametropus neavei* (Ephemeroptera).

Sediments at the *test* and *baseline* stations of the Clearwater River were composed of sand, with concentrations of hydrocarbon fractions and PAHs below detection limits or in very low concentrations. Chronic toxicity tests yielded high survival and growth rates for the midge *Chironomus* and the amphipod *Hyalella* at both stations, indicating low toxicity of sediments. The SQI value for both the *test* and *baseline* stations of the Clearwater River in fall 2014 was 100, indicating **Negligible-Low** differences from regional *baseline* conditions.

The benthic invertebrate community at the *baseline* reach of the High Hills River contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and chironomids that reflected good water quality conditions. The relative abundance of naidid worms (50%) was much higher in 2013, but similar to 2011 and 2012. The *baseline* reach of the High Hills River was used as a regional *baseline* reach for comparisons to *test* reaches. Sediment quality monitoring was not conducted on the High Hills River given it is an erosional river.

Fish Populations (fish inventory) The objective of the fish inventory program on the Clearwater River was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years included:

- The total catch in spring and summer of 2014 decreased by 440 and 420 fish from 2013, respectively. Comparisons were unable to be carried out in fall because the *baseline* reaches were not sampled due to low water levels.
- The abundance of goldeye in spring 2014 was the highest recorded since 2009. This increase may be related to an increase in survival rates among the population given that the dominant age class was five years in 2011 but now has shifted to an older age class of seven years in 2013 and 2014.
- The dominant age classes for northern pike have been two and three year-olds since 2012, which has been a shift towards a younger age class.
- The percentage of external abnormalities increased in 2014 from 2013, with the majority of abnormalities observed in white sucker and a higher percentage of overall abnormalities observed in summer. The increase in abnormalities was primarily driven by the increase in parasites on fish, which could be related to higher water temperatures in the river.

Fish Populations (fish assemblages) The fish assemblage at the *baseline* reach of the High Hills River was consistent with other *baseline* reaches of similar habitat conditions. Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

Christina River Watershed

Hydrology For the 2014 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrographs for the Christina River were 0.1%, 0.0%, 0.1% and 0.1%, respectively. These differences were classified as **Negligible-Low**.

In the 2014 WY, the water level of Christina Lake decreased slightly from November 2013 to early April 2014, and remained below historical median levels throughout this period. By early April, the lake level was close to the historical minima, but then increased in late April due to the spring thaw. The annual peak occurred on June 5, shortly after rainfall accumulations. The lake level decreased after this peak, dropping below historical median levels after mid-July and was close to historical minima from early August until late September. The annual minimum lake level occurred on September 24, and the lake level then remained relatively constant until the end of the 2014 WY.

In the 2014 WY, Jackfish River flows declined gradually from November until mid-April, and then increased due to the spring thaw in late April. Flows increased again in late May, shortly after rainfall accumulations. All flows from May 30 to June 12 exceeded historical maxima recorded on these dates. Flows then decreased rapidly until late July, and stabilized thereafter, remaining within the historical interquartile range until the end of the year.

Water Quality In fall 2014, water quality at *test* stations of the lower, middle, and upper Christina River, Jackfish River, Sawbones Creek, Sunday Creek, and two unnamed creeks (east and south of Christina Lake), and *baseline* stations of Birch Creek, upper Christina River, and upper Sunday Creek indicated **Negligible-Low** differences from regional *baseline* conditions. The *test* station of the lower Gregoire River indicated **Moderate** differences from regional *baseline* water quality conditions, given that concentrations of several water quality measurement endpoints (e.g., total metals) exceeded relevant guidelines and regional *baseline* conditions in 2014. Gregoire River had many guideline exceedances in spring and summer 2014, whereas there were no guideline exceedances at Gregoire Lake, where the river flows from. Due to limited historical data at most sampling stations, it was only possible to compare the lower and middle *test* stations of the Christina River to historical results. Generally these stations were similar to previous years, but many ions in fall 2014 had higher concentrations than previously-measured maximums. Despite higher ion concentrations, the ionic composition at the two *test* stations remained similar across sampling years. Where comparisons were possible to recent years, the ionic composition at all other stations has also remained similar across sampling years.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at the lower and middle *test* stations of the Christina River, where monthly sampling occurred in 2014. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months at the lower *test* station, while the middle *test* station did not show any fluctuation in ionic composition throughout the year. The highest number of water quality guideline and regional fall *baseline* concentration exceedances occurred in May, June, July, and August, which were also the months where maximum yearly concentrations of metals were most frequently reached at both stations.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Christina River were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time and the significant difference in 2014 CA Axis 1 scores relative to the mean of previous years were not indicative of a negative change at the lower *test* reach. All measurement endpoints were within the inner tolerance limits of the normal range of variation for means from previous years of sampling. Although overall abundance was low, the relative abundance of worms was high, and the reach contained mayflies and stoneflies, suggesting reasonably good habitat quality.

Differences in measurement endpoints for benthic invertebrate communities at the middle *test* reach of the Christina River were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time reflected a shift in taxa composition at this *test* reach in 2014, with the absence of several relatively abundant taxa found in previous years, including Tubificidae, Bivalvia, Ephemeroptera, and Trichoptera. Other missing taxa in 2014 included Enchytraeidae, Hydracarina, Coleoptera, and Odonata. In 2014, chironomids were one of the only taxa found at this reach. All measurement endpoints were within the inner tolerance limits of the normal range of variation for previous years of sampling at this reach.

Differences in measurement endpoints for benthic invertebrate communities at the upper *test* reach of the Christina River were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches. This reach was sampled in erosional habitat with a Hess sampler in 2013 and in depositional habitat using an Ekman grab in 2014, confounding any assessment of changes in composition (or condition). The benthic fauna at this reach in 2014, were representative of good habitat quality, with the presence of mayflies, stoneflies, and caddisflies, and only a small relative abundance of worms.

Differences in measurement endpoints at the lower *test* reach of Sunday Creek were classified as **Moderate.** The reach contained a benthic invertebrate community with lower abundance, richness, and percentage of EPT taxa, and higher CA Axis 2 scores than the upper *baseline* reach, indicating that the lower *test* reach was of lower quality than the upper *baseline* reach. However, taxa richness and the percentage of EPT taxa have increased over the past three years of sampling at the lower *test* reach, indicating improving conditions. Additionally, all measurement endpoints for the lower *test* reach have consistently remained within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches, indicating generally acceptable conditions at this reach.

Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Sawbones Creek were classified as **Negligible-Low.** Although there were large variations in abundance, total numbers were well within the inner tolerance limits of regional *baseline* conditions for depositional reaches. None of the other measurement endpoints varied significantly, and all were within the range of regional *baseline* conditions for depositional reaches. The benthic invertebrate community of this *test* reach was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects.

Differences in measurement endpoints of benthic invertebrate communities at the *test* reaches of two unnamed creeks (east and south of Christina Lake) were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of regional *baseline* depositional reaches. Richness was higher than the *baseline* range of variability in 2014 at the *test* reach of Unnamed Creek, south of Christina Lake and equitability for the *test* reach of Unnamed Creek east of Christina Lake was just below the lower outer limit of the *baseline* range, neither of which indicated a negative change. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects.

Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Jackfish River were classified as **Negligible-Low** because the community was highly diverse, and the statistically significant increases in richness and percentage of EPT taxa in 2014 were considered to be positive changes. All measurement endpoints, with the exception of abundance, were within regional *baseline* ranges. Abundance was higher than the inner tolerance limit for the 95^{th} percentile of regional *baseline* reaches.

Gregoire River was sampled for the first time in 2014. Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Gregoire River were classified as **Negligible-Low.** Although naidid worms accounted for a large proportion of the benthic fauna (>40%), flying insects were present in relatively high numbers.

Differences in measurement endpoints of the benthic invertebrate community at Christina Lake in fall 2014 were classified as **Moderate** because several measurement endpoints (richness, abundance, EPT taxa) were lower than the previous two years, indicating a potential negative change. However, the lake still contained a diverse benthic fauna that included several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies and caddisflies). Differences in measurement endpoints of the benthic invertebrate community at Gregoire Lake in fall 2014 were classified as **Negligible-Low** given that amphipods, chironomids, and bivalves were abundant, the abundance of worms was relatively low, and there were no concerns regarding water quality in the lake in 2014.

In fall 2014, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations at all stations of the Christina River watershed, except total PAHs (absolute) and PAH hazard index values at the lower *test* station and upper *baseline* station of the Christina River, and the *test* stations of Sunday Creek and one unnamed creeks (south of Christina Lake), which were below regional *baseline* ranges. Sediment quality at all stations in fall 2014 indicated **Negligible-Low** differences compared to regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations for Christina and Gregoire lakes because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012 and 2013. Sediment quality monitoring was not conducted on the Gregoire River and Jackfish River given these rivers are erosional.

Fish Populations (fish assemblages) Information on fish assemblages for the southern oil sands region is just beginning to be collected; therefore, a comparison with *baseline* conditions in the northern region was conducted. Differences in measurement endpoints for the lower and upper *test* reaches of the Christina River were classified as **Negligible-Low** because all measurement endpoints were within the range of *baseline* variability. Differences in measurement endpoints for the middle *test* reach of the Christina River were also classified as **Negligible-Low** because only two measurement endpoints (abundance and catch per unit effort) were below the range of *baseline* variability. Differences in measurement endpoints for the *test* reach of Gregoire River were classified as **Negligible-Low** because all measurement endpoints were within the *baseline* range of variability. Differences in measurement endpoints for the *test* reach of Jackfish River were classified as **Negligible-Low** because although diversity and richness exceeded the *baseline* range of variability, this was indicative of a positive change in the fish assemblage. Only abundance was below the *baseline* range of variability, indicating a potential negative change in the fish assemblage. Differences in measurement endpoints for fish assemblages for the *test* reach of Sunday Creek were classified as **Negligible-Low** because all measurement endpoints were within the range of *baseline* variability. Differences in measurement endpoints for fish assemblages at the *test* reaches of Sawbones Creek, and two unnamed creeks (east and south of Christina Lake) were classified as **High** because all endpoints were near or below the *baseline* range of variability due to low or no catch of fish at these reaches. It should be noted that an effort was made to survey other areas of these creeks to find more suitable fish habitat; however, the creeks were primarily deep-water, depositional, and often flooded muskeg habitat along most of the length of the watercourse. This type of habitat is generally not suitable for many fish species in the region that prefer faster water, with harder substrate.

Hangingstone River Watershed

Hydrology For the 2014 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were 0.2%, -0.1%, 0.2%, and 0.2%, respectively. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2014 between the lower *test* station (downstream of the town of Fort McMurray) and the middle *test* station (upstream of the town of Fort McMurray) and regional *baseline* fall conditions were classified as **Moderate**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative to regional *baseline* concentrations. In addition, concentrations of a few metals and ions exceeded their historical range (2004 to 2008 and 2013) for the middle *test* station. Despite having higher concentrations of dissolved ions in 2014, the ionic composition at the middle *test* station was similar to previous years and similar to the *test* station downstream of Fort McMurray.

Pierre River Area

Water Quality Differences in water quality in fall 2014 between *baseline* stations on Big Creek, Eymundson Creek, Pierre River and Red Clay Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. The *baseline* station at Eymundson Creek differed from the other stations in this area in its ionic composition, with a higher concentration of sulphate and lower concentration of bicarbonate, which may suggest greater groundwater influence at this station. Eymundson Creek also had a higher concentration of total suspended solids than the other stations.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at *baseline* reaches of Big Creek, Eymundson Creek, and the Pierre River were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; but also an increasing proportion of EPT taxa and more sensitive fauna. With the decrease in the abundance of worms and an increase in EPT taxa, the *baseline* reach of the Pierre River, in particular, showed improving conditions from 2013. The benthic invertebrate communities at the *baseline* reach of Red Clay Creek had a greater proportion of tolerant worms in 2014 than 2013 but continued to maintain a good proportion of EPT taxa, indicating good habitat quality. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the Athabasca oil sands region.

All sediment stations of the Pierre River area had sediment quality index values indicating **Negligible-Low** differences from regional *baseline* conditions. Concentrations of sediment quality measurement endpoints did not exceed any sediment or soil quality guidelines at the *baseline* station of Big Creek, while total arsenic exceeded the guideline at *baseline* stations of Eymundson Creek and the Pierre River, and F3 hydrocarbons and predicted PAH toxicity also exceeded guidelines at the *baseline* station of the Pierre River. Survival of the midge *Chironomus* was fairly low at *baseline* stations of Big Creek and the Pierre River in 2014 (52% and to 58%, respectively). In general, all sediment quality measurement endpoints at all locations in fall 2014 were similar to results from fall 2013. Sediment quality monitoring was not conducted at Red Clay Creek given it is an erosional river.

Fish Populations (fish assemblages) The fish assemblages at *baseline* reaches of Big Creek, Eymundson Creek, Pierre River, and Red Clay Creek were similar to other *baseline* reaches in the region, and with each other. Species composition was generally the same across each reach and there was a decrease in the catch of burbot in 2014 compared to 2013 at all reaches.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all 68.4% lower in the observed *test* hydrograph for Mills Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**. These **High** magnitude of changes were due to land disturbance located immediately upstream of the hydrology station. Given the limited size of the Mills Creek watershed downstream of JOSMP Station S6, the magnitude of impact would remain high along the entire length of Mills Creek; therefore, a longitudinal classification of Mills Creek was not conducted.

In the 2014 WY, the water level of Isadore's Lake slowly decreased by about 0.1 m from November to early April, and was within the historical interquartile range for this period. During spring thaw, the lake level initially rose by approximately 0.15 m, and then decreased sharply in mid-May. A second rise occurred in late May following rainfall accumulations, and lasted until the first week in June. The lake level then gradually increased until early September, until the peak annual lake level occurred before gradually decreasing until the end of October.

Differences in water quality in fall 2014 between Mills Creek and regional *baseline* fall conditions were classified as **Moderate**, due to relatively high concentrations of many ions that exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water of Isadore's Lake and Mills Creek showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

Differences in measurement endpoints of the benthic invertebrate community at Isadore's Lake were classified as **Negligible-Low** because although there were significant time trends in the percentage of EPT taxa and CA Axis 1, both were indicative of improving habitat quality. The percentage of EPT taxa has been higher than usual since 2013. Several of the measurement endpoints exceeded the tolerance limits of the normal range of variation; however, none of the exceedances were considered an indication of degrading conditions. Isadore's Lake, historically, has had low diversity and high abundances of nematodes making it unique in comparison to the other lakes in the program. In 2014, the relative abundance of nematodes was lower but the abundance of naidid worms was higher than previously observed in Isadore's Lake. The percentage of EPT taxa and taxa richness have increased in recent years, suggesting that water and sediment quality of Isadore's Lake was potentially improving over time.

Sediment quality measurement endpoints for Isadore's Lake were generally within the range of previously-measured concentrations, with the exception of F2 hydrocarbons, retene, and total arsenic that exceeded previously-measured maximum concentrations and naphthalene, which was below the previously-measured minimum concentration. Concentrations of total arsenic, and F1, F2, and F3 hydrocarbons exceeded sediment quality guidelines in fall 2014, with the concentration of F3 hydrocarbons significantly higher than the guideline value. A SQI was not calculated for Isadore's Lake because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers and because there are limited *baseline* lake data for the oil sands region.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2014 at Shipyard Lake were within previously-measured concentrations. The ionic composition of water at Shipyard Lake continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with oil sands development in the upper portion of the watershed (91% of the Shipyard Lake watershed has been disturbed). The Water Quality Index (WQI) was not calculated for lakes in 2014 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the lack of *baseline* data for lakes in the region.

Differences in measurement endpoints of benthic invertebrate communities for Shipyard Lake in 2014 were classified as **Negligible-Low**. The increasing trend in taxa richness and lower equitability in 2014 were indicative of improving habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams, and snails, indicating generally good water and sediment quality. In fall 2014, some sediment quality measurement endpoints exceeded previously-measured maximum concentrations at Shipyard Lake, including percent sand, total organic carbon, and all hydrocarbons (BTEX and F1 to F4 fractions), while percent clay and silt were below predicted-measured minimum values. Concentrations of total arsenic, F1, F2, and F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene) exceeded sediment or soil quality guidelines in 2014. Shipyard Lake was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

Poplar Creek and Beaver River The 2014 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -1.8%, +3.7% and -1.8%, respectively, in the observed *test* hydrograph for Poplar Creek than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The 2014 WY mean open-water discharge was 22.7% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph and this difference was classified as **High**. Assessed changes to the hydrology of Poplar Creek, were classified as **High** from the mouth of the creek until the confluence with the Poplar Creek spillway (approximately 2 km upstream of JOSMP Station S11), and **Negligible-Low** upstream of the confluence. The results from the longitudinal assessment suggested that the extent of **High** hydrologic change was only limited to the lowest 4 km of Poplar Creek.

Concentrations of several water quality measurement endpoints, primarily ions, exceeded regional *baseline* concentrations at *test* stations of Poplar Creek and the lower Beaver River, resulting in **Moderate** differences from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at the upper *baseline* station of the Beaver River, differences in water quality in fall 2014 between the *baseline* station of the Beaver River and regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of most water quality measurement endpoints exhibited some variability throughout the year at Poplar Creek (sampled monthly in 2014), which was apparent in the ionic composition of water, which showed seasonal variability. Generally the highest concentrations of ions and metals occurred in September. Guideline exceedances occurred most frequently in January, June, August, and November; however, most monthly concentrations of water quality measurement endpoints were within the range of regional *baseline* fall conditions.

Differences in measurement endpoints of benthic invertebrate communities at Poplar Creek were classified as **Negligible-Low** because although there were significant and large differences in equitability and the percentage of EPT taxa at this *test* reach compared to the *baseline* reach of the upper Beaver River (connected hydrologically to lower Poplar Creek), these changes were not indicative of degradation. In addition, the percentage of EPT taxa was higher in 2014 than 2013 and diversity has been steadily increasing over the last three years at the *test* reach of Poplar Creek. The benthic invertebrate community of lower Poplar Creek was in generally good health and was comprised of what would be expected for a sand-bottomed river dominated by worms and chironomids. The relative abundance of fingernail clams was higher in 2014 compared to 2013. Differences in sediment quality observed in fall 2014 at the *test* station of Poplar Creek and the *baseline* station of the Beaver River compared to the regional *baseline* conditions were classified as **Negligible-Low.** Concentrations of total hydrocarbons and PAHs at Poplar Creek and the Beaver River were within historical ranges, with the exception of F2 hydrocarbons at the *test* station of Poplar Creek, which exceeded the previously-measured maximum concentration, and total parent PAHs and the predicted PAH toxicity at the *baseline* station of the Beaver River, which were below previously-measured minimum concentrations. No sediment quality measurement endpoints exceeded CCME guidelines, with the exception of F2 and F3 hydrocarbons at the *test* station of Poplar Creek.

Differences in measurement endpoints of the fish assemblage at the *test* reach of Poplar Creek were classified as **Negligible-Low** because the significant increases in richness, diversity, and catch per unit effort (CPUE) and the significant decrease in the assemblage tolerance index (ATI) were not indicative of a negative change in the fish assemblage. In addition, all measurement endpoints for this *test* reach were within the inner tolerance limits of the *baseline* range of variability.

McLean Creek Concentrations of water quality measurement endpoints at the *test* station of lower McLean Creek were generally within the range of previously-measured concentrations in fall 2014. The WQI value indicated **Moderate** differences between this *test* station and regional *baseline* concentrations, mostly attributed to high levels of dissolved ions and total metals. Despite having no significant temporal trends, total dissolved solids and several ions have shown consistent annual increases since 2009.

Fort Creek The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 20.24% lower in the observed *test* hydrograph for Fort Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**. This **High** magnitude of change was due to land disturbances throughout most of the watershed, upstream of JOSMP Station S12 (i.e., 84% of the watershed has been developed). Given the small size of the Fort Creek watershed, downstream of JOSMP Station S12, the magnitude of impacts would remain **High** along the entire length of Fort Creek; therefore, a longitudinal classification was not conducted for this watershed.

Concentrations of most water quality measurement endpoints for Fort Creek were within the range of previously-measured concentrations and regional *baseline* concentrations in fall 2014. Differences in water quality between the *test* station of Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**. Many significant temporal trends in water quality measurement endpoints continued to be observed, including decreasing concentrations of dissolved phosphorus, total arsenic, and total nitrogen, and increasing concentrations of calcium, magnesium, potassium, total boron, total dissolved solids, total strontium, and sulphate. The ionic composition of water has showed a continued shift in anions over time, having a greater influence of sulphate in fall 2014 compared to earlier sampling years.

Differences in measurement endpoints for benthic invertebrate communities at the *test* reach of Fort Creek were classified as **Moderate.** There were statistically significant and large variations in abundance, richness, and equitability, indicating potential degradation of habitat conditions. In addition, the percentage of EPT taxa was below the inner tolerance limits of the normal range of variability for this reach, but was still higher than values from *baseline* years (2001 to 2003). Lower richness and higher equitability during the *test* years were potentially suggestive of moderate degradation, but the presence of clams, snails, and particularly stoneflies suggested that habitat quality was not significantly degraded. The benthic invertebrate community of Fort Creek has typically had low diversity including during the *baseline* period, and the community in 2014 was consistent with previous years.

Sediment quality at the *test* station of Fort Creek in fall 2014 showed **Negligible-Low** differences from regional *baseline* conditions. All sediment quality measurement endpoints were within the range of previously-measured concentrations, with concentrations of F3 hydrocarbons, dibenz(a,h)anthracene, and chrysene exceeding sediment quality guidelines in 2014.

Differences in measurement endpoints for the fish assemblage at the *test* reach of Fort Creek were classified as **Moderate** because there were significant decreases in abundance, richness, and catch per unit effort, implying a negative change to the fish assemblage.

Susan Lake Outlet Peak flow from Susan Lake in the 2014 open-water period occurred on May 30. Flows decreased after this peak, and fluctuated until the end of the open-water period. Flows remained above historical median values on most dates, and often above historical maxima, especially during the month of June, but the historical record was limited.

Acid-Sensitive Lakes

Results of the analysis of the ASL lakes in 2014 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 45 lakes across years that could be attributed to acidification. These results were consistent with the revised estimates of potential acid input (PAI) suggesting that only 14 of the 45 lakes were actually exposed to acidifying deposition.

A summary of the state of the ASL lakes in 2014, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In 2014 there were no exceedances of the criterion for any of the measurement endpoints in any of the subregions. Therefore, all subregions were classified as having a **Negligible-Low** indication of incipient acidification.

Summary assessment of the 2014 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions					Fish Populations: Human Health Risk from Mercury in Fish Tissue[6]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[7]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Assemblages[5]	Species	Subsistence Fishers	General Consumers	
Athabasca River	🟡	🟡	-	-	-	LKWH	🟡	🟡	-
						WALL	🟤	🟤	
Athabasca River Delta	-	-	🟡/🟠/🟤	🟡	n/a		-		-
Muskeg River	🟠	🟡	🟡	🟡	🟡/🟠/🟤		-		-
Jackpine Creek	nm	🟡	🟡	🟡	🟤		-		-
Kearl Lake	nm	🟠/🟡	🟡	n/a	-		-		-
Steepbank River	🟡	🟠	🟠	-	🟤		-		-
Tar River	🟤	🟡	🟤	🟡	🟡		-		-
MacKay River	🟡	🟡	🟠/🟡	-	🟠/🟡		-		-
Calumet River	🟡	🟡	nm	nm	nm		-		-
Firebag River	🟡	🟡	-	-	-		-		-
McClelland Lake	nm	n/a	🟡	n/a	-		-		-
Johnson Lake	-	n/a	n/a	n/a	-		-		-
Ells River	🟡	🟡	🟠	🟡	🟠		-		-
Gardiner Lake	-	-	n/a	n/a	-				
Namur Lake	-	-	-	-	-		-		-
Clearwater River	nm	🟡	🟡	🟡	-		-		-
High Hills River	-	🟡	n/a	-	n/a		-		-
Christina River	🟡	🟡/🟠	🟡	🟡	-		-		-
Christina Lake	nm	n/a	🟠	n/a	-		-		-
Gregoire Lake	nm	n/a	🟡	n/a	-				
Gregoire River	nm	🟠	🟡	n/a	🟡				
Jackfish River	nm	🟡	🟡	🟡	🟡		-		-
Sawbones Creek	nm	🟡	🟡	🟡	🟤		-		-
Sunday Creek	nm	🟡	🟠	🟡	🟡		-		-
Birch Creek	nm	🟡	n/a	🟡	n/a		-		-
Unnamed Creeks (east and south of Christina Lake)	nm	🟡	🟡	🟡	🟤/🟤		-		-
Hangingstone River	🟡	🟠	-	-	-		-		-
Fort Creek	🟤	🟡	🟠	🟡	🟠		-		-
Beaver River	-	🟠	-	-	-		-		-
McLean Creek	-	🟠	-	-	-		-		-
Mills Creek	🟤	🟠	-	-	-		-		-
Isadore's Lake	nm	n/a	🟡	n/a	-		-		-
Poplar Creek	🟤	🟠	🟡	🟡	🟡		-		-
Shipyard Lake	-	n/a	🟡	n/a	-		-		-
Big Creek	-	🟡	n/a	🟡	n/a		-		-
Pierre River	-	🟡	n/a	🟡	n/a		-		-
Red Clay Creek	-	🟡	n/a	🟡	n/a		-		-
Eymundson Creek	-	🟡	n/a	🟡	n/a		-		-
Stony Mountains	-	-	-	-	-		-		🟡
West of Fort McMurray	-	-	-	-	-		-		🟡
Northeast of Fort McMurray	-	-	-	-	-		-		🟡
Birch Mountains	-	-	-	-	-		-		🟡
Canadian Shield	-	-	-	-	-		-		🟡

Legend and Notes

🟡 Negligible-Low change

🟠 Moderate change

🟤 High change

"-" program was not completed in 2014; nm – not measured in 2014.

n/a – classification could not be completed because there were no *baseline* conditions to compare against or reach was sampled to add to the regional *baseline* dataset.

[1] **Hydrology:** Calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% – Negligible-Low; ± 15% – Moderate; > 15% – High.

Note: As not all hydrology measurement endpoints were calculated for each watershed because of differing lengths of the hydrographic record for 2014, hydrology results were for those measurement endpoints that were calculated.

Note: Mean Open-Water Season Discharge and Annual Maximum Daily Discharge in the Muskeg River were assessed as Moderate; Mean Winter Discharge was assessed as Negligible-Low, and Minimum Open-Water Season Discharge was assessed as High.

Note: Mean Open-Water Season Discharge, Mean Winter Discharge, and Annual Maximum Daily Discharge in Poplar Creek were assessed as Negligible-Low; Mean Open-Water Discharge was assessed as High.

[2] **Water Quality:** Classification based on adaptation of CCME water quality index.

Note: Water Quality in the Steepbank River was assessed as Moderate at the lower station, and Negligible-Low at all other stations.

[3] **Benthic Invertebrate Communities:** Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches or between *baseline* and *test* periods or trends over time for a reach as well as comparisons to regional *baseline* conditions.

Note: Benthic invertebrate communities in the Athabasca River Delta were assessed as Negligible-Low at Big Point Channel and the Embarras River, Moderate at Fletcher Channel, and High at Goose Island Channel.

[4] **Sediment Quality:** Classification based on adaptation of CCME sediment quality index.

[5] **Fish Populations (fish assemblages):** Classification based on exceedances of measurement from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Note: Fish assemblages in the Muskeg River were assessed as Moderate at the lower reach, Negligible-Low at the middle reach, and High at the upper reach.

Note: Fish assemblages in the MacKay River were assessed as High at the lower reach and Negligible-Low at the middle reach.

[6] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. LKWH – lake whitefish; WALL – walleye; Subsistence fishers and General consumers as defined by Health Canada (see Section 3.2.4.2).

[7] **Acid-Sensitive Lakes:** Classification based the frequency in each subregion with which values of seven measurement endpoints in 2014 were more than twice the standard deviation from their long-term mean in each lake.

1.0 INTRODUCTION

In 2012, the governments of Canada and Alberta developed a "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring" (Canada and Government of Alberta 2012) specific to the Athabasca oil sands region of northeastern Alberta. The implementation plan was to build and expand on existing environmental monitoring programs for the region, including the Regional Aquatics Monitoring Program (RAMP, www.ramp-alberta.org). RAMP was implemented in 1997 as a multi-stakeholder aquatics monitoring program that assessed the health of rivers and lakes within the oil sands region, and to assess potential cumulative effects of oil sands development. The intent of the new joint implementation plan was to enhance these monitoring activities and work to integrate environmental monitoring across all environmental components (i.e., air, water, land, and biodiversity), which were historically monitored independently through separate organizations or programs.

As a result of the implementation plan, the Joint Oil Sands Monitoring Plan (JOSMP, www.jointoilsandsmonitoring.ca) was initiated over three years (2012 to 2015) to characterize the state of the environment in the Athabasca oil sands region, understand the cumulative effects and changes, and develop recommendations for an integrated environmental monitoring program, with an adaptive management framework for implementation in the oil sands region. From 2012 to 2014, the RAMP Committees worked with the governments of Canada and Alberta to align aquatics monitoring activities historically undertaken by RAMP into the JOSMP, completing this process by April 1, 2014.

Established in 2014, the Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA, www.aemera.org) is an arm's length organization responsible for collecting credible scientific data and other relevant information on the condition of Alberta's environment and providing the public with open and transparent reporting and access to the data and information. AEMERA is responsible for the coordination and implementation of the JOSMP in the oil sands region, as well as the integration of all environmental monitoring in the Province of Alberta. The intent of this agency is to provide timely collection and objective reporting of scientific data and information on air, land, water, and biodiversity, including information necessary to understand cumulative effects, in order to better inform the understanding of the public, policy makers, regulators, planners, researchers, communities, and industries (www.aemera.org).

This report presents the 2014 results for aquatics monitoring in the oil sands regions in support of the JOSMP that were historically conducted under the RAMP. Additional aquatics monitoring under the JOSMP were conducted by Alberta Environment and Sustainable Resource Development (AESRD) and Environment Canada; results from these monitoring activities are not provided in this report.

1.1 ATHABASCA OIL SANDS REGION BACKGROUND

With an estimated 293.1 billion m^3 (1.845 trillion barrels) of total reserves of bitumen (initial volume in place) (AER 2014), the Alberta oil sands (i.e., Athabasca, Cold Lake, and Peace River deposits) are the largest of Canada's known petroleum resources. The Alberta oil sands are a significant component of the world's petroleum resources, with its 26.56 billion m^3 (167.1 billion barrels) of remaining established bitumen reserves[1] (AER 2014) being equivalent to 11% of the world's known reserves of conventional

[1] Established crude bitumen reserves were defined as mineable reserves that were anticipated to be recovered by surface mining operations and in situ reserves that were anticipated to be recovered through wellbores using in situ recovery methods (AER 2014). Remaining established bitumen reserves were established bitumen reserves less cumulative bitumen production.

crude oil[2] (US Energy Information Administration 2014). Total bitumen deposits in the Athabasca oil sands region (including Wabasca) are the largest of Alberta's three oil sands regions, containing 82.7% of the total provincial reserves, with the total deposits in the Cold Lake and Peace River areas being significantly smaller (AER 2014).

In 1967, Great Canadian Oil Sands Ltd. (now Suncor Energy Inc.) initiated the first commercially successful bitumen extraction and upgrading facility in the Athabasca oil sands region. Since that time, investment and development in the Athabasca oil sands region near Fort McMurray in the Regional Municipality of Wood Buffalo (RMWB) has increased substantially. Approximately 31.7% of the estimated established bitumen reserves in the Athabasca oil sands region were under active development as of the end of 2013, and 4.9% of the estimated established bitumen reserves of the Athabasca oil sands region had been extracted by the end of 2013 (Table 1.1-1).

Table 1.1-1 Status of bitumen reserves in the Athabasca oil sands region.

Bitumen Reserve and Production Indicators		Amount (million barrels)	
Initial Volume in Place (total reserves)			1,522,743
Estimated Established Reserves			145,936*
Established Reserves under Active Development as of 31 December 2013			46,280
	Mineable	44,544	
	in situ	1,737	
Cumulative Production as of 31 December 2013			7,114
	Mineable	5,852	
	in situ	1,262	
Remaining Established Reserves			138,822

Data from AER (2014); all figures are as of December 31, 2013.

* Estimated, established reserves were estimated by applying the ratio of estimated established to the total bitumen reserves for the entire province to total reserves in the Athabasca oil sands region.

The increasing development of the Athabasca oil sands resource has been accompanied by an increase in environmental monitoring and research conducted in the Athabasca oil sands region and increasing interest among stakeholders in ensuring that measures in place to monitor any potential effects on the environment are effective. Site-specific monitoring is conducted by individual oil sands operators to meet approval requirements. Oil sands companies also provide support to research to gain a better understanding of local aquatic resources and their response to regional development. Cumulative long-term regional monitoring (i.e., for status and trends reporting) and surveillance monitoring (i.e., typically short-term to address specific questions) of water, biodiversity, and air, in the Athabasca oil sands region is now directed through AEMERA in collaboration with other organizations, universities, and oil sands operators. In 2012, AESRD developed the Lower Athabasca Regional Plan (LARP) that identifies and sets resource and environmental management outcomes for air, land, water and biodiversity, and will guide future resource decisions while considering social and economic impacts (Government of Alberta 2012).

[2] The world's known reserves of conventional crude oil were based on 2013 data as 2014 data were not available (US Energy Information Administration 2014).

1.1.1 Objectives

There were a number of objectives that were taken into account during the development of the JOSMP by the governments of Canada and Alberta for monitoring in the oil sands region, including:

- to support sound decision-making by governments as well as stakeholders;
- to ensure transparency through accessible, comparable, and quality-assured data;
- to enhance science-based monitoring for improved characterization of the state of the environment and collect the information necessary to understand cumulative effects;
- to improve analysis of existing monitoring data to develop a better understanding of historical baselines and changes; and
- to reflect the trans-boundary nature of the issue and promote collaboration with the governments of Saskatchewan and the Northwest Territories.

The development of this portion of the aquatics component of the JOSMP was based on the following historical objectives outlined for the RAMP (RAMP 2014), which maintain relevancy:

- Monitor aquatic environments in the Athabasca oil sands region to detect and assess cumulative effects and regional trends;
- Collect baseline data to characterize variability in the Athabasca oil sands region;
- Collect and compare data against which predictions contained in Environmental Impact Assessments (EIAs) can be assessed;
- Collect data that assists with the monitoring required by regulatory approvals of oil sands and other developments; and
- Continuously review and adjust the program to incorporate monitoring results, technological advances, and community concerns and new or changed approval conditions.

These objectives have guided the scope and implementation of the monitoring program over time.

1.2 STUDY AREA

The study area that was used for this portion of aquatics monitoring under the JOSMP was defined as the major watersheds in the Athabasca oil sands region, where oil sands development has been approved or are active (Figure 1.2-1), while the geographic scope of the entire JOSMP encompasses a larger area, particularly to the north (Canada and Government of Alberta 2012). The lower Athabasca River is the dominant waterbody within the study area and hydrologically links the upper (southern) portion of the study area to the lower (northern) portion. The Athabasca River flows a distance of more than 1,200 km from its headwaters in the Columbia Ice Fields near Banff, Alberta to the Athabasca River Delta (ARD) on the western end of Lake Athabasca.

The southern portion of the study area is within the Mid-Boreal Uplands and Wabasca Lowland Ecoregions, both of which are part of the Boreal Plains Ecozone. This area is dominated by the Clearwater and Christina rivers, as well as a series of smaller rivers, primarily the Hangingstone, Gregoire, and Horse rivers. The area is characterized by a predominantly sub-humid mid-boreal ecoclimate, closed stands of trembling aspen, balsam poplar with white spruce, black spruce, and balsam fir occurring in late successional stages, as well as cold and poorly-drained fens and bogs covered primarily with tamarack and black spruce. The western part of the southern portion of the study area has little relief and is poorly-drained.

The northern portion of the study area, dominated by the Athabasca River from Fort McMurray to the ARD, is part of the Slave River Lowlands Ecoregion of the Boreal Plains Ecozone. The mineable portion of the estimated, established bitumen reserves of the Athabasca oil sands region lies within this portion of the study area and is characterized by an undulating sandy plain containing mixed boreal forest. Approximately 50% of this portion of the study area is covered by peatlands and sporadic discontinuous permafrost. The area is partially bordered to the west by the Birch Mountains and to the east by intermittent slopes including the Muskeg Mountains, which extend northward from the Clearwater River Valley. At the ARD, the Athabasca River becomes an interconnected series of braided channels and wetlands flowing into Lake Mamawi and Lake Athabasca. This area experiences a low subarctic ecoclimate, with black spruce as the climax tree species, and with characteristically open stands of low, stunted black spruce with dwarf birch and Labrador tea, and a ground cover of lichen and moss prevailing. The northern portion of the RMWB is within the Selwyn Lake Upland Ecoregion, part of the Taiga Shield Ecozone.

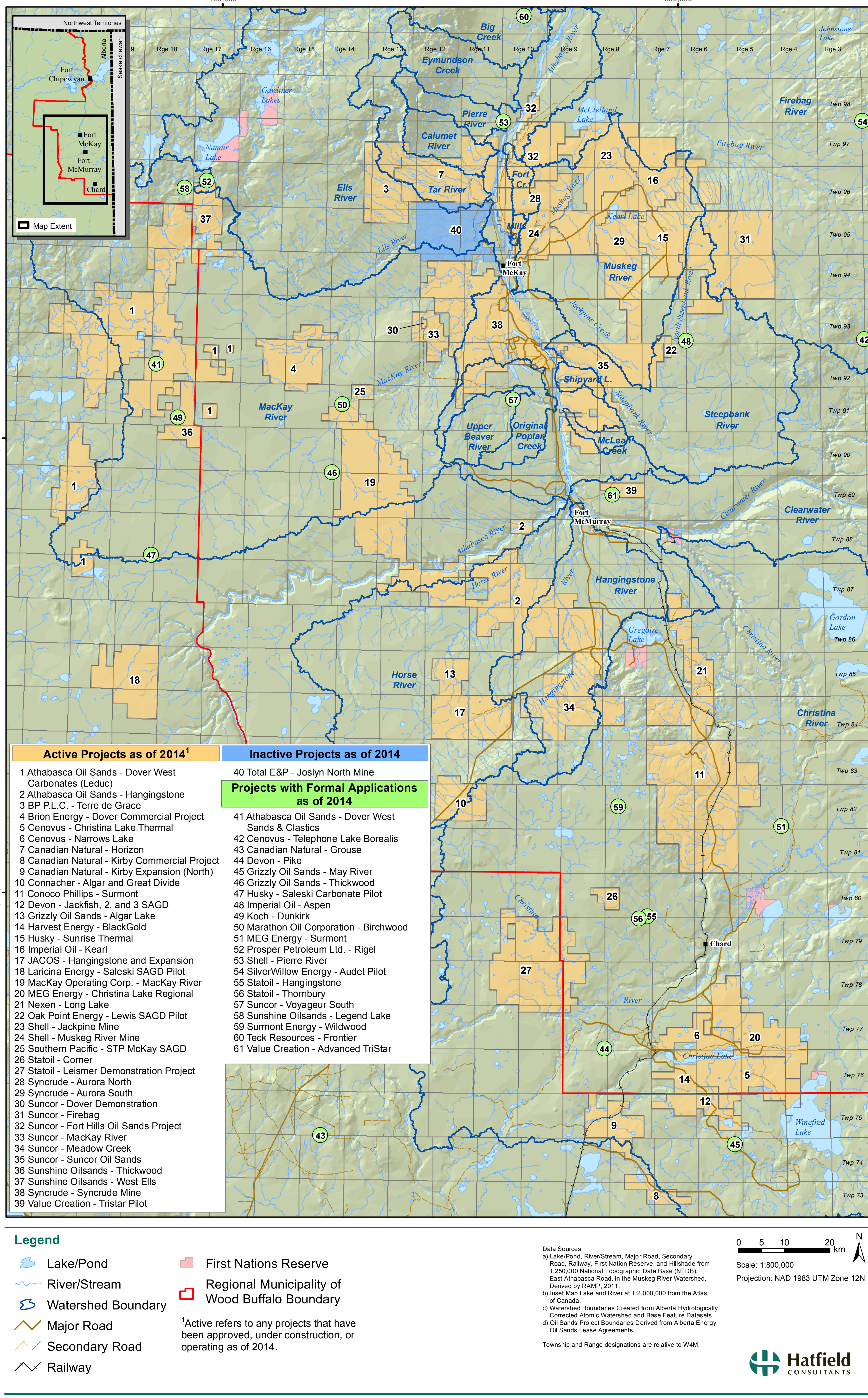
As the Athabasca River flows northward, several smaller tributary streams and rivers join and contribute to the overall flow. Figure 1.2-2 is a hydrologic schematic of the study area showing the size of the larger tributaries relative to the lower Athabasca River. Although approximate, the diagram shows that: (a) there is a range of tributary sizes; and (b) the size of the lower Athabasca River is much larger than any tributary, even the Clearwater River. Some of the larger of these tributaries include, in upstream to downstream order:

- Clearwater-Christina rivers – the Clearwater originates in Saskatchewan, joins the Athabasca River at Fort McMurray, and includes the contribution of the Christina River, a large tributary of the Clearwater River whose watershed includes several in situ oil sands developments including the Cenovus Christina Lake, West Kirby, and Narrow Lake projects, the ConocoPhillips Surmont, Devon Jackfish and Pike (in application) projects, Grizzly Algar Lake and May River projects, Harvest Energy BlackGold Project, MEG Energy Christina Lake and Surmont (in application) projects, N-Solv Corp. Dover Project, Nexen Long Lake Project, SilverWillow Energy Audet Project (in application), Statoil Leismer, Hangingstone (in application), and Thornbury (in application) projects, Surmont Energy Wildwood Project (in application), Suncor Meadow Creek Project, and a portion of the Canadian Natural Kirby and Grouse (in application) projects;

- Hangingstone River – a river originating in the southwestern portion of the study area, joining the Clearwater River immediately upstream of Fort McMurray, and whose watershed includes portions of the JACOS Hangingstone, Nexen Long Lake, and Value Creation Tristar projects;

- Horse River – a river originating in the southwestern portion of the study area, joining the Athabasca River upstream of Fort McMurray, and whose watershed includes the JACOS and Athabasca Oil Sands Hangingstone projects and portions of the Connacher Great Divide and Algar projects;

Figure 1.2-1 Location of oil sands developments in watersheds where aquatics monitoring activities occurred in support of the JOSMP.



K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_A_StudyArea_20150423_ss.mxd

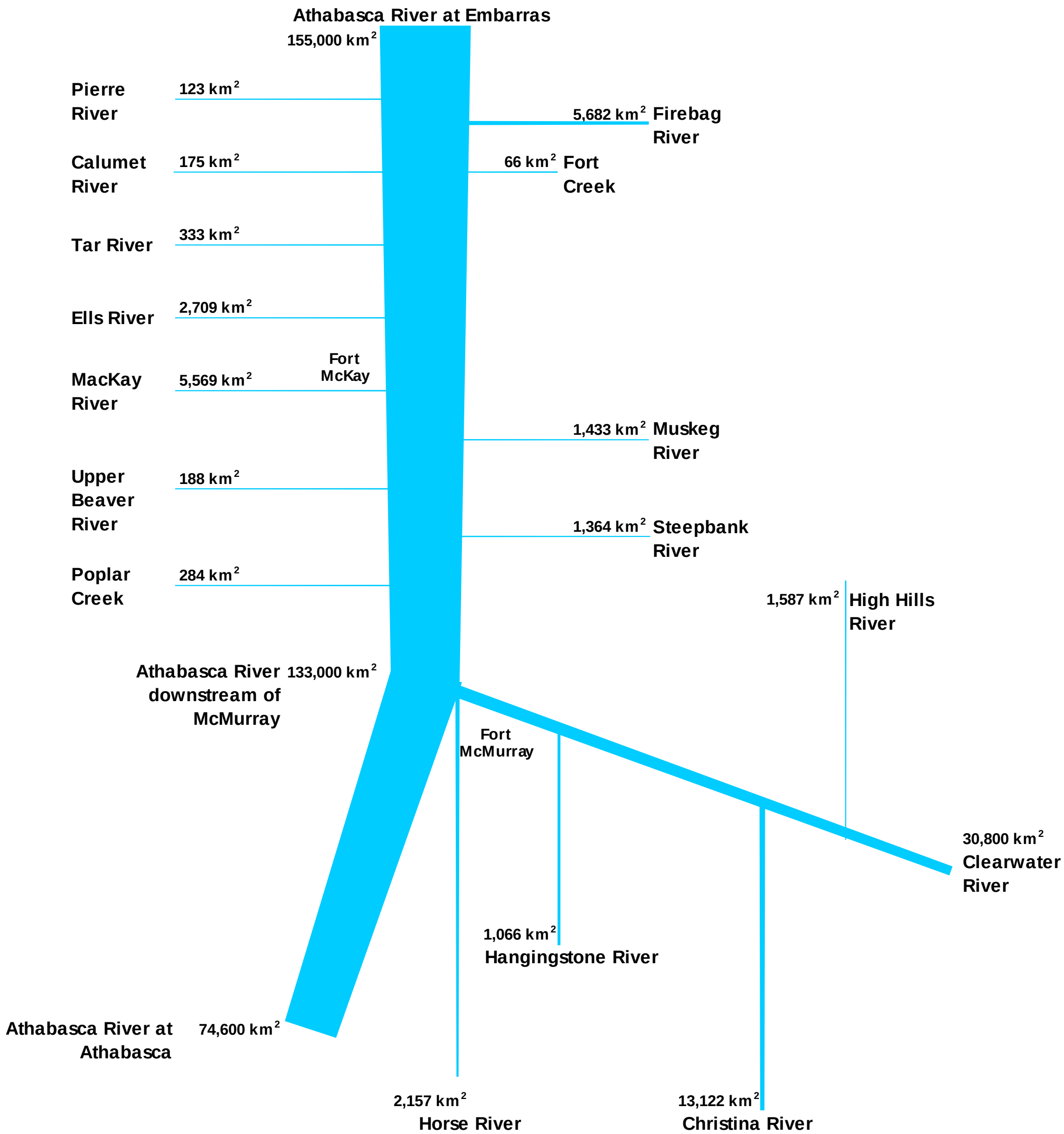
- Steepbank River – joins the Athabasca River from the east and whose watershed includes the Suncor Steepbank and Millennium mines, the Suncor North Steepbank Extension, and portions of the Suncor in situ Firebag and the Husky in situ Sunrise Thermal projects;
- Muskeg River – flows from the east and drains several oil sands development areas and whose watershed includes the Shell Muskeg River Mine and Expansion, Shell Jackpine Mine and Expansion, Syncrude Aurora North and South mines, and portions of the Suncor in situ Firebag and Fort Hills, Imperial Oil Kearl, and Husky Sunrise projects, and the Hammerstone Muskeg Valley Quarry;
- MacKay River – flows from the west and whose watershed includes the Athabasca Oil Sands Dover West Project, Brion Energy MacKay Project, Koch Dunkirk Project (in application), MacKay Operating Corp. MacKay Project, Southern Pacific STP-McKay Project, Marathon Oil Birchwood Project (in application), Suncor MacKay River and Dover projects, Sunshine Oil Sands Thickwood Project, and a portion of the Syncrude Mildred Lake Project;
- Ells River – flows from the west and whose watershed includes the Athabasca Oil Sands Dover West Project, Brion Energy Dover Project, Sunshine Oilsands West Ells and Legend Lake (in application) projects, Oak Point Energy Lewis Project; the Total E&P Joslyn North Mine (inactive); and portions of the Canadian Natural Horizon Mine and the BP Terre de Grace Project; this river is also the drinking water source for the community of Fort McKay;
- Tar River – flows from the west and whose watershed contains most of the Canadian Natural Horizon Mine, and portions of the Total E&P Joslyn North Mine (inactive) and the BP Terre de Grace Project;
- Calumet River – also flows from the west and whose watershed is partly within the Canadian Natural Horizon Mine; and
- Firebag River – a river flowing from Saskatchewan whose watershed includes the Suncor Fort Hills, Cenovus Telephone Lake (in application), Imperial Oil Aspen (in application), and Prosper Petroleum Rigel (in application) projects, most of the Suncor in situ Firebag Project, and portions of the Husky Sunrise Thermal and Imperial Oil Kearl projects.

Other waterbodies monitored under the JOSMP and within existing or proposed oil sands developments include:

- tributaries within watersheds described above such as Muskeg Creek, Jackpine Creek, Stanley Creek, and Wapasu Creek in the Muskeg River watershed;
- smaller river tributaries of the Athabasca River (Fort Creek, Mills Creek, Poplar Creek, McLean Creek, Beaver River, and Fort Creek) that contain parts of a number of oil sands projects, including the Brion Energy MacKay Project, Grizzly Oil Sands Thickwood Project (in application), Husky Saleski Project (in application), Shell Pierre River Mine (inactive), JACOS Hangingstone Project, Saleski Pilot Project, Shell Muskeg River Mine and Expansion, Suncor Base Mine and Voyageur Upgrader, Suncor Fort Hills Project (Fort Creek), Syncrude Mildred Lake (Beaver River), Teck Frontier Project (in application), and Value Creation Advanced Tristar Project (in application);
- specific lakes and wetlands such as Isadore's Lake, Shipyard Lake, McClelland Lake, Kearl Lake, Namur Lake, Gregoire Lake, Gardiner Lake, Christina Lake, and Johnson Lake; and
- a set of lakes for the purpose of assessing lake sensitivity to acidifying emissions.

Finally, there are a number of waterbodies and watercourses that are used as *baseline* areas for certain monitoring components.

Figure 1.2-2 Hydrologic schematic of the study area for monitoring activities conducted by Hatfield under the JOSMP.



Note: Drainage areas of Athabasca River tributaries derived from watershed boundaries provided by AESRD.

1.3 GENERAL MONITORING AND ANALYTICAL APPROACH

1.3.1 Overall Monitoring Approach

The monitoring approach for this portion of aquatics monitoring under the JOSMP (hereafter also referred to as the Program) incorporates a combination of both stressor- and effects-based monitoring approaches. The stressor-based approach is derived primarily from EIAs prepared for each of the oil sands projects. EIAs are undertaken in part to evaluate the potential impacts that the proposed project, alone or in combination with other developments, could have on the local and regional environment. To date, EIAs conducted for projects in the Athabasca oil sands region have used primarily a stressor-based approach. A potential stressor is any factor (e.g., chemicals, temperature, water flow, nutrients, food availability, and biological competition) that either currently exists in the environment and will be influenced by the proposed project or will be potentially introduced into the environment as a result of the proposed project. Using this approach, the impact of a development is evaluated by predicting the potential impact of each identified stressor on valued components of the environment (Munkittrick et al. 2000). Using impact predictions from various EIAs, specific potential stressors have been identified that are monitored to document *baseline* conditions, establish natural variation in those conditions, as well as to identify potential changes related to development. Examples include specific water quality variables and changes in water quantity (RAMP 2009b).

Although the stressor-based impact assessment has been successful, the inherent risk of the approach is that it assumes that all potential stressors can be identified and evaluated. Accordingly, an effects-based approach has been advocated for impact assessments and subsequent monitoring efforts (Munkittrick et al. 2000). This approach focuses on evaluating the performance of biological components of the environment (e.g., fish and benthic invertebrates) because they integrate the potential effects of complex and varied stressors over time. This approach is independent of stressor identification, and focuses on understanding the accumulated environmental state resulting from the summation of all stressors. For example, the current federal Environmental Effects Monitoring (EEM) program for the pulp and paper and metal mining industries incorporates an effects-based monitoring approach (Environment Canada 2010). There is a strong emphasis in the Program on monitoring sensitive biological indicators such as benthic invertebrates and fish populations that reflect and integrate the overall condition of the aquatic environment. By combining both monitoring approaches, a more holistic understanding of potential effects on the aquatic environment related to the development of oil sands projects can be achieved.

1.3.2 Monitoring Components

In 2014, the Program focused on six components of boreal aquatic ecosystems:

- **Climate and Hydrology** – monitors changes in the quantity of water flowing through rivers and creeks in the study area, lake levels in selected waterbodies, and local climatic conditions;
- **Water Quality** in rivers, lakes, and some wetlands – reflects habitat quality and potential exposure of fish and invertebrates to organic and inorganic chemicals;
- **Benthic Invertebrate Communities** and **Sediment Quality** in rivers, lakes, and some wetlands – benthic invertebrate communities serve as biological indicators and are important

components of fish habitat, while sediment quality is a link between physical and chemical habitat conditions to benthic invertebrate communities;

- **Fish Populations** in rivers and lakes – biological indicators of ecosystem integrity and a highly-valued resource in the Athabasca oil sands region; and
- **Acid-Sensitive Lakes** – monitors water quality in regional lakes in order to assess potential changes in water quality as a result of acidification.

1.3.3 Definition of Terms

The analysis for each component is based on a selection of sampling stations and monitoring years to be used in the analysis for each watershed/river basin. For the analysis, the sampling stations and monitoring years are categorized into combinations of spatial and temporal treatments and controls, as described below:

- ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of oil sands developments; data collected from these locations are designated as *test* for the purposes of data analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2014) or were (prior to 2014) upstream of all oil sands developments; data collected from these locations are designated as *baseline* for the purposes of data analysis, assessment, and reporting.

The terms *test* and *baseline* depend solely on location of the aquatic resource in relation to the location of oil sands development to allow for long-term comparison of trends between *baseline* and *test* stations.

1.3.4 Monitoring Approaches

Details on the monitoring design and rationale for the 2014 Program are consistent with the historical RAMP and described in the RAMP Technical Design and Rationale document (RAMP 2009b). A summary of the monitoring design and rationale for each component is provided below.

1.3.4.1 Climate and Hydrology

The quantity of water in a system affects its capacity to support aquatic and terrestrial biota. Changes in the amount or timing of water flow may occur due to natural fluctuations related to climate, or due to human activities such as discharges, withdrawals, or diversions. Accordingly, climate and hydrologic data are collected to:

- facilitate the interpretation of data collected by the other monitoring components by placing them in the context of current hydrologic conditions relative to historical mean and extreme conditions;
- document stream-specific *baseline* hydrologic conditions and regional climate to characterize natural variability and to allow detection of regional trends; and
- quantify and assess the transport and loadings of oil sands contaminants that enter waterbodies.

The Climate and Hydrology component focuses on key elements of the hydrologic cycle, including rainfall, snowfall, streamflow, and lake water levels. Climate, streamflow, and lake levels are monitored to develop an understanding of the hydrologic system, including natural variability, short and long-term trends, and potential changes related to development.

Watercourses in the same region may have different hydrologic characteristics related to differences in topography, vegetation, surficial geology, lake storage, groundwater-surface water interaction, and geographic influences on precipitation. Accordingly, the scope of the Climate and Hydrology component has gradually expanded geographically to include watersheds affected, or expected to be affected, by oil sands development in the area around Fort McMurray. Some watersheds that do not contain any oil sands development are also monitored to provide *baseline* data. The monitoring program includes the Athabasca River, numerous smaller rivers and streams, and some mine water releases. Data from long-term Environment Canada (i.e., the Water Survey of Canada) and AESRD climatic and hydrologic monitoring stations in the Athabasca oil sands region are also integrated into the analyses to provide greater spatial and temporal context.

Some streams are monitored year-round, while others, particularly smaller streams that tend to freeze completely in winter, are monitored only during the open-water season.

1.3.4.2 Water Quality

Monitoring of water quality is conducted in order to identify anthropogenic and natural factors affecting the quality of streams and lakes in the Athabasca oil sands region. Monitoring the chemical signatures of water provides point-in-time measurements; these data help to identify potential chemical exposure pathways between the physical environment and biotic communities in the aquatic environment.

The objectives of the Water Quality component are to:

- quantify and assess the sources, transport, loadings, fate, and types of oil sands contaminants that enter waterbodies;
- monitor potential changes in water quality that may identify chemical inputs from point and non-point sources;
- assess the suitability of waterbodies to support aquatic life; and
- provide supporting data to facilitate the interpretation of biological surveys.

In order to determine if and how a development may be affecting water quality, *test* stations downstream of development are compared to upstream *baseline* stations (where possible), located beyond the influence of developments, and against an appropriate range of regional *baseline* variability. Water quality is monitored over time to characterize natural temporal variability in *baseline* conditions and to identify potential trends in water quality related to development.

A range of characteristics are measured in the Water Quality component, including: conventional variables, major ions, nutrients, biological oxygen demand, polycyclic aromatic hydrocarbons (PAHs), other organics, and total and dissolved metals.

Water quality stations are located throughout the study area, from the upper Christina River to the Athabasca River downstream of development. Water quality is monitored annually each fall when water flows are generally low and the resulting assimilative capacity of a receiving waterbody is limited. New water quality stations are sampled seasonally (i.e., in winter, spring, summer, and fall) for three years to determine seasonal variation in water quality. Three years of seasonal *baseline* data are collected at stations established in new waterbodies and watercourses. In addition, as of 2013, a subset of water quality stations on key tributaries are monitored on a monthly basis to determine variability within a year.

1.3.4.3 Benthic Invertebrate Communities and Sediment Quality

Benthic invertebrate communities are a commonly-used indicator of aquatic environmental conditions and are included as a monitoring component because:

- they integrate biologically relevant variations in water, sediment, and habitat quality;
- they are limited in their mobility and reflect local conditions, they can thus be used to identify point sources of inputs or disturbance;
- the short life span of benthic invertebrates (typically about one year) allows them to integrate the physical and chemical aspects of water quality and sediment quality over annual time periods and provide early warning of possible changes to fish communities (e.g., Kilgour and Barton 1999); and
- based on known tolerances of benthic taxa, it is possible to re-create the environmental conditions by determining which animals are present (Rooke and Mackie 1982).

The objectives of the Benthic Invertebrate Communities component are to:

- establish the current status of benthic invertebrate communities and function in the region;
- collect scientifically defensible *baseline* and historical data to characterize variability in benthic invertebrate communities in the Athabasca oil sands region; and
- monitor aquatic environments in the Athabasca oil sands region to detect and assess cumulative effects and regional trends.

The focus of characterizing benthic invertebrate communities is on the basis of total abundance, taxonomic richness, and equitability in areas downstream of oil sands developments relative to benthic invertebrate communities upstream of oil sands developments.

This Program's Benthic Invertebrate Communities component of the JOSMP focuses on tributaries of the Athabasca River and regional wetlands (shallow lakes). Environment Canada conducted benthic sampling on the mainstem Athabasca River.

With increasing oil sands development, the component has expanded to include new Athabasca River tributaries and additional stations on previously-monitored Athabasca River tributaries near active development sites. A reach consists of relatively homogeneous stretches of river ranging from 2 to 5 km in length, depending on habitat availability. Within reaches, samples are collected from either erosional or depositional habitats depending on which one is the dominant habitat type within a tributary. Within lakes, sampling effort is distributed over the entire open-water area, but restricted to a narrow range in water depth to minimize natural variations in communities.

Benthic sampling is conducted in the fall of each year to limit potential seasonal variability in the composition of benthic communities. Where available, historical data collected in previous years of the Program are used to place current results in the context of historical trends in benthic invertebrate communities that may be occurring.

Until 2006, sediment quality was a separate monitoring component under the RAMP. Beginning in 2006, sediment quality sampling was integrated into the Benthic Invertebrate Communities component to provide a better link of physical and chemical habitat conditions to a specific biological endpoint. Beginning in 2006, sediment quality was assessed only in depositional benthic invertebrate community sampling locations. Despite the change in focus of sediment quality sampling, sediment quality monitoring objectives remain to:

- monitor potential changes in sediment quality that may identify chemical inputs from point and non-point sources;
- assess the suitability of waterbodies to support aquatic life; and
- provide supporting data to facilitate the interpretation of biological surveys.

Taken together, sediment quality and water quality data help identify potential chemical exposure pathways between the physical environment and biological communities in the aquatic environment.

A range of compounds are measured to characterize sediment quality, including particle size, carbon content, target and alkylated PAHs, total hydrocarbons, and metals. Sublethal bioassay tests also are conducted to assess potential toxicity related to chronic exposure of different aquatic organisms to sediments from selected stations.

1.3.4.4 Fish Populations

The goal of the Program's Fish Populations component is to monitor the health status of fish populations within the Athabasca oil sands region. Monitoring activities focus on the Athabasca River and its main tributaries potentially influenced by oil sands development. Fish populations are monitored because they are key components of the aquatic ecosystem and important ecological indicators that integrate natural and anthropogenic influences. Fish are also an important subsistence and recreational resource. In this regard, there are expectations from regulators, Aboriginal peoples, and the general public with respect to comprehensive monitoring of fish populations in the Athabasca oil sands region.

The specific objectives of the Fish Populations component are to:

- establish the current status of fish population health and function in the region;
- collect fish population data to characterize natural or *baseline* variability;
- monitor fish populations for changes that may be due to stressors or impact pathways (chemical, physical, biological) resulting from development by assessing attributes such as growth, reproduction, and survival;

- assess whether the incidence of fish abnormalities is elevated or changing; and
- assess the suitability of fisheries resources in high-use areas of the Athabasca oil sands region for human consumption.

To meet the specific component objectives, there is a range of core monitoring activities that are intended to assess and document ecological characteristics of fish populations, chemical burdens, and habitat use in the Athabasca oil sands region. The core elements of the Fish Populations component are:

- fish inventories on the larger rivers (i.e., Athabasca and Clearwater rivers) – monitor and assess temporal and spatial changes in species presence, relative abundance and population variables in the spring, summer, and fall. In addition to their scientific value, the fish inventories provide useful information to local stakeholders on species diversity, the relative strength of age classes, and the incidence of fish abnormalities;
- fish tissue sampling for organic and inorganic chemicals – quantify and monitor chemical levels in relation to the suitability of the fish resource for human consumption and to identify potential risk related to fish health. Muscle tissues are collected from lake whitefish and walleye from the Athabasca River and northern pike from the Clearwater River. Tissues are analyzed for metals, including mercury, and specific organic compounds known to cause tainting of fish flesh. Fish tissue analyses (mercury only) also are conducted in conjunction with sampling programs conducted by the AESRD on selected lakes in the region;
- sentinel fish species monitoring in the Athabasca River and select tributaries – monitoring potential effects of stressors on populations of fish species that have limited movement relative to the location of the potential stressors. The underlying premise of the approach is that the health of the selected sentinel species reflects the overall condition of the aquatic environment in which the fish population of that species resides. The approach has also been included as part of the federal government's EEM programs under the pulp and paper (Environment Canada 2010) and metal mining (Environment Canada 2012) effluent regulations;
- fish assemblage monitoring and fish habitat assessments in tributaries – focuses on characterizing the fish assemblage on the basis of total abundance, taxonomic richness, diversity, and an assemblage tolerance index, in areas downstream of development relative to fish assemblages upstream of development. Also assesses habitat conditions and any potential change(s) over time that would influence the fish assemblage in a river; and
- monitoring of spring spawning use of tributary habitat – historically, fish fence monitoring has been conducted on the Muskeg River and used to obtain information on the biology and use of habitat by spawning populations of large-bodied fish species that use the Muskeg River and its tributaries.

Specific key indicator fish species (or key indicator resources, KIRs) have been identified for the Athabasca River and selected tributaries. These species were selected through consultation with Aboriginal peoples, government and industry representatives, and include goldeye, lake whitefish, longnose sucker, white sucker, northern pike, trout-perch, and walleye (CEMA 2001; RAMP 2009b). Although the Fish Populations component evaluates the integrity of the total fish community, particular emphasis is placed on the selected key fish species based on their ecological importance and value to local communities.

1.3.4.5 Acid-Sensitive Lakes

The Regional Sustainable Development Strategy (RSDS) identified the importance of protecting the quality of water, air, and land within the Athabasca oil sands region (AENV 1999). Acid deposition was identified in the RSDS as a regional issue. Actions taken to address this issue were designed to support the goal of conserving acid-sensitive soils, rivers, lakes, wetlands and associated vegetation complexes as a result of the deposition of acidifying materials. The RSDS called for the collection of information on this issue through long-term monitoring of regional receptors of acidifying emissions under TEEM for terrestrial receptors and the Program for aquatic receptors.

The Acid-Sensitive Lakes (ASL) component was initiated in 1999 under the RAMP to conduct annual monitoring of water chemistry in regional lakes to determine long-term changes in these lakes in response to acid deposition on these lakes and their catchment basins. The objectives of the ASL component are to:

- establish a database of water quality to detect and assess cumulative effects and regional trends that would provide specific measurement endpoints capable of detecting incipient lake acidification;
- collect scientifically defensible *baseline* and historical data (both chemical and biological) to characterize the natural variability of these measurement endpoints in the regional lakes;
- collect data on the regional lakes against which predictions contained in environmental impact assessments (EIAs) could be verified; and
- quantify and document individual lake sensitivity to acidification.

Lakes are monitored for various chemical and biological variables that are capable of indicating long-term trends in acidification, including: pH; total and Gran alkalinity (acid-neutralizing capacity); base cations; sulphate; chloride; nitrates; dissolved organic carbon; dissolved inorganic carbon; and chlorophyll *a*.

The ASL component contains the following features:

1. The locations of the lakes are selected to represent a gradient in acid deposition from both current and anticipated developments in the region.
2. For scientific validity, the lake selection includes lakes in the Canadian Shield that are distant from the sources of acidifying emissions.
3. Certain regional lakes, which have been the subject of long-term monitoring by AESRD, are included to maintain the continuity of their data and to provide additional information on potential trends.
4. The lakes selected for monitoring exhibit moderate to high sensitivity to acidification as defined by a total alkalinity less than 400 µeq/L.
5. Sampling occurs in the late summer or early fall season. While fall sampling captures a picture of lake water chemistry after conditions have stabilized following high spring flows, it does not necessarily capture any acidification at other times of the year such as spring pulses of acidity during snowmelt.

6. In recent surveys, small waterbodies (ponds) have been included in the ASL component because of their proximity to oil sands projects and the possibility that they might be low in alkalinity and; therefore, more sensitive to acid deposition.

1.3.5 Overall Analytical Approach for 2014

The overall analytical approach for the 2014 Program report is a weight-of-evidence approach that builds on analytical approaches used in previous years by the RAMP and described in the RAMP Technical Design and Rationale (RAMP 2009b) (Figure 1.3-1). Key features of the overall analytical approach are as follows.

First, the analysis for each monitoring component uses a set of measurement endpoints (Table 1.3-1) representing the health and integrity of valued environmental resources within the component. These are the same measurement endpoints that were used in the historical RAMP 2004 to 2013 Technical Reports (RAMP 2005; RAMP 2006; RAMP 2007; RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012; RAMP 2013; and RAMP 2014).

Second, the analysis of results for 2014 compared to previous monitoring years is conducted for the Athabasca River and ARD, as well as at the watershed/river basin level to assess temporal trends.

Third, a set of criteria are used for determining whether or not there has been a change in the values of the measurement endpoints: (i) at *test* stations; and (ii) compared to *baseline* range of natural variability (Table 1.3-1).

Fourth, the magnitude of these changes in the values of the measurement endpoints is summarized and locations or watersheds with moderate or high levels of change become candidate sites for additional studies to identify the causes of the changes being measured.

Figure 1.3-1 Overall analytical approach for 2014.

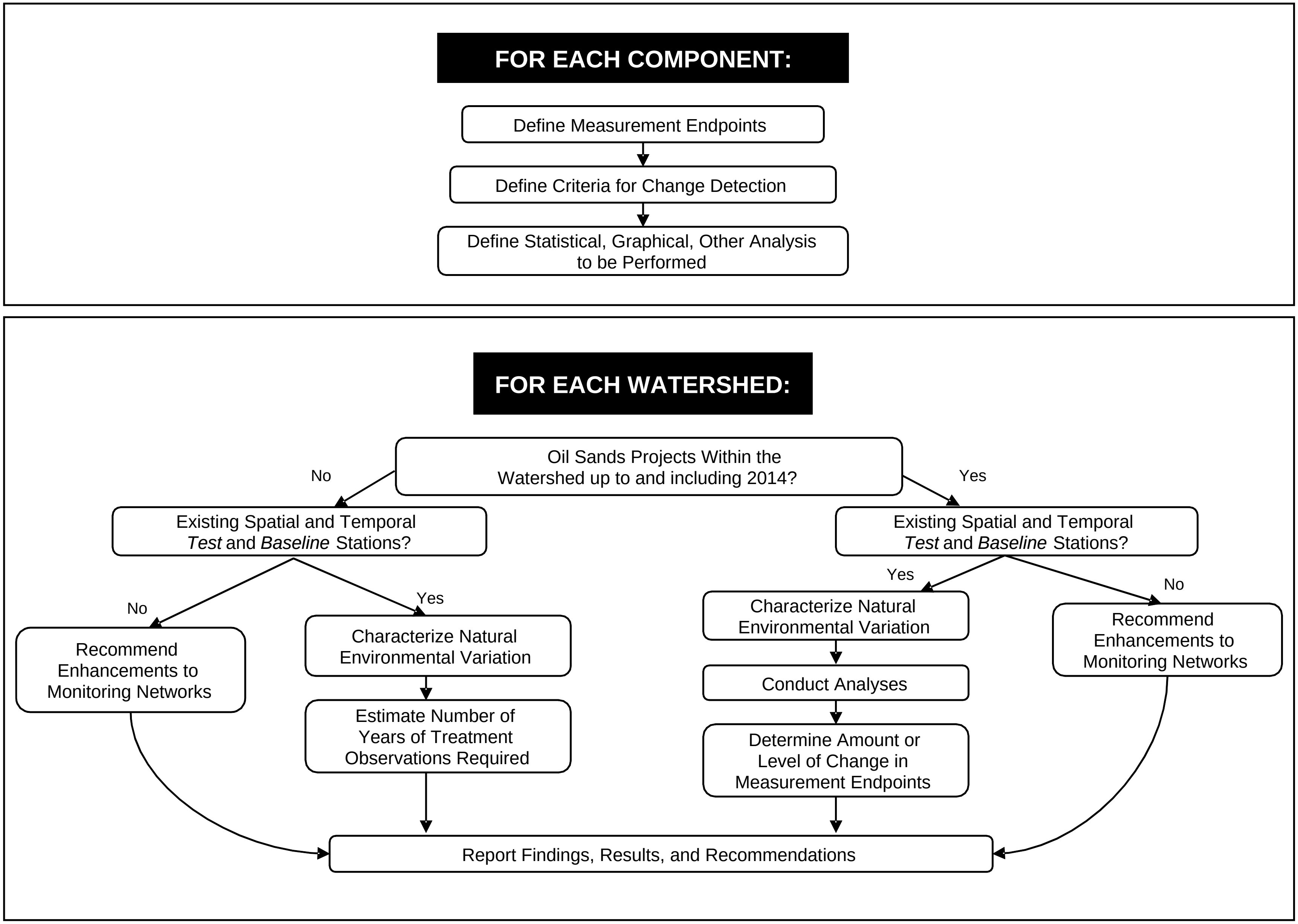


Table 1.3-1 Measurement endpoints and criteria for determination of change used in the 2014 analysis.

Component	Measurement Endpoints Used in 2014 Program Report[1]	Criteria for Determining Change Used in 2014 Program Report
Climate and Hydrology	Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Open-water season minimum daily discharge	Differences between observed *test* and estimated *baseline* hydrographs (i.e., the hydrograph that would have been observed had oil sands developments not occurred in the drainage, so that changes in water withdrawals, discharges, and diversions are accounted for) as follows: Negligible-Low: ± 5% ; Moderate: ± 15%;High: > 15%.
Water Quality	pH Total suspended solids Dissolved phosphorus Total nitrogen and nitrate-nitrite Various ions (sodium, chloride, sulphate) Total alkalinity, Total dissolved solids Dissolved organic carbon Total and dissolved aluminum Total arsenic, Total boron Total molybdenum, Total strontium Ultra-trace mercury, Naphthenic acids Various PAH end-points, including: Total PAHs Total Low-Molecular Weight PAHs Total High-Molecular Weight PAHs Naphthelene, Retene Total dibenzothiophenes Overall ionic composition	Comparison to range of regional *baseline* conditions. Comparison to CCME and other water quality guidelines. Calculation of water quality index based on CCME water quality index found at http://www.ccme.ca/ourwork/water.html?category_id=102 , with water quality index scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions 60 to 80: Moderate difference from regional *baseline* conditions Less than 60: High difference from regional *baseline* conditions
Benthic Invertebrate Communities	Abundance Richness (number of taxa) Equitability (measure of diversity) Abundance of EPT (mayflies, stoneflies, caddisflies) Axes of Correspondence Analysis ordination	Exceedance of regional range of *baseline* variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* reaches/lakes as compared to *baseline* reaches/lakes or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches/lakes, with low “noise” in the statistical test. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-4 and Table 3.1-9.
CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

Table 1.3-1 (Cont'd.)

Component	Measurement Endpoints Used in 2014 Program Report[1]	Criteria for Determining Change Used in 2014 Program Report
Sediment Quality	Particle size distribution (clay, silt, and sand) Total organic carbon Total hydrocarbons (CCME and Alberta Tier 1) Various PAH end-points, including: Total PAHs Total Low-Molecular Weight PAHs Total High-Molecular Weight PAHs Naphthelene, Retene Total dibenzothiophenes Predicted PAH toxicity Metals, Chronic toxicity	Comparison to CCME Interim Sediment Quality Guidelines (ISQG) and other guidelines. Calculation of sediment quality index based on CCME water quality index found at http://www.ccme.ca/ourwork/water.html?category_id=103, with sediment quality index scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions 60 to 80: Moderate difference from regional *baseline* conditions Less than 60: High difference from regional *baseline* conditions
Fish Populations: Fish Inventory	Relative abundance (catch per unit effort) Age-frequency/Size-at-Age Percent composition Condition factor	The fish inventory activity is generally considered to be a stakeholder-driven activity that is best suited for assessing general trends in abundance and population parameters for large-bodied species. It is not specifically designed for assessing environmental effects of oil sands development.
Fish Populations: Fish Assemblage Monitoring	Abundance Richness (number of taxa) Simpson's Diversity Assemblage Tolerance Index	Exceedance of regional range of *baseline* variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* reaches/lakes as compared to *baseline* reaches or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches, , with low "noise" in the statistical test. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years. Statistical comparisons were only completed for reaches with three or more years of data. For all other reaches, assessments were conducted solely based on comparisons to the *baseline* range of variability.
Fish Populations: Fish Tissue	Mercury concentration in fish muscle tissue	Risk to Human Health 1. Negligible-Low: Fish tissue concentrations for mercury below Health Canada criteria for recreational and subsistence fishers and the general consumer. 2. High (subsistence): Fish tissue concentrations for mercury above Health Canada criteria for subsistence fishers, but below criteria for recreational fishers and general consumers. 3. High (general consumer): Fish tissue concentrations for mercury above Health Canada criteria for general consumers, and recreational and subsistence fishers.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-4 and Table 3.1-9. CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

Table 1.3-1 (Cont'd.)

Component	Measurement Endpoints Used in 2014 Program Report[1]	Criteria for Determining Change Used in 2014 Program Report
Fish Populations: Sentinel Species Monitoring	Age Growth Relative Gonad Weight Condition Factor Relative Liver Weight	Comparison to Environment Canada's Environmental Effects Monitoring (EEM) criteria (Environment Canada 2010) where an effect is determined by a difference of ± 10% in condition, ± 25% in age, growth, relative gonad weight, and relative liver weight of fish at the *test* site relative to fish condition at the *baseline* site. 1. Negligible-Low: no exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site. 2. Moderate: exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, but not in two consecutive years of sampling including the current year. 3. High: exceedance greater than ± 10% in condition ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, and exceedance observed in two consecutive years of sampling including the current year.
Acid-Sensitive Lakes	Critical Load of acidity pH Gran alkalinity Base cation concentrations Nitrate plus nitrite concentrations Dissolved Organic Carbon Aluminum	Exceedance of Critical Load of acidity of a particular lake by the measured or modeled value of the Potential Acid Input (PAI) to that lake. A statistically significant change in any of the measurement endpoints beyond natural variability, resulting in a reduction of lake pH, Gran alkalinity, Critical Load or base cation concentrations, or an increase in nitrates or aluminum concentrations. For each lake, mean and standard deviation calculated for each of seven measurement endpoints over all the monitoring years. The number of lakes in 2014 within each subregion with endpoint values greater than two standard deviations from the mean is calculated. 1. Negligible-Low: subregion has <2% of endpoint-lake combinations exceeding ± 2SD criterion. 2. Moderate: subregion has 2% to 10 % of endpoint-lake combinations exceeding ± 2SD criterion. 3. High: subregion has > 10% of endpoint-lake combinations exceeding ± 2SD criterion.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-4 and Table 3.1-9.
CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

1.4 ORGANIZATION OF THIS REPORT

Together with this Introduction, the 2014 Program Report contains nine sections within which the results of the 2014 monitoring program developed by the JOSMP Water Component Advisory Committee and implemented by the Hatfield Team are presented.

Section 2: Activities in the Study Area in 2014 – This section contains:

- a list of oil sands projects that were either active (operating or under construction), had received approval, or were in the application stage as of 2014;
- a list of oil sands project water withdrawal and discharge locations; and
- a summary of land change occurring up to 2014 as a result of oil sands development.

This provides a synthesis of information related to development activities that may be influencing aquatic environmental resources within the Athabasca oil sands region.

Section 3: 2014 Monitoring Activities – This section of the report contains concise descriptions of the monitoring program that was conducted in 2014 for each component, and includes:

- an overview of the 2014 Program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, stakeholders, and oil sands operators, knowledge obtained from local communities, and other sources);
- an overview of field methods;
- a description of changes in monitoring network from the 2013 field program;
- a description of the challenges and issues encountered during 2014 and the means by which these challenges and issues were addressed; and
- a summary of the component data that are now available.

Each component section of Section 3 then presents a description of the detailed approach used for analyzing the data, including:

- a description and explanation of the measurement endpoints that were selected;
- a description of the statistical, graphical, or other analyses that were performed on the monitoring data to assess whether or not changes in the selected measurements endpoints have occurred over time and space; and
- a description and explanation of the criteria that were used in assessing whether or not changes in the selected measurement endpoints have occurred.

Section 4: Climatic and Hydrologic Characterization of the Athabasca oil sands region in 2014 – This section of the report describes the 2014 water year (WY) (November 1, 2013 to October 31, 2014) and how the 2014 WY compares with previous years with respect to climatic and hydrologic conditions. This information helps set the context for the results, analyses, and assessments presented in Section 5.

Section 5: Assessment of 2014 Results – This is the main results section of the report consisting of three major parts:

- Section 5.1 is the report of 2014 findings for the mainstem Athabasca River and the Athabasca River Delta;
- Sections 5.2 to 5.13 are watershed-level reports of the 2014 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations; and
- Section 5.14 is the report of 2014 findings for the Acid-Sensitive lakes component.

Each of these sections presents the results following the analytical approaches contained in each of the component sections of Section 3, as described above. Each section begins with a summary assessment of the overall status of aquatic environmental resources and possible relation to oil sands projects.

Section 6: Synthesis of 2014 Results – This section of the report contains a summary of the findings, conclusions, and recommendations from 2014. The recommendations include proposed changes to the monitoring network for consideration in future years based on the results from the 2014 Program.

The main report concludes with **Section 7: References** and **Section 8: Glossary and List of Acronyms**. In addition, the report is supported by a series of technical appendices that present the detailed analytical results and supporting material for each component.

All data are publicly available on the historical RAMP website (www.ramp-alberta.org) and can be accessed directly or through the AEMERA website (www.aemera.org). The database was updated on a quarterly basis with 2014 provisional data, with finalized data posted following the release of this report in spring 2015.

2.0 SUMMARY OF OIL SANDS PROJECT ACTIVITIES IN 2014

This section provides information on oil sands developments in watersheds of the Athabasca oil sands region that was needed to support the assessment of the 2014 monitoring results. In particular, this information is important for confirming the classification of sampling stations as *baseline* or *test* as development continues to expand over time resulting in changes to these classifications. Three sets of information are considered: development status of oil sands projects (mining and in situ); summary of water withdrawals and discharges from surface water sources; and land change analysis for 2014.

2.1 DEVELOPMENT STATUS OF OIL SANDS PROJECTS

The development status of all oil sands projects in the Athabasca oil sands region, as of the end of 2014, is presented in Table 2.2-1. Areas downstream of oil sands developments that have started land disturbance activities are designated as *test*. Data obtained from sampling stations in these *test* areas are also designated as *test* for the purposes of analysis, assessment, and reporting (Section 1.4.4). Conversely, areas upstream of oil sands developments or downstream of oil sands developments that have no specified year of first disturbance are designated as *baseline*. Data obtained from sampling stations in these *baseline* areas are also designated as *baseline* for the purposes of analysis, assessment, and reporting. Additional information provided in Table 2.2-1 is used to interpret the 2014 monitoring results for all monitoring components.

2.2 WATER USE RELATED TO OIL SANDS PROJECTS IN 2014

Oil sands developments obtain water for their operations largely from nearby surface water or groundwater sources. To accurately assess the hydrologic conditions of each watershed for the Climate and Hydrology component, water withdrawal and discharge data were collected from oil sands projects that were active (i.e., operational or under construction) and incorporated into the hydrologic water balance model outlined in Section 3.2.1.4. The hydrologic water balance model incorporates only water that was withdrawn from one surface waterbody and discharged directly to another surface waterbody. Further information was received from industry but not included in the water balance calculations, including: (i) data classified as muskeg dewatering, groundwater extraction, or other processes not affecting natural surface watercourses and waterbodies; (ii) operator withdrawal and discharge data located downstream of the corresponding observed *test* monitoring station; and (iii) withdrawal and discharges occurring on days when observed *test* monitoring did not occur (e.g., during winter months for open-water monitoring stations, or when data collection was prevented due to unforeseen circumstances. Table 2.2-2 provides a summary of water use for each active oil sands project within the 2014 Water Year (i.e., November 1, 2013 to October 31, 2014) for consistency with analyses conducted for the Climate and Hydrology Component. The source of water withdrawals and location of discharge points for each active mining or in situ project are provided in Figure 2.2-1.

Table 2.2-1 Status and activities of mining and in situ developments in the Athabasca oil sands region, as of 2014.

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Athabasca Oil Corp.	Birch Phase 1	100-15-W4M	in situ	12,000	–	–	Announced
	Dover West Carbonates Phase 1 Demonstration	95-18-W4M	in situ	6,000	–	2016	Approved
	Dover West Carbonates Phase 2 Demonstration		in situ	6,000	–	–	Application
	Dover West Sands & Clastics Phase 1	92-18-W4M	in situ	12,000	–	2016	Application
	Dover West Sands & Clastics Phase 2		in situ	35,000	–	2019	Announced
	Dover West Sands & Clastics Phase 3		in situ	35,000	–	2020	Announced
	Dover West Sands & Clastics Phase 4		in situ	35,000	–	2022	Announced
	Dover West Sands & Clastics Phase 5		in situ	35,000	–	2024	Announced
	Hangingstone HS-1	86,87,88-10,11,12,13-W4M	in situ	12,000	–	2015	Construction
	Hangingstone HS-2A Debottleneck (1 and 2)		in situ	8,000	–	2017	Application
	Hangingstone HS-2B Expansion		in situ	32,000	–	2019	Application
	Hangingstone HS-3		in situ	30,000	–	2021	Application
BlackPearl Resources Inc.	Blackrod Pilot	02-36-076-18-W4M	in situ	800	–	2011	Operational
	Blackrod Phase 1		in situ	20,000	–	2015	Application
	Blackrod Phase 2		in situ	30,000	–	2018	Application
	Blackrod Phase 3		in situ	30,000	–	2021	Application
BP p.l.c	Terre de Grace Pilot	95,96,97-13,14-W4M	in situ	10,000	–	–	Approved
Brion Energy Corp.	MacKay River Phase 1	92, 93-12-W4M	in situ	35,000	2010	2015	Construction
	MacKay River Phase 2		in situ	40,000	2010	2018	Approved
	MacKay River Phase 3		in situ	40,000	2010	2020	Approved
	MacKay River Phase 4		in situ	35,000	2010	2022	Approved
	Dover Experimental Pilot	87,88,89,90,91-12-W4M	in situ	2,000	–	2017	Approved
	Dover North Phase 1		in situ	50,000	2010	2016	Approved
	Dover North Phase 2		in situ	50,000	2010	2018	Approved
	Dover North Phase 3		in situ	50,000	2010	2021	Approved
	Dover North Phase 4		in situ	50,000	2010	2023	Approved
	Dover South Phase 5		in situ	50,000	2010	2025	Approved
Canadian Natural Resources Ltd.	Horizon Phase 1	96-11/12-W4M, 96-13-W4M, 97-11-W4M, 97-12-W4M, 97-13-W4M	mine	135,000	2002	2008	Operational
	Horizon Phase 2A		mine	12,000	–	2014	Operational
	Horizon Phase 2B		mine	45,000	–	2016	Construction
	Horizon Phase 3		mine	80,000	–	2017	Construction
	Horizon Tranche 2		mine	5,000	–	2014	Operational
	Birch Mountain Phase 1	97-19-W4M	in situ	60,000	–	2019	Announced
	Birch Mountain Phase 2		in situ	60,000	–	2023	Announced
	Gregoire Lake Phase 1	86-8-W4M	in situ	60,000	–	–	Announced
	Gregoire Lake Phase 2		in situ	60,000	–	–	Announced
	Grouse Commercial	74-12-W4M	in situ	40,000	–	2020	Application
	Kirby North Phase 1	73,74,75-7,8,9-W4M	in situ	40,000	–	2017	Approved
	Kirby North Phase 2		in situ	60,000	–	2022	Approved
	Kirby South Phase 1		in situ	40,000	–	2013	Operational

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Cavalier Energy Inc	Hoole Phase 1	12-81-24-W4M	in situ	10,000	–	2017	Approved
	Hoole Phase 2		in situ	35,000	–	–	Announced
	Hoole Phase 3		in situ	35,000	–	–	Announced
Cenovus Energy	East McMurray Phase 1	89-8-W4M	in situ	30,000	–	–	Announced
	Steepbank Phase 1	92-5-W4M	in situ	30,000	–	–	Announced
	Telephone Lake Borealis Phase A	94,95-3-W4M	in situ	45,000	–	–	Application
	Telephone Lake Borealis Phase B		in situ	45,000	–	–	Application
	Christina Lake Phase 1A	75,76-5,6-W4M	in situ	10,000	–	2002	Operational
	Christina Lake Phase 1B		in situ	8,800	–	2008	Operational
	Christina Lake Phase C		in situ	40,000	–	2011	Operational
	Christina Lake Phase D		in situ	40,000	–	2012	Operational
	Christina Lake Phase E		in situ	40,000	2009	2013	Operational
	Christina Lake Optimization (phases C,D,E)		in situ	22,000	–	2015	Approved
	Christina Lake Phase F		in situ	50,000	–	2016	Construction
	Christina Lake Phase G		in situ	50,000	2009	2017	Approved
	Christina Lake Phase H		in situ	50,000	–	2019	Application
	Foster Creek Phase A	70-4-W4M	in situ	24,000	–	2001	Operational
	Foster Creek Phase B Debottleneck		in situ	6,000	–	2003	Operational
	Foster Creek Phase C Stage 1		in situ	10,000	–	2005	Operational
	Foster Creek Phase C Stage 2		in situ	20,000	–	2007	Operational
	Foster Creek Phase D		in situ	30,000	–	2009	Operational
	Foster Creek Phase E		in situ	30,000	–	2009	Operational
	Foster Creek Phase F		in situ	45,000	–	2014	Operational
	Foster Creek Phase G		in situ	40,000	–	2015	Construction
	Foster Creek Phase H		in situ	40,000	–	2016	Construction
	Foster Creek Phase J		in situ	50,000	–	2019	Application
	Foster Creek Future Optimization		in situ	15,000	–	–	Announced
	Narrows Lake Phase A	76,77-6,7-W4M	in situ	45,000	2010	2017	Construction
	Narrows Lake Phase B and C		in situ	85,000	2010	–	Approved
	Pelican Lake Pilot	83-21-W4M	in situ	600	–	2011	Operational
	Pelican Upper Grand Rapids Phase A		in situ	10,000	–	2017	Approved
	Pelican Upper Grand Rapids Phase B		in situ	32,000	–	–	Approved
	Pelican Upper Grand Rapids Phase C		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase D		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase E		in situ	32,000	–	–	Approved
	Pelican Upper Grand Rapids Phase F		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase E		in situ	19,000	–	–	Approved
	West Kirby Phase 1	75-8-W4M	in situ	30,000	–	–	Announced
	Winefred Lake Phase 1	76-4-W4M	in situ	30,000	–	–	Announced

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Connacher Oil and Gas	Great Divide Pod One	82,83-11,12-W4M	in situ	10,000	–	2007	Operational
	Great Divide Algar		in situ	10,000	–	2010	Operational
	Great Divide Expansion 1A		in situ	12,000	–	–	Approved
	Great Divide Expansion 1B		in situ	12,000	–	–	Approved
ConocoPhillips	Surmont Phase 1	81,82,83-5,6,7-W4M	in situ	30,000	2001	2007	Operational
	Surmont Phase 2		in situ	118,000	–	2015	Construction
	Surmont Phase 3 – Tranche 1		in situ	45,000	–	2020	Application
	Surmont Phase 3 – Tranche 2		in situ	45,000	–	2021	Application
	Surmont Phase 3 – Trance 3		in situ	45,000	–	2023	Application
	Pilot		in situ	1,200	–	1997	Operational
Devon Energy	Jackfish Phase 1	75,76-6,7-W4M	in situ	35,000	2003	2007	Operational
	Jackfish Phase 2		in situ	35,000	2006	2011	Operational
	Jackfish Phase 3		in situ	35,000	2010	2014	Operational
	Jackfish East Expansion	76-5-W4M	in situ	20,000	–	2018	Announced
	Pike 1A	73,74,75-4,5,6,7,8-W4M	in situ	35,000	–	2016	Application
	Pike 1B		in situ	35,000	–	2017	Application
	Pike 1C		in situ	35,000	–	2018	Application
E-T Energy Ltd.	Poplar Creek Experimental Pilot	90-9-W4M	in situ	1,000	–	2012	Suspended
	Poplar Creek Phase 1		in situ	10,000	–	–	On Hold
	Poplar Creek Phase 2		in situ	40,000	–	–	On Hold
Grizzly Oil Sands ULC	Algar Lake Phase 1	85-12-W4M	in situ	6,000	–	2014	Operational
	Algar Lake Phase 2		in situ	6,000	–	–	Approved
	May River Phase 1	12-77-9-W4M	in situ	6,000	–	2016	Application
	May River Phase 2		in situ	6,000	–	–	Application
	Thickwood Phase 1	90-15-W4M	in situ	6,000	–	2017	Application
	Thickwoood Phase 2		in situ	6,000	–	–	Application
Harvest Operations Corp.	BlackGold Phase 1	76-7-W4M	in situ	10,000	–	2015	Operational
	BlackGold Phase 2		in situ	20,000	–	–	Approved
Husky Energy	Saleski Carbonate Pilot	16-31-87-19-W4	in situ	3,000	–	2017	Application
	Sunrise Phase 1	94-97-6,7-W4M	in situ	60,000	–	2014	Construction
	Sunrise Phase 2A		in situ	70,000	–	2018	Approved
	Sunrise Phase 2B		in situ	70,000	–	2020	Approved
Imperial Oil Resources	Kearl Lake Phase 1	95,96,97-6,7,8-W4M	mine	110,000	2005	2013	Operational
	Kearl Lake Phase 2		mine	110,000	–	2015	Construction
	Kearl Lake Phase 3		mine	80,000	–	2020	Approved
	Kearl Lake Phase 4 Debottleneck		mine	45,000	–	–	Approved
	Aspen Phase 1	93-7-W4M	in situ	45,000	–	2020	Application
	Aspen Phase 2		in situ	45,000	–	–	Application
	Aspen Phase 3		in situ	45,000	–	–	Application

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Ivanhoe Energy Inc	Tamarack Phase 1	22-90-9-W4M	in situ	20,000	–	–	Application
	Tamarack Phase 2		in situ	20,000	–	–	Application
JACOS	Hangingstone Pilot	84-10,11,12-W4M	in situ	11,000	–	1999	Operational
	Hangingstone Expansion		in situ	20,000	–	2016	Construction
Koch Exploration Canada Corp.	Dunkirk Phase 1	10-91-18-W4M	in situ	30,000	–	2018	Announced
	Dunkirk Phase 2		in situ	30,000	–	–	Announced
	Muskwa Pilot	14-84-23-W4M	in situ	10,000	–	2015	Approved
Laricina Energy Ltd.	Germain Phase 1 CDP	30-85-22-W4M	in situ	5,000	–	2013	Operational
	Germain Phase 2		in situ	30,000	–	2018	Application
	Germain Phase 3		in situ	60,000	–	–	Application
	Germain Phase 4		in situ	60,000	–	–	Application
	Saleski Experimental Pilot	84-19-W4M	in situ	1,800	–	2011	Operational
	Saleski Phase 1		in situ	10,700	–	2017	Approved
	Saleski Phase 2		in situ	30,000	–	–	Announced
	Saleski Phase 3		in situ	60,000	–	–	Announced
	Saleski Phase 4		in situ	60,000	–	–	Announced
	Saleski Phase 5		in situ	60,000	–	–	Announced
	Saleski Phase 6		in situ	60,000	–	–	Announced
Marathon Oil Corp.	Birchwood Demonstration	20-91-15-W4M	in situ	12,000	–	2017	Application
MEG Energy	Christina Lake Phase 1 Pilot	76,78-4,6-W4M	in situ	3,000	2004	2008	Operational
	Christina Lake Phase 2A		in situ	22,000	2005	2009	Operational
	Christina Lake Phase 2B		in situ	35,000	2007	2013	Operational
	Christina Lake Phase 3A		in situ	50,000	2008	2016	Approved
	Christina Lake Phase 3B		in situ	50,000	2009	2018	Approved
	Christina Lake Phase 3C		in situ	50,000	2011	2020	Approved
	Surmont Phase 1-3	81,82-5-W4M	in situ	123,000	2012	–	Application
Nexen	Long Lake Phase 1	85-6-W4M	in situ	72,000	2000	2008	Operational
	Long Lake South (Kinosis) Phase 1A	84-7-W4M	in situ	40,000	2006	–	Construction
	Long Lake South (Kinosis) Phase 1B		in situ	40,000	2006	–	Approved
Oak Point Energy Ltd.	Lewis Pilot	93, 94-7-W4M	in situ	1,720	–	–	Approved
Osum Oil Sands Corp.	Sepiko Kesik Phase 1	21-85-18-W4M	in situ	30,000	–	2018	Application
	Sepiko Kesik Phase 2		in situ	30,000	–	2020	Application
Prosper Petroleum Ltd.	Rigel Phase 1	20-96-17-W4M	in situ	10,000	–	2017	Application
PTT Exploration and Production	Mariana – Hangingstone Phase 1	83-10-W4M	in situ	20,000	–	–	Application
	Mariana – South Leismer Phase 1	77-10-W4M	in situ	20,000	–	–	Application
	Mariana – Thornbury Phase 1	80-12-W4M	in situ	40,000	–	–	Application
	Mariana – Thornbury Expansion		in situ	20,000	–	–	Application
Renergy Petroleum (Canada) Co. Ltd.	Muskwa Experimental Pilot	13-4-85-25-W4M	in situ	–	–	2015	Application

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Shell Canada Energy	Muskeg River Mine Commercial	95-10-W4M	mine	155,000	1997	2002	Operational
	Muskeg River Mine Expansion & Debottlenecking	95-8,9-W4M, 94-10-W4M	mine	115,000	2005	–	Approved
	Jackpine Mine Phase 1A	95-8-W4, 95-9-W4	mine	100,000	2002	2010	Operational
	Jackpine Mine Phase 1B	95-8-W4, 95-9-W4	mine	100,000	–	–	Approved
	Jackpine Mine Expansion	96,97-8,9-W4M	mine	100,000	2007	2017	Approved
	Pierre River Mine Phase 1	97,98,99-10,11-W4M	mine	100,000	2007	–	On Hold
	Pierre River Mine Phase 2	97,98,99-10,11-W4M	mine	100,000	–	–	On Hold
SilverWillow Energy Corp.	Audet Pilot	98-3-W4M	in situ	12,000	–	2018	Application
Southern Pacific Resource Corp.	STP-McKay Phase 1	91-14,15-W4M	in situ	12,000	–	2012	Operational
	STP-McKay Phase 1 Expansion	91-14,15-W4M	in situ	6,000	–	2016	Application
	STP-McKay Phase 2A	91-14,15-W4M	in situ	12,000	–	2018	Application
	STP-McKay Phase 2B	91-14,15-W4M	in situ	6,000	–	2018	Application
Statoil Canada Ltd.	Corner Phase 1	80-8-W4M	in situ	40,000	–	–	Approved
	Corner Expansion	80-8-W4M	in situ	40,000	–	–	Application
	Leismer Demonstration	79-10-W4M	in situ	10,000	–	2010	Operational
	Leismer Commercial	79-10-W4M	in situ	10,000	–	–	Approved
	Leismer Expansion	79-10-W4M	in situ	20,000	–	–	Approved
	Leismer Northwest	79-10-W4M	in situ	20,000	–	–	Application
Suncor Energy	Millennium Mine	92,93-9-W4M	mine	294,000	1998	1967	Operational
	Steepbank Debottleneck Phase 3	92,93-9-W4M	mine	4,000	–	2007	Operational
	North Steepbank Mine Extension	92,93-9-W4M	mine	180,000	2006	2012	Operational
	Millennium Debottlenecking	91,92-9-W4M	mine	23,000	–	2008	Operational
	Voyageur South Mine	91,92-10-W4M	mine	250,000	-	2020	Application
	Dover Demonstration Plant	93-12-W4M	in situ	500	–	2013	Construction
	Firebag Stage 1	93,94,95,96-4,5,6,7-W4M	in situ	35,000	2000	2004	Operational
	Firebag Stage 2	93,94,95,96-4,5,6,7-W4M	in situ	35,000	–	2006	Operational
	Firebad Congeneration and Expansion	93,94,95,96-4,5,6,7-W4M	in situ	25,000	–	2007	Operational
	Firebag Stage 3	93,94,95,96-4,5,6,7-W4M	in situ	42,500	–	2011	Operational
	Firebag Stage 4	93,94,95,96-4,5,6,7-W4M	in situ	42,500	–	2012	Operational
	Firebag Stage 5	93,94,95,96-4,5,6,7-W4M	in situ	62,500	–	–	Approved
	Firebag Stage 6	93,94,95,96-4,5,6,7-W4M	in situ	62,500	–	–	Approved
	Firebag Stages 3 to 6 Debottlenecking	93,94,95,96-4,5,6,7-W4M	in situ	23,000	–	–	Application
	Fort Hills Phase 1	96-11-W4M, 97,98-10-W4M	mine	160,000	2001	2017	Construction
	Fort Hills Debottleneck	96-11-W4M, 97,98-10-W4M	mine	20,000	–	–	Approved
	Lewis Phase 1	91-7-W4M	in situ	40,000	–	2026	Announced
	Lewis Phase 2	91-7-W4M	in situ	40,000	–	2026	Announced

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2014 Status
Suncor Energy (Cont'd.)	MacKay River Phase 1	92, 93-12-W4M	in situ	33,000	1998	2002	Operational
	MacKay River Debottleneck		in situ	5,000	–	2014	Operational
	MacKay River Expansion (MR2)		in situ	20,000	2005	2017	Approved
	Meadow Creek Phase 1	84,85-8,9,10-W4M	in situ	20,000	2001	2020	Approved
	Meadow Creek Phase 2		in situ	20,000	–	2022	Approved
	Meadow Creek Phase 3		in situ	30,000	–	–	Approved
Sunshine Oilsands Ltd.	Legend Lake Phase A1	96-18-W4M	in situ	10,000	–	2016	Application
	Legend Lake Phase A2		in situ	30,000	–	–	Announced
	Legend Lake Phase B1		in situ	30,000	–	–	Announced
	Legend Lake Phase B2		in situ	30,000	–	–	Announced
	Thickwood Phase A1	90-18-W4M	in situ	10,000	–	2015	Approved
	Thickwood Phase A2		in situ	30,000	–	2017	Announced
	Thickwood Phase B		in situ	30,000	–	2021	Announced
	West Ells Phase A1	94,95,96-17,18-W4M	in situ	5,000	–	2015	Construction
	West Ells PhaseA2		in situ	5,000	–	–	Approved
	West Ells Phase A3		in situ	30,000	–	–	Announced
	West Ells Phase B		in situ	20,000	–	–	Announced
	West Ells Phase C1		in situ	30,000	–	–	Announced
	West Ells Phase C2		in situ	30,000	–	–	Announced
Surmont Energy Inc.	Wildwood Phase 1	20-82-8-W4M	in situ	12,000	–	2015	Application
Syncrude Canada	Mildred Lake and Aurora North Base Mine Stage 1 and 2 Expansion	6-93-10-W4M; 96-9,10,11-W4M	mine	290,700	1973	1978	Operational
	Mildred Lake and Aurora North Stage 3 Expansion	6-93-10-W4M; 96-9,10,11-W4M	mine	116,300	2001	2006	Operational
	Centrifuge Tailings Management	6-15-93-11-W4M	mine	NA	–	2015	Construction
	Aurora South Train 1	94, 95-7,8-W4M	mine	100,000	–	-	Approved
	Aurora South Train 2		mine	100,000	–	-	Approved
	Mildred Lake Mine Extension	6-15-93-11-W4M	mine	TBD	–	2023	Announced
Teck Resources Ltd.	Frontier Phase 1	99-11, 100,101-9,10,11-W4M	mine	74,600	2011	2021	Application
	Frontier Phase 2		mine	84,000	2011	2024	Application
	Frontier Phase 3		mine	79,300	2011	2027	Application
	Frontier Phase 4 Equinox		mine	39,400	2011	2030	Application
Total E&P Joslyn	Joslyn North Mine Project Phase 1	94,95,96-11-W4M, 94-12-W4M	mine	100,000	2006	–	On Hold
Value Creation Inc.	Advanced TriStar ATS-1	25-89-8-W4M	in situ	15,000	–	2016	Application
	Advanced TriStar ATS-2		in situ	30,000	–	2018	Application
	Advanced TriStar ATS-3		in situ	30,000	–	2020	Application
	TriStar Pilot	29-87-8-W4M	in situ	1,000	–	–	Approved

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), AER (2014), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

SAGD is steam-assisted gravity drainage.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-2 Summary of water withdrawals and discharges for active (operating or under construction) oil sands projects, used in the water balance analysis for the 2014 Water Year.

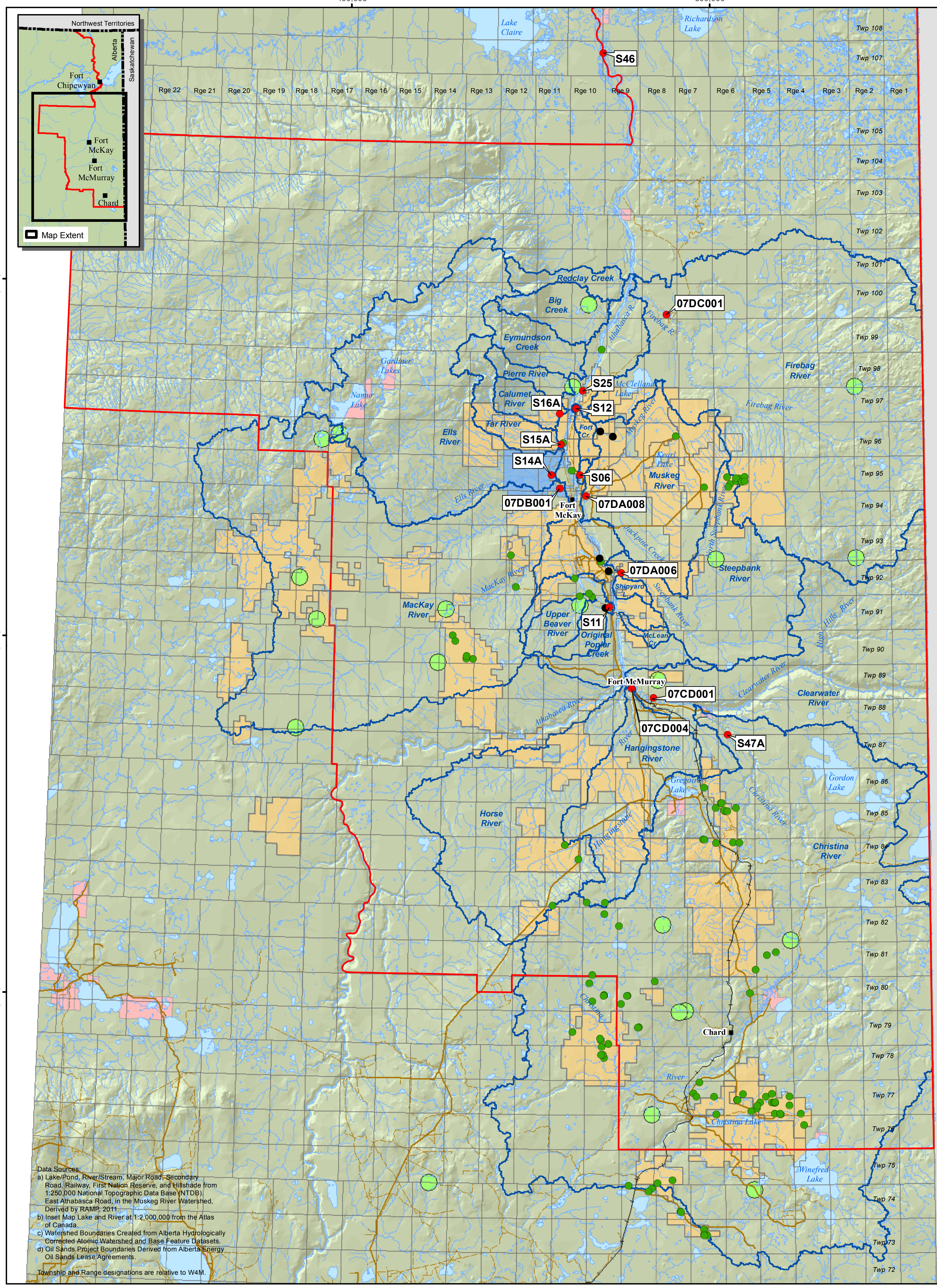
Operator	Project	Water Withdrawal from a Surface Waterbody		Water Release to a Surface Waterbody	
		Volume (Million m^3)	Location	Volume (Million m^3)	Location
Brion Energy Corp.	MacKay River	0.072	MacKay River watershed	-	
Canadian Natural Resources Ltd.	Kirby	0.021	Christina River watershed	-	
	Horizon	20.39	Athabasca River	-	
Imperial Oil Resources	Kearl	0.003	Wapasu Creek	-	
		6.06	Athabasca River	-	
MEG Energy Corp.	Christina Lake	0.128	Christina River watershed	-	
Nexen	Long Lake	0.127	Christina River watershed	-	
		0.009	Hangingstone River watershed	-	
Shell Canada Energy	Jackpine & MRM	16.33	Athabasca River	0.385	Jackpine Creek
Statoil Canada Ltd.	Leismer	0.022	Christina River watershed	-	
Suncor Energy Inc.	Firebag	0.004	Wapasu Creek	-	
		0.015	Steepbank River watershed	-	
		0.013	Firebag River watershed	-	
	North Steepbank Extension	19.56	Athabasca River	1.49	Athabasca River
	MacKay River	0.007	MacKay River watershed	-	
		0.008	Upper Beaver watershed	-	
Syncrude Canada Ltd.	Mildred Lake/Aurora North	38.35	Athabasca River	6.42	Stanley Creek
				7.94	Poplar Creek
		6.56	Upper Beaver watershed	0.290	Athabasca River

Note: Reported withdrawal and release volumes were reported to Hatfield for inclusion of this report and may not include all reported volumes in the Athabasca oil sands region.

Note: Values represent the final values reported in the Chapter 5 water balance analyses, and satisfy the following criteria: (1) were classified to be withdrawn or released to the environment; (2) were mapped within the analysis watershed; and (3) occurred concurrently with periods of recorded hydrograph data within the analysis watershed.

Note: For clarity, values shown were rounded to three decimal places for sums <1 million m^3, and two decimal places otherwise.

Figure 2.2-1 Locations of surface water withdrawals and discharges for active oil sands projects used in the water balance calculations, 2014 Water Year.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Projects with Formal Applications as of 2014
- Active Projects as of 2014
- Inactive Projects as of 2014
- Hydrometric Station for Water Balance Analysis
- Water Withdrawal Location
- Water Discharge Location

0 5 10 20 km

Scale: 1:1,100,000

Projection: NAD 1983 UTM Zone 12N

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2.3 LAND CHANGE AS OF 2014 RELATED TO OIL SANDS ACTIVITIES

Land change due to development activities occurring in 2014 was estimated with satellite imagery in conjunction with more detailed maps provided by a number of oil sand companies. Seventy-four RapidEye 5-m resolution images (33 north of Fort McMurray and 41 south of Fort McMurray) were acquired on July 13, 14, 15, and 21, and August 17, 2014. The imagery acquired on August 17, 2014 were used to replace the July 2014 cloud-covered areas (less than 5%) to improve visual quality for interpretation and image classification purpose. A land change classification protocol was developed and applied to the imagery to identify and delineate two types of land change in 2014 from the projects listed in Table 2.2-1. Developed areas where there was no natural exchange of water with the rest of the watershed (e.g., tailings ponds) were designated as hydrologically closed-circuited. Developed areas where there was natural exchange of water with the rest of the watershed (e.g., cleared land) were designated as not hydrologically closed-circuited.

Based on the resolution of the satellite imagery, a development of 0.5 ha would be the smallest entity delineated. Details of the land change estimation procedure are provided in Appendix A. Drafts of the land change maps were provided to companies where the classification required further verification, and recommendations for revision of the maps were used to produce the final set of 2014 land change maps.

Land change area as of 2014 is presented in Figure 2.3-1 and Figure 2.3-2 for north and south of Fort McMurray, respectively. Table 2.3-1 provides a tabular summary of the total area and percent land change in each of the major watersheds of the Athabasca oil sands region, by land change type. Land change as of 2014 was estimated to be approximately 123,990 ha, which was an increase from 118,750 ha in 2013. The total area of land change represented approximately 3.5% of the total area, compared to 3.3% in 2013. The percentage of the area of watersheds with land change as of 2014 varied from less than 1% for many watersheds (MacKay, Horse, Pierre River, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, Ells, Christina, and Hangingstone watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

Land change area within the city of Fort McMurray in 2014 was estimated at approximately 7,442 ha. Almost half of this land change was in watersheds of smaller tributaries of the Athabasca River, with the other land change occurring in the Clearwater, Hangingstone, and Horse watersheds. The land change area within the city of Fort McMurray increased from approximately 5,100 ha in 2013.

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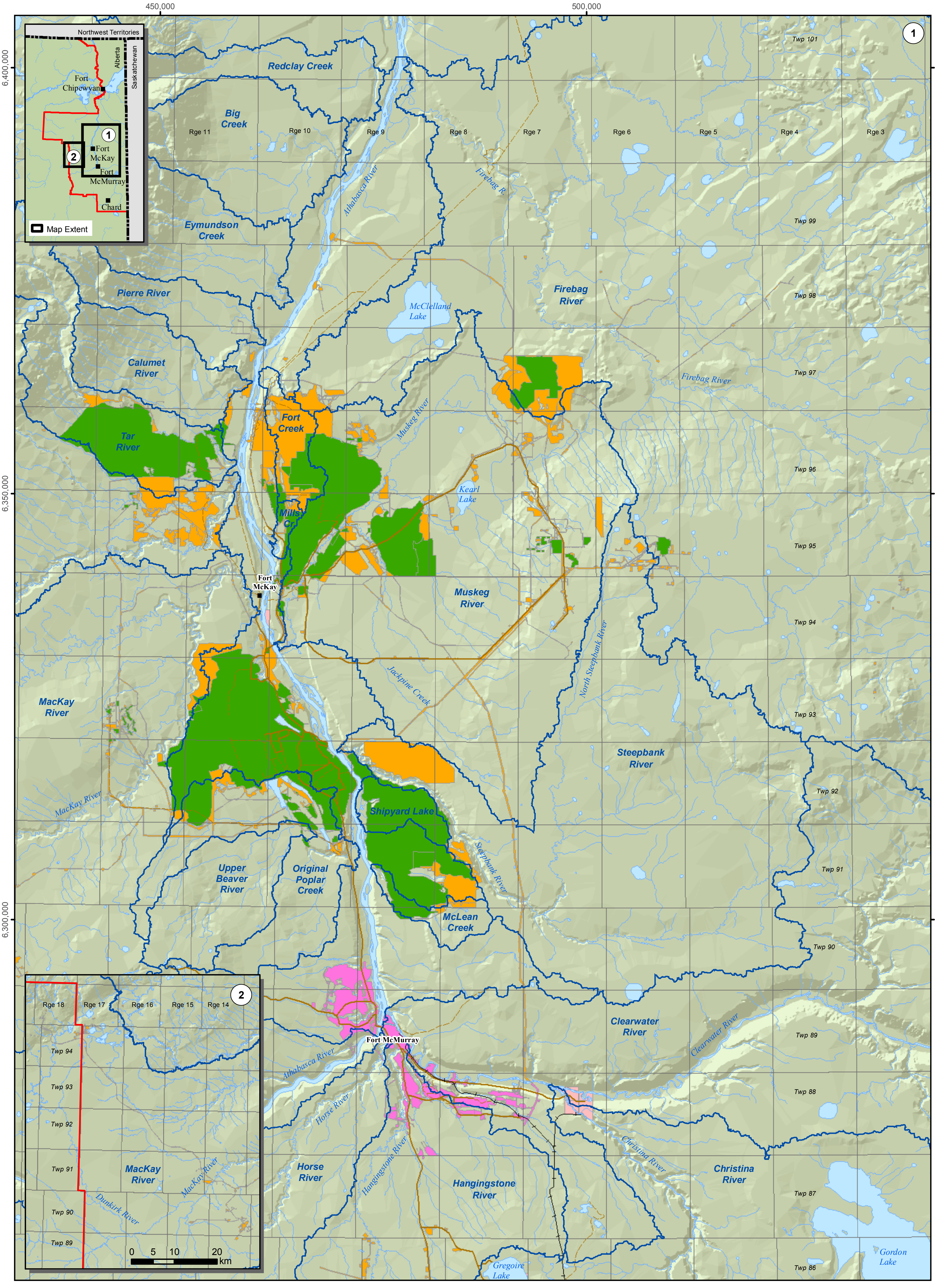
Figure 2.3-1 Land change classes derived from 5-m RapidEye (July and August 2014) multispectral satellite imagery, north of Fort McMurray.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Town of Fort McMurray

Land Change Area as of 2014[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Areas Delineated from 5-m RapidEye (July and August 2014) Multispectral Imagery.

Township and Range designations are relative to W4M.

0 2.5 5 10 km

Scale: 1:450,000

Projection: NAD 1983 UTM Zone 12N

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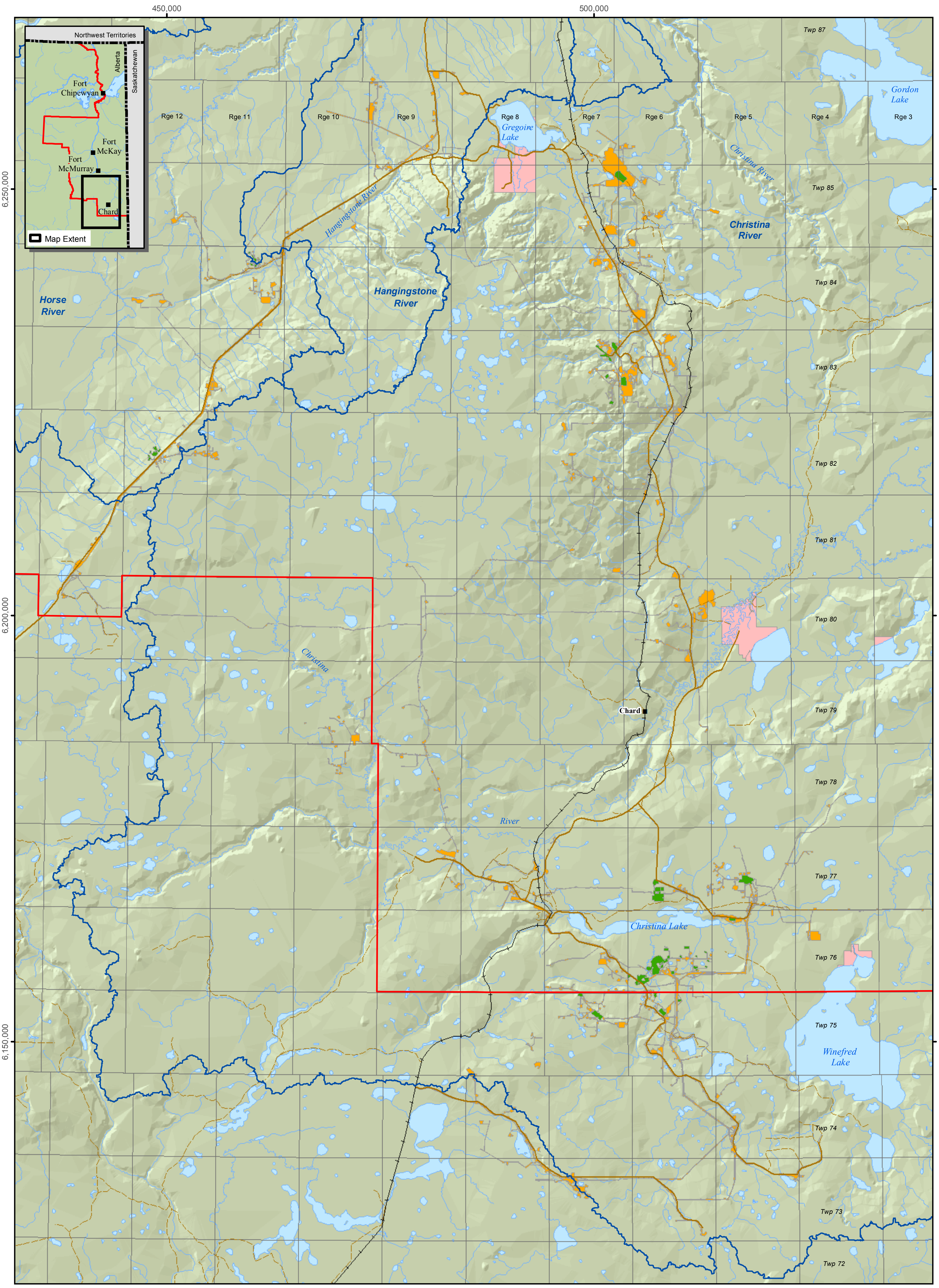
Figure 2.3-2 Land change classes derived from 5-m RapidEye (July and August 2014) multispectral satellite imagery, south of Fort McMurray.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary

Land Change Area as of 2014[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Areas Delineated from 5-m RapidEye (July and August 2014) Multispectral Imagery.

Township and Range designations are relative to W4M.

0 2.5 5 10 km

Scale: 1:450,000

Projection: NAD 1983 UTM Zone 12N

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Table 2.3-1 Total area and percentage of land change in watersheds of the Athabasca oil sands region related to oil sands development in 2014.

Watershed	Total Watershed Area (ha)	Watershed Area with Land Change (ha)					
		Not-Closed Circuited (ha)		Closed-Circuited (ha)		Watershed Total (ha and %)	
		Area (ha)	Percent	Area (ha)	Percent		
Calumet River	17,523	129	0.74	70	0.40	199	1.14
Christina River	1,312,160	12,356	0.94	1,400	0.11	13,756	1.05
Ells River	270,945	3,615	1.33	355	0.13	3,970	1.47
Firebag River	568,190	4,795	0.84	2,343	0.41	7,138	1.26
Hangingstone River	106,572	1,196	1.12	32	0.03	1,228	1.15
Fort Creek	6,640	3,548	53.43	2,001	30.14	5,549	83.57
Horse River	215,740	1,734	0.80	97	0.04	1,831	0.85
MacKay River	556,871	3,978	0.71	734	0.13	4,712	0.85
McLean Creek	4,643	347	7.47	1,071	23.07	1,418	30.54
Mills Creek	1,424	244	17.13	664	46.63	908	63.76
Muskeg River	143,304	8,575	5.98	14,758	10.30	23,333	16.28
Original Poplar[1]	28,388	1,586	5.59	3,802	13.39	5,388	18.98
Pierre River	13,824	18	0.13	0	0.00	18	0.13
Shipyard Lake	5,113	15	0.29	4,629	90.53	4,644	90.83
Steepbank River	136,395	4,913	3.60	538	0.39	5,451	4.00
Tar River	33,264	1,330	4.00	9,842	29.59	11,172	33.59
Upper Beaver River	18,796	39	0.21	82	0.44	121	0.64
Minor Athabasca River Tributaries[2]	135,132	5,834	4.32	27,319	20.22	33,153	24.53
Total	**3,574,924**	**55,224**	**1.54**	**68,766**	**1.92**	**123,990**	**3.47**
Lac La Biche[3]	864,496	588	0.07	0	0	588	0.07

[1] Original Poplar refers to the Poplar Creek watershed prior to the Beaver Creek diversion, while "Upper Beaver" refers to that part of the Beaver Creek drainage that now drains into Poplar Creek as a result of the Beaver Creek diversion. Drainage boundaries were estimated from maps provided in Syncrude Canada Ltd. (1977).

[2] Refers to Athabasca River tributaries from upstream of Fort McMurray to the mouth of the Firebag River excluding the watersheds explicitly listed in this table.

[3] The Lac La Biche watershed was added in 2011 given some of the Canadian Natural Kirby project is located within this watershed. This watershed; however, is not part of the Athabasca oil sands region currently monitored under the JOSMP.

3.0 2014 MONITORING ACTIVITIES

This section contains a description of monitoring conducted as part of the JOSMP in 2014 and previously conducted under RAMP following the same methodology. The description for each component includes the following:

- Summary of 2014 monitoring activities and field methods;
- Description of any other information obtained (i.e., information from regulatory agencies, owners and operators of oil sands projects, knowledge obtained from local communities, and other sources);
- Description of changes in the monitoring network from the 2013 RAMP program;
- Description of the challenges and issues encountered during 2014 and the means by which these challenges and issues were addressed;
- Summary of the component data that are now available; and
- A description of the approach used for analyzing the data.

Monitoring activities for all components in 2014 were implemented according to the monitoring protocols, field methods, and Standard Operating Procedures (SOPs) as outlined in the RAMP Technical Design and Rationale (RAMP 2009b). Any changes in monitoring protocols, field methods, and SOPs from those contained in RAMP (2009b) are noted below.

Quality Assurance and Quality Control (QA/QC) procedures were employed throughout and for all aspects of the monitoring conducted in 2014. Appendix B contains a detailed description of the QA/QC procedures used for monitoring in 2014.

All 2014 monitoring data collected have been added to the database, which is currently located on the RAMP website (www.ramp-alberta.org) and through the AEMERA website (www.aermera.org).

3.1 FIELD DATA COLLECTION

3.1.1 Climate and Hydrology Component

The 2014 Climate and Hydrology monitoring network, including the seven hydrometric stations operated by WSC, consisted of:

- 22 *baseline* streamflow stations;
- 16 streamflow stations with less than 5% of the watershed affected by land change due to oil sands development;
- 19 streamflow stations with more than 5% of the watershed affected by land change due to oil sands development;
- 12 stations collecting climate data; and
- an area-wide snowcourse survey program.

3.1.1.1 Overview of 2014 Climate and Hydrology Monitoring Activities

Climate monitoring (Table 3.1-1, Figure 3.1-1) in 2014 consisted of:

- monitoring air temperature, relative humidity, total precipitation, wind speed and direction, solar radiation, and snow depth at the Aurora, Horizon, Steepbank, Pierre, and Surmont climate stations;
- monitoring barometric pressure at five stations;
- monitoring total precipitation, air temperature, and relative humidity at the Kearl Lake and McClelland Lake stations;
- measuring rainfall, from May 1 to October 31, at five hydrometric monitoring stations; and
- conducting snowcourse surveys during the months of February, March, and April covering four distinct bio-geographic land cover types in four representative regions of the study area.

Hydrology monitoring (Table 3.1-1, Figure 3.1-2) in 2014 consisted of:

- 17 open-water streamflow stations;
- four year-round lake/wetland water level monitoring stations;
- monitoring water temperature at 50 streamflow stations; and
- measuring total suspended solids (TSS) throughout the open-water season at all streamflow stations during each visit.

Appendix C provides specific station information for all climate and hydrology stations in the 2014 program.

3.1.1.2 Field Methods

Field methods described in this section include procedures for streamflow measurements, water level surveys, climate station visits, and snowcourse surveys. More detail and specific procedures for each component can be found in the RAMP Design and Rationale document (RAMP 2009b).

General

Field crews conducted ten visits in 2014 for the Climate and Hydrology component:

- Five field visits during the open-water season at the year-round and open-water stations;
- Five field visits during the winter season to all year-round stations; and
- Three field visits (in three of the five winter visits) for the regional snowcourse survey.

Field visits included manual measurements of streamflow and water level, data retrieval, and station maintenance. Stage-discharge relationships were developed and refined using the manual streamflow and water level data collected during the field visits.

Table 3.1-1 Climate and hydrometric stations operating in support of the 2014 JOSMP.

Station	UTM Coordinates (Easting, Northing)	Operating Season	Variables Measured and Telemetry Type[4]
C1 Aurora Climate Station	475229, 6344053	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, wind speed and direction (C)
C2 Horizon Climate Station	443364, 6360510	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction (C)
C3 Steepbank Climate Station	473950, 6320500	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction (C)
C4 Pierre Climate Station	460898, 6378737	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction (C)
C5 Surmont Climate Station	502542, 6230964	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction (C)
L1 McClelland Lak	483398, 6372186	all year	water level, total precipitation, humidity, air temperature, water temperature (C)
L2 Kearl Lake	484815, 6351080	all year	water level, total precipitation, humidity, air temperature, water temperature (C)
L3 Isadore's Lake	463297, 6342981	all year	water level, water temperature (C)
L4 Namur Lake	402886, 6370260	all year	water level, discharge, water temperature (G)
S2 Jackpine Creek at Canterra Road	474971, 6344091	all year	water level, discharge, water temperature (C)
S3 Iyinimin Creek above Kearl Lake	489423, 6345196	open-water	water level, discharge, rainfall, water temperature (C)
S5 Muskeg River above Stanley Creek	479761, 6356759	all year	water level, discharge, water temperature (C)
S5A Muskeg River above Muskeg Creek	476042, 6351803	all year	water level, discharge, barometric pressure, water temperature (C)
S6 Mills Creek at Highway 63	463755, 6344927	all year	water level, discharge, water temperature (C)
07DA008/S7 Muskeg River near Fort McKay	465552, 6338804	all year[1]	discharge
S9 Kearl Lake Outlet	483983, 6347020	all year	water level, discharge, water temperature (C)
S10A Wapasu Creek near the mouth	488573, 6358554	all year	water level, discharge, water temperature (C)
S11 Poplar Creek at Highway 63 (formerly 07DA007)	471972, 6307825	all year	water level, discharge, water temperature (C)
S12 Fort Creek at Highway 63	462620, 6363554	open-water	water level, discharge, water temperature (C)
S14A Ells River at the Canadian Natural Bridge	455738, 6344944	all year	water level, discharge, water temperature (C)
S15A Tar River near the mouth	458458, 6353439	open-water	water level, discharge, water temperature (C)
S16A Calumet River near the mouth	458096, 6362020	open-water	water level, discharge, water temperature (C)
S19 Tar River Lowland Tributary near the mouth	457326, 6352850	open-water	water level, discharge, water temperature, rainfall (C)
S20A Muskeg River Upland	492230, 6354940	open-water	water level, discharge, water temperature (C)
S22 Muskeg Creek near the mouth	480969, 6349071	all year	water level, discharge, water temperature (C)
S24 Athabasca River below Eymundson Creek	466305, 6372764	all year	water level, discharge, water temperature (C)
S25 Susan Lake Outlet	464513, 6368477	open-water	water level, discharge, water temperature (R-C)
07DB001/S26 MacKay River near Fort McKay	458019, 6341008	all year[1]	discharge

[1] Stations were monitored year-round by WSC in 2014.

[2] Station was installed in May 2014

[3] Telemetry equipment was removed in October 2014

[4] (C), (R-C), (G) telemetry using cellular, radio-cellular relay, and GOES satellite telemetry equipment, respectively.

Table 3.1-1 (Cont'd.)

Station	UTM Coordinates (Easting, Northing)	Operating Season	Variables Measured and Telemetry Type[4]
07DC001/S27 Firebag River near the mouth	487914, 6389855	all year[1]	discharge
07CE002/S29 Christina River near Chard	508211, 6187940	all year[1]	discharge
S31 Hangingstone Creek at North Star Road	469812, 6236089	all year	water level, discharge, water temperature (C)
S32 Surmont Creek at Highway 881	490250, 6254524	all year	water level, discharge, water temperature (C)
S33 Muskeg River at the Aurora North/Muskeg River Mine Boundary	474878, 6350204	all year	water level, discharge, water temperature (C)
S34 Tar River above Horizon Lake	440745, 6361662	all year	water level, discharge, water temperature (C)
S36 McClelland Lake Outlet above Firebag River	490635, 6384056	all year	water level, discharge, water temperature (G)
S37 East Jackpine Creek near the 1,300 m contour	487850, 6325416	open-water	water level, discharge, water temperature
07DA006/S38 Steepbank River near Fort McMurray	475296, 6317398	all year[1]	discharge
07DA018/S39 Beaver River above Syncrude	465560, 6311437	all year[1]	discharge
S40 MacKay River at Petro-Canada Bridge	444949, 6314178	all year	water level, discharge, water temperature, rainfall (C)
07DC005/S42 Clearwater River above Christina River	504427, 6279666	all year[1]	discharge
S43 Firebag River upstream of Suncor Firebag	531704, 6354796	all year	water level, discharge, water temperature, rainfall (G)
S44 Pierre River near Fort McKay (formerly 07DA013)	460769, 6369299	open-water	water level, discharge, water temperature (C)
S45 Ells River above Joslyn Creek Diversion	440325, 6342418	all year	water level, discharge, water temperature (C)
S46 Athabasca River near Embarras Airport	470241, 6463209	all year	water level, discharge, water temperature (G)[3]
S47A Christina River near the mouth	505048, 6272065	all year	water level, discharge, water temperature (G)
S48 Big Creek	470817, 6389113	open-water	water level, discharge, water temperature (R-C)
S49 Eymundson Creek near the mouth	465473, 6372694	open-water	water level, discharge, water temperature (C)
S50A Red Clay Creek	474954, 6396094	open-water	water level, discharge, water temperature (R-C)
S51 High Hills River near the mouth	532571, 6290998	all year	water level, discharge, water temperature (G)
S53 Dover River near the mouth (formerly 07DB002)	451453, 6337017	all year	water level, discharge, water temperature (R-C)
S54 Dunkirk River near Fort McKay (formerly 07DB003)	395815, 6302067	all year	water level, discharge, water temperature (G)
S55 Gregoire River near the mouth	510185, 6259986	all year	water level, discharge, water temperature (R-C)
S56 Jackfish River below Christina Lake (formerly 07CE005)	493753, 6169685	all year	water level, discharge, water temperature (C)
S57 Sunday Creek above Christina Lake	506227, 6158403	all year	water level, discharge, water temperature (C)
S58 Sawbones Creek above Christina Lake	511444, 6167182	open-water	water level, discharge, water temperature (C)
S60 Unnamed Creek South of Christina Lake	511145, 6159877	open-water	water level, discharge, water temperature (C)
S61 Christina River above Statoil Leismer	466037, 6193791	all year	water level, discharge, water temperature (C)
S62 Birch Creek at Hwy 881	492232, 6163213	all year	water level, discharge, water temperature (C)
S63 Sunday Creek at Hwy 881	494283, 6157255	all year	water level, discharge, water temperature (C)
S64 Unnamed Creek East of Christina Lake	517384, 6163640	open-water	water level, discharge, water temperature (C)
S65 North Green Stockings Creek at East Athabasca Hwy	489845, 6333039	open-water	water level, discharge, water temperature (C)
S66 Steepbank River below the North Steepbank River	491438, 6302625	all year[2]	water level, discharge, water temperature (G)

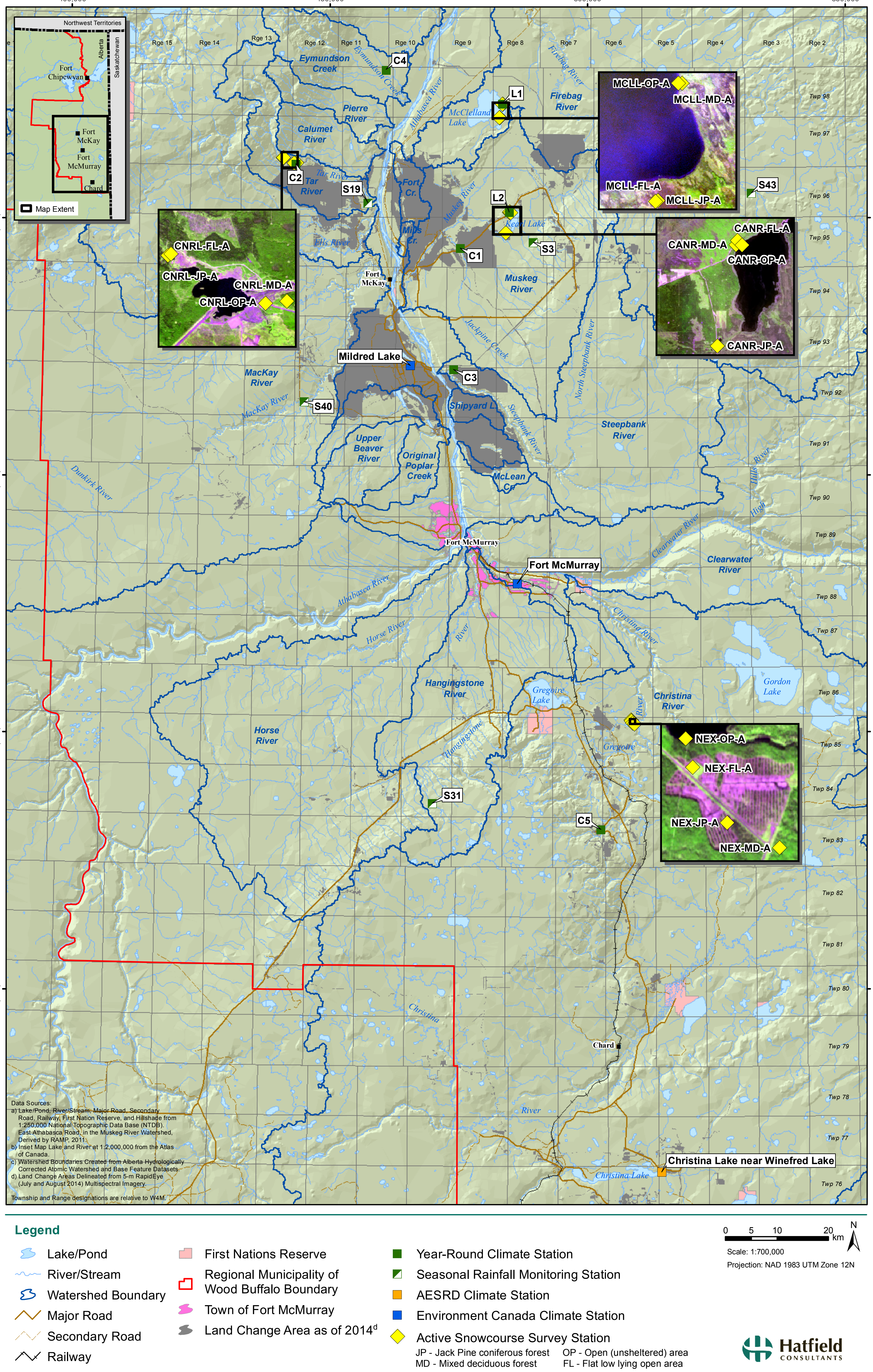
1 Stations were monitored year-round by WSC in 2014.

2 Station was installed in May 2014

3 Telemetry equipment was removed in October 2014

4 (C), (R-C), (G) telemetry using cellular, radio-cellular relay, and GOES satellite telemetry equipment, respectively.

Figure 3.1-1 Locations of climate stations and snowcourse survey stations monitored in support of the 2014 JOSMP.



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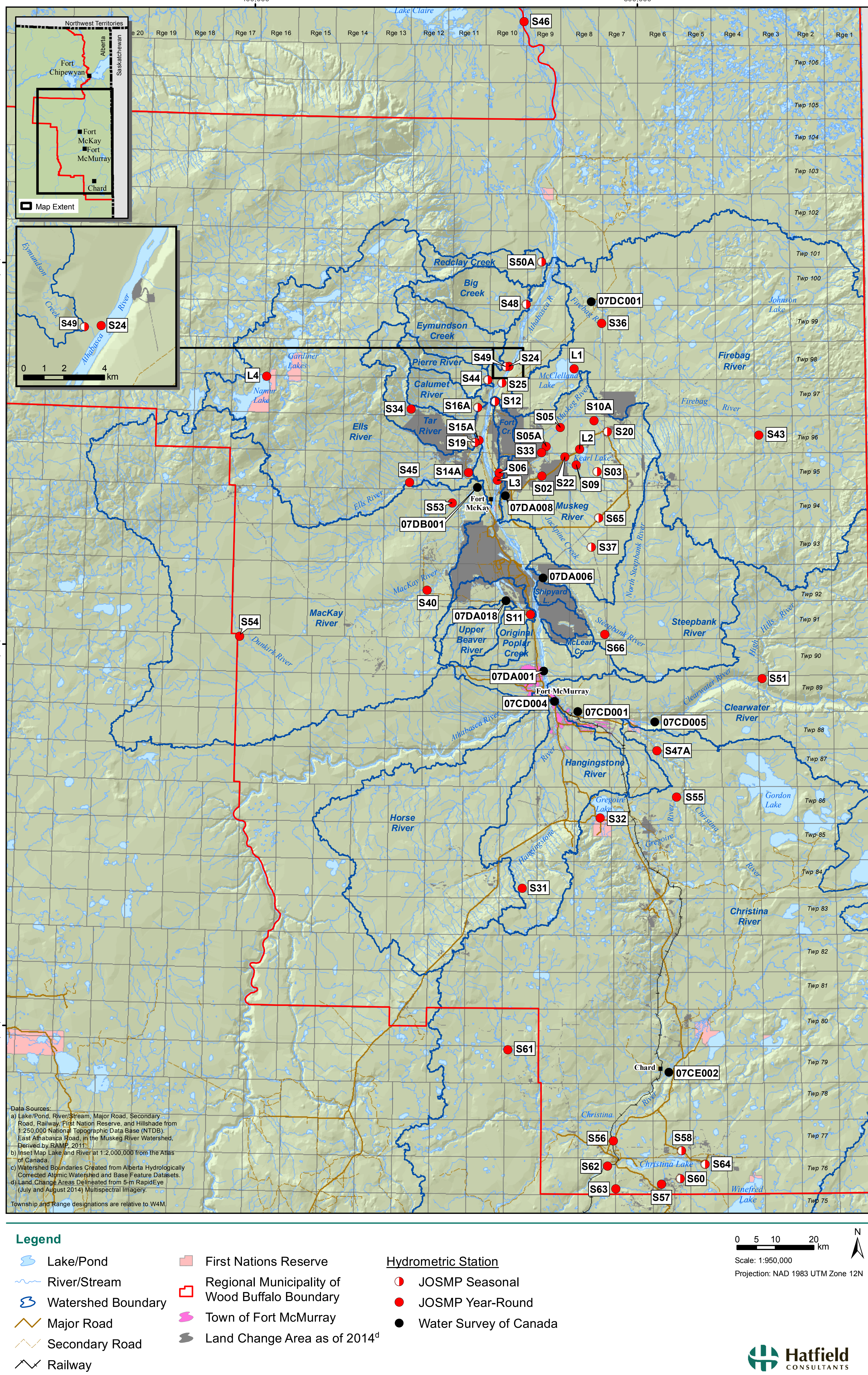
K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_D_Climate_201500330_ss.mxd

Figure 3.1-2 Locations of hydrometric stations operated in support of the 2014 JOSMP.



K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_E_Hydro_20150330_ss.mxd

Streamflow Measurement

Streamflow measurement procedures and standards used for the Climate and Hydrology Component were consistent with Water Survey of Canada (WSC 2001), United States Geological Survey (USGS 1982), and BC Ministry of Environment (BC MOE 2009) recommendations and protocols, and are presented in the RAMP Design and Rationale Document (RAMP 2009b). QA/QC procedures are provided in Appendix B of this report.

Standards for velocity-area streamflow measurements are summarized as follows:

- Number of verticals – minimum of 20, or at a spacing of 0.05 m in small streams;
- Where depth is 0.75 m or less, one observation is made at 60% of the depth below the surface;
- Where depth is greater than 0.75 m, velocity is observed once at 20% and once at 80% of the depth;
- Number of velocity readings for a measurement under ice – the same procedures were used for under ice velocity observations as for open-water velocity observations, with the exception that velocity was observed at 50% of the under-ice depth (effective depth) for depths less than 0.75 m;
- Under ice velocity observations conducted at 50% of the effective depth were subject to a velocity correction of 0.88 due to the addition of the ice as a confining layer, panels measured with two velocity measurements were not subject to any velocity correction; and
- Velocity averaging – at least 40-second averages for the Sontek FlowTracker ADV (Acoustic Doppler Velocimeter), OTT ADC (Acoustic Digital Current meter), and electromagnetic meters (Hach HF950 and Marsh McBirney Flo-Mate 2000).

Standards for Acoustic Doppler Current Profiler (ADCP) streamflow measurements were consistent with standards and procedures set by the Water Survey of Canada (WSC 2014) and were as follows:

- ADCP was moved across the measurement cross section at a steady pace, where the float velocity must not exceed the velocity of the water in the channel;
- Streamflow was calculated from at least four “good” passes of the cross section. A “good” pass was based on the following criteria: (i) each pass was within 5% of the mean measured discharge; (ii) at least 50% of the total calculated discharge in a pass was measured; (iii) the flow angle was minimal; (iv) the pitch and roll of the measurement platform was less than 5%; and (v) a minimum of ten ensembles were measured at the start and end positions; and
- Under-ice ADCP discharge measurements were conducted using at least 20 stationary measurements from holes augered into the river ice. Ice thickness and transducer depth were entered into the ADCP software for each measurement location.

Water Level Surveys

Field crews conducted water level surveys at both streamflow and lake/wetland stations to reference the continuous water level record to the surface water level. Procedures for conducting the water level survey were derived from standards in BC MOE (2009):

- Level readings using an automatic level were made to the nearest 0.001 m;
- Surveys were made using at least two independent benchmarks; and
- Each survey was conducted using two set-ups with a closing error of less than 0.004 m.

Climate Station Visits

Field crews visited climate stations to conduct data logger downloads, preliminary quality assurance to check station function, data reliability, and maintenance needs. Precipitation gauges were inspected to ensure sufficient levels of anti-freeze and hydraulic fluid were present.

Snowcourse Surveys

Snowcourse survey procedures were developed from principles outlined in the British Columbia Ministry of Environment Procedure Manual (Volume 6, Section 9, Subsection 01, Page 5 of 72) (BC MOE 1982) and included the following:

- 40 snow depths were measured in each study plot (jack pine coniferous forest, mixed deciduous forest, open area, flat low-lying open area);
- Snow depth and the mass of a vertical profile of the snowpack were measured four times in each plot to calculate snow density;
- Forty snow water equivalent (SWE) values were calculated in each plot by multiplying individual snow depth values by mean snow density. A mean SWE value was calculated for each plot; and
- Station photos were taken to provide a visual record of ground snow conditions (e.g., patchiness) and any intercepted snow in treed stands.

3.1.1.3 Changes in Monitoring Network from 2013

Monitoring at the following stations was conducted by Water Survey of Canada (WSC) in 2014: S7/07DA008 Muskeg River near Fort McKay, S26/07DB001 MacKay River near Fort McKay, S27/07DC001 Firebag River near the mouth, S29/07CE002 Christina River near Chard, S38/07DA006 Steepbank River near Fort McMurray, S39/07DA018 Beaver River above Syncrude, and S42/07CD005 Clearwater River above Christina River. Data were provided by WSC to Hatfield for inclusion in the program report.

Monitoring of these stations during the winter was previously conducted by RAMP until the end of 2013.

New Monitoring Stations

In order to characterize upstream hydrologic conditions of the Steepbank River, Station S66 Steepbank River below the North Steepbank River, was installed at a location 6 km downstream of the confluence with the North Steepbank River. This station became operational in May 2014 for year-round monitoring of discharge, water level, and water temperature.

Modified Stations

The following modifications and field equipment upgrades were made in 2014 to support station function and reliability of data collection:

- Station S31 was relocated 30 m upstream of the North Star Road Bridge to avoid conflict with construction of a new power line;
- Fence panels were installed to create protective barriers against wildlife, around the monitoring equipment at stations S36 McLelland Lake Outlet above Firebag River; S51 High Hills River near

the mouth; S61 Christina River above Statoil Leismer; and telemetry relay stations at S48 Big Creek and S50A Red Clay Creek;

- Climate sensors were exchanged for calibration at the C1 Aurora and C3 Steepbank climate stations;
- HMP-model temperature/relative humidity sensors were replaced for calibration based on a two-year exchange cycle, at stations L1 McClelland Lake, and L2 Kearl Lake; and
- Twenty stations had pressure transducers replaced for scheduled calibration based on a two-year exchange cycle for all stations with year-round deployed sensors. These stations included L3 Isodore's Lake; L4 Namur Lake; S5A Muskeg River above Muskeg Creek; S6 Mills Creek at Highway 63; S9 Kearl Lake Outlet; S11 Poplar Creek at Highway 63; S22 Muskeg Creek near the mouth; S31 Hangingstone Creek at North Star Road; S32 Surmont Creek at Highway 881; S33 Muskeg River at the Aurora North/Shell MRM Boundary; S34 Tar River above Horizon Lake; S36 McClelland Lake Outlet above Firebag River; S47A Christina River near the mouth; S51 High Hills River near the mouth; S53 Dover River near the mouth; S54 Dunkirk River near Fort McKay; S55 Gregoire River near the mouth; S57 Sunday Creek above Christina Lake; S62 Birch Creek at Highway 881; and S63 Sunday Creek at Highway 881.

3.1.1.4 Challenges Encountered and Solutions Applied

Wildlife and Environmental Challenges

The following wildlife and environmental challenges were addressed in 2014:

- Wildlife activity at Station S3 Iyinimin Creek above Kearl Lake, caused damage to the tipping bucket rain gauge and disconnected the power supply to the station on August 4, 2014. The station was reinstated without the tipping bucket during the next field visit on August 9. Another wildlife incident in late August disconnected telemetry cables, but resulted in no interruption to data collection. The tipping bucket rain gauge was reinstalled and telemetry repairs were completed during the next field visit on September 24, 2014.
- Wildlife activity caused the solar panel cables to be disconnected at Station S10A Wapasu Creek near the mouth, on August 10, 2014. Repairs were conducted during the next field visit on September 12, 2014, and there was no disruption to data collection.
- Low water level caused the pressure transducer at Station S11 Poplar Creek at Highway 63, to be out of the water from July 12 to July 18, 2014. As a result, the water level could not be measured during this period. The pressure transducer was moved to a deeper location during the next field visit on August 8, 2014 to avoid future data loss from low water levels.
- Bank erosion during the spring freshet caused the monitoring equipment at Station S16A Calumet River near the mouth, to fall into the river on May 31, 2014. Data collection was interrupted from May 31 to June 20, 2014 when the equipment was replaced and the station was reinstated.
- The pressure transducer at Station S24 Athabasca River below Eymundson Creek, was severed by ice movement during river break-up on April 23, 2014. Station monitoring was interrupted from April 23 to May 20, 2014 when the station was reinstated.

- The tipping bucket at Station S43 Firebag River upstream of Suncor Firebag, was damaged by wildlife following the September 12, 2014 field visit. Accordingly, data collected during this time was not considered reliable and was discarded for the period of September 12 to October 15, 2014. The instrument was repaired during the field visit on October 15, 2014.

- The pressure transducer at Station S46 Athabasca River near Embarras Airport was severed on April 27, 2014 by ice movement during river break-up. Station monitoring was interrupted from April 27 to May 16 when the station was reinstated.

- Ice movement during river break-up at Station S47A Christina River near the mouth, caused the pressure transducer to be disconnected from the data logger on April 28, 2014. Data were not collected until a new pressure transducer was installed on May 21, 2014, during the next field visit.

Data Logger Malfunctions and Attrition

The following data logger malfunctions and equipment challenges were addressed in 2014:

- Weak batteries, poor light conditions, and faulty power supplies caused intermittent data collection for portions of 2014 at stations L4 Namur Lake, S2 Jackpine Creek at Canterra Road, S36 McClelland Lake Outlet above Firebag River, S49 Eymundson Creek near the mouth, S58 Sawbones Creek above Christina Lake, S62 Birch Creek at Hwy 881, and S64 Unnamed Creek East of Christina Lake. Batteries were replaced or more batteries were added to stations where weak batteries or poor lighting conditions occurred, respectively. Components of faulty power supplies were replaced as necessary to reinstate station function; and

- A faulty data logger at Station S62 Birch Creek at Highway 881 caused monitoring to be intermittent from July 14, 2014 to October 10, 2014. The data logger was replaced during the October 10 field visit and full station function was restored.

3.1.1.5 Other Information Obtained

Streamflow data from WSC were obtained and incorporated into the database for stations where data was used in the analysis and reporting of the 2014 program report. These data were received as provisional and flagged as such in the database.

Climate data from the Environment Canada stations at Fort McMurray and Mildred Lake, and the AESRD station at Christina Lake near Winfred Lake, were used in the preparation of the 2014 program report.

3.1.1.6 Summary of Component Data Now Available

Table 3.1-2 summarizes the available climate and hydrology data collected to date. Additional climate data can be obtained from the following sources: Wood Buffalo Environmental Association (WBEA), Environment Canada (EC), and the Alberta Government using the following links:

- http://www.wbea.org/

- http://www.climate.weatheroffice.gc.ca/Welcome_e.html

- http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

Table 3.1-2 Summary of data available for the Climate and Hydrology component in support of the JOSMP, 1997 to 2014. (Page 1 of 2)

see symbol key at bottom

Location	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014				2014
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	Status
Athabasca River Mainstem																																																																									
Athabasca River below Eymundson Creek (S24)																		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	n/a
Athabasca River near Embarras Airport (S46)																																																												2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	n/a
Athabasca River East Tributaries																																																																									
Fort Creek at Highway 63 (S12)														2	2	2		2	2	2		2	2	2														2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	>5% Land Change
Isadore's Lake (L3)													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t	>5% Land Change
Mills Creek at Highway 63 (S6)		2	2	2		2	2	2		2	2	2		2d	2d	2d		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Susan Lake Outlet (S25)																						2	2	2														2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline
Muskeg River Basin																																																																									
Aurora Climate Station (C1)	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	n/a
Kearl Lake (L2)										1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	>5% Land Change
Alsands Drain (S1)		2	2			2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2																																																	
Jackpine Creek at Canterra Road (S2)		2	2	2		2	2			2	2			2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Iyinimin Creek above Kearl Lake (S3)		2	2	2		2a	2a	2a		2a	2a	2a						2a	2a	2a		2a	2a	2a		2a	2	2		2	2	2		2a	2a	2		2a	2a	2a		2	2a	2		2a	2a	2a		2	2	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta		2ta	2ta	2ta		2ta	2ta	2ta	>5% Land Change
Blackfly Creek near the Mouth (S4)		2	2	2		2	2	2																																																																	
Muskeg River above Stanley Creek (S5)																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Muskeg River above Muskeg Creek (S5A)		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2d	2d	2d	2d	2d	2d	2d	2d	2d	2d	2d	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	>5% Land Change
Muskeg River near Fort McKay (07DA008/S7)													2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2t	4	4	4	2t	4	4	4	4	4	4	4	>5% Land Change
Stanley Creek near the mouth (S8)											1	1		1	1	1		1	1	1		1	1	1		1	1	1																																													
Kearl Lake Outlet (S9)						2	2	2		2e	2e	2e						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	>5% Land Change
Wapasu Creek at Canterra Road (S10/S10A)		2								2	2	2						2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Albian Pond 3 Outlet (S13)														2	2	2		2	2	2		2	2	2																																																	
Muskeg River Upland (S20)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	>5% Land Change
Shelley Creek near the mouth (S21)																		1	1	1		1	1	1		1	1	1																																												
Muskeg Creek near the Mouth (S22)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Aurora Boundary Weir (S23)																	2	2	2	2	2	2	2	2																																																	
Khahago Creek below Black Fly Creek (S28)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2																												
Muskeg River at the Aurora/Albian Boundary (S33)																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
East Jackpine Creek near the 1300 m Contour (S37)																																												2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline
North Green Stockings Creek at East Athabasca Highway (S65)																																																																		2t	2t	2t		2t	2t	2t	Baseline
Muskeg River High Water Gauging			3				3				3				3				3																																																						
Jackpine Creek High Water Gauging			3				3												3																																																					
Steepbank River Basin																																																																									
Steepbank Climate Station (C3)																																																			b	b	b	b	b	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	n/a
Steepbank River near Fort McMurray (07DA006/S38)																																																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	<5% Land Change
Steepbank River below North Steepbank River (S66)																																																																						2t	2t	2t	<5% Land Change
Firebag River Basin																																																																									
McClelland Lake (L1)			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2a	2a	2a	2a	2a	2a	2	2	2a	2a	2a		2	2	2	1	1b	1b	1bf	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1th	1th	1h	1h	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	<5% Land Change
Firebag River near the Mouth (07DC001/S27)																					2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	<5% Land Change
McClelland Lake Outlet at McClelland Lake (S35)																																														2	2	2		2	2	2																					
McClelland Lake Outlet above Firebag River (S36)																																														2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Firebag River upstream of Suncro Firebag (S43)																																																		2	2	2		2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	Baseline
Athabasca River West Tributaries																																																																									
Pierre Climate Station (C4)																																																											gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	n/a
Pierre River near Fort McKay (S44)																																																		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline
Big Creek (S48)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline
Eymundson Creek near the mouth (S49)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline
Red Clay Creek (S50/S50A)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	Baseline

Note: Monitoring for the Climate and Hydrology Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

a = rainfall
b = rainfall and snowfall, or total precipitation
c = snowcourse survey
d = barometric pressure
e = air temperature
f = relative humidity
g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground
h = air temperature, total precipitation and relative humidity

1 = water levels
2 = water levels and discharge
3 = high water gauging
4 = hydrometric data collected by Environment Canada
t = water temperature

Test (downstream of focal projects)
Baseline (upstream of focal projects)

Table 3.1-2 (Cont'd.) (Page 2 of 2)

see symbol key at bottom

Location	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014				2014
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	Status
Ells River Basin																																																																									
Namur Lake near the Outlet (L4/S52)																																																													2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Ells River above Joslyn Creek (S14)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2																											
Ells River at Canadian Natural Bridge (S14A)																																2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	<5% Land Change
Ells River above Joslyn Creek Diversion (S45)																																																		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Mackay River Basin																																																																									
MacKay River near Fort McKay (07DB001/S26)																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	<5% Land Change
MacKay River at Petro-Canada Bridge (S40)																																													2	2t	2t	2t	2t	2t	2t	2t	2t	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2t	2ta	2ta	2ta	Baseline
Dover River near the mouth (S53)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Dunkirk River near Fort McKay (S54)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Tar River Basin																																																																									
Horizon Climate Station (C2)																																																g	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	n/a
Tar River near the mouth (S15/S15A)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t	>5% Land Change
Tar River Upland Tributary (S17)																		2	2	2		2	2	2		2	2	2		1	1	1																																									
Tar River Lowland Tributary near the mouth (S19)																		2	2	2		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a	b	2b	2b	2b	b	2b	2b	2b	b	2b	2b	2b	b	2b	2b	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta		2ta	2ta	2ta		2ta	2ta	2ta	>5% Land Change
Tar River above Horizon Lake (S34)																																		2	2	2		2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Calumet River Basin																																																																									
Calumet River near the mouth (S16/S16A)																		2	2	2		2g	2g	2g	be	2tbe	2tbe	2tbe	e	2be	2be	2tbe	be	be	e																			2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t	<5% Land Change
Upland Calumet River (S18)																		2	2	2																																																					
Calumet River Upland Tributary (S18A)																						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2																					
Poplar River Basin																																																																										
Poplar Creek at Highway 63 (S11)			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	>5% Land Change
Beaver River above Syncrude (07DA018/S39)																																													2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	Baseline
Clearwater River Tributaries																																																																									
Surmont Climate Station (C5)																																																											gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	n/a
Christina River near Chard (S29)																					2	4a	4a	4a	2	4a	4a	4a	2	4a	4a	4a	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	<5% Land Change
Hangingstone River at Highway 63 (S30)																						2	2	2																																																	
Hangingstone Creek at North Star Road (S31)																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	Baseline
Surmont Creek at Highway 881 (S32)																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Clearwater River above Christina River (07DC005/S42)																																																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	Baseline
Christina River near the mouth (S47/S47A)																																																											2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	<5% Land Change
High Hills River near the mouth (S51)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	Baseline
Gregoire River near the mouth (S55)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	<5% Land Change
Jackfish River below Christina Lake (S56)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	<5% Land Change
Sunday Creek above Christina Lake (S57)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	<5% Land Change
Sawbones Creek above Christina Lake (S58)																																																														2t	2t	2t	2t	2t	2t	2t		2t	2t	2t	<5% Land Change
Unnamed Creek South of Christina Lake (S60)																																																																		2t	2t	2t		2t	2t	2t	>5% Land Change
Christina River above Statoil Leismer (S61)																																																																		2t	2t	2t	2t	2t	2t	2t	Baseline
Birch Creek at Hwy 881 (S62)																																																																		2t	2t	2t	2t	2t	2t	2t	Baseline
Sunday Creek at HWY 881 (S63)																																																																		2t	2t	2t	2t	2t	2t	2t	Baseline
Unamed Creek East of Christina Lake (S64)																																																																		2t	2t	2t		2t	2t	2t	<5% Land Change
Snow Course Surveys																																																																									
Muskeg River Basin Snowcourse Survey		c				c				c				c				c																																																							
Fort Creek Basin Snowcourse Survey														c																																																									
Canadian Natural Area Snowcourse Survey																		c				c				c																																															
Wide-Area Snowcourse Survey																													c				c				c				c				c				c				c				c				c				c				c				n/a

Note: Monitoring for the Climate and Hydrology Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

a = rainfall
b = rainfall and snowfall, or total precipitation
c = snowcourse survey
d = barometric pressure
e = air temperature
f = relative humidity
g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground
h = air temperature, total precipitation and relative humidity

1 = water levels
2 = water levels and discharge
3 = high water gauging
4 = hydrometric data collected by Water Survey of Canada
t = water temperature

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

3.1.2 Water Quality Component

3.1.2.1 Overview of 2014 Monitoring Activities

Monitoring activities for the Water Quality component were conducted in twelve sampling campaigns in 2014: monthly sampling (five locations in January and February, and seven locations in April, June, August, October, November, December), and larger, seasonal campaigns in winter (March 5 to 11); spring (May 6, 8, 9, 13, 14, 20, and 26); summer (July 9 to 11, 19); and fall (September 2 to 14).

Water quality sampling focused on the lower Athabasca River and its major tributaries as well as regionally important lakes and wetlands. Water quality was sampled at 62 stations in 2014.

Figure 3.1-3 provides the locations of water quality sampling in 2014. Table 3.1-3 summarizes the location of the 2014 water quality sampling stations, seasonal distribution of the sampling effort, and water quality variables measured at each station. Sampling intensity was greatest during the fall campaign, with samples collected from all 2014 monitoring stations in that season. For newly-established stations, standard protocols include seasonal sampling for three years and then sampling once in fall in subsequent years (Table 3.1-3). In addition, since 2013, a subset of stations have been sampled monthly. In 2014, monthly water quality sampling was continued at five locations to assess seasonal changes in water quality in greater detail. Two additional monthly water quality sampling stations were added to the sampling program starting in April, based on direction through the JOSMP.

3.1.2.2 Summary of Field Methods and Sample Analysis

Station locations were identified using GPS coordinates, Alberta Forestry, Lands, and Wildlife Resource Access Maps, and where applicable, written descriptions from past RAMP reports. Stations were accessed by boat, helicopter, or four-wheel drive vehicle.

At all water quality stations, in situ measurements of dissolved oxygen (DO, mg/L), temperature (°C), pH, and conductivity (µS/cm) were collected using a YSI Model 85 multi-probe water meter or a handheld thermometer (temperature), a handheld pH/conductivity meter (pH and conductivity), and a LaMotte portable Winkler titration kit (dissolved oxygen).

Field sampling involved the collection of single grab samples of water from smaller creeks or rivers, bank-adjacent grab samples in large rivers, and collection of single grab samples in lakes and wetlands.

Grab samples were collected by submerging each sample bottle to a depth of approximately 30 cm, uncapping and filling the bottle, and recapping at depth. The only exceptions to this were samples collected for total hydrocarbons and BTEX analyses, which were taken from the surface of the water to ensure capture of any floating hydrocarbons, and to ensure that the pre-charged preservative stayed in the sample. The ultra-trace mercury bottle was triple-rinsed prior to the final sample collection, following guidance from the analytical laboratory.

Samples taken at the mouth of tributaries were collected approximately 100 m upstream of the confluence where possible to avoid influences of mainstem water on sampled water quality at each station. Similarly, stations located on river mainstems near tributaries were sampled approximately 100 m upstream of the tributary confluence.

Sampling methods were modified in winter in response to environmental conditions, and to account for and preclude any sampling error or contamination associated with the requisite use of secondary sample transfer vessels and ice augers (all waterbodies sampled during other seasons were free of ice). Water was collected through holes drilled into the river/lake ice using a gas-powered auger. For grab samples, one hole was drilled at the estimated stream thalweg. Samples were collected from as far as possible below the surface of the water using a dipped bottle. This method was used rather than use of a peristaltic pump (as in previous recent years) because air temperatures were too low to allow free flow of water through the pump tubing to sampling bottles (i.e., water froze in the tubing). Following collection, samples were then preserved as required.

All water samples were collected, preserved, and shipped according to protocols specified by consulting laboratories. The number and assortment of sampling bottles provided for some conventional variables (i.e., nutrients, BOD, dissolved organic carbon [DOC], and major ions) was modified by ALS Environmental in 2014; as part of this change, samples collected for analysis of DOC were no longer filtered in the field through a disposable, 0.45-µm filter, as done in previous years. Instead, these samples were provided to the ALS laboratory in Fort McMurray on the same day of sampling, and filtered at the laboratory.

All water quality samples taken in all sampling seasons in 2014 were analyzed for standard variables that have been historically sampled by RAMP (Table 3.1-4, Table 3.1-5). All analyses were conducted by ALS Environmental Ltd. (Fort McMurray and Edmonton, Alberta), with the exception of total and dissolved metals (including ultra-trace mercury) and acid-extractable organics (naphthenic acids), which were analyzed by Alberta Innovates Technology Futures (AITF) in Vegreville, Alberta, and PAHs, which were analyzed by AXYS Analytical Services Ltd. in Sidney, BC. Samples collected from regional lakes were also analyzed for chlorophyll *a* by ALS.

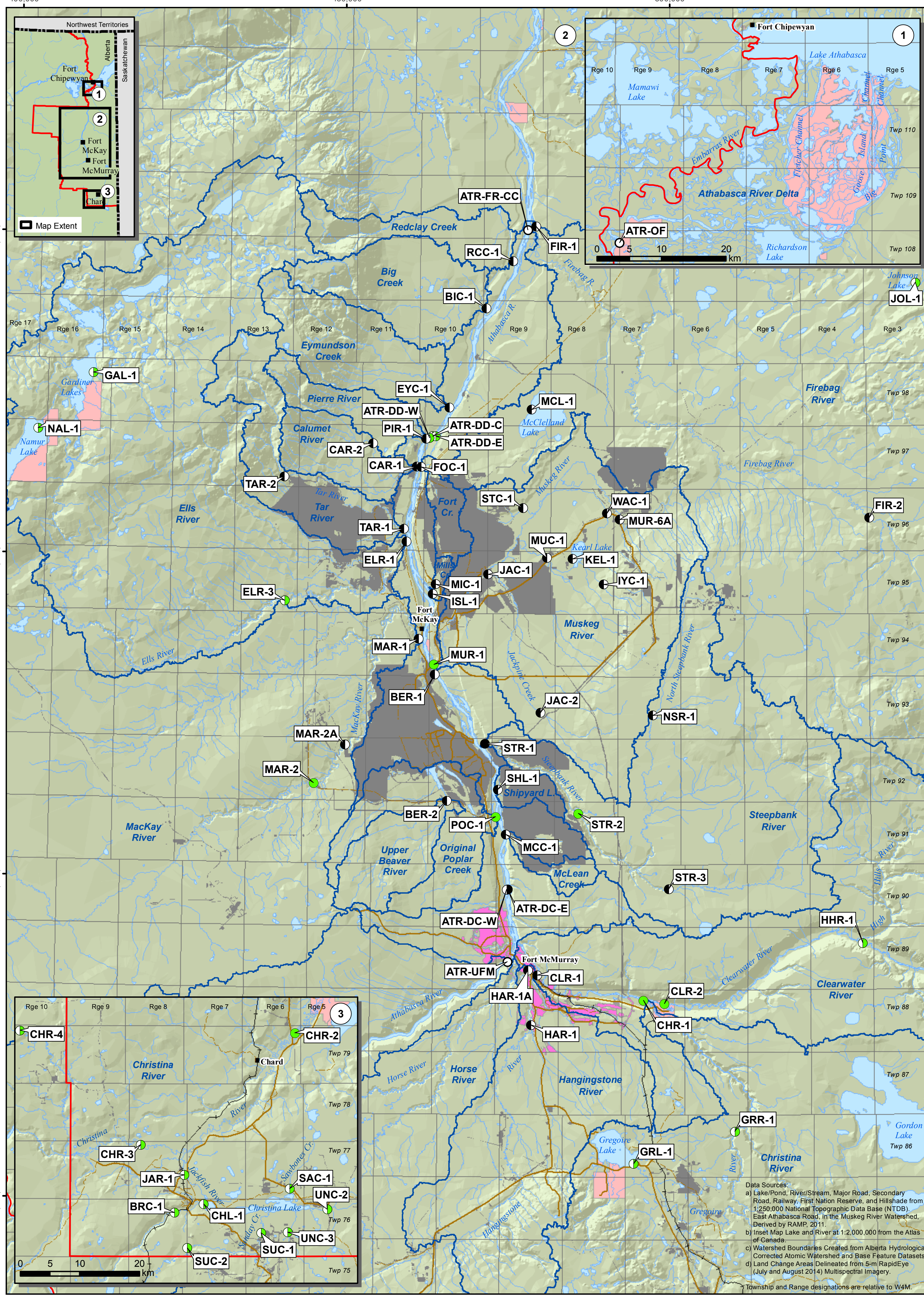
Details of analytical chemistry methods and associated detection limits for the Water Quality component are provided in Table 3.1-4 and Table 3.1-5. Although detection limits could vary between individual analyses based on sample-specific laboratory QA data (e.g., spike recoveries, method blank results, etc.), standard method detection limits typically were applied to all non-detectable data, with the notable exception of ultra-trace PAHs, where blank-corrected detection limits were applied.

Blank Correction of Detection Limits for Ultra-trace PAHs

Ultra-trace analysis of PAHs in water was introduced in 2011, with analysis conducted by AXYS Analytical Ltd. (AXYS) using low-resolution mass spectrometry (LRMS). Results for 43 parent and alkylated PAH homologues were reported, with analytical reporting (detection) limits of approximately 0.1 ng/L.

Analytical results from AXYS presented reporting limits (RL, equal to sample-specific detection limits) for each PAH compound (ranging from 0.05 to 0.24 ng/L); these were calculated for each sample tested based on various internal QA performance assessments undertaken with each analysis. Given that the RLs were variable among tests and measurements in trip blanks exceeded RLs in some cases (typically in different analytical batches), data were subsequently blank-corrected to calculate project-wide, consistent detection limits (DLs) for each PAH compound. This allowed for consistent comparisons of all PAH data collected in 2014. This blank-correction procedure followed methods developed in conjunction with AXYS for the RAMP 2011 data (RAMP 2012) so that all results measured for a given PAH compound had the same detection limit applied for data from all stations and seasons. Project-wide, blank-corrected DLs for each PAH species (or, in the case of alkylated forms, groups of compounds) were generated by calculating DLs for each PAH equal to 2x the standard deviation of concentrations of that compound measured in all project trip blanks.

Figure 3.1-3 Locations of water quality stations monitored in support of the 2014 JOSMP.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Town of Fort McMurray
- Land Change Area as of 2014[d]

Water Quality Station

- AESRD Monthly
- JOSMP Monthly
- JOSMP Seasonal
- JOSMP Fall Only
- JOSMP Winter Only
- JOSMP Winter and Fall

0 2.5 5 10 km

Scale: 1:600,000

Projection: NAD 1983 UTM Zone 12N

Hatfield CONSULTANTS

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Table 3.1-3 Sampling summary for the Water Quality component in support of the 2014 JOSMP.

Station Identifier and Location		UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	Winter	Spring	Summer	Fall	
Athabasca River								
ATR-DD-E	Athabasca River downstream of all development (east bank)	463808	6367911	1	1	1	1	East bank grab
ATR-DD-W	Athabasca River downstream of all development (west bank)	462818	6367661	1	1	1	1	West bank grab
ATR-DD-C	Athabasca River downstream of all development (centre channel)	463300	6367880	1	1	1	1	Mid-channel grab
Tributaries to the Athabasca River (Southern)								
Clearwater River and Tributaries								
CLR-1	Clearwater River upstream of Fort McMurray	479500	6284210	-	-	-	1	Mid-channel grab
CLR-2*	Clearwater River upstream of Christina River	499210	6279831	1	1	1	1	Mid-channel grab
HAR-1	Hangingstone River (upstream of Fort McMurray)	478539	6276489	-	-	-	1	Mid-channel grab
HAR-1A	Hangingstone River (lower)	478093	6284967	-	-	-	1	Mid-channel grab
Christina River and Tributaries								
CHR-1*	Christina River upstream of Fort McMurray	495968	6280327	1	1	1	1	Mid-channel grab
CHR-2*	Christina River upstream of Janvier	511754	6192348	-	1	1	1	Mid-channel grab
CHR-3	Christina River upstream of Jackfish River	486512	6174647	1	1	1	1	Mid-channel grab
CHR-4	Christina River upstream of development	466231	6193833	1	1	1	1	Mid-channel grab
GRR-1	Gregoire River (lower)	510152	6259979	1	1	1	1	Mid-channel grab
JAR-1	Jackfish River	493812	6169530	1	1	1	1	Mid-channel grab
SUC-1	Sunday Creek downstream	506690	6159784	1	1	1	1	Mid-channel grab
SUC-2	Sunday Creek upstream	494290	6157246	1	1	1	1	Mid-channel grab
SAC-1	Sawbones Creek	511458	6167194	1	1	1	1	Mid-channel grab
UNC-2	Unnamed Creek east of Christina Lake	517814	6163718	1	1	1	1	Mid-channel grab
UNC-3	Unnamed Creek south of Christina Lake	511159	6159892	1	1	1	1	Mid-channel grab
BRC-1	Birch Creek	492165	6163211	1	1	1	1	Mid-channel grab
High Hills River								
HHR-1	High Hills River (mouth)	529929	6289270	1	1	1	1	Mid-channel grab
Tributaries to the Athabasca River (Eastern)								
FOC-1	Fort Creek	461524	6363111	-	-	-	1	Mid-channel grab
MCC-1	McLean Creek (mouth)	474637	6306051	-	-	-	1	Mid-channel grab
Steepbank River								
NSR-1	North Steepbank River	497388	6324553	-	-	-	1	Mid-channel grab
STR-1	Steepbank River (mouth)	471387	6320175	1	-	-	1	Mid-channel grab
STR-2*	Steepbank River upstream of Suncor Millennium	485838	6309341	-	1	1	1	Mid-channel grab
STR-3	Steepbank River upstream of North Steepbank River	499874	6297592	-	-	-	1	Mid-channel grab
Muskeg River and Muskeg River Tributaries								
MUR-1*	Muskeg River (mouth)	463519	6332463	1	1	1	1	Mid-channel grab
MUR-6A	Muskeg River upstream of Wapasu Creek	492237	6354936	-	-	-	1	Mid-channel grab
JAC-1	Jackpine Creek (mouth)	471866	6346436	-	-	-	1	Mid-channel grab
JAC-2	Jackpine Creek (upstream)	480033	6324995	-	-	-	1	Mid-channel grab
MUC-1	Muskeg Creek (mouth)	481030	6349015	-	-	-	1	Mid-channel grab
IYC-1	Iyinimin Creek	489748	6344886	-	-	-	1	Mid-channel grab
STC-1	Stanley Creek (mouth)	477300	6356710	-	-	-	1	Mid-channel grab
WAC-1	Wapasu Creek at Canterra Road crossing	490287	6355908	-	-	-	1	Mid-channel grab

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids) + PAHs

2 = standard water quality + chlorophyll-a + PAHs

* = monthly sampling

Table 3.1-3 (Cont'd.)

Station Identifier and Location		UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	Winter	Spring	Summer	Fall	
Firebag River								
FIR-1	Firebag River (mouth)	479369	6400440	-	-	-	1	Mid-channel grab
FIR-2	Firebag River upstream of Suncor Firebag	530900	6355270	-	-	-	1	Mid-channel grab
Tributaries to the Athabasca River (Western)								
BER-1	Beaver River (mouth)	463620	6330924	-	-	-	1	Mid-channel grab
POC-1*	Poplar Creek (mouth)	473045	6308835	1	1	1	1	Mid-channel grab
BER-2	Beaver River (upper)	465473	6311287	-	-	-	1	Mid-channel grab
CAR-1	Calumet River (mouth)	460808	6363189	-	-	-	1	Mid-channel grab
CAR-2	Calumet River (upper river)	454027	6366799	-	-	-	1	Mid-channel grab
ELR-1	Ells River (mouth)	459254	6351516	-	-	-	1	Mid-channel grab
ELR-3	Ells River (upstream)	440398	6342423	1	1	1	1	Mid-channel grab
TAR-1	Tar River (mouth)	458846	6353513	-	-	-	1	Mid-channel grab
TAR-2	Tar River upstream of Canadian Natural Horizon	440347	6361661	-	-	-	1	Mid-channel grab
PIR-1	Pierre River (mouth)	462262	6367486	-	-	-	1	Mid-channel grab
EYC-1	Eymundson Creek (mouth)	465876	6372331	-	-	-	1	Mid-channel grab
BIC-1	Big Creek (mouth)	471619	6387768	-	-	-	1	Mid-channel grab
RCC-1	Red Clay Creek (mouth)	475771	6395073	-	-	-	1	Mid-channel grab
MacKay River								
MAR-1	MacKay River (mouth)	461100	6336452	-	-	-	1	Mid-channel grab
MAR-2*	MacKay River upstream of Suncor MacKay	444868	6314100	1	1	1	1	Mid-channel grab
MAR-2A	MacKay River upstream of Suncor Dover	449746	6320067	-	-	-	1	Mid-channel grab
Lakes and Wetlands								
ISL-1	Isadore's Lake	463304	6343405	-	-	-	2	Mid-lake grab
KEL-1	Kearl Lake	484933	6348857	-	-	-	2	Mid-lake grab
MCL-1	McClelland Lake	478648	6372008	-	-	-	2	Mid-lake grab
SHL-1	Shipyard Lake	473405	6313057	-	-	-	2	Mid-lake grab
JOL-1	Johnson Lake	538072	6391747	2	2	2	2	Mid-lake grab
CHL-1	Christina Lake	497045	6164621	2	2	2	2	Mid-lake grab
NAL-1	Namur Lake	402184	6369225	2	2	2	2	Mid-lake grab
GAL-1	Gardiner Lake	410783	6377852	2	2	2	2	Mid-lake grab
GRL-1	Gregoire Lake	494459	6254984	2	2	2	2	Mid-lake grab
Tributaries to Lakes								
MIC-1	Mills Creek, tributary to Isadore's Lake	463758	6344925	-	-	-	1	Mid-channel grab
QA/QC[1]								
-				1	1	1	1	Trip and field blanks, split, duplicate

Legend

1 = standard water quality variables (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids) + PAHs

2 = standard water quality + chlorophyll-a + PAHs

* = monthly sampling

Table 3.1-4 Standard water quality variables measured in support of the 2014 JOSMP.

Group	Analyte	Units	Detection Limit	Analytical Method	VMV Code	Lab
Conventional Variables	Conductivity	µS/cm	0.2	APHA 4500-H, 2510, 2320	2041	ALS
	Dissolved Organic Carbon	mg/L	1	APHA 5310 C-Instrumental	6101	ALS
	Hardness (as $CaCO_3$)	mg/L	-	APHA 1030E	10602	ALS
	pH	pH	0.1	APHA 4500-H, 2510, 2320	10301	ALS
	Total alkalinity	mg/L	2	APHA 4500-H, 2510, 2320	10165	ALS
	Total Dissolved Solids	mg/L	12	APHA 2540 C	99558	ALS
	Total Dissolved Solids (Calculated)	mg/L	-	APHA 1030E	203	ALS
	Total Organic Carbon	mg/L	1	APHA 5310 C-Instrumental	6001	ALS
	Total Suspended Solids	mg/L	3	APHA 2540 D	102455	ALS
	True Colour	TCU	2	APHA 2120	2021	ALS
General Organics	Benzene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108880	ALS
	CCME Fraction 1 (BTEX)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	107875	ALS
	CCME Fraction 1 (C6-C10)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	107874	ALS
	CCME Fraction 2 (C10-C16)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107876	ALS
	CCME Fraction 3 (C16-C34)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107878	ALS
	CCME Fraction 4 (C34-C50)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107880	ALS
	Ethylbenzene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108916	ALS
	m+p-Xylene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108937	ALS
	Naphthenic acids	mg/L	0.02	GC/MS-ion-trapping, 2011 standard	108338	AITF
	Oilsands extractable	mg/L	0.1	GC/MS-ion-trapping, 2011 standard	108477	AITF
	o-Xylene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108936	ALS
	Toluene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108925	ALS
	Total phenolics	mg/L	0.001	AB ENV.06537-COLORIMETRIC	6537	ALS
	Total recoverable hydrocarbons	mg/L	1	APHA 5520 F		ALS
	Xylenes	mg/L	0.00071	EPA 5021/8015&8260 GC-MS & FID	109160	ALS
Major ions	Bicarbonate (HCO_3)	mg/L	5	APHA 4500-H, 2510, 2320	6201	ALS
	Calcium (Ca)	mg/L	0.5	APHA 3030 B&E/EPA SW-846 6020A	104568	ALS
	Carbonate (CO_3)	mg/L	5	APHA 4500-H, 2510, 2320	6301	ALS
	Chloride (Cl)	mg/L	0.5	APHA 4110 B-ION CHROMATOGRAPHY	99494	ALS
	Hydroxide (OH)	mg/L	5	APHA 4500-H, 2510, 2320	8501	ALS
	Ion Balance	%	-	APHA 1030E	118	ALS
	Magnesium (Mg)	mg/L	0.1	APHA 3030 B&E/EPA SW-846 6020A	104587	ALS
	Potassium (K)	mg/L	0.5	APHA 3030 B&E/EPA SW-846 6020A	104599	ALS
	Sodium (Na)	mg/L	1	APHA 3030 B&E/EPA SW-846 6020A	104609	ALS
	Sulphate (SO_4)	mg/L	0.5	APHA 4110 B-ION CHROMATOGRAPHY	98228	ALS
	Sulphide	mg/L	0.0015	APHA 4500 -S E-Auto-Colorimetry	-	ALS
Nutrients and BOD	Ammonia-N	mg/L	0.05	APHA 4500 NH3-NITROGEN (AMMONIA)	-	ALS
	Biochemical Oxygen Demand	mg/L	2	APHA 5210 B-5 day Incub.-O2 electrode	8202	ALS
	Nitrate	mg/L	0.05	APHA 4110 B-ION CHROMATOGRAPHY	102961	ALS
	Nitrate+Nitrite	mg/L	0.054	CALCULATION	103392	ALS
	Nitrite	mg/L	0.02	APHA 4110 B-ION CHROMATOGRAPHY	102962	ALS
	Phosphorus, dissolved	mg/L	0.001	APHA 4500-P PHOSPHORUS	15113	ALS
	Phosphorus, total	mg/L	0.001	APHA 4500-P PHOSPHORUS	15406	ALS
	Total Kjeldahl Nitrogen	mg/L	0.2	APHA 4500-NORG (TKN)	7021	ALS
	Total nitrogen	mg/L	-	(Calculated)	-	-
Total Metals	Aluminum	mg/L	0.0002	ICP/MS by DRC-II	103999	AITF
	Antimony	mg/L	0.000001	ICP/MS by DRC-II	80043	AITF
	Arsenic	mg/L	0.000004	ICP/MS by DRC-II	80020	AITF
	Barium	mg/L	0.000004	ICP/MS by DRC-II	80022	AITF
	Beryllium	mg/L	0.000008	ICP/MS by DRC-II	80023	AITF
	Bismuth	mg/L	0.000001	ICP/MS by DRC-II	80024	AITF
	Boron	mg/L	0.0001	ICP/MS by DRC-II	80021	AITF
	Cadmium	mg/L	0.000002	ICP/MS by DRC-II	80026	AITF
	Calcium	mg/L	0.01	ICP/MS by DRC-II	80025	AITF
	Chlorine	mg/L	0.04	ICP/MS by DRC-II	80027	AITF

Table 3.1-4 (Cont'd.)

Group	Analyte	Units	Detection Limit	Analytical Method	VMV Code	Lab
Total Metals (Cont'd.)	Chromium	mg/L	0.00003	ICP/MS by DRC-II	80029	AITF
	Cobalt	mg/L	0.000002	ICP/MS by DRC-II	80028	AITF
	Copper	mg/L	0.00005	ICP/MS by DRC-II	80030	AITF
	Iron	mg/L	0.0007	ICP/MS by DRC-II	80031	AITF
	Lead	mg/L	0.000003	ICP/MS by DRC-II	80041	AITF
	Lithium	mg/L	0.00005	ICP/MS by DRC-II	80034	AITF
	Manganese	mg/L	0.000005	ICP/MS by DRC-II	80036	AITF
	Mercury	mg/L	0.000008	ICP/MS by DRC-II	80032	AITF
	Mercury (Hg), ultra-trace	ng/L	0.08	ICP/MS by DRC-II	74475	AITF
	Molybdenum	mg/L	0.000002	ICP/MS by DRC-II	80037	AITF
	Nickel	mg/L	0.000008	ICP/MS by DRC-II	80039	AITF
	Selenium	mg/L	0.00006	ICP/MS by DRC-II	80044	AITF
	Silver	mg/L	0.000002	ICP/MS by DRC-II	103998	AITF
	Strontium	mg/L	0.000001	ICP/MS by DRC-II	80047	AITF
	Sulphur	mg/L	0.2	ICP/MS by DRC-II	80042	AITF
	Thallium	mg/L	0.0000009	ICP/MS by DRC-II	80053	AITF
	Thorium	mg/L	0.0000009	ICP/MS by DRC-II	80048	AITF
	Tin	mg/L	0.000003	ICP/MS by DRC-II	80046	AITF
	Titanium	mg/L	0.00005	ICP/MS by DRC-II	80049	AITF
	Uranium	mg/L	0.000003	ICP/MS by DRC-II	80054	AITF
	Vanadium	mg/L	0.00001	ICP/MS by DRC-II	80055	AITF
	Zinc	mg/L	0.0001	ICP/MS by DRC-II	80056	AITF
Dissolved Metals	Aluminum	mg/L	0.00013	ICP/MS by DRC-II	103927	AITF
	Antimony	mg/L	0.000008	ICP/MS by DRC-II	103951	AITF
	Arsenic	mg/L	0.000003	ICP/MS by DRC-II	103928	AITF
	Barium	mg/L	0.00005	ICP/MS by DRC-II	103930	AITF
	Beryllium	mg/L	0.000009	ICP/MS by DRC-II	103931	AITF
	Bismuth	mg/L	0.000003	ICP/MS by DRC-II	103932	AITF
	Boron	mg/L	0.00013	ICP/MS by DRC-II	103929	AITF
	Cadmium	mg/L	0.000002	ICP/MS by DRC-II	103934	AITF
	Calcium	mg/L	0.03	ICP/MS by DRC-II	103933	AITF
	Chlorine	mg/L	0.03	ICP/MS by DRC-II	103935	AITF
	Chromium	mg/L	0.0001	ICP/MS by DRC-II	103937	AITF
	Cobalt	mg/L	0.000002	ICP/MS by DRC-II	103936	AITF
	Copper	mg/L	0.00008	ICP/MS by DRC-II	103938	AITF
	Iron	mg/L	0.0006	ICP/MS by DRC-II	103939	AITF
	Lead	mg/L	0.000004	ICP/MS by DRC-II	103949	AITF
	Lithium	mg/L	0.00002	ICP/MS by DRC-II	103942	AITF
	Manganese	mg/L	0.00001	ICP/MS by DRC-II	103944	AITF
	Mercury	mg/L	0.000009	ICP/MS by DRC-II	103940	AITF
	Molybdenum	mg/L	0.000002	ICP/MS by DRC-II	103945	AITF
	Nickel	mg/L	0.000006	ICP/MS by DRC-II	103947	AITF
	Selenium	mg/L	0.00004	ICP/MS by DRC-II	103952	AITF
	Silver	mg/L	0.000001	ICP/MS by DRC-II	103926	AITF
	Strontium	mg/L	0.00007	ICP/MS by DRC-II	103955	AITF
	Sulphur	mg/L	0.2	ICP/MS by DRC-II	103950	AITF
	Thallium	mg/L	0.0000004	ICP/MS by DRC-II	103958	AITF
	Thorium	mg/L	0.0000008	ICP/MS by DRC-II	103956	AITF
	Tin	mg/L	0.000003	ICP/MS by DRC-II	103954	AITF
	Titanium	mg/L	0.00008	ICP/MS by DRC-II	103957	AITF
	Uranium	mg/L	0.000002	ICP/MS by DRC-II	103959	AITF
	Vanadium	mg/L	0.00002	ICP/MS by DRC-II	103960	AITF
	Zinc	mg/L	0.00009	ICP/MS by DRC-II	103961	AITF

Table 3.1-5 PAH variables measured in water collected in support of the 2014 JOSMP.

Group	Analyte	Units	Average Reporting Limit	Blank-Corrected Detection Limit	Analytical Method	Lab
	Biphenyl	ng/L	0.094	1.631	LR GC/MS	AXYS
	C1-Biphenyls	ng/L	0.084	9.498	LR GC/MS	AXYS
	C2-Biphenyls	ng/L	0.131	45.410	LR GC/MS	AXYS
	Naphthalene	ng/L	0.159	34.517	LR GC/MS	AXYS
	C1-Naphthalenes	ng/L	0.135	16.678	LR GC/MS	AXYS
	C2-Naphthalenes	ng/L	0.215	4.813	LR GC/MS	AXYS
	C3-Naphthalenes	ng/L	0.141	2.860	LR GC/MS	AXYS
	C4-Naphthalenes	ng/L	0.185	4.611	LR GC/MS	AXYS
	Acenaphthylene	ng/L	0.091	.272	LR GC/MS	AXYS
	Acenaphthene	ng/L	0.116	.477	LR GC/MS	AXYS
	C1-Acenaphthenes	ng/L	0.114	.479	LR GC/MS	AXYS
	Fluorene	ng/L	0.069	.497	LR GC/MS	AXYS
	C1-Fluorenes	ng/L	0.138	5.475	LR GC/MS	AXYS
	C2-Fluorenes	ng/L	0.120	2.744	LR GC/MS	AXYS
	C3-Fluorenes	ng/L	0.200	8.118	LR GC/MS	AXYS
	Phenanthrene	ng/L	0.081	1.566	LR GC/MS	AXYS
	Anthracene	ng/L	0.083	0.154	LR GC/MS	AXYS
	C1-Phenanthrenes/Anthracenes	ng/L	0.111	0.887	LR GC/MS	AXYS
	C2-Phenanthrenes/Anthracenes	ng/L	0.079	2.248	LR GC/MS	AXYS
	C3-Phenanthrenes/Anthracenes	ng/L	0.122	1.844	LR GC/MS	AXYS
	C4-Phenanthrenes/Anthracenes	ng/L	0.237	3.717	LR GC/MS	AXYS
PAHs	Retene	ng/L	0.241	0.591	LR GC/MS	AXYS
	Dibenzothiophene	ng/L	0.090	0.439	LR GC/MS	AXYS
	C1-Dibenzothiophenes	ng/L	0.120	0.251	LR GC/MS	AXYS
	C2-Dibenzothiophenes	ng/L	0.124	1.346	LR GC/MS	AXYS
	C3-Dibenzothiophenes	ng/L	0.159	1.546	LR GC/MS	AXYS
	C4-Dibenzothiophenes	ng/L	0.144	2.547	LR GC/MS	AXYS
	Fluoranthene	ng/L	0.053	0.649	LR GC/MS	AXYS
	Pyrene	ng/L	0.052	0.486	LR GC/MS	AXYS
	C1-Fluoranthenes/Pyrenes	ng/L	0.202	1.253	LR GC/MS	AXYS
	C2-Fluoranthenes/Pyrenes	ng/L	0.174	1.539	LR GC/MS	AXYS
	C3-Fluoranthenes/Pyrenes	ng/L	0.166	0.894	LR GC/MS	AXYS
	Benz[a]anthracene	ng/L	0.070	0.176	LR GC/MS	AXYS
	Chrysene	ng/L	0.070	0.299	LR GC/MS	AXYS
	C1-Benzo[a]anthracenes/Chrysenes	ng/L	0.081	0.371	LR GC/MS	AXYS
	C2-Benzo[a]anthracenes/Chrysenes	ng/L	0.108	0.398	LR GC/MS	AXYS
	Benzo[b,j,k]fluoranthene	ng/L	0.099	0.230	LR GC/MS	AXYS
	Benzo[a]pyrene	ng/L	0.149	0.217	LR GC/MS	AXYS
	C1-Benzofluoranthenes/Benzopyrenes	ng/L	0.177	0.819	LR GC/MS	AXYS
	C2-Benzofluoranthenes/Benzopyrenes	ng/L	0.185	0.995	LR GC/MS	AXYS
	Indeno[1,2,3-c,d]-pyrene	ng/L	0.122	0.227	LR GC/MS	AXYS
	Dibenz[a,h]anthracene	ng/L	0.129	0.703	LR GC/MS	AXYS
	Benzo[g,h,i]perylene	ng/L	0.107	0.153	LR GC/MS	AXYS

Where a mean RL was greater than the blank-corrected DL, the RL was adopted as the project-wide DL. In most cases, the blank-corrected DL was higher than the mean RL, resulting in the adoption of the blank-corrected DL as the project-wide DL. This resulted in an increase in detection limits for most PAH compounds, typically of less than one order of magnitude. However, for some PAHs, the DL increased by over an order of magnitude. Both PAH-specific RLs and associated, blank-corrected DLs are provided in Table 3.1-5.

A result of applying these blank-corrected detection/reporting limits was an increase in the number of non-detectable concentrations. However, this was necessary to reduce the likelihood of false positives in the dataset. Conversely, concentrations of total PAHs were increased by use of this blank-correction method for DLs, given that total PAHs were reported as the sum of all PAH compounds calculated using 1x the project-wide DL, to be conservative (i.e., estimate on the high side) and to be consistent with other summation variables presented in this report (e.g., total PAHs in sediments).

3.1.2.3 Changes in Monitoring Network from 2013

The 2014 monitoring network for the Water Quality component was the same as the 2013 monitoring network with the following exceptions:

- Four seasonal *test* stations were removed from the sampling program including; Athabasca River east and west bank upstream of the Steepbank River (ATR-SR-E and ATR-SR-W) and Athabasca River east and west bank upstream of the Muskeg River (ATR-MR-E and ATR-MR-W);
- Athabasca River east and west bank upstream of the Donald Creek (ATR-DC-E and ATR-DC-W) was only sampled in March 2014 and then removed from the program;
- Athabasca River downstream of development center channel (ATR-DD-C) was added to the seasonal sampling program starting in the spring sampling event;
- Two stations were added to the monthly sampling program starting in April 2014, including the Steepbank River upstream of Suncor Millennium (STR-2) and the Christina River upstream of Janvier (CHR-2); and
- Four new stations were established, including the Gregoire River (GRR-1, *test*), Namur Lake (NAL-1, *baseline*), Gardiner Lake (GAL-1, *baseline*), and Gregoire Lake (GRL-1, *test*) and sampled seasonally starting in the spring.

3.1.2.4 Changes in Analytical Chemistry Methods from 2013

No changes were made in analytical chemistry methods from 2013 to 2014.

3.1.2.5 Challenges Encountered and Solutions Applied

All planned sampling was undertaken without major issue or incident.

3.1.2.6 Other Information Obtained

All sampling in 2014 was conducted by the Hatfield implementation team, with the exception of three stations on the mainstem Athabasca River (ATR-UFM, ATR-OF, and ATR-FR) that were sampled by AESRD, with the data for ATR-UFM and ATR-OF provided for inclusion in the analyses contained in this report (Table 3.1-3). The analytical package used by AESRD for PAHs, CCME hydrocarbons, and BTEX differed from this program's analytical procedures, with higher detection limits in the AESRD data.

3.1.2.7 Summary of Component Data Now Available

Water quality data collected to date are summarized in Table 3.1-6. Table 3.1-6 does not include all data collected by AESRD, only the data provided for this report.

Table 3.1-6 Summary of data available for the Water Quality component of the JOSMP, 1997 to 2014. (Page 1 of 2)

See symbol key below.

Waterbody and Location	Station	1997 W	1997 S	1997 S	1997 F	1998 W	1998 S	1998 S	1998 F	1999 W	1999 S	1999 S	1999 F	2000 W	2000 S	2000 S	2000 F	2001 W	2001 S	2001 S	2001 F	2002 W	2002 S	2002 S	2002 F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11
Upstream Donald Creek (cross channel)	ATR-DC-CC		1	1	1																				3
(west bank) [b]	ATR-DC-W								1								1				3				1
(east bank) [b]	ATR-DC-E								1								1				3				1
(middle)	ATR-DC-M																1								
Upstream of the Steepbank River (middle)	ATR-SR-M																1								
(west bank)	ATR-SR-W																1				1				1
(east bank)	ATR-SR-E																1				1				1
Upstream of the Muskeg River (middle)	ATR-MR-M																1								
(west bank) [b c]	ATR-MR-W								1								1				1				1
(east bank) [b c]	ATR-MR-E								1								1				1				1
Upstream Fort Creek (cross channel)	ATR-FC-CC-D		1	1	1																				
(west bank) [b c]	ATR-FC-W								1								1				3				1
(east bank) [b c]	ATR-FC-E								1								1				3				1
(middle)	ATR-FC-M																1								
Downstream of all development (cross channel)	ATR-DD-CC																					1	1	1	3
(centre channel)	ATR-DD-C																								
(east bank)	ATR-DD-E																								
(west bank)	ATR-DD-W																								
Upstream of mouth of Firebag River	ATR-FR-CC																								1
Upstream of the Embarras River (cross channel)	ATR-ER									1							1				3				
Embarras River	EMR-1																								
At Old Fort (grab) [d]	ATR-OF													11	11	11	11	11	11	11	11	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1											1					1				1				
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1											6	7		6	6	9		6	6	9		6	6	7
(100 m upstream)	MCC-2											6	6												
Steepbank River (mouth)	STR-1	3	1	1	1		1	1	1	1							1				1	1			1
(upstream of Project Millennium)	STR-2																					1			1
(upstream of Nt. Steepbank)	STR-3																								
North Steepbank River (upstream of Suncor Lewis)	NSR-1																						1	1	1
Fort Creek (mouth)	FOC-1														7		7		6	6	7		6	6	7
Muskeg River																									
Mouth [f i]	MUR-1			1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1
Upstream of Wapasu Creek	MUR-6								1,2		7	7	7		6	6	9		6	6	7		6	6	7
(1000 m upstream of MUR-6)	MUR-6A																								
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10
Jackpine Creek (mouth) [g]	JAC-1					13	13	13	11	13	13	13	11,1				1				1				1
(upper)	JAC-2																								
Shelley Creek (mouth)	SHC-1								11				11,1												
Muskeg Creek (mouth)	MUC-1								11,2				11,1				1				1				1
Stanley Creek (mouth)	STC-1								11				11,1								1	1	1	1	1
Iyinimin Creek (mouth)	IYC-1																								
Wapasu Creek (Canterra Road Crossing)	WAC-1								11,2	1			11,1												

Waterbody and Location	Station	2003 W	2003 S	2003 S	2003 F	2004 W	2004 S	2004 S	2004 F	2005 W	2005 S	2005 S	2005 F	2006 W	2006 S	2006 S	2006 F	2007 W	2007 S	2007 S	2007 F	2008 W	2008 S	2008 S	2008 F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	11	13	11	13
Upstream Donald Creek (cross channel)	ATR-DC-CC				3				1				1	1			1				1				
(west bank) [b]	ATR-DC-W				1				1				1				1				1	1			1
(east bank) [b]	ATR-DC-E				1				1				1				1				1	1			1
(middle)	ATR-DC-M																								
Upstream of the Steepbank River (middle)	ATR-SR-M																								
(west bank)	ATR-SR-W				1				1				1				1				1				1
(east bank)	ATR-SR-E				1				1				1				1				1				1
Upstream of the Muskeg River (middle)	ATR-MR-M																								
(west bank) [b c]	ATR-MR-W				1				1				1				1				1				1
(east bank) [b c]	ATR-MR-E				1				1				1				1				1				1
Upstream Fort Creek (cross channel)	ATR-FC-CC-D																								
(west bank) [b c]	ATR-FC-W				1																				
(east bank) [b c]	ATR-FC-E				1																				
(middle)	ATR-FC-M																								
Downstream of all development (cross channel)	ATR-DD-CC	1,1	1	1	3	1,1	1	1	3	1,1	1	1	1												
(centre channel)	ATR-DD-C																								
(east bank)	ATR-DD-E									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(west bank)	ATR-DD-W									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Upstream of mouth of Firebag River	ATR-FR-CC				1				1				1				1				1				1
Upstream of the Embarras River (cross channel)	ATR-ER								1																
Embarras River	EMR-1				1																				
At Old Fort (grab) [d]	ATR-OF	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1				1				1																
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1		6	6	7		6	6	9		7	7	9		6	6	9				9				1
(100 m upstream)	MCC-2																								
Steepbank River (mouth)	STR-1				1				1				1				1				1	1			1
(upstream of Project Millennium)	STR-2				1				1				1				1				1				1
(upstream of Nt. Steepbank)	STR-3					1	1	1	1	1	1	1	1		1	1	1	1	1	1	1				1
North Steepbank River (upstream of Suncor Lewis)	NSR-1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
Fort Creek (mouth)	FOC-1		6	6	7										6	6	7				7		6	6	7
Muskeg River																									
Mouth [f i]	MUR-1				1				1				1				1				1				1
Upstream of Wapasu Creek	MUR-6		6	6	7		6	6	7		6	6	7		6	6	7				7		6	6	7
(1000 m upstream of MUR-6)	MUR-6A																								
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1	4	10	10	10	4	10	10	10																
Jackpine Creek (mouth) [g]	JAC-1				1		1	1	1				1				1				1				1
(upper)	JAC-2																								1
Shelley Creek (mouth)	SHC-1																1				1				
Muskeg Creek (mouth)	MUC-1				1	1	1	1	1				1				1				1	1	1	1	1
Stanley Creek (mouth)	STC-1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
Iyinimin Creek (mouth)	IYC-1																			1	1				1
Wapasu Creek (Canterra Road Crossing)	WAC-1								1				1				1				1				1

Waterbody and Location	Station	2009 W	2009 S	2009 S	2009 F	2010 W	2010 S	2010 S	2010 F	2011 W	2011 S	2011 S	2011 F	2012 W	2012 S	2012 S	2012 F	2013 W	2013 S	2013 S	2013 F	2014 W	2014 S	2014 S	2014 F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13
Upstream Donald Creek (cross channel)	ATR-DC-CC																								
(west bank) [b]	ATR-DC-W	1			1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3			
(east bank) [b]	ATR-DC-E	1			1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3			
(middle)	ATR-DC-M																								
Upstream of the Steepbank River (middle)	ATR-SR-M																								
(west bank)	ATR-SR-W				1				1				3				3				3				
(east bank)	ATR-SR-E				1				1				3				3				3				
Upstream of the Muskeg River (middle)	ATR-MR-M																								
(west bank) [b c]	ATR-MR-W				1				1				3				3				3				
(east bank) [b c]	ATR-MR-E				1				1				3				3				3				
Upstream Fort Creek (cross channel)	ATR-FC-CC-D																								
(west bank) [b c]	ATR-FC-W																								
(east bank) [b c]	ATR-FC-E																								
(middle)	ATR-FC-M																								
Downstream of all development (cross channel)	ATR-DD-CC																								
(centre channel)	ATR-DD-C																						3	3	3
(east bank)	ATR-DD-E	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
(west bank)	ATR-DD-W	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Upstream of mouth of Firebag River	ATR-FR-CC				1				1				3				3								
Upstream of the Embarras River (cross channel)	ATR-ER																								
Embarras River	EMR-1																								
At Old Fort (grab) [d]	ATR-OF	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1																								
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1				1				1				3				3				3				3
(100 m upstream)	MCC-2																								
Steepbank River (mouth)	STR-1	1			1	1			1	1			3	3			3	3			3	3			3
(upstream of Project Millennium)	STR-2				1				1				3				3				3		3	3	3
(upstream of Nt. Steepbank)	STR-3				1				1				3				3				3				3
North Steepbank River (upstream of Suncor Lewis)	NSR-1				1				1				3				3				3				3
Fort Creek (mouth)	FOC-1		6	6	7				1				3				3				3				3
Muskeg River																									
Mouth [f i]	MUR-1				1				1				3				3	3	3	3	3	3	3	3	3
Upstream of Wapasu Creek	MUR-6				1				1				3				3								
(1000 m upstream of MUR-6)	MUR-6A																				3				3
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1																								
Jackpine Creek (mouth) [g]	JAC-1				1				2				3				3				3				3
(upper)	JAC-2				1				2				3				3				3				3
Shelley Creek (mouth)	SHC-1				1								3												
Muskeg Creek (mouth)	MUC-1												3				3				3				3
Stanley Creek (mouth)	STC-1				1				1				3				3				3				3
Iyinimin Creek (mouth)	IYC-1								1				3				3				3				3
Wapasu Creek (Canterra Road Crossing)	WAC-1				1				1				3				3				3				3

Note: Monitoring for the Water Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard water quality variables (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard w.q. + chronic toxicity testing (Pseudokirchneriella subcapitata, *Ceriodaphnia dubia*, Pimephales promelusfathead minnow)
3 = standard water quality + PAHs
4 = standard water quality + chronic tox testing + PAHs
5 = standard water quality for OPTI lakes
6 = thermograph
7 = thermograph + standard water quality
8 = thermograph + standard water quality + PAHs
9 = thermograph + standard water quality + chronic tox. testing
10 = thermograph + standard water quality + chronic tox testing + PAHs
11 = AESRD routine variables (conventional variables, major ions, nutrients and total metals)
12 = AESRD routine variables + RAMP standard variables
13 = AESRD routine variables + PAHs
14 = AESRD routine variables + Datasonde
15 = AESRD routine variables + PAHs + Datasonde
16 = standard water quality + chlorophyll-a
17 = standard water quality + chlorophyll-a + PAHs

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2, and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional variables; quarterly sampling for total and dissolved metals
[e] In 1999, one composite samples was prepared with water from Big Point, Goose Island, Embarras River, and an unnamed side channel
[f] All testing, with the exception of thermographs, is conducted by individual industry
[g] AESRD collects/collected nine samples throughout the year, although only three are/were analyzed for PAHs
[h] In 1999, MUR-4 was located upstream of Shelley Creek
[i] Monthly sampling initiated in 2013.

- (blue) *Test* (downstream of oil sands developments)
- (light green) *Baseline* (upstream of oil sands developments)
- (dark green) *Baseline*, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.
- (purple) *Sampling was scheduled but didn't occur* (station was frozen to depth, dry or couldn't be sampled due to another circumstance)

√ = allowance made for potential TIE

Table 3.1-6 (Cont'd.) (Page 2 of 2)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western)																																					
Poplar Creek (mouth)[i]	POC-1																1				1				1				1				1				1
Beaver River (mouth)	BER-1																											1	1			1	1			1	1
(upper)	BER-2																																				
MacKay River (mouth)	MAR-1								1								1				1	1			1				1	1	1	1	1				1
(mid-river, upstream of Suncor Dover)	MAR-2A																																				
(upstream of Suncor MacKay)[i]	MAR-2																					1			1	1	1	1	1				1				1
Dunkirk River (Fish program support)	DUR-1																																				
Ells River (mouth)	ELR-1						1	1	1						11	11	11	11					1	1	2	1	1	1	2	1	1	1	2	1	1	1	2
(upstream of Total Joslyn Mine)	ELR-2														11	11	11	14												1	1	1	2	1	1	1	1
(upstream of the Fort MacKay water intake)	ELR-2A																																				
(upper)	ELR-3																																				
Tar River (mouth)	TAR-1						1	1	1														1	1	2	1	1	1	2	1	1	1	1	1	1	1	1
(upstream of Canadian Natural Horizon)	TAR-2																													1	1	1	1	1	1	1	1
Calumet River (mouth)	CAR-1																						1	1	2	1	1	1	2	1	1	1	2	1	1	1	2
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2																																	1	1	1	2
Firebag River (mouth)	FIR-1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(upstream of Suncor Firebag)	FIR-2																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pierre River (mouth)	PIR-1																																				
Eymundson Creek (mouth)	EYC-1																																				
Big Creek (mouth)	BIC-1																																				
Red Clay Creek (mouth)	RCC-1																																				
Athabasca River tributaries (Southern)																																					
Clearwater River (upstream of Fort McMurray)	CLR-1																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7
(upstream of Christina River)[i]	CLR-2																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7
Christina River (upstream of Fort McMurray)[i]	CHR-1																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1
(upstream of Janvier)	CHR-2																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1
(mid)	CHR-2A																																				
(upstream of Jackfish River)	CHR-3																																				
(upstream of development)	CHR-4																																				
Jackfish River (outlet of Christina Lake)	JAR-1																																				
Sunday Creek (inlet to Chistina Lake)	SUC-1																																				
Sunday Creek (upstream)	SUC-2																																				
Sawbones Creek (inlet to Chistina Lake)	SAC-1																																				
Unnamed Creek (east of Christina Lake)	UNC-2																																				
Unnamed Creek (south of Christina Lake)	UNC-3																																				
Birch Creek	BRC-1																																				
Gregoire River	GRR-1																																				
Hangingstone River (upstream of Fort McMurray)	HAR-1																													1	1	1	1	1	1	1	1
Hangingstone River (mouth)	HAR-1A																																				
Horse River (Fish program support)	HOR-1																																				
High Hills River (mouth)	HHR-1																																				
Lake Tributaries																																					
Mills Creek	MIC-1																																				
Wetlands (Lakes)																																					
Kearl Lake	KEL-1							16+3	16+3								16+3			16	16				1	1			1			16	16			16	16
Isadore's Lake	ISL-1							16									16			16	16											16	16			16	16
Shipyard Lake	SHL-1							16			1	16	1			16	1			16	16			16	16			1	1			16	16			16	16
McClelland Lake	MCL-1																16			1	16				1				1								
Johnson Lake	JOL-1																																				
Christina Lake	CHL-1																																				
Namur Lake	NAL-1																																				
Gregoire Lake	GRL-1																																				
Gardiner Lake	GAL-1																																				
Additional Sampling (Non-Core Programs)																																					
Unnammed Creek north of Ft. Creek (mouth)	UNC-1																1																				
Nexen Lakes	-																		5		5		5		5							5	5		5		5
Potential TIE	-																								√				√				√				
QA/QC																																					
Field and trip blanks, one split and duplicate	-														1	1	1			1	1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Waterbody and Location	Station	2006				2007				2008				2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western)																																					
Poplar Creek (mouth)[i]	POC-1				1				1				1				1				1				3				3	3	3	3	3	3	3	3	3
Beaver River (mouth)	BER-1				1				1	1			1				1				1				3				3				3				3
(upper)	BER-2										1	1	1	1	1	1	1	1	1	1	1				3				3				3				3
MacKay River (mouth)	MAR-1				1				1	1	1	1	1	1	1	1	1				1				3				3				3				3
(mid-river, upstream of Suncor Dover)	MAR-2A													1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3				3				3
(upstream of Suncor MacKay)[i]	MAR-2				1				1	1	1	1	1	1	1	1	1				1				3				3	3	3	3	3	3	3	3	3
Dunkirk River (Fish program support)	DUR-1																1																				
Ells River (mouth)	ELR-1				1				1				1				1				1				3				3				3				3
(upstream of Total Joslyn Mine)	ELR-2	1	1	1	1	1	1	1	1				1				1				1				3				3								
(upstream of the Fort MacKay water intake)	ELR-2A																				1	1	3	3	3	3			3								
(upper)	ELR-3																													3	3	3	3	3	3	3	3
Tar River (mouth)	TAR-1				1				1				1		1	1	1				1				3				3				3				3
(upstream of Canadian Natural Horizon)	TAR-2	1	1	1	2	1	1	1	2				1		1	1	1				1				3				3				3				3
Calumet River (mouth)	CAR-1				1				1				1				1				1				3				3				3				3
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2	1	1	1	2	1	1	1	2				1				1				1				3				3				3				3
Firebag River (mouth)	FIR-1				1				1				1				1				1				3				3				3				3
(upstream of Suncor Firebag)	FIR-2				1				1				1				1				1				3				3				3				3
Pierre River (mouth)	PIR-1																					1	3	3	3	3	3	3	3	3	3	3	3	3			3
Eymundson Creek (mouth)	EYC-1																					1	3	3	3	3	3	3	3	3	3	3	3	3			3
Big Creek (mouth)	BIC-1																					1	3	3	3	3	3	3	3	3	3	3	3	3			3
Red Clay Creek (mouth)	RCC-1																					1	3	3	3	3	3	3	3	3	3	3	3	3			3
Athabasca River tributaries (Southern)																																					
Clearwater River (upstream of Fort McMurray)	CLR-1	1	7	7	7		7	7	7				1				1				1				3				3	3			3				3
(upstream of Christina River)[i]	CLR-2		6	6	7		6		7				1				1				1				3				3		3	3	3	3	3	3	3
Christina River (upstream of Fort McMurray)[i]	CHR-1				1	1			1				1				1				1				3				3	3	3	3	3	3	3	3	3
(upstream of Janvier)	CHR-2				1	1			1				1				1				1				3				3				3		3	3	3
(mid)	CHR-2A					1			1																												
(upstream of Jackfish River)	CHR-3																													3	3	3	3	3	3	3	3
(upstream of development)	CHR-4																													3	3	3	3	3	3	3	3
Jackfish River (outlet of Christina Lake)	JAR-1																										3	3	3	3	3	3	3	3	3	3	3
Sunday Creek (inlet to Chistina Lake)	SUC-1																										3	3	3	3	3	3	3	3	3	3	3
Sunday Creek (upstream)	SUC-2																													3	3	3	3	3	3	3	3
Sawbones Creek (inlet to Chistina Lake)	SAC-1																										3	3	3	3	3	3	3	3	3	3	3
Unnamed Creek (east of Christina Lake)	UNC-2																													3	3	3	3	3	3	3	3
Unnamed Creek (south of Christina Lake)	UNC-3																													3	3	3	3	3	3	3	3
Birch Creek	BRC-1																													3	3	3	3	3	3	3	3
Gregoire River	GRR-1																																		3	3	3
Hangingstone River (upstream of Fort McMurray)	HAR-1	1	1	1	1		1	1	1				1																				3				3
Hangingstone River (mouth)	HAR-1A																																3				3
Horse River (Fish program support)	HOR-1																1																				
High Hills River (mouth)	HHR-1																					1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Lake Tributaries																																					
Mills Creek	MIC-1																				1				3				3				3				3
Wetlands (Lakes)																																					
Kearl Lake	KEL-1				16			16	16				16				16				16				17				17				17				17
Isadore's Lake	ISL-1			16	16			16	16			16	16				16				16				17				17				17				17
Shipyard Lake	SHL-1			16	16			16	16			16	16				16				16				17				17				17				17
McClelland Lake	MCL-1				16				16				16				1				16				17				17				17				17
Johnson Lake	JOL-1																					16	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Christina Lake	CHL-1																										17	17	17	17	17	17	17	17	17	17	17
Namur Lake	NAL-1																																		17	17	17
Gregoire Lake	GRL-1																																		17	17	17
Gardiner Lake	GAL-1																																		17	17	17
Additional Sampling (Non-Core Programs)																																					
Unnammed Creek north of Ft. Creek (mouth)	UNC-1																																				
Nexen Lakes	-		5		5										5		5						5		5						5		5				
Potential TIE	-																																				
QA/QC																																					
Field and trip blanks, one split and duplicate	-	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Note: Monitoring for the Water Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard water quality variables (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard w.q. + chronic toxicity testing (Pseudokirchneriella subcapitata, *Ceriodaphnia dubia,* Pimephales promelusfathead minnow)
3 = standard water quality + PAHs
4 = standard water quality + chronic tox testing + PAHs
5 = standard water quality for OPTI lakes
6 = thermograph
7 = thermograph + standard water quality
8 = thermograph + standard water quality + PAHs
9 = thermograph + standard water quality + chronic tox. testing
10 = thermograph + standard water quality + chronic tox testing + PAHs
11 = AESRD routine variables (conventional variables, major ions, nutrients and total metals)
12 = AESRD routine variables + RAMP standard variables
13 = AESRD routine variables + PAHs
14 = AESRD routine variables + Datasonde
15 = AESRD routine variables + PAHs + Datasonde
16 = standard water quality + chlorophyll-a
17 = standard water quality + chlorophyll-a + PAHs

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2, and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional parameters; quarterly sampling for total and dissolved metals
[e] In 1999, one composite samples was prepared with water from Big Point, Goose Island, Embarras River, and an unnamed side channel
[f] All testing, with the exception of thermographs, is conducted by individual industry
[g] AESRD collects/collected nine samples throughout the year, although only three are/were analyzed for PAHs
[h] In 1999, MUR-4 was located upstream of Shelley Creek
[i] Monthly sampling initiated in 2013.

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)
Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.
Sampling was scheduled but didn't occur (station was frozen to depth, dry or couldn't be sampled due to another circumstance)

√ = allowance made for potential TIE

3.1.3 Benthic Invertebrate Communities and Sediment Quality

3.1.3.1 Overview of 2014 Monitoring Activities for the Benthic Invertebrate Communities Component

Benthic invertebrate communities were sampled from August 19 to 21 and September 2 to 19, 2014. A total of 470 samples were collected from 36 river reaches, four delta channels, and nine lakes (Table 3.1-7, Figure 3.1-4). As in previous years, sampled habitats were classified as either depositional (dominated by fine sediment deposits and low to negligible flow) or erosional (dominated by rocky substrates and frequent riffle areas). These habitat classes have not changed from year to year within a reach. Sampling methods were specific to the habitat class, as described below.

Field Methods

Benthic invertebrates communities were sampled according to standard methods used in previous years by RAMP (Golder 2003, RAMP 2009b), which were developed from Alberta Environment (1990); Environment Canada (1993); Klemm et al. (1990); and Rosenberg and Resh (1993). A Hess cylinder (0.093-m^2 opening and 210-μm mesh) was used for collection of benthic invertebrates in erosional areas. An Ekman grab (0.023 m^2, 6” x 6”) was used for benthic invertebrate collections in depositional habitats. Ekman grab samples were collected by hand in water <1 m deep, and by rope and messenger when water was deeper.

Ten replicate samples were collected from within pre-established river reaches that were typically 1 to 2 km long. Five replicate samples were collected from Athabasca River Delta (ARD) channels. Samples were selected from within each reach, based on habitat availability and approximately equal spacing. The same sampling locations were re-visited from year to year, when conditions permitted. Water level variations from year to year frequently required that sampling be undertaken at different locations than those sampled the previous year.

Ten replicate samples were randomly collected from the littoral area of lakes. The depth sampled in lakes was similar from year to year, and generally between 1 and 2 m.

Samples collected with Ekman grabs (i.e., depositional habitat) were sieved in the field using a 250-μm screen, preserved in 10% buffered formalin, and bottled for transport. Samples collected with Hess cylinders were also preserved in 10% buffered formalin, and bottled for transport.

As in previous years, a series of measurements were recorded as supporting information:

- Wetted and bankfull channel widths – visual estimate (for rivers/streams only);
- Field water quality measurements – dissolved oxygen, conductivity, temperature, and pH. The instrument (hand-held Hanna meter) used to measure conductivity and pH was calibrated according to manufacturer’s instructions; dissolved oxygen was measured by field titrations (portable Winkler titration kit);
- Water velocity – determined by measuring the time for a semi-submerged object to travel a known distance (2 m);

- Water depth at the benthos sampling location – measured with a graduated device (pole or Hess cylinder);
- Amount of benthic algae at erosional stations (for chlorophyll *a* measurement) – obtained by scraping of a 1 cm x 1 cm square from three randomly-selected cobbles and combining these into one composite sample per station;
- Substrate particle size distribution (erosional stations only) – visual estimates of areal coverage by particles in standard size categories using the modified Wentworth classification system (Cummins 1962) and expressed as percentages;
- An additional Ekman grab sample collected at depositional stations for analysis of total organic carbon (TOC, as a dry weight percentage) and particle size (% sand, silt and clay, as dry weight);
- Geographical position – using a hand-held Magellan Global Positioning System (GPS) unit; and
- General station appearance.

Laboratory Methods

ALS Laboratories (Edmonton, Alberta) conducted the chlorophyll *a* analyses for erosional stations and analysis of TOC and particle size distribution for depositional stations.

Dr. Jack Zloty in Summerland, BC performed sorting and taxonomic identifications, as in previous years. Samples were sieved in the laboratory using a 250-μm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by the sieve was elutriated using a flotation technique to separate organic material from sand and gravel, and invertebrates from organic material. Samples containing bitumen were treated with paint thinner to remove hydrocarbons prior to sorting. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. The remaining organic material was separated into coarse and fine size fractions using a 1-mm sieve. The fine size fraction of large samples was sub-sampled using a modification of the method described by Wrona et al. (1982) in which fine materials were scanned for invertebrates with the aid of a dissecting microscope at a magnification of 10X to 20X. All sorted material was preserved for random checks of removal efficiency. QA/QC procedures related to sample processing for benthic invertebrate communities are discussed in Appendix B.

Organisms were identified to lowest practical taxonomic levels using up-to-date taxonomic literature, and as per the guidelines in Appendix D.

Table 3.1-7 Summary of sampling locations for the Benthic Invertebrate Communities component of the 2014 JOSMP.

Waterbody and Location	Habitat[1]	Reach or Station	UTM Coordinates (NAD 83, Zone 12)			
			Downstream Limit of Reach		Upstream Limit of Reach	
			Easting	Northing	Easting	Northing
Athabasca River Delta						
Goose Island Channel	depositional	GIC-1	509483	6494586	509589	6494201
Big Point Channel	depositional	BPC-1	512095	6494150	512088	6494156
Fletcher Channel	depositional	FLC-1	496561	6491825	496342	6491460
Embarrass River	depositional	EMR-2	494745	6492140	494521	6491833
Steepbank River						
Lower Reach	erosional	STR-E1	471387	6320175	472501	6320064
Upper Reach	erosional	STR-E2	499874	6297592	500790	6297515
Muskeg River						
Lower Reach	erosional	MUR-E1	463864	6332369	465091	6332576
Middle Reach	depositional	MUR-D2	466236	6339505	466596	6340498
Upper Reach	depositional	MUR-D3	480075	6357942	482142	6359778
Jackpine Creek						
Lower Reach	depositional	JAC-D1	471866	6346436	473074	6346331
Upper Reach	depositional	JAC-D2	480033	6324995	480771	6324641
Beaver River						
Upper Reach	depositional	BER-D2	465475	6311286	465426	6311013
Poplar Creek						
Lower Reach	depositional	POC-D1	473045	6308835	472533	6308616
Pierre River						
Lower Reach	depositional	PIR-D1	462262	6367486	461920	6367989
Red Clay Creek						
Lower Reach	erosional	RCC-E1	475771	6395073	475469	6395369
Big Creek						
Lower Reach	depositional	BIC-D1	471619	6387768	470920	6387768
Birch Creek						
Lower Reach	depositional	BRC-D1	492165	6163211	491342	6163019
Eymundson Creek						
Lower Reach	depositional	EYC-D1	465876	6372229	465483	6372705
Clearwater River						
Lower Reach	depositional	CLR-D1	479500	6284210	481475	6283377
Upper Reach	depositional	CLR-D2	499210	6279831	501146	6279686
MacKay River						
Lower Reach	erosional	MAR-E1	461554	6336030	460683	6336707
Middle Reach	erosional	MAR-E2	449746	6320067	448860	6319343
Upper Reach	erosional	MAR-E3	444831	6314083	443549	6314148

[1] Sediment quality sampling was conducted at depositional reaches and in lakes.

[2] UTM coordinates of first replicate station.

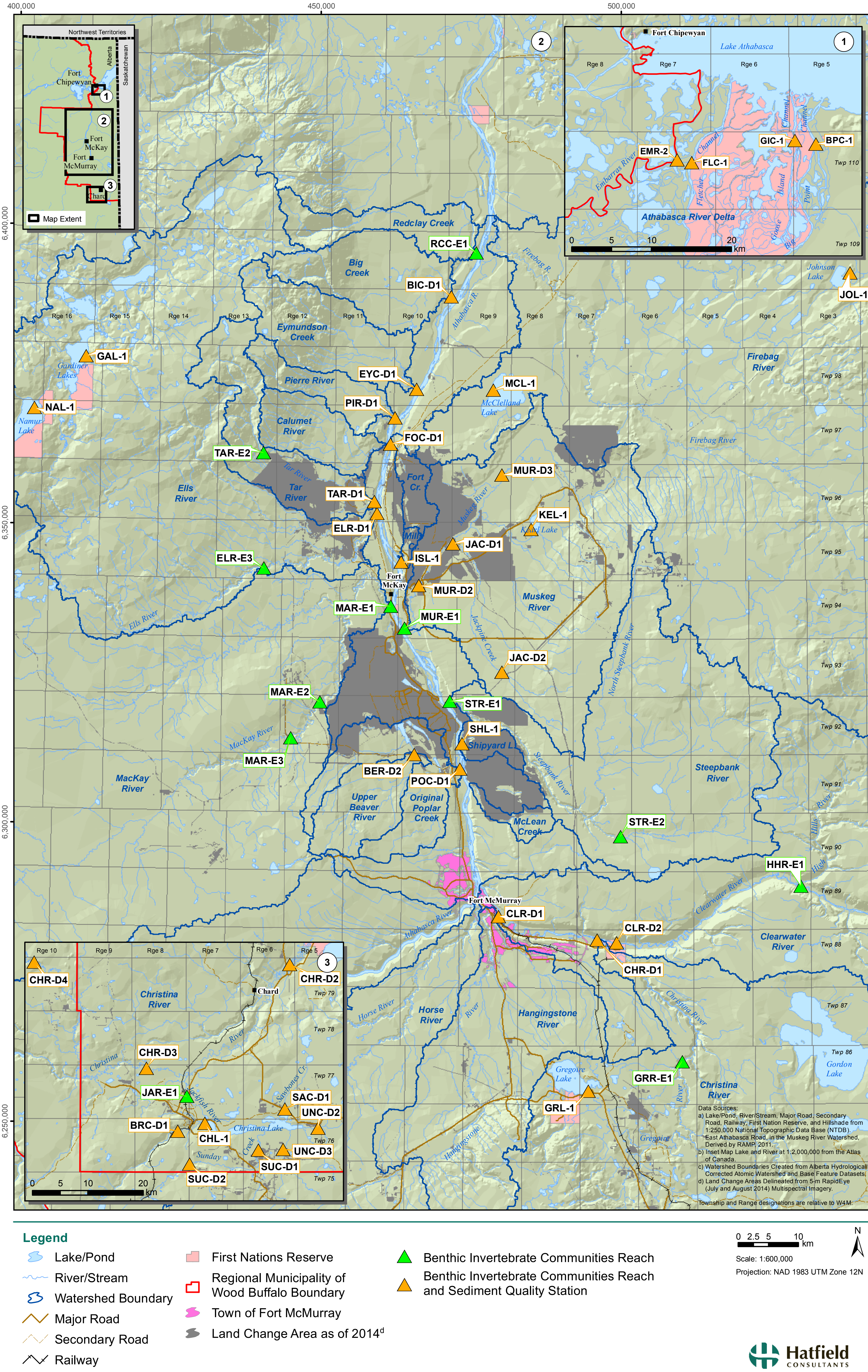
Table 3.1-7 (Cont'd.)

Waterbody and Location	Habitat[1]	Reach or Station	UTM Coordinates (NAD 83, Zone 12)			
			Downstream Limit of Reach		Upstream Limit of Reach	
			Easting	Northing	Easting	Northing
Christina River						
Lower Reach	depositional	CHR-D1	495944	6280314	497674	6278555
Middle Reach	depositional	CHR-D2	512342	6193401	511907	6192464
Middle Reach	depositional	CHR-D3	486502	6174644	486003	6175252
Upper Reach	depositional	CHR-D4	466227	6193840	465868	6193734
Tar River						
Lower Reach	depositional	TAR-D1	458846	6353513	458578	6353569
Upper Reach	erosional	TAR-E2	440347	6361661	439871	6362082
Ells River						
Lower Reach	depositional	ELR-D1	459254	6351516	458602	6351524
Upper Reach	erosional	ELR-E3	440398	6342423	439342	6342675
Unnamed Creek (east of Christina Lake)						
Middle Reach	depositional	UNC-D2	517466	6163740	517883	6163729
Unnamed Creek (south of Christina Lake)						
Upper Reach	depositional	UNC-D3	511159	6159892	510933	6159494
High Hills River						
Lower Reach	erosional	HHR-E1	529929	6289270	530134	6289826
Gregoire River						
Lower Reach	erosional	GRR-E1	510152	6259979	509568	6258954
Fort Creek						
Lower Reach	depositional	FOC-D1	461524	6363111	461729	6363063
Jackfish River						
Lower Reach	erosional	JAR-E1	493813	6169530	494181	6168851
Sawbones Creek						
Lower Reach	depositional	SAC-D1	511458	6167194	511492	6167892
Sunday Creek						
Lower Reach	depositional	SUC-D1	506690	6159784	506272	6159698
Upper Reach	depositional	SUC-D2	494290	6157246	494012	6156737
Lakes[2]						
Kearl Lake	lake	KEL-1	484933	6348857	485348	6349700
McClelland Lake	lake	MCL-1	478620	6372105	478676	6371950
Shipyard Lake	lake	SHL-1	473404	6313057	473611	6313130
Christina Lake	lake	CHL-1	497045	6164620	497805	6163426
Johnson Lake	lake	JOL-1	538059	6391708	537415	6391502
Isadore's Lake	lake	ISL-1	463304	6343405	463712	6343491
Gardiner Lake	lake	GAL-1	410780	6377851	410547	6376984
Gregoire Lake	lake	GRL-1	494459	6254984	493670	6256972
Namur Lake	lake	NAL-1	402184	6369225	402347	6370436

[1] Sediment quality sampling was conducted at depositional reaches and in lakes.

[2] UTM coordinates of first replicate station.

Figure 3.1-4 Locations of benthic invertebrate community reaches and sediment quality stations monitored in support of the 2014 JOSMP.



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Changes in Monitoring Network from 2013

The 2014 monitoring network for the Benthic Invertebrate Communities component was the same as the 2013 monitoring network, with the exception of the following additions and changes:

- A new *test* reach on the Gregoire River (GRR-E1) was added;
- The lower Christina River (*test* reach CHR-D1 and *test* reach CHR-D2) was sampled in 2014, following the rotating panel design of the program;
- The middle Christina River (*test* reach CHR-D3) was changed from an erosional reach (sampled in 2013) to a depositional reach in 2014 for consistency with other reaches on the Christina River;
- The Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2) was sampled in 2014, following the rotating panel design of the program;
- The Firebag River (*test* reach FIR-D1 and *baseline* reach FIR-E2) was not sampled in 2014, following the rotating panel design of the program; and
- Three lakes, Gregoire Lake (*test* lake GRL-1), Gardiner Lake (*baseline* lake GAL-1), and Namur Lake (*baseline* lake NAL-1) were added to program.

Challenges Encountered and Solutions Applied

All planned sampling was undertaken without major issue or incident.

Other Information Obtained

No other information was obtained for this report.

Summary of Component Data Now Available

As of 2014, 3,989 benthic invertebrate community samples have been collected for this program as part of RAMP until 2013 and now in support of the JOSMP. The distribution of stations and reaches, and the time-series of data available for individual locations are presented in Table 3.1-8.

3.1.3.2 Overview of 2014 Monitoring Activities for the Sediment Quality Component

Sediment samples were collected from August 19 to 21 and September 2 to 19, 2014 at the most downstream replicate sampling location in each depositional reach sampled for benthic invertebrate communities (total of 28 depositional reaches), and nine regionally important lakes (Table 3.1-9, Figure 3.1-4).

Summary of Field Methods and Sample Shipping and Analysis

Sediment sampling locations were identified using historical GPS coordinates and, when available, station descriptions recorded for benthic invertebrate community sampling locations. Stations were accessed by helicopter, boat, or all-terrain vehicle.

At each station, sediment grabs were collected with a 6” x 6” Ekman dredge (0.023 m^2). Grab samples were transferred to a stainless-steel pan; once sufficient sediment had been collected for analysis, all samples were homogenized in the pan into a single composite sample with a stainless steel spoon. To minimize potential for sample contamination, pans, spoons, and the dredge were cleaned with Liquinox metal-free soap, rinsed with hexane and acetone, and triple-rinsed with ambient water at each station prior to sampling.

Homogenized samples were transferred into labeled, sterilized glass jars for chemical analyses, sealable plastic bags for metals, and to a sealable plastic bucket for chronic toxicity testing. All samples were stored on ice or refrigerated prior to and during shipment to analytical laboratories. Sediment samples were also collected from each benthic replicate location and placed in sealable plastic bags for particle size and TOC analyses.

All chemical and physical (e.g., particle size, TOC) analyses were conducted by ALS (Edmonton, Alberta), with the exception of PAHs, which were analyzed by AXYS Analytical Services Ltd. (Sidney, British Columbia). Evaluation of sediment toxicity was undertaken by HydroQual Laboratories Ltd. (Calgary, Alberta). Metals were analyzed using ICP/MS. PAHs were analyzed using a high-resolution GC/MS method.

Sediments were analyzed for the standard sediment quality variables previously used by RAMP (Table 3.1-10), with tests of sediment toxicity to aquatic organisms. Sediment toxicity tests followed published Environment Canada protocols (Environment Canada 2010).

A full list of analytical methods and detection limits for sediment quality variables measured in 2014 are provided in Table 3.1-10.

Changes in Monitoring Network from 2013

Given the three-year sampling rotation for some stations, *test* station FIR-D1 (lower reach on the Firebag River) was sampled in 2013, but not in 2014. *Test* station CHR-D1 (lower reach on the Christina River), *test* station CHR-D2 (middle reach on the Christina River), *test* station CAR-D1 (lower reach on the Calumet River), and *baseline* reach CAR-D2 (upper reach on the Calumet River) were sampled in 2014, but not in 2013. Four new stations were added to the sediment sampling network in 2014: *test* station CHR-D3 (middle reach on the Christina River); *test* station GRL-1 (Gregoire Lake); *baseline* station GAL-1 (Gardiner Lake); and *baseline* station NAL-1 (Namur Lake).

Challenges Encountered and Solutions Applied

Due to control-culture test failures at the consulting laboratory, chironomid toxicity results for the four delta stations (*test* stations BPC-1, GIC-1, FLC-1, EMR-2) were not considered valid and could not be used for analysis.

Other Information Obtained

No additional sediment quality information for 2014 was obtained.

Summary of Component Data Now Available

Table 3.1-11 summarizes historical sediment quality sampling undertaken since 1997.

Table 3.1-8 Summary of data available for the Benthic Invertebrate Communities component in support of the JOSMP, 1997 to 2014. (Page 1 of 2)

see symbol key at bottom

WATERBODY AND LOCATION	TYPE	HABITAT	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Delta																																																																										
Athabasca River Delta	1	depositional	ATR,FLC,GIC,BPC																								1				1				1				1								1				1				1				1				1				1				1				1
Embarras River	1	depositional	EMR-1																																																												1				1				1				
Embarras River	1	depositional	EMR-2																																																								1																1
Calumet River																																																																											
Lower Reach	1,2[1]	depositional	CAR-D1																				2				1				1				1				1																1												1								
Upper Reach	1	depositional	CAR-D2																												1				1				1				1												1												1								
Christina River																																																																											
Lower Reach	1	depositional	CHR-D1																								1				1				1				1				1				1								1												1								1
Middle Reach	1	erosional	CHR-E2A																																												1																												
Upper Reach	1	depositional	CHR-D2																								1				1				1				1				1												1												1								1
Upstream of Jackfish River	1	depositional	CHR-D3																																																																				1*				1
Upstream of Development	1	depositional	CHR-D4																																																																					1				1
Clearwater River																																																																											
Downstream of Christina River	1	depositional	CLR-D1																				1				1				1				1				1												1												1												1
Upstream of Christina River	1	depositional	CLR-D2																				1				1				1				1				1												1												1												1
Ells River																																																																											
Lower Reach	1	depositional	ELR-D1																												1				1				1				1				1												1				1				1				1				1
Middle Reach	1	erosional	ELR-E2																												1				1				1				1																								1								
Historical Upper Reach	1	erosional	ELR-E2A																																																								1				1				1								
Upper Reach	1	erosional	ELR-E3																																																																					1				1
Firebag River																																																																											
Lower Reach	1	depositional	FIR-D1																												1				1				1				1				1												1												1				
Upper Reach	1	erosional	FIR-E2																												1				1				1				1				1												1												1				
Fort Creek																																																																											
Lower Reach	1	depositional	FOC-D1												2								1				1				1								1				1				1				1								1				1				1				1				1
Gregoire River																																																																											
Gregoire River	1	erosional	GRR-E1																																																																									1
Hangingstone River																																																																											
Lower Reach	1	erosional	HAR-E1																																1				1				1				1				1																								
High Hills River																																																																											
Lower Reach	1	erosional	HHR-E1																																																													1				1				1				1
Jackpine Creek																																																																											
Lower Reach	1	depositional	JAC-D1																								1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	depositional	JAC-D2																												1				1				1				1				1				1				1				1				1				1				1				1
MacKay River																																																																											
Lower Reach	1	erosional	MAR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1
Middle Reach	1	erosional	MAR-E2																								1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	MAR-E3																																																								1				1				1				1				1
Muskeg River																																																																											
Lower Reach	1	erosional	MUR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1
Middle Reach	1	depositional	MUR-D2																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	depositional	MUR-D3																								1				1				1				1				1				1				1				1				1				1				1				1				1
Big Creek																																																																											
Lower Reach	1	depositional	BIC-D1																																																																						1				1
Eymundson Creek																																																																											
Lower Reach	1	depositional	EYC-D1																																																																						1				1
Pierre River																																																																											
Lower Reach	1	depositional	PIR-D1																																																																						1				1
Red Clay Creek																																																																											
Lower Reach	1	erosional	RCC-E1																																																																						1				1
Steepbank River																																																																											
Lower Reach	1	erosional	STR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	STR-E2																												1				1				1				1				1				1				1				1				1				1				1				1

Note: Monitoring for the Benthic Inverebrate Communities Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Type Legend:

1 = RAMP station

2 = Sampled outside of RAMP (data available to RAMP)

,1 = RAMP standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)

,2 = RAMP standard sediment quality + sediment toxicity (*Chironomus tentans, Hyalella azteca*)

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

[1] sampled outside of RAMP in 2001, became RAMP station in 2002

* sampled in erosional habitat in 2013.

Table 3.1-8 (Cont'd.) (Page 2 of 2)

see symbol key at bottom

WATERBODY AND LOCATION	TYPE	HABITAT	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Tar River																																																																									
Lower Reach	1[1]	depositional	TAR-D1																				2				1				1				1				1				1												1				1				1				1				1				1
Historical Upper Reach	1	erosional	TAR-E1																												1				1				1				1																																
Upper Reach	1	erosional	TAR-E2																																																				1				1				1				1				1				1
Beaver River																																																																									
Lower Reach	1	depositional	BER-D2																																														1				1				1				1				1				1				1
Poplar Creek																																																																									
Lower Reach	1	depositional	POC-D1																																														1				1				1				1				1				1				1
Jackfish River																																																																									
Lower Reach	1	erosional	JAR-E1																																																														1				1				1
Sawbones Creek																																																																									
Lower Reach	1	depositional	SAC-D1																																																														1				1				1
Sunday Creek																																																																									
Lower Reach	1	depositional	SUC-D1																																																														1				1				1
Upper Reach	1	depositional	SUC-D2																																																																		1				1
Birch Creek																																																																									
Lower Reach	1	depositional	BRC-D1																																																																		1				1
Unnamed Creek south of Christina Lake																																																																									
Lower Reach	1	depositional	UNC-D3																																																																		1				1
Unnamed Creek east of Christina Lake																																																																									
Lower Reach	1	depositional	UNC-D2																																																																		1				1
Wetlands and Lakes																																																																									
Christina Lake	1	lake	CHL-1																																																														1				1				1
Gardiner Lake	1	lake	GAL-1																																																																						1
Gregoire Lake	1	lake	GRL-1																																																																						1
Isadore's Lake	1	lake	ISL-1																																						1				1				1				1				1				1				1				1				1
Johnson Lake	1	lake	JOL-1																																																								1				1				1				1
Kearl Lake	1	lake	KEL-1																				1				1				1				1				1				1				1				1				1				1				1				1				1				1
McClelland Lake	1	lake	MCL-1																								1				1												1				1				1				1				1				1				1				1				1
Namur Lake	1	lake	NAL-1																																																																						1
Shipyard Lake	1	lake	SHL-1																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1
Historical Data																																																																									
Historical Data Review																1	1	1	1					1	1	1	1																																														
5-Year Summary Report																																																																									
Summary Report																								1	1																																																
Locations No Longer in Sample Design																																																																									
Athabasca River																																																																									
Near Fort Creek (east bank)	1	depositional	ATR-B-A1 to A3				1																																																																
(west bank)	1	depositional	ATR-B-A4 to A6				1																																																																
Near Donald Creek (east bank)	1	depositional	ATR-B-B1 to B3				1																																																																
(west bank)	1	depositional	ATR-B-B4 to B6				1																																																																	
Suncor near-field monitoring	2	depositional	-																				2																																																				
MacKay River																																																																									
200 m upstream of mouth	1	erosional	MAR-1								1																																																												
500 m upstream of mouth	1	erosional	MAR-2								1																																																												
1.2 km upstream of mouth	1	erosional	MAR-3								1																																																												
Muskeg River																																																																									
50 m upstream of mouth	1	erosional	MUR-1								1																																																												
200 m upstream of mouth	1	erosional	MUR-2								1																																																												
450 m upstream of mouth	1	erosional	MUR-3								1																																																												
Steepbank River																																																																									
50 m upstream of mouth	1	erosional	STR-1								1																																																												
150 m upstream of mouth	1	erosional	STR-2								1																																																												
300 m upstream of mouth	1	erosional	STR-3								1																																																												

Note: Monitoring for the Benthic Inverebrate Communities Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Type Legend:
1 = RAMP station
2 = Sampled outside of RAMP (data available to RAMP)

,1 = RAMP standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)
,2 = RAMP standard sediment quality + sediment toxicity (*Chironomus tentans, Hyalella azteca*)

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)
Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

[1] sampled outside of RAMP in 2001, became RAMP station in 2002
* sampled in erosional habitat in 2013.

Table 3.1-9 Sampling summary for the Sediment Quality component of the 2014 JOSMP (September survey).

Station Identifier and Location		UTM Coordinates (NAD83, Zone12)		Analytical Package
		Easting	Northing	
Athabasca Delta				
FLC-1	Fletcher Channel	496561	6491825	2
GIC-1	Goose Island Channel	509483	6494586	2
BPC-1	Big Point Channel	512095	6494150	2
Embarras River				
EMR-2	Embarras River	494745	6492140	2
Tributaries to the Athabasca River (Eastern)				
FOC-D1	Fort Creek	461524	6363111	2
Tributaries to the Athabasca River (Western)				
BER-D2	Beaver River (upper reach)	465475	6311286	2
ELR-D1	Ells River (lower reach)	459254	6351516	2
TAR-D1	Tar River (lower reach)	458846	6353513	2
POC-D1	Poplar Creek (lower reach)	473045	6308835	2
PIR-D1	Pierre River	462262	6367486	
EYC-D1	Eymundson Creek	465876	6372229	2
BIC-D1	Big Creek	471619	6387768	2
Tributaries to the Athabasca River (Southern)				
CLR-D1	Clearwater River (upstream of Fort McMurray)	479500	6284210	2
CLR-D2	Clearwater River (upstream of Christina River)	499210	6279831	2
CHR-D1	Christina River (upstream of Fort McMurray)	495944	6280314	2
CHR-D2	Christina River (upstream of Janvier)	512342	6193401	2
CHR-D3	Christina River (upstream of Jackfish River)	486502	6174644	2
CHR-D4	Christina River (above Statoil Leismer)	466227	6193840	2
SUC-D1	Sunday Creek (lower reach)	506690	6159784	2
SUC-D2	Sunday Creek (upper reach)	494290	6157246	2
SAC-D1	Sawbones Creek (lower reach)	511458	6167194	2
BRC-D1	Birch Creek	492165	6163211	2
UNC-D2	Unnamed Creek (east of Christina Lake)	517466	6163740	2
UNC-D3	Unnamed Creek (south of Christina Lake)	511159	6159892	2
Muskeg River				
MUR-D2	Muskeg River (middle reach)	466236	6339505	2
MUR-D3	Muskeg River (upper reach)	480075	6357942	2
JAC-D1	Jackpine Creek (lower reach)	471866	6346436	2
JAC-D2	Jackpine Creek (upper reach)	480033	6324995	2
Regional Lakes				
KEL-1	Kearl Lake	484933	6348857	2
MCL-1	McClelland Lake	478620	6372105	2
SHL-1	Shipyard Lake	473404	6313057	2
ISL-1	Isadore's Lake	463304	6343405	2
JOL-1	Johnson Lake	538059	6391708	2
CHL-1	Christina Lake	497045	6164620	2
GAL-1	Gardiner Lake	410780	6377851	2
GRL-1	Gregoire Lake	494459	6254984	2
NAL-1	Namur Lake	402184	6369225	2
QA/QC				
-	Two sets of split and duplicate samples			1
-	Two rinsate blanks			metals, PAHs

Legend to Analytical Packages:

1. Standard variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)
2. Standard variables + toxicity (*Chironomus tentans, Hyalella azteca*)

Table 3.1-10 Standard sediment quality variables measured in support of the 2014 JOSMP.

Group	Analyte	Units	Detection Limit	Analytical Method (VMV code)	Lab
Hydrocarbons and Organic Compounds	2-Bromobenzotrifluoride	%	1	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Benzene	mg/kg	0.005*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 1 (BTEX)	mg/kg	10*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 1 (C6-C10)	mg/kg	10*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 2 (C10-C16)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 3 (C16-C34)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 4 (C34-C50)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Ethylbenzene	mg/kg	0.015	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	m+p-Xylene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	o-Xylene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Toluene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Total Hydrocarbons (C6-C50)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Xylenes	mg/kg	0.1	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
Physical Properties	% Clay	%	0.1	Burt (2009) P46-53	ALS
	% Moisture	%	0.1	Oven dry 105C-Gravimetric (VMV 10042)	ALS
	% Sand	%	0.1	Burt (2009) P46-53	ALS
	% Silt	%	0.1	Burt (2009) P46-53	ALS
	$CaCO_3$ Equivalent	%	0.8	Loeppert and Suarez (1996) P455-456	ALS
	Inorganic Carbon	%	0.1	Loeppert and Suarez (1996) P455-456 (VMV 50303)	ALS
	Texture		-	Burt (2009) P46-53	ALS
	Total Carbon by Combustion	%	0.1	Loeppert and Suarez (1996) P. 973-974 (VMV 6075)	ALS
	Total organic carbon	%	0.1	Loeppert and Suarez (1996) P455-456 (VMV 6078)	ALS
Total Metals	Aluminum (Al)	mg/kg	50	EPA 200.2/6020A	ALS
	Antimony (Sb)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Arsenic (As)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Barium (Ba)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Beryllium (Be)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Bismuth (Bi)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Cadmium (Cd)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Calcium (Ca)	mg/kg	100	EPA 200.2/6020A	ALS
	Chromium (Cr)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Cobalt (Co)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Copper (Cu)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Iron (Fe)	mg/kg	50	EPA 200.2/6020A	ALS
	Lead (Pb)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Lithium (Li)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Magnesium (Mg)	mg/kg	20	EPA 200.2/6020A	ALS

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al (2005).

* Detection limit varied with moisture content in sediment.

Table 3.1-10 (Cont'd.)

Group	Analyte	Units	Detection Limit	Analytical Method (VMV code)	Lab
Total Metals (Cont'd.)	Manganese (Mn)	mg/kg	1	EPA 200.2/6020A	ALS
	Mercury (Hg)	mg/kg	0.05	EPA 200.2/245.1	ALS
	Molybdenum (Mo)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Nickel (Ni)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Phosphorus (P)	mg/kg	50	EPA 200.2/6020A	ALS
	Potassium (K)	mg/kg	50	EPA 200.2/6020A	ALS
	Selenium (Se)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Silver (Ag)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Sodium (Na)	mg/kg	100	EPA 200.2/6020A	ALS
	Strontium (Sr)	mg/kg	1	EPA 200.2/6020A	ALS
	Thallium (Tl)	mg/kg	0.05	EPA 200.2/6020A	ALS
	Tin (Sn)	mg/kg	2	EPA 200.2/6020A	ALS
	Titanium (Ti)	mg/kg	1	EPA 200.2/6020A	ALS
	Uranium (U)	mg/kg	0.05	EPA 200.2/6020A	ALS
	Vanadium (V)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Zinc (Zn)	mg/kg	5	EPA 200.2/6020A	ALS
PAHs	Acenaphthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Acenaphthylene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benz[a]anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[a]pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[b,j,k]fluoranthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[g,h,i]perylene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Biphenyl	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Benzofluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Benzofluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al (2005).

* Detection limit varied with moisture content in sediment.

Table 3.1-10 (Cont'd.)

Group	Analyte	Units	Detection Limit	Analytical Method (VMV code)	Lab
PAHs (Cont'd.)	C3-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Chrysene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Dibenz[a,h]anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Dibenzothiophene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Dimethyl-Biphenyl	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Fluoranthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Fluorene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Indeno[1,2,3-c,d]-pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Methyl Acenaphthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Methyl-Biphenyl	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Naphthalene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Phenanthrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Retene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
Toxicity	*Chironomus dilutus* - 10d growth	mg/organism	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius*, 1997. Environment Canada EPS 1/RM/32.	HydroQual
	Chironomus dilutus - 10d growth - % of Control	%	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius*, 1997. Environment Canada EPS 1/RM/32.	HydroQual
	Chironomus dilutus - 10d survival	# surviving	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius*, 1997. Environment Canada EPS 1/RM/32.	HydroQual
	Chironomus dilutus - 10d survival - % of Control	%	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius*, 1997. Environment Canada EPS 1/RM/32.	HydroQual
	Hyalella azteca - 14d growth	mg/organism	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	HydroQual
	Hyalella azteca - 14d survival	# surviving	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	HydroQual
	Hyallela azteca - 14d growth - % of Control	%	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	HydroQual
	Hyallela azteca - 14d survival - % of Control	%	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	HydroQual

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al (2005).
* Detection limit varies with moisture content in sediment.

Table 3.1-11 Summary of data available for the Sediment Quality component in support of the JOSMP, 1997 to 2014.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007				2008				2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																																									
Upstream of Fort McMurray (cross channel)	ATR-UFM																								1				2				1																																								
Upstream of Donald Creek (west bank)[a]	ATR-DC-W				2				2								1				2				1				2				1																																								
(east bank)[a]	ATR-DC-E				2				2								1				2				1				2				1																																								
Upstream of Steepbank River (west bank)	ATR-SR-W																1				2				1				2				1																																								
(east bank)	ATR-SR-E																1				2				1				2				1																																								
Upstream of the Muskeg River (west bank)[a b]	ATR-MR-W								2								1				2				1				2				1																																								
(east bank)[a b]	ATR-MR-E								2								1				2				1				2				1																																								
Upstream of Fort Creek (west bank)[a b]	ATR-FC-W				2				2								1				2				1				2																																												
(east bank)[a b]	ATR-FC-E				2				2								1				2				1				2																																												
Testing inter-site variability (3 composite samples)	-															|1							|1																																																		
Downstream of all development (west bank)	ATR-DD-W																								1				2				1																																								
(east bank)	ATR-DD-E																								1				2				1																																								
Upstream of mouth of Firebag River (west bank)	ATR-FR-W																								1				2				1																																								
(east bank)	ATR-FR-E																								1				2				1																																								
Upstream of the Embarras River	ATR-ER																3				1				1				2				1				1								1				2				2				2				2				2				2				
Athabasca Delta / Lake Athabasca																																																																									
Delta composite[c]	ARD-1												2																																																												
Big Point Channel	BPC-1												2				2				2				2				2								1								1				2				2				2				2				2				2				2
Goose Island Channel	GIC-1																				2				2				2								1								1				2				2				2				2				2				2				2
Fletcher Channel	FLC-1																				2				2				2								1								1				2				2				2				2				2				2				2
Flour Bay	FLB-1																2																																																								
Extensive Survey (6 sites)	[d]																																			|1																																						
Embarras River																																																																									
Embarras River	EMR-1																																				1																								2												
Embarras River	EMR-2																																				1																				2								2				2				2
Athabasca River Tributaries (South of Fort McMurray)																																																																									
Clearwater River (upstream of Fort McMurray)	CLR-1/CLR-D1																				1				2				2																				2												2												2
(upstream of Christina River)	CLR-2/CLR-D2																				1				2				2																				2												2												2
Christina River (upstream of Fort McMurray)	CHR-1																								1				2				2																																								
(upstream of Janvier)	CHR-2																								1				2				2																																								
(benthic reach at mouth)	CHR-D1																																								2				1								2												2								2
(benthic reach at upper Christina River)	CHR-D2																																								2												2												2								2
(upstream of Jackfish River)	CHR-D3																																																																								2
(upstream of development)	CHR-D4																																																																				2				2
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																2				2																																				
Sunday Creek	SUC-D1																																																															2				2				2
Sunday Creek (upstream)	SUC-D2																																																																			2				2
Unnamed Creek 2 (east of Christina Lake)	UNC-D2																																																																			2				2
Unnamed Creek 3 (south of Christina Lake)	UNC-D3																																																																			2				2
Birch Creek	BRC-D1																																																																			2				2
Sawbones Creek	SAC-D1																																																															2				2				2
Athabasca River Tributaries (North of Fort McMurray)																																																																									
McLean Creek (mouth)	MCC-1												2				2				1				2												2																																				
Beaver River	BER-D2																																																2				2				2				2				2				2				2
Poplar Creek (mouth)	POC-1/POC-D1				1																				2								2																2				2				2				2				2				2				2
Steepbank River (mouth)	STR-1				1				1																2												2																																				
(upstream of Suncor Project Millennium)	STR-2																								2												2																																				
(upstream of North Steepbank)	STR-3																																				2																																				
North Steepbank River (upstream of Suncor Lewis)	NSR-1																								2				2				1				1																																				
MacKay River (mouth)	MAR-1				1				1												2				2								2																																								
(upstream of Suncor MacKay)	MAR-2																				1												2																																								

Note: Monitoring for the Sediment Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)

2 = standard sediment quality + toxicity testing

√ = allowance made for potential TIE

* Sediment program integrated with Benthic Invertebrate Community component in 2006.

Footnotes

[a] Sample stations were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)

[b] Samples were collected downstream of tributary in 1998

[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

[d] Stations are BEC, BPC-1, CRC-1, EMR-2, JFC-1

[e] In previous RAMP reports, this station was called MUR-D2 (upstream of Stanley Creek) from 2003-2005

[f] In previous RAMP reports, this station was called MUR-2 from 2000-2005

Test (downstream of focal projects)

Baseline (upstream of focal projects)

Table 3.1-11 (Cont'd.)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007				2008				2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Tributaries (North of Fort McMurray) (cont'd)																																																																								
Ells River (mouth)	ELR-1								1																2				2				2				1																																		
(benthic reach at mouth)	ELR-D1																																								2				2												2				2				2				2				2
(upstream of Total Joslyn Mine)	ELR-2																																2				1																																		
Tar River (mouth)	TAR-1								1																2				2				1				1																																		
(benthic reach at mouth)	TAR-D1																																								2												2				2				2				2				2				2
(upstream of Canadian Natural Horizon)	TAR-2																																1				1																																		
Calumet River (mouth)	CAR-1																								2								2				2																																		
(benthic reach at mouth)	CAR-D1																																																				2												2								
(upstream of Canadian Natural)	CAR-2																																				2																																		
(benthic reach at upper Calumet)	CAR-D2																																								2												2												2								
Fort Creek (mouth)	FOC-1																1								2																																																
(benthic reach at mouth)	FOC-D1																																								2				2				2								2				2				2				2				2
Big Creek	BIC-D1																																																																				2				2
Pierre River	PIR-D1																																																																				2				2
Eymundson Creek (mouth)	EYC-1																																																																				2				2
Firebag River (mouth)	FIR-1																								2				2				1																																						
(benthic reach at mouth)	FIR-D1																																								2				1												2												2				
(upstream of Suncor Firebag)	FIR-2																												2				1																																						
Muskeg River																																																																										
Mouth	MUR-1				1				1				2				1				1				2				2				2				2																																		
1 km upstream of mouth	MUR-1b																1												1																																										
Upstream of Jackpine Creek	MUR-4				1												1												1																																										
Upstream of Muskeg Creek	MUR-5																1												1																																										
Upstream of Wapasu Creek	MUR-6																1												1																																										
(benthic reach - downstream of Jackpine Creek) [e]	MUR-D2																1												2				2				2				2				2				2				1				1				1				1				2				2
(benthic reach - upstream of Stanley Creek) [f]	MUR-D3																												2				2				2				2				2				2				1				1				1				1				2				2
Muskeg River Tributaries																																																																										
Jackpine Creek (mouth)	JAC-1				1																												2																																						
(benthic reach at mouth)	JAC-D1																																								2				1				2				2				2				2				2				2				2
(benthic reach at upper Jackpine Creek)	JAC-D2																																								2				1				2				2				2				2				2				2				2
Stanley Creek (mouth)	STC-1																												1																																												
Wetlands																																																																											
Kearl Lake (composite)	KEL-1																				1												1								2				2				2				1				1				1				2				2				2
Isadore's Lake (composite)	ISL-1																				1																				2				2				2				1				1				1				2				2				2
Shipyard Lake (composite)	SHL-1																				1				2				1				2								2				2				2				1				1				1				2				2				2
McClelland Lake (composite)	MCL-1																								1				1												2				2				2				1				1				1				2				2				2
Johnson Lake (composite)	JOL-1																																																														1				2				2				2
Christina Lake (composite)	CHL-1																																																																			2				2				2
Gregoire Lake (composite)	GRL-1																																																																									2
Gardiner Lake (composite)	GAL-1																																																																									2
Namur Lake (composite)	NAL-1																																																																									2
Additional Sampling (Non-Core Programs)																																																																											
Potential TIE	-																				√																																																				
QA/QC																																																																											
One split and one duplicate sample	-																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1

Note: Monitoring for the Sediment Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)

2 = standard sediment quality + toxicity testing

√ = allowance made for potential TIE

* Sediment program integrated with Benthic Invertebrate Community component in 2006.

Footnotes

[a] Sample stations were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)

[b] Samples were collected downstream of tributary in 1998

[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

[d] Stations are BEC, BPC-1, CRC-1, EMR-2, JFC-1

[e] In previous RAMP reports, this station was called MUR-D2 (upstream of Stanley Creek) from 2003-2005

[f] In previous RAMP reports, this station was called MUR-2 from 2000-2005

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

3.1.4 Fish Populations Component

3.1.4.1 Overview of 2014 Monitoring Activities

The following monitoring activities were conducted in 2014 for the Fish Populations component:

- Spring, summer, and fall fish inventories on the Athabasca and Clearwater rivers;
- Fish assemblage monitoring (FAM) on tributaries to the Athabasca and Clearwater rivers, and channels of the Athabasca River Delta;
- Tissue analyses of lake whitefish and walleye from the Athabasca River.

Sampling locations are presented in Figure 3.1-5. Common and scientific names for each fish species noted in this report are listed in Appendix E.

3.1.4.2 Summary of Field Methods

Athabasca River and Clearwater River Fish Inventories

The objectives of the 2014 Athabasca River and Clearwater River inventories were to:

- document information about fish populations (both resident and seasonal); and
- respond to concerns and needs of the various stakeholders and local communities using the fish resources.

In 2014, spring, summer, and fall inventories of the fish community focusing on the following key indicator fish species (analogous to Key Indicator Resources, KIRs) were conducted on the Athabasca and Clearwater rivers:

- Goldeye (*Hiodon alosoides*);
- Longnose sucker (*Catostomus catostomus*);
- Northern pike (*Esox lucius*);
- Lake whitefish (*Coregonus clupeaformis*) (Athabasca River only);
- Walleye (*Sander vitreus*);
- White sucker (*Catostomus commersoni*); and
- Trout-perch (*Percopis omiscomaycus*) (Athabasca River only).

Spring, summer, and fall sampling was conducted between May 11 and June 12, 2014, July 19 and July 24, 2014, and September 10 and September 16, 2014, respectively. Approximately five days of sampling on the Athabasca River and two days of sampling on the Clearwater River were conducted in each of the three seasons.

Sampling on the Athabasca River was implemented within six areas historically established for the RAMP fish inventory program and continued under the JOSMP (Table 3.1-12, Figure 3.1-5):

- Upstream of Fort McMurray (Reach -3);
- Poplar Area (Reaches 0 and 1);
- Steepbank Area (Reaches 4, 5, and 6);
- Muskeg Area (Reaches 10 and 11);
- Tar-Ells Area (Reaches 16 and 17); and
- Fort-Calumet Area (Reach 19).

With the exception of the area upstream of Fort McMurray, all of the areas have been sampled annually since 1997, and a number of which have been sampled annually since 1987 by Syncrude Canada Ltd. The reach upstream of Fort McMurray, was established in 2011 to provide *baseline* data for the fish inventory program (Table 3.1-12, Figure 3.1-5).

Spring, summer, and fall sampling in the Clearwater River was conducted at three reaches (CR1, CR2, and CR3) (Table 3.1-12, Figure 3.1-5).

Sampling was conducted on both rivers in areas conducive to electrofishing, primarily in shallow-river margins deep enough to be accessible by boat.

Fish were sampled using a Smith-Root model SR-18 electrofishing boat equipped with a 2.5 GPP electrofishing unit, configured with two anode boom arrays and multiple dropper cables. Stunned fish were captured with dip nets and held in an on-board flow-through live well. Fish observed but not captured were enumerated by species, when possible.

Captured fish were measured for fork length (±1 mm) and weight (±1 g), and sex and state of maturity were recorded when discernible by external examination. An external assessment was conducted to evaluate the general health (e.g., presence of disease, incidence of parasites, physical abnormalities, etc.) of each fish. The examination was conducted using an inventory-specific coding system (Appendix E) that focused on the following structures: body (form and surface); lips and jaws; snout; barbels; anus; opercles; isthmus; fins; gills; pseudobranchs; thymus; eyes; and urogenital area.

The total number of abnormalities was calculated by season for all species and compared against previous sampling years. An external pathology assessment was completed by calculating the percentage of pathological abnormalities, including body deformities, growths, tumors, and parasites from the total number of fish captured for all species by year and for all species combined.

Figure 3.1-5 Locations of fish monitoring activities conducted in support of the 2014 JOSMP.

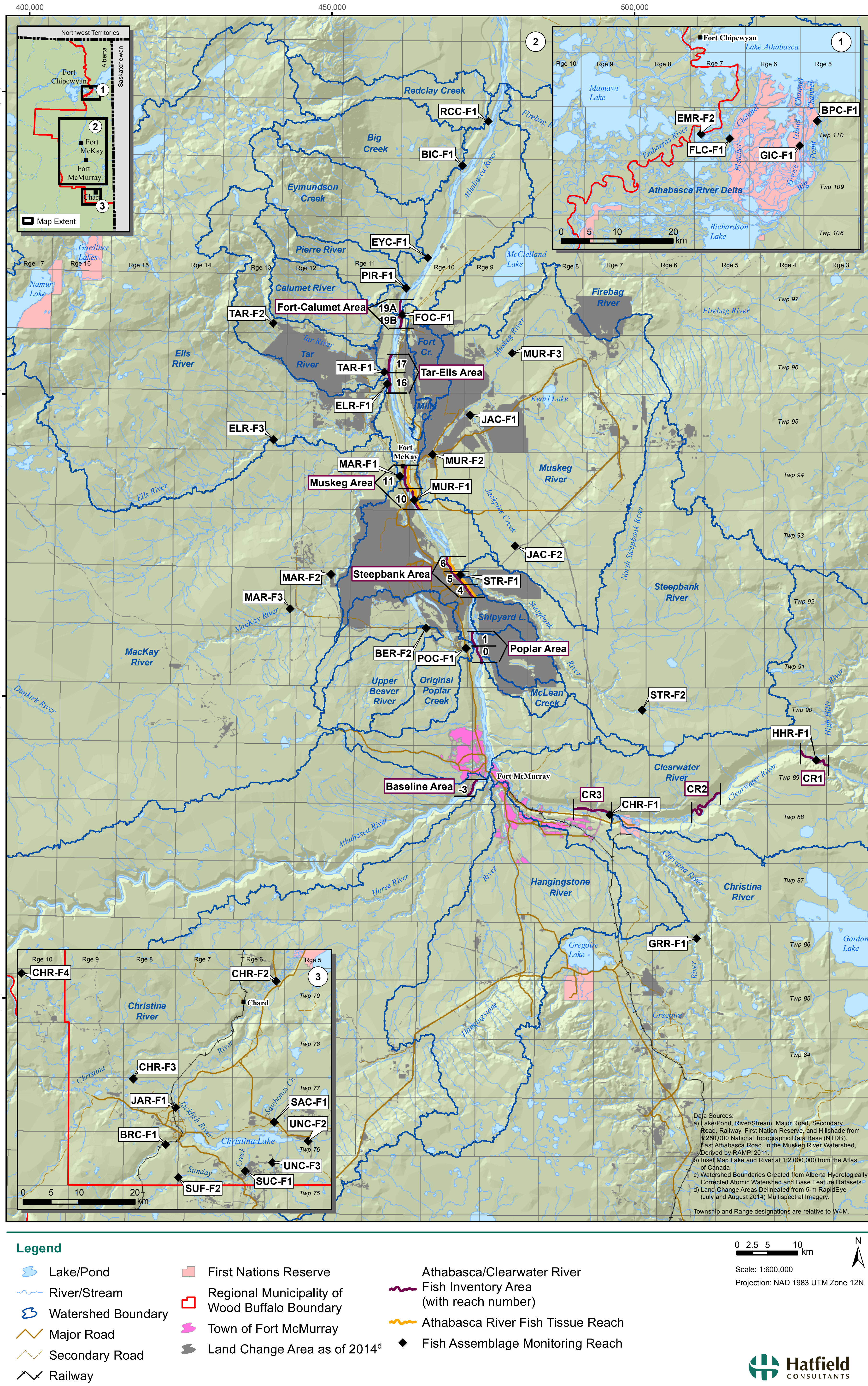

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Table 3.1-12 Locations of fish inventory areas on the Athabasca and Clearwater rivers surveyed in support of the 2014 JOSMP.

Area	Reach Number	Subreach Number	UTM Coordinates (NAD 83, Zone 12)	
			Upstream Limit of Reach	Downstream Limit of Reach
Athabasca River				
Upstream of Fort McMurray	-03B[1]		482473 E / 6283525 N	473942 E / 6285983 N
Poplar Area	00B		474646 E / 6305438 N	473932 E / 6308141 N
	01A		473480 E / 6307893 N	473103 E / 6310531 N
Steepbank Area	04A		472890 E / 6316361 N	471314 E / 6318285 N
	04B		471314 E / 6318285 N	469636 E / 6320525 N
	05A		469636 E / 6320525 N	468911 E / 6323011 N
	05B		473156 E / 6316650 N	471877 E / 6318562 N
	06A		471877 E / 6318562 N	470153 E / 6320420 N
Muskeg Area	10B		464172 E / 6330904 N	462582 E / 6334464 N
	11A		462220 E / 6333918 N	462025 E / 6337965 N
Tar-Ells Area	16A		459425 E / 6350065 N	458958 E / 6353380 N
	17A		458958 E / 6353380 N	459360 E / 6356213 N
Fort-Calumet Area	19A		461057 E / 6362604 N	460943 E / 6365216 N
	19B		461181 E / 6360892 N	461417 E / 6363621 N
Clearwater River				
Upstream of the High Hills River and Christina River confluences	CR1[1]	CR1A*	531982 E / 6288505 N	529592 E / 6289549 N
		CR1B	529592 E / 6289549 N	527714 E / 6291560 N
Upstream of the Christina River confluence	CR2[1]	CR2A	514112 E / 6283950 N	512193 E / 6282517 N
		CR2B*	512193 E / 6282517 N	510345 E / 6281510 N
		CR2C*	510345 E / 6281510 N	509500 E / 6280700 N
Downstream of the Christina River confluence	CR3	CR3A*	496071 E / 6280509 N	493022 E / 6280960 N
		CR3B*	493022 E / 6280960 N	489943 E / 6281368 N

[1] Reaches -03B, CR1, and CR2 are designated as *baseline*. All other reaches are designated as *test*.

* Reaches were sampled in spring and fall 2014, based on a rotating panel design for the *baseline* reaches. The *test* reaches are sampled every season and year and all reaches are sampled in summer.

Fish Tag Return Assessment

Tagging of sportfish species has been a part of the Fish Populations component since 1999. The fish tags are uniquely identified by a colour and ID number (for tracking fish in the event of recapture), as well as a contact phone number that anglers can use to report catch information to the Fort McMurray Fish and Wildlife office of Alberta Environment and Sustainable Resource Development (AESRD). Tag number, tag colour, species, basic morphology (fish length and weight), maturity, sex (if possible), external health condition, date, and location were recorded at the time of tagging.

Athabasca River Fish Tissue

Walleye and lake whitefish were the target species for the 2014 fish tissue study on the Athabasca River. Tissue samples were acquired from fish captured in the Muskeg and Steepbank areas of the Athabasca River in September 2014 (Figure 3.1-5). Muscle tissue was collected non-lethally for mercury analysis, and lethal dissections were performed for internal health assessments and the collection of tissue for analyses of tainting compounds (organics) and metals.

Individual walleye and lake whitefish selected for tissue sampling were kept live in cold water. Following non-lethal mercury tissue sampling, all walleye and lake whitefish not designated for lethal dissections were released immediately into the calm margins of the river to limit additional handling and confinement stress. Individuals selected for lethal dissections were transported back to an indoor facility to minimize contamination from precipitation, wind and debris. Tissue samples were collected for the two types of analyses, using the methods described below.

Non-Lethal Tissue Analysis for Mercury A target of 25 individuals of each species was set for non-lethal mercury tissue analysis, with specific targets of five fish (irrespective of sex) in each of five size classes of 100 mm increments in fork length from 200 mm to 700 mm for walleye and of 50 mm increments in fork length from 200 mm to 450 mm for lake whitefish. These size classes were selected in order to:

- ensure adequate representation of typical size ranges for lake whitefish and walleye observed in the fall during past inventories on the river (RAMP 2004; 2006; 2008; 2009a; 2012);
- ensure an even distribution of tissue samples across a wide range of fish sizes and ages; and
- ensure consistency with those size classes targeted in the fall during past tissue programs on the river (RAMP 2004; 2006; 2008; 2009a; 2012), and to allow comparisons with historical data.

The distribution of fish captured from the Athabasca River for tissue analysis for mercury is provided in Table 3.1-13. Following the collection of fish measurements for the fish inventory survey, muscle tissue was then sampled non-lethally from each walleye and lake whitefish for mercury analysis using a clean, unused 4 mm dermal biopsy punch (Acuderm Inc.). Prior to sampling, a few scales were removed from the fish and the dermal punch was then positioned on the surface of the skin over the dorsal musculature. The punch was then pushed into the dorsal musculature, using pressure and a twisting motion moderate enough to penetrate the muscle, but not to penetrate through to the fish cavity. Upon extraction, the punch was rotated in a twisting motion using slight angular pressure in order to assist in obtaining the muscle plug sample. The tissue plug was then blown through the hollow punch into a sterile, pre-labelled, pre-weighed (± 0.001 g) 4 mL externally-threaded cryovial. The wet weight of the plug was then recorded (± 0.001 g) for the calculation of total mercury concentration, and was placed immediately on dry ice in a cooler. After extraction of the punch, the void left in the fish was filled with a waterproof "bandage" sealant (Nexaband S/C, Topical Tissue Adhesive, Formulated Cyanoacrylate) following methods described by Baker et al. (2004), in order to decrease the chance of infection.

All sampling equipment was rinsed using metals-free soap and distilled water, hexane, then acetone, and re-rinsed with deionized water after each fish to avoid cross contamination. Tissue samples were transported in a cooler on dry ice and held in the Hatfield freezer (Fort McMurray) before being shipped on dry ice to Flett Research (Winnipeg) for mercury analysis.

Table 3.1-13 Number of fish by species captured in each size class from the Athabasca River for fish tissue analyses of mercury measured in support of the 2014 JOSMP.

Species	Size Class (mm)					
	201-300	**301-400**	**401-500**	**501-600**	**601-700**	
Walleye	3	5	7	1	1	
	200-250	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**
Lake whitefish	0	0	0	4	16	7

Lethal Dissections and Tissue Analysis for Tainting Compounds and Metals A target of five fish for each of the two species (target male fork length: 450–500 mm for walleye and 400–450 mm for lake whitefish; target female fork length: 500–550 mm for walleye and 400–450 mm for lake whitefish) was set for dissection and comprehensive tissue sampling for tainting compounds (organics) and metals analysis. These sex/length combinations were set as targets in an attempt to minimize potential variability associated with size and age, and to allow for direct comparisons with data from previous tissue surveys conducted by RAMP (RAMP 2004; 2006; 2008; 2009a; 2012).

The distribution of fish captured for tissue analysis for tainting compounds is provided in Table 3.1-14.

Table 3.1-14 Sex/length combinations of walleye and lake whitefish captured from the Athabasca River for fish tissue analyses of metals and organics in support of the 2014 JOSMP.

Species	Sex	Size Class	Number Captured
Walleye	Male	450-500 mm (target)	5
	Female	500-550 mm (target)	0
Lake whitefish	Male	400-450 mm	6
	Female	400-450 mm	5

Each sacrificed fish was dissected and an internal assessment was conducted to evaluate general health (e.g., presence of disease, incidence of parasites, physical and other abnormalities) based on the following structures and characteristics: liver; kidney; spleen; hindgut; gall bladder; fat content; and the presence of parasites.

For each fish, the sex, stage of maturity, liver weight (± 0.01 g), and gonad weight (± 0.01 g) were recorded. Ageing structures (otoliths and two leading rays from the right pelvic fin) were then collected, dried, and stored in labeled coin envelopes to be sent to North/South Consultants Inc. (Winnipeg) for analysis.

Tissues were then removed from the musculature above the lateral line and posterior to the dorsal fin on the left side of each fish for analysis of tainting compounds, and from the right side of each fish for assessing metals (RAMP 2009b). Minimum muscle tissue requirements per fish were 20 g (50 to 100 g preferred) for tainting compounds analyses and 2 g (5 g preferred) for metals analyses. Skin and bone were removed from the muscle tissue. Samples collected for organics analysis were individually wrapped in solvent-rinsed aluminum foil, and samples collected for metals analysis were individually placed in clean, sealable plastic bags. All samples were labeled and kept frozen until they were shipped on ice to ALS Laboratory Group Edmonton for chemical analysis.

Organics and metals analyses were performed on the composite samples of female and male target-sized fish in order to facilitate comparison of results with data from previous surveys. The composites were prepared at ALS by combining an equal weight of muscle tissue from each fish. Two sets of each composite were prepared for the following analyses:

- Metals – aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, vanadium, and zinc; and

- Tainting Compounds (PAHs) – thiophene, toluene, M+P-xylenes, 1,3,5-trimethylbenzene, and naphthalene.

Methods and detection limits used for all chemical analyses, including tainting compounds, metals, and mercury are presented in Table 3.1-15. All remaining tissue samples were archived at the testing laboratory for additional analyses, if required.

Table 3.1-15 Methods of analyses and detection limits for mercury, metals, and tainting compounds analyzed in fish collected from the Athabasca River in support of the 2014 JOSMP.

Variable	Detection Limit (mg/kg, wet weight)	Method of Analysis
Metals		
Aluminum (Al)	2	EPA 200.3/200.7-ICPOES
Antimony (Sb)	0.01	EPA 200.3/200.8-ICPMS
Arsenic (As)	0.01	EPA 200.3/200.8-ICPMS
Barium (Ba)	0.02	EPA 200.3/200.8-ICPMS
Beryllium (Be)	0.1	EPA 200.3/200.8-ICPMS
Bismuth (Bi)	0.06	EPA 200.3/200.8-ICPMS
Cadmium (Cd)	0.006	EPA 200.3/200.8-ICPMS
Calcium (Ca)	2	EPA 200.3/200.7-ICPOES
Chromium (Cr)	0.05	EPA 200.3/200.7-ICPOES
Cobalt (Co)	0.02	EPA 200.3/200.8-ICPMS
Copper (Cu)	0.04	EPA 200.3/200.8-ICPMS
Iron (Fe)	1	EPA 200.3/200.7-ICPOES
Lead (Pb)	0.02	EPA 200.3/200.8-ICPMS
Lithium (Li)	0.1	EPA 200.3/200.8-ICPMS
Magnesium (Mg)	1	EPA 200.3/200.8-ICPMS
Manganese (Mn)	0.01	EPA 200.3/200.8-ICPMS
Mercury (Hg)	0.006[1] and 0.002[2]	Cold Vapor Atomic Fluorescence Spectraphotometry (CVAFS)[1] and EPA 200.3/EPA 245.1[2]
Molybdenum (Mo)	0.01	EPA 200.3/200.8-ICPMS
Nickel (Ni)	0.02	EPA 200.3/200.8-ICPMS
Phosphorus (P)	5	EPA 200.3/200.7-ICPOES
Potassium (K)	5	EPA 200.3/200.7-ICPOES
Selenium (Se)	0.06	EPA 200.3/200.8-ICPMS
Silver (Ag)	0.05	EPA 200.3/200.8-ICPMS
Sodium (Na)	20	EPA 200.3/200.7-ICPOES
Strontium (Sr)	0.01	EPA 200.3/200.8-ICPMS
Thallium (Tl)	0.01	EPA 200.3/200.8-ICPMS
Tin (Sn)	0.05	EPA 200.3/200.8-ICPMS
Titanium (Ti)	0.1	EPA 200.3/200.7-ICP-OES
Uranium (U)	0.002	EPA 200.3/200.8-ICPMS
Vanadium (V)	0.1	EPA 200.3/200.8-ICPMS
Zinc (Zn)	0.1	EPA 200.3/200.7-ICPOES
Tainting Compounds (PAHs)		
1,3,5-Trimethylbenzene	0.01	EPA 5000/8260-Headspace GC/MS
m+p-Xylene	0.01	EPA 5000/8260-Headspace GC/MS
Naphthalene[3]	0.05	EPA 3540/8270-GC/MS
Thiophene	0.01	EPA 5000/8260-Headspace GC/MS
Toluene	0.01	EPA 5000/8260-Headspace GC/MS

[1,2] Analyzed by Flett Research and ALS, respectively (all other variables analyzed by ALS only).

[3] Naphthalene was analyzed for three target compounds, 1-Methylnaphthalene, 2,6-Dimethylnaphthalene, 2,3,5-Trimethylnaphthalene, all with the same detection limit and all using the same analytical method.

Fish Assemblage Monitoring Program

Fish assemblage monitoring (FAM) in tributaries to the Athabasca and Clearwater rivers was incorporated into RAMP in 2011; 2014 was the fourth year of monitoring on tributaries and the second year of monitoring in the ARD. The objective of this monitoring component was to evaluate fish assemblages in reaches where water quality, and benthic invertebrate communities and sediment quality were also assessed. Accordingly, fish assemblage monitoring was conducted at all benthic invertebrate sampling reaches on tributaries surveyed in fall 2014 (Table 3.1-16). The FAM program was conducted from August 19 to 21, 2014 in channels of the ARD and from September 3 to 17, 2014 in tributary reaches to assess changes in the fish assemblage of rivers that may potentially be influenced by oil sands development.

The methods used to develop the FAM program for RAMP and now under the JOSMP, were adopted from the United States Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) for stream monitoring programs throughout the United States (Peck et al. 2006). The procedures described were modified to include appropriate indicators related to the study area and outline protocols to collect measurements describing physical habitat, the fish assemblage, water and sediment chemistry, and benthic invertebrate communities.

Fish Sampling Each reach was approximately 20 times the wetted width, which was divided into five sub-reaches to assess variability within a reach (based on precision analysis conducted in RAMP [2011]). Tributary reaches were sampled using a backpack or portable boat electrofisher, dependent on channel depth; the reaches of the ARD were sampled using a boat electrofisher given the depth of the channels. Sampling was focused on the shoreline area of the river and the width of the electrofishing pass was approximately 2 to 3 m, or from the river bank to a point mid-river based on what the electrofisher operator could reach.

Fish collected from each sub-reach were kept in a holding bucket of river water until the completion of all fishing. For each sub-reach, captured fish were measured for length (± 1 mm) and weight (± 0.01 g) and an external assessment was conducted to evaluate the general health.

Table 3.1-16 Locations of reaches surveyed for the fish assemblage monitoring program, August and September, in support of the 2014 JOSMP.

Watercourse	Reach	Habitat Type	Reach Designation	UTM Coordinates (NAD 83, Zone 12)	
				Downstream Boundary	Upstream Boundary
Athabasca River Delta	EMR-F2	depositional	*test*	494794 E 6492144 N	491047 E 6490830 N
	BPC-F1	depositional	*test*	511785 E 6497992 N	511828 E 6493157 N
	FLC-F1	depositional	*test*	497332 E 6494106 N	496227 E 6490049 N
	GIC-F1	depositional	*test*	508803 E 6488786 N	509729 E 6494113 N
Beaver River	BER-F2	depositional	*baseline*	465483 E 6311289 N	465457 E 6311138 N
Big Creek	BIC-F1	depositional	*baseline*	471527 E 6387792 N	471315 E 6387804 N
Birch Creek	BRC-F1	depositional	*baseline*	492005 E 6163125 N	491879 E 6163008 N
Christina River	CHR-F1	erosional	*test*	497715 E 6278551 N	498097 E 6278180 N
	CHR-F2	depositional	*test*	511819 E 6192380 N	511134 E 6192481 N
	CHR-F3	erosional	*test*	486219 E 6175064 N	485726 E 6175279 N
	CHR-F4	depositional	*baseline*	466224 E 6193839 N	466024 E 6193825 N
Ells River	ELR-F1	depositional	*test*	459063 E 6351670 N	459063 E 6352009 N
	ELR-F3	erosional	*baseline*	440394 E 6342411 N	440033 E 6342601 N
Eymundson Creek	EYC-F1	depositional	*baseline*	465862 E 6372334 N	465820 E 6372577 N
Fort Creek	FOC-F1	depositional	*test*	461545 E 6363107 N	461724 E 6363065 N
Gregoire River	GRR-1	erosional	*test*	510192 E 6259875 N	510054 E 6259943 N
High Hills River	HHR-F1	erosional	*baseline*	529943 E 6289291 N	529988 E 6289542 N
Jackfish River	JAR-F1	erosional	*test*	493796 E 6169761 N	493825 E 6169513 N
Jackpine Creek	JAC-F1	depositional	*test*	472805 E 6346510 N	472964 E 6346496 N
	JAC-F2	depositional	*baseline*	480284 E 6324869 N	480431 E 6324796 N
MacKay River	MAR-F1	erosional	*test*	461153 E 6336395 N	460437 E 6336773 N
	MAR-F2	erosional	*test*	449741 E 6320228 N	449568 E 6319954 N
	MAR-F3	erosional	*baseline*	445206 E 6314610 N	444952 E 6314293 N
Muskeg River	MUR-F1	erosional	*test*	463542 E 6332450 N	463897 E 6332099 N
	MUR-F2	depositional	*test*	466519 E 6339971 N	466663 E 6340158 N
	MUR-F3	depositional	*test*	479753 E 6356804 N	479824 E 6356936 N
Pierre River	PIR-F1	depositional	*baseline*	462202 E 6367488 N	462260 E 6367729 N
Poplar Creek	POC-F1	depositional	*test*	472102 E 6307923 N	471844 E 6307777 N
Red Clay Creek	RCC-F1	erosional	*baseline*	475809 E 6395071 N	475578 E 6395145 N
Sawbones Creek	SAC-F1	depositional	*test*	511495 E 6167203 N	511548 E 6167430 N
Steepbank River	STR-F1	erosional	*test*	471194 E 6320052 N	471614 E 6320363 N
	STR-F2	erosional	*baseline*	500448 E 6297485 N	500598 E 6297453 N
Sunday Creek	SUC-F1	erosional	*test*	506314 E 6158409 N	506376 E 6158269 N
	SUC-F2	depositional	*baseline*	494288 E 6157256 N	494104 E 6157189 N
Tar River	TAR-F1	depositional	*test*	458582 E 6353573 N	458345 E 6353410 N
	TAR-F2	erosional	*baseline*	440735 E 6361657 N	440525 E 6361638 N
Unnamed Creek (east of Christina Lake)	UNC-F2	depositional	*test*	517580 E 6163722 N	517762 E 6163681 N
Unnamed Creek (south of Christina Lake)	UNC-F3	depositional	*test*	511132 E 6159871 N	511062 E 6159654 N

Fish Habitat Assessments Habitat assessments were completed at two transects at the downstream and upstream ends of each reach. Habitat assessment methods involved recording a range of variables relating to channel morphology, substrate, water quality, and stream cover similar to that outlined in RAMP (2009b) and Peck et al*.* (2006). The following information was collected at each transect:

- Habitat type (Table 3.1-17);
- Wetted width (m);
- Maximum depth (m);
- Velocity and depth (m/sec) (at 25%, 50%, and 75% of the wetted width);
- Overhead and instream cover (%) (Table 3.1-18);
- Substrate (dominant and subdominant particle size) (Table 3.1-19);
- Bank slope (degrees);
- Bank height (m); and
- Large and small woody debris (count of debris in length/size classes).

In situ water quality variables including temperature (ºC), DO (mg/L), pH, and conductivity (µS/cm) were measured using a Hanna hand-held probe (temperature, conductivity, pH) and a LaMotte Winkler titration kit (DO) at the downstream end of each reach.

Table 3.1-17 Habitat type and code used for the fish assemblage monitoring program of the 2014 JOSMP (adapted from Peck et al*.* 2006).

Habitat Type (code)	Description
Plunge pool (PP)	Pool at base of plunging cascade or falls
Trench pool (PT)	Pool-like trench in the centre of the stream
Lateral Scour Pool (PL)	Pool scoured along a bank
Backwater Pool (PB)	Pool separated from main flow off the side of the channel (large enough to offer refuge to small fishes). Includes sloughs (backwater with vegetation), and alcoves (a deeper area off a wide and shallow main channel).
Impoundment Pool (PD)	Pool formed by impoundment above dam or constriction
Pool (P)	Pool (unspecified type)
Run (Ru)	Water moving slowly, with a smooth, unbroken surface. Low turbulence.
Riffle (RI)	Water moving, with small ripples, waves and eddies-waves not broken, surface tension not broken.
Dry Channel (DR)	No water in the channel or flow is submerged under the substrate.

Table 3.1-18 Percent cover rating for instream and overhead cover at each transect used for the fish assemblage monitoring program of the 2014 JOSMP (adapted from Peck et al. 2006).

Code	Percent Cover
0	absent, zero cover
1	sparse, <10%
2	moderate, 10-40%
3	heavy, 40-75%
4	very heavy, >75%

Table 3.1-19 Substrate size class codes used for the fish assemblage monitoring program of the 2014 JOSMP (adapted from Peck et al. 2006).

Code	Description
RS	bedrock (smooth) - larger than a car
RR	bedrock (rough) - larger than a car
RC	asphalt/concrete
XB	large boulder (1000-4000 mm) - metre stick to a car
SB	small boulder (250-1000 mm) - basketball to a metre stick
CB	cobble (64-250 mm) - tennis ball to basketball
GC	coarse gravel (16-64 mm) - marble to tennis ball
GF	fine gravel (2-16 mm) - ladybug to marble
SA	sand (0.06 to 2 mm) - gritty, up to ladybug size
FN	silt/clay - not gritty
HP	hardpan - firm consolidated fine substrate

3.1.4.3 Changes in Monitoring Network from 2013

The 2014 monitoring activities for the Fish Populations component differed from those carried out in 2013 in the following ways:

- Fish assemblage reaches were added to the program based on the benthic sampling design; the program was expanded to include a new *test* reach on the Gregoire River, a tributary to the Christina River;

- Given the three-year sampling rotation, fish assemblage monitoring was not conducted on the Calumet River (*test* reach CAR-F1 and *baseline* reach CAR-F2) or the Firebag River (*test* reaches FIR-F1 and FIR-F2) in 2014;
- Given the three-year sampling rotation of the fish tissue sampling program, fish tissue sampling was conducted on the Athabasca River (last conducted in 2011) but not the Clearwater River (last conducted in 2012);
- The regional lakes fish tissue program, in collaboration with AESRD, was not conducted in fall 2014; and
- Given the three-year sampling rotation, lethal sentinel species monitoring program was not conducted for trout-perch on the Athabasca River, nor slimy sculpin on select tributaries, in 2014.

3.1.4.4 Challenges Encountered and Solutions Applied

The following challenges were encountered during the Fish Populations component activities in 2014:

- Athabasca Inventory – due to restrictions stated in the Fish Research License related to electrofishing during fish spawning periods, fish sampling ceased at *baseline* reach -03B, upstream of Fort McMurray, in May following the capture of spawning walleye. In addition, the fall program was conducted earlier than previous years to avoid capturing spawning lake whitefish. As a result, fewer lake whitefish were captured than in previous years;
- Clearwater Inventory – due to low the water level in fall, it was not possible to complete fish sampling at *baseline* reaches CR-1 and CR-2;
- Athabasca Fish Tissue – Fishing effort was maximized in an effort to capture the required number of fish for fish tissue analysis; however, smaller size classes of lake whitefish and larger size classes of walleye were not obtained in 2014; and
- Regional lakes – due to logistical difficulties in collecting and storing tissue samples at remote lakes, personnel from AESRD were not able to retain fish samples from the FWIN program for the analysis of mercury.

3.1.4.5 Other Information Obtained

Additional fish tissue and ageing samples for walleye and lake whitefish from the Athabasca River were collected by personnel from Environment Canada under the JOSMP and provided to Hatfield.

3.1.4.6 Summary of Component Data Now Available

Fish Populations component data collected to date are summarized in Table 3.1-20.

Table 3.1-20 Summary of data available for the Fish Populations component in support of the JOSMP, 1997 to 2014.

WATERBODY AND LOCATION	Site ID	1997				1998				1999				2000				2001				2002			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3																								
Poplar Area	0/1		1	1,5	1,5		1,6	1,5	1,3,6														1		
Steepbank Area	4[a]/5[a]/6		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Muskeg Area	10/11		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Tar-Ells Area	16/17		1	1,5	1,5		1,6	1	1,3,6									7					1		
Fort-Calumet Area	19[a]																								
Canadian Natural/TrueNorth Area (Fort/Asphalt reaches)																							1		
Reference Area - about 200 km upstream [b]	5/6							1,5	1,3,6																
Reference Area - upstream of Fort McMurray[c]			1																						
Radiotelemetry study region[d]					2		2		2						2	2	2	2	2						
Reference site upstream of Ft. McMurray STP	ATR-1																								3
Reference site between STP and Suncor	ATR-2												1,3												3
Downstream of Suncor's Discharge	ATR-3												1,3												10,3
Below Muskeg River	ATR-4												1,3												10,3
Downstream of Development (near Firebag River)	ATR-5																								
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																								
Embarras River	EMR-F2																								
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1														1,8,5,9	1									
Poplar Creek (mouth)	POC-F1																								
Beaver River (upper)	BER-F2																								
Pierre River (mouth)	PIR-F1														1,8,5,9	1									
Eymundson Creek (mouth)	EYC-F1																								
Red Clay Creek (mouth)	RCC-F1																								
Big Creek (mouth)	BIC-F1																								
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1																								
Clearwater River Reach	CR-1																								
Clearwater River Reach	CR-2																								
Clearwater River Reach	CR-3																								
Christina River (mouth)	CHR-F1																								
Christina River (upstream of Janvier) [h]	CHR-F2																								
Christina River (upstream of Jackfish River)	CHR-F3																								
Christina River (upstream of development)	CHR-F4																								
Jackfish River	JAR-F1																								
Unnamed Creek (east of Christina Lake)	UNC-F2																								
Unnamed Creek (south of Christina Lake)	UNC-F3																								
Sunday Creek (lower reach)	SUC-F1																								
Sunday Creek (upper reach)	SUC-F2																								
Birch Creek	BRC-F1																								
Sawbones Creek	SAC-F1																								
Ells River																									
Upper Ells River	ELR-F3												1,3												
Upper Ells River[g,i]	ELR-F2A												1,3												
Middle Ells River	ELR-F2																								
Lower Ells River[g,i]	ELR-F1												1,3												
MacKay River																									
Lower reach (mouth) [i]	MAR-F1		1																				1		
Mid-River (upstream of Suncor MacKay)	MAR-F2																								
Upper MacKay River reach	MAR-F3																								
Horse and Dunkirk rivers	HR-R/DR-R																3				3				
Tar River																									
Lower Tar River	TAR-F1												1,3												
Upper Tar River	TAR-F2												1,3												
Calumet River																									
Lower Calumet River	CAR-F1																								
Upper Calumet River	CAR-F2																								
Firebag River																									
Lower Firebag River	FIR-F1																								
Upper Firebag River	FIR-F2																								
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1												1,3						4		3		4		4
Lower 35 km below Jackpine Creek confluence	MUR-F2			1			4						1,3		2,8	2	2	2	2	1	6			1	6
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																						1,4		1,4
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2																								
Jackpine Creek (accessible areas of lower creek)	JAC-F1														8					1				1	
Muskeg Creek (Canterra road crossing)[e]																							1,4		1,4
Wapasu Creek (mouth or Canterra road) [e]																							1,4		1,4
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014			1																					
Lower Steepbank River (current *test* site)	STR-F1/SR-E																								
Lower Steepbank River (original *test* site)	SR-MN												1,3								3				
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R												1,3				3				3				
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2																								
Regionally-Important Lakes																									
Christina Lake	CHL-F1																								
Various lakes in water/air emissions pathway																									

WATERBODY AND LOCATION	Site ID	2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3																								
Poplar Area	0/1						1		1		1		1		1		1		1		1		1	1	1,6
Steepbank Area	4[a]/5[a]/6				6		1		1		1		1,6		1		1		1		1		1	1	1,6
Muskeg Area	10/11				6		1		1		1		1,6		1		1		1		1		1	1	1,6
Tar-Ells Area	16/17						1		1		1		1		1		1		1		1		1	1	1
Fort-Calumet Area	19[a]														1		1		1		1		1	1	1
Canadian Natural/TrueNorth Area (Fort/Asphalt reaches)																									
Reference Area - about 200 km upstream [b]	5/6																								
Reference Area - upstream of Fort McMurray[c]																									
Radiotelemetry study region[d]																									
Reference site upstream of Ft. McMurray STP	ATR-1				10															3	3				
Reference site between STP and Suncor	ATR-2				10															3	3				
Downstream of Suncor's Discharge	ATR-3				10															3	3				
Below Muskeg River	ATR-4				10															3	3				
Downstream of Development (near Firebag River)	ATR-5				10,6															3	3				
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																								
Embarras River	EMR-F2																								
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1																								
Poplar Creek (mouth)	POC-F1																								
Beaver River (upper)	BER-F2																								
Pierre River (mouth)	PIR-F1																								
Eymundson Creek (mouth)	EYC-F1																								
Red Clay Creek (mouth)	RCC-F1																								
Big Creek (mouth)	BIC-F1																								
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1																								
Clearwater River Reach	CR-1		1		1		1		1,6		1		1		1		1,6		1		1,6		1		1
Clearwater River Reach	CR-2		1		1		1				1				1		1,6		1		1,6		1		1
Clearwater River Reach	CR-3		1	10	1		1				1				1		1,6		1		1,6		1		1
Christina River (mouth)	CHR-F1																								
Christina River (upstream of Janvier) [h]	CHR-F2								1																
Christina River (upstream of Jackfish River)	CHR-F3																								
Christina River (upstream of development)	CHR-F4								1																
Jackfish River	JAR-F1																								
Unnamed Creek (east of Christina Lake)	UNC-F2																								
Unnamed Creek (south of Christina Lake)	UNC-F3																								
Sunday Creek (lower reach)	SUC-F1																								
Sunday Creek (upper reach)	SUC-F2																								
Birch Creek	BRC-F1																								
Sawbones Creek	SAC-F1																								
Ells River																									
Upper Ells River	ELR-F3						4		3		4		3							3	3				
Upper Ells River[g,i]	ELR-F2A						4		3		4		3							3	3				
Middle Ells River	ELR-F2																								
Lower Ells River[g,i]	ELR-F1						4		3		4		3							3	3				
MacKay River																									
Lower reach (mouth) [i]	MAR-F1			10			4																		
Mid-River (upstream of Suncor MacKay)	MAR-F2																								
Upper MacKay River reach	MAR-F3																								
Horse and Dunkirk rivers	HR-R/DR-R								3							3	3								
Tar River																									
Lower Tar River	TAR-F1																								
Upper Tar River	TAR-F2																								
Calumet River																									
Lower Calumet River	CAR-F1																								
Upper Calumet River	CAR-F2																								
Firebag River																									
Lower Firebag River	FIR-F1																								
Upper Firebag River	FIR-F2																								
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1		4						3						4	3	3								
Lower 35 km below Jackpine Creek confluence	MUR-F2							1	6							1	6								
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																								
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2																								
Jackpine Creek (accessible areas of lower creek)	JAC-F1							1																	
Muskeg Creek (Canterra road crossing)[e]																									
Wapasu Creek (mouth or Canterra road) [e]																									
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014																								
Lower Steepbank River (current *test* site)	STR-F1/SR-E								3							3	3								
Lower Steepbank River (original *test* site)	SR-MN																								
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R								3																
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2															3	3								
Regionally-Important Lakes																									
Christina Lake	CHL-F1																								
Various lakes in water/air emissions pathway					6				6											6	6				6

WATERBODY AND LOCATION	Site ID	2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3										1	1	1		1	1	1		1	1	1		1	1	1
Poplar Area	0/1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Steepbank Area	4[a]/5[a]/6		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Muskeg Area	10/11		1	1	1		1	1	1		1	1	1,6		1	1	1		1	1	1		1	1	1
Tar-Ells Area	16/17		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Fort-Calumet Area	19[a]		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Canadian Natural/TrueNorth Area (Fort/Asphalt reaches)																									
Reference Area - about 200 km upstream [b]	5/6																								
Reference Area - upstream of Fort McMurray[c]																									
Radiotelemetry study region[d]																									
Reference site upstream of Ft. McMurray STP	ATR-1								3												3				
Reference site between STP and Suncor	ATR-2								3												3				
Downstream of Suncor's Discharge	ATR-3								3												3				
Below Muskeg River	ATR-4								3												3				
Downstream of Development (near Firebag River)	ATR-5								3												3				
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																10				10				10
Embarras River	EMR-F2																10				10				10
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1												10				10				10				10
Poplar Creek (mouth)	POC-F1				10								10				10				10				10
Beaver River (upper)	BER-F2				10								10				10				10				10
Pierre River (mouth)	PIR-F1																				10				10
Eymundson Creek (mouth)	EYC-F1				10																10				10
Red Clay Creek (mouth)	RCC-F1				10																10				10
Big Creek (mouth)	BIC-F1				10																10				10
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1												10				3,10				10				10
Clearwater River Reach	CR-1		1	1	1,6		1	1	1		1	1			1	1	1,6		1	1	1		1	1	1
Clearwater River Reach	CR-2		1	1	1,6		1	1	1		1	1			1	1	1,6		1	1	1		1	1	1
Clearwater River Reach	CR-3		1	1	1,6		1	1	1		1	1	1		1	1	1,6		1	1	1		1	1	1
Christina River (mouth)	CHR-F1																10								10
Christina River (upstream of Janvier) [h]	CHR-F2																10								10
Christina River (upstream of Jackfish River)	CHR-F3																10				10				10
Christina River (upstream of development)	CHR-F4																10				10				10
Jackfish River	JAR-F1																10				10				10
Unnamed Creek (east of Christina Lake)	UNC-F2																				10				10
Unnamed Creek (south of Christina Lake)	UNC-F3																				10				10
Sunday Creek (lower reach)	SUC-F1																10				10				10
Sunday Creek (upper reach)	SUC-F2																				10				10
Birch Creek	BRC-F1																				10				10
Sawbones Creek	SAC-F1																10				10				10
Ells River																									
Upper Ells River	ELR-F3								10				10				10				10				10
Upper Ells River[g,i]	ELR-F2A								10				10				10								
Middle Ells River	ELR-F2																10								
Lower Ells River[g,i]	ELR-F1								10				10				10				10				10
MacKay River																									
Lower reach (mouth) [i]	MAR-F1				10								10				10				10				10
Mid-River (upstream of Suncor MacKay)	MAR-F2												10				10				10				10
Upper MacKay River reach	MAR-F3												10				10				10				10
Horse and Dunkirk rivers	HR-R/DR-R			3	3,10												3								
Tar River																									
Lower Tar River	TAR-F1				10								10				10				10				10
Upper Tar River	TAR-F2												10				10				10				10
Calumet River																									
Lower Calumet River	CAR-F1																10								
Upper Calumet River	CAR-F2																10								
Firebag River																									
Lower Firebag River	FIR-F1																				10				
Upper Firebag River	FIR-F2																				10				
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1		4	3	3,10				10				10				3,10				10				10
Lower 35 km below Jackpine Creek confluence	MUR-F2				10								10				10				10				10
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3												10				10				10				10
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2				10				10				10				10				10				10
Jackpine Creek (accessible areas of lower creek)	JAC-F1				10				10				10				10				10				10
Muskeg Creek (Canterra road crossing)[e]																									
Wapasu Creek (mouth or Canterra road) [e]																									
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014																								
Lower Steepbank River (current *test* site)	STR-F1/SR-E			3	3,10				10				10				3,10				10				10
Lower Steepbank River (original *test* site)	SR-MN																								
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R																								
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2			3	3								10				3,10				10				10
Regionally-Important Lakes																									
Christina Lake	CHL-F1																10				6				
Various lakes in water/air emissions pathway					6				6								6				6				

Note: Monitoring for the Fish Populations Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

w=winter; s=spring and summer; fall=fall

1 = fish inventory

2 = radiotelemetry; 1997-1998 walleye, lake whitefish (Athabasca River)
2000-2001: longnose sucker, northern pike, Arctic grayling (Athabasca River and Muskeg River)

3 = sentinel fish monitoring; 1998-1999: longnose sucker (Athabasca River)
2002-2013: trout-perch (Atha. River); slimy sculpin (Muskeg, Steepbank, Dunkirk, Horse, High Hills)

4 = fish fence: aluminum counting fence (large bodied fish); small-mesh fyke nets (small bodied fish)

5 = fish habitat association

6 = fish tissue: walleye and lake whitefish (Athabasca River); northern pike (Muskeg River), northern pike (Clearwater River), northern pike, walleye, and lake whitefish (lakes)

7 = winter fish habitat sampling

8 = spawning survey

9 = benthic drift survey

10 = fish assemblage monitoring (FAM) program

Footnotes

(a) Reaches include east and west banks

(b) Reference area upstream of Fort McMurray; includes a 22 km section extending 1 km upstream of the Duncan Creek Confluence downstream to Iron Point

(c) Reference area upstream of Fort McMurray. It was investigated as a potential reference area for longnose sucker sentinel species monitoring but found to be inadequate due to habitat differences and concerns about longnose sucker mobility.

(d) Radiotelemetry region includes the area 60 km upstream of Fort McMurray to 250 km downstream of Fort McMurray.

(e) small-bodied fish inventory done by fish fence (fyke net) to record fish movements in and out of watercourse. Needed to be done prior to Kearl Project.

(f) Located from 3 to 11 km upstream of the confluence with the Athabasca River.

(g) In 2004 the Ells River was evaluated as a potential reference site for sentinel species (slimy sculpin) monitoring on the Muskeg and Steepbank Rivers. Several sites were sampled but no slimy sculpin were captured. Hence, the site was determined not to be suitable as a reference site for this species.

(h) Reconaissance inventory carried out in the Christina River upstream and downstream of the Hwy 881 bridge crossing.

(i) In 2004 a fish fence reconnaissance was carried out on the Ells and MacKay rivers.

Blue: *Test* (downstream of oil sands developments)
Green: *Baseline* (upstream of oil sands developments)

3.1.5 Acid-Sensitive Lakes Component

3.1.5.1 Overview of 2014 Monitoring Activities

The 2014 Acid-Sensitive Lakes (ASL) component consisted of water quality sampling at 45 lakes and ponds within and beyond the study area. The location of each lake is presented in Figure 3.1-6. The 45 lakes are located in five physiographic regions:

- Stony Mountains;
- Birch Mountains;
- West of Fort McMurray;
- Northeast of Fort McMurray; and
- Canadian Shield.

The date of sampling and the UTM coordinates for each lake are presented in Table 3.1-21. Each lake is identified by an AESRD number as well as a unique identification number ascribed to each lake by the NO_xSO_x Management Working Group (NSMWG) lake sensitivity mapping program (WRS 2004). The original AESRD name of each lake is also included in Table 3.1-21.

The sampling design for the ASL component reflects the natural geographic distribution of lakes within the study region. The 45 lakes represented a majority of the major lakes within the monitoring region that are unaffected by oil sands development (except through deposition). There are very few lakes close to the major oil sands developments (e.g., Syncrude and Suncor) that are not clearly influenced by the developments themselves. The closest lakes are those lakes in the Muskeg River uplands and the area northwest of Fort McMurray, which are well represented in the set of ASL component lakes. The set of lakes included a large number of small ponds that are less than 0.5 km^2 in area; however, beaver ponds were not considered to be permanent lakes. Low alkalinity lakes are represented in the upland areas (Birch Mountains, Stony Mountains). Five lakes in the Canadian Shield are remote from emission sources of NO_xSO_x and were selected as *baseline* lakes.

Timing of Sampling

Sampling was conducted in late summer from August 17 to 21, 2014, when chemical conditions were considered to have stabilized and thermal stratification (if it occurred) would have broken down. A late summer or fall sampling program is consistent with most of the major lake surveys that have been conducted in Alberta (e.g., Saffron and Trew 1996). In order to address the possibility of a spring pulse in acidity that could be missed in this sampling regime, a seasonal sampling program was conducted for five years by AESRD (as recommended in CEMA 2004b) on ten representative lakes scattered around the oil sands region. The results were summarized in the 2008 RAMP technical report (RAMP 2009a). The CEMA/AESRD study showed that much of the water in these shallow lakes (median depth 1.8 m) freezes during the winter resulting in dramatic changes in lake chemistry. Large decreases in pH and increases in Gran alkalinity were observed during the winter accompanied by low oxygen levels and high levels of sulphide (strong sulphide odour). In spring, the lakes recovered from the low pH and high alkalinity as the water melts and oxygen was re-introduced. Detecting a decrease in pH or decrease in Gran alkalinity in the spring during this recovery period was not possible in the CEMA/AESRD study. Further study of the spring acid pulse phenomenon was initiated by RAMP in 2012 and the results were reported in the 2012 Technical Report (RAMP 2013).

Summary of Field Methods

AESRD provided the sampling equipment and logistical support for the lake sampling. A float plane was used to access the majority of study lakes while a helicopter with floats was used to reach the smaller lakes. AESRD water quality sampling protocols were used as the basis for the field methods (AENV 2006a). Water samples were collected (approximately 10 L of water in total) from the euphotic zone (defined as twice the Secchi disk depth) at a single deep-water site in each major basin of a lake using weighted Tygon tubing. When the euphotic zone extended to the lake bottom, sampling was restricted to depths greater than 1 m above the lake bottom. In shallow lakes (<3 m deep), composite samples were created from five to ten 1-L grab samples collected at 0.5 m depth along a transect dictated by wind direction (upwind to downwind shore). Samples taken from a given lake were then combined to form a single composite sample.

Vertical profiles (1-m intervals) of dissolved oxygen (mg/L), temperature (ºC), conductivity (µS/cm), and pH were measured at the deepest location using a field-calibrated Hydrolab Minisonde 5 water quality meter. Secchi depth was also recorded. Samples for chemical analysis were stored on ice and shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection, and analyzed for the water quality variables listed in Table 3.1-22. The analytical methods for each water quality variable are described in the database available on the RAMP website (www.ramp-alberta.org).

Subsamples of 150 mL were taken from the composite samples for phytoplankton taxonomy and preserved using Lugol's solution. One or two replicate zooplankton samples were also collected from each lake as vertical hauls through the euphotic zone, using a #20 mesh (63 µm), conical plankton net. Zooplankton samples were preserved in approximately 5% formalin after anaesthetizing in soda water. Plankton samples were archived at AESRD and the zooplankton samples were sent to Environment Canada for analysis.

3.1.5.2 Changes in Monitoring Network from 2014

Five lakes from the Caribou Mountains to the northeast of the Athabasca oil sands region were considered outside of the JOSMP study area; therefore, sampling was discontinued at these lakes in 2014, as part of the ASL component. In addition, these lakes are affected by local hydrologic changes and potentially through changes associated with forest fires (e.g., change in permafrost extent); therefore, regional-scale comparisons, with these lakes acting as *baseline*, were no longer appropriate.

3.1.5.3 Challenges Encountered and Solutions Applied

There were no exceptional challenges encountered in implementing the field activities for the ASL Component in 2014.

Figure 3.1-6 Locations of Acid-Sensitive Lakes monitored in support of the 2014 JOSMP.

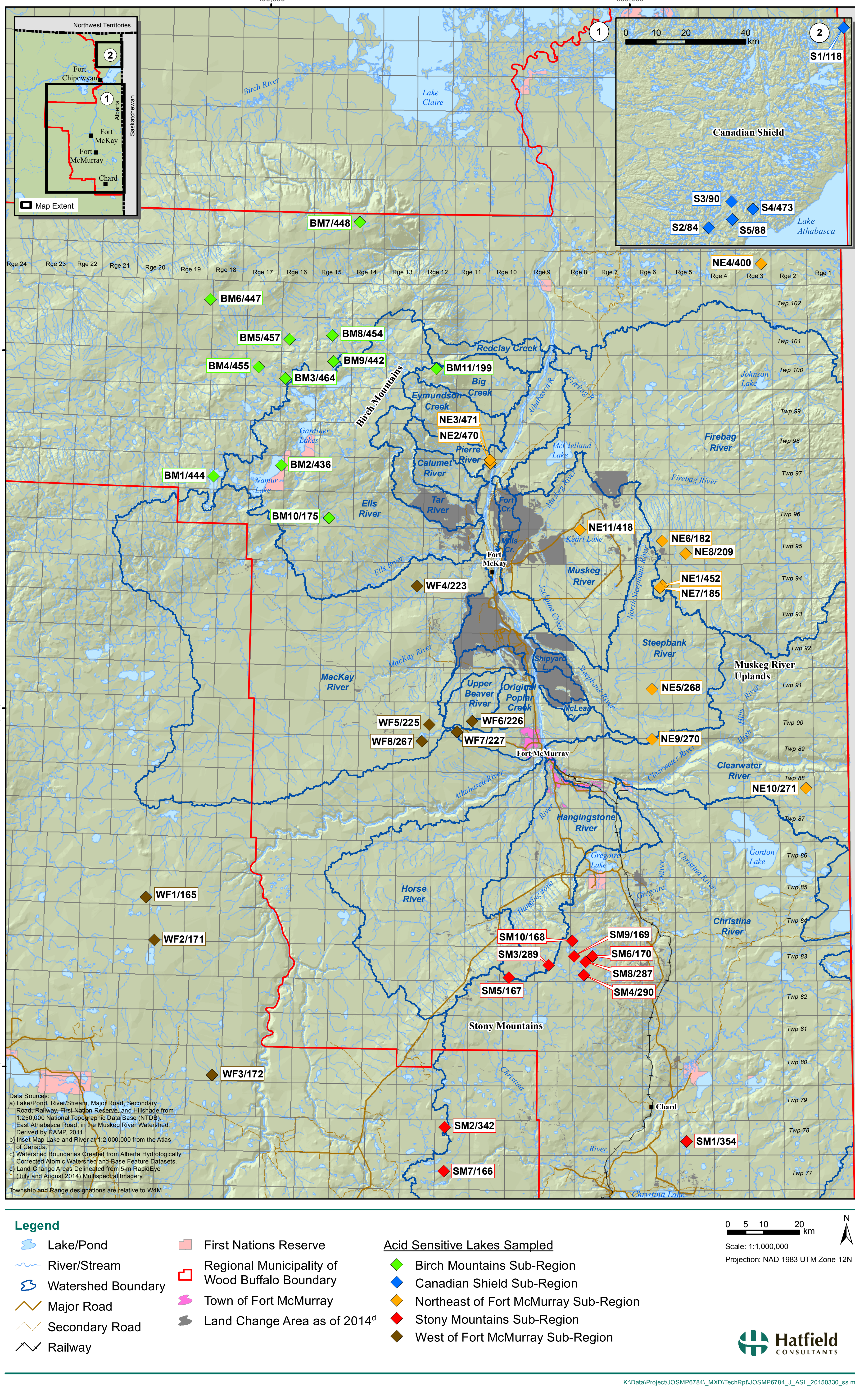

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Table 3.1-21 Lakes sampled for the Acid-Sensitive Lakes component of the 2014 JOSMP.

Lake Identification			Lake Area (km²)	UTM Coordinates (NAD83, Zone12)		Sampling Date month/day/year
AESRD Name	Unique ID[1]	Original Name		Easting	Northing	
SM10	168	A21	1.38	483819	6235130	08/20/14
SM9	169	A24	1.45	484387	6230872	08/20/14
SM6	170	A26	0.71	489502	6230877	08/20/14
SM5	167	A29	1.05	466180	6224950	08/20/14
SM7	166	A86	1.44	448014	6170896	08/20/14
SM8	287	25	2.18	487594	6229281	08/20/14
SM3	289	27	1.83	477248	6228400	08/20/14
SM4	290	28	0.54	487068	6225576	08/20/14
SM2	342	82	1.97	448271	6183205	08/21/14
SM1	354	94	2.50	515689	6179207	08/21/14
BM2	436	L18/Namur	43.39	402704	6368016	08/19/14
BM9	442	L23/Otasan	3.44	417321	6396959	08/19/14
BM1	444	L25/Legend	16.80	383849	6364923	08/19/14
BM6	447	L28	1.30	382996	6414339	08/18/14
BM7	448	L29/Clayton	0.65	424694	6435790	08/19/14
BM8	454	L46/Bayard	1.20	416941	6404239	08/19/14
BM4	455	L47	4.37	396500	6395456	08/19/14
BM5	457	L49	2.61	404995	6403111	08/19/14
BM3	464	L60	0.91	403796	6392247	08/19/14
BM10	175	P13	0.38	416003	6353212	08/17/14
BM11	199	P49	2.61	446002	6394961	08/17/14
NE1	452	L4 (A-170)	0.61	508990	6334305	08/21/14
NE2	470	L7	0.33	515029	6327465	08/21/14
NE3	471	L8	0.56	524390	6322556	08/21/14
NE4	400	L39/E9/A-150	1.12	536495	6424234	08/18/14
NE5	268	E15	1.87	506092	6305335	08/19/14
NE6	182	P23	0.28	509000	6346712	08/17/14
NE7	185	P27	0.09	508300	6333712	08/17/14
NE8	209	P7	0.15	515399	6343212	08/17/14
NE9	270	4	3.44	506113	6291421	08/19/14
NE10	271	6	4.31	549064	6277789	08/21/14
NE11	418	Kearl	5.34	485939	6349881	08/19/14
WF1	165	A42	3.20	365015	6247322	08/21/14
WF2	171	A47	0.47	367321	6235430	08/21/14
WF3	172	A59	2.06	383467	6197733	08/21/14
WF4	223	P94	0.03	440557	6334112	08/17/14
WF5	225	P96	0.21	444002	6295513	08/17/14
WF6	226	P97	0.16	456002	6296463	08/17/14
WF7	227	P98	0.08	451762	6293513	08/17/14
WF8	267	1	2.22	441917	6290884	08/21/14
S4	473	A301	1.40	525150	6559733	08/18/14
S1	118	L107/Weekes	3.73	555469	6620456	08/18/14
S2	84	L109/Fletcher	1.29	510321	6553552	08/18/14
S5	88	O-10	0.70	518279	6556260	08/18/14
S3	90	R1	0.55	517889	6562197	08/18/14

[1] Derived from the Lake Sensitivity Mapping Program conducted by NSMWG (WRS 2004).

Table 3.1-22 Water quality variables analyzed in lake water sampled for the Acid-Sensitive Lakes component of the 2014 JOSMP.

pH	bicarbonate	total dissolved nitrogen
turbidity	Gran bicarbonate	ammonia
colour	chloride	nitrite + nitrate
total suspended solids	sulphate	total Kjeldahl nitrogen
total dissolved solids	calcium	total nitrogen
dissolved organic carbon	potassium	total phosphorus
dissolved inorganic carbon	sodium	total dissolved phosphorus
conductivity	magnesium	chlorophyll *a*
total alkalinity (fixed point titration to pH 4.5)	iron	
Gran alkalinity	silicon	

3.1.5.4 Other Information Obtained

AESRD collected additional water samples for metals analyses from each lake surveyed during the 2014 field season (Table 3.1-21). These water samples were sent to Alberta Innovates Technology Futures (AITF), Vegreville, Alberta for analysis of the total and dissolved fractions of the metals listed in Table 3.1-23. The results of the metals analyses are reported in Appendix F. The mercury concentrations were subjected to low-level (ng/L) analysis. As in 2013, samples for low-level methyl mercury were also collected in 2014 and reported in Appendix F.

Table 3.1-23 Metals analyzed in lake water sampled for the Acid-Sensitive Lakes component of the 2014 JOSMP.

silver	copper	selenium
aluminum	iron	tin
antimony	mercury	strontium
arsenic	methyl mercury	thorium
barium	lithium	titanium
beryllium	manganese	thallium
bismuth	mercury (low level)	uranium
cadmium	molybdenum	vanadium
cobalt	nickel	zinc
chromium	lead	

3.1.5.5 Summary of Component Data Now Available

The selection of lakes sampled during the sixteen years of the ASL component is summarized in Table 3.1-24.

Table 3.1-24 Summary of lakes sampled for the Acid-Sensitive Lakes component, 1999 to 2014.

AESRD Name	NO_xSO_x GIS No.	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SM10	168	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM9	169	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM6	170	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM5	167	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM7	166	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
SM8	287				+	+	+	+	+	+	+	+	+	+	+	+	+
SM3	289				+	+	+	+	+	+	+	+	+	+	+	+	+
SM4	290				+	+	+	+	+	+	+	+	+	+	+	+	+
SM2	342				+	+	+	+	+	+	+	+	+	+	+	+	+
SM1	354				+	+	+	+	+	+	+	+	+	+	+	+	+
WF1	165	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF2	171	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF3	172	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF4	223				+	+	+	+	+	+	+	+	+	+	+	+	+
WF5	225				+	+	+	+	+	+	+	+	+	+	+	+	+
WF6	226				+	+	+	+	+	+	+	+	+	+	+	+	+
WF7	227				+	+	+	+	+	+	+	+	+	+	+	+	+
WF8	267				+	+	+	+	+	+		+	+	+	+	+	+
NE1	452	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE2	470	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE3	471	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE4	400	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE5	268		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE6	182				+	+	+	+	+	+	+	+	+	+	+	+	+
NE7	185				+	+	+	+	+	+	+	+	+	+	+	+	+
NE8	209				+	+	+	+	+	+	+	+	+	+	+	+	+
NE9	270				+	+	+	+	+	+	+	+	+	+	+	+	+
NE10	271				+	+	+	+	+	+	+	+	+	+	+	+	+
NE11	418					+	+	+	+	+	+	+	+	+	+	+	+
BM2	436	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM9	442	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM1	444	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM6	447	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM7	448	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM8	454	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM4	455	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM5	457	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM3	464	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM10	175				+	+	+	+	+	+	+	+	+	+	+	+	+
BM11	199				+	+	+	+	+	+	+	+	+	+	+	+	+
S4	473			+	+	+	+	+	+		+	+	+	+	+	+	+
S1	118		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S2	84	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S5	88	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+
S3	90	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
CM1	146	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
CM2	152	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
CM3	89		+	+	+	+	+	+	+	+	+	+	+	+	+	+	
CM4	97	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
CM5	91	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	

3.2 ANALYTICAL APPROACH

A weight-of-evidence approach is used for the analysis of data by applying multiple analytical methods to interpret results and determine whether any changes have occurred due to oil sands development.

The approach used for analyzing the data is as follows:

- A description and explanation of the measurement endpoints that were selected;
- A description of the statistical, graphical, or other analyses that were performed on the monitoring data to assess whether or not changes in the selected measurement endpoints have occurred temporally and/or spatially;
- A comparison of the monitoring data to published guidelines to assess whether any exceedances in variables measured have occurred;
- A comparison of the 2014 monitoring data to regional *baseline* ranges to assess whether any of the selected measurement endpoints fall outside of natural variability; and
- A description and explanation of the criteria that were used to assess whether or not changes in the selected measurement endpoints have occurred.

3.2.1 Climate and Hydrology Component

3.2.1.1 Selection of Measurement Endpoints

The following measurement endpoints, previously used by RAMP (RAMP 2009b), were used in the water balance analysis of the hydrologic data:

- Mean open-water season (May 1, 2014 to October 31, 2014) discharge;
- Mean winter (November 1, 2013 to March 31, 2014) discharge;
- Annual maximum daily (November 1, 2013 to October 31, 2014) discharge; and
- Open-water season minimum daily discharge.

These measurement endpoints are used in various oil sands project EIAs (RAMP 2009b) and can be calculated from one year of data. Values for each of these four measurement endpoints were calculated for the *test* and *baseline* hydrographs as discussed below. A percent change in the measurement endpoints between the *test* and *baseline* values was also calculated.

3.2.1.2 Temporal Comparisons of Climate and Hydrologic Conditions

For each hydrometric station, records for the 2014 water year (WY) were assessed using Exploratory Data Analysis (EDA) (Kundzewicz and Robson 2004), in relation to the historical context (as available) based on past records for the location. Historical values, including daily median, upper quartile, lower quartile, historical maximum, and historical minimum values were calculated and presented graphically.

Observed (*test*) and calculated *baseline* (described below) hydrographs were plotted and described in the context of historical data. The robustness of the historical data was dependent on the period of record available for the specific locations and varied from station to station throughout the study area. As data continues to be collected, the EDA method will provide a more robust analysis of the temporal context and will support the use of other methods that incorporate statistical analyses. Where possible, hydrometric monitoring locations with extensive data records, were selected, to accurately evaluate regional and site-specific trends in hydrologic regimes. The period of record was provided when describing the temporal context of the 2014 WY observations and calculated *baseline* conditions using the EDA approach.

3.2.1.3 Comparison to *Baseline* Conditions

The 2014 hydrologic data were analyzed using a water balance approach consistent with previous analytical methods from 2004 to 2013. The water balance approach, as described below, is applicable for stations with 2014 WY flow records and associated land use and industrial flow data. The water balance approach thereby provides a consistent approach for the 2014 WY for all watersheds in the study area.

The water balance approach was used to develop *baseline* and *test* hydrographs for each watershed with oil sands development. The *test* hydrographs were developed from recorded water level and flow measurement data, while the *baseline* hydrographs were developed using land change information and water withdrawal and discharge information from oil sands developments. This approach identified the influence of development on the 2014 hydrograph. Additional details regarding this analytical approach are found in RAMP (2008) and Appendix C of this report.

The 2014 hydrology water balance analysis consisted of:

- establishing observed (*test*) hydrographs using water level records and associated stage/discharge relationships, which were developed using Aquatic Informatics Aquarius software (Aquarius 3.6, Aquatic Informatics ™);
- estimating the 2014 *baseline* hydrographs (described below);
- calculating hydrologic measurement endpoints (described above) for both the *baseline* and *test* hydrographs; and
- applying criteria to assess the percentage change in the hydrologic measurement endpoints from estimated *baseline* and observed (*test*) hydrographs.

Estimation of 2014 Baseline Hydrograph

The 2014 WY *baseline* hydrographs were defined for this analysis as the hydrographs that would have been observed in the 2014 WY had there been no oil sands development in the watershed. Therefore, the *baseline* hydrograph was derived for the purpose of assessing any change due to oil sands development, and should not be considered as a fully naturalized hydrograph. The equation provided below describes the method used to calculate the 2014 WY *baseline* hydrographs for the outlet of each major watershed:

$$Q_{nat} = Q_{Obs} + Q_w - Q_r + Q_{HI} - Q_c$$

where,

- Q_{nat} is the calculated baseline or naturalized hydrograph for the 2014 WY;
- Q_{obs} is the test hydrograph which was observed in the 2014 WY;
- Q_w are the water withdrawals from the watercourse;
- Q_r are the water releases to the watercourse;

- Q_{HI} is the natural runoff that would have occurred in the watershed, but was intercepted or closed-circuited by oil sands development in the 2014 WY; and

- Q_c is the incremental increase in runoff caused by land cleared within the watershed.

This water balance approach provided an evaluative technique that identified the approximate magnitude of changes in the above measurement endpoints at the mouth of major watercourses. It did not; however, account for changes in runoff timing, watershed responsiveness, or storage properties that could be associated with development activities. For instance, surface runoff or dewatered volumes that were collected by mines and detained within a water management system (typically including structures such as pits, ditches, and sedimentation ponds) until the water quality met acceptable guidelines for release into surface watercourses and waterbodies, were not accounted for within the water balance, given there should be no volumetric changes of released water relative to *baseline* conditions. Water volumes withdrawn (and not returned) from these structures for purposes such as construction and drilling, or dust suppression, would be included given there was a net loss of water released from the mine area. Additionally, surface water volumes diverted into or out of a particular watershed for operational purposes were treated, respectively, as water releases and withdrawals relative to *baseline* conditions.

The water balance excluded influences from groundwater inputs to surface water and did not address changes in watershed responsiveness caused by changes in the watershed. In addition, this approach assumed that areas of land change not closed-circuited would be estimated to have an increased runoff of 20%. This value is based on the following considerations:

- The Spring Creek study conducted over a 36-year period in the boreal forest area of northern Alberta, which concluded that "the first four years after harvesting indicated minor increases in annual runoff from the Rocky Creek watershed" (AENV 2000). Within the study area, land cleared for industrial purposes (and still contributing to flow) are slated to become hydrologically closed-circuited as part of the development process and while these areas are classified as "cleared and contributing" they are generally within the four-year post-harvesting period. The assumption of increasing flow for these areas is consistent with the Spring Creek study.

- While the use of 20% is a generalized assumption, the effect of clearing in most watersheds, related to oil sands development, is (as discussed above, and unlike forestry) a temporary land classification with cleared areas being slated for near-term development. These areas will be incorporated into the closed-circuited areas of the developments as mining plans unfold. In most cases the percentage of the areas of watersheds that were cleared and contributing was relatively small compared to the overall land-cover of the watershed such that this assumption (whether it be from 15 to 25%) would have a minor impact on the overall calculation results when considering the drainage basin as a whole.

3.2.1.4 Classification of Results

The percent difference between the *test* and *baseline* values of the hydrologic measurement endpoints developed through the water balance analyses were used to classify results as follows: ± 5% – Negligible-Low; ± 15% – Moderate; > 15% – High. These ranges were derived from criteria for determining effects on hydrologic measurement endpoints in a number of EIAs prepared for oil sands projects (RAMP 2009b).

3.2.1.5 Longitudinal Change Classification

The water balance provided results for an entire watershed based on calculations conducted for the mouth of each watershed. To provide additional spatial context of the water balance results, longitudinal change classification was conducted for rivers that reported water balance results of moderate and high change in any measurement endpoints in the 2014 WY. For the longitudinal change classification, the same general water balance methodology was used to define change to the hydrology of the entire river length but taking into account that cleared areas, closed-circuited areas, industrial withdrawals and diversions, and industrial releases were calculated at select nodes where change from development occurred along the river mainstem and tributaries. This classification did not assess the measurement endpoints specifically but rather assessed change based on the introduction of land development along nodes of each river. This assessment allowed the river mainstem and specific developed tributaries to be categorized longitudinally with the level of change as a result of the development. For watersheds, where changes any one of the measurement endpoints (see above) were classified as Moderate or High, these results were presented in map format showing the length of the river and the sections categorized as Negligible-Low, Moderate, and High change from pre-development condition.

3.2.2 Water Quality Component

The analytical approach used in 2014 for the Water Quality component under the JOSMP was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2009b) and consisted of:

- reviewing and selecting particular water quality variables as water quality measurement endpoints;
- reviewing and selecting criteria to be used in detecting changes in water quality measurement endpoints;
- updating regional *baseline* data ranges for each water quality measurement endpoint; and
- presenting results in tabular and graphical format comparing 2014 concentrations of water quality measurement endpoints to historical concentrations of each endpoint at each station, water quality regional *baseline* conditions, and selected criteria for determining change in water quality.

3.2.2.1 Review and Selection of Water Quality Measurement Endpoints

The selection of water quality measurement endpoints was guided by:

- water quality measurement endpoints used in the EIAs of oil sands projects (RAMP 2009b);
- a draft list of water quality variables of concern in the lower Athabasca region developed by CEMA (2004a);
- water quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the RAMP 1997 to 2007 water quality dataset indicating significant inter-correlation of various water quality variables, particularly metals (RAMP 2008); and
- water quality variables to assist in interpreting results of the Benthic Invertebrate Communities and the Fish Populations components.

Table 3.2-1 presents the water quality variables listed in these various sources.

Table 3.2-1 Potential water quality measurement endpoints.

Group	Variables Listed in EIAs RAMP (2009b)	CEMA Variables of Concern (CEMA 2004a)	RAMP 5-year Report (Golder 2003)	Variables to Support Other Monitoring Components[1]	Additional Suggested Variables[2]
Physical Variables	Temperature TSS Dissolved oxygen Conductivity pH	(None)	pH TSS	Temperature Dissolved oxygen pH TSS Conductivity	
Nutrients	Ammonia-N Total nitrogen Total phosphorus	Ammonia-N Total nitrogen Total phosphorus	Dissolved organic carbon Total Kjeldahl nitrogen Total phosphorus	Dissolved phosphorus Nitrate+nitrite	
Ions and Ion Balance	Chloride Sulphide TDS	Sodium Chloride Potassium Fluoride Sulphate	TDS Sulphate Total alkalinity	Total alkalinity Hardness	Carbonate Bicarbonate Magnesium Calcium
Dissolved and Total Metals	Aluminum Arsenic Barium Boron Cadmium Chromium Copper Iron Manganese Mercury Molybdenum Selenium Silver Zinc	Aluminum Antimony Boron Cadmium Chromium Lithium Molybdenum Nickel Strontium Vanadium	Total chromium Total boron Total aluminum	Total & dissolved copper Total & dissolved lead Total & dissolved nickel Total & dissolved zinc Ultra-trace mercury	Total strontium Total arsenic
Organics/ **Hydrocarbons**	Oil and grease Naphthenic acids Total phenolics	Oil and grease Total hydrocarbons Naphthenic acids Toluene Xylene	(None)	(None)	(None)

All variables are currently monitored by JOSMP except those in **bold**.

Note: JOSMP analyzes tainting compounds in fish tissue.

[1] Primarily Benthic Invertebrate Communities and Fish Populations components (inferred).

[2] Suggested by the RAMP Technical Program Committee, February 2006 and February 2008, and from ongoing review of stakeholder concerns.

Table 3.2-1 (Cont'd.)

Group	Variables Listed in EIAs RAMP (2009b)	CEMA Variables of Concern (CEMA 2004a)	RAMP 5-year Report (Golder 2003)	Variables to Support Other Monitoring Components[1]	Additional Suggested Variables[2]
PAHs	Benzo(a)anthracene Benzo(a)pyrene Miscellaneous PAHs	Naphthalene Biphenyl Acenapthene Acenaphthylene Fluorene Fluoranthene Alkyl-naphthalenes Alkyl-biphenyls Alkyl-acenaphthene Alkyl-benzo(a)anthracene Alkyl-fluorenes Alkyl-phenanthrenes Dibenzothiophene Alkyl-dibenzothiophenes	(None)	(None)	(None)
Effects-based Endpoints	Acute toxicity Chronic toxicity	Acute toxicity Chronic toxicity **Fish tainting**			

All variables are currently monitored by JOSMP except those in **bold**.

Note: JOSMP analyzes tainting compounds in fish tissue.

[1] Primarily Benthic Invertebrate Communities and Fish Populations components (inferred).

[2] Suggested by the RAMP Technical Program Committee, February 2006 and February 2008, and from ongoing review of stakeholder concerns.

The water quality measurement endpoints used in 2014 were:

- *pH* – an indicator of acidity;
- *Conductivity* – basic indicator of overall ion concentration;
- *Total suspended solids (TSS)* – a variable strongly associated with several other measured water quality variables, including total phosphorus, total aluminum, and numerous other metals;
- *Dissolved phosphorus, total nitrogen, and nitrate+nitrite* – indicators of nutrient status. Dissolved phosphorus rather than total phosphorus is included because it is the primary biologically-available species of phosphorus and because total phosphorus levels are strongly associated with TSS (RAMP 2006);
- *Various ions (sodium, chloride, calcium, magnesium, sulphate)* – indicators of ion balance, which could be affected by discharges or seepages from oil sands development or by changes in the water table and changes in the relative influence of groundwater;
- *Total alkalinity* – an indicator of the buffering capacity and acid sensitivity of waters;
- *Total dissolved solids (TDS) and dissolved organic carbon (DOC)* – indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively;

- *Total and dissolved aluminum* – aluminum is mentioned as a variable of interest in some oil sands EIAs, by CEMA, and in the RAMP 5-year report (Table 3.2-1). Total aluminum, for which water quality guidelines exist, has been demonstrated to be strongly associated with TSS (Golder 2003). Dissolved aluminum more accurately represents biologically available forms of aluminum that may be toxic to aquatic organisms (Butcher 2001);
- *Total boron, total molybdenum, total strontium* – three metals found in predominantly-dissolved form in waters of the Athabasca oil sands region (RAMP 2004), and may be indicators of groundwater influence in surface waters;
- *Total arsenic* and *total mercury (ultra-trace)* – metals of potential importance to the health of aquatic life and human health;
- *Naphthenic acids* – relatively-labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern;
- *Total hydrocarbons (CCME fractions + BTEX)* – indicators of the total hydrocarbon content in water, including indicators (fractions) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene, and xylene (collectively called BTEX), based on methods presented by CCME (2001) (added in 2011, as an intended replacement for Total Recoverable Hydrocarbons);
- Various PAH measurement endpoints, including:
    - *Total PAHs* – a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
    - *Total parent PAHs* – a sum of concentrations of all non-alkylated PAHs measured in a given sample;
    - *Total alkylated PAHs* – a sum of concentrations of all alkylated PAHs measured in a given sample;
    - *Naphthalene* – a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;
    - *Total dibenzothiophenes* – a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic); and
    - *Retene* – an alkylated phenanthrene generated through decomposition of plant materials (i.e., biogenic rather than petrogenic).
- In addition to the above water quality measurement endpoints, overall ionic composition at each station was assessed graphically using Piper diagrams (Section 3.2.2.2).

3.2.2.2 Assessment of Results

Temporal Trend Analysis

Statistical trend analysis was conducted on water quality measurement endpoints at those sampling stations where there were at least seven consecutive years of fall water quality data. A non-seasonal Mann-Kendall trend analysis was conducted on RAMP/JOSMP fall data using the program WQStat Plus, with a level of significance of α=0.05. Values were not discharge-averaged before trend analysis.

Trend analysis also was undertaken on water quality data for the Athabasca River, at stations that have been monitored continuously by AESRD since 1976. Seasonal Mann-Kendall analysis was applied to monthly AESRD water quality data from the Athabasca River upstream of Fort McMurray (station ATR-UFM, approximately 100 m upstream of the Horse River), and the Athabasca River at Old Fort (station ATR-OF, located in the Athabasca River Delta, downstream of the Embarras River distributary).

Trend analysis was conducted on specific water quality measurement endpoints including total suspended solids, total dissolved solids, dissolved phosphorus, total nitrogen, total boron, total strontium, calcium, chloride, magnesium, potassium, sodium, sulphate and total arsenic from the period of sampling (1997 to 2014), to assess trends potentially related to development between the two stations during this time period.

Ion Balance

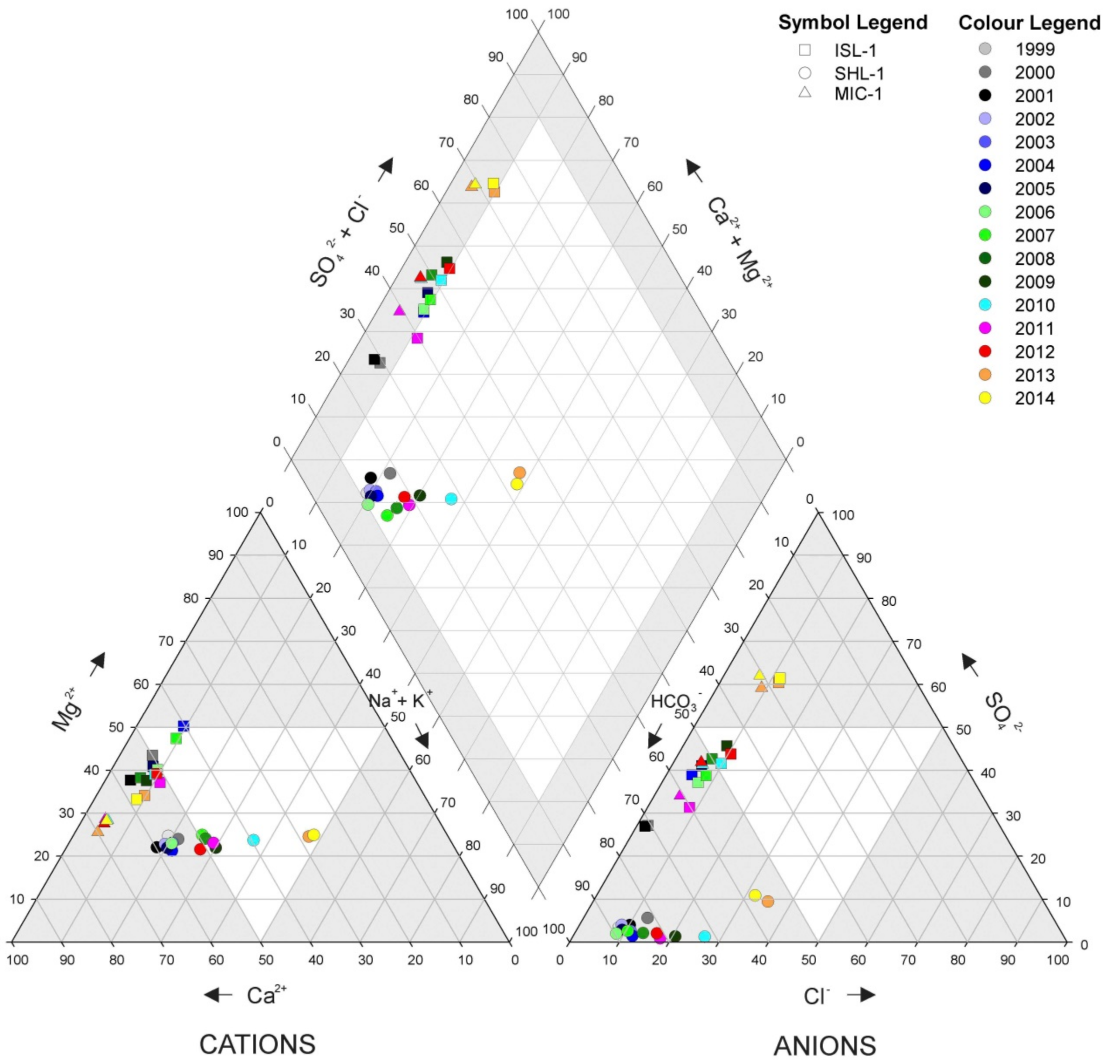
Piper diagrams were used to examine the ion balance at each station or at multiple stations within a watershed, to assess temporal or spatial differences in the ionic composition of water. Piper diagrams display the relative concentrations of major cations and anions on two separate ternary (triangular) plots, together with a central diamond plot where points from the two ternary plots are projected to describe the overall character, or type of water (Güler et al. 2004) (Figure 3.2-1).

Comparison to Water Quality Guidelines and Historical Data

The 2014 value (fall, seasonal, or monthly) of each water quality measurement endpoint was tabulated for each station sampled. Historical variability was presented for each water quality measurement endpoint, represented by minimum, maximum, and median values observed, as well as the number of observations, at each station from 1997 to 2014 (fall observations only).

All cases in which concentrations of any water quality variable, including water quality measurement endpoints and other monitored water quality variables, exceeded relevant guidelines, were also reported (all seasons).

Figure 3.2-1 Example Piper diagram, illustrating relative ion concentrations in waters from Isadore's Lake, Mills Creek, and Shipyard Lake, 1999 to 2014.

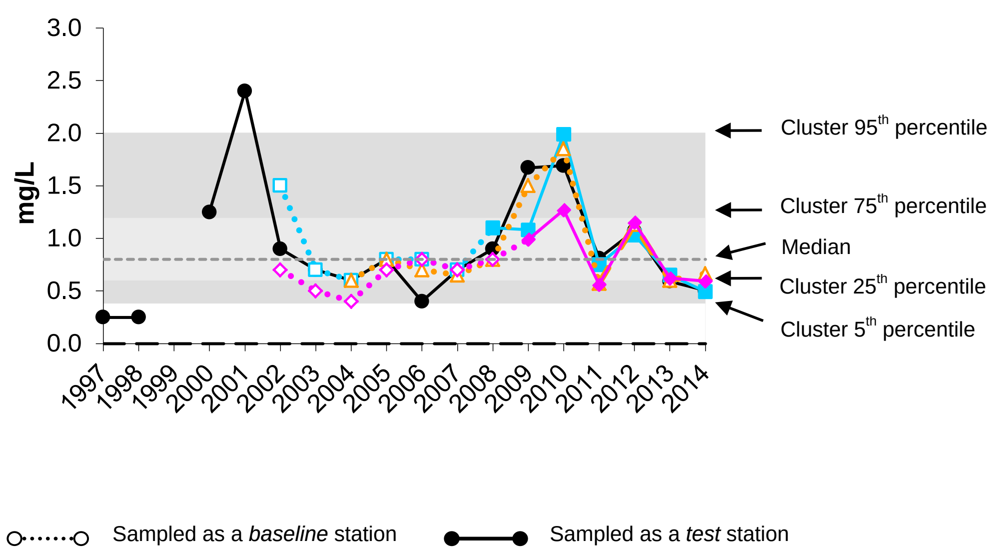


Comparison to Regional Baseline Concentrations

To allow for a regional comparison, untransformed data for 22 water quality measurement endpoints from all *baseline* stations sampled from 1997 to 2014 (fall only) were pooled from each cluster of similar stations. Descriptive statistics describing *baseline* water quality characteristics for each cluster were calculated including the 5th, 25th, 50th (median), 75th, and 95th percentiles for comparison against station-specific data (Table 3.2-3, Table 3.2-4, Table 3.2-5). The number of observations varied by cluster for each of the selected water quality measurement endpoints. The median rather than the mean was used as an indicator of typical conditions; given water quality data are characteristically positively skewed. Regional *baseline* ranges did not include and were not applied to lakes sampled in 2014, to address concerns expressed by the RAMP 2010 Peer Review (AITF 2011) in combining water quality data from streams and lakes in regional *baseline* ranges. Given the limited *baseline* data available for lakes, regional *baseline* ranges were not calculated for lakes.

Data for 14 of the 22 selected water quality measurement endpoints (Section 3.2.2.1) were presented graphically in the context of relevant regional variability by presenting data for each station for all years of sampling to allow assessment of any temporal trends (Figure 3.2-2). Where possible, stations located upstream and downstream on specific watersheds were presented together to allow assessment of any differences in values or trends between upstream/downstream locations.

Figure 3.2-2 Example of a comparison of data from a specific watershed against regional *baseline* concentrations and water quality guidelines, in this case, total nitrogen in the Steepbank River watershed.



For stations with monthly data collected in 2014, monthly results were presented against the fall range of *baseline* concentrations appropriate for that station. It should be noted that the fall range of *baseline* water quality is not necessarily representative of water quality for samples collected outside of fall. To address this discrepancy, monthly data outside of fall (September/October) were only screened informally against these regional *baseline* fall concentrations (i.e., comments are made in relevant sections of

Section 5 regarding how monthly data compared to fall *baseline* ranges, but non-fall data were not used to determine potential effects within the analytical framework of this report).

Development of Regional *Baseline* Concentrations Descriptions of regional *baseline* water quality conditions were developed from existing data collected since 1997, from *baseline* stations throughout the study area. These ranges of regional natural variability in water quality were used as one method of screening water quality observed at all stations in fall 2014, to assess whether water quality conditions at the time of sampling were similar to, or differed from those typically observed in the region.

This analytical approach is similar to that of the Reference Condition Approach to biomonitoring (Bailey et al. 2004), also used in the Benthic Invertebrate Communities component, and incorporates elements of control charting (Morrison 2008), which also is a feature of the Benthic Invertebrate Communities and Acid-Sensitive Lakes components. This approach is more fully described in the RAMP Technical Design and Rationale document (RAMP 2009b). It also shares similarities with CCME's prescribed approach for developing site-specific water quality objectives (SSWQOs), which uses the 90^{th} percentile of upstream water quality observations to define benchmarks for assessment of water quality in a given waterbody, typically downstream of some kind of development (CCME 2011). This approach of comparing observed data against a defined range of natural variability also aligns with the Alberta Water Council's (2009) definition of a healthy aquatic ecosystem as "…*an aquatic environment that sustains its ecological structure, processes, functions and resilience within its range of natural variability.*"

In previous years, multivariate data analysis was used to develop descriptions of regional *baseline* water quality that were then applied to water quality measurements from *baseline* and *test* stations. In this approach, water quality data from all *baseline* water quality stations from 2002 onward were pooled using cluster analysis. Similar approaches to consolidation and analysis of large water quality datasets are common in the water quality assessment literature (e.g., Boyacioglu and Boyacioglu 2010; Astel et al. 2007; Singh et al. 2004; Jones and Boyer 2002; Güler et al. 2004). Details describing the cluster analysis methodology have been reported in previous RAMP technical reports (e.g., RAMP 2011).

For 2014, a cluster analysis confirmed overall patterns previously seen in the data: stations generally grouped together based on geographical location rather than sampling year. Rank and scale transformations of the data produced similar cluster memberships for most of the stations, suggesting that clustering based on water quality data in 2014 was based on strong relationships. To preserve clustering of station-data combinations located within specific watersheds, multivariate analysis was not used exclusively to determine cluster membership. For determination of regional ranges of natural variability, stations were grouped together based on cluster analysis and geographical location. This method incorporated both overall patterns determined from cluster analysis with ecological knowledge of the area. Three "clusters" were determined: 1. Athabasca River and Delta; 2. Southern Tributaries plus McLean Creek and the Mackay, Ells, Steepbank, and Firebag Rivers; 3. Poplar, Fort, Big, Red Clay, and Eymundson Creeks and the Beaver, Tar, Calumet, Pierre, and Muskeg Rivers. Stations included in each group of *baseline* data, and those compared against these groups are provided in Table 3.2-2. Ranges of regional *baseline* values calculated for each group of stations and used for comparisons are provided in Table 3.2-3 to Table 3.2-5.

Table 3.2-2 Regional *baseline* water quality data groups and station comparisons.

Regional *Baseline* Grouping (Cluster)	*Baseline* Stations Used in Creating Regional Comparison[1]	Stations (2014) Compared Against Regional *Baseline* Range
1. Athabasca River and Delta	ATR-DC-CC, ATR-DC-E, ATR-DC-W, ATR-DC-M	ATR-DD-E, ATR-DD-W, ATR-DD-C
2. Southern Tributaries plus McLean Creek and the MacKay, Ells, Steepbank, and Firebag rivers	BRC-1, CHR-2, CHR-2A, CHR-4, CLR-HAR-1, HHR-1, HOR-1, SUC-2, DUR-1, ELR-2, ELR-2A, ELR-3, FIR-2, MAR-2, NSR-1, STR-2, STR-3	BRC-1, CLR-1, CLR-2, HHR-1, CHR-1, CHR-2, CHR-3, CHR-4, GRR-1, JAR-1, SAC-1, SUC-1, SUC-2, UNC-2, UNC-3, ELR-1, ELR-3, HAR-1, HAR-1A, FIR-1, FIR-2, MAR-1, MAR-2, MAR-2A, MCC-1, NSR-1, STR-1, STR-2, STR-3
3. Poplar, Fort, Big, Red Clay, and Eymundson creeks, and the Beaver, Tar, Calumet, Pierre, and Muskeg rivers	BER-2, BIC-1, CAR-1, CAR-2, EYC-1, FOC-1, IYC-1, JAC-1, JAC-2, MUC-1, MUR-6, PIR-1, RCC-1, STC-1, TAR-1, TAR-2, WAC-1	BER-1, BER-2, BIC-1, CAR-1, CAR-2, EYC-1, FOC-1, IYC-1, JAC-1, JAC-2, MUC-1, MUR-1, MUR-6A, MIC-1, PIR-1, POC-1, RCC-1, STC-1, TAR-1, TAR-2, WAC-1

[1] See Table 3.1-6 for classification of station status by year. Where station status changed from *baseline* to *test* from 1997 to 2014, only *baseline* data were used in the determination of regional water quality characteristics.

Table 3.2-3 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2014, Group 1 Athabasca River and Delta.

Measurement Endpoint	n	Percentiles						
		Min	5^{th}	25^{th}	Median	75^{th}	95^{th}	Max
Physical Variables								
pH	42	7.70	7.86	8.02	8.19	8.24	8.33	8.40
Total suspended solids	42	3	3	10	18	49	135	180
Conductivity	42	202	204	240	270	295	441	596
Nutrients								
Total dissolved phosphorus	42	0.003	0.005	0.008	0.012	0.019	0.028	0.030
Total nitrogen	42	0.25	0.30	0.47	0.56	0.70	0.97	1.10
Nitrate+nitrite	42	0.05	0.05	0.07	0.10	0.10	0.10	0.29
Dissolved organic carbon	42	1.50	3.05	6.00	7.50	10.90	23.29	31.20
Ions								
Sodium	42	8.00	8.62	10.00	13.00	17.60	22.60	28.00
Calcium	42	17.70	18.93	24.35	32.50	34.80	52.25	76.50
Magnesium	42	5.49	5.76	7.22	9.05	9.87	14.68	22.30
Chloride	42	1.52	2.00	3.00	5.47	16.53	25.00	36.00
Sulphate	42	5.67	6.54	11.45	25.45	31.05	103.63	137.00
Potassium	42	0.75	0.80	0.88	1.00	1.20	1.96	2.96
Total dissolved solids	42	40	90	156	170	186	330	425
Total alkalinity	42	63	69	85	101	111	145	177
Selected metals								
Total aluminum	42	0.03	0.14	0.47	0.69	1.34	3.74	5.13
Dissolved aluminum	42	0.01	0.01	0.01	0.01	0.03	0.12	1.10
Total arsenic	42	0.0005	0.0006	0.0007	0.0009	0.0010	0.0024	0.0038
Total boron	42	0.01	0.02	0.02	0.03	0.04	0.09	0.11
Total mercury (ultra-trace)	31	0.60	1.20	1.20	1.20	3.40	12.95	21.00
Total molybdenum	42	0.0002	0.0002	0.0004	0.0006	0.0007	0.0013	0.0025
Total strontium	42	0.09	0.10	0.13	0.20	0.23	0.29	0.30

Table 3.2-4 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2014, Group 2 southern tributaries plus McLean Creek and the Mackay, Ells, Steepbank, and Firebag rivers.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical Variables								
pH	132	7.20	7.60	8.00	8.10	8.27	8.39	8.70
Total suspended solids	132	2	3	3	5	10	33	174
Conductivity	132	80	138	175	208	249	351	703
Nutrients								
Total dissolved phosphorus	132	0.002	0.004	0.012	0.026	0.041	0.069	0.118
Total nitrogen	131	0.25	0.38	0.60	0.80	1.20	2.01	3.20
Nitrate+nitrite	132	0.05	0.05	0.07	0.10	0.10	0.10	0.10
Dissolved organic carbon	132	6.00	8.00	13.00	17.00	24.05	33.73	44.80
Ions								
Sodium	132	2.00	3.00	5.00	9.95	16.00	25.00	70.00
Calcium	132	10.00	11.90	20.25	23.75	30.20	44.32	70.50
Magnesium	132	2.86	4.19	6.42	7.45	10.13	16.39	22.90
Chloride	132	0.50	0.50	0.77	1.12	3.00	30.77	43.00
Sulphate	132	0.50	0.57	2.03	4.40	9.70	22.78	36.40
Potassium	132	0.50	0.50	0.70	0.90	1.10	2.87	3.47
Total dissolved solids	132	40	110	139	160	190	266	464
Total alkalinity	132	30	46	81	97	124	176	333
Selected metals								
Total aluminum	131	0.003	0.015	0.035	0.105	0.288	1.080	5.000
Dissolved aluminum	131	0.0004	0.0010	0.0047	0.0100	0.0174	0.0387	0.1850
Total arsenic	131	0.0001	0.0002	0.0005	0.0008	0.0010	0.0016	0.0026
Total boron	131	0.01	0.01	0.03	0.05	0.06	0.11	0.25
Total mercury (ultra-trace)	113	0.26	0.76	1.20	1.20	1.80	3.96	13.70
Total molybdenum	131	0.00001	0.00004	0.00013	0.00022	0.00048	0.00091	0.00156
Total strontium	131	0.03	0.05	0.07	0.10	0.13	0.18	0.29

Table 3.2-5 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2014, Group 3 Poplar, Fort, Mills, Big, Red Clay, and Eymundson creeks and the Beaver, Tar, Calumet, Pierre, and Muskeg rivers.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical Variables								
pH	93	7.16	7.46	7.90	8.10	8.23	8.40	8.52
Total suspended solids	93	3	3	3	6	10	48	243
Conductivity	93	73	186	255	346	493	691	1,172
Nutrients								
Total dissolved phosphorus	94	0.005	0.010	0.014	0.021	0.037	0.118	0.305
Total nitrogen	94	0.26	0.40	0.61	0.90	1.19	2.41	5.54
Nitrate+nitrite	94	0.05	0.05	0.07	0.10	0.10	0.10	0.10
Dissolved organic carbon	93	6.00	8.42	14.00	21.00	27.30	47.64	54.40
Ions								
Sodium	93	2.00	3.00	9.00	12.00	27.00	70.70	96.20
Calcium	93	7.50	22.02	31.40	44.50	55.20	72.20	83.50
Magnesium	93	2.42	6.72	10.30	13.40	16.50	21.64	26.60
Chloride	93	0.50	0.50	1.00	2.00	3.00	23.58	80.20
Sulphate	93	0.67	1.93	3.60	7.60	23.50	62.96	111.00
Potassium	93	0.30	0.50	0.87	1.23	2.03	3.81	5.33
Total dissolved solids	93	30	146	200	250	324	488	547
Total alkalinity	93	26	93	127	185	225	303	354
Selected metals								
Total aluminum	94	0.01	0.01	0.04	0.09	0.29	0.93	4.10
Dissolved aluminum	94	0.0005	0.0015	0.0051	0.0100	0.0183	0.0460	0.1700
Total arsenic	94	0.0001	0.0003	0.0005	0.0010	0.0013	0.0024	0.0050
Total boron	94	0.01	0.01	0.04	0.06	0.09	0.19	0.42
Total mercury (ultra-trace)	68	0.23	0.66	1.20	1.20	1.73	4.09	10.60
Total molybdenum	94	0.00003	0.00005	0.00010	0.00019	0.00056	0.00142	0.00640
Total strontium	94	0.04	0.07	0.09	0.15	0.20	0.32	0.44

3.2.2.3 Classification of Results

The following criteria were used for assessing water quality results:

- Trend Analysis – Any significant (α=0.05) trends over time in water quality measurement endpoints.
- Comparison to Historical Concentrations – Fall 2014 data for each of the selected water quality measurement endpoints at a given station were assessed against all historical observations for that endpoint at that station, with historically high or low observations identified.
- Comparison to Published Water Quality Guidelines – All water quality data collected in 2014 in any season or month were screened against Alberta acute and chronic water quality guidelines for the protection of aquatic life (AESRD 2014) and CCME Canadian Water Quality Guidelines (CWQG) (CCME 2007). Variables for which there were no AESRD or CCME guidelines were screened against applicable guidelines from other jurisdictions where appropriate (Table 3.2-6). All values that exceeded these guidelines were reported explicitly in Section 5.
- Comparison to Regional *Baseline* Conditions – 2014 water quality data for each of the selected water quality measurement endpoints were assessed against a defined range of natural variability in concentrations of each of these measurement endpoints.
- Calculation of a Water Quality Index – Described below.

Water quality at each monitoring station in fall 2014 was summarized into a single index value, ranging from 0 to 100, using an approach based on the CCME Water Quality Index. This index was calculated using comparisons of observed water quality against user-specified benchmark values, such as water quality guidelines or background concentrations. It considered three factors: (i) the percentage of variables with values that exceeded a given user-specified benchmark; (ii) the percentage of comparisons that exceeded a given user-specified benchmark; and (iii) the degree to which observed values exceeded user-specified benchmark values. A detailed description of the index and how it is calculated is found at http://www.ccme.ca/ourwork/water.html?category_id=102. Its specific application is described below.

Index calculations for water quality data used regional *baseline* conditions, calculated and described in Section 3.2.2.2, as the benchmark for comparison. Specifically, individual water quality observations were compared to the 95th percentile of *baseline* concentrations (for the appropriate water quality station cluster) for each water quality variable.

Variables included in the calculation of the water quality index included all water quality measurement endpoints (Section 3.2.2.1), with the exception of total nitrogen, which was excluded because of autocorrelation with nitrate+nitrite and ammonia, both of which were included in index calculations. Index values were calculated for all *baseline* and *test* stations. Calculation of water quality index values for all stations sampled in fall since 1997 (n=631) yielded index values ranging from 40.4 to 100. It should be noted that historical index values calculated for specific observations may change annually, given that 95th percentile values for individual variables included in the index may change with addition of new *baseline* data to the data record.

Water-quality-index scores were classified using the following scheme:

- 80 to 100: Negligible-Low difference from regional *baseline* conditions;
- 60 to 80: Moderate difference from regional *baseline* conditions; and
- Below 60: High difference from regional *baseline* conditions.

This classification scheme, based on similarity to regional *baseline* conditions, differs somewhat from that used by CCME to classify water quality based on water quality guidelines. Specifically, only three categories were used (versus five used by CCME), to ensure consistency with classification schemes used for other monitoring components. A classification of a “Negligible-Low” difference from *baseline,* corresponds with CCME guideline-based index classes “Good” and “Excellent”; a classification of a “Moderate” difference from *baseline* generally corresponds with CCME class “Fair”; and a classification of a “High” difference from *baseline* corresponds with CCME classes “Marginal” and “Poor”. Although the CCME index is typically calculated using comparisons against water quality guidelines, it is customized for each station where it is applied to suit local conditions and concerns, and the use of regional norms as benchmarks, is an appropriate use of this index (Government of Canada 2008, S. Pappas, Environment Canada, pers. comm. 2009).

Water Quality Index values were not calculated for lakes because of concerns raised by the RAMP Peer Review (AITF 2011) regarding combining lakes and streams in regional *baseline* ranges.

Table 3.2-6 Water quality guidelines used to screen data collected for the Water Quality Component of the 2014 JOSMP.

Water Quality Variable	Units	AESRD[b] Acute	AESRD[b] Chronic	CCME[a]	Other Jurisdictions[c]
Conventional variables					
pH	pH units	-	6.5-9.0	6.5 to 9.0	-
Dissolved oxygen	mg/L	5.0 (min)	6.5-9.5[p]	5.5 to 9.5[k]	-
Temperature	^{o}C	-	-	-	-
Suspended Solids	mg/L	varies[o]	varies[o]	-	-
Turbidity	NTU	-	-	-	-
Major ions					
Sulphate	mg/L	-	128 to 429[q]	-	-
Sulphide (as H_2S)	mg/L	-	1.9	-	0.002[c]
Chloride (Cl)	mg/L	640	120	120	230 (BC), 860 (USEPA)
Nutrients					
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-
Ammonia	mg/L	-	0.018 to 190[j]	0.021 to 231[j]	-
Nitrate-N	mg/L	124	3	13	-
Nitrite-N	mg/L	0.06-0.6[r]	0.02-0.2[r]	0.060	-
Total Nitrogen	mg/L	-	-	-	-
Total Dissolved Phosphorus	mg/L	-	-	-	-
Total Phosphorus	mg/L	-	-	-	-
Organics					
Total phenols	mg/L	-	0.004	0.004	0.05[n]
Naphthenic acids	mg/L	-	-	-	-
Total and dissolved metals					
Aluminum (Al)	mg/L	0.10 (dissolved)[l]	0.05 (dissolved)[l]	0.005, 0.1[d]	0.05 (dissolved)[l]
Antimony (Sb)	mg/L	-	-	-	0.020
Arsenic (As)	mg/L	-	0.005	0.0050	-
Barium (Ba)	mg/L	-	-	-	5
Beryllium (Be)	mg/L	-	-	-	-
Bismuth (Bi)	mg/L	-	-	-	-
Boron (B)	mg/L	29	1.5	1.5	1.2
Cadmium (Cd)	mg/L	0.00011[s]	0.00004[e]	0.00004[e]	-
Calcium (Ca)	mg/L	-	-	-	-
Chromium III (Cr^{3+})	mg/L	-	0.0089	0.0089	-
Chromium VI (Cr^{6+})	mg/L	-	0.0010	0.0010	-
Cobalt (Co)	mg/L	-	0.0025	-	0.004
Copper (Cu)	mg/L	0.0009 to 0.062[t]	0.007	0.002 to 0.004[f]	-
Iron (Fe)	mg/L	-	0.3	0.300	-
Lead (Pb)	mg/L	-	0.001 to 0.007[g]	0.001 to 0.007[g]	-
Lithium (Li)	mg/L	-	-	-	0.87
Magnesium (Mg)	mg/L	-	-	-	-
Manganese (Mn)	mg/L	-	-	-	0.8 to 3.8[m]
Mercury (Hg)[h]	mg/L	0.000013	0.000005	0.000026	-
Molybdenum (Mo)	mg/L	-	0.073	0.073	-
Nickel (Ni)	mg/L	0.037 to 1.52[v]	0.004 to 0.170[u]	0.025 to 0.150[i]	-
Phosphorus (P)	mg/L	-	-	-	-
Potassium (K)	mg/L	-	-	-	-
Selenium (Se)	mg/L	-	0.0010	0.0010	-
Silver (Ag)	mg/L	-	0.0001	0.0001	-
Sodium (Na)	mg/L	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-
Sulphur (S)	mg/L	-	-	-	-
Thallium (Tl)	mg/L	-	0.0008	0.0008	0.0008
Tin (Sn)	mg/L	-	-	-	-
Titanium (Ti)	mg/L	-	-	-	-
Uranium (U)	mg/L	0.033	0.015	0.015	-
Vanadium (V)	mg/L	-	-	-	-
Zinc (Zn)	mg/L	-	0.030	0.030	-
Polycyclic Aromatic Hydrocarbons (PAHs)					**[BC Chronic]**
Acenaphthene	ng/L	-	-	5,800	6,000
Anthracene	ng/L	-	-	12	4,000
Benzo(a)anthracene	ng/L	-	-	18	100
Benzo(a)pyrene	ng/L	-	-	15	10
Fluoranthene	ng/L	-	-	40	4,000
Fluorene	ng/L	-	-	3,000	12,000
Naphthalene	ng/L	-	-	1,100	1,000
Phenanthrene	ng/L	-	-	400	300
Pyrene	ng/L	-	-	25	-

a: CCME (2007)

b: AESRD (2014)

c: All from British Columbia (2006), except chloride (USEPA 1999), and sulphide (USEPA 1999)

d: 0.005 at pH<6.5 and 0.100 at pH>=6.5

e: Hardness-dependant. Guideline = 0.04 µg/L at $[CaCO_3]$= 0 to 17 mg/L, guideline = $10^{(0.86[log(hardness)]-2.46)}/1000$ at $[CaCO_3]$=17 to 280 mg/L, 0.37 µg/L at $[CaCO_3]$ >280 mg/L

f: Hardness-dependant. Guideline =$0.2*e^{(0.8545*[ln(hardness)]-1.465)}/1000$; 0.002 at $[CaCO_3]$=0 to 82 mg/L; 0.004 at $[CaCO_3]$>180 mg/L

g: Hardness-dependant. Guideline = $10^{(1.273*[ln(hardness)]-4.705)}/1000$; 0.001 at $[CaCO_3]$=0 to 60 mg/L; 0.007 at $[CaCO_3]$ > 180 mg/L

h: for inorganic mercury

i: Hardness-dependant. Guideline = $e^{(0.76*[ln(hardness)]+1.06)}/1000$. 0.025 at $[CaCO_3]$=0 to 60 mg/L; 0.150 at $[CaCO_3]$>180 mg/L

j: Guidelines for total ammonia are temperature and pH dependent; see CCME (2007) and AESRD (2014) for additional information

k: For cold-water biota, 9.5 mg/L for early life stages, 6.5 mg/L for other life stages. For warm-water biota, 6.0 mg/L for early life stages, 5.5 mg/L for other life stages

l: For dissolved Al at pH>=6.5. At pH<6.5, guidelines are $e^{1.209-2.426*pH+0.286*pH2}$ (maximum concentration) and $e^{1.6-3.327*median\ pH+0.402*pH2}$ (30-Day average)

m: Hardness-dependant. Guideline = 0.01102*hardness+0.54

n: For all phenolic compounds except 3- and 4-hydroxyphenol, which have separate guidelines

o: Dependent on background levels, see AESRD (2014) for mor infomration

p: Oxygen values are minima, and are temporally and spatially dependent, see AESRD (2014) for more information

q: Hardness-dependent Guideline = 128 mg/L at hardness 0-30 mg/L, 218 mg/L at hardness 31-75 mg/L, 309 at hardness 76-180 mg/L, 429 mg/L at hardness 181-250 mg/L

r: Guidelines for nitrite are chloride dependent; see CCME (2007) and AESRD (2014) for additional information.

s: Hardness-dependant. Guideline = 0.11 µg/L at $[CaCO_3]$= 0 to 5.3 mg/L, guideline = $10^{(1.016[log(hardness)]-1.71)}/1000$ at $[CaCO_3]$= 5.3 to 360 mg/L, 7.7 µg/L at $[CaCO_3]$>360 mg/L

t: Hardness-dependant. Guideline = $e^{(0.979123*[ln(hardness)]-8.64497)}/1000$

u: Hardness-dependant. Guideline = $e^{(0.846*[ln(hardness)]+2.25)}/1000$

v: Hardness-dependant. Guideline = $e^{(0.846*[ln(hardness)]+0.8584)}/1000$

3.2.3 Benthic Invertebrate Communities and Sediment Quality

3.2.3.1 Benthic Invertebrate Communities Component

The analytical approach used in 2014 for the Benthic Invertebrate Communities component was based on the analytical approach described in the RAMP Technical Design and Rationale (RAMP 2009b) and consisted of:

- selecting benthic invertebrate community measurement endpoints;
- detailed data analysis, consisting of:
  - analysis of variance (ANOVA) testing for differences between upstream *baseline* and downstream *test* reaches, and/or differences in time trends;
  - calculation of regional *baseline* conditions or historical conditions for benthic invertebrate community measurement endpoints and comparison of data from reaches designated as *test* to reaches designated as *baseline* to determine how the communities compare to regional *baseline* conditions or historical conditions;
  - control charts to indicate when a reach was shifting from *baseline* conditions; and
- developing criteria to be used in detecting changes in benthic invertebrate community measurement endpoints.

Selection of Benthic Invertebrate Community Measurement Endpoints

For each sample, the following benthic invertebrate community measurement endpoints were calculated (Environment Canada 2010):

- Abundance (mean number of individuals per replicate sample);
- Taxon richness (number of distinct taxa);
- Equitability, where

$$\text{Equitability} = \frac{1}{\frac{\sum (p_i)^2}{S}}$$

and S is the total number of taxa in the sample. A higher equitability is indicative of a lower evenness of species in a reach; and

- Percent EPT (Ephemeroptera, Plecoptera, Trichoptera).

In addition to these core benthic invertebrate community measurement endpoints, the data were also ordinated using Correspondence Analysis (CA) to provide a multivariate assessment of spatial and temporal variations in composition (see Appendix D for a full description of the method). Separate ordinations were carried out for benthos from the Athabasca River Delta, lakes, erosional river reaches, and depositional river reaches, because these four classes of habitat can be anticipated to produce unique fauna, and on the basis of previous analyses, had demonstrated differences in composition among those four habitat types.

All measurement endpoints for benthic invertebrate communities were calculated for each sample and then averaged for each reach or lake for the purpose of illustrating time trends. The measurement endpoints were calculated for all data dating from 1998 onward to evaluate trends in these measures over time.

Temporal Trends and Spatial Comparisons

Possible changes in benthic invertebrate communities were evaluated by comparing measurement endpoints in reaches designated as *test* to upstream *baseline* reaches and/or to pre-development conditions with ANOVA. When necessary, the measurement endpoints were $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances. Variation in measurement endpoints were adjusted to account for the influence of water depth (lake samples), based on relationships observed for *baseline* samples. One-way ANOVAs were conducted for each benthic invertebrate community measurement endpoint with each reach-year (or lake-year, as appropriate) combination as the factorial variable. Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to identify differences between *baseline* and *test* reaches (or lakes), between *baseline* and *test* periods, and differences in time trends between lower *test* reaches and upper *baseline* reaches (or lakes, as appropriate). In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

Analysis of variance was used to test for variations over time for reaches or lakes that have been exposed to oil sands development since RAMP started in 1997. The ANOVA used variations within reaches (or lakes) to judge the significance of linear time trends. Linear contrasts were used to carry out the analysis of variance and to test the specific hypotheses related to potential changes associated with oil sands operations. The specific testable hypotheses varied with the availability of *baseline* and *test* period data at both *test* and *baseline* reaches. Some of the lower *test* reaches (e.g., lower Jackpine Creek) have an upstream *baseline* reach (in the case of Jackpine Creek it is JAC-D2) that is considered a local or upstream *baseline* that can be used to 'control' for natural climate-related variability. In those cases, and when there were data for both reaches in both *baseline* and *test* periods, the testable hypotheses were:

- H_{O1}: No change in the differences of means of measurement endpoints from *baseline* to *test* periods;
- H_{O2}: No difference in time trends of means of measurement endpoints in the *test* period, between *baseline* and *test* reaches; and
- H_{O3}: No change in the differences of means of measurement endpoints between the *test* and *baseline* reaches in the current year, compared to the differences in the *baseline* period.

In the case when there was an upstream *baseline* reach, but no *baseline* period data for the *test* reach, the testable hypothesis was:

- H_{O4}: No difference in time trends of means of measurement endpoints between the *test* and *baseline* reaches in the *test* period.

Some of the lower reaches did not have a similar local or upstream *baseline* reach (e.g., lower Tar River). In the case when there was *baseline* and *test* period data for a lower *test* reach, the testable hypotheses were:

- H_{O5}: No difference from *baseline* to *test* periods in means of measurement endpoints; and
- H_{O6}: No difference in time trend of means of measurement endpoints during the *test* period.

In the case when there were no *baseline* period data for a lower *test* reach, the testable hypothesis was:

- H_{O7}: No trend over time in means of measurement endpoints.

For completeness, additional analyses were carried out to determine how unusual the current year of data was relative to the mean of the nearest, most appropriate *baseline* data. The data from the current year of sampling were compared to its own *baseline* data if those were available, or to data from an upstream *baseline* reach if they were available. Data from the current year were also compared to all historical data when *baseline* data were not available.

The statistical power associated with these various hypothesis-testing procedures is high with an error-degrees-of-freedom that is frequently >100. The ability to detect differences is quite substantive, with the detectable effect sizes much less than the within-reach-standard deviation (SD) (i.e., small differences, Cohen 1977; Kilgour et al. 1998). Statistically significant differences; therefore, may be minor, subtle, or otherwise trivial. The nature of statistically significant differences was, therefore, examined to determine if the difference was consistent with a negative change in the benthic invertebrate community. A decrease in taxa richness and percent EPT would each be considered a negative change or difference. An increase in equitability would be considered a negative change. Excessively high abundance would be considered a negative change if the fauna was dominated by one or a few taxa (see Kilgour et al. 2005), and might be consistent with a nutrient enrichment effect (Lowell et al. 2003). Prior analysis of benthic data has suggested that changes were more easily interpreted when the change accounted for at least 20% of the variation in the annual means, so that additional criterion is used this year to identify interpretable changes. A change that explains 20% of the noise is equivalent to an effect size of 1 standard deviation (i.e., means differ by 1 SD).

Comparison to Published Literature

Baseline benthic invertebrate measurement endpoints vary in relation to local and regional variations in climatic conditions, hydrological influences, and underlying geological conditions. The *baseline* database; therefore, provides (de facto) the most appropriate set of regional *baseline* conditions and information against which to assess differences observed in *test* reaches. The literature pertaining to freshwater benthic macro invertebrates; however, has been well developed over the past ~60 years, with the general ecological requirements and tolerances of many taxa encountered in the oil sands region being relatively well described. Some consideration for general tolerances/ requirements; therefore, was taken from Hynes (1970); Plafkin et al. (1989); Klemm et al. (1990); Thorp and Covich (1991); Bode (1996); and Mandeville (2002); among others.

Determination of Normal Ranges

The term "normal range" means the range of values that a measurement endpoint might be expected to vary within, given the conditions of that reach, channel, or lake. The normal range for this analysis, which has been used in other studies (e.g., Bloom 1980; Kersting 1991; Yan et al. 1996; and Findlay and Kasian 1996) is defined as the range of values that includes 95% of possible observations using the annual mean value of a measurement endpoint.

The limits of the normal range, based on 95% of possible observations, can be calculated as:

$$\bar{x} \pm 2SD$$

Where,

- SD is the standard deviation of observations; the 5th and 95th percentiles can be used as surrogates for 2SD (Environment Canada 2010).

Normal ranges for the assessment of *test* reaches in 2014 were calculated as: (i) the within-reach normal range using data from all previous years for a *test* reach (or lake or delta channel), where more than eight years of data exists or within a lake where a regional assessment was not possible (Figure 3.2-3); and (ii) the among-*baseline*-reach normal range using all available data from *baseline* reaches, grouped by erosional or depositional habitat, up to and including 2013. The within-reach (or lake or channel) normal range was considered first. An exceedance of limits of the within-reach normal range was followed up with a comparison to regional normal ranges.

Tolerance limits were then calculated for the 5th and 95th percentiles for normal ranges and for within-reach normal ranges (as per Hunt et al. 2001; Smith 2002; Krishnamoorthy and Mathew 2009).

The tolerance limit for the pth percentile (i.e., 5th or 95th percentile) is:

$$\bar{x} \pm k \bullet SD$$

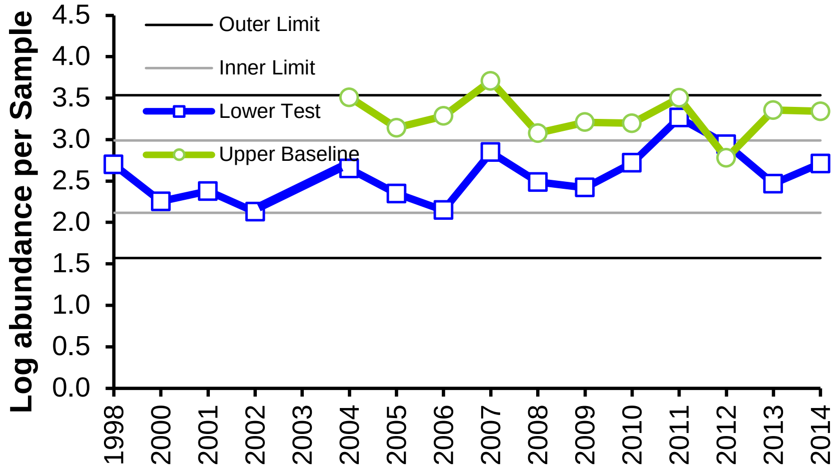
Where,

- $k = \frac{t_{\gamma,N-1,\delta}}{\sqrt{N}}$;
- $t_{\gamma,N-1,\delta}$ is a non-central t-statistic (where γ indicates the lower 5th or upper 95th percentile of the non-central t distribution);
- $\delta = z_p \sqrt{N}$; and
- Z_p is the Z-statistic at the pth percentile (Z = 1.96 for the 95th percentile).

The value for δ depends on sample size, as then does the non-central t-statistic and ultimately k.

There are two intrinsic benefits of using tolerance limits on percentiles. Values inside the inner tolerance limit clearly are not unusual, while values outside the outer tolerance limit clearly are unusual, relative to the 'normal range'. Values between the inner and outer tolerance limits are in a 'grey' zone of uncertainty that may or may not be unusual dependent on the collection of more data but can be flagged as a trigger for further investigation, if required. The potential criticism of using small sample sizes is diminished when inner and outer tolerance limits are used given that small sample sizes will lead to broad limits on extreme percentiles, resulting in more observations being classed as "potentially" unusual.

Figure 3.2-3 Example of a time trend chart showing the total abundance (log_{10}) of a benthic invertebrate community in relation to the within-reach range of variability, in this case, for the lower Steepbank River.



Note: The inner and outer tolerance limits are the confidence region for each of the lower 5^{th} and upper 95^{th} percentiles.

Environmental Variables

A number of environmental variables, including physical substrate condition and water temperature, chemistry, and flow velocities were measured at each reach. These environmental variables were measured because they influence the kinds of benthic invertebrate fauna found at a reach or in a lake. Where benthic invertebrate communities are shown to vary over time in a manner consistent with the development of oil sands projects, the variation may be attributed to changes in one or more of these environmental variables. An examination of these potential associations was made if the criteria for determination of effect in benthic invertebrate communities were met.

In addition, some general conclusions about the condition of a reach (or lake) can be made using a number of the environmental variables:

- Dissolved oxygen is typically above concentrations considered critical for the protection of aquatic life (5.0 mg/L; AESRD 2014). Concentrations below this guideline are indicative of potential risks to aquatic life, especially if those concentrations are observed during the day, which is the time of sampling occurs for the Benthic Invertebrate Communities component; and
- Chlorophyll *a*, one of the environmental variables measured in erosional reaches, was identified early in the Alberta Oil Sands Environmental Research Program (AOSERP) studies as a potential indicator of oil sands activity (Barton and Lock 1979) (i.e., removal of cover over a watercourse through development would increase chlorophyll *a* concentrations). Upper and lower tolerance limits of the normal range of chlorophyll *a* values from reaches designated as *baseline* were determined (Appendix D) and provided in figures that illustrate trends over time in chlorophyll *a* values.

Classification of Results

The criteria used for classifying results of benthic invertebrate communities was whether or not the core measurement endpoints for benthic invertebrate communities at a given location (i.e., river reach or lake) designated as *test* either exceeds regional *baseline* conditions, has significantly changed from when the reach was designated as *baseline*, or is significantly different from the upstream *baseline* reach (if applicable).

Measured changes were classified as Negligible-Low, Moderate, or High on the basis of the strength of the statistical signal from a reach/lake for changes in core measurement endpoints for benthic invertebrate communities (Table 3.2-7). Strong statistical signals are considered to be differences that are statistically significant ($p<0.05$) and that are as strong as, or stronger, than the background “noise” in reach-year variations. For the purpose of this report, a change was additionally considered “strong” (i.e., interpretable) if the change explained >20% of the variation in annual means, or if the mean in 2014 fell between the inner and outer tolerance limits for the 5th or 95th percentiles or was outside the outer tolerance limits. There are four core measurement endpoints for benthic invertebrate communities (abundance, taxa richness, equitability, and percent EPT), and two more if the multivariate ordination axes are considered. If any one of those measurement endpoints produced a strong signal of a change, then the conclusion will be that a ‘Moderate’ change has been detected. If any three of the measurement endpoints produces a strong statistical signal, then the conclusion will be that a ‘High’ change had been detected. If no measurement endpoints produces a strong statistical signal, or if all of the signals indicate a benthic community that is in good condition, then the conclusion will be that a “Negligible-Low” change has been detected.

Table 3.2-7 Classification of results for Benthic Invertebrate Communities component of the 2014 JOSMP.

Criterion	Classification			“Yes”
	Negligible-Low	Moderate	High	
Statistical significance	No	Yes	Yes	Strong statistical signal on any one of the key measurement endpoints in 2014, with difference from *baseline* implying a negative change.
Exceed *baseline* range of variation	No	No	Yes	Strong signal in three key measurement endpoints in 2014, with the difference from *baseline* implying a negative change.

3.2.3.2 Sediment Quality Component

The analytical approach undertaken for the Sediment Quality component in 2014 included:

- the review and selection of particular sediment quality variables as measurement endpoints including predicted toxicity of sediments due to PAHs (calculated using an equilibrium-partitioning model);

- a tabular presentation of 2014 results, comparing 2014 concentrations of the sediment quality measurement endpoints to concentrations previously observed within the station, where data were available, and sediment quality guidelines;
- a graphical presentation of 2014 results describing particle-size distribution, TOC, total metals (both absolute and normalized to percent-fines), total hydrocarbons, total PAHs (both absolute and normalized to 1% TOC), and predicted PAH toxicity, using an equilibrium-partitioning approach to assessing potential for chronic toxicity from PAH mixtures in sediments described by Neff et al. (2005); and
- the calculation of a Sediment Quality Index (described below).

Selection of Sediment Quality Measurement Endpoints

The selection of sediment quality measurement endpoints (Table 3.2-8) was guided by:

- sediment quality measurement endpoints listed in the EIAs of oil sands projects as being potentially affected by oil sands development activities (RAMP 2009b);
- sediment quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the RAMP 1997 to 2004 sediment quality dataset indicating significant inter-correlation of various sediment quality variables; and
- sediment quality variables that assist in interpreting the results of the Benthic Invertebrate Communities component.

Table 3.2-8 Potential sediment quality measurement endpoints.

Variable Group	Variables Listed in EIAs (RAMP 2009b)	RAMP 5-Year Report (Golder 2003)	Variables to Support Other Monitoring Components[1]	Additional Suggested Variables[2]
Physical Variables	(None)	(None)	Particle size distribution	-
Carbon Content	(None)	(None)	Total organic carbon	Total inorganic carbon Total organic carbon
Total Hydrocarbons	(None)	Total recoverable hydrocarbons	CCME F1, F2	CCME F1 to F4 +BTEX
Metals	(None)	Total metals	Total metals	Total arsenic and metals that exceed sediment quality guidelines
PAHs	General PAHs	Naphthalene C1-Naphthalene	Total PAHs (parent+alkylated)	Parent PAHs Alkylated PAHs Naphthalene Dibenzothiophenes Retene Predicted PAH Toxicity
Effects-Based Endpoints	Sublethal toxicity	-	Sublethal toxicity	-

[1] Primarily Benthic Invertebrate Communities component (inferred).

[2] Suggested based on ongoing review of stakeholder concerns.

The sediment quality measurement endpoints selected for use included the following:

- *Particle size distribution (clay, silt, and sand)* – sediment particle size is an indicator of depositional regime at a given station, and an important factor affecting organic chemical sorption;
- *Total organic carbon* – an indicator of organic matter in sediment, including hydrocarbons;
- *Total hydrocarbons (CCME fractions + BTEX)* – indicators of the total hydrocarbon content of sediments, with each indicator (fraction) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene, and xylene (collectively called BTEX), based on methods presented by CCME (2001);
- *Various PAH measurement endpoints,* including:
    - *Total PAHs* – a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
    - *Total parent PAHs* – a sum of concentrations of all non-alkylated PAHs measured in a given sample;
    - *Total alkylated PAHs* – a sum of concentrations of all alkylated PAHs measured in a given sample;
    - *Naphthalene* – a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;
    - *Total dibenzothiophenes* – a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic);
    - *Retene* – an alkylated phenanthrene generated through decomposition of plant materials (i.e., biogenic rather than petrogenic); and
    - *Predicted PAH toxicity* – an estimate of the cumulative potential for chronic toxicity of all PAHs in a sediment sample, following methods described in Neff et al*.* (2005). Sediments with a calculated hazard index value greater than 1.0 have the potential to be toxic to aquatic organisms (USEPA 2004). See Appendix D for further details on the calculation of the predicted PAH toxicity;
- *Metals* – With the exception of sum of total metals, only metals in sediment that exceeded CCME Interim Sediment Quality Guideline (ISQG) values (CCME 2002) were presented, as metals in sediments are not listed in oil sands EIAs as being potentially affected by development (RAMP 2009b); and
- *Sublethal toxicity* – sublethal toxic effects of whole sediment samples on the survival and growth of the amphipod (seed-shrimp) *Hyalella azteca* (14-day test) and the midge *Chironomus tentans* (10-day test).

Tabular and Graphical Presentation of 2014 Sediment Quality Results

The 2014 sediment quality data for each sediment quality measurement endpoint were tabulated for each station sampled. Historical variability also was presented for each measurement endpoint, represented by minimum, maximum, and median values observed (as well as number of observations) from 1997 to

2013. Concentrations of any sediment quality measurement endpoint and any metal that exceeded relevant guidelines were also reported.

Data for the selected sediment quality measurement were presented graphically in the context of relevant regional variability (5th and 95th percentiles of regional *baseline* data) by presenting data for each station for all years of sampling to allow for the assessment of any temporal trends.

Classification of Results

Sediment quality in each depositional benthic invertebrate sampling reach in fall 2014 was summarized using the CCME Sediment Quality Index calculator available at the CCME website (http://www.ccme.ca/ourwork/water.html?category_id=103). This index uses an identical calculation to that developed by CCME for water quality (see Section 3.2.2.2), also yielding a single index value ranging from 0 to 100.

Like the CCME Water Quality Index, the sediment quality index was calculated using comparisons of observed sediment quality against benchmark values, such as guidelines or background concentrations. It considered three factors: (i) the percentage of variables with values that exceeded a given benchmark; (ii) the percentage of comparisons that exceeded a given benchmark; and (iii) the degree to which observed values exceeded benchmark values. Further details describing this calculation may be found at the CCME website listed above.

Index calculations for sediment quality data used regional *baseline* conditions as benchmarks for comparison. All sediment quality data collected by RAMP/JOSMP since 1997 at all stations classified as *baseline* were used to develop *baseline* ranges of sediment quality. Specifically, 5th or 95th percentiles of *baseline* values for all variables included in the index were used as benchmarks against which individual sediment quality observations were compared.

Seventy-eight sediment quality variables were included in calculation of the index, including total and fractional hydrocarbons, all parent and alkylated PAHs, all metals measured consistently in sediments by RAMP since 1997, and sediment toxicity endpoints. For hydrocarbons and metals, data were compared against the 95th percentile of *baseline* data, while for sediment toxicity endpoints, data were compared against the 5th percentile. Index values were calculated for all *baseline* and *test* stations. For all sediment quality station observations from 1997 to 2014 (n=394), sediment quality index values of 33.7 to 100.0 were calculated.

Sediment quality index scores were classified using the following scheme:

- 80 to 100: Negligible-Low difference from regional *baseline* conditions;
- 60 to 80: Moderate difference from regional *baseline* conditions; and
- Below 60: High difference from regional *baseline* conditions.

Sediment quality index scores were not calculated for lakes, following concerns expressed by the 2011 RAMP Peer Review (AITF 2011) regarding combining streams and lakes in the determination of regional *baseline* ranges.

3.2.4 Fish Populations Component

The analytical approach used in 2014 for the Fish Populations component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2009b) and consisted of:

- selecting fish population measurement endpoints;
- conducting analysis of covariance (ANCOVA), analysis of variance (ANOVA), or Mann-Kendall trend analysis on fish population measurement endpoints to test for differences in time trends, and/or differences between *baseline* and *test* reaches;
- presenting results in tabular and graphical format comparing 2014 fish population measurements endpoints to historical or *baseline* results for each monitoring activity; and
- selecting and using criteria to assess change in fish population measurement endpoints both spatially and temporally.

3.2.4.1 Fish Inventories

Selection of Measurement Endpoints

Measurement endpoints for the Athabasca River and Clearwater River fish inventories included:

- percent species composition (relative to all fish captured);
- index of relative abundance (catch per unit effort – CPUE);
- age-frequency distributions (measure of survival);
- size-at-age (measure of growth);
- condition factor; and
- incidence of external health abnormalities.

Temporal Trends and Spatial Comparisons

Temporal comparisons were conducted to assess changes across years in each season for each measurement endpoint. Spatial comparisons were then conducted to assess differences between areas of the river for each measurement endpoint in 2014. Measurement endpoints calculated from data collected during the fish inventories on the Athabasca and Clearwater rivers were used to evaluate general trends in fish abundance and population characteristics, with a focus on large-bodied Key Indicator Resource (KIR) species (i.e., walleye, northern pike, white sucker, longnose sucker, goldeye, and lake whitefish) and one small-bodied KIR species (trout-perch).

Species Composition and Relative Abundance (CPUE) All fish captured in the Athabasca River and Clearwater River fish inventories were summarized by percent species composition (relative to total catch for all species), and a measure of relative abundance for each species (catch per unit effort – CPUE). These measurement endpoints were calculated for each area of a river, for each season. Temporal and spatial comparisons were graphically presented in order to compare species composition and CPUE between 1987 and 2014 for each of the large-bodied KIR species (and lake whitefish in fall only), for each season. In addition, seasonal Mann-Kendall trend analyses (i.e., addresses variability due to seasonality and allows evaluation of overall trends in the time series) were conducted on CPUE for each KIR species in each area, across years, with a level of significance of α=0.05 (Nielsen 2005).

Age-Frequency Distributions Age-frequency distributions (i.e., number of fish per age class) were calculated for large-bodied KIR fish species. Age classes were divided into one-year increments for each of the species. Relative age-frequency distributions were displayed graphically for each year (all seasons combined) in order to evaluate trends in dominant age classes over time and survival of fish to older age classes. Analysis of covariance (ANCOVA) followed by Tukey post-hoc tests were used to compare differences across years for length-at-age of each fish species, where length was the dependent variable, year was the independent variable, and age was the covariate. If the ANCOVA showed a statistically significant difference among years, the direction and magnitude of the change was calculated. Magnitude was defined as the percentage change in the adjusted means of length at age from an earlier year to a later year; magnitude values greater than 25% were considered to be a significant change (Environment Canada 2010).

Condition Factor Fish condition was evaluated over time as a measure of change in energy storage for each KIR fish species. The following analyses were performed in order to evaluate condition:

- Fish condition (or "how fat a fish is") was compared between *baseline* years (1987 to 1996) and 2014 for each season using analysis of covariance (ANCOVA; α=0.05), where body weight (log_{10}-transformed) was the dependent variable, year was the independent variable, and fork length (log_{10}-transformed) was the covariate; and
- Fulton's Condition Factor was calculated as K= (body weight/fork length^3)x100, and used in tabular and graphical presentations showing mean condition for each species, per season, over time (1997 to 2012) compared to *baseline* variability in fish condition (i.e., condition of fish captured from 1987 to 1996, period prior to major oil sands development) estimated as the 5th and 9th percentiles, which is a surrogate for $\bar{x} \pm 2SD$.

In order to be consistent with past analyses, the 2014 analyses of condition were restricted to fish of the following species-specific minimum lengths: walleye >400 mm; lake whitefish >350 mm; northern pike >400 mm; goldeye >300 mm; longnose sucker >350 mm; white sucker >350 mm; and trout-perch >50 mm.

Summer and fall condition for each KIR species was evaluated over time. Spring condition for most KIR species and fall condition for lake whitefish was not evaluated given that the variability in condition of fish could be related to an increase in reproductive tissue during the spawning period and not reflective of changes in energy storage.

Incidence of External Health Abnormalities The incidence of external fish health abnormalities were evaluated for all species captured during the Athabasca River and Clearwater River fish inventories. The following metrics were calculated relative to the total number of fish captured:

- Percent of fish in each season with fin erosion and body wounds; and
- Percent of fish with external pathology, including parasites, growths/lesions, and body deformities.

Fish Tag Return Assessment

RAMP/JOSMP and AESRD Fish & Wildlife maintain records of tagged fish recaptured by anglers or during fish inventory surveys. In general, information reported and recorded from angler recaptures has been limited to the recapture date, tag number, species, and a description of the geographical recapture location. This information is compared to data compiled at the time of tagging and used to analyze patterns of fish movements over time. Information reported and recorded from recaptures of RAMP/JOSMP-tagged fish can include re-evaluations of fish length and weight, and external health. These data can be used to analyze changes over time in basic morphology and health.

A spatial presentation of tag return information (location tagged and location recaptured) was prepared for the tag returns received by anglers in 2014.

Classification of Results

As indicated in Section 1.4.4.4, the fish inventories are considered to be stakeholder-driven activities best suited for assessing general trends in abundance and population variables for large-bodied species. They are not specifically designed for assessing change potentially due to oil sands development and; therefore, no criteria were used to classify measurement endpoints calculated from the results of the Athabasca River and Clearwater River fish inventories.

3.2.4.2 Athabasca River Fish Tissue Program

Selection of Measurement Endpoints

Measurement endpoints used to analyze fish tissue results from the Athabasca River included whole-organism metrics (fork length, body weight, and age), incidence of external/internal health anomalies, and concentrations of all metals (including mercury) and tainting compounds measured (Table 3.2-12).

Temporal Trends and Spatial Comparisons

Whole-organism Metrics Whole-organism metrics (i.e., fork length, body weight, age) were reported along with gender and stage of maturity for walleye and lake whitefish collected during the tissue program on the Athabasca River.

Mercury Mercury results were reported for individual fish collected from the Athabasca River. Scatterplots were then used to initially assess relationships between mercury concentrations and whole-organism metrics for each species and sex combination. Mercury concentrations among years (2002, 2003, 2005, 2008, 2011, and 2014) for the Athabasca River were compared graphically and statistically using ANCOVA (α=0.05), with mercury concentration (log_{10}-transformed) as the dependent variable, year as the independent variable, and fork length (log_{10}-transformed) as the covariate. The first step in the analysis was to compare slopes of regressions from different years to ensure they were equal ($p>0.01$), and the second step was to compare the intercepts of the regressions (the p-value for the intercept was provided in the results).

Total Metals and Organic Compounds Results for total metals and tainting compounds were reported for walleye and lake whitefish collected during the Athabasca River fish tissue program. Temporal comparisons of 2014 results were made with data from walleye and lake whitefish tissue studies previously completed on the Athabasca River (2002, 2003, 2005, 2008, and 2011) by RAMP.

Comparison to Published Guidelines

Mercury measured in fish collected from the Athabasca River was used to evaluate potential risk to human health.

Potential Risk to Human Health Potential Risk to Human Health To assess potential risk to human health due to ingestion of fish tissues, fish tissue data were screened against the following criteria:

- Government of Alberta Human Health Risk Assessment for Mercury in Fish in the Athabasca oil sands region area (GOA 2009) (Table 3.2-9);
- Health Canada Guidelines for general fish consumption (Health Canada 2007, last updated July 2007) and subsistence level fish consumption (Health and Welfare Canada 1979) (Table 3.2-10);
- Region III USEPA risk-based criteria for consumption of fish tissue for recreational and subsistence fishers (USEPA 2000) (Table 3.2-10); and
- National USEPA risk-based screening values for consumption of fish tissue (USEPA 2000, updated May 2014) (Table 3.2-10).

Mercury has a Health Canada consumption guideline, both for general and subsistence consumers, which are risk-based values that take into account the toxicity (including carcinogenicity) of the contaminant, body weight of the consumer, and exposure rate. In addition, the Government of Alberta has released fish consumption guidelines for fish captured within the Athabasca oil sands region, developed through a risk assessment of fish mercury data collected through past RAMP surveys (GOA 2009). The consumption limits were established for fish species from specific waterbodies previously sampled by RAMP and AESRD, including the Athabasca River.

Health Canada's mercury guideline is for total mercury and not methylmercury, which is the form of mercury taken up by fish. The guideline makes the conservative assumption that, for the purposes of screening for human health risks, 100% of total mercury in edible fish tissue is present as methylmercury (Bloom 1992; Health Canada 2007). Guidance accompanying the mercury guideline recommends that most health risk assessments employ the less costly method of analyzing for total mercury, while screening against methylmercury and mercury guidelines interchangeably.

Health Canada's guideline for general consumption (0.5 mg/kg) of total mercury in fish (Health Canada 2007) is less conservative than its guideline for subsistence-level consumption (0.2 mg/kg) of total mercury (INAC 2003), which was originally derived from various studies on the toxicity of methylmercury to Aboriginal consumers (Health and Welfare Canada 1979).

Total arsenic is reported for fish tissue samples; however, studies have shown that inorganic arsenic should be analyzed rather than total arsenic, which is inclusive of both inorganic and organic forms (USEPA 2000). Although both are naturally occurring within the environment, organic arsenic does not appear to bioaccumulate in aquatic organisms (NAS 1977) and has not been considered a significant risk to human health (IRIS 1998). Inorganic arsenic, a minor component of total arsenic, bioaccumulates minimally in finfish (NAS 1977) and has been classified as a human carcinogen (IRIS 1998). Because it is the concentration of inorganic arsenic in fish and shellfish that poses the greatest threat to human health, EPA recommends that inorganic arsenic (not total arsenic) be analyzed in contaminant monitoring programs (USEPA 2000).

To assess whether arsenic concentrations in fish may be harmful to human health through consumption, concentrations of total arsenic were converted to estimates of inorganic arsenic based on the assumption that inorganic arsenic represented 10% of the total arsenic concentration. This assumption was considered conservative from the perspective of protecting human health as other studies have found that the concentration of inorganic arsenic has been less than 5% of the total arsenic concentration (ATSDR 2009).

Potential Risk to Fish Health To assess potential risk to fish health, fish tissue data were screened against minimum lethal (survival) and non-lethal (growth and reproduction) effects and no-effects thresholds (Table 3.2-11) derived from laboratory-based studies summarized in Jarvinen and Ankley (1999). These criteria were only available for some of the fish tissue measurement endpoints, including several metals, including mercury, but not for any of the tainting compounds. The thresholds were developed based on ranges of fish tissue residue concentrations linked to both effects and a lack of effects on both sublethal (e.g., growth) and lethal (survival) measurement endpoints; the lowest (i.e., most conservative) concentrations were used to evaluate risk.

Table 3.2-9 Fish consumption limits for watercourses within the Athabasca oil sands region, Alberta (GOA 2009).

Waterbody	Species	Weight (g)*	Consumption Limit (serving/week)**			
			Women	Child (1-4 yr)	Child (5-11 yr)	Adult +
Athabasca River (downstream of Fort McMurray)	Walleye	908	2	0.5	1	8
Clearwater River	Walleye	908	2	0.5	1	8
	Northern pike	908	8	2	4	no limit
Muskeg River	Northern pike	908	8	2	4	no limit
Christina Lake	Walleye	1,816	2	0.5	1	8
	Northern pike	3,632	2	0.5	1	8
Gregoire Lake	Walleye	908	8	2	4	no limit
	Northern pike	908	8	2	4	no limit
Winefred Lake	Walleye	1,362	8	2	4	no limit

* 454 g = 1 lb

** 1 serving=75 g, 1/2 cup, 2.5 ounces, or a piece of cooked fish that fits into the palm of a hand.

"Women" refers to women of child-bearing age (15-49 yr) and pregnant women.

"Adult +" refers to adults and children over 12 yrs.

Shading denotes waterbody where fish tissue sampling was undertaken by JOSMP in 2014.

Table 3.2-10 Standards used for evaluating potential risk of fish consumption to human health.

Measurement Endpoint[1]	Units	Health Canada		National USEPA[4]		Region III USEPA[5]
		General[2]	Subsistence[3]	Recreational	Subsistence	Risk-based Criteria
Total Metals						
Aluminum (Al)	mg/kg	nc	nc	nc	nc	0.0015
Antimony (Sb)	mg/kg	nc	nc	nc	nc	0.62
Arsenic (As)[6]	mg/kg	nc	nc	0.026	0.00327	0.0028
Barium (Ba)	mg/kg	nc	nc	nc	nc	310
Beryllium (Be)	mg/kg	nc	nc	nc	nc	3.1
Bismuth (Bi)	mg/kg	nc	nc	nc	nc	nc
Cadmium (Cd)	mg/kg	nc	nc	4.0	0.491	1.5
Calcium (Ca)	mg/kg	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	nc	nc	nc	nc	4.6
Cobalt (Co)	mg/kg	nc	nc	nc	nc	0.46
Copper (Cu)	mg/kg	nc	nc	nc	nc	62
Iron (Fe)	mg/kg	nc	nc	nc	nc	1,100
Lithium (Li)	mg/kg	nc	nc	nc	nc	3.1
Magnesium (Mg)	mg/kg	nc	nc	nc	nc	nc
Manganese (Mn)	mg/kg	nc	nc	nc	nc	220
Mercury (Hg)[7]	mg/kg	0.5	0.2	0.4	0.049	0.15
Molybdenum (Mo)	mg/kg	nc	nc	nc	nc	7.7
Nickel (Ni)	mg/kg	nc	nc	nc	nc	31

[1] Measurement endpoints listed are for variables that have human health criteria under Health Canada or National USEPA.

[2] Last updated July 2007; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[3] Health and Welfare Canada (1979).

[4] USEPA (2000) (Chapter 5).

[5] Last updated May 2014; found at http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2014_FISH_THQ1_watermark.pdf

[6] Criteria are for inorganic arsenic. Total arsenic data were converted to inorganic arsenic based on ATSDR (2009).

[7] Criteria are for total mercury and methylmercury, assuming equivalence.

nc – no criterion

Table 3.2-10 (Cont'd.)

Measurement Endpoint[1]	Units	Health Canada		National USEPA[4]		Region III USEPA[5]
		General[2]	Subsistence[3]	Recreational	Subsistence	Risk-based Criteria
Phosphorus (P)	mg/kg	nc	nc	nc	nc	nc
Potassium (K)	mg/kg	nc	nc	nc	nc	nc
Selenium (Se)	mg/kg	nc	nc	20	2.457	7.7
Silver (Ag)	mg/kg	nc	nc	nc	nc	7.7
Sodium (Na)	mg/kg	nc	nc	nc	nc	nc
Strontium (Sr)	mg/kg	nc	nc	nc	nc	930
Thallium (Tl)	mg/kg	nc	nc	nc	nc	0.015
Tin (Sn)	mg/kg	nc	nc	nc	nc	930
Titanium (Ti)	mg/kg	nc	nc	nc	nc	nc
Vanadium (V)	mg/kg	nc	nc	nc	nc	7.8
Zinc (Zn)	mg/kg	nc	nc	nc	nc	460
Tainting Compounds						
1,3,5-trimethylbenzene	mg/kg	nc	nc	nc	nc	150
2-Methylthiophene	mg/kg	nc	nc	nc	nc	nc
Toluene	mg/kg	nc	nc	nc	nc	120
Thiophene	mg/kg	nc	nc	nc	nc	nc
m+p-xylene	mg/kg	nc	nc	nc	nc	310

1 Measurement endpoints listed are for variables that have human health criteria under Health Canada or National USEPA.
2 Last updated July 2007; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html
3 Health and Welfare Canada (1979).
4 USEPA (2000) (Chapter 5).
5 Last updated May 2014; found at http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2014_FISH_THQ1_watermark.pdf
6 Criteria are for inorganic arsenic. Total arsenic data were converted to inorganic arsenic based on ATSDR (2009).
7 Criteria are for total mercury and methylmercury, assuming equivalence.
nc – no criterion

Table 3.2-11 Criteria used for evaluating potential risk to fish health based on concentrations of metals that have lethal, sublethal, or no effects on freshwater fish.

Variable	Endpoint		Concentrations (mg/kg)	Tissue	Species	Life Stage or Size	Route	(Days)
Metals								
Aluminum	Survival	no effects	1.0-1.15	muscle	rainbow trout, Atlantic salmon	171 g, alevin	oral, water	30-42
		effects	20-36.8	whole body	Atlantic salmon	alevin	water	30
Antimony	Survival	no effects	5	whole body	rainbow trout	fingerling (1.2 g)	water	30
		effects	9	whole body	rainbow trout	fingerling (1.2 g)	water	30
Arsenic	Survival	no effects	2.6-11.4	carcass, whole body	rainbow trout	juvenile	oral, water	21-56
		effects	11.2-17.9	carcass	rainbow trout	juvenile	oral	56
	Growth	no effects	0.9-6.5	carcass, whole body	rainbow trout	juvenile	oral, water	21-56
		effects	3.1	carcass	rainbow trout	juvenile	oral	56
Cadmium	Survival	no effects	0.02-2.8	muscle	rainbow trout, brook trout	150-200 g, adult	water, ip injection[2]	210-455
		effects	0.14-0.7	whole body	rainbow trout, brook trout	5-15 g	water	29-30
	Growth	no effects	0.09-2.8	muscle, whole body	rainbow trout, brook trout	3.1 g, 5 g, adult	water	30-455
		effects	0.12-0.96	muscle, whole body	rainbow trout, Atlantic salmon	3.1 g, alevin	water	92-210
	Reproduction	no effects	0.4	muscle	rainbow trout	adult	water	455
		effects	0.6	muscle	rainbow trout	adult	water	455
Copper	Survival	no effects	0.5-3.4	muscle	rainbow trout, brook trout	embryo-adult-juvenile	water	0.33-720
		effects	0.5	muscle	rainbow trout	138 g	water	0.33
	Growth	no effects	3.4	muscle	brook trout	embryo-adult-juvenile	water	720
	Reproduction	no effects	3.4	muscle	brook trout	embryo-adult-juvenile	water	720
Lead	Survival	no effects	4.0	carcass	rainbow trout	under-yearlings (6.5 g)	water	224

- = no data; [1] methylated forms of mercury; [2] ip = intraperitoneal injection is the injection of a substance into the body cavity.

Only thresholds derived from the most relevant studies were used to screen the fish tissue data; those derived from studies on small-bodied fish or tropical fish species, and those that simultaneously evaluated effects of conventional variables on toxicity or maternal transfer studies, were excluded. Effects concentrations associated with acute exposures were only included for contaminants where few other data existed.

Table 3.2-11 (Cont'd.)

Variable	Endpoint		Concentrations (mg/kg)	Tissue	Species	Life Stage or Size	Route	(Days)
Mercury[1]	Survival	no effects	1.91-35.0	whole body, muscle	rainbow trout, brook trout	10-20 mm, juvenile, fingerling, yearling-adult, adult	ip injection[2], oral, water	15-273
		effects	3.7-31	whole body, muscle	rainbow trout, brook trout	10-20 mm, subadult (100-150 g)	ip injection[2], oral	186-273
					northern pike	yearling-adult, adult	water	
	Growth	no effects	2.28-29.0	whole body, muscle	rainbow trout	fingerling, juvenile	oral, water	24-105
		effects	8.6-35.0	whole body, muscle	rainbow trout	fingerling	oral	84-105
	Reproduction	no effects	9.2	muscle	brook trout	yearling-adult	water	273
		effects	23.5	muscle	brook trout	yearling-adult	water	273
Nickel	Survival	no effects	0.82-58.0	muscle	rainbow trout, carp	15 g, 150-200 g	water	5-180
		effects	118.1	muscle	Carp	15 g	water	4
Selenium	Survival	no effects	0.28-3.1	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, egg-juvenile,	water, oral	28-308
					largemouth bass	fingerling-juvenile, juvenile		
		effects	0.92-2.5	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, fingerling-juvenile	water, oral	28-168
	Growth	no effects	0.08-1.08	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, egg-juvenile	oral	60-308
						fingerling-juvenile, juvenile		
		effects	0.32-2.08	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, fingerling-juvenile, juvenile	oral	60-168
Silver	Survival	no effects	0.003	carcass	largemouth bass	young-of-year	water	180
	Growth	no effects	0.003	carcass	largemouth bass	young-of-year	water	180
Vanadium	Survival	no effects	5.33	carcass	rainbow trout	juvenile	oral	84
	Growth	no effects	0.02	carcass	rainbow trout	juvenile	oral	84
		effects	0.41	carcass	rainbow trout	juvenile	oral	84
Zinc	Survival	no effects	60	whole body	Atlantic salmon	juvenile	water	80
	Growth	no effects	60	whole body	Atlantic salmon	juvenile	water	80

- = no data; [1] methylated forms of mercury; [2] ip = intraperitoneal injection is the injection of a substance into the body cavity.

Only thresholds derived from the most relevant studies were used to screen the fish tissue data; those derived from studies on small-bodied fish or tropical fish species, and those that simultaneously evaluated effects of conventional variables on toxicity or maternal transfer studies, were excluded. Effects concentrations associated with acute exposures were only included for contaminants where few other data existed.

Classification of Results

Criteria for classifying fish tissue concentrations of mercury were developed for determining risk to human health based on the exceedances of subsistence fisher and general consumer consumption guidelines for mercury. Fish tissue results were classified taking into account the consumption differences between general consumers and subsistence fishers and the variance in mercury concentrations across size classes of individual fish to accurately assess the risk to human health in relation to the amount of fish consumed and the size of fish consumed. Table 3.2-12 provides the classification of results for risk to human health for subsistence fishers and general consumers. A Moderate classification is not defined for subsistence fishers given that the consumption guideline is low due to larger quantities of fish consumed by this group, which poses a higher risk to human health.

Table 3.2-12 Classification of fish tissue results for risk to human health.

Classification	Subsistence Fishers	General Consumers
Negligible-Low	Mean mercury concentration below the subsistence fisher guideline (0.2 mg/kg)	Mean mercury concentration below the subsistence fisher guideline (0.2 mg/kg)
Moderate	-	Mean mercury concentration above the subsistence fisher guideline and below the general consumer guideline (0.2 to 0.5 mg/kg)
High	Mean mercury concentrations above the subsistence fisher guideline (0.2 mg/kg)	Mean mercury concentration above the general consumer guideline (0.5 mg/kg)

3.2.4.3 Fish Assemblage Monitoring Program

Selection of Measurement Endpoints

Several conventional measurement endpoints of fish assemblages were calculated using the fish data:

- Total Abundance – the total number of fish caught in the reach, divided by the lineal length of the reach (# of fish/m);
- Catch-per-unit-effort – the total number of fish caught per 100 seconds of electrofishing;
- Richness – the total number of fish species collected per reach. Higher richness values are typically used to infer a “healthier” fish assemblage;
- Diversity – this measurement endpoint was computed for each reach following the calculation for Simpson’s Diversity (D):

  $$D = 1 - \sum (p_i)^2$$

  Where,

  - p_i is the proportion of the total abundance accounted for by species *i.*

  Higher diversity values are typically used to infer a “healthier” fish assemblage; and

- Assemblage Tolerance Index (ATI) – The ATI was developed by Whittier et al. (2007) for stream and river fish assemblages in the western United States to quantify a species’ tolerance to an overall human disturbance gradient (Table 3.2-13). For species captured in the Athabasca oil sands region, but not assessed by Whittier et al. (2007), a number was assigned based on species similarity to those with calculated values. With this index, lower tolerance values imply a species that is more sensitive to disturbance.

Table 3.2-13 Tolerance values for fish collected during the fish assemblage monitoring program of the 2014 JOSMP (adapted from Whittier et al. 2007).

Common Name	Species Code	Tolerance Value
Arctic grayling	ARGR	2.0
brook stickleback*	BRST	9.4
burbot	BURB	2.0[1]
cisco	CISC	2.5[1]
emerald shiner	EMSH	6.9
finescale dace*	FNDC	7.0
fathead minnow*	FTMN	8.3
goldeye	GOLD	9.3
lake chub*	LKCH	5.5
lake whitefish*	LKWH	2.5[1]
longnose dace*	LNDC	6.2
longnose sucker*	LNSC	4.6
northern redbelly dace*	NRDC	7.0[1]
northern pike	NRPK	7.8
pearl dace*	PRDC	6.7
slimy sculpin*	SLSC	3.0[1]
spoonhead sculpin	SPSC	3.0[1]
spottail shiner*	SPSH	7.7
trout-perch*	TRPR	8.4
walleye	WALL	8.7
white sucker*	WHSC	7.6
yellow perch	YLPR	7.4

* Commonly caught fish species of Athabasca River tributaries in the Alberta oil sands region.

[1] Judgment-based score from values for similar species.

Temporal Trends and Spatial Comparisons

Possible changes in fish assemblages were evaluated by comparing measurement endpoints in reaches designated as *test* to upstream *baseline* reaches and regional *baseline* reaches and/or across years within a reach. When necessary, the measurement endpoints were $\log_{10}$-transformed or ranked to meet assumptions of normality and homogeneity of variances. For reaches where there were three years of data, one-way ANOVAs were conducted for each fish assemblage measurement endpoint with each reach-year combination as the factorial variable. The ANOVA used variations within reaches to judge the significance of linear time trends. Linear contrasts were used to carry out the analysis of variance and to test the specific hypothesis. Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to identify differences in time trends between lower *test* reaches and upper *baseline* reaches. In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

The nature of statistically significant differences was examined to determine if the difference was consistent with a negative change in the fish assemblage. A decrease in taxa richness and an increase in ATI would each be considered a negative change or difference. A decrease in diversity would be considered a negative change. Similar to statistical analyses conducted for the Benthic Invertebrate Communities component, changes are more easily interpreted when the change accounts for at least 20% of the variation in the annual means, so that additional criterion is used this year to identify interpretable effects. An effect that explains 20% of the noise is equivalent to an effect size of 1 standard deviation; i.e., means differ by 1 SD.

In cases where there is an upstream *baseline* reach, the testable hypothesis was:

- H_{O1}: No difference in time trends in mean values of measurement endpoints between *test* and *baseline* reaches.

In the case when there were no local *baseline* data for a lower *test* reach, the testable hypothesis was:

- H_{O2}: No trend over time in mean values of measurement endpoints.

Comparison to Published Literature

There are no conventional "guidelines" *per se* against which to judge observed differences in measurement endpoints of fish assemblages given *baseline* ranges of variation tend to depend on local or regional climatic, hydrological, and geological conditions. Consequently, *baseline* reach data, data for select reaches from the two-year pilot study, and published literature of fish surveys conducted within the region (i.e., Golder 2004; AOSERP; FWMIS database) provide the most appropriate set of regional *baseline* conditions and information against which to assess potential change(s) observed in *test* reaches.

Determination of Normal Ranges

The normal range for *baseline* reaches were calculated similarly to the ranges for benthic invertebrate communities (see Section 3.2.3.1) (within-reach ranges were not calculated given the small sample size of data available for each reach). The first step was to determine which fish assemblage reaches were similar in habitat conditions in order to group *baseline* reaches according to their similarities. A principal components analysis of the physical and chemical habitat data for each of the 48 *baseline* reach x year combinations was conducted in order to determine how the various habitat attributes covaried, and to select a sub-set of variables that would be used to explore causes of variation in measurement endpoints of fish assemblage composition. The PCA was conducted using the following suite of variables: maximum water depth, bankfull width, wetted channel width, left bank height, right bank height, left bank angle, right bank angle, flow at mid-channel, depth at mid-channel, dissolved oxygen concentration, conductivity, pH, water temperature at the time of the sampling, instream cover as algae, instream cover as macrophytes, instream cover as large woody debris (LWD), instream cover as small woody debris (SWD), instream cover as trees, instream cover as undercut banks, instream cover as boulders, small tree canopy scores for both left and right banks, large tree canopy scores for both left and right banks, understory scores for both left and right banks, canopy LWD scores for both left and right banks, and canopy SWD scores for both left and right banks. Data for all habitat variables were scaled by unit variance prior to conducting the PCA to ensure that all data were comparable.

Principal component axes explaining >10% of the total variance in habitat features were carried forward for further interpretation (Jackson 1993). Pearson correlations (i.e., Pearson *r*-values) between individual variables and the “significant” PCA axes that were >|0.6| were considered strongly associated with an axis. Variables that strongly correlated with an axis were considered at least somewhat redundant.

Based on the results of the PCA, variables that explained some variability across *baseline* reaches included (see Appendix E for the complete analysis):

- Mean bankfull and wetted width;
- Depth at mid-channel;
- Instream macrophytes;
- Instream cover as boulders;
- Big tree canopy cover for both left and right banks;
- Understory shrub cover for both left and right banks;
- SWD for both left and right banks; and
- Right bank LWD.

Spearman rank correlations were calculated between these habitat variables that were highly correlated with PCA axes 1, 2, and 3 and measurement endpoints (CPUE, total abundance, richness, diversity, and ATI). This step identified which habitat characteristics were driving changes in measurement endpoints at all reaches (see Appendix E for the complete analysis).

Using habitat variables that were significantly correlated with PCA axes and measurement endpoints, a cluster analysis was performed to group reaches of similar habitat variables. Three main groupings of *baseline* and *test* reaches were observed based on wetted width, mid-channel depth, instream macrophyte coverage, instream boulder coverage, big tree canopy coverage, and understory shrub coverage. Therefore, normal ranges of *baseline* variation were calculated by grouping *baseline* reaches using the following characteristics (Table 3.2-14):

- Cluster group 1 – narrow, deep channel with lots of instream macrophytes, and small amount of instream boulders and big tree canopy coverage;
- Cluster group 2 – medium width, shallow channel with little instream macrophytes, small amount of big tree canopy coverage and understory shrubs, but lots of instream boulders; and
- Cluster group 3 – wide, shallow channel with little instream macrophytes, some instream boulders, and lots of big tree canopy coverage and understory shrubs.

Table 3.2-14 Regional *baseline* fish assemblage data groups and reach comparisons.

Regional Grouping (Cluster)	*Baseline* Reaches Used in Creating Regional Comparison[1]	Reaches (2014) Compared Against Regional *Baseline* Range
1. Beaver River, Birch Creek, Calumet River, Middle/Upper Muskeg River, Unnamed Creek East of Christina Lake, Sawbones Creek	BER-F2, BRC-F1, CAR-F2	MUR-F2, MUR-F3, SAC-F1, UNC-F2
2. Big Creek, Christina River (Lower and Above Jackfish River), Upper Ells River, Eymundson Creek, Firebag River, High Hills River, Upper Jackpine Creek, MacKay River, Pierre River, Red Clay Creek, Upper Steepbank River, and Sunday Creek	BIC-F1, CHR-F4, ELR-F3, EYC-F1, FIR-F2, HHR-F1, JAC-F2, MAR-F3, PIR-F1, RCC-F1, STR-F2, SUC-F2	CHR-F1, ELR-F1, FOC-F1, GRR-F1, MAR-F2, MUR-F1, POC-F1, SUC-F1, TAR-F1, UNC-F3, CHR-F3
3. Middle Ells River, Tar River, Middle Christina River, Lower Jackpine Creek, Lower MacKay River, Lower Steepbank River	ELR-F2, ELR-F2A, TAR-F2	CHR-F2, JAC-F1, JAR-F1, MAR-F1, STR-F1

[1] See Table 3.1-20 for classification of reach status by year. Where reach status changed from *baseline* to *test* from 2009 to 2014, only *baseline* data were used in the determination of regional fish habitat characteristics.

The normal range for the assessment of *test* reaches in 2014 was calculated as the among-*baseline*-reach range using all available data from *baseline* reaches, grouped by the above classifications, up to and including the current year (i.e., 2014) (Table 3.2-15).

Similar to the analysis for the Benthic Invertebrate Communities component, tolerance limits were then calculated for the 5th and 95th percentiles for among-*baseline*-reach normal ranges (as per Hunt et al. 2001; Smith 2002; Krishnamoorthy and Mathew 2009).

The tolerance limit for the pth percentile (5th or 95th percentile) is:

$$\bar{x} \pm k \bullet SD$$

Where,

- $k = \frac{t_{\gamma,N-1,\delta}}{\sqrt{N}}$;
- $t_{\gamma,N-1,\delta}$ is a non-central t-statistic (where γ indicates the lower 5th or upper 95th percentile of the non-central t distribution);
- $\delta = z_p\sqrt{N}$; and
- Z_p is the Z-statistic at the pth percentile (Z = 1.96 for the 95th percentile).

The value for δ depends on sample size, as then does the non-central t-statistic and ultimately k.

Table 3.2-15 Regional *baseline* ranges for fish assemblage measurement endpoints for each cluster group.

Cluster Group	Measurement Endpoint	Outer Tolerance Limit on the 5th Percentile	5th percentile	Inner Tolerance Limit on the 5th Percentile	Inner Tolerance Limit on the 95th Percentile	95th percentile	Outer Tolerance Limit on the 95th Percentile
1	Mean Abundance (#/m)	0.00	0.01	0.01	0.29	0.29	0.58
	Total Richness	0.00	0.48	0.43	6.22	6.30	12.23
	Mean Diversity	0.00	0.00	0.00	0.64	0.61	1.00
	Mean ATI	0.00	4.08	4.59	9.04	8.82	10.00
	CPUE (No./100 sec)	0.00	0.23	0.00	5.68	6.42	11.80
2	Mean Abundance (#/m)	0.00	0.03	0.00	0.43	0.41	0.57
	Total Richness	0.09	2.00	1.12	8.13	9.00	11.00
	Mean Diversity	0.00	0.07	0.08	0.78	0.70	0.98
	Mean ATI	2.33	3.77	3.69	7.74	7.98	9.11
	Mean CPUE (No./100 sec)	0.00	0.69	0.32	7.27	7.52	9.59
3	Mean Abundance (#/m)	0.00	0.28	0.29	0.88	0.89	1.58
	Total Richness	0.00	1.60	2.18	6.39	6.00	11.43
	Mean Diversity	0.00	0.03	0.01	0.64	0.66	1.00
	Mean ATI	0.00	3.04	2.50	6.85	6.81	10.00
	Mean CPUE (No./100 sec)	0.00	4.78	4.83	10.84	11.25	18.03

Classification of Results

The criteria used for classifying results of fish assemblages focused on whether or not the measurement endpoints for the fish assemblage at a *test* reach either exceeded normal ranges of *baseline* variability, had significantly changed across years, or was significantly different from the upstream *baseline* reach (if applicable).

Measured changes were classified as Negligible-Low, Moderate, and High on the basis of the strength of the statistical signal from a reach for changes in measurement endpoints for fish assemblages, and for exceedances from the normal *baseline* range of variability (Table 3.2-16). There are five measurement endpoints assessed for fish assemblages (abundance, CPUE, richness, Simpson's Diversity, and the Assemblage Tolerance Index). If any one of those measurement endpoints produced a significant change in 2014 compared to previous years ($p<0.05$) and/or if the mean in 2014 fell between the inner and outer tolerance limits or outside the outer tolerance limits for the 5th or 95th percentile for the normal range of *baseline* variability, then the 'Moderate' criterion was considered to have been met. This criterion was particularly relevant for the assessment of reaches for which there was at least a three-year data record. Allowing any one of the five measurement endpoints to trigger this criterion assumed that each measurement endpoint represented an attribute of the assemblage that was important. If any three of the key measurement endpoints produced a strong statistical signal, then the conclusion was that a 'High' level of change had been detected. The second criterion was considered to be met (producing a "yes" in Table 3.2-16) if any three measurement endpoint values had fallen outside of the normal range of *baseline* variability within the current year or if a measurement endpoint was outside the normal range of *baseline* variability for three consecutive years.

Table 3.2-16 Classification of results for the fish assemblage monitoring program of the 2014 JOSMP.

Criterion	Classification			"Yes"
	Negligible-Low	Moderate	High	
Statistical significance	No	Yes	Yes	Strong statistical signal on any one of five measurement endpoints (Moderate), with a difference implying a negative change and statistical signal on at least four of the five endpoints (High).
Exceed *baseline* range of variation	No	No	Yes	Any three of the five measurement endpoints outside the inner tolerance limits of the 5^{th} and 95^{th} percentiles or three consecutive years of a measurement endpoint outside the normal *baseline* range of variability, in a direction implying a negative change.

3.2.5 Acid-Sensitive Lakes Component

The measurement endpoints for the ASL component in 2014 were as follows:

- pH;
- Gran alkalinity;
- Base cation concentrations;
- Nitrate plus nitrite;
- Sulphate;
- Dissolved organic carbon; and
- Dissolved aluminum.

Gran alkalinity and pH are considered the principal ASL measurement endpoints. Sulphate is included in the list of measurement endpoints but, unlike many lakes in eastern North America, sulphate and acidity (H^+) in Alberta lakes are poorly correlated because of the abundance of neutral sulphate compounds in wet and dry deposition (AEP 1990; Lau 1982; Legge 1988; RAMP 2004). Concentrations of sulphate in the ASL component lakes were typically low and, despite high rates of deposition in the past, were found to be sequestered and immobilized within the individual catchment basins (Whitfield et al. 2010).

3.2.5.1 Temporal Trends

The data analysis focused on the detection and evaluation of potential temporal trends in the ASL measurement endpoints in the study lakes that would indicate incipient acidification of the lakes. In this regard, four specific data analyses were conducted and described in this section.

Among-Year Comparisons of Measurement Endpoints using an ANOVA

A one-way Analysis of Variance (ANOVA) was conducted to determine whether there have been any significant changes in mean concentrations of each ASL measurement endpoint in the 45 lakes during the thirteen years of monitoring when all lakes were sampled (2002 to 2014). An ANOVA was run after testing for the homogeneity of the variance of each variable between years. When the variance of a variable was found to be non-homogeneous, a non-parametric test (Kruskal-Wallis one-way ANOVA) was applied to detect changes in the median concentrations. Tukey's post-hoc test was used to examine individual differences in mean values among years when the ANOVA indicated significant differences. Any observed changes were discussed in relation to acidification, natural variability and other possible causes unrelated to emissions of acidifying substances (e.g., hydrologic events).

Among-Year Comparisons of Measurement Endpoints using the General Linear Model

An ANOVA using the General Linear Model (GLM) was applied to examine trends in measurement endpoints over time in the study lakes. The model regresses the concentration of a measurement endpoint against time in each individual lake and determines the overall significance of the regressions over the 45 lakes. This test is more powerful than the one-way ANOVA for detecting potential changes in a measurement endpoint over time because potential changes are examined in each individual lake rather than between the mean values across lakes. The GLM was applied to the population of 45 lakes as well as subsets of the 45 lakes that included both *baseline* and *test* lakes.

Mann–Kendall Trend Analysis on Measurement Endpoints in Individual Lakes

Potential trends in measurement endpoints were examined in all 45 lakes using a Mann-Kendall trend analysis. Significant trends were examined and discussed in relation to previous hydrologic events and the logical consistencies (or inconsistencies) of these observed trends. The program used for the analysis (MAKESENS) calculates the Mann-Kendall statistic S on lakes having fewer than ten years of data. For lakes having at least ten years of data, a normal approximation test was applied to calculate the Z test statistic. To assist in interpreting the results of the trend analyses, control charts were provided of measurement endpoints in those lakes where significant changes occurred in a direction indicative of acidification.

Control Charting of Measurement Endpoints in Lakes Most Likely to Acidify

The pH, Gran alkalinity, sulphate, sum of base cations, nitrates, and dissolved organic carbon were charted in Shewhart control plots for the ten lakes deemed most at risk to acidification. Five lakes were selected for control charting on the basis of the ratio of the modeled Potential Acid Input to Critical Load (PAI to CL). The higher the ratio in a given lake, the greater the risk for acidification of this lake. The control plots followed standard analytical control chart theory where control limits representing two and three standard deviations were plotted on the graphs with the points and the mean value (Gilbert 1987; Systat 2004). The two and three standard deviations were calculated using all historical data for a lake (1999 to 2013). A trend in the value of a measurement endpoint was determined on the basis of the criteria described below. Given the low probability (1% or less) that these criteria would be violated in a truly random population of a measurement endpoint, there is a high probability of detecting a true trend in a measurement endpoint over time. The visual presentation of the data in control charts permitted the detection of trends before significant changes actually occur.

The following criteria were used to identify a trend or potential risk for acidification using Shewhart control plots (from Systat 2004):

- One year where a measurement endpoint was beyond three standard deviations (on either side);
- Nine consecutive years where a measurement endpoint was on one side of central line (mean value);
- Six consecutive years where a measurement endpoint was steadily increasing or decreasing;
- Two out of three consecutive years where a measurement endpoint was outside the two standard deviations limit (on one side). This is a modified version of the first test. This gives an early warning that the measurement endpoints might be going "out-of-control"; and
- Four out of five consecutive years where a measurement endpoint was outside the one standard deviation limit (on one side). This test is similar to the previous one and may also be considered to be an early warning indicator of a measurement endpoint going "out-of-control".

3.2.5.2 Calculation of Critical Loads of Acidity and Comparison to Modeled Potential Acid Input

The critical load of acidity (CL), in units of keq H+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology; and represents a measure of a lake's sensitivity to acidification. CLs for the lakes in 2014 were calculated using the Henriksen steady state water chemistry model modified for the effects of organic acids on buffering and acid sensitivity. Details of the model and its assumptions are described below.

The Modified Henriksen Model

The original Henriksen model was modified to account for both the buffering of weak organic anions and the lowering of acid neutralizing capacity (ANC) attributable to strong organic acids. The modified model assumed that DOC, with its associated buffering from weak organic acids (ANC_{org}) and reduction of ANC from strong organic acids (A^{-}_{SA}), was exported from the catchment basin to each lake in the same way that we assume the export of base cations (carbonate alkalinity) to each lake. The modified Henriksen model is:

$$CL= ([BC]^*_0 + ANC_{org} - A^{-}_{SA} - ANC_{lim}) .Q$$

Where,

- $[BC]^*_0$ is the original base cation concentration before acidification;

- ANC_{lim} is the limiting acid-neutralizing capacity of the lake required to maintain a healthy and functional aquatic ecosystem;
- $ANC_{org} = 0.00680^{*} DOC^{(0.8833^{*}pH)}$;
- $A^{-}_{SA} = 6.05 ^{*}DOC +21.04$; and
- Q is the runoff to each lake from the catchment and lake area.

The modifications of the Henriksen model for organic acids and the empirical relationships for developed for ANC_{org} and A_{-SA} are described in WRS (2006) and RAMP (2009b).

Calculation of Runoff (Q)

The runoff (Q) to each lake, was calculated from the analysis of heavy isotopes of oxygen (^{18}O) and (^{2}H) in each lake conducted, and provided by John Gibson (University of Victoria). With this technique, the natural evaporative enrichment of ^{18}O and ^{2}H in each lake is used to partition water losses between evaporation and liquid outflow and hence derive an estimate of runoff (Gibson 2002; Gibson et al. 2002; Gibson and Edwards 2002; Gibson et al. 2010). This technique utilizes a different set of assumptions from traditional hydrometric methods that extrapolate water yields from one or more gauged catchments to the ungauged lake catchments. Potential inaccuracies in the traditional hydrometric method, especially in low-relief catchments, have previously been recognized in lakes in the oil sands region (WRS 2004). The isotopic technique also permits examination of annual changes in runoff to each lake which will affect the critical load.

Original Base Cation Concentration ($[BC]^{*}_{0}$)

During the process of acidification of a catchment, base cations are released from the soils to the lake waters. In previous years of applying the Henriksen model (2002 to 2013), it was assumed that base cations have not increased in these lakes as a result of acidic deposition; that is, the current base cation concentrations were equivalent to the original values. This simplifying assumption was adopted for the following two reasons:

- The discrepancy between the original and the current base cation concentrations in a lake is normally calculated by an equation presented in Brakke et al. (1990) based on increases in sulphur concentrations in a lake resulting from aerial deposition. Calculations of $[BC]^{*}_{0}$ using the Brakke et al. (1990) equation indicated that the differences between the current and calculated original base cation concentrations in all 45 lakes were insignificant.
- A study by Whitfield et al. (2010) in which the Magic Model (Model of Acidification of Groundwater in Catchments) was applied to the Athabasca oil sands region concluded that, to date, sulphate deposition levels have resulted in only a limited removal of base cations from the soil.

Despite indications that base cations have not increased in the ASL component lakes in 2014, $[BC_{o}]$ was calculated for each lake by applying a modified Brakke et al. (1990) equation. This process was followed in order to be consistent with international methodologies. The calculation of BC_{0} followed the equations published in the “Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads” (CLRTAP 2004; Henriksen et al. 2002). $[BC_{0}]$ was calculated as:

$$[BC_{o\}} = [BC_T] – F(SO_{4,T} - SO_{4,o} + NO_{3,T} - NO_{3,o})$$

Where,

- $[BC_T]$ is the current base cation concentration;
- F is the “F factor” describing the ratio of the change in base cations to the additions of strong acids to each lake from acid deposition;
- $SO_{4,T}$ and $SO_{4,o}$ are the current and original sulphate concentrations in each lake, respectively; and
- $NO_{3,T}$ and $NO_{3,o}$ are the current and original nitrate concentrations in each lake, respectively.

The F factor is defined as:

$$F = \sin(\Pi/2 \cdot Q \cdot [BC_T]/S)$$

Where,

- S is the base cation flux when all acid deposition is neutralized in the catchment (F=1); and
- Q and $[BC_T]$ are defined above.

Following Henriksen et al. (2002) and CLRTAP (2004), S was assumed to be 400 $meq/m^2/y$. Further details on these calculations of CL are presented in Section 5.14 and Appendix F.

Choice of ANC_{lim}

The critical load concept as expressed in the Henriksen model assumes a dose-response relationship between a water quality variable and an aquatic indicator organism. In this case, the water quality variable is the acid-neutralizing capacity (alkalinity) required to maintain a healthy fish population. In applying the Henriksen model in Europe, a critical threshold ANC_{lim} of 20 μeq/L was set to protect brown trout, the most common European salmonid, and to ensure that no toxic acidic episodes occur to this species during the year.

In North America, the effects of acidification on biota have been historically related to pH rather than alkalinity or acid-neutralizing capacity. Research on pH tolerance of a wide range of aquatic organisms has shown that a pH>6 is required to maintain aquatic ecosystem functioning and protect both fish and other organisms (RMCC 1990; Environment Canada 1997; Jeffries and Lam 1993). Within a given region, lake pH has been empirically and theoretically related to alkalinity as an inverse hyberbolic sine function (Small and Sutton 1986) and this relationship has been used to equate the two variables for the purpose of critical load modeling (e.g., Jeffries and Lam 1993). The relationship between pH and alkalinity for the Athabasca oil sands region was derived from a water quality survey conducted on lakes in the ALPAC forest management area (WRS 2001, see Appendix F). Across these lakes, a pH of 6 was associated with an alkalinity of ~75 μeq/L. Accordingly, this value was chosen for ANC_{lim} in the Acid Deposition Management Framework for the Athabasca oil sands region (CEMA 2004b) and has been applied in numerous studies (e.g., Gibson et al. 2010).

Comparisons to Modeled PAI

The critical loads for each lake were compared to the modeled rates of the Potential Acid Input (PAI) to each lake catchment calculated for Teck Energy's Frontier Project and published in Davies et al. (2015). The PAI represents the sum of the acidifying nitrogen and sulphur species deposited in each catchment minus the base cation deposition. The ability of nitrates to be assimilated and used as a nutrient by plants within each lake catchment was accounted for by applying the approach adopted by CEMA and AESRD, whereby any nitrogen deposition in excess of 10 kg/ha/y and 25% of the first 10 kg/ha/y deposited N were considered acidifying (CEMA 2008; AENV 2007). An "existing conditions" EIA emissions scenario was assumed in the modeling. The PAI predictions reflected new estimates of base cation deposition determined from mixed-bed ion exchange resin collectors deployed for one year (2009 to 2010) at WBEA's Terrestrial Environmental Effects Monitoring (TEEM) study sites in the oil sands region (Fenn et al. 2015). Bulk base cation deposition rates from open study sites were selected for the estimates of PAI rather than rates measured in "flow-through" sites representing deposition to the forest canopy. The open sites typically displayed lower rates of base cation deposition and; therefore, resulted in higher (more conservative) estimates of PAI. The 2015 PAI modeling also included the deposition of reduced forms of nitrogen (i.e., ammonia and ammonium).

3.2.5.3 Supporting Analyses

The following supporting data analyses were also conducted on the study lakes, the results of which are presented in Appendix F:

- Update of the ASL database, calculation of summary statistics, identification of lakes with unusual chemical characteristics, and comparisons of the chemistry of the lakes in 2014 to the range of chemical characteristics of lakes within the oil sands region;
- Classification of lake chemistry using Piper plots; and
- Analysis of metals in individual lakes.

Update of the ASL Database, Summary Statistics and Comparisons of ASL Chemistry to Regional Lake Chemistry

The water chemistry data from 2014 and all previous monitoring years combined were tabulated and summarized statistically. Lakes with unusual chemical characteristics were identified based on the 5th and 95th percentiles in the values of the measurement endpoints. The chemical characteristics of the lakes were compared to those of 450 regional lakes reported in the lake sensitivity mapping study produced for the NO_xSO_x Management Working Group (NSMWG, WRS 2004). The following comparisons were conducted to determine how typical the study lakes are of lakes within the oil sands region:

- examination of the range, median, and mean values of key chemical variables for 2014 in the lakes relative to the regional dataset;
- graphical presentation of both datasets in box-plots; and
- statistical comparison of chemical variables between the ASL component lakes and the regional dataset.

Classification of the Lakes using Piper Plots

Piper plots were used to characterize the water in each of the study lakes according to the major chemical constituents. A Piper diagram is a multivariate graphical technique that is used to divide the lakes into four water types on the basis of major cations and anions (Güler et al. 2002; Freeze and Cherry 1979; Back and Hanshaw 1965). The four water types include:

- Type I Ca^{2+} - Mg^{2+} - HCO_3^-;
- Type II Na^+ - K^- - HCO_3^-;
- Type III Na^+- K^- - Cl^- - SO_4^{2-}; and
- Type IV Ca^{2+} - Mg^{2+} - Cl^- - SO_4^{2-}.

Analysis of Metal Concentrations in the Lakes

The total and dissolved metal fractions in the lakes from 12 years of monitoring by AESRD (2001, 2003 to 2014) were tabulated and summarized statistically. Lakes having relatively high metal concentrations were identified as those exceeding the 95th percentile concentration for individual metals. Exceedances of the Alberta and CCME surface water quality guidelines were also identified (CEMA 2010; AESRD 2014). The lakes and physiographic regions having the highest metal concentrations were identified and plotted on regional maps.

In 2014, additional analyses were conducted to detect potential changes in metal concentrations attributable to acidification. These analyses included:

- a comparison of selected metals between physiographic regions using an Analysis of Variance (ANOVA);
- a comparison of metal concentrations between *baseline* and *test* lakes using an ANOVA; and
- a Mann Kendall trend analysis on selected metals for all 50 lakes from 2003 to 2014. The metals showing significant increases in individual lakes were plotted in control charts and interpreted as described in Section 3.2.5.2.

3.2.5.4 Classification of Results

A summary of the state of the ASL component lakes in 2014 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of the measurement endpoints for each lake within each subregion. The measurement endpoint and the relevant trend that is indicative of acidification are as follows: Gran alkalinity (downwards); pH (downwards); sum base cations (upwards); nitrates (upwards); dissolved organic carbon (downwards); sulphate (upwards); and aluminum (upwards).

For each lake, the mean and standard deviation were calculated for each measurement endpoint across all monitoring years. The number of lakes in 2014 within each subregion having measurement endpoint values greater than two standard deviations (SD) (above or below the mean as indicated above) was calculated. The number of exceedances of measurement endpoints greater than 2SDs was expressed as a percentage of the total number of lake-measurement endpoint combinations for each subregion. The results were classified as follows:

- Negligible-Low – subregion has <2% measurement endpoint-lake combinations exceeding ± 2 SD criterion;
- Moderate – subregion has 2% to 10% measurement endpoint-lake combinations exceeding ± 2 SD criterion; and
- High – subregion has >10% of measurement endpoint-lake combinations exceeding ± 2 SD criterion.

4.0 CLIMATE AND HYDROLOGIC CHARACTERIZATION OF THE ATHABASCA OIL SANDS REGION IN 2014

4.1 INTRODUCTION

This section summarizes the 2014 regional climate and hydrology data and trends for the Athabasca oil sands region. It also provides a comparison of the 2014 data with long-term historical data. The comparison is based primarily on federal and provincial climatic and hydrologic monitoring stations because of the long-term data records available at those stations. The information in this section is intended to provide context for the monitoring results in support of the 2014 Joint Oil Sands Monitoring Plan (JOSMP). A number of the climate and snowpack monitoring stations are also used to provide additional regional context. The following discussion is based on the 2014 Water Year (WY) from November 1, 2013 to October 31, 2014.

4.2 CLIMATE CHARACTERIZATION

The climate characterization of the Athabasca oil sands region is based on air temperature, precipitation, and snowpack data to provide both historical and regional context of conditions in the 2014 WY. Long-term context is provided by the Fort McMurray Environment Canada (EC) station that has a historical record since 1945 while context on regional variability are provided by stations operated under the JOSMP and by AESRD and JOSMP snow course transects (Figure 3.1-1).

Since 1945, daily precipitation and air temperature data have been collected at the Fort McMurray airport at four stations operated by Environment Canada (EC) (Table 4.2-1). The combined data record for these stations spans 70 years (1945 to 2014). It is noted that the period of record varies for these stations, as some were decommissioned or moved. However, the data from these stations is considered to be representative of a single location, based on the proximity of the stations being within 1 km of each other and a comparison of overlapping data records showed minimal variation between locations. Therefore, for purposes of the analyses conducted in this report, precipitation and air temperature records from these stations were consolidated into one long-term data series from 1945 to 2014. This data series will be referred hereafter as the Fort McMurray climate data set.

Table 4.2-1 Long-term climate data available from Environment Canada stations operated at the Fort McMurray Airport, AB.

Station Name	Station ID[1]	UTM Coordinate (NAD83 Zone 12)		Elevation (m)	Period of Record	Mean Daily Air Temperature (°C)	Daily Total Precipitation (mm)
		Easting	Northing				
Fort McMurray A	3062693	486715	6278448	369.1	1945 to 2008	✓	✓
Fort McMurray AWOS A	3062700	486307	6278820	369.1	2008 to 2011	✓	✓
Fort McMurray Alberta	3062697	486307	6278820	369.1	2011 to 2014	✓	✓
Fort McMurray CS	3062696	486919	6278571	368.8	1999 to 2014	✓	✓

[1] Unique seven digit station identifier assigned by Environment Canada.

4.2.1 Air Temperature

Daily mean air temperatures measured at Fort McMurray for the 2014 WY generally followed the mean historical values (Figure 4.2-1). Winter air temperatures from November to mid-April were more variable than the remainder of the year and followed the general historical annual trend.

Monthly mean air temperatures in the 2014 WY varied between the historical maximum and historical minimum monthly mean air temperatures (Figure 4.2-2). Air temperature followed a consistent pattern in the 2014 WY, with temperatures generally below the mean in winter months and above the mean in summer months. The exceptions to this pattern were observed in the months of January and May, which where warmer and cooler than the historical monthly mean, respectively.

Figure 4.2-1 2014 WY daily mean air temperature at Fort McMurray compared to historical values (1945 to 2013).

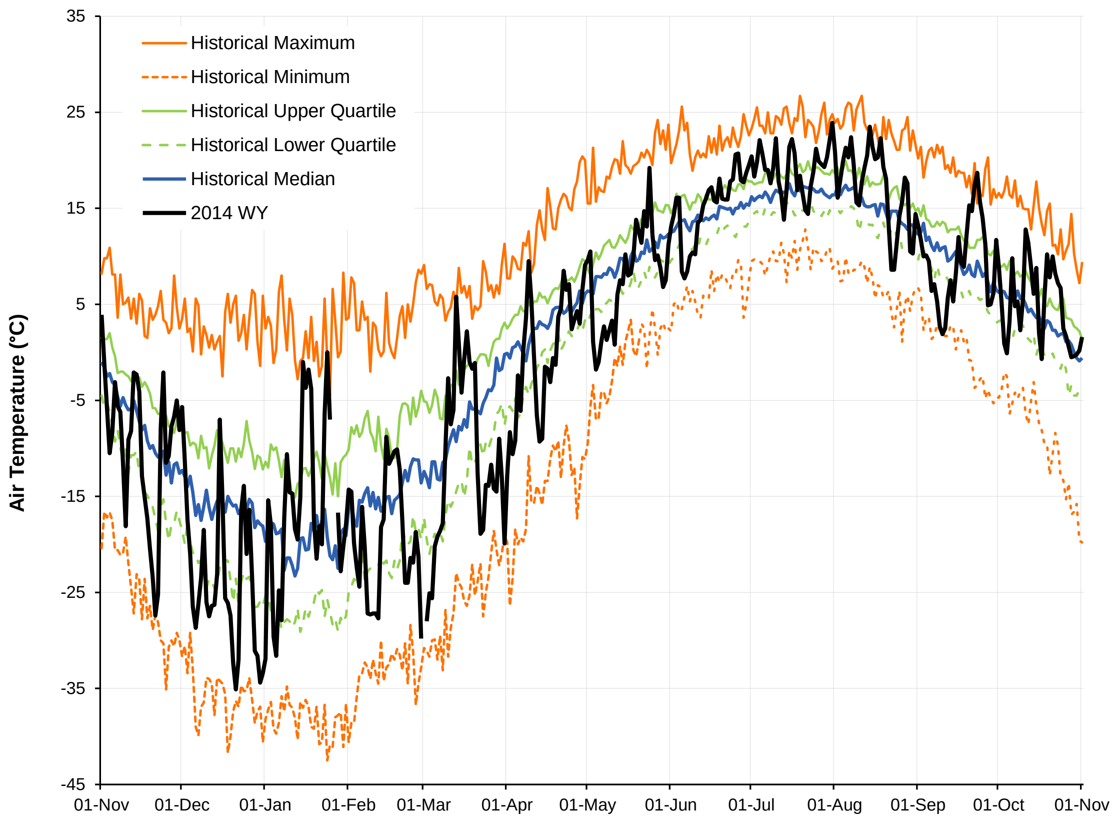
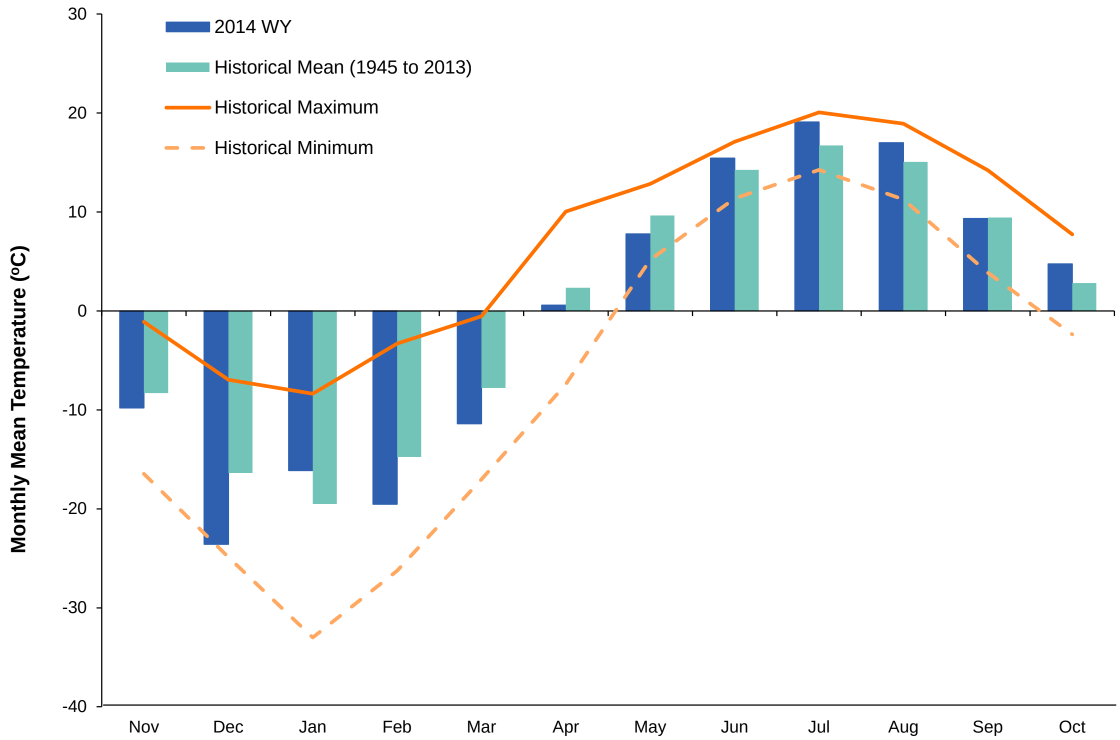


Figure 4.2-2 2014 WY monthly mean air temperatures at Fort McMurray compared to historical values (1945 to 2013).



Note: Daily mean air temperatures for Fort McMurray were averaged for each month for the period 1945 to 2013. These values are compared to monthly means for the 2014 WY.

4.2.2 Precipitation

Long-term WY precipitation measured at Fort McMurray is summarized in Figure 4.2-3. Total precipitation for the 2014 WY was similar to the long-term mean value of 417.8 mm. The winter period, from November 1, 2013 to March 31, 2014, was dryer than average with 51.2 mm of precipitation falling as snow, which was approximately 45% lower than the historical mean for this period. Conversely, total precipitation (assumed to be rainfall) from April 1 to October 31, 2014, was 366.6 mm and approximately 8% higher than the historical mean value for the same period. With a dryer than average winter period, the total precipitation in the 2014 WY was approximately 4% lower than the long-term annual mean of 435.3 mm.

Monthly total precipitation during the winter period (November to April) was generally below the historical mean for each month, with the exception of December (Figure 4.2-4). Monthly precipitation from May to October showed more variability than the winter period with total precipitation in July and August below their respective monthly historical means and the remaining months above their respective historical means. The wettest month in the 2014 WY was May, with a total precipitation of 82.9 mm, which represented an increase of 145.6% from the historical mean. The amount of precipitation in May accounted for 20% of the total precipitation in the 2014 WY.

Figure 4.2-3 Historical annual precipitation at Fort McMurray, 1945 WY to 2014 WY.

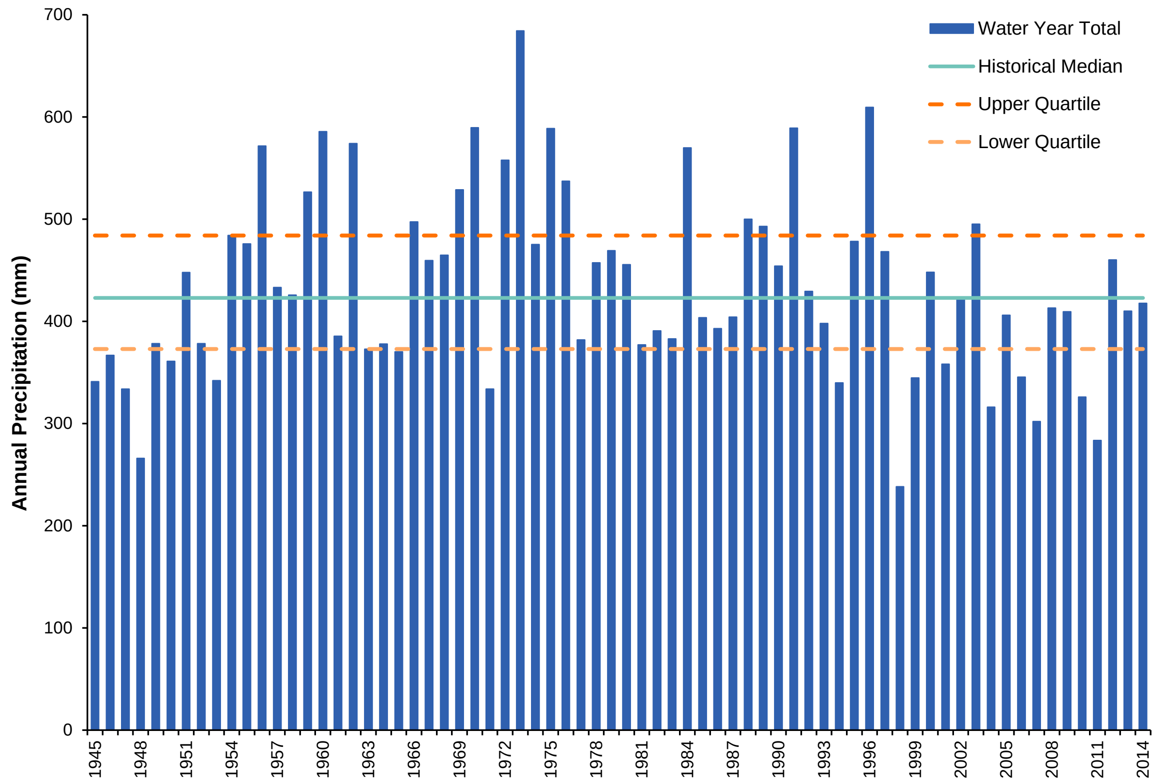
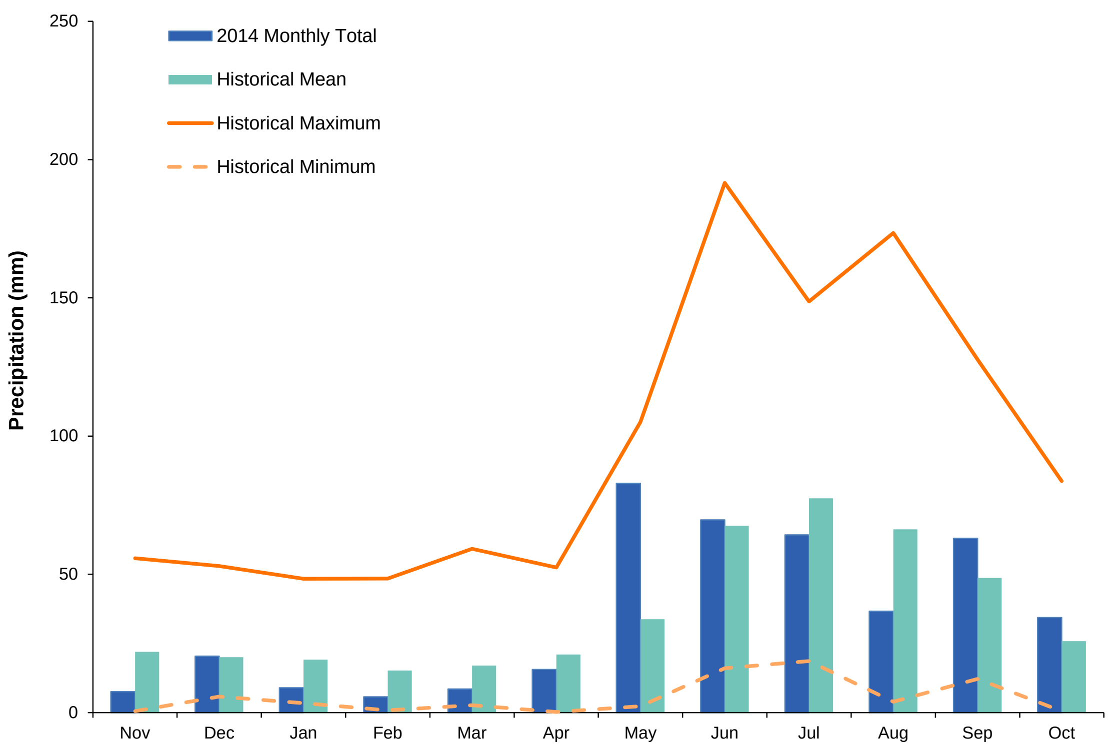


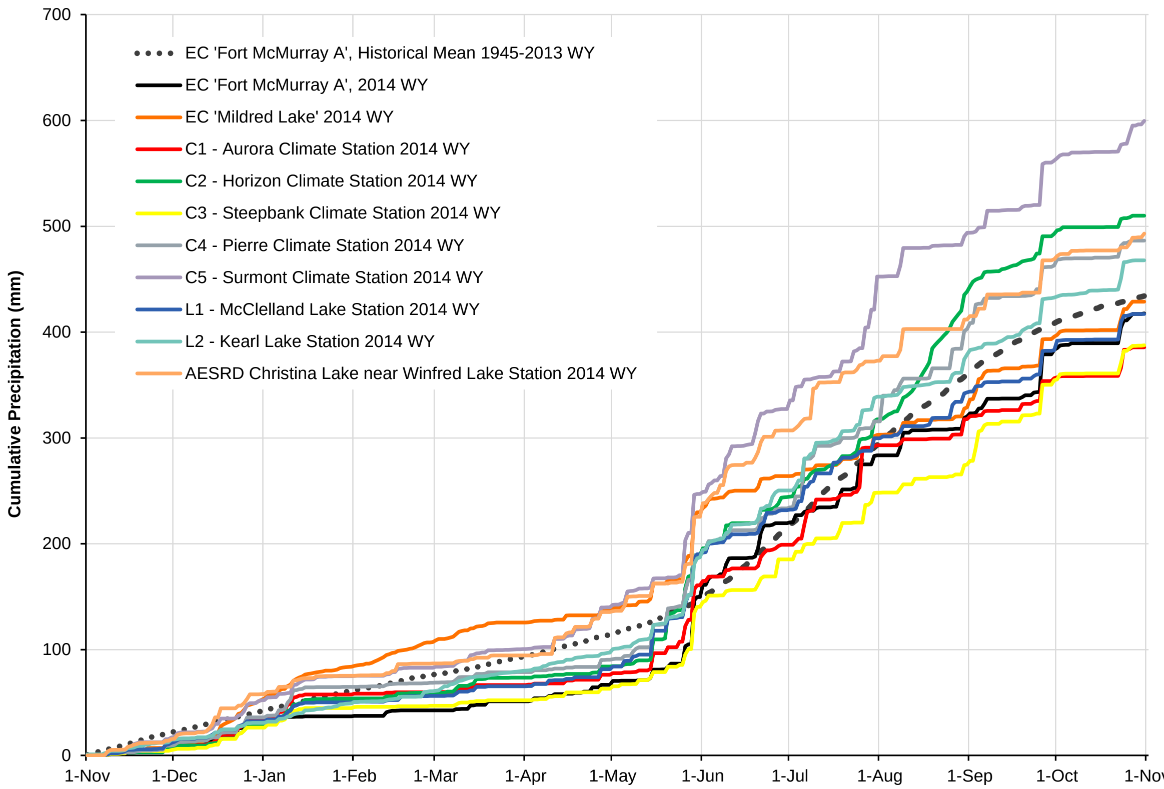
Figure 4.2-4 Total monthly precipitation at Fort McMurray in 2014.



Regional precipitation patterns were characterized using records from additional stations in the Athabasca oil sands region, including the EC Mildred Lake station (ID# 3064528), the AESRD Christina Lake near Winefred Lake station (ID# 3061580), and stations C1 Aurora, C2 Horizon, C4 Pierre, C3 Steepbank, C5 Surmont, L1 McClelland Lake, and L2 Kearl Lake operated in support of the JOSMP (Figure 4.2-5). Most stations reported below historical mean winter precipitation and above mean summer precipitation compared to the long-term Fort McMurray historical mean, which suggested lower runoff during spring freshet and increased runoff during summer as a result of increased rainfall.

Climate stations located to the north and northeast of Fort McMurray, such as the Fort McMurray, Mildred Lake, C1 Aurora, C3 Steepbank, and L1 McClelland Lake stations generally recorded cumulative precipitation for the 2014 WY below the long-term historical cumulative precipitation. Stations C2-Horizon and C4-Pierre stations, located in the northwest area of the oil sands region, recorded below mean winter precipitation but higher than average rainfall compared to the historical cumulative precipitation measured at Fort McMurray. The two stations located to the south of Fort McMurray (Station C5 Surmont and the Christina Lake station) recorded precipitation that was above the historical Fort McMurray cumulative precipitation for all months except November and December 2013.

Figure 4.2-5 Cumulative total precipitation at climate stations in the Athabasca oil sands region in 2014.



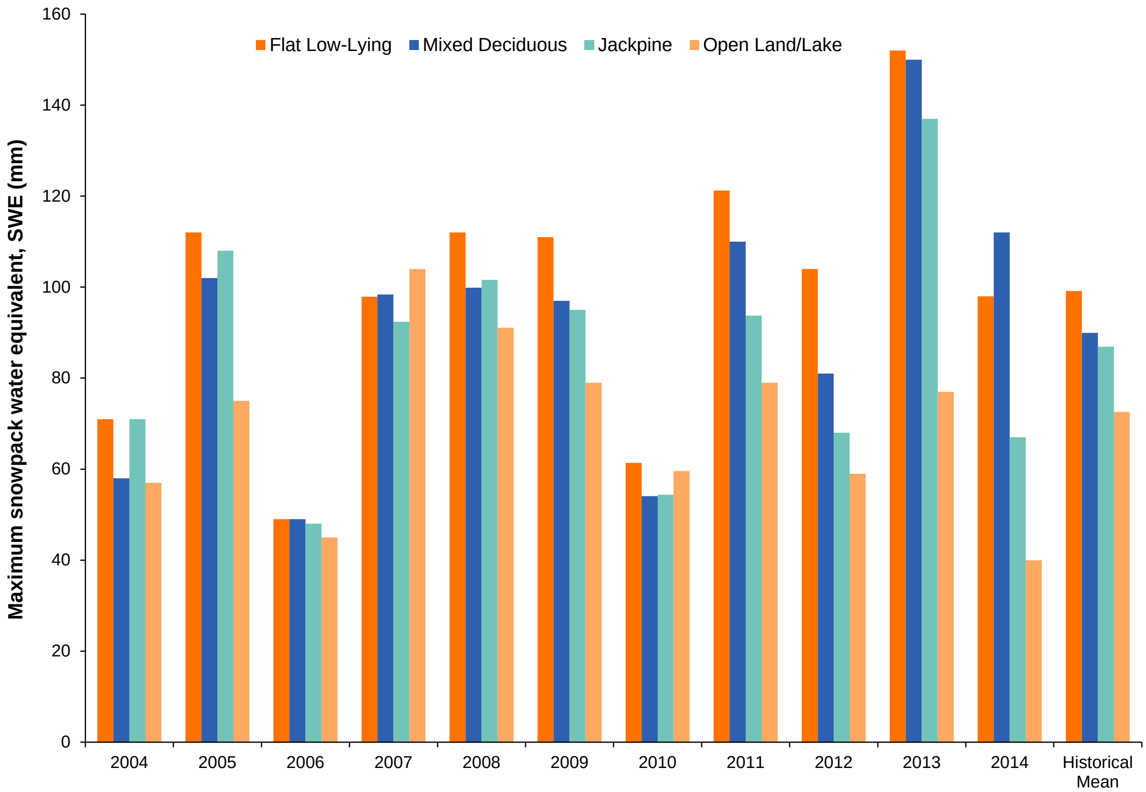
4.2.3 Snowpack

Snowpack data provides context for the amount of water that is stored in snow and contributes to the runoff of the spring freshet. Snowpack amounts (in terms of mm snow water equivalent or SWE) were measured at four regional locations during the periods of February 2 to 8, March 3 to 6, and March 28 to April 2, 2014, with four land category types sampled for each regional location (i.e., flat low-lying, mixed deciduous, jackpine, and open land/lake). These land cover types were selected as the most common land cover types in the region.

The maximum mean SWE value recorded for each land category is presented in Figure 4.2-6, with historical maximum mean SWE values for the period of 2004 to 2013 included for comparison. Unlike previous years, the mean SWE values in 2014 were highest in mixed deciduous terrain, with a decreasing trend through flat low-lying, jackpine, and open land/lake terrains. The mixed deciduous mean maximum SWE value was 25% higher than the historical mean maximum, while the flat low-lying, jackpine, and open land/lake terrains were below the historical mean maximum SWE value by 1%, 23%, and 45%, respectively.

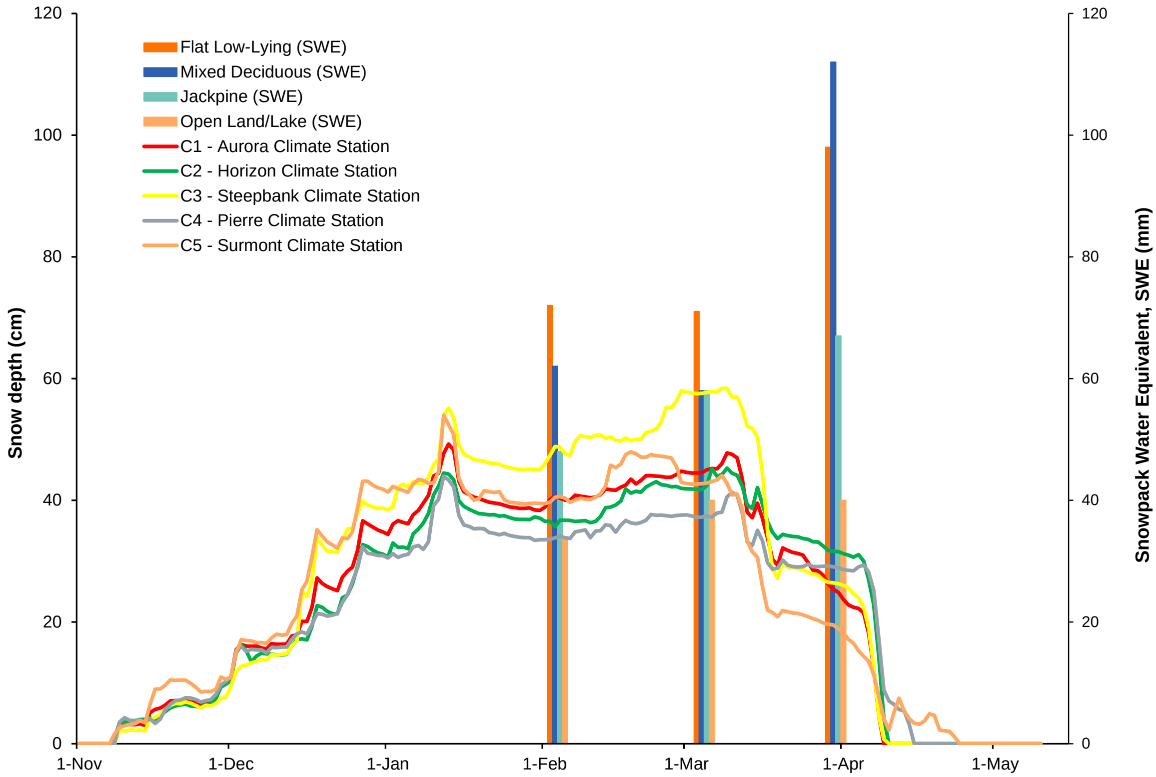
Snow depths measured at climate stations C1-Aurora, C2-Horizon, C3-Steepbank, C4-Pierre, and C5-Surmont corresponded with mean SWE by land category type until early March (Figure 4.2-7). Snow depths measured at the climate stations from early March until spring melt in mid-April decreased, however all terrain types showed increases in SWE, with the exception of open land/lake which showed no change from the early March SWE values. These trends were likely attributed to warmer air temperatures during this period, causing melting and compaction of the snowpack, reducing the overall depth of the snowpack. The snowpack started melting in early April and was completely melted by late April (Figure 4.2-7). Detailed information for the 2014 snow surveys conducted at each station is included in Appendix C.

Figure 4.2-6 Maximum measured snowpack amounts in the Athabasca oil sands region, 2004 to 2014.



Note: Similarly to previous years, four snowcourses were sampled in each of four land categories (Figure 3.1-1), in February, March, and early April 2014. Mean snow water equivalent (SWE) values shown here represented the maximum monthly mean values recorded for each land category and year.

Figure 4.2-7 Comparison of snowpack depth (cm) observed at climate stations and snow water equivalent (SWE, mm) measured in each land category in 2014.



4.3 HYDROLOGIC CHARACTERIZATION

Daily discharge hydrographs were developed for four long-term Water Survey of Canada (WSC) stations and compared to their respective 2014 WY provisional data. The four stations are located on the Athabasca, Muskeg, MacKay, and Christina rivers (Figure 3.1-2, Table 4.3-1). These stations were chosen because they represent four primary areas of interest (i.e., mainstem Athabasca River [north of Fort McMurray], the east and west sides of the Athabasca River, and south of Fort McMurray) in the Athabasca oil sands region and have at least 31 years of historical data.

Hydrologic variables and runoff for the Athabasca River were compared for the WY, while hydrographs for the Muskeg, MacKay, and Christina river stations were compared for the seasonal basis (March to October) to account for data gaps for the months of November to February from 1988 to 2000 when these stations were operated seasonally.

Table 4.3-2 summarizes the historical and 2014 runoff and minimum/maximum discharges for the four WSC stations.

Table 4.3-1 Long-term discharge data available from select Water Survey of Canada stations located in the Athabasca oil sands region.

Station Name	Station ID	Representative Area	Drainage Area (km^2)	Period of Record
Athabasca River below Fort McMurray	07DA001	Athabasca River upstream of oil sands development	132,585	1957 to 2014
Muskeg River near Fort McKay	07DA008	Eastern tributary of the Athabasca River	1,457	1974 to 2014
MacKay River near Fort McKay	07DB001	Western tributary of the Athabasca River	5,569	1972 to 2014
Christina River near Chard	07CE002	South of Fort McMurray	4,863	1982 to 2014

Table 4.3-2 Summary of 2014 hydrologic variables compared to historical values measured in the Athabasca oil sands region.

Variable	Athabasca River below Fort McMurray (07DA001)	Muskeg River near Fort McKay (07DA008)	MacKay River near Fort McKay (07DB001)	Christina River near Chard (07CE002)
Effective Drainage Area (km^2)	132,585	1,457	5,569	4,863
Period of Record	1958 to 2014	1974 to 2014	1973 to 2014	1983 to 2014
Runoff Volume (March to October)[1]				
Historical[2] mean (million m^3)	19,543	117.9	427.2	450.5
2014 (million m^3)	19,172	140.3	401.1	655.0
Maximum Daily Discharge (March to October)[1]				
Historical mean (m^3/s)	2,545	26.7	113.0	86.6
2014 (m^3/s)	2,430	41.1	120.0	177.0
Minimum Daily Discharge (May to October)[3]				
Historical mean (m^3/s)	423.5	1.1	3.6	6.5
2014 (m^3/s)	334.0	0.7	3.2	5.2

[1] Annual water year (November 1 to October 31) runoff volume and maximum daily discharge provided for the Athabasca River below Fort McMurray (07DA001), while seasonal (March to October) runoff volume and maximum daily flow are provided for the other three stations.

[2] The historical mean includes all data up to the end of the 2013 WY.

[3] Open-water season is based on values from May to October for all stations.

4.3.1 Athabasca River

The total annual flow volume for the Athabasca River measured at WSC Station 07DA001, Athabasca River below McMurray, was 19,172 million m^3 for the 2014 WY (Table 4.3-2). This was similar to the historical mean flow volume of 19,543 million m^3 over the station's 55-year period of record (1958 to 2013) (Figure 4.3-1).

Flows generally decreased from November 2013 to January 2014, with flows from November 2013 to mid-January 2014 remaining similar to historical lower quartile values. From January to mid-April, flows followed the historical trend in median flow, with the exception of an increase in flow in late January due to warm weather conditions (Figure 4.3-2). Freshet started in late April and peaked at 2,430 m^3/s on May 2. This peak coincided with the maximum recorded daily flow in the 2014 WY, which was 5% lower than the mean historical maximum daily flow of 2,545 m^3/s.

Flows also increased from early June to early July, which coincided with local rainfall events as well inferred melt conditions from the upper portion of the watershed. Following the early July event, flows decreased and generally remained between the historical lower quartile and historical minimum flow values. A small increase in flow occurred in early October and then followed historical lower quartile trends for the rest of October. The minimum flow for the 2014 open-water period (May to October) was 334 m^3/s recorded on October 31, and was 21% lower than the mean historical minimum daily flow of 423.5 m^3/s (Table 4.3-2).

Figure 4.3-1 Historical annual runoff volume in the Athabasca River basin, 1958 to 2014.

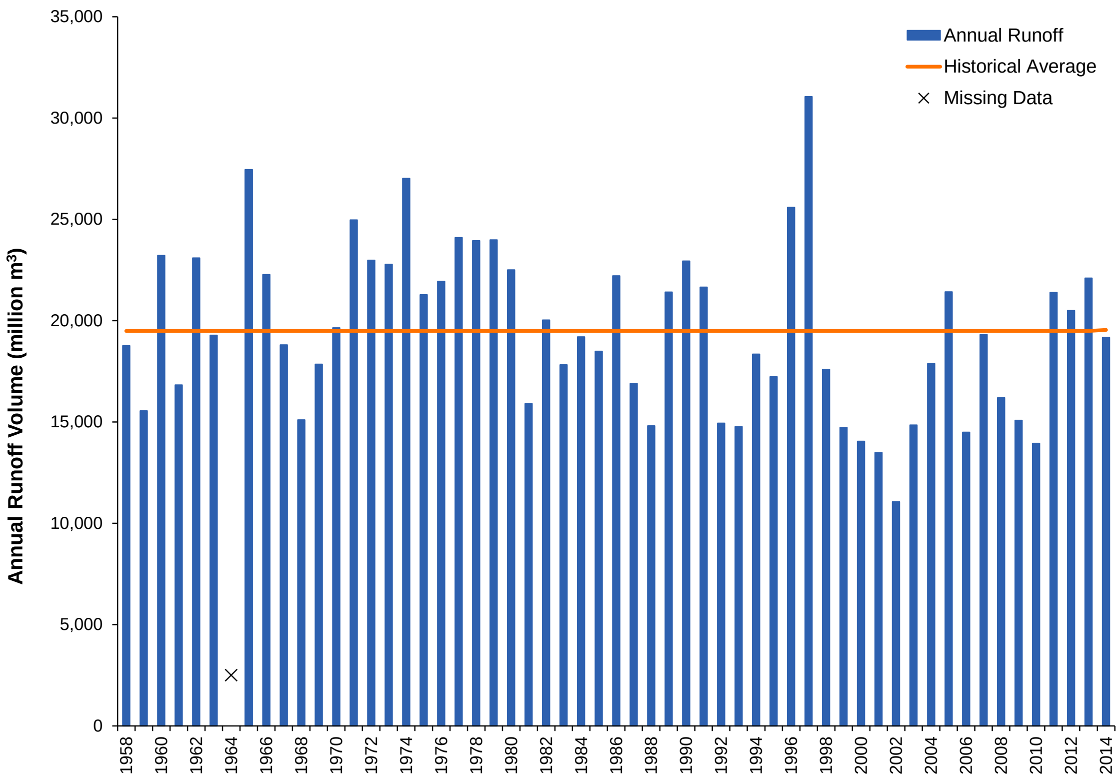
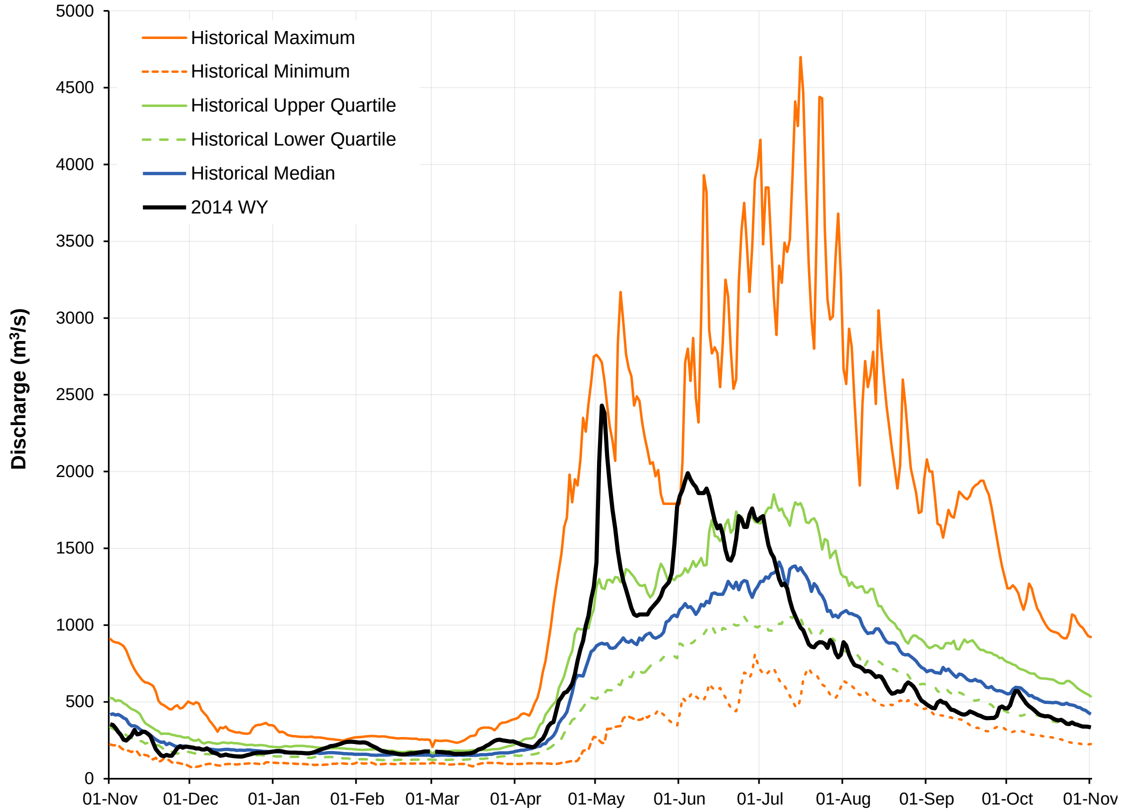


Figure 4.3-2 The 2014 WY Athabasca River hydrograph compared to historical values.



4.3.2 Muskeg River

The Muskeg River is a watershed that was chosen to represent streamflow in the northeast area of the oil sands region. The 2014 seasonal (March to October) runoff volume for the Muskeg River watershed recorded at WSC Station 07DA008, Muskeg River near Fort McKay, was 140 million m^3 (Table 4.3-2). This was approximately 19% higher than the long-term mean seasonal runoff volume of 118 million m^3, based on the station's 40-year period of record (Figure 4.3-3).

Winter flow in the 2014 WY generally remained near the historical median values until mid-May (Figure 4.3-4). The spring freshet started in late April and reached a peak of 9.1 m^3/s on May 4 and only reached the historical mean for this station. Flows recorded in late May were above the historical upper quartile and exceeded the historical maximum values in early June. The peak flow for the 2014 WY was 41.1 m^3/s on June 5, 2014, which was 58% higher than the mean historical maximum daily discharge of 26.1 m^3/s. Precipitation correlated with this peak in flow as well as other increases in flow in the 2014 WY shown by precipitation data collected at the C1-Aurora climate station (Figure 4.3-4).

Flows began to decrease in early July until reaching the historical lower quartile in late August, and continued to remain between the lower quartile and the historical median values until late October. Rainfall events in late October resulted in increased flows reaching the historical median values for the rest of the month. The 2014 open-water season (May to October) minimum daily flow of 0.69 m^3/s on September 25 was 35% lower than the historical mean minimum daily flow of 1.05 m^3/s (Table 4.3-2).

Figure 4.3-3 Historical seasonal (March to October) runoff volume in the Muskeg River basin, 1974 to 2014.

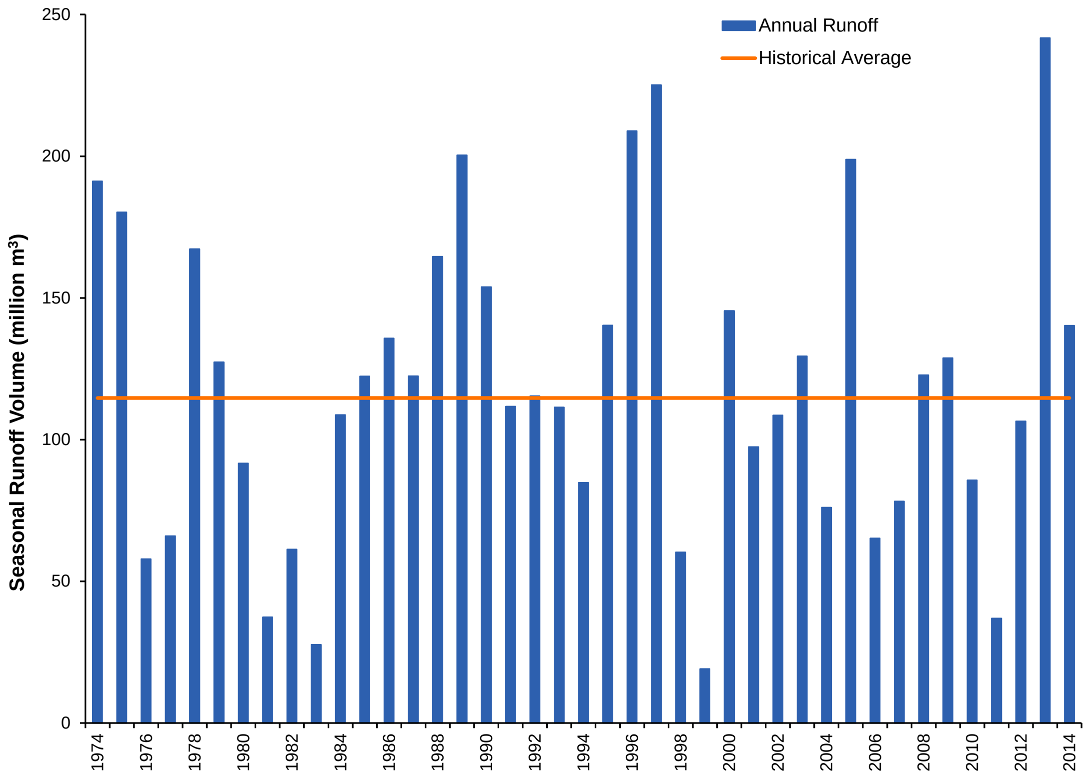
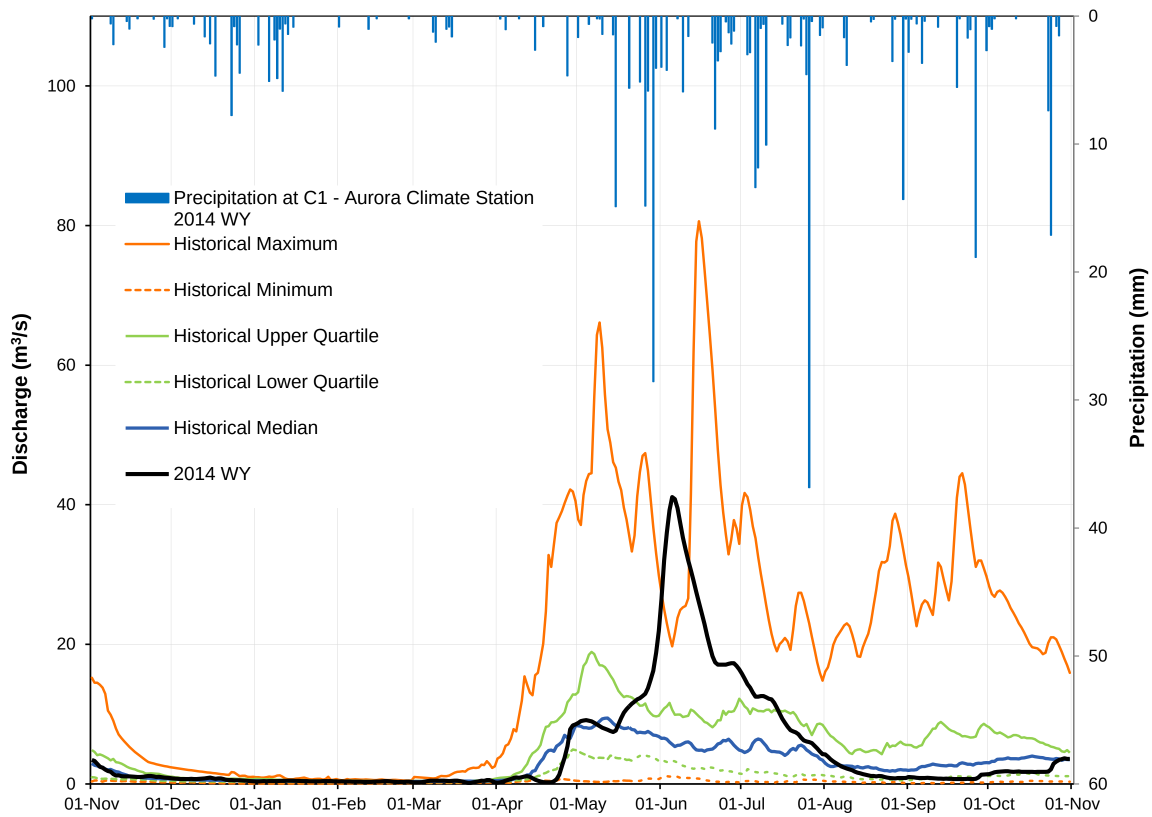


Figure 4.3-4 The 2014 WY Muskeg River hydrograph compared to historical values and 2014 daily precipitation data at the C1 Aurora Climate Station.



4.3.3 MacKay River

The MacKay River drains into the Athabasca River north of Fort McMurray and represents the western area of the oil sands region. The 2014 seasonal (March to October) runoff volume for the MacKay River watershed recorded at WSC Station 07DB001, MacKay River near Fort McKay, was 401.1 million m^3 (Table 4.3-2). This was approximately 6% lower than the long-term mean seasonal runoff volume of 427.2 million m^3, based on a 41-year period of record (Figure 4.3-5, Table 4.3-2). Flows recorded during the 2014 open-water period correlated with rainfall events, as shown by precipitation data from the EC Mildred Lake station (Figure 4.3-6).

Winter flows in the 2014 WY generally remained within the inter-quartile range until mid-April, after which flows remained below lower quartile values until the beginning of a late (early May) spring freshet. The freshet peak was below the historical median and decreased to near the lower quartile by mid-May. Following freshet, flows remained within the inter-quartile range until late May when a rainfall event resulted in a peak flow of 120 m^3/s on May 31. This peak was the 2014 WY maximum daily flow and 17% greater than the mean historical maximum daily discharge of 102.6 m^3/s, and exceeded historical maximum values from May 30 to June 1. Flows also increased in response to rainfall in late June, reaching a daily flow of 66.1 m^3/s on June 28, 2014.

Following this event, flows decreased to between the inter-quartile range in mid-July, and remained there for the rest of the 2014 WY. Increases in flows during late September and late October were a result of precipitation. The 2014 open-water season (May to October) minimum daily flow of 3.2 m^3/s on September 2 was approximately 12% lower than the mean historical minimum daily flow of 3.6 m^3/s.

Figure 4.3-5 Historical seasonal (March to October) runoff volume in the MacKay River basin, 1973 to 2014.

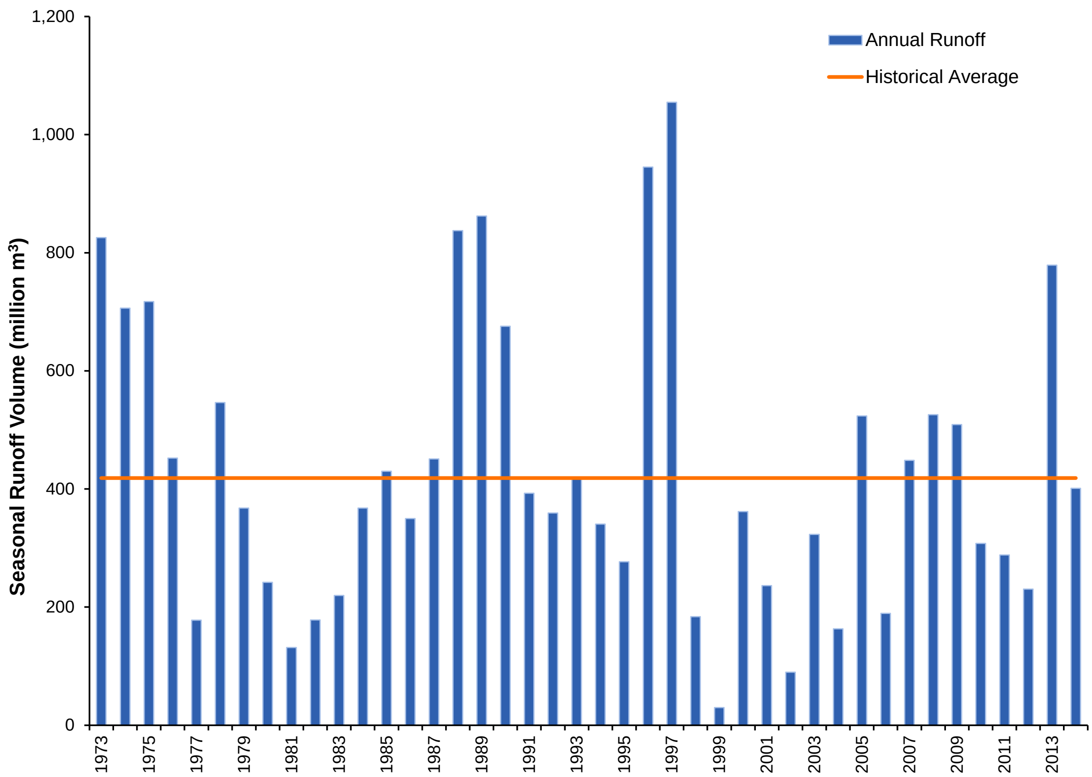
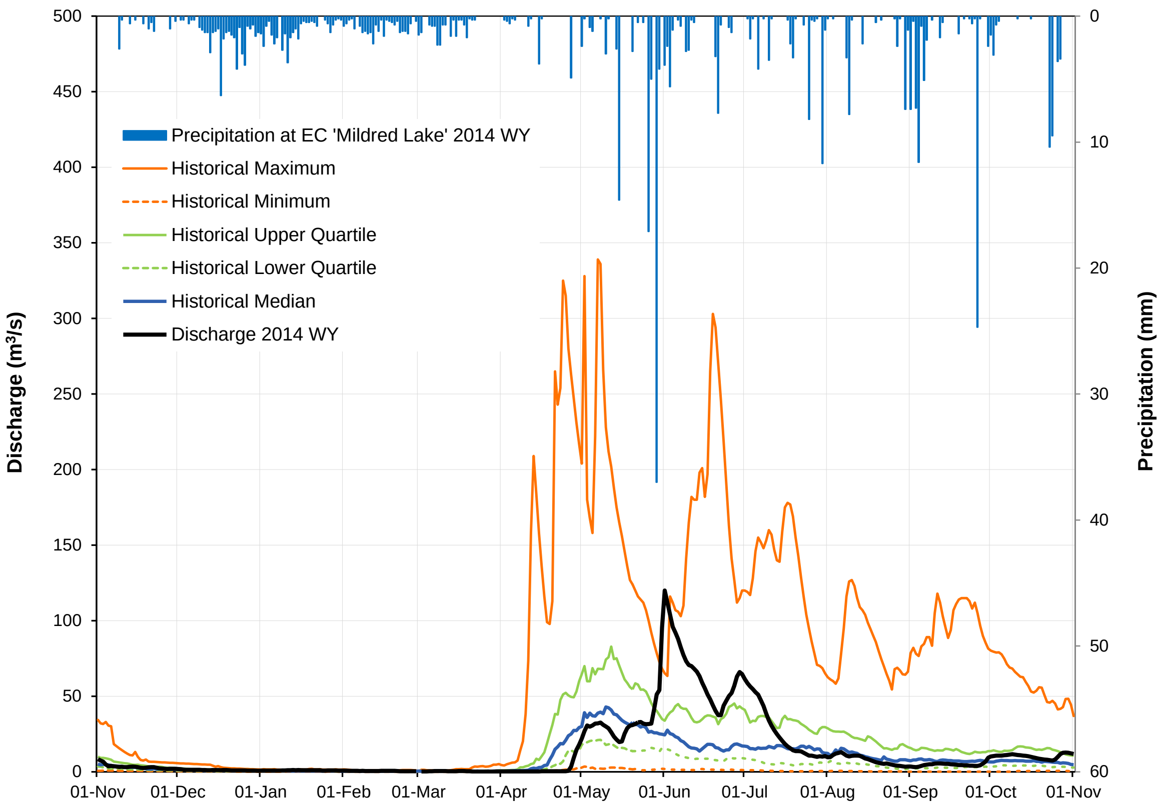


Figure 4.3-6 The 2014 WY MacKay River hydrograph compared to historical values and 2014 daily precipitation data at the EC Mildred Lake climate station.



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4.3.4 Christina River

The Christina River watershed is located south of Fort McMurray and is considered representative of runoff from the southern area of the oil sands region. The 2014 seasonal (March to October) runoff volume for the Christina River recorded at WSC station 07CE002, Christina River near Chard, was 655 million m^3 (Table 4.3-2). This was approximately 45% higher than the long-term mean seasonal runoff volume of 450.5 million m^3 (Figure 4.3-7). The 2014 WY was the eleventh consecutive year when seasonal flow volumes were above the mean recorded at this station (Figure 4.3-7). Flows recorded during the 2014 open-water period correlated with rainfall events, as shown by precipitation values at the C5-Surmont climate station (Figure 4.3-8).

Winter flows generally remained within the historical inter-quartile range from November 2013 to mid-April 2014, before increasing above the upper quartile range during spring freshet from late April to early May to a maximum flow of 85.0 m^3/s on May 1. Flows decreased following the freshet peak, until rainfall from late May to early June resulted in a daily peak flow of 137.0 m^3/s on June 3 and 4, 2014. This peak exceeded mean historical maximum flows from May 30 to June 4 and coincided with the maximum daily flow recorded in the 2014 WY, which was 58% greater than the mean historical maximum daily discharge of 86.6 m^3/s.

In addition to the high flows in early June, flows in late June and early October also increased in response to rainfall events. Flows from mid-July to the end of the 2014 WY generally remained below the historical median. The daily minimum discharge of 5.2 m^3/s for the 2014 open-water season occurred from September 21 to 24, and was approximately 20% lower than the historical open-water minimum daily flow of 6.5 m^3/s (Table 4.3-2).

Figure 4.3-7 Historical seasonal (March to October) runoff volume in the Christina River basin, 1983 to 2014.

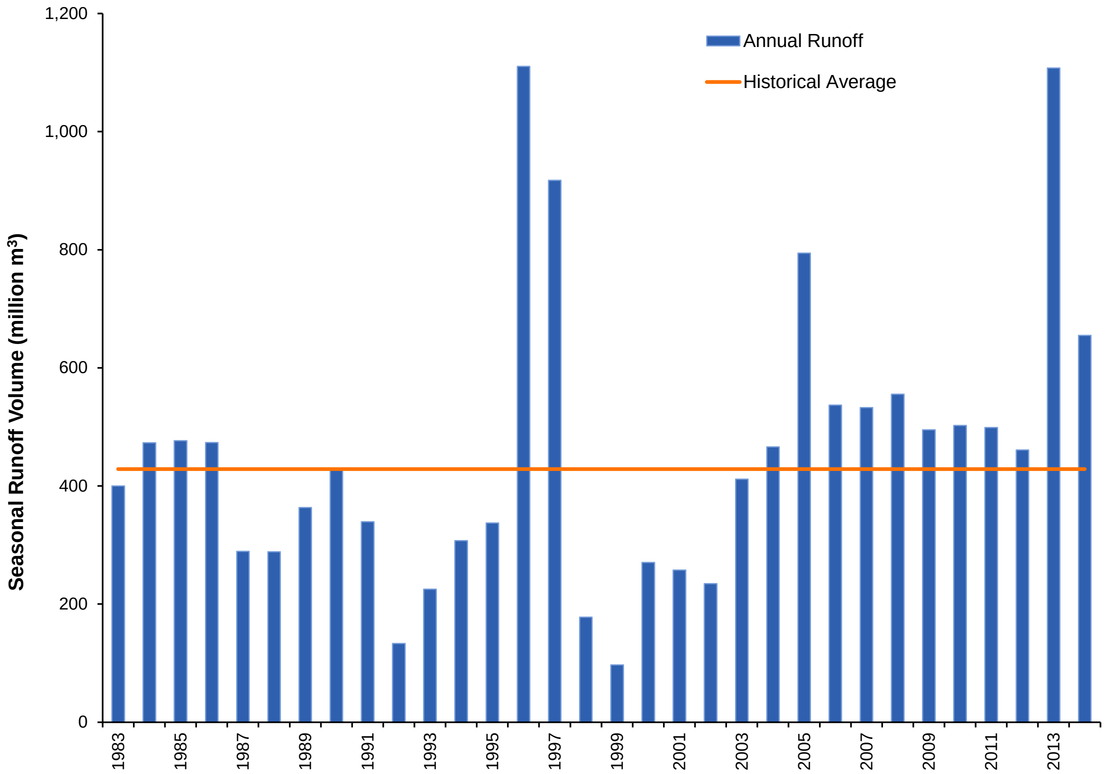
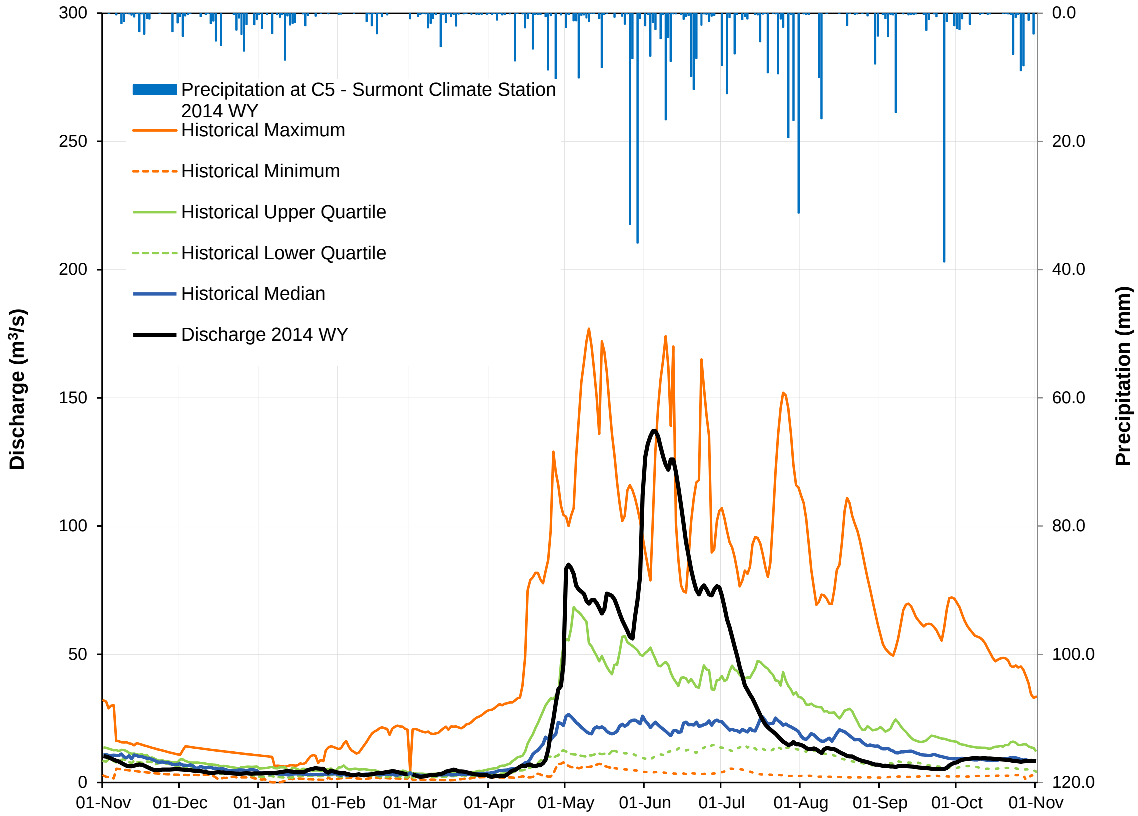


Figure 4.3-8 The 2014 WY Christina River hydrograph compared to historical values and 2014 daily precipitation data at the C5 Surmont climate station.



4.4 SUMMARY

In summary, the climate and hydrology of the Athabasca oil sands region during the 2014 WY was characterized by the following conditions:

1. Annual precipitation measured at Fort McMurray was 417.8 mm and 4% lower than the historical mean, with monthly total precipitation below the long-term mean in seven of the 12 months, primarily through the winter period. The wettest months in the 2014 WY were May (82.9 mm total) and June (69.7 mm total), which accounted for 19.8% and 16.7%, respectively, of the total precipitation in the 2014 WY. Precipitation falling as snow (November to April) was 45% lower than the long-term mean, while precipitation as rainfall (May to October) was 8% higher than the long-term mean.

2. Mean daily air temperatures in the 2014 WY were generally between the historical minimum and maximum values. The mean monthly air temperatures during the winter months (November to March) were lower than the historical mean monthly air temperatures, with the exception of January. Seven of the twelve months during the 2014 WY had temperatures below historical

mean monthly air temperatures; however, mean temperatures in June, July, and August 2014 were higher than their historical mean monthly air temperatures.

3. Cumulative precipitation in the 2014 WY varied by approximately 220 mm across the Athabasca oil sands region. Precipitation in winter was below the historical mean for most stations, with the exception of stations located to the northwest and south of Fort McMurray, which recorded the highest precipitation in the 2014 WY and exceeded the historical mean at Fort McMurray.

4. Measured SWE values were greatest in the mixed deciduous land-cover type, as opposed to previous years when SWE values were normally highest in flat low-lying terrain. The 2014 maximum SWE value for the mixed deciduous land cover was 25% greater than historical mean values, whereas values measured in flat low-lying, jackpine, and open area/lake areas were 1%, 23%, and 45% lower than the historical maximums, respectively. Melting of the snowpack began in early April, with complete melting by late April.

5. The 2014 WY runoff volume at WSC Station 07DA001, Athabasca River below Fort McMurray, was 19,172 million m^3 and near the historical mean annual runoff volume for this station. The 2014 WY runoff volume was 13.2% lower than the recorded volume in the 2013 WY and was the first year since 2010 that was lower, although only slightly, than the historical mean value. The maximum daily flow values for the 2014 WY were primarily influenced by the spring freshet in early May.

6. Seasonal (March to October) runoff volumes were 19% higher, 6% lower, and 45% higher for the Muskeg River, MacKay River, and Christina River, respectively.

7. Annual maximum daily flows in the 2014 WY were largely influenced by rainfall events from late May to early June in the Muskeg, MacKay, and Christina rivers, as shown by the strong relationship between flows recorded in these rivers and daily precipitation measured at nearby climate stations.

5.0 2014 MONITORING RESULTS

The following chapter consists of two parts. The first part focuses on detailed monitoring results specific to individual watersheds within the Athabasca oil sands region. Monitoring in these watersheds includes the collection of data characterizing hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations. The second part presents data specific to the Acid-Sensitive Lakes component and focuses on water quality monitoring at 45 lakes and ponds located throughout the Athabasca oil sands region.

For the watershed analyses, Section 5.1 presents 2014 results for the Athabasca River and the Athabasca River Delta (ARD); Sections 5.2 to 5.12 present 2014 watershed results for the major tributaries of the Athabasca River within the oil sands region; and Section 5.13 contains the results for miscellaneous aquatic systems that were monitored in 2014. Table 5-1 provides a guide to assist the reader in finding watershed-specific results. For the Acid-Sensitive Lakes component, all monitoring results are presented in Section 5.14.

Table 5-1 Page number guide to watersheds and component reports.

	Athabasca River and Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Firebag	Ells	Clearwater	Christina	Hangingstone	Pierre River Area	Miscellaneous Aquatic Systems	Acid-Sensitive Lakes
Climate and Hydrology	5-8	5-104	5-203	5-245	5-282	5-327	5-344	5-382	5-432	5-501	5-643	-	5-692	-
Water Quality	5-10	5-107	5-205	5-247	5-283	5-328	5-346	5-384	5-433	5-504	5-644	5-660	5-692	-
Benthic Invertebrate Communities	5-13	5-111	5-208	5-248	5-286	-	5-348	5-386	5-437	5-509	-	5-662	5-692	-
Sediment Quality	5-16	5-118	5-211	5-250	5-289	-	5-350	5-389	5-440	5-520	-	5-664	5-692	-
Fish Populations	5-18	5-120	5-211	5-251	5-289	-	-	5-390	5-441	5-523	-	5-665	5-692	-

Definitions for Monitoring Status

The Program Report uses the following definitions for monitoring status:

1. ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of one or more oil sands developments; data collected from these locations are designated as *test* for the purposes of analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and

2. ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2014) or were (prior to 2014) upstream of oil sands developments; data collected from these locations are to be designated as *baseline* for the purposes of data analysis, assessment, and reporting. The terms *test* and *baseline* depend solely on the location of the aquatic resource in relation to the location of oil sands development to allow for long-term comparison of trends between *baseline* and *test* stations.

5.1 ATHABASCA RIVER AND ATHABASCA RIVER DELTA

Table 5.1-1 Summary of Results for the Athabasca River and Athabasca River Delta.

Athabasca River and Delta	Summary of 2014 Conditions											
	Athabasca River								*Athabasca River Delta*			
Climate and Hydrology												
Criteria	no station	no station	no station	no station	no station	no station	**S24** Athabasca River below Eymundson Creek	**S46** Athabasca River near Embarras Airport	no stations			
Mean open-water season discharge							not measured	○ (Negligible-Low)				
Mean winter discharge							not measured	○ (Negligible-Low)				
Annual maximum daily discharge							not measured	○ (Negligible-Low)				
Minimum open-water season discharge							not measured	○ (Negligible-Low)				
Water Quality												
Criteria	**ATR-DC-E** upstream of Donald Creek (east bank)	**ATR-DC-W** upstream of Donald Creek (west bank)	no station	no station	no station	**ATR-DD-E** downstream of all development (east bank)	**ATR-DD-E** downstream of all development (centre channel)	**ATR-DD-W** downstream of all development (west bank)	no stations			
Water Quality Index	winter only					○ (Negligible-Low)	○ (Negligible-Low)	○ (Negligible-Low)				
Benthic Invertebrate Communities and Sediment Quality												
Criteria	no reaches sampled								**FLC-1** Fletcher Channel	**GIC-1** Goose Island Channel	**BPC-1** Big Point Channel	**EMR-2** Embarras River
Benthic Invertebrate Communities									● (Moderate)	● (High)	○ (Negligible-Low)	○ (Negligible-Low)
Sediment Quality Index									n/a	n/a	n/a	n/a
Fish Populations												
Criteria	**Fish Inventory Reaches (-3, 0, 1)** upstream of development		**Fish Inventory Reaches (4, 5, 6)** near Steepbank River	**Fish Inventory Reaches (10, 11)** downstream of Muskeg River	**Fish Inventory Reaches (16, 17, 19)** near Tar, Ells, and Calumet rivers and Fort Creek				**FLC-F1** Fletcher Channel	**GIC-F1** Goose Island Channel	**BPC-F1** Big Point Channel	**EMR-F2** Embarras River
Human Health	no reach		**Sub.**: WALL ● (High); LKWH ○ (Negligible-Low)	**Gen.**: WALL ● (Moderate); LKWH ○ (Negligible-Low)	no reach				no reach	no reach	no reach	no reach
Fish Assemblages	no criteria established for fish inventory survey								n/a	n/a	n/a	n/a

Legend and Notes

○ Negligible-Low — *baseline* (green shading)

● Moderate (orange) — *test* (blue shading)

● High (brown)

n/a – not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

ns – not sampled

[1] Species (Sp.): LKWH= lake whitefish, WALL=walleye

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

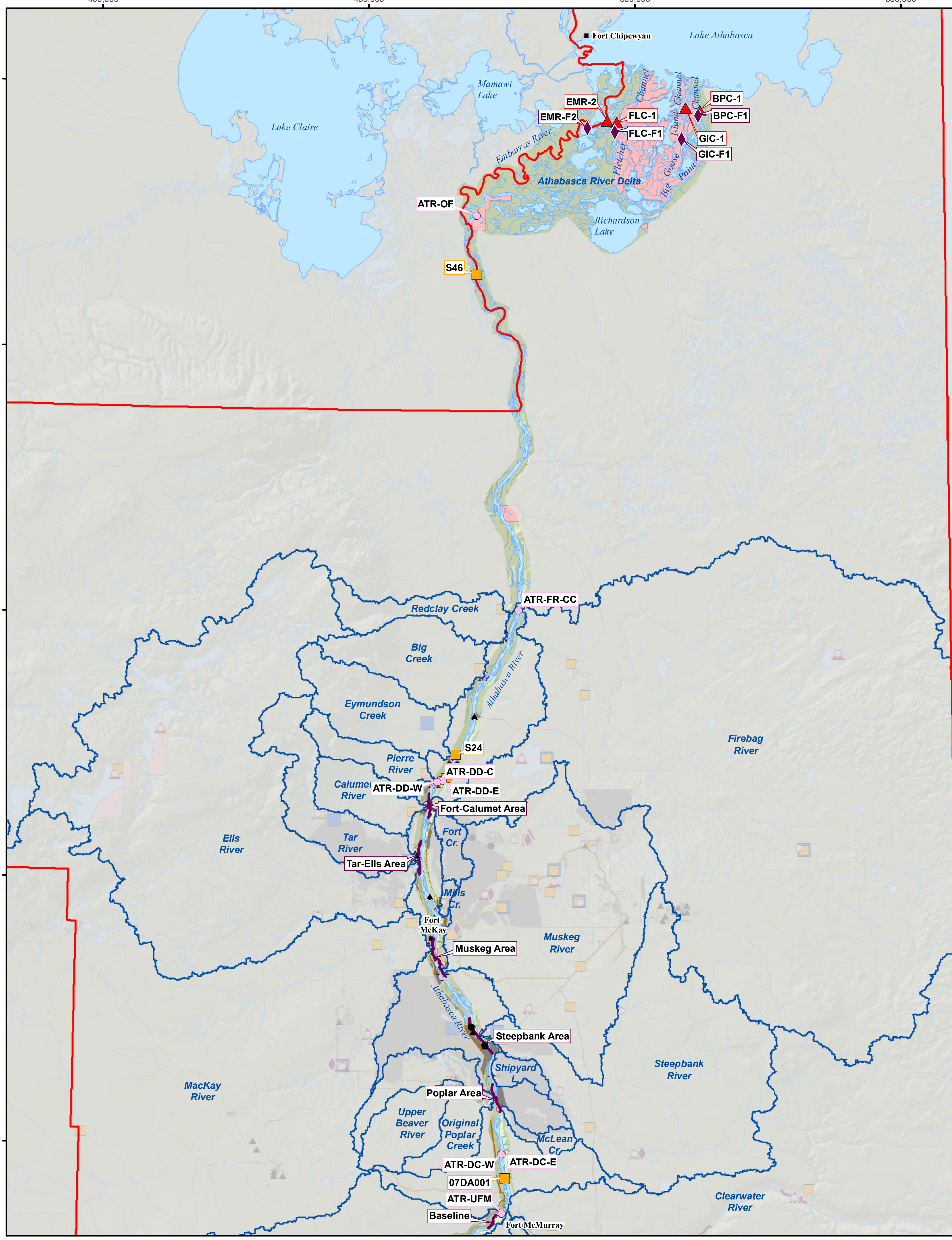
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional baselines; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (human health): Uses various USEPA and Health Canada criteria for risks to human health, fish health, and tainting from fish tissue concentrations of various substances, see Section 3.4.7.3 for a detailed description of the classification methodology.

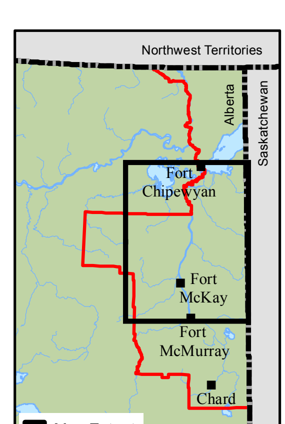
[2] Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.4.7.3)

Figure 5.1-1 Athabasca River and Athabasca River Delta.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach



0 5 10 20 km
N

Scale: 1:750,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.1-2 Representative monitoring stations of the Athabasca River and Athabasca River Delta, fall 2014.

Hydrology Station S24: Athabasca River below Eymundson Creek

Hydrology Station S46: Athabasca River near Embarras Airport

Water Quality Station ATR-DD-W: Athabasca River, downstream of development

Water Quality Station ATR-DD-E: Athabasca River, downstream of development

Benthic and Sediment Quality Station BIC-1: Athabasca River Delta – Big Point Channel

Benthic and Sediment Quality Station GIC-1: Athabasca River Delta – Goose Island Channel

Benthic and Sediment Quality Station EMR-2: Athabasca River Delta – Embarras River

Benthic and Sediment Quality Station FLC-1: Athabasca River Delta – Fletcher Channel

5.1.1 Summary of 2014 Conditions

As of 2014, approximately 3.5% (123,990 ha) of the Athabasca oil sands region had undergone land change from oil sands developments (Table 2.3-1). Approximately 24.5% (33,153 ha) of the minor Athabasca River tributary watersheds had undergone land change as of 2014 from oil sands developments (Table 2.5-2). For 2014, the confluence of McLean Creek with the Athabasca River demarcates the *baseline* (upstream) and *test* (downstream) portions of the Athabasca River, north of Fort McMurray and the Clearwater River confluence.

Table 5.1-1 is a summary of the 2014 assessment for the Athabasca River and Athabasca River Delta, while Figure 5.1-1 denotes the location of the monitoring stations for each monitoring component, reported water withdrawal and discharge locations, and the land change area as of 2014. Figure 5.1-2 contains summer and fall 2014 photos of a number of monitoring stations in the Athabasca River and Athabasca River Delta.

Hydrology For the 2014 WY, the mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.7%, 1.6%, 0.6%, and 1.1% lower, respectively, in the Athabasca River observed (*test*) hydrograph than in the estimated (*baseline*) hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2014 at all stations of the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints were consistent with regional *baseline* conditions and generally consistent with previously-measured concentrations. Similarities of exceedances of guideline concentrations and regional *baseline* concentrations were generally observed across all three stations. Concentrations of total aluminum exceeded the guideline at all stations in fall 2014 and total boron continued to show an increasing trend at *test* station ATR-DD-W.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at *test* reach BPC-1 were classified as **Negligible-Low** because although there was a significant change in CA Axis 1 scores over time, the change was not indicative of degradation. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variation for all previous sampling years at reaches of the ARD.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **Moderate** because of the significant and large decreases in abundance and CA Axis 1 scores, and increase in equitability, over time. However, *test* reach FLC-1 showed numerous indications of a stable community including a higher richness in 2014 and the presence of EPT taxa.

Differences in measurement endpoints for *test* reach GIC-1 were classified as **High** because there were significant differences for all measurement endpoints. Abundance and richness were lower and equitability was higher in 2014 than any previous year of sampling, indicating potential negative changes to the benthic invertebrate community. The percentage of EPT taxa was higher in 2014 (4%) than previously observed and was increasing over time. CA Axis 1 scores were decreasing over time and were lower in 2014 than previous years and CA Axis 2 scores were increasing over time. Abundance and richness were below the tolerance limits of the 5th percentile for the means of previous years of sampling in the ARD. Chironomids were nearly absent in 2014 and tubificids dominated the relative abundance of organisms at this reach, potentially reflecting the high silt content in sediments.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were classified as **Negligible-Low** because although there were significant decreases in abundance, percentage of fauna as EPT taxa, and CA Axis 1 and 2 scores, the percentage of EPT taxa has actually remained stable over the past three years and abundance was higher in 2014 than 2013. There were no measurement endpoints that exceeded the tolerance limits for the normal range of variation for previous years of sampling in the ARD indicating that there was no concern that conditions were significantly degraded.

In 2014, all stations of the ARD were dominated by silt. All sediment quality measurement endpoints at *test* stations BPC-1 and FLC-1 were within previously-measured concentrations. Concentrations of F2, F3, and F4 hydrocarbons at *test* station GIC-1 reached maximum values in fall 2014, while only F4 hydrocarbons exceeded the previously-measured maximum concentration at *test* station EMR-2. Concentrations of retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs exceeded previously-measured maximum concentrations, while naphthalene was below the previously-measured minimum concentration at *test* station GIC-1. At *test* station EMR-2, concentrations of retene and total dibenzothiophenes also exceeded previously-measured maximum concentrations, while naphthalene and total parent PAHs were below previously-measured minimum results. Concentrations of PAHs at all stations in fall 2014 were dominated by alkylated species, indicating a petrogenic origin of these compounds. At all stations, with the exception of *test* station FLC-1, the PAH Hazard Index value exceeded the potential chronic toxicity threshold of 1.0. The concentration of F3 hydrocarbons exceeded the CCME guideline at *test* station GIC-1, while concentrations of total arsenic exceeded the CCME guideline at *test* stations FLC-1, GIC-1, and EMR-2. All toxicity test measurements were within the range of previously-measured results at all stations for the amphipod *Hyalella*. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

Fish Populations (fish inventory) The objective of the fish inventory program was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years are as follows:

- Total catch in summer and fall 2014 was much lower compared to 2013. The lower catch in fall was attributed primarily to the timing of sampling with respect to the migration of lake whitefish from Lake Athabasca to spawning grounds in the Athabasca River. Due to restrictions outlined in the Fish Research License issued by AESRD, sampling could not occur during the spawning period, as it has in previous years. Lower water levels were also observed in fall 2014, limiting habitat availability as well as boat access and fishing efficiency. These factors also may have contributed to the reduction in total catch and richness observed in 2014.
- A large change in species composition was observed in fall with a record low percentage of lake whitefish captured. In years where lake whitefish were the most abundant species in fall in the Athabasca River, sampling was generally conducted in the last ten days of September (compared to 2014 when sampling was conducted from September 10 to 15).
- There was a decrease in CPUE of white sucker in 2014 compared to 2013 in spring. However, the highest CPUE of white sucker continued to be observed in the Muskeg area, which is a river that white sucker use for spawning.

- The dominant age class of northern pike in 2013 and 2014 was one and two years, respectively; dominance was most pronounced at five years in 2012 and from 1997 to 2011. The increased frequency of younger northern pike in the Athabasca River suggested higher levels of recruitment or increased selection on older individuals from fishing pressure. The limited catch of younger lake whitefish is typical as lake whitefish are only commonly caught in the Athabasca River in the fall as adults migrate from Lake Athabasca to spawning grounds upstream of Fort McMurray.
- Overall, the 2014 fish health assessment indicated that abnormalities observed among all species were within the historical range (1987 to 2013), despite the higher than average incidence of abnormalities observed in northern pike (14.8%), related primarily to fin erosion. These findings were also consistent with previously cited studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Fish Populations (fish tissue) Measurement endpoints used in the assessment for the Athabasca River fish tissue program included concentrations of metals and tainting compounds in fish tissue of both individual and composite samples. Potential human health risks from contaminated fish tissue were predicted from both individual and composite samples. In 2014, the mean concentration of mercury in lake whitefish was slightly higher than 2011, but within the range of concentrations observed in previous sampling years. The mean mercury concentration across all size classes of lake whitefish were below the Health Canada guideline for subsistence fishers indicating a **Negligible-Low** risk to human health. The mean concentration of mercury in walleye was higher in 2014 compared to previous years. The mean mercury concentration in size classes of walleye greater than 300 mm exceeded the subsistence fishers guideline for consumption indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

Fish Populations (fish assemblages) Results of the fish assemblage monitoring in the ARD indicated a decrease in abundance across all reaches relative to 2013. All other measurement endpoints were generally consistent across channels, with high values of ATI reflecting the tolerant nature of fish species in the delta. Water temperatures during the 2013 fish assemblage monitoring program in the ARD ranged from 19.5˚C to 20.4˚C with a mean of 19.8˚C, whereas water temperatures during the 2014 monitoring program were higher ranging from 20.4˚C to 23.4˚C, with a mean of 22.1˚C. The higher temperatures in 2014 could have resulted in fish being in deeper, cooler waters, where boat electrofishing was not effective. The most abundant large-bodied species were goldeye and northern pike; goldeye was dominant at *test* reaches BPC-F1, GIC-F1, and FLC-F1, while northern pike was dominant at *test* reach EMR-F2.

5.1.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Athabasca River in the 2014 WY was conducted at the following stations:

- JOSMP Station S46 (formerly WSC Station 07DD001), Athabasca River near Embarras Airport;
- JOSMP Station S24, Athabasca River below Eymundson Creek; and
- WSC Station 07DA001, Athabasca River below Fort McMurray.

Data from JOSMP Station S46 were used for the water balance analysis and are presented below. Daily flows from April 28 to May 15 were missing at this station; therefore, flows were estimated using data from the WSC Station 07DA001 to complete the annual flow record for JOSMP Station S46. Note that prior to the 2012 WY, data from JOSMP Station S24, Athabasca River below Eymundson Creek, were used for the water balance analysis.

Historical statistics were composed of data from JOSMP Station S46 and WSC Station 07DD001. Data from the WSC station were recorded annually from 1971 to 1976, and during open-water months (May to October) from 1977 to 1984. Continuous hydrometric data have been collected at Station S46 since August 2011.

The historical flow record for JOSMP Station S46 is summarized in Figure 5.1-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Athabasca River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season, and generally decrease from November until mid-March. Spring thaw, and the resulting rapid increase in flows, typically begins in early April. Monthly flows are highest in June, at the peak of freshet, and often remain elevated in July. The timing of peak flow and the initiation of freshet are often delayed compared to the tributaries in the oil sands region, due to the large size of the Athabasca River watershed and glacial-fed headwaters. Flows generally recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.1-3). Flows decreased from November to mid-March, and were generally within the historical inter-quartile range during this period. Flows then increased rapidly during spring thaw in early April. An initial peak of 2,430 m^3/s (as measured at WSC Station 07DA001) occurred on May 2, followed by a second peak of 2,464 m^3/s (measured at JOSMP Station S46) on June 4. This second (annual) peak was 16% lower than the historical mean annual maximum daily flow (2,945 m^3/s). Flows on most dates from late April to early July were above historical median values. Flows then generally decreased through the summer, until late September before briefly rising in response to regional rainfall accumulations. Daily flows from August 4 to September 30 were all below historical minima recorded on these dates. The minimum open-water daily flow of 345.8 m^3/s was recorded on October 24 and was 38% lower than the historical mean minimum daily flow of 554.1 m^3/s calculated for the open-water period.

Overall, the annual runoff volume in the 2014 WY was 21,313 million m^3. This value was 11% lower than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Athabasca River watershed, at JOSMP Station S46, is summarized in Table 5.1-2. Key changes in flows and water diversions included:

1. The closed-circuited land area as of 2014 in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River, and Upper Beaver River was estimated to be 366.9 km^2 (Table 2.5-1). The loss of flow to the Athabasca River that would have otherwise occurred from this land area was estimated at 50.54 million m^3.

2. As of 2014, the area of land change in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River and upper Beaver River that was not closed-circuited was estimated to be 87.3 km^2 (Table 2.5-1). The increase in flow to the Athabasca River that would not have otherwise occurred from this land area was estimated at 2.40 million m^3.

3. Water withdrawals directly from the Athabasca River in the 2014 WY were 100.69 million m^3.

4. Water discharges directly to the Athabasca River in the 2014 WY were 1.78 million m^3.

5. The 2014 WY discharge into the Athabasca River from major tributaries (i.e., Calumet River, Christina River, Ells River, Firebag River, Fort Creek, Hangingstone River, MacKay River, Mills Creek, Muskeg River, Poplar Creek, Steepbank River, and Tar River) was estimated to be 28.90 million m^3 less than the discharge would have been in the absence of oil sands development in those watersheds.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2014 WY was a loss of flow of 175.94 million m^3 at JOSMP Station S46 on the Athabasca River. The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.7%, 1.6%, 0.6%, and 1.1% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.1-3). These differences were classified as **Negligible-Low** (Table 5.1-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.1.3 Water Quality

In 2014, water quality samples were taken from the Athabasca River at:

- *test* stations ATR-DD-E and ATR-DD-W, east and west banks, "downstream of development" (near Susan Lake) in winter, spring, summer, and fall (data available from 2005 to 2014); and
- *test* station ATR-DD-C, centre of channel between the east and west bank stations "downstream of development" (near Susan Lake), initiated in spring 2014 and sampled in spring, summer, and fall.

Samples were also collected at *baseline* stations ATR-DC-E and ATR-DC-W, east and west banks, upstream of Donald creek in winter 2014 (data available most years from 1997 to 2014). Following the winter sampling program, these stations were removed from the sampling design following technical guidance under the JOSMP.

Additionally, monthly water quality sampling of the Athabasca River was undertaken by AESRD at their Long-Term Regional Network (LTRN) stations, including stations upstream of Fort McMurray (ATR-UFM) and downstream near the Athabasca Delta at Old Fort (ATR-OF), and a newly established Medium-Term Regional Network (MTRN) station upstream of the Firebag River (ATR-FR). ATR-FR was previously sampled in the fall under RAMP from 2002 to 2010, and was called "ATR-FR-CC".

Temporal Trends The following significant trends (α=0.05) in fall concentrations of water quality measurement endpoints at JOSMP stations were detected:

- An increasing concentration of total dissolved solids at *test* station ATR-DD-E; and
- An increasing concentration of total boron at *test* station ATR-DD-W.

A trend analysis could not be conducted on *test* station ATR-DC-C given 2014 was the first sampling year.

Water quality data also were collected monthly by AESRD at stations upstream of Fort McMurray (ATR-UFM) and downstream near the Athabasca Delta at Old Fort (ATR-OF). These data were assessed for seasonal trends from 1997 to 2014. The following significant trends (α=0.05) in concentrations of water quality measurement endpoints were detected from monthly AESRD data for the Athabasca River mainstem:

- Increasing concentrations of total arsenic, total and dissolved aluminum, total Kjeldahl nitrogen, and total phosphorus at *baseline* station ATR-UFM (upstream of Fort McMurray and upstream of oil sands development); and
- Increasing concentrations of total arsenic, total boron, dissolved aluminum, total nitrate, total sodium, total magnesium, total phosphorus, and total dissolved solids (calculated) at *test* station ATR-OF (near the Athabasca River Delta [ARD], downstream of oil sands development).

2014 Results Relative to Historical Concentrations Several water quality measurement endpoints were outside the range of previously-measured concentrations in fall 2014 at *test* stations ATR-DD-E and ATR-DD-W (Table 5.1-4):

- Concentrations below previously-measured minimum concentrations at *test* station ATR-DD-E included total suspended solids (12.2 mg/L versus 13.0 mg/L), total dissolved phosphorus (0.0045 mg/L versus 0.0074 mg/L), total nitrogen (0.26 mg/L versus 0.43 mg/L), dissolved organic carbon (5.6 mg/L versus 7.2 mg/L), total arsenic (0.00066 mg/L versus 0.00068 mg/L), total PAHs (122.5 ng/L versus 158.5 ng/L), total Parent PAHs (14.7 ng/L versus 20.1 ng/L), and total alkylated PAHs (107.9 ng/L versus 133.7 ng/L) (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- Concentrations that exceeded previously-measured maximum concentrations at *test* station ATR-DD-E included conductivity (300 mg/L versus 294 mg/L), sodium (15 mg/L versus 13.3 mg/L), chloride (11.6 mg/L versus 10.3 mg/L), total dissolved solids (183 mg/L versus 178 mg/L), and total molybdenum (0.00070 mg/L versus 0.00069 mg/L);
- Concentrations below previously-measured minimum concentrations at *test* station ATR-DD-W included dissolved phosphorus (0.0048 mg/L versus 0.0061 mg/L), total nitrogen (0.32 mg/L versus 0.40 mg/L), dissolved organic carbon (5.9 mg/L versus 6.0 mg/L), and total parent PAHs (15.1 ng/L versus 18.8 ng/L); and
- Concentrations that exceeded previously-measured maximum concentrations at *test* station ATR-DD-W included conductivity (302 mg/L versus 285 mg/L), sodium (15.9 mg/L versus 13.5 mg/L), chloride (12.0 mg/L versus 10.1 mg/L), and total boron (0.34 mg/L versus 0.033 mg/L).

Water quality measurements at *test* station ATR-DD-C could not be compared to historical data because sampling was initiated in 2014.

Ion Balance The ionic composition in fall 2014 at stations of the Athabasca River was consistent with the ionic composition at these stations since 2005, and was dominated by calcium and bicarbonate (Figure 5.1-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints were below water quality guidelines in fall 2014, with the exception of total aluminum at all three stations (Table 5.1-4).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Athabasca River mainstem in fall 2014 (Table 5.1-5):

- Total iron at all stations; and
- Total chromium at *test* stations ATR-DD-E and ATR-DD-C.

Concentrations of water quality measurement endpoints that exceeded relevant water quality guidelines in other seasons included (Table 5.1-5):

- total aluminum at *baseline* station ATR-DC-E in winter;
- total aluminum and total iron at *test* stations ATR-DD-E and ATR-DD-W in winter;
- total phenols at *test* station ATR-DD-E in winter;
- sulphide, total aluminum, total chromium, total copper, total iron, and total mercury (ultra-trace) at all stations in spring;
- total phenols at *test* station ATR-DD-C and ATR-DD-W in spring;
- dissolved copper and dissolved iron at *test* station ATR-DD-W in spring;
- total copper and total mercury (ultra-trace) at *test* station ATR-DD-E in summer;
- total iron, total chromium, and total aluminum at all stations in summer; and
- sulphide and total mercury (ultra-trace) at *test* station ATR-DD-W in summer.

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of the following water quality measurement endpoints were outside of the range of regional *baseline* concentrations in fall 2014 (Figure 5.1-5):

- Dissolved phosphorus at all stations, with concentrations below the 5^{th} percentile of the regional *baseline* concentrations; and
- Total nitrogen at *test* stations ATR-DD-E and ATR-DD-C, with concentrations below the 5^{th} percentile of the regional *baseline* concentrations.

Water Quality Index The WQI values at all stations of the Athabasca River mainstem in fall 2014 indicated **Negligible-Low** differences from regional *baseline* water quality conditions, with WQI values of 98.7 (ATR-DD-W) and 100.0 (ATR-DD-E and ATR-DD-C).

Classification of Results Differences in water quality in fall 2014 at all stations of the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints were consistent with regional *baseline* conditions and generally consistent with previously-measured concentrations. Similarities of exceedances of guideline concentrations and regional *baseline* concentrations were generally observed across all three stations.

Concentrations of total aluminum exceeded the guideline at all stations in fall 2014 and total boron continued to show an increasing trend at *test* station ATR-DD-W.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

Benthic invertebrate community samples were collected from four depositional channels of the ARD in fall 2014:

- Depositional *test* reach BPC-1 in Big Point Channel, sampled from 2002 to 2005 and 2007 to 2014;
- Depositional *test* reach FLC-1 in Fletcher Channel, sampled from 2002 to 2005 and 2007 to 2014;
- Depositional *test* reach GIC-1 in Goose Island Channel, sampled from 2002 to 2005 and 2007 to 2014; and
- Depositional *test* reach EMR-2 in the Embarras River, sampled since 2010.

2014 Habitat Conditions *Test* reaches BPC-1, GIC-1, FLC-1, and EMR-2 of the ARD were sampled in water that was between about 1.5 and 2.4 m deep. Water quality at these reaches was neutral to weakly basic, with dissolved oxygen >6.0 mg/L, water temperatures between 20°C and 24°C, and conductivity of ~250 µS/cm (Table 5.1-6). The substrate of Goose Island, Big Point, and Fletcher channels was dominated by sand and silt (Table 5.1-6). The substrate of the Embarras River was dominated by silt and clay, with a small amount of sand (Table 5.1-6). The organic carbon content of the sediments was low at all reaches (<3%).

Relative Abundance of Benthic Invertebrate Community Taxa in 2014 The benthic invertebrate communities of *test* reach BPC-1 in fall 2014 was dominated by Chironomidae (44%) and tubificid worms (41%) (Table 5.1-7). Chironomids were primarily of the genera *Tanytarsus*, *Procladius*, *Polypedilum*, *Paralauterborniella*, and *Stempellinella*. Flying insects consisted of only a few *Gomphus* dragonflies. Mayflies, stoneflies, and caddisflies were absent at *test* reach BPC-1 in 2014. Permanent aquatic forms (Bivalvia: *Pisidium/Sphaerium* and Gasropoda: *Probythinella*) were present in low relative abundances.

The benthic invertebrate communities of *test* reach FLC-1 in fall 2014 was dominated by chironomids (52%) and tubificid worms (21%) with subdominant taxa consisting of Ceratopogonidae (14%) (Table 5.1-8). Chironomids at *test* reach FLC-1 consisted primarily of the genera *Paralauterborniella* though *Tanytarsus*, *Paracladopelma,* and *Procladius* were also relatively abundant. A single *Ephemera* mayfly was found at *test* reach FLC-1 as were *Gomphus* and *Ophiogomphus* dragonflies. *Pisidium/Sphaerium* bivalves were present in low relative abundances.

The benthic invertebrate community of *test* reach GIC-1 was dominated by tubificid worms (63%) with subdominant taxa consisting of oligochaete cocoons (15%), which have not previously been recorded at this reach, and chironomids (7%) (Table 5.1-9). Six chironomid taxa were present at *test* reach GIC-1, with *Paralauterborniella* and *Polypedilum* as the most abundant. Mayflies (*Hexagenia limbata*) and dragonflies (*Gomphus*) were present in low relative abundances in some replicate samples from *test* reach GIC-1 (Table 5.1-9).

The benthic invertebrate community at *test* reach EMR-2 was dominated by tubificid worms (41%) and chironomids (27%), with subdominant taxa consisting of Bivalvia (10%), Nematoda (9%), and Gastropoda (8%) (Table 5.1-9). Chironomids were primarily from the genera *Tanytarsus* and *Procladius*. Flying insects (Trichoptera: *Oecetis*) were found in one replicate sample. Bivalves (*Pisidium/Sphaerium*) were present and gastropods were primarily *Probythinella* and *Valvata sincera*.

Temporal Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the channels of the ARD. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

The temporal comparisons for each reach included testing for:

- changes over time in values of measurement endpoints (Hypothesis 7, Section 3.2.3.1); and
- a difference between 2014 and all previous years of sampling.

Big Point Channel

Temporal Comparison Results There was a significant decrease over time in CA Axis 1 scores, accounting for 28% of annual means (Table 5.1-10). The decrease CA Axis 1 scores was possibly due to an increase in ceratopogonids and a decrease in the relative abundance of gastropods over time (Figure 5.1-6).

Comparison to Published Guidelines The relative abundance of tubificid worms (41%) at *test* reach BPC-1 has been lower in recent years compared to historical results indicating that conditions in this channel were fair (Griffiths 1998). EPT taxa, which have been present in previous years, were absent in 2014; however, permanent aquatic forms (Bivalvia and Gastropoda) were present. The composition of the benthic invertebrate community in 2014 was generally what would be expected in shifting-sand environment (Barton and Smith 1984).

2014 Results Relative to Historical Conditions Values of measurement endpoints of benthic invertebrate communities at *test* reach BPC-1 were within the inner tolerance limits for the means of all previous years in the ARD (Figure 5.1-7).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach BPC-1 were classified as **Negligible-Low** because although there was a significant change in CA Axis 1 scores over time, the change was not indicative of degradation. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variation for all previous sampling years at reaches of the ARD.

Fletcher Channel

Temporal Comparison Results There was a significant decrease over time in abundance and CA Axis 1 scores for *test* reach FLC-1, accounting for 21% and 46% of the variance in annual means, respectively (Table 5.1-11). Equitability increased over time, with the change explaining 28% of the variance in annual means.

Comparison to Published Guidelines The benthic invertebrate community of *test* reach FLC-1 in 2014 was typical of a shifting-sand riverine environment (Barton and Smith 1984). Shifting sands typically support chironomids, worms, and ceratopogonids, which were present at this reach. EPT taxa, which were present (although in relatively low abundance), are often difficult to collect in these types of environments (Barton and Smith 1984).

2014 Results Relative to Historical Conditions Values of measurement endpoints of benthic invertebrate communities at *test* reach FLC-1 were within the inner tolerance limits for the for the means of all previous years in the ARD (Figure 5.1-7).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **Moderate** because of the significant and large decreases in abundance and CA Axis 1 scores, and increase in equitability, over time. However, *test* reach FLC-1 showed numerous indications of a stable community including a higher richness in 2014 and the presence of EPT taxa.

Goose Island Channel

Temporal Comparison Results Abundance and richness were significantly lower in 2014 than the mean of all previous years, accounting for 46% and 43% of the variance in annual means, respectively (Table 5.1-12). Equitability was higher in 2014 than the mean of previous years, accounting for 32% of the variance in annual means.

The percentage of the fauna as EPT taxa increased over time and was higher in 2014 than the mean of previous years, with these changes accounting for 55% and 45% of the variation in annual means, respectively (Table 5.1-12).

The CA Axis 1 scores decreased over time and were lower in 2014 than the mean of previous years, accounting for 62% and 21% of the variance in annual means, respectively (Table 5.1-12). The CA Axis 2 scores increased over time, accounting for 40% of the variance in annual means. The shift in CA Axis 1 and 2 scores could be due to the increase in the relative abundance of tubificid worms, which comprised nearly the entire composition of the benthic invertebrate community at *test* reach GIC-1 in 2014 (Figure 5.1-6).

Comparison to Published Guidelines Although the taxa composition was still what was expected of a shifting-sand riverine environment (Barton and Smith 1984), the benthic invertebrate community of *test* reach GIC-1 in 2014 was less abundant and diverse than any other previous year of sampling. The percentage of the fauna as EPT taxa has been steadily increasing over time and was higher in 2014 than the mean of all previous years; however, the absence of chironomids and the increasing relative abundance of tubificid worms could be a signal of degradation. Oligochaete cocoons, which have not been recorded at this reach in the past were relatively abundant in 2014, which caused a shift in taxa composition.

2014 Results Relative to Historical Conditions Values of abundance and richness exceeded the outer and inner tolerance limits of the 5^{th} percentile, respectively, for the means of previous years of sampling in the ARD (Figure 5.1-7). Abundance and richness were lower in 2014 than previously-measured values for *test* reach GIC-1.

Classification of Results Differences in measurement endpoints for *test* reach GIC-1 were classified as **High** because there were significant differences for all measurement endpoints. Abundance and richness were lower and equitability was higher in 2014 than any previous year of sampling, indicating potential negative changes to the benthic invertebrate community. The percentage of EPT taxa was higher in 2014 (4%) than previously observed and was increasing over time. CA Axis 1 scores were decreasing over time and were lower in 2014 than previous years and CA Axis 2 scores were increasing over time. Abundance and richness were below the tolerance limits of the 5th percentile for the means of previous years of sampling in the ARD. Chironomids were nearly absent in 2014 and tubificids dominated the relative abundance of organisms at this reach, potentially reflecting the high silt content in sediments.

Embarras River

Temporal Comparison Results Abundance and the percentage of the fauna as EPT taxa decreased over time at *test* reach EMR-2 (Table 5.1-13). These changes accounted for 44% and 77% of the variance in annual means, respectively.

Taxa composition at *test* reach EMR-2 has altered over time which was supported by the decreasing trend in CA Axis 1 and 2 scores over time, accounting for 38% and 39% of the variance in annual means, respectively (Table 5.1-13).

Comparison to Published Guidelines The benthic invertebrate community at *test* reach EMR-2 was typical of a shifting-sand environment, with a higher relative abundance of tubificid worms (41%) than previous years (<21% from 2010 to 2013). Chironomids were abundant as were permanent aquatic forms such as gastropods and bivalves (*Pisidium/Sphaerium*) indicating a taxa composition that was typical of good conditions (Hynes 1960; Griffiths 1998).

2014 Results Relative to Historical Conditions Values of measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were within the inner tolerance limits for the for the means of all previous years in the ARD (Figure 5.1-7).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were classified as **Negligible-Low** because although there were significant decreases in abundance, percentage of fauna as EPT taxa, and CA Axis 1 and 2 scores, the percentage of EPT taxa has actually remained stable over the past three years and abundance was higher in 2014 than 2013. There were no measurement endpoints that exceeded the tolerance limits for the normal range of variation for previous years of sampling in the ARD indicating that there was no concern that conditions were significantly degraded.

5.1.4.1 Sediment Quality

In fall 2014, sediment quality was sampled in the Athabasca River Delta at:

- *test* station BPC-1 in Big Point Channel, sampled from 1999 to 2003, 2005, and 2007 to 2014;
- *test* station FLC-1 in Fletcher Channel, sampled from 2001 to 2003, 2005, and 2007 to 2014;
- *test* station GIC-1 in Goose Island Channel, sampled from 2001 to 2003, 2005, and 2007 to 2014; and
- *test* station EMR-2 in the Embarras River, sampled in 2005, 2010, and 2012 to 2014.

It should be noted that *Chironomus* toxicity results for *test* stations EMR-2, BPC-1, FLC-1, and GIC-1 did not meet the control validity criteria for survival (<70% survival in the control); therefore, no results for this test were reported in this section. Due to limited substrate, HydroQual Laboratory was unable to reassess the toxicity of sediment from these stations. Further explanation of issues surrounding toxicology results in 2014 are presented in Appendix B.

Temporal Trends No significant (α=0.05) trends in sediment quality measurement endpoints were observed at *test* stations BPC-1 and FLC-1. A significant decreasing trend over time in concentrations of total parent PAHs was detected at *test* station GIC-1. Trend analysis could not be conducted for *test* station EMR-2 due to limited historical data (n=5).

2014 Results Relative to Historical Concentrations Concentrations of sediment quality measurement endpoints at all stations were compared to historical concentrations, with changes highlighted as follows:

- All sediment quality measurement endpoints for *test* station BPC-1 were within the range of previously-measured concentrations in fall 2014. Direct toxicity measurements indicated high survival rate (86%) of the amphipod *Hyalella* and a 14-day growth rate within previously-measured values (0.15 mg/organism) (Table 5.1-14). Sediment at *test* station BPC-1 was dominated by silt (56%), which differed from the previous three years when the dominant substrate was sand, but was similar in composition to earlier sampling years (Figure 5.1-8).
- All sediment quality measurement endpoints at *test* station FLC-1 were within the range of previously-measured concentrations (Table 5.1-15). Sediment at *test* station FLC-1 in fall 2014 was dominated by silt (56.8%), with sediment composition similar to fall 2013. The PAH hazard index was below the potential chronic toxicity threshold in fall 2014 (Table 5.1-15 and Figure 5.1-9). Sediment toxicity testing indicated a high survival (90%) and 14-day growth rate (0.23 mg/organism) of the amphipod *Hyalella,* with values within the range of previously-measured results (Table 5.1-15).
- Sediments at *test* station GIC-1 were dominated by silt (63.7%) with smaller amounts of clay (18.9%) and sand (17.4%) (Table 5.1-16). In 2014, the percentage of silt exceeded the previously-measured maximum value measured at this station. Concentrations of F2, F3 and F4 hydrocarbons, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs exceeded previously-measured maximum concentrations, while the concentration of naphthalene was below the previously-measured minimum concentration (Table 5.1-16). When total PAHs were normalized to percent fines; however, the concentration was within previously-measured concentrations (Figure 5.1-10). Direct test of sediment toxicity indicated a high survival (90%) and 14-day growth rate (0.27 mg/organism) of the amphipod *Hyalella*, with both values within the previously-measured range (Table 5.1-16).
- Sediment at *test* station EMR-2 was dominated by silt (67.1%), which exceeded the previously-measured maximum value in fall 2014 (Table 5.1-17). The composition of clay was similar to previous years in fall 2014; however, the percentage of sand (1.1%) was below the previously-measured minimum value (Table 5.1-17). Concentrations of naphthalene and total parent PAHs were below previously-measured minimum concentrations, while retene and total dibenzothiophenes exceeded previously-measured maximum concentrations at *test* station EMR-2 in 2014. The concentration of total arsenic exceeded the previously-measured maximum concentration, while total metals normalized to percent fines was below the previously-measured minimum concentration (Table 5.1-17 and Figure 5.1-11). Direct measurements of sediment toxicity were within the range of previously-measured values, with survival of 86% and a 14-day growth rate of 0.19 mg/organism for the amphipod *Hyalella* (Table 5.1-17).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Measurement endpoints of sediment quality were below guideline concentrations in fall 2014, with the following exceptions:

- Total arsenic, which exceeded the CCME guideline of 5.9 mg/kg at *test* stations FLC-1, GIC-1, and EMR-2;
- Fraction 3 hydrocarbons (C16-C34), which exceeded the CCME guideline of 300 mg/kg at *test* station GIC-1; and
- Predicted PAHs toxicity, which exceeded the potential chronic toxicity threshold value of 1.0 at *test* stations BPC-1, GIC-1 and EMR-2.

2014 Results Relative to *Baseline* Concentrations There was no *baseline* sediment quality data for the ARD; therefore, results were not compared to *baseline* ranges of variability.

Sediment Quality Index The SQI values for stations of the ARD were not calculated for fall 2014 given the absence of *baseline* data for this region.

Summary of Results In 2014, all stations of the ARD were dominated by silt. All sediment quality measurement endpoints at *test* stations BPC-1 and FLC-1 were within previously-measured concentrations. Concentrations of F2, F3, and F4 hydrocarbons at *test* station GIC-1 reached maximum values in fall 2014, while only F4 hydrocarbons exceeded the previously-measured maximum concentration at *test* station EMR-2. Concentrations of retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs exceeded previously-measured maximum concentrations, while naphthalene was below the previously-measured minimum concentration at *test* station GIC-1. At *test* station EMR-2, concentrations of retene and total dibenzothiophenes also exceeded previously-measured maximum concentrations, while naphthalene and total parent PAHs were below previously-measured minimum results. Concentrations of PAHs at all stations in fall 2014 were dominated by alkylated species, indicating a petrogenic origin of these compounds. At all stations, with the exception of *test* station FLC-1, the PAH Hazard Index value exceeded the potential chronic toxicity threshold of 1.0. Concentration of F3 hydrocarbons exceeded the CCME guideline at *test* station GIC-1, while concentrations of total arsenic exceeded the CCME guideline at *test* stations FLC-1, GIC-1, and EMR-2. All toxicity test measurements were within the range of previously-measured results at all stations for the amphipod *Hyalella*. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

5.1.5 Fish Populations

Fish population monitoring in 2014 consisted of a spring, summer, and fall fish inventory, a fish tag return assessment, and fish tissue monitoring on the Athabasca River mainstem as well as fish assemblage monitoring in four channels of the Athabasca River Delta.

5.1.5.1 Athabasca River Fish Inventory

The fish inventory program on the Athabasca River in 2014 consisted of a spring, summer, and fall fish survey. The *test* areas (Poplar, Steepbank, Muskeg, Tar-Ells, and Fort-Calumet) of the river, located downstream of oil sands development have been continually sampled by RAMP since 1997 and now in support of the JOSMP. From 1987 to 1996, these areas were sampled by Syncrude and have been designated as *baseline* years given that sampling was conducted prior to major oil sands development. A *baseline* reach (-03B), located upstream of Fort McMurray has been sampled since 2011.

Temporal and Spatial Comparisons

Temporal and spatial comparisons were carried out to assess seasonal changes in each area of the river for the following measurement endpoints: species composition, species richness, catch per unit effort (CPUE, as an index of relative abundance), age-frequency distributions, size-at-age, and condition factor.

Total Catch and Species Richness A total of 2,704 fish representing 15 species were captured in 14 standardized reaches within six areas of the Athabasca River during the spring, summer, and fall fish inventories (Table 5.1-18 and Figure 5.1-12), of which:

- 1,275 fish representing 13 species were caught in spring;
- 699 fish representing 13 species were caught in summer; and
- 730 fish representing 13 species were caught in fall.

Total species richness decreased in 2014 following a relatively stable period from 2010 to 2013, with only 15 species recorded in 2014 while 19 species were recorded from 2012 to 2013 and 20 species in 2010 and 2011. The lowest and highest species richness since the implementation of standardized reaches in 2006 were documented in 2009 (16 species) and 2008 (23 species) (Figure 5.1-12). Richness was generally higher throughout the *test* areas when compared to the *baseline* reach; a lower richness was observed only in the Fort-Calumet and Tar-Ells *test* areas in summer (Figure 5.1-13).

Compared to 2013, the total catch in 2014 decreased by 1,703 fish in fall. The total catch in summer 2014 also decreased (368 less fish) from 2013 while the spring total catch of 1,275 fish was consistent in 2013 and 2014 (Table 5.1-19 and Figure 5.1-14).

Species Composition The most abundant large-bodied fish species in 2014 was white sucker and goldeye in spring; goldeye and walleye in summer; and walleye and longnose sucker in fall. White sucker and goldeye have been the most abundant species in spring for the past two years, while white sucker and walleye have been the two most abundant species since 2007. Goldeye and walleye have also been the most abundant large-bodied fish species in summer since sampling was re-initiated in 2008. The abundance of lake whitefish in fall 2014 was the lowest recorded during sampling of the Athabasca River; longnose sucker replaced lake whitefish as one of the three most abundant species in fall for the first time since 2002 (Figure 5.1-15).

Goldeye was the most abundant large-bodied species at the *baseline* reach (upstream of Fort McMurray) across all seasons. White sucker and goldeye were the most abundant species across all *test* areas in spring; goldeye was also the most abundant species at all *test* areas in summer; and walleye was most abundant species in fall at all *test* areas (Table 5.1-19). The most abundant small-bodied species at the *baseline* reach was trout-perch in spring, emerald shiner in summer, and flathead chub in fall. Trout-perch was the most abundant species at all *test* areas in spring, while flathead chub and emerald shiner were the most abundant species at *test* areas in summer; trout-perch and flathead chub were dominant at *test* areas in fall (Table 5.1-19).

Catch Per Unit Effort In order to provide a standardized comparison across time, catch per unit effort (CPUE) was calculated only for reaches that were sampled by JOSMP in 2014 (i.e., the 14 reaches in six areas of the Athabasca River). Historically, other reaches in the Athabasca River have been sampled; however, these data were not included for comparisons of CPUE. Comparisons of CPUE over time has focused on KIR fish species (i.e., goldeye, lake whitefish, longnose sucker, northern pike, trout-perch, walleye, and white sucker) given their importance to stakeholders and their suitability for assessing localized conditions of the river (e.g., white sucker and longnose sucker are bottom feeders; trout-perch is a non-migratory sentinel species; and walleye and lake whitefish are highly migratory throughout the system).

Mean CPUE for each KIR fish species by area and season in 2014 is provided in Figure 5.1-16. Mean CPUE for each KIR fish species was compared across areas and seasons between three sampling periods: 1987 to 1996, designated as "prior to major oil sands development"; 1997 to 2004, designated as "prior to enhanced standardization of sampling reaches"; and 2005 to 2014, designated as "post-reach standardization" (Figure 5.1-17 to Figure 5.1-23). Since the initiation of standardized reaches in 2005, an effort has been made to target the whole fish community and ensure consistent sampling methodology across reaches; consequently, total CPUE has generally been higher in the last eight years of the program.

Spatial comparisons were conducted to assess differences in CPUE of KIR fish species between each area of the Athabasca River (Figure 5.1-24). Species-specific results were as follows:

- With the exception of the Poplar Creek area in spring, CPUE of goldeye was lower at all *test* areas compared to the *baseline* area in spring and fall. In summer, goldeye CPUE at all *test* areas were lower than the *baseline* area with the exception of the Steepbank area;
- CPUE of longnose sucker was higher at all *test* areas compared to the *baseline* reach in spring with the exception of the Fort-Calumet area; only the Poplar and Steepbank *test* areas had a higher CPUE than the *baseline* reach in summer;
- CPUE of northern pike was lower across all *test* areas in spring and summer than the *baseline* area; there were no northern pike caught in the *baseline* area in fall;
- CPUE of trout-perch was higher at all *test* areas in spring compared to the *baseline* reach, with the exception of the Tar-Ells *test* area. Very few trout-perch were caught in summer, with a slightly higher CPUE at the *baseline* area compared to the Poplar and Steepbank *test* areas. All *test* areas with the exception of the Steepbank and Fort-Calumet areas exhibited higher CPUE compared to the *baseline* area in fall;
- In spring and summer, CPUE of walleye was higher at the *baseline* reach compared to all *test* areas; there were no walleye captured at the *baseline* reach in fall;
- Spatial comparisons of CPUE of white sucker were not conducted given the absence of white sucker at the *baseline* reach in all three seasons; and
- Lake whitefish were only captured in fall when the adult spawning population was in the Athabasca River. With the exception of the Poplar Creek area, CPUE of lake whitefish was higher at all *test* areas compared to the *baseline* area.

Temporal comparisons of CPUE were conducted using a trend analysis ($p<0.05$) for KIR fish species in each area from 1997 to 2014 (Table 5.1-20). Species-specific results were as follows:

- There was a significant increasing trend in CPUE of goldeye exhibited at the Poplar area ($p=0.03$) in fall and a decreasing trend at the Fort-Calumet area ($p=0.04$) in spring;
- A significant increase in CPUE of longnose sucker over time was observed in fall at the Poplar Creek area ($p=0.007$);
- Significant increases in CPUE of trout-perch over time was observed in spring and fall at all areas ($p<0.05$), with the exception of the Fort-Calumet area;
- There was a significant increasing trend in CPUE of walleye at the Poplar area in fall ($p<0.05$);
- There was a significant increasing trend in CPUE of white sucker in spring at the Poplar, Muskeg, and Tar-Ells areas and in fall at the Poplar and Steepbank areas ($p<0.05$); and
- There was a significant increasing trend in CPUE of lake whitefish at all *test* areas in fall ($p<0.05$), with the exception of the Poplar and Fort-Calumet areas.

Age-Frequency Distributions Relative age-frequency distributions and size-at-age relationships for large-bodied KIR fish species across all seasons are presented in Figure 5.1-24 to Figure 5.1-29. Given the number of years of data, the relative age-frequency distributions for large-bodied KIR species were displayed for 1997 to 2011 and individually from 2012 to 2014. Statistical comparisons were conducted only on large-bodied KIR fish species with adequate samples sizes ($n\geq20$ and equal regression slopes [$p>0.01$]) and only significant differences were reported; sample sizes with respect to the number of fish that have been aged over time are provided in Table 5.1-21. Species-specific results were as follows:

- The dominant age class of goldeye in 2014 was three years with sub dominance at six years. Similarly, dominant age classes in 2013 were centered on three and six years, while the majority of goldeye were observed at five years in 2012. Furthermore, the dominant age class of goldeye from 1997 to 2011 was four and five years, indicating a gradual shift to a younger population;
- There were no dominant age classes observed in 2014; similar findings have been observed throughout past sampling years. There was a significant difference in size-at-age of longnose sucker between 2013 and 2014 ($p=0.04$), with smaller longnose sucker across ages in 2014;
- The dominant age class of northern pike in 2014 was two years of age, which was similar to 2013 (dominant age class of one year). This was a shift from a dominant age class of five years from 1997 or 2012, indicating a higher level of recruitment to the northern pike population in 2013 and 2014 (Figure 5.1-33) or potential greater fishing pressure on older, larger fish. Age-frequency data could not be statistically analyzed because of unequal regression slopes ($p<0.01$);
- There was no defined dominant age class for walleye in 2014, with the majority of fish between four and nine years of age. This represents a slight shift from 2013 when a majority of walleye were between four and eight years of age;
- The dominant age class of white sucker was ten years in 2014 and 2013, whereas the dominant among age classes in 2012 ranged from four to ten years. This continued shift towards an older population has been observed since 2011; and

- The dominant age class of lake whitefish in 2014 was eight years of age; the dominant age class has ranged from six to ten years since 1997. It should be noted that there were 61 fewer individuals captured in 2014 from 2013, which likely impacted statistical comparisons.

Condition Factor Mean condition factor of large-bodied KIR fish species captured in the Athabasca River were compared over time and relative to a *baseline* period (1987 to 1996) prior to major oil sands development (Figure 5.1-30 to Figure 5.1-35). Fish captured in spring were not considered in this assessment as most species are spring spawners. As such, condition would be strongly influenced by advanced gonadal development of pre-spawning fish or reduced gonad size of spent fish. Similar reasoning was applied to lake whitefish in fall during their spawning period. Species-specific results for summer and fall were as follows:

- Mean condition of goldeye in summer and fall 2014 was lower than 2013 and slightly below the *baseline* mean condition;
- Mean condition of longnose sucker in fall 2014 was above the *baseline* mean condition for the first time since 2011. Conversely, mean condition in summer 2014 was substantially lower than both the *baseline* and the 2011 mean while only slightly lower than mean condition in 2012;
- Mean condition of northern pike in summer 2014 was lower than 2013 and well below the *baseline* mean condition. Similarly, mean condition in fall 2014 also decreased from 2013 and has remained below the *baseline* mean condition since 2009;
- Mean condition of walleye in summer and fall 2014 exhibited a slight decrease towards the *baseline* mean condition; mean condition in both summer and fall 2013 were above the *baseline* mean for the first time since 2009;
- Mean condition of white sucker was slightly higher in fall 2014 compared to 2013 and has remained above the *baseline* mean condition since 1997; and
- Mean condition of lake whitefish in fall 2014 was slightly lower than 2013 but above the *baseline* mean condition.

Statistical differences between 2014 and the *baseline* period (1987 to 1996) for summer and fall were tested using analysis of covariance (ANCOVA). Only large-bodied KIR fish species with adequate samples sizes ($n \geq 20$) and equal slopes between length and weight ($p>0.01$) were included and only significant differences were reported. The number of fish from the adult size classes of each large-bodied KIR species are provided in Table 5.1-22. Condition of goldeye in summer 2014 was 8.2% lower relative to summer 2013 ($p>0.001$). Similarly, fall condition of goldeye was lower in 2014 ($p=0.02$, 5.1%) compared to fall 2013 but higher than *baseline* years ($p=0.006$, 7.5%). Walleye had a significantly higher mean condition in fall 2013 than 2014 ($p<0.001$, 8.9% difference).

External Health Assessment

Observed abnormalities were primarily associated with minor skin aberrations or wounds, scars, and fin erosion, but infrequent cases of parasites, growths, lesions (open sores) or body deformities were also observed. In 2014, 3.0%, 4.5%, and 0.8% of fish were found to have some type of external abnormality in spring, summer, and fall, respectively. Incidences of external abnormalities in 2014 were higher than 2013 across all seasons, with the exception of summer (3.2% in 2013).

Of the 2,628 fish captured during the 2014 Athabasca River inventory, 51 (1.9%) fish exhibited some form of external pathological abnormality such as parasites, growths, lesions (open sores), or body deformities. The percentage of fish exhibiting some form of pathology by year for all seasons combined is summarized in Table 5.1-23 and Figure 5.1-36. For each type of external pathology, there has been no increasing trend observed over time ($p>0.05$). External pathology was primarily observed in northern pike (14.8%) and lake whitefish (10.3%) in 2014 and related to fin erosion. The percent of external pathology in 2014 exceeded the historical range documented for northern pike (0% to 11.9%) but was within the historical range for lake whitefish (0% to 20%). Other species for which pathological abnormalities were recorded, mostly due to their higher capture frequency compared to other species in the river, included white sucker (5.3%), goldeye (3.8%), lake chub (3.0%), longnose sucker (2.4%), walleye (1.4%), flathead chub (1.13%), and emerald shiner (0.7%).

Similar levels of fish abnormalities have been documented in previous studies in the Athabasca River and other regional waterbodies. A Northern River Basins Study completed fish health assessments from 1992 to 1994 on reaches of the Athabasca River, upstream of Fort McMurray (Mill et al. 1996). Abnormalities recorded included tumors, lesions, scars or injuries, skin discoloration, deformities, and parasites. Similar to what has been observed during JOSMP fish inventories, emerald shiner, goldeye, lake whitefish, longnose sucker, walleye, and white sucker were the primary species that exhibited some type of external pathology. In another study of the Athabasca River conducted in 1992, external abnormalities were found in northern pike, longnose sucker and white sucker accounting for 8.7%, 45.6%, and 50% of the total fish captured of each species, respectively (Barton et al. 1993). In a separate study in 1993, 0.8% of mountain whitefish and 76.7% of lake whitefish had some type of external abnormality (Mill et al. 1996). For comparison, other studies conducted on the Wapiti, Smoky, and Peace rivers documented abnormalities among 33% of burbot (Hvenegaard and Boag 1993). In the Peace Athabasca Delta, a study in 1993 documented 0.95% of lake whitefish captured with some type of external abnormality (Balagus et al. 1993). Other studies have documented no external abnormalities in any fish in the upper portion of the Athabasca River (R.L. & L. 1994), while other studies in the upper portion of the Athabasca River have documented a range between 0% and 15.7% of the total number of fish captured with some type of external abnormality (Mill et al. 1996).

Summary Assessment for the Fish Inventory

The objective of the fish inventory program was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years, are summarized in this section.

Total Catch and Species Richness Total catch in summer and fall 2014 was much lower compared to 2013, although catch in spring was similar to 2013. The lower catch in fall was attributed primarily to the timing of sampling with respect to the migration of lake whitefish from Lake Athabasca to spawning grounds in the Athabasca River. Due to restrictions outlined in the Fish Research License issued by AESRD, sampling could not occur during the spawning period, as it has in previous years. Lower water levels were also observed in fall 2014, limiting habitat availability as well as boat access and fishing efficiency. These factors also may have contributed to the reduction in total catch and richness observed in 2014.

Species Composition A large change in species composition was observed in fall with a record low percentage of lake whitefish captured. In years where lake whitefish were the most abundant species in fall in the Athabasca River, sampling was generally conducted in the last ten days of September (compared to 2014 when sampling was conducted from September 10 to 15).

Catch per Unit Effort There was a decrease in CPUE of white sucker in 2014 compared to 2013 in spring. However, the highest CPUE of white sucker continued to be observed in the Muskeg area, which is a river that white sucker use for spawning (RAMP 2010).

Age-Frequency Distributions The dominant age class of northern pike in 2013 and 2014 was one and two years, respectively; dominance was most pronounced at five years in 2012 and from 1997 to 2011. The increased frequency of younger northern pike in the Athabasca River suggested higher levels of recruitment or increased selection on older individuals from fishing pressure. The absence of lake whitefish in younger age classes may indicate poor recruitment of young individuals to the population or that the sampling period only coincides with the adult spawning population and does not overlap with periods of feeding or rearing of juvenile fish in the river.

External Health Assessment Overall, the 2014 fish health assessment indicated that abnormalities observed among all species were within the historical range (1987 to 2013), despite the higher than average incidence of abnormalities observed in northern pike (14.8%). These findings were also consistent with previously cited studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

5.1.5.2 Fish Tag Return Assessment

Angler Returns

There was one walleye captured and reported by an angler in 2014. The walleye was originally sampled and tagged (tag number 15274) on September 10, 2014 and recaptured by the angler on September 21, 2014 near the water treatment plant upstream of Fort McMurray. The distance between the initial capture and the recapture locations was approximately 23 km (Figure 5.1-37).

Fish Inventory Returns

A total of two walleye and one northern pike were recaptured during the 2014 inventories:

- One walleye was recaptured (tag number 14668) on May 13, 2014 at Reach 00B of the Poplar area; this fish was originally captured on July 23, 2012 at the same reach; and
- One walleye was recaptured (tag number 13976) on July 20, 2014 at Reach 19B of the Fort-Calumet area; this fish was originally captured on May 11, 2011 at the same reach.

One northern pike was recaptured (tag number 15626) on July 24, 2014 at Reach CR2A of the Clearwater River; the original capture location was Reach CR2C on June 11, 2014.

5.1.5.3 Athabasca River Fish Tissue Monitoring

The fish tissue program on the Athabasca River in 2014 consisted of a fall fish survey that was concurrent with the fish inventory program. Walleye and lake whitefish from the Steepbank and Muskeg *test* areas of the river have been collected by RAMP in 2002, 2003, 2005, 2008, and 2011 and in 2014 in support of the JOSMP.

Whole-Organism Metrics

A total of 17 walleye (nine male, three female, and five unsexed) and 29 lake whitefish (five male, 11 female, and 13 unsexed) were collected from the Athabasca River for fish tissue analysis in conjunction with the 2014 fall fish inventory. Sizes of walleye captured ranged from 269 mm to 614 mm. The mean length of walleye was 412 mm, with females (mean length: 457 mm) being larger than males (mean length: 434 mm). The size of captured lake whitefish ranged from 385 to 505 mm. The mean length of lake whitefish was 431 mm, with males (mean length: 433 mm) being slightly larger than females (mean length: 427 mm).

External fish health assessments were conducted on all fish collected and internal fish health assessments were conducted on all fish that were sacrificed for metal and organics tissue analyses**.** There were no abnormalities observed in any of the sacrificed fish, or on any of the fish from which tissue was sampled non-lethally.

Mercury

Concentrations of total mercury in muscle tissue of lake whitefish and walleye from the Athabasca River in fall 2014 are presented in Table 5.1-26. Concentrations of mercury in lake whitefish ranged from 0.04 to 0.47 mg/kg, with a mean concentration of 0.10 mg/kg. Concentrations of mercury in walleye ranged from 0.14 to 0.83 mg/kg, with a mean concentration of 0.42 mg/kg.

Temporal trends in absolute concentrations of mercury and length-normalized concentrations of mercury in lake whitefish and walleye are presented in Figure 5.1-38 and Figure 5.1-39, respectively. The mean concentration of mercury in lake whitefish in 2014 (0.10 mg/kg) was higher than 2011 (0.08 mg/kg), but within the range of previously-measured concentrations from historical sampling years (i.e., 2002 to 2008). The mean concentration of mercury in walleye in 2014 (0.42 mg/kg) was higher than 2011 (0.31 mg/kg), but concentrations were within the range of previously-measured concentrations from 2002 to 2008. Length-normalized (to the mean length of captured fish) concentrations of mercury were slightly lower than the absolute concentrations of mercury, and ranged from 0.12 to 0.70 mg/kg in lake whitefish and 0.04 to 0.44 mg/kg in walleye.

Absolute concentrations of mercury for individual lake whitefish and walleye of each size class from 2002 to 2014 are presented in Figure 5.1-40. Mercury concentrations in lake whitefish remained fairly consistent within each size class across years and below the subsistence (0.20 mg/kg) and general consumer (0.50 mg/kg) guidelines, with the exception of a few individuals greater than 350 mm in length. Concentrations of mercury in walleye greater than 400 mm exceeded the subsistence and general consumer guidelines demonstrating the bioaccumulation of mercury in fish as they grow and that mercury concentrations are greater in walleye given they are piscivorous species, whereas lake whitefish are generally benthivores (Scott and Crossman 1973).

In 2014, mercury concentrations (log-transformed) in muscle tissue of individual lake whitefish were not statistically different across length of fish ($p=0.06$; $R^2=0.09$) or age of fish ($p=0.05$; $R^2=0.10$) (Figure 5.1-41). When comparing mercury concentrations relative to length across years, mercury concentrations in lake whitefish were significantly higher in 2014 than 2008 ($p=0.017$). However, 2008 had the lowest mercury concentrations relative to length of lake whitefish across the monitoring period and there were no significant differences with any other sampling year. In 2014, concentrations of mercury (log-transformed) relative to age were not significantly different in lake whitefish compared to previous years (e.g., 2002 and 2011) ($p \geq 0.11$).

In 2014, mercury concentrations (log-transformed) in muscle tissue from individual walleye were significantly different across length of fish ($p<0.001$, $R^2=0.76$), with mercury increasing with length (Figure 5.1-41). In 2014, concentrations of mercury (log-transformed) relative to length in walleye were significantly higher than 2005 ($p=0.003$), 2008 ($p<0.001$), and 2011 ($p<0.001$). Statistical comparisons were not performed for age versus mercury given the limited data obtained in 2014.

Other Chemicals

Composite samples of muscle tissue taken from male and female lake whitefish and male walleye were analyzed for concentrations of metals and tainting compounds. Eleven of the 28 metals analysed were below the analytical detection limit in all composite samples (Table 5.1-27). In 2014, all tainting compounds were below analytical detection limits in all composite tissue samples (Table 5.1-27).

Potential Risk to Human Health

Mercury In 2014, concentrations of mercury in lake whitefish and walleye were screened against human health criteria for fish consumption established by Health Canada and the United States Environmental Protection Agency (USEPA) (Table 5.1-26). There were two lake whitefish captured in 2014 with concentrations of mercury (0.21 mg/kg and 0.47 mg/kg) that exceeded guidelines for subsistence fishers (0.20 mg/kg). The composite sample of female lake whitefish also exceeded the guideline for subsistence fishers with mercury concentrations of 0.21 mg/kg. The mean mercury concentration for walleye (0.42 mg/kg) exceeded the Health Canada consumption guideline for subsistence fishers (0.20 mg/kg). Thirteen of the seventeen walleye captured exceeded the Health Canada consumption guideline for subsistence fishers (0.2 mg/kg) and of those thirteen, six exceeded the Health Canada consumption guideline for general consumers (0.5 mg/kg) (Table 5.1-26).

In 2014, 35% of walleye captured were greater than or equal to 908 g in weight. According to the Government of Alberta (2009), the consumption limits for walleye taken from the Athabasca River with a weight of 908 g or greater are as follows: women at the reproductive age (15 to 49 years) or pregnant should only consume two servings (75 g) per week; a child of one to four years old should only consume half a serving a week; children five to eleven years should only consume one serving a week; and adults (includes adults and children over 12 years) should only consume eight servings a week.

Concentrations of mercury in composite samples of muscle tissue taken from female lake whitefish exceeded the guideline for subsistence fishers (0.2 mg/kg) while concentrations of mercury in composite samples taken from male lake whitefish and male walleye were below consumption guidelines.

Other Chemicals Concentrations of total arsenic in female and male lake whitefish (400-450 mm) exceeded the USEPA subsistence guideline and recreational guideline (Table 5.1-27). However, the guideline is established for inorganic arsenic not total arsenic. To be conservative, the concentration of inorganic arsenic was estimated to be 10% of the total arsenic concentration, although in other studies inorganic arsenic has been documented to be less than five percent of the total arsenic concentration (ATSDR 2009). The estimated concentrations of inorganic arsenic exceeded the USEPA guideline for subsistence fishers (Table 5.1-27).

Potential Risk to Fish and Fish Health

The following were the results of screening for potential risks of concentrations of chemicals to fish and fish health (Table 5.1-28):

- Concentrations of mercury in lake whitefish and walleye did not exceed any of the effects (or no-effects) thresholds for fish and fish health;
- The concentration of lead exceeded the lethal no-effects threshold for male walleye (450 to 500 mm); and
- The concentration of selenium exceeded the lethal no-effects threshold for male and female lake whitefish (400 to 500 mm), and male walleye (450 to 500 mm).

The criteria for evaluating potential risk to fish health is subject to further investigation given that sublethal and lethal thresholds are determined in controlled laboratory conditions and may; therefore, not reflect the conditions of the water quality in the Athabasca River as it related to toxicity of metals to fish (RAMP 2009a).

Potential Risk on Fish Palatability

Concentrations of all tainting compounds in lake whitefish and walleye from the Athabasca River were below the 1 mg/kg threshold for effects on palatability as outlined in Jardine and Hrudey (1998) (Table 5.1-28).

Summary Assessment for Fish Tissue

Measurement endpoints used in the assessment for the Athabasca River fish tissue program included concentrations of metals and tainting compounds in fish tissue of both individual and composite samples. Potential human health risks from contaminated fish tissue were predicted from both individual and composite samples. In 2014, the mean concentration of mercury in lake whitefish was slightly higher than 2011, but within the range of concentrations observed in previous sampling years. The mean mercury concentration across all size classes of lake whitefish were below the Health Canada guideline for subsistence fishers indicating a **Negligible-Low** risk to human health. The mean concentration of mercury in walleye was higher in 2014 compared to previous years. The mean mercury concentration in size classes of walleye greater than 300 mm exceeded the subsistence fishers guideline for consumption indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

5.1.5.4 Athabasca River Delta Fish Assemblage Monitoring

A pilot study on fish assemblage monitoring was conducted in channels of the Athabasca River Delta (ARD) in 2012 using a variety of fishing gear (RAMP 2013). The results of the pilot study showed that hoopnets, seining, and minnow traps did not provide adequate effort or spatial coverage to properly sample fish assemblages in these channels. In 2013 and 2014, given the higher water levels, it was possible to conduct fish assemblage monitoring by boat electrofishing. Fish assemblages were sampled in August at:

- *test* reach EMR-F2 in the Embarras River (this reach is at the same location as the benthic invertebrate community *test* reach EMR-2);
- *test* reach FLC-F1 in Fletcher Channel (this reach is at the same location as the benthic invertebrate community *test* reach FLC-1);

- *test* reach BPC-F1 in Big Point Channel (this reach is at the same location as the benthic invertebrate community *test* reach BPC-1); and
- *test* reach GIC-F1 in Goose Island Channel (this reach is at the same location as the benthic invertebrate community *test* reach GIC-1).

2014 Habitat Conditions *Test* reach BPC-F1 was comprised entirely of deep run habitat, with wetted and bankfull widths of 115 m, a maximum depth of 4.5, and negligible velocity (Table 5.1-29). The substrate was dominated by silt and fine organics and the water had a pH of 7.07, high conductivity (259 µS/cm), moderate dissolved oxygen (6.2 mg/L), and a temperature of 20.4˚C. Instream cover consisted primarily of small woody debris and overhanging vegetation along the banks (Table 5.1-29).

Test reach FLC-F1 was comprised entirely of deep run habitat, with wetted and bankfull widths of 67 m, a maximum depth of 2.9 m, and negligible velocity (Table 5.1-29). The substrate was predominately silt and the water had a pH of 7.5, high conductivity (244 µS/cm), moderate dissolved oxygen (8.0 mg/L), and a temperature of 23.2˚C. Instream cover consisted of small and large woody debris along the banks as well as macrophytes at greater depths (Table 5.1-29).

Test reach GIC-F1 was comprised entirely of deep run habitat, with a wetted width of 150 m, a bankfull width of 154 m, a maximum depth of 8.3 m, and negligible velocity (Table 5.1-29). The substrate was dominated entirely by silt and sand and the water had a pH of 7.7, moderate conductivity (249 µS/cm), moderate dissolved oxygen (8.2 mg/L), and a temperature of 21.5˚C. Instream cover consisted of small woody debris, live trees/roots, and overhanging vegetation along undercut banks (Table 5.1-29).

Test reach EMR-F2 was comprised entirely of deep run habitat, with a wetted width of 63 m, a bankfull width of 64.5 m, a maximum depth of 2 m, and negligible velocity (Table 5.1-29). The substrate was dominated by silt and the water had a pH of 8.0, high conductivity (262 µS/cm), moderate dissolved oxygen (7.0 mg/L), and a temperature of 16.1˚C. Instream cover consisted of macrophytes and small woody debris with overhanging vegetation along the banks (Table 5.1-29).

Spatial and Temporal Comparisons of Measurement endpoints The relative abundance (#/m) decreased in 2014 compared to 2013, primarily at *test* reaches EMR-F2, BPC-F1, and FLC-F1 where abundance was 8.7, 11.0, and 7.1 times greater in 2013, respectively. Similarly, CPUE decreased in 2014 from 2013 at *test* reaches EMR-F2, BPC-F1, and FLC-F1 by 7.4, 11.6, and 5.4 times, respectively. Abundance and CPUE were considerably lower at *test* reach GIC-F1 compared to the other reaches but similar between years. Emerald shiner was the dominant small-bodied fish species at all *test* reaches in 2014. The most abundant large-bodied species were goldeye and northern pike; goldeye was dominant at *test* reaches BPC-F1, GIC-F1, and FLC-F1 while northern pike was dominant at *test* reach EMR-F2 (Table 5.1-30).

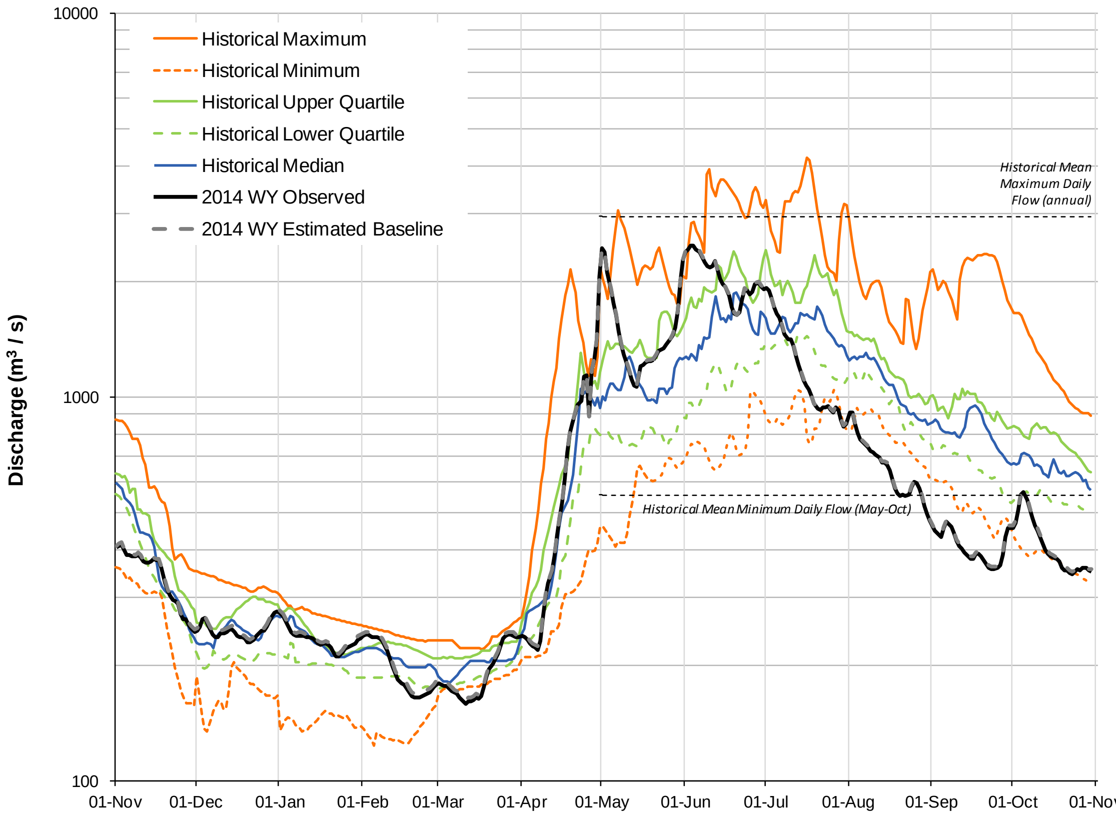
Species richness was highest with six species at *test* reach GIC-F1 in 2014. The largest difference in richness between years was observed at *test* reach BPC-1 with seven fewer species documented in 2014. The assemblage tolerance index (ATI) was similar between reaches and years, and ranged from 7.37 (*test* reach BPC-F1) to 8.65 (*test* reach FLC-F1) in 2014 (Table 5.1-31). Species diversity was also comparable between reaches and years, with the lowest diversity observed at *test* reach FLC-F1 in both 2013 and 2014 (Figure 5.1-41).

Comparison to Published Literature There have been very few surveys conducted on fish populations in channels of the ARD and only catch records from 2013 were available to provide context to the 2014 results. A study, using seining, angling, and gill netting was completed in the 1970s by the Alberta Oil Sands Environmental Research Program (AOSERP) that documented 18 species in the Athabasca River Delta (Bond 1980), which included all of the species captured by JOSMP in August 2014. Additional species historically documented in the ARD included mountain whitefish, longnose dace, and ninespine stickleback. Similar fish species were captured during the Athabasca River fish inventory surveys. In 2012, RAMP conducted a pilot fish monitoring program in the delta using hoopnets, seining, and minnow trapping (RAMP 2013). The limitations in spatial coverage of these fishing methods limited the range of species in the fish assemblage that were captured. In the past two years, with the use of boat electrofishing, it is likely that the full fish assemblage of these channels was captured given the species composition was similar to what is observed in the fish inventory survey on the Athabasca River.

2014 Results Relative to Historical or *Baseline* Conditions Given the different habitat conditions between the ARD and tributaries to the Athabasca River where fish assemblage monitoring was conducted, the measurements for *test* reaches of the ARD were not compared to regional *baseline* conditions.

Summary of Results Results of the fish assemblage monitoring in the ARD indicated a decrease in abundance across all reaches. All other measurement endpoints were fairly consistent across channels, with high ATI values reflecting the tolerant nature of fish species in the delta. Similar results were observed during the Athabasca River Inventory where lower catch numbers were primarily attributed to higher water temperatures. Water temperatures during the 2013 fish assemblage monitoring program in the ARD ranged from 19.5˚C to 20.4˚C with a mean of 19.8˚C, whereas water temperatures during the 2014 monitoring program were higher ranging from 20.4˚C to 23.4˚C, with a mean of 22.1˚C. The most abundant large-bodied species were goldeye and northern pike; goldeye was dominant at *test* reaches BPC-F1, GIC-F1, and FLC-F1, while northern pike was dominant at *test* reach EMR-F2.

Figure 5.1-3 The observed (test) hydrograph and estimated *baseline* hydrograph for the Athabasca River near Embarras Airport in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Athabasca River near Embarras (JOSMP Station S46) data. The upstream drainage area is 156,000 km^2. Continuous hydrometric data have been collected for Station S46 since August 2011. Historical statistics are composed of data from S46 and WSC Station 07DD001. Data from the WSC station covered the period from 1971 to 1976 (annual coverage), and 1977 to 1984 (coverage from May to October).

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.1-2 Estimated water balance at Station S46, Athabasca River near Embarras Airport, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**21,313.15**	**Observed discharge, obtained from Athabasca River near Embarras, (JOSMP Station S46)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-50.53	Estimated 366.9 km^2 of the Athabasca River watershed is closed-circuited as of 2014 (Table 2.3-1).
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	2.40	Estimated 87.3 km^2 of the Athabasca River watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1).
Water withdrawals from the Athabasca River near Embarras Airport station, relative to the estimated *baseline* hydrograph	-19.56	Withdrawals by Suncor (daily values provided).
	-20.39	Withdrawals by Canadian Natural (daily values provided).
	-38.35	Withdrawals by Syncrude (daily values provided).
	-6.06	Withdrawals by Imperial (daily values provided).
	-16.33	Withdrawals by Shell (daily values provided).
Water releases into the Athabasca River near Embarras Airport station, relative to the estimated *baseline* hydrograph	1.49	Releases by Suncor (daily values provided).
	0.29	Releases by Syncrude (daily values provided).
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	-28.88	Net sum of incremental volume results from the major tributaries as listed in Section 5.2 to Section 5.13[1]
Estimated *baseline* hydrograph (total discharge)	**21,489.07**	**Estimated *baseline* discharge at Athabasca River near Embarras (JOSMP Station S46)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-175.91	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-0.82**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values and percentages in this table are presented to two decimal places.

[1] It is assumed that discharges entering the Athabasca River mainstem from the Upper Beaver watershed via the Poplar Creek spillway would have entered the Athabasca River mainstem via the Original Beaver River watershed; therefore, the incremental changes of the Beaver Creek diversion on the Athabasca River mainstem flows were assumed to be zero.

Table 5.1-3 Calculated change in hydrologic measurement endpoints for the Athabasca River in the 2014 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	1,044.8	1,052.0	-0.7%
Mean winter discharge	241.7	245.7	-1.6%
Annual maximum daily discharge	2,464.0	2,480.0	-0.6%
Open-water season minimum daily discharge	345.8	349.7	-1.1%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated using data from JOSMP Station S46.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to one decimal place.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.1-4 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2014.

Measurement Endpoint	Units	Guideline[a]	Downstream of Development (ATR-DD-E, ATR-DD-C, ATR-DD-W) East[d]	Centre[e]	West[d]
Physical variables					
pH	pH units	6.5-9.0	8.2	8.2	8.2
Total suspended solids	mg/L	-	12.2	15.9	15.5
Conductivity	µS/cm	-	300	300	302
Nutrients					
Total dissolved phosphorus	mg/L	-	0.005	0.002	0.005
Total nitrogen	mg/L	-	0.26	0.27	0.32
Nitrate+nitrite	mg/L	-	<0.054	<0.054	<0.054
Dissolved organic carbon	mg/L	-	5.6	5.7	5.9
Ions					
Sodium	mg/L	-	15.0	15.6	15.9
Calcium	mg/L	-	33.1	31.6	33
Magnesium	mg/L	-	8.0	7.9	7.9
Chloride	mg/L	120	11.6	11.7	12.0
Sulphate	mg/L	309[b]	24.2	24	24.2
Total dissolved solids	mg/L	-	183	109	180
Total alkalinity	mg/L	-	106	105	106
Selected metals					
Total aluminum	mg/L	0.1	**0.77**	**0.76**	**0.74**
Total arsenic	mg/L	0.005	0.00066	0.00067	0.00067
Dissolved aluminum	mg/L	0.05	0.0089	0.0085	0.0093
Total boron	mg/L	1.2	0.030	0.031	0.034
Total molybdenum	mg/L	0.073	0.00070	0.00073	0.00077
Total mercury (ultra-trace)	ng/L	5, 13	1.65	1.71	1.75
Total strontium	mg/L	-	0.182	0.181	0.191
Total hydrocarbons					
BTEX	mg/L	-	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.11	0.17	0.16
Oilsands extractable	mg/L	-	0.60	0.30	0.30
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	ng/L	-	<7.21	<7.21	<7.21
Retene	ng/L	-	1.21	1.64	2.00
Total dibenzothiophenes	ng/L	-	18.8	22.3	35.9
Total PAHs[c]	ng/L	-	122.5	130.6	167.7
Total Parent PAHs[c]	ng/L	-	14.7	14.9	15.1
Total Alkylated PAHs[c]	ng/L	-	107.9	115.8	152.6
Other variables that exceeded CCME/AESRD guidelines in 2014					
Total chromium	mg/L	0.001	**0.00106**	**0.00107**	0.00096
Total iron	mg/L	0.3	**0.780**	**0.826**	**0.799**

Values in **bold** are above the guideline; underlined values are outside historical range of fall observations for station (single line = historical high; double underline = historical low).

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

[c] Non-detectable values treated in summary calculations as 1 x calculated Method Detection Limit.

[d] Historical comparison to 14 years of fall data (1998 to 2013).

[e] Historical comparison to eight years of fall data (2005 to 2013).

Figure 5.1-4 Piper diagram of ion concentrations in the Athabasca River mainstem (*test* stations ATR-DD), fall 1997 to 2014.

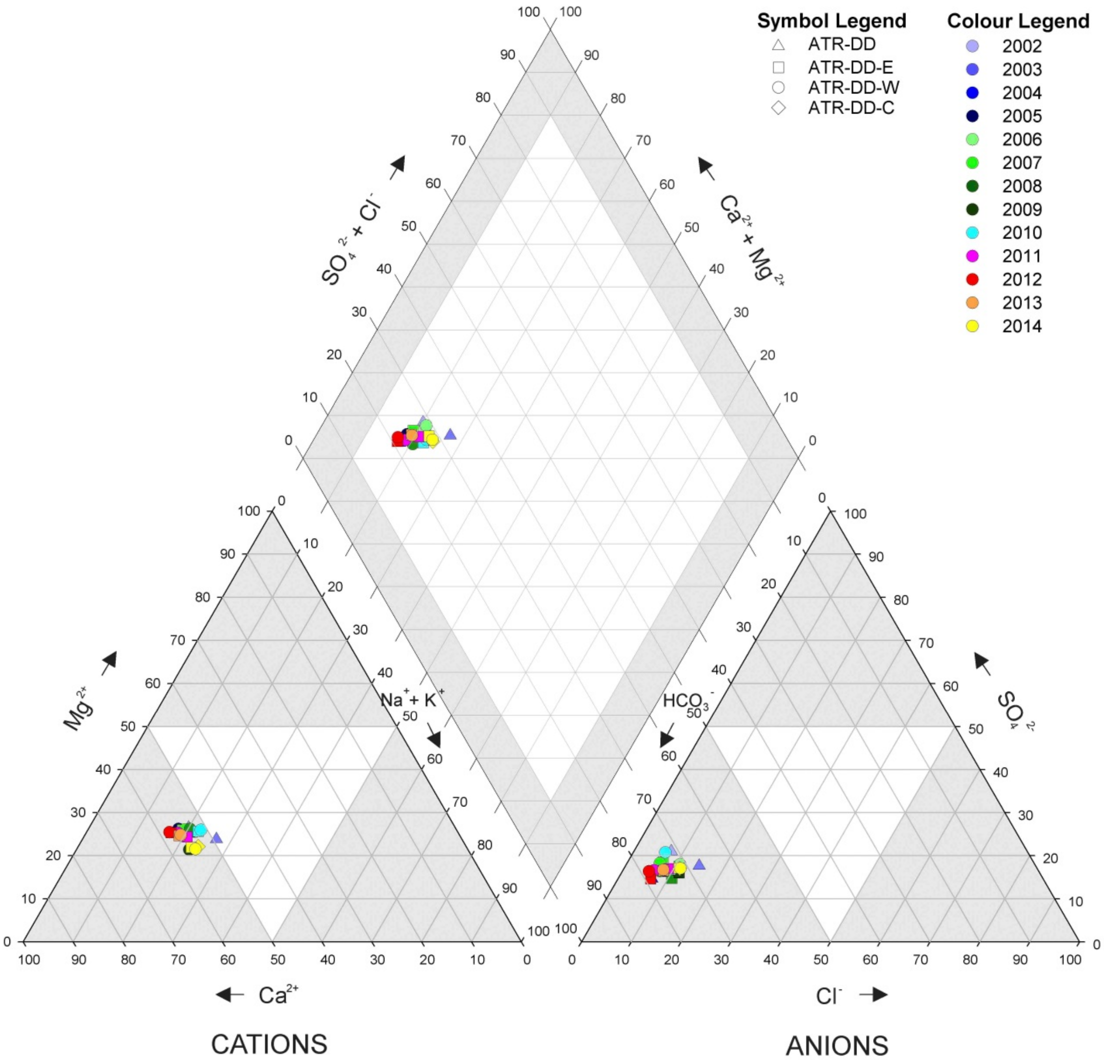


Table 5.1-5 Water quality guideline exceedances in the Athabasca River mainstem, 2014.

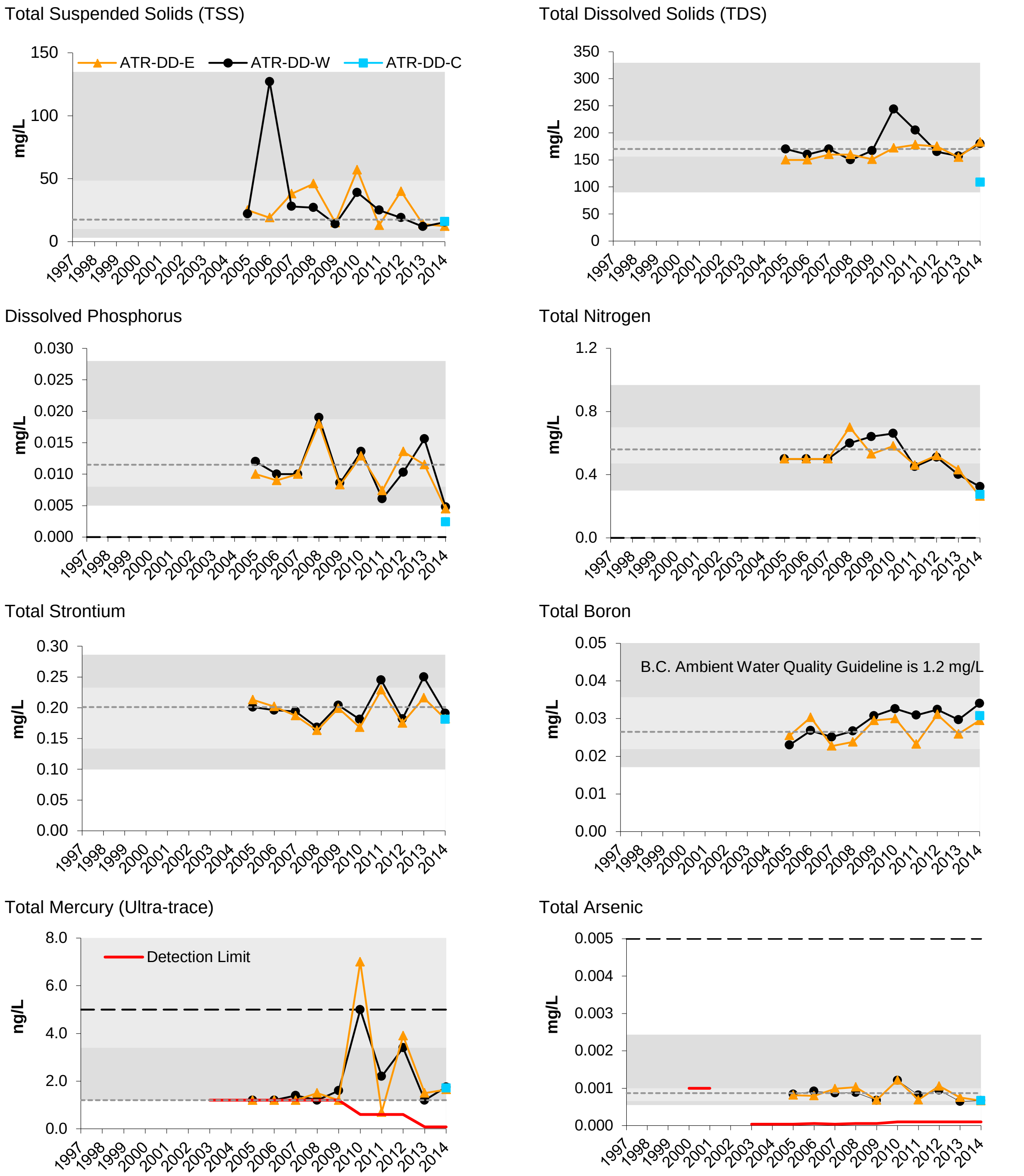
Parameter	Units	Guideline[a]	Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)		Downstream of Development (ATR-DD-E, ATR-DD-C ATR-DD-W)		
			East[1]	West	East	Centre	West
Winter							
Total aluminum	mg/L	0.1	0.119	-	0.188	ns	0.146
Total iron	mg/L	0.3	-	-	0.436	ns	0.408
Total phenols	mg/L	0.004	-	-	0.004	ns	-
Spring							
Dissolved copper	mg/L	0.002[b]	ns	ns	-	-	0.0025
Dissolved iron	mg/L	0.3	ns	ns	-	-	0.305
Sulphide	mg/L	0.002	ns	ns	0.0034	0.0034	0.0048
Total aluminum	mg/L	0.1	ns	ns	1.1	5.0	4.8
Total chromium	mg/L	0.001	ns	ns	0.0011	0.0044	0.0044
Total copper	mg/L	0.002[b]	ns	ns	0.0027	0.0046	0.0040
Total iron	mg/L	0.3	ns	ns	1.6	3.9	3.5
Total mercury (ultra-trace)	ng/L	5, 13	ns	ns	8.01	11	11.7
Total phenols	mg/L	0.004	ns	ns	-	0.0051	0.0053
Summer							
Sulphide	mg/L	0.002	ns	ns	-	-	0.003
Total aluminum	mg/L	0.1	ns	ns	3.27	2.25	2.78
Total chromium	mg/L	0.001	ns	ns	0.0029	0.0020	0.0025
Total copper	mg/L	0.002[b]	ns	ns	0.0024	-	-
Total iron	mg/L	0.3	ns	ns	2.53	1.67	2.08
Total mercury (ultra-trace)	ng/L	5, 13	ns	ns	11.8	-	5.74
Fall							
Total aluminum	mg/L	0.1	ns	ns	0.771	0.759	0.741
Total chromium	mg/L	0.001	ns	ns	0.00106	0.00107	-
Total iron	mg/L	0.3	ns	ns	0.780	0.826	0.799

ns = not sampled

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

Figure 5.1-5 Concentrations of selected water quality measurement endpoints (fall data) relative to historical concentrations and regional *baseline* fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD).



Non-detectable values are shown at the detection limit.

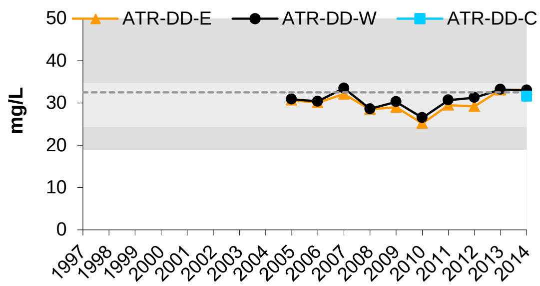
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

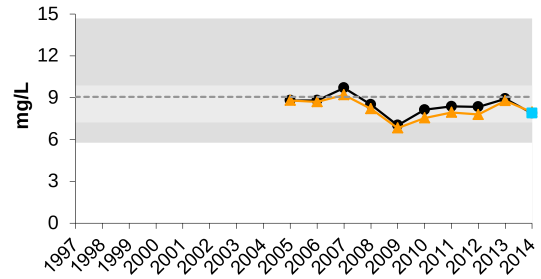
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-5 (Cont'd.)

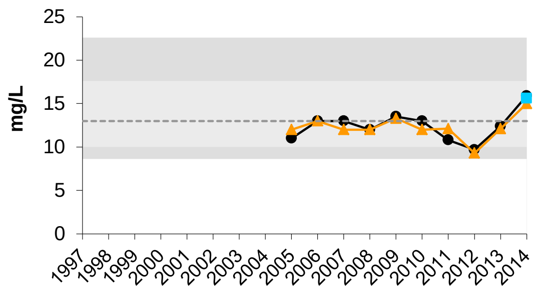
Calcium



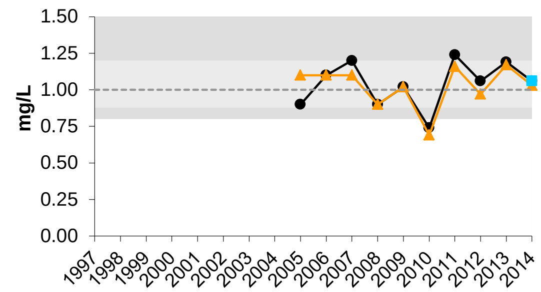
Magnesium



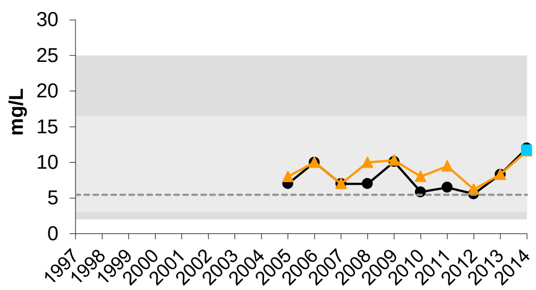
Sodium



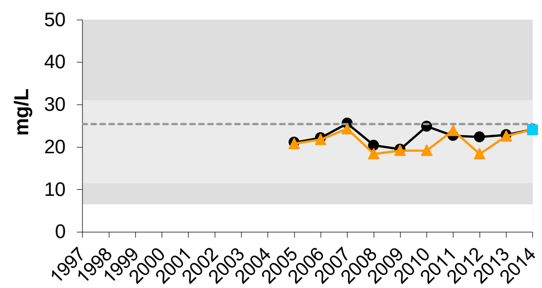
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.1-6 Average habitat characteristics of benthic invertebrate community sampling locations of the Athabasca River Delta, fall 2014.

Variable	Units	BPC-1 Big Point Channel	FLC-1 Fletcher Channel	GIC-1 Goose Island Channel	EMR-2 Embarras River
Sample date	-	Aug 21, 2014	Aug 19, 2014	Aug 20, 2014	Aug 19, 2014
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	1.7	1.5	1.5	2.4
Current velocity	m/s	0.35	0.15	0.34	0.05
Field Water Quality					
Dissolved oxygen	mg/L	8.2	8.0	8.2	7.0
Conductivity	µS/cm	261	244	249	255
pH	pH units	7.3	7.5	7.7	7.2
Water temperature	°C	20.3	23.2	21.5	23.8
Sediment Composition (mean ± 1SD)					
Sand	%	36±15	28±4	23±8	2±2
Silt	%	48±12	55±3	59±7	68±3
Clay	%	17±4	17±1	18±1	30±4
Total Organic Carbon	%	1.6±0.4	2.0±0.2	2.5±0.6	2.4±0.3

Table 5.1-7 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Big Point Channel of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Big Point Channel		
	2003	2004-2013	2014
Nematoda	<1	<1 to 7	<1
Oligochaeta (cocoon)	-	-	2
Naididae	1	0 to 7	3
Tubificidae	75	29 to 75	41
Erpobdellidae	-	0 to <1	-
Hydracarina	<1	0 to <1	-
Amphipoda	-	0 to 2	-
Gastropoda	4	0 to 12	<1
Bivalvia	10	<1 to 37	4
Ceratopogonidae	1	<1 to 7	6
Chironomidae	6	3 to 64	44
Diptera (misc)	0 to <1	0 to 4	-
Ephemeroptera	<1	0 to 2	-
Odonata	<1	0 to <1	<1
Plecoptera	-	0 to <1	-
Trichoptera	1	0 to 4	-
Heteroptera	<1	0 to <1	-
Megaloptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	267	36 to 2,359	440
Richness	11	6 to 15	12
Equitability	0.17	0.15 to 0.74	0.29
% EPT	1	0 to 19	0

Table 5.1-8 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Fletcher Channel of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Fletcher Channel		
	2002	2003-2013	2014
Nematoda	5	0 to 22	<1
Oligochaeta (cocoon)	-	-	4
Naididae	<1	0 to 15	3
Tubificidae	2	10 to 81	21
Hydracarina	-	0 to <1	-
Gastropoda	1	0 to 14	-
Bivalvia	1	<1 to 13	4
Ceratopogonidae	2	<1 to 10	14
Chironomidae	86	4 to 79	52
Diptera (misc)	0 to <1	0 to <1	-
Ephemeroptera	<1	0 to 2	<1
Odonata	-	0 to <1	<1
Plecoptera	-	0 to 1	-
Trichoptera	-	0 to 3	-
Heteroptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	1,034	6 to 2,639	187
Richness	12	4 to 12	14
Equitability	0.20	0.13 to 0.89	0.36
% EPT	1	0 to 6	<1

Table 5.1-9 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Goose Island Channel and the Embarras River of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Goose Island Channel			Embarras River		
	2002	2003-2013	2014	2010	2011-2013	2014
Hydra	-	2	-	-	-	-
Nematoda	5	0 to 2	<1	1	6 to 12	9
Oligochaeta (cocoon)	-	-	15	-	0 to <1	<1
Naididae	-	0 to 8	6	<1	<1 to 7	1
Tubificidae	<1	13 to 62	63	1	<1 to 21	41
Lumbriculidae	-	0 to <1	-	-	-	-
Erpobdellidae	-	-	-	-	0 to <1	-
Glossiphoniidae	-	-	-	-	0 to 1	-
Hydracarina	<1	0 to <1	-	<1	0 to <1	-
Amphipoda	-	0 to <1	-	-	-	-
Gastropoda	5	0 to 24	-	<1	<1-11	8
Bivalvia	13	<1 to 4	-	29	2 to 7	10
Ceratopogonidae	1	1 to 17	2	4	16 to 20	4
Chironomidae	74	13 to 66	7	41	29 to 81	27
Diptera (misc.)	-	0 to 1	-	-	-	-
Ephemeroptera	-	0 to 1	4	<1	<1 to 10	-
Odonata	<1	0 to 1	1	-	-	-
Trichoptera	<1	0 to 2	-	3	<1	<1
Heteroptera	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	781	41 to 806	48	1,022	27 to 360	1,177
Richness	14	8 to 12	5	23	5 to 13	14
Equitability	0.18	0.24 to 0.52	0.45	0.33	0.24 to 0.56	0.25
% EPT	<1	0 to 3	4.37	3	<1 to 10	<1

Table 5.1-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Big Point Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**0.029**	0.950	11	0	Decreasing over time.
Log of Richness	0.326	0.303	7	8	No change.
Equitability	0.101	0.734	10	0	No change.
Log of EPT	0.061	**0.041**	8	10	No change.
CA Axis 1	**<0.001**	**0.004**	28	8	Decreasing over time; lower in 2014 than mean of previous years.
CA Axis 2	0.791	**0.037**	0	16	Lower in 2014 than mean of previous years.

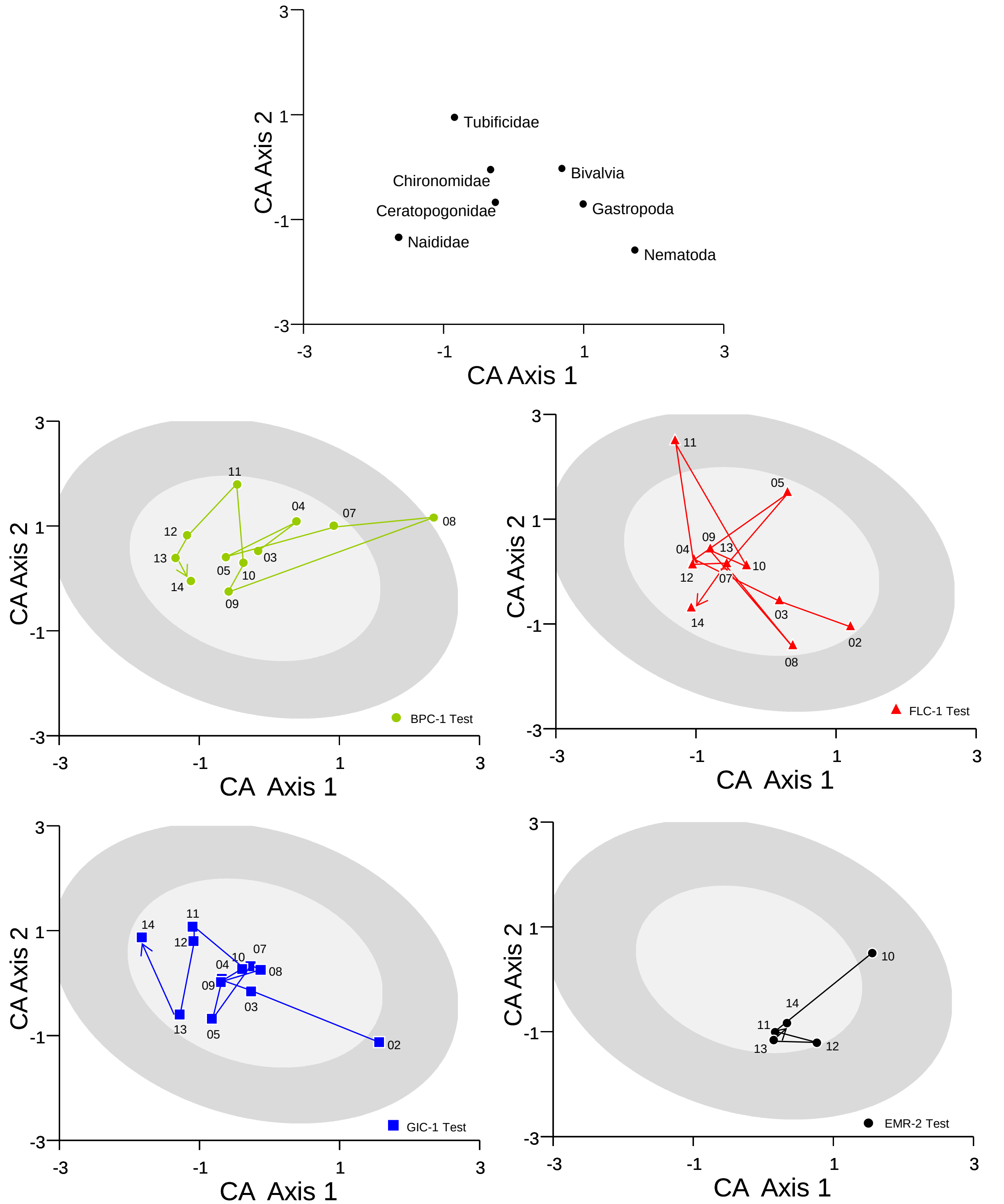
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

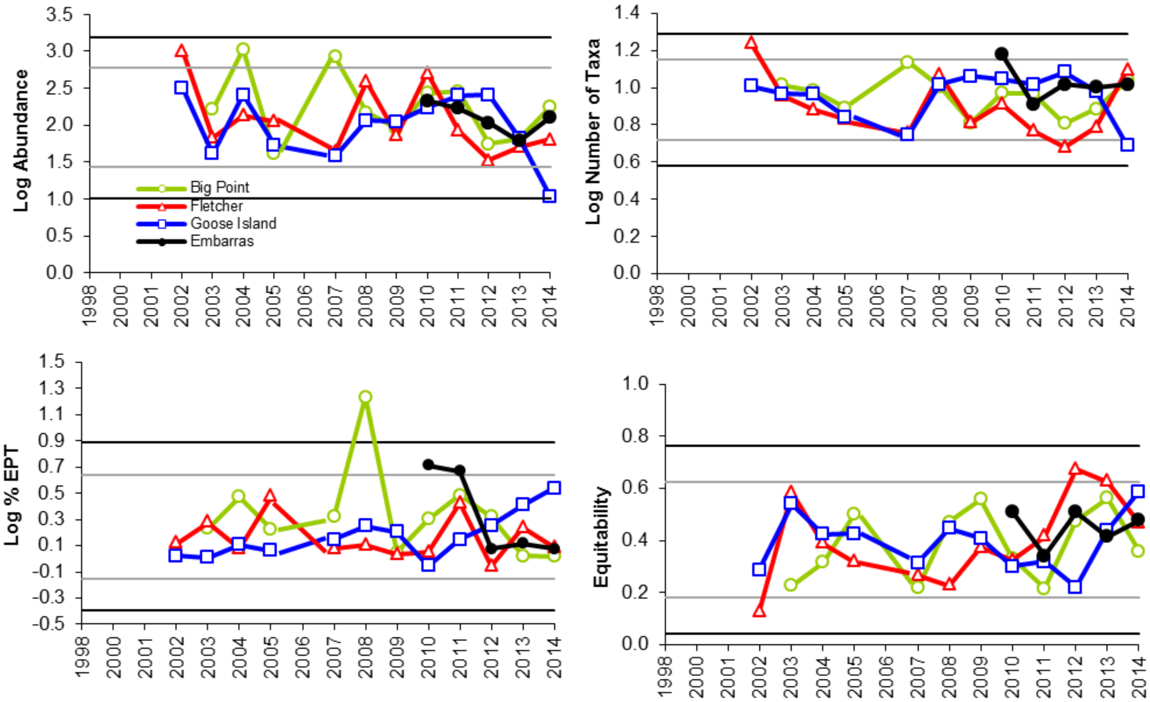
Note: Data for abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.1-6 Ordination (Correspondence Analysis) of benthic invertebrate communities of channels of the ARD.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile all ARD reaches for years up to and including 2013.

Figure 5.1-7 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta, 2002 to 2014.



Note: Tolerance limits for the 5th and 95th percentiles (grey and black lines) were calculated using data from all ARD reaches for years up to and including 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.1-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Fletcher Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**0.014**	0.328	21	3	Decreasing over time.
Log of Richness	0.078	0.059	12	14	No change.
Equitability	**<0.001**	0.289	28	2	Increasing over time.
Log of EPT	0.509	0.568	3	2	No change.
CA Axis 1	**<0.001**	**0.017**	46	8	Decreasing over time; lower in 2014 than mean of all previous years.
CA Axis 2	0.010	**0.004**	6	7	Lower in 2014 than mean of all previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.1-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Goose Island Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	0.115	**<0.001**	6	46	Lower in 2014 than mean of all previous years.
Log of Richness	0.719	**0.003**	1	43	Lower in 2014 than mean of all previous years.
Equitability	0.797	**0.002**	0	32	Lower in 2014 than mean of all previous years.
Log of EPT	**0.001**	**0.003**	55	45	Increasing over time; higher in 2014 than mean of all previous years.
CA Axis 1	**<0.001**	**<0.001**	62	21	Decreasing over time; lower in 2014 than mean of all previous years.
CA Axis 2	**<0.001**	**<0.001**	40	8	Increasing over time; lower in 2014 than mean of all previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.1-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Embarras River of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**0.041**	0.892	44	0	Decreasing over time.
Log of Richness	**0.025**	0.735	15	0	Decreasing over time.
Equitability	0.973	0.679	0	4	No change.
Log of EPT	**0.001**	0.071	77	18	Decreasing over time.
CA Axis 1	**<0.001**	0.161	38	4	Decreasing over time.
CA Axis 2	**<0.001**	0.540	39	1	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}$ (x+1) transformed.

Table 5.1-14 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC-1).

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	16.2	12	3.36	16.5	32
Silt	%	-	56	12	4.95	44.5	58
Sand	%	-	27.8	12	10	38.5	91.7
Total organic carbon	%	-	1.46	12	0.1	1.15	2.24
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<10	<21
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<10	<21
Fraction 2 (C10-C16)	mg/kg	150[1]	28	8	<5	<20	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	216	8	27	150	**307**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	158	8	29	101	199
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.005	12	0.002	0.008	0.024
Retene	mg/kg	-	0.058	12	0.016	0.048	0.096
Total dibenzothiophenes	mg/kg	-	0.321	12	0.104	0.228	0.358
Total PAHs	mg/kg	-	1.627	12	0.571	1.34	2.028
Total Parent PAHs	mg/kg	-	0.101	12	0.037	0.104	0.209
Total Alkylated PAHs	mg/kg	-	1.526	12	0.534	1.235	1.879
Predicted PAH toxicity[3]	H.I.	1.0	**1.16**	12	0.83	**1.221**	**2.59**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	NR[4]	11	3.2	7	9
Chironomus growth - 10d	mg/organism	-	NR[4]	11	0.89	1.85	4.11
Hyalella survival - 14d	# surviving	-	8.6	11	6.6	8	10
Hyalella growth - 14d	mg/organism	-	0.15	11	0.05	0.12	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

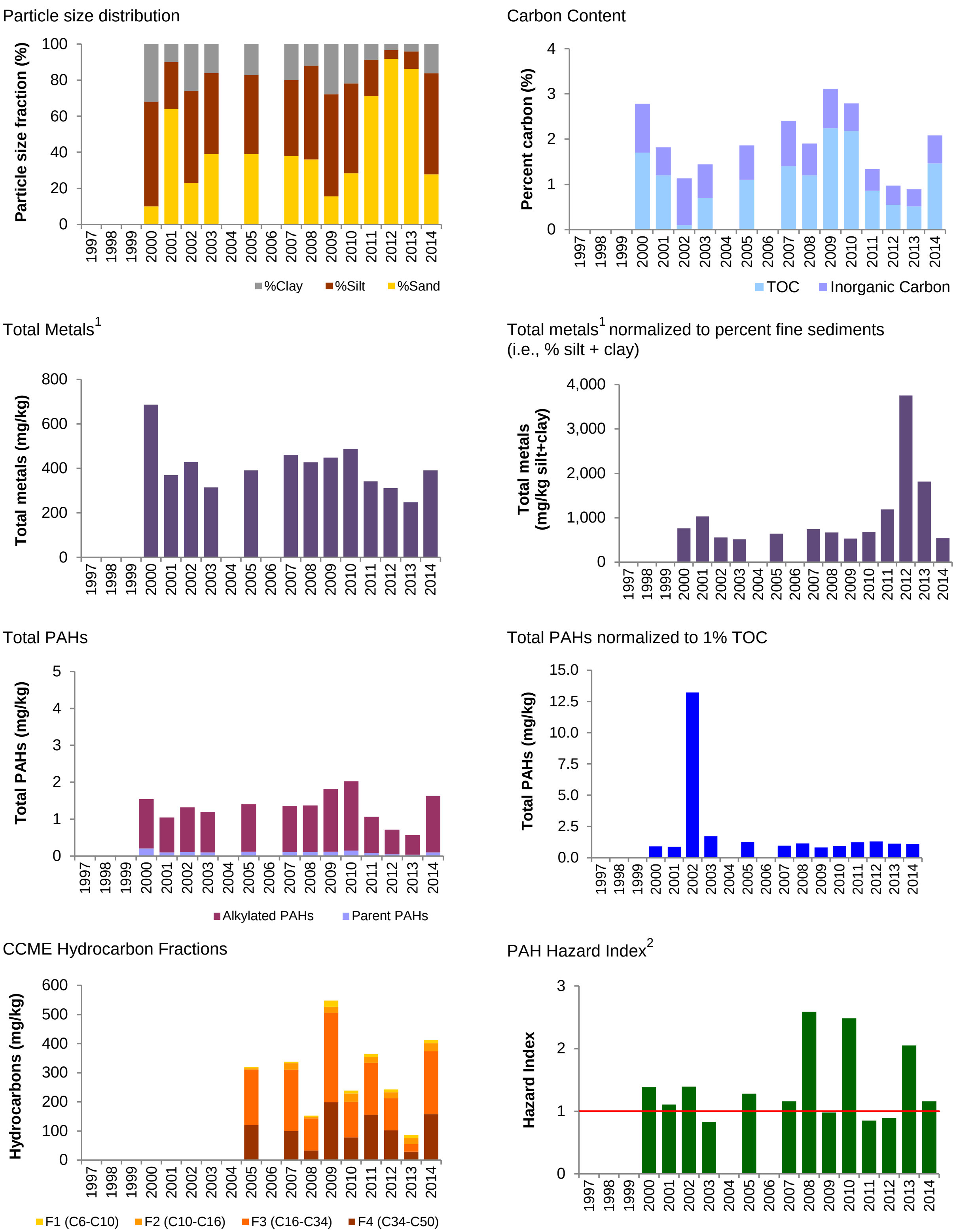
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[4] Laboratory control criteria not met, test results not reported.

Figure 5.1-8 Characteristics of sediment collected in Big Point Channel (BPC-1), 1999 to 2014 (fall data only).



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-15 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC-1).

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	16.8	11	3.56	14	22.8
Silt	%	-	56.8	11	3.44	38	72
Sand	%	-	26.4	11	11	46.6	93
Total organic carbon	%	-	1.89	11	0.58	1.3	2.22
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<10	30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<10	30
Fraction 2 (C10-C16)	mg/kg	150[1]	31	8	<5	22	37
Fraction 3 (C16-C34)	mg/kg	300[1]	260	8	68	249	**430**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	187	8	49	180	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0045	10	0.0021	0.0082	0.0156
Retene	mg/kg	-	0.054	11	0.02	0.044	0.157
Total dibenzothiophenes	mg/kg	-	0.361	11	0.089	0.185	0.686
Total PAHs	mg/kg	-	1.626	11	0.586	1.213	3.206
Total Parent PAHs	mg/kg	-	0.089	11	0.041	0.1	0.16
Total Alkylated PAHs	mg/kg	-	1.537	11	0.545	1.113	3.065
Predicted PAH toxicity[3]	H.I.	1.0	0.975	11	0.4	0.883	**5.357**
Metals that exceeded CCME guidelines in 2014							
Total Arsenic		5.9	**6.09**	11	3.20	4.78	**6.20**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	NR[4]	9	3.4	6.8	9.4
Chironomus growth - 10d	mg/organism	-	NR[4]	9	1.08	2.29	4.26
Hyalella survival - 14d	# surviving	-	9.0	9	8.0	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.21	9	0.1	0.23	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

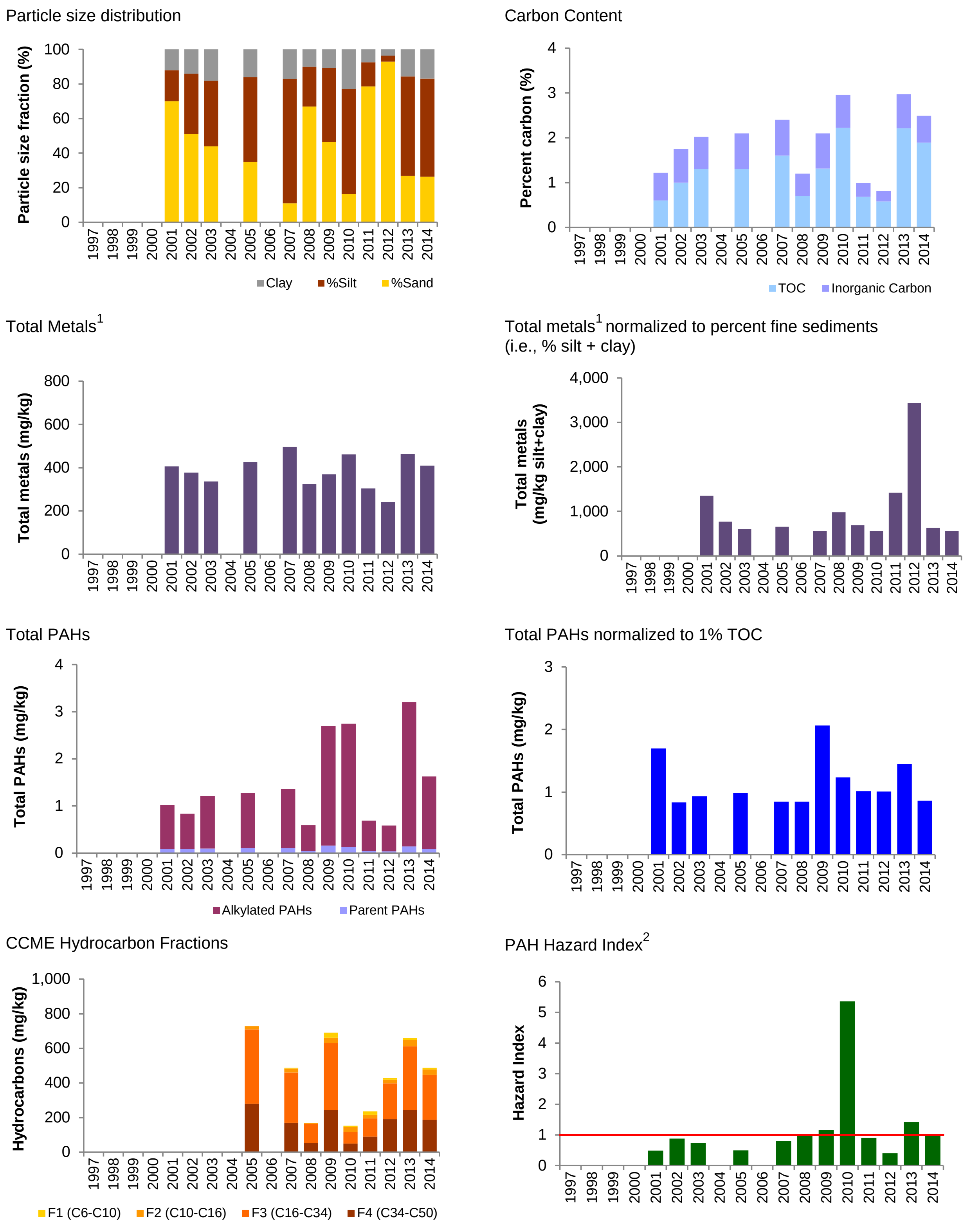
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[4] Laboratory control criteria not met, test results not reported.

Figure 5.1-9 Characteristics of sediment collected in Fletcher Channel (FLC-1), 2001 to 2014 (fall data only).



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-16 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC-1).

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	18.9	11	2.2	14.1	28
Silt	%	-	63.7	11	8.8	46	58
Sand	%	-	17.4	11	17	38.5	89
Total organic carbon	%	-	2.37	11	0.47	1.43	2.4
Total hydrocarbons							
BTEX	mg/kg	-	<20	8	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	8	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	48	8	<5	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	**395**	8	39.0	169	**360**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	275	8	46.0	113	200
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<0.00014	11	0.0028	0.0069	0.0146
Retene	mg/kg	-	0.116	11	0.006	0.044	0.078
Total dibenzothiophenes	mg/kg	-	0.825	11	0.043	0.223	0.412
Total PAHs	mg/kg	-	3.151	11	0.294	1.239	2.161
Total Parent PAHs	mg/kg	-	0.133	11	0.021	0.11	0.177
Total Alkylated PAHs	mg/kg	-	3.017	11	0.273	1.126	1.984
Predicted PAH toxicity[3]	H.I.	1.0	**1.26**	11	0.64	**1.1**	**1.88**
Metals that exceeded CCME guidelines in 2014							
Total Arsenic	mg/kg	5.9	**7.27**	11	2.93	4.51	**6.60**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	NR[4]	9	4.0	7.2	8.4
Chironomus growth - 10d	mg/organism	-	NR[4]	9	1.34	2.15	4.22
Hyalella survival - 14d	# surviving	-	9.0	9	7.0	9.0	10
Hyalella growth - 14d	mg/organism	-	0.27	9	0.1	0.18	0.3

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

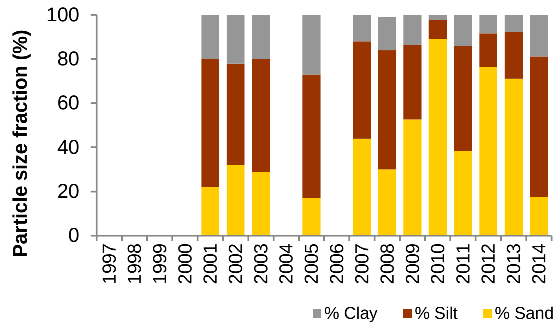
2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

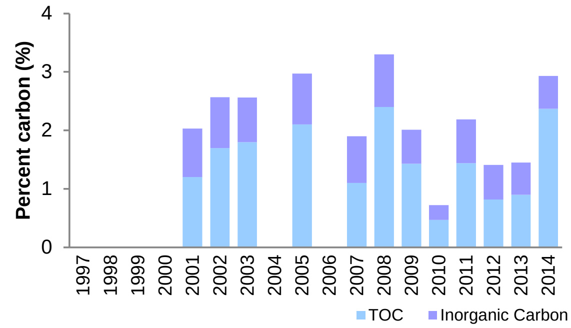
4 Laboratory control criteria not met, test results not reported.

Figure 5.1-10 Characteristics of sediment collected in Goose Island Channel (GIC-1), 2001 to 2014 (fall data only).

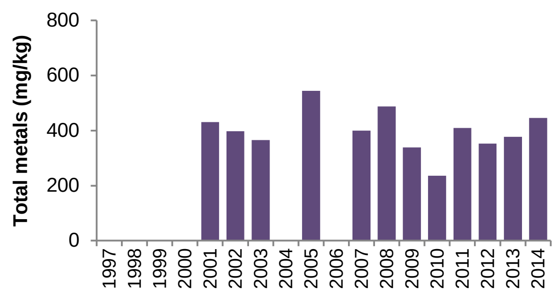
Particle size distribution



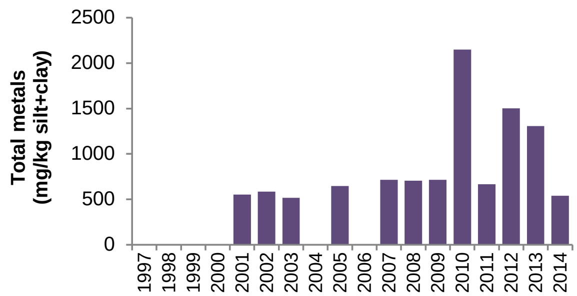
Carbon Content



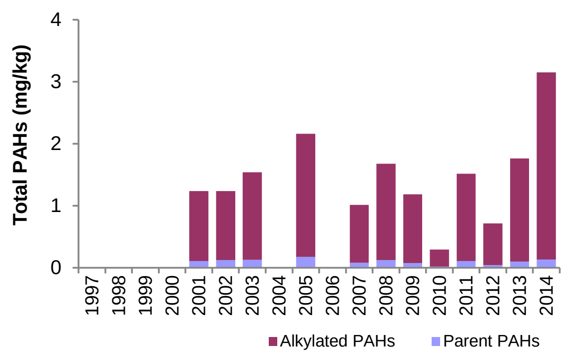
Total Metals[1]



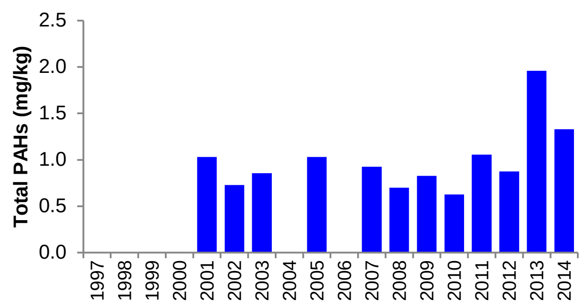
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



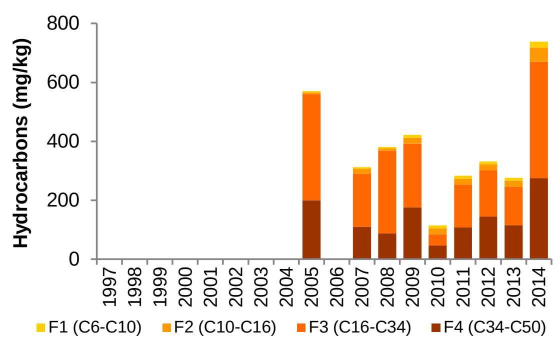
Total PAHs



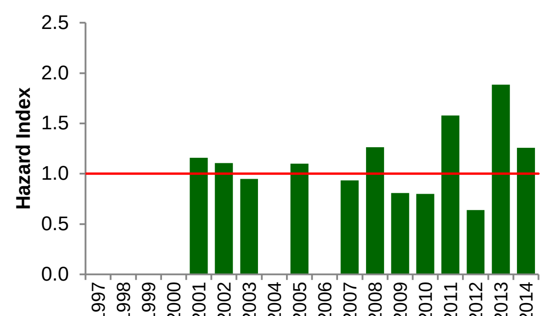
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-17 Concentrations of sediment quality measurement endpoints, Embarras River (EMR-2).

Variables	Units	Guideline	September 2014	2005-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	31.8	4	27.5	34.1	43.0
Silt	%	-	<u>67.1</u>	4	46.8	54.0	57.4
Sand	%	-	<u>1.1</u>	4	4.0	9.8	25.7
Total organic carbon	%	-	2.45	4	2.41	2.59	2.68
Total hydrocarbons							
BTEX	mg/kg	-	<20	4	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	4	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	38	4	<5	<33	54
Fraction 3 (C16-C34)	mg/kg	300[1]	292	4	54	262	**390**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<u>196</u>	4	36	169	190
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0058</u>	4	0.0113	0.0152	0.0245
Retene	mg/kg	-	<u>0.139</u>	4	0.072	0.105	0.13
Total dibenzothiophenes	mg/kg	-	<u>0.577</u>	4	0.278	0.488	0.507
Total PAHs	mg/kg	-	2.46	4	2.09	2.62	2.69
Total Parent PAHs	mg/kg	-	<u>0.131</u>	4	0.163	0.17	0.204
Total Alkylated PAHs	mg/kg	-	2.33	4	1.92	2.44	2.53
Predicted PAH toxicity[3]	H.I.	1.0	**1.34**	4	**1.29**	**1.42**	**5.96**
Metals that exceeded CCME guidelines in 2014							
Total Arsenic	mg/kg	5.9	**<u>8.9</u>**	4	**7.0**	**7.8**	**8.2**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	NR[4]	3	6.2	6.8	7.4
Chironomus growth - 10d	mg/organism	-	NR[4]	3	1.62	2.04	2.45
Hyalella survival - 14d	# surviving	-	8.6	3	4.2	8.8	9.4
Hyalella growth - 14d	mg/organism	-	0.19	3	0.1	0.2	0.21

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

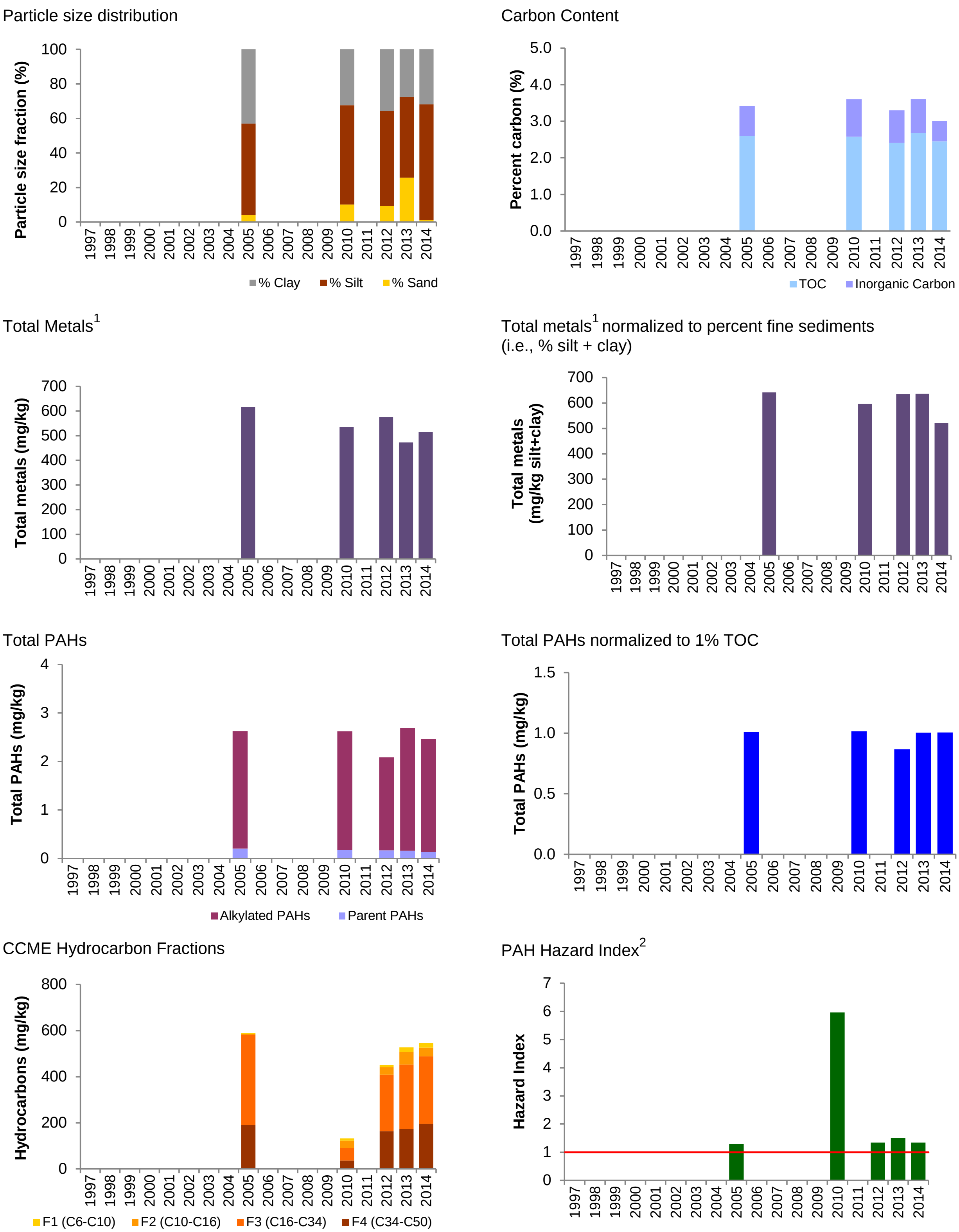
1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

4 Laboratory control criteria not met, test results not reported.

Figure 5.1-11 Characteristics of sediment collected in the Embarras River (EMR-2), 2005, 2010, and 2012 to 2014 (fall data only).



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-18 Total number and percent composition of fish species captured in the Athabasca River during the spring, summer, and fall fish inventories, 2014.

Species	Spring		Summer		Fall	
	No.	%	No.	%	No.	%
burbot	9	0.7	7	1.0	4	0.6
emerald shiner	6	0.5	109	15.6	24	3.3
flathead chub	91	7.1	149	21.3	221	30.3
goldeye*	231	18.1	302	43.2	51	7.0
lake chub	8	0.6	16	2.3	10	1.4
lake whitefish*	7	0.6	4	0.6	18	2.5
longnose sucker*	46	3.6	27	3.9	58	8.0
mountain whitefish	-	-	1	0.1	-	-
northern pike*	18	1.4	4	0.6	5	0.7
pearl dace	2	0.2	-	-	-	-
spottail shiner	7	0.6	22	3.3	9	1.2
trout-perch*	308	24.2	19	2.7	155	21.2
walleye*	106	8.3	36	5.2	142	19.5
white sucker*	436	34.2	3	0.4	15	2.1
yellow perch	-	-	-	-	18	2.5
Total	**1,275**	**100**	**699**	**100**	**730**	**100**

* Denotes KIR species.

Figure 5.1-12 Total species richness and catch from all sampled reaches of the Athabasca River, 1987 to 2014.

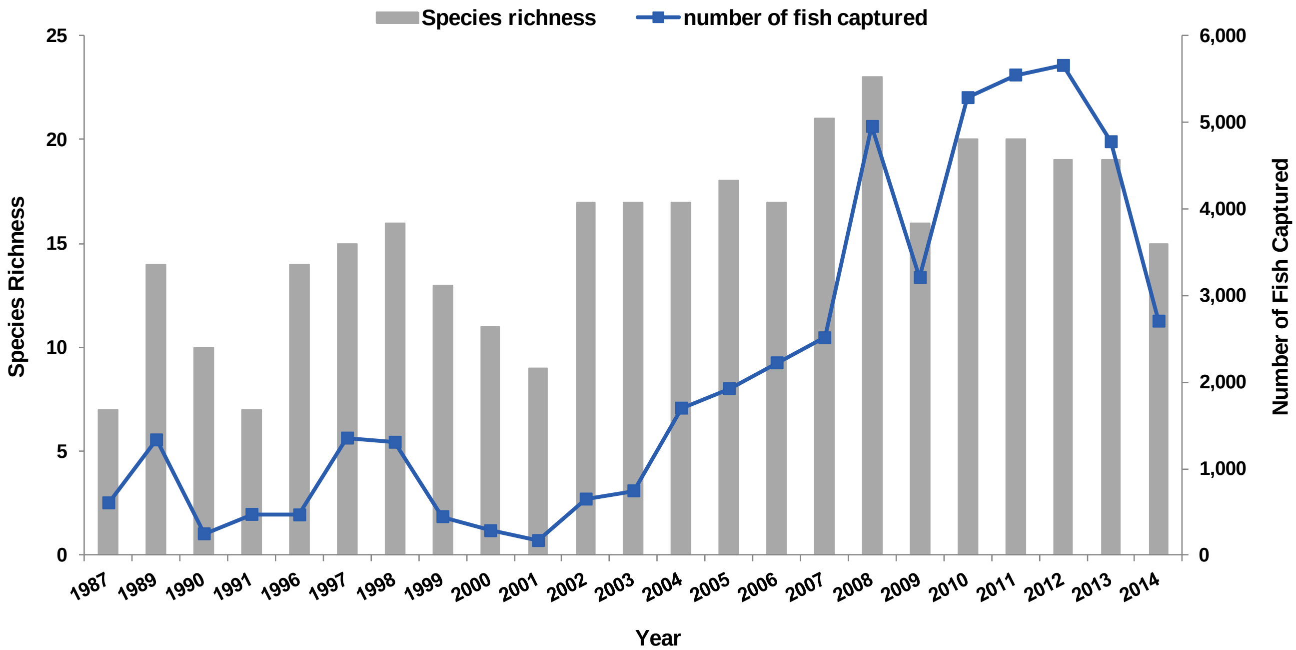


Figure 5.1-13 Number of species captured in each sampling area of the Athabasca River during the spring, summer, and fall fish inventories, 2009 to 2014.

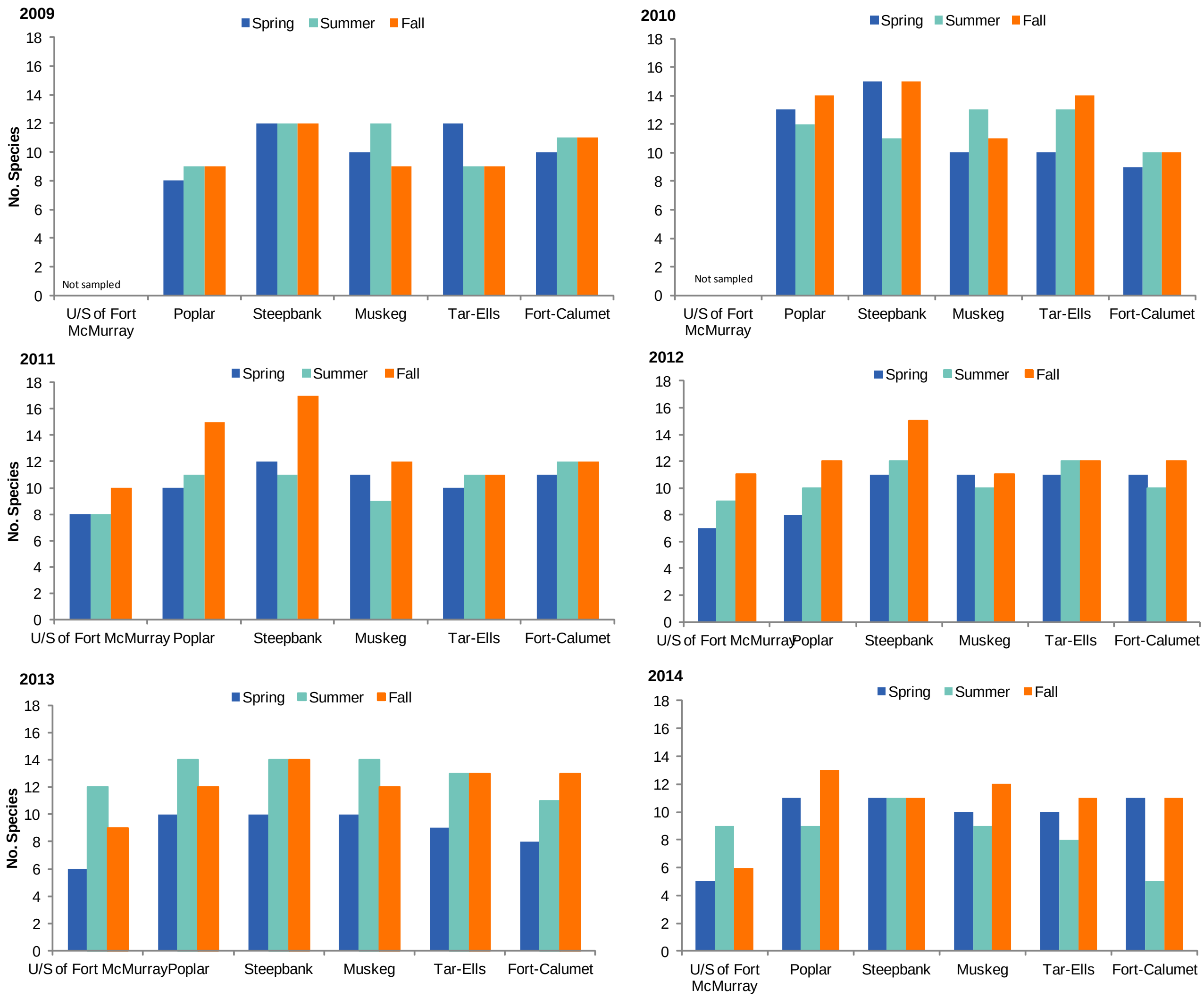
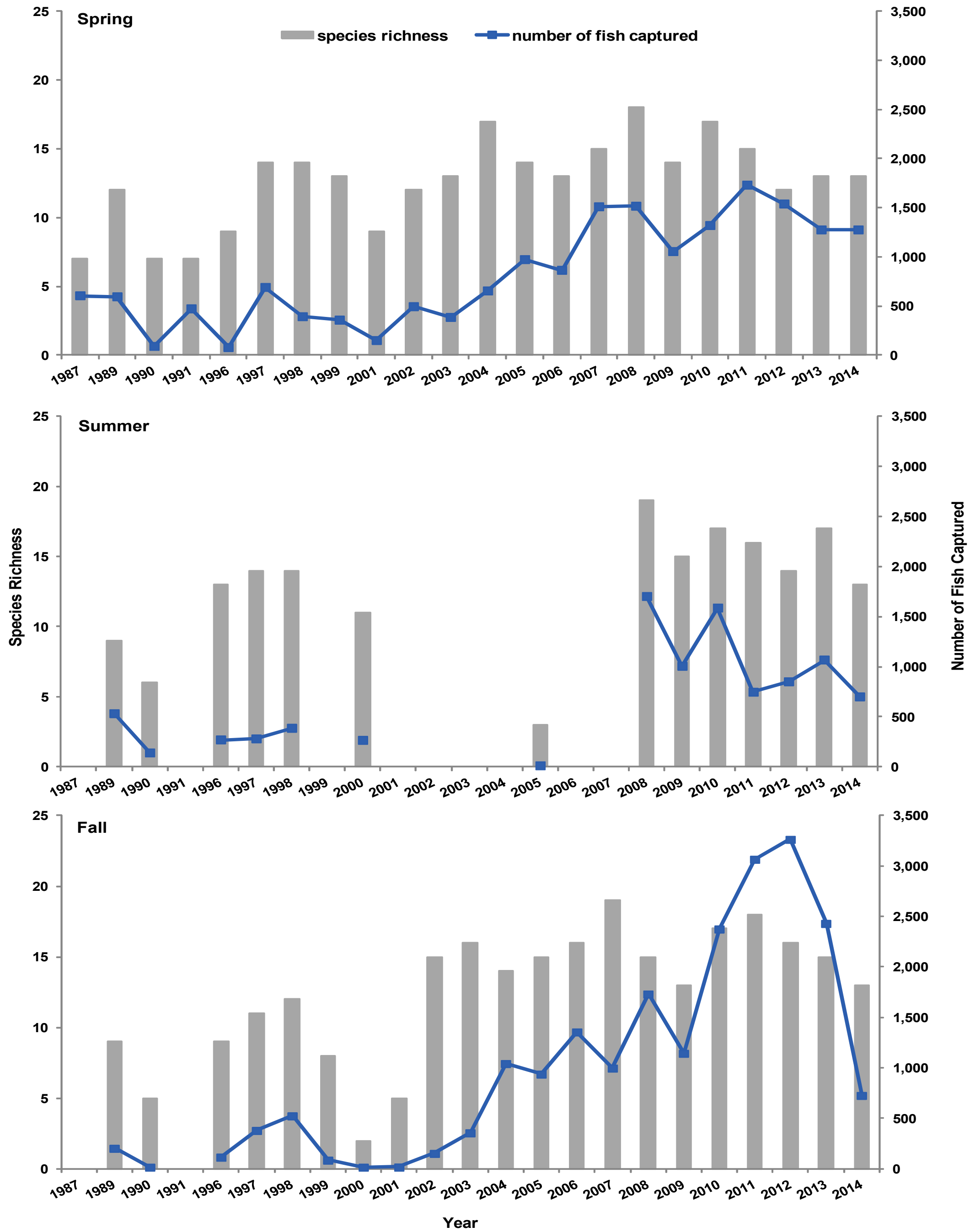


Figure 5.1-14 Total species richness and catch from all sampled reaches of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: The large decrease in total catch in fall 2014 was due to a restriction outlined in the AESRD FRL, which did not allow fishing during the lake whitefish spawning period. Therefore, sampling was conducted earlier than in previous years.

Figure 5.1-15 Percent composition of large-bodied KIR species captured during the Athabasca River spring, summer, and fall fish inventories, 1987 to 2014.

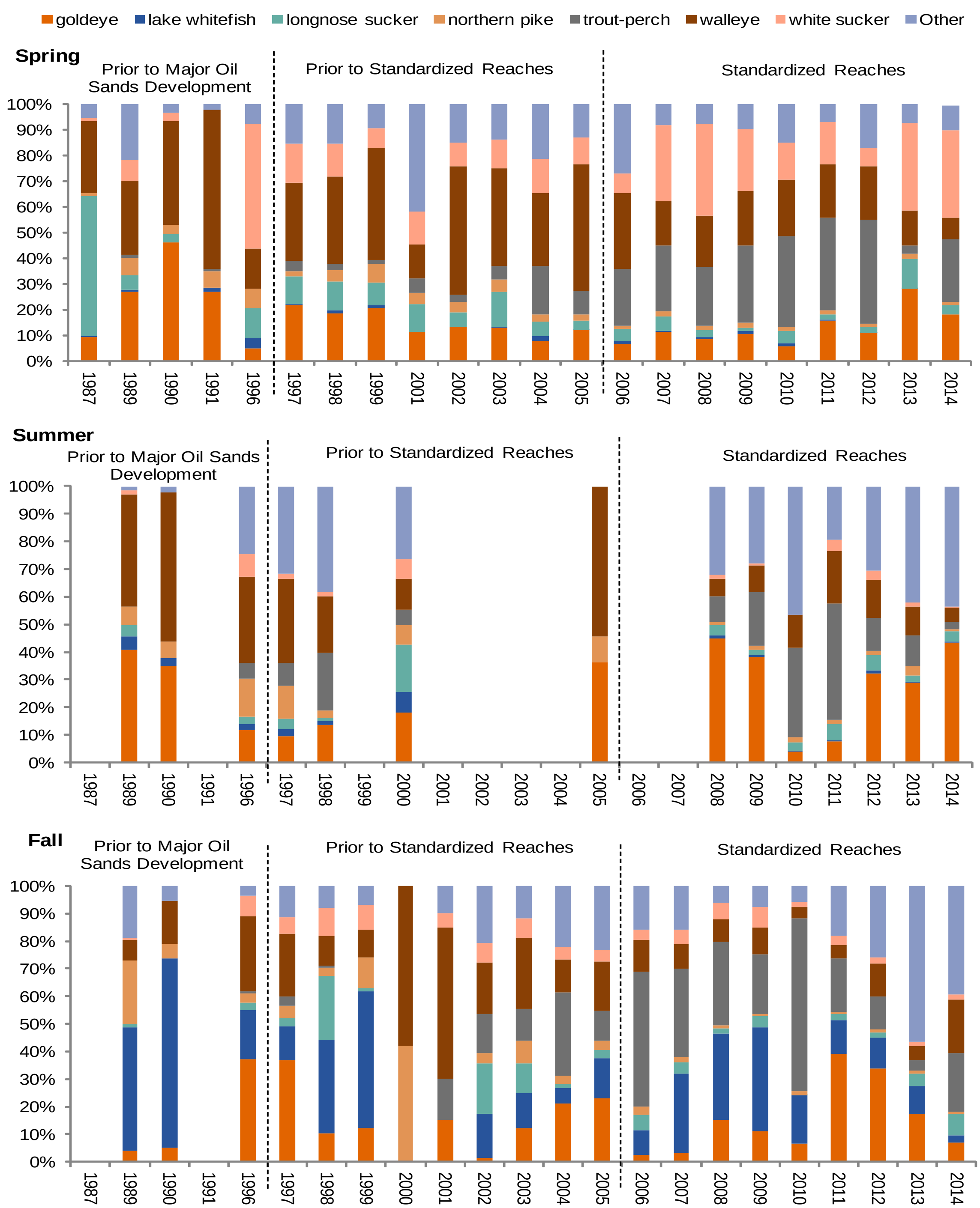


Table 5.1-19 Percent composition of species in the Athabasca River captured in each area during the spring, summer, and fall fish inventories, 2014.

Species	Spring						Summer						Fall					
	U/S of Fort McMurray	Poplar	Steepbank	Muskeg	Tar-Ells	Fort-Calumet	U/S of Fort McMurray	Poplar	Steepbank	Muskeg	Tar-Ells	Fort-Calumet	U/S of Fort McMurray	Poplar	Steepbank	Muskeg	Tar-Ells	Fort-Calumet
burbot	-	-	1.2	0.3	1.5	0.7	-	-	1.3	3.9	-	1.8	-	0.7	1.6	0.5	-	-
emerald shiner	-	1.1	-	-	0.7	2.2	**25.6**	13.6	**18.7**	3.9	13.0	1.8	-	2.8	-	3.8	4.7	7.3
flathead chub	-	1.7	9.4	5.9	5.8	13.3	23.2	**24.6**	14.0	**38.5**	**23.2**	**35.1**	**31.7**	19.2	12.7	**48.3**	18.6	**47.6**
goldeye	**33.3**	**38.3**	15.5	11.9	10.2	**23.0**	**32.9**	**31.4**	**47.4**	**32.7**	**55.1**	**54.4**	**19.5**	5.0	15.1	6.6	0.8	2.4
lake chub	-	1.1	0.7	-	-	2.2	3.7	2.5	1.6	5.8	2.9	-	-	0.7	4.8	-	0.8	2.4
lake whitefish	-	0.6	0.5	0.8	-	0.7	-	-	-	5.8	1.5	-	-	0.7	7.1	1.4	2.3	2.4
mountain whitefish	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-
longnose sucker	4.8	5.6	3.9	2.3	6.6	0.7	1.2	9.3	3.4	5.8	1.5	-	17.1	15.6	7.9	5.7	4.7	1.2
pearl dace	-	-	-	0.3	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-
northern pike	4.8	1.7	0.7	1.3	3.7	0.7	1.2	-	0.6	-	1.5	-	-	1.4	-	1.0	-	1.2
spottail shiner	-	0.6	1.5	-	-	-	1.2	5.1	4.7	-	-	-	4.9	0.7	2.4	1.0	0.8	-
trout perch	**9.5**	**20.0**	**40.1**	**13.9**	**7.3**	**29.6**	2.4	9.3	1.9	-	-	-	12.2	**24.1**	**16.7**	15.6	**41.1**	10.9
walleye	47.6	10.6	9.2	4.1	7.3	9.6	8.5	2.5	6.2	1.9	1.5	7.2	14.6	**27.0**	**23.8**	**9.0**	**24.0**	**22.0**
white sucker	-	18.9	17.4	**59.3**	**56.2**	17.0	-	1.7	-	1.9	-	-	-	0.7	4.0	2.8	1.6	1.2
yellow perch	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	4.0	4.3	0.8	1.2
Total # of species	**2**	**11**	**11**	**10**	**10**	**11**	**9**	**9**	**11**	**9**	**8**	**5**	**6**	**13**	**11**	**12**	**11**	**11**
Total Count	**21**	**180**	**414**	**388**	**137**	**135**	**82**	**118**	**321**	**52**	**69**	**57**	**41**	**141**	**126**	**211**	**129**	**82**

Note: Underlined bold values denote the most abundant large-bodied species; **bold** values denote the most abundant small-bodied species.

Figure 5.1-16 Mean CPUE (±1SD) of KIR fish species captured from each area of the Athabasca River during spring, summer, and fall fish inventories in 2014.

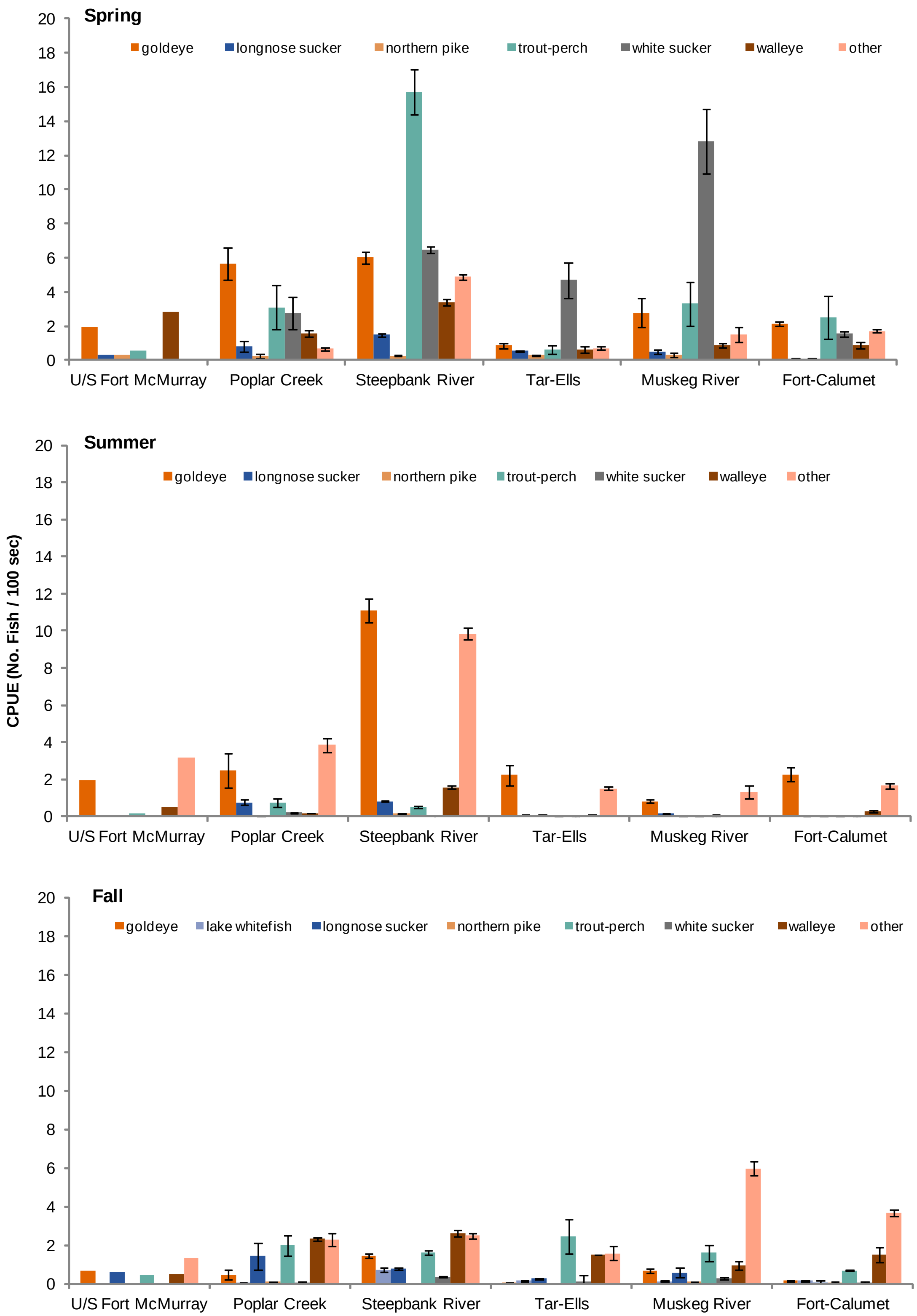
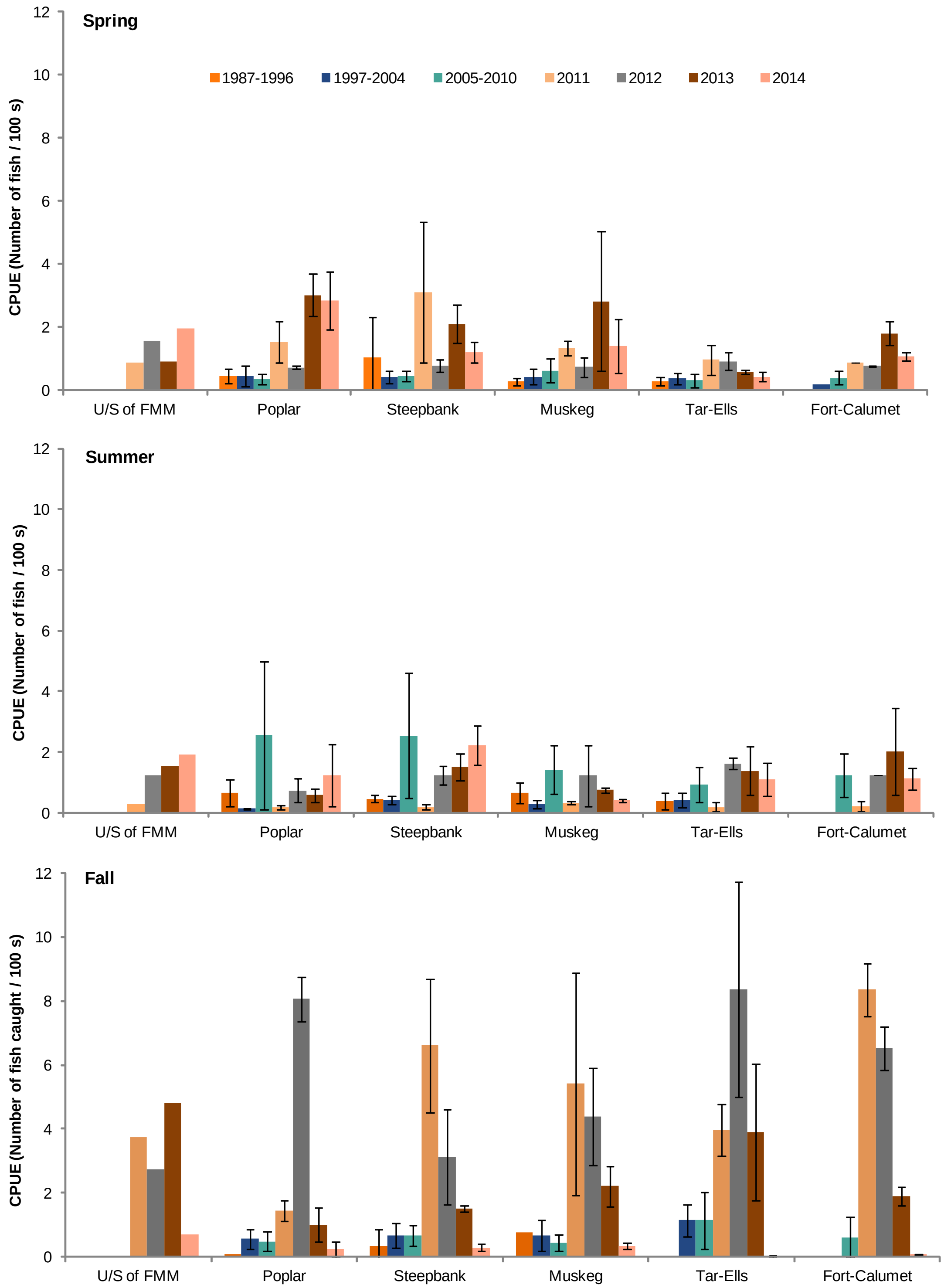


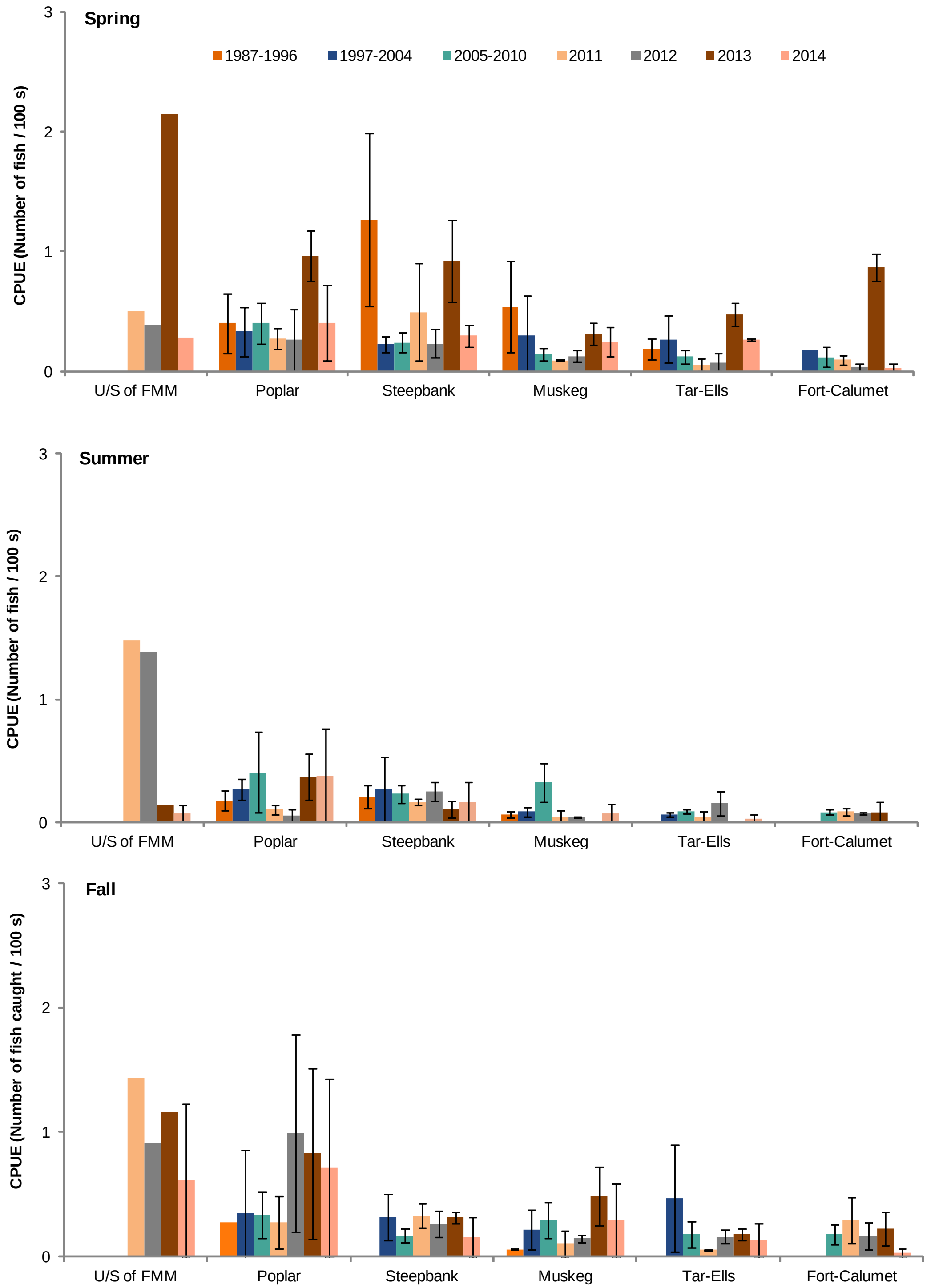
Figure 5.1-17 Mean CPUE (±1SD) of goldeye captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

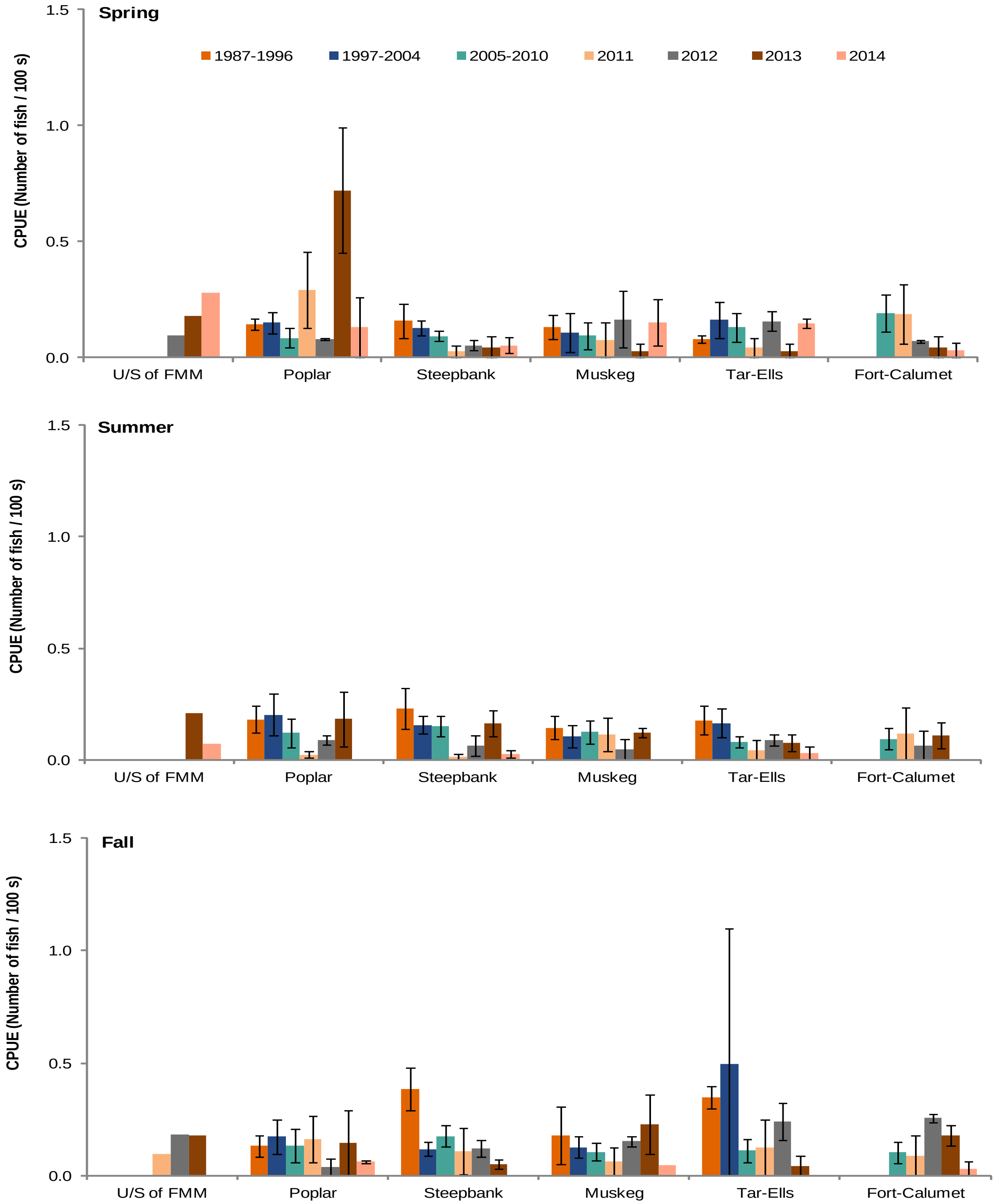
Figure 5.1-18 Mean CPUE (±1SD) of longnose sucker captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

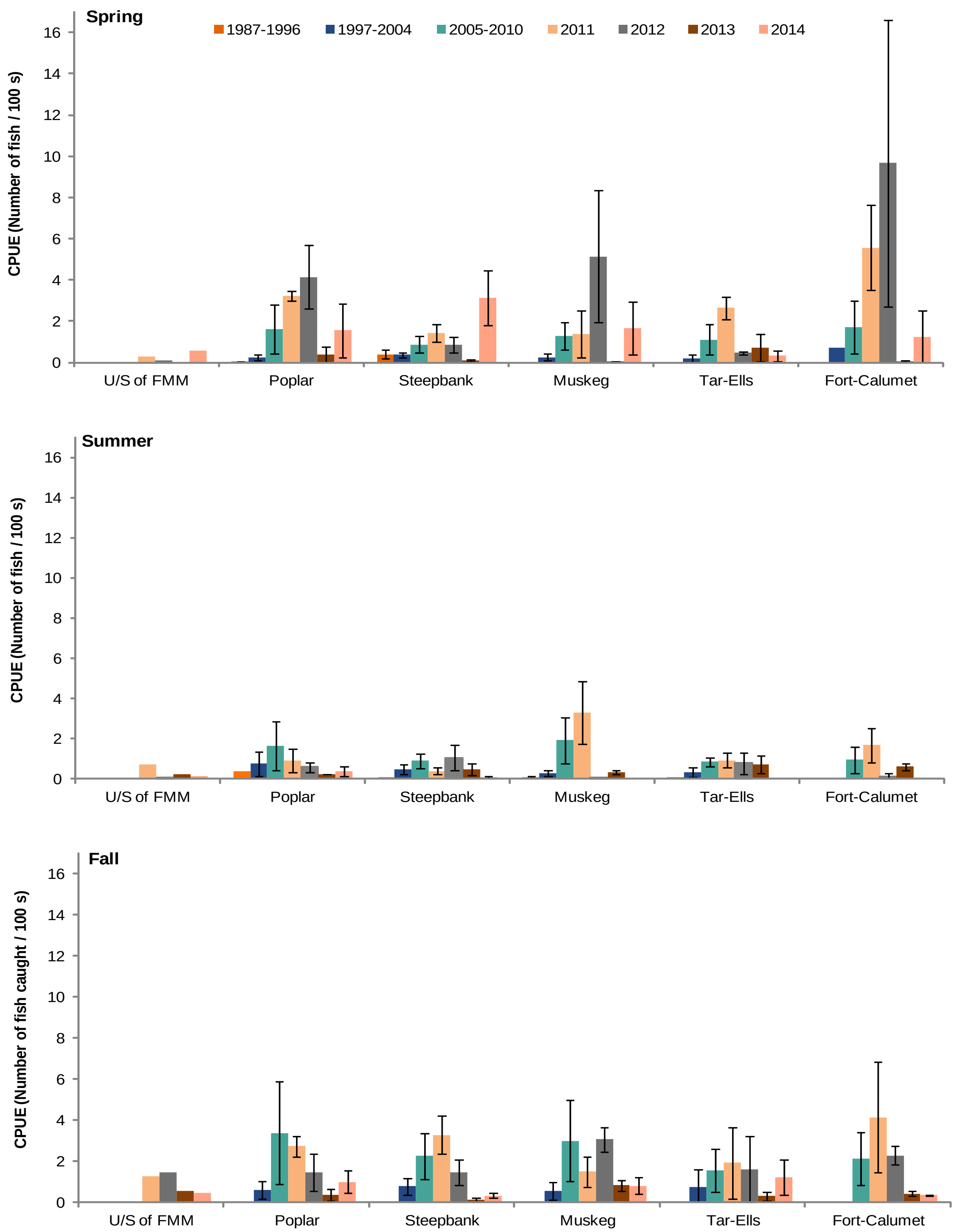
Figure 5.1-19 Mean CPUE (±1SD) of northern pike captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

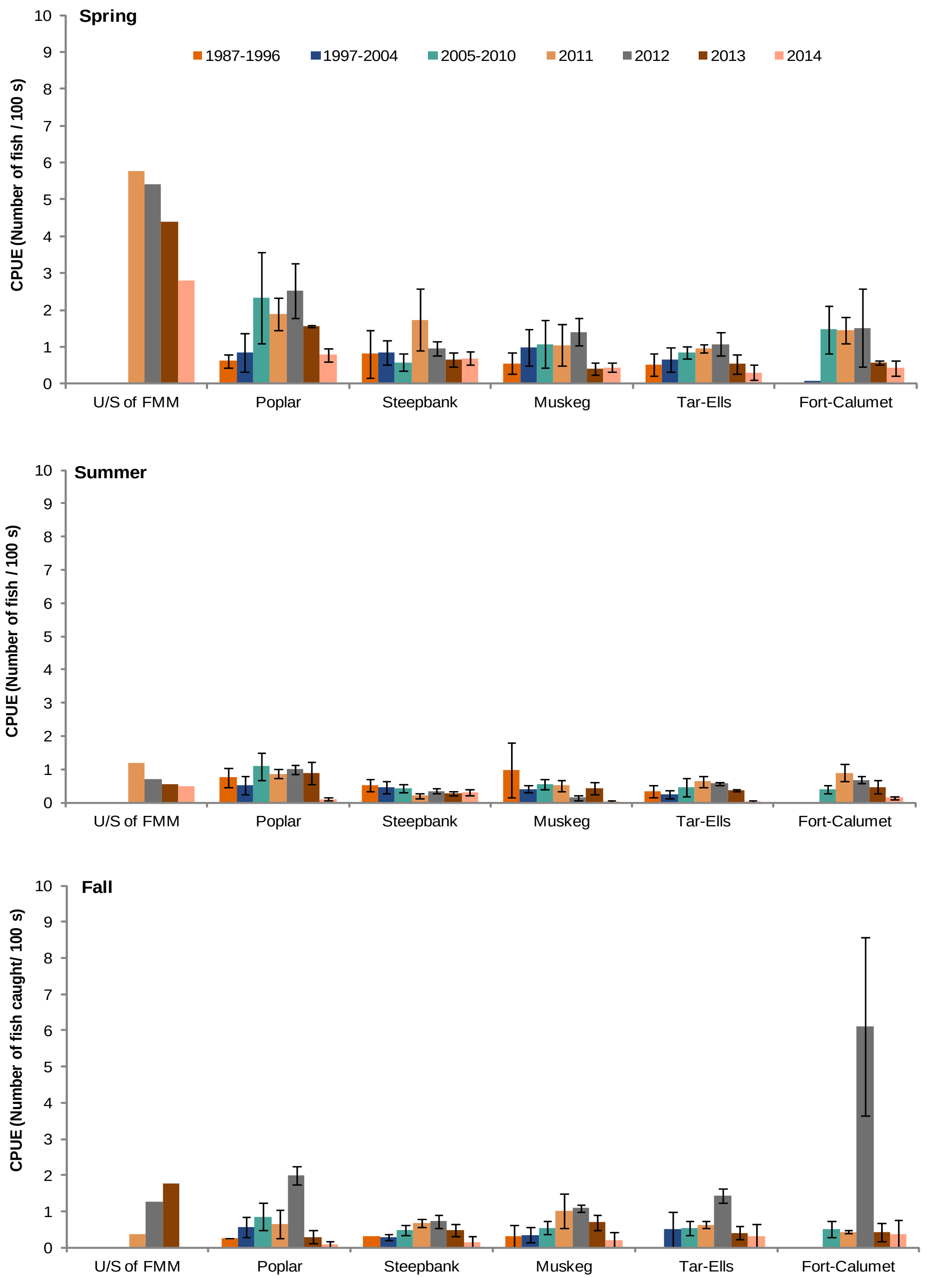
Figure 5.1-20 Mean CPUE (±1SD) of trout-perch captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

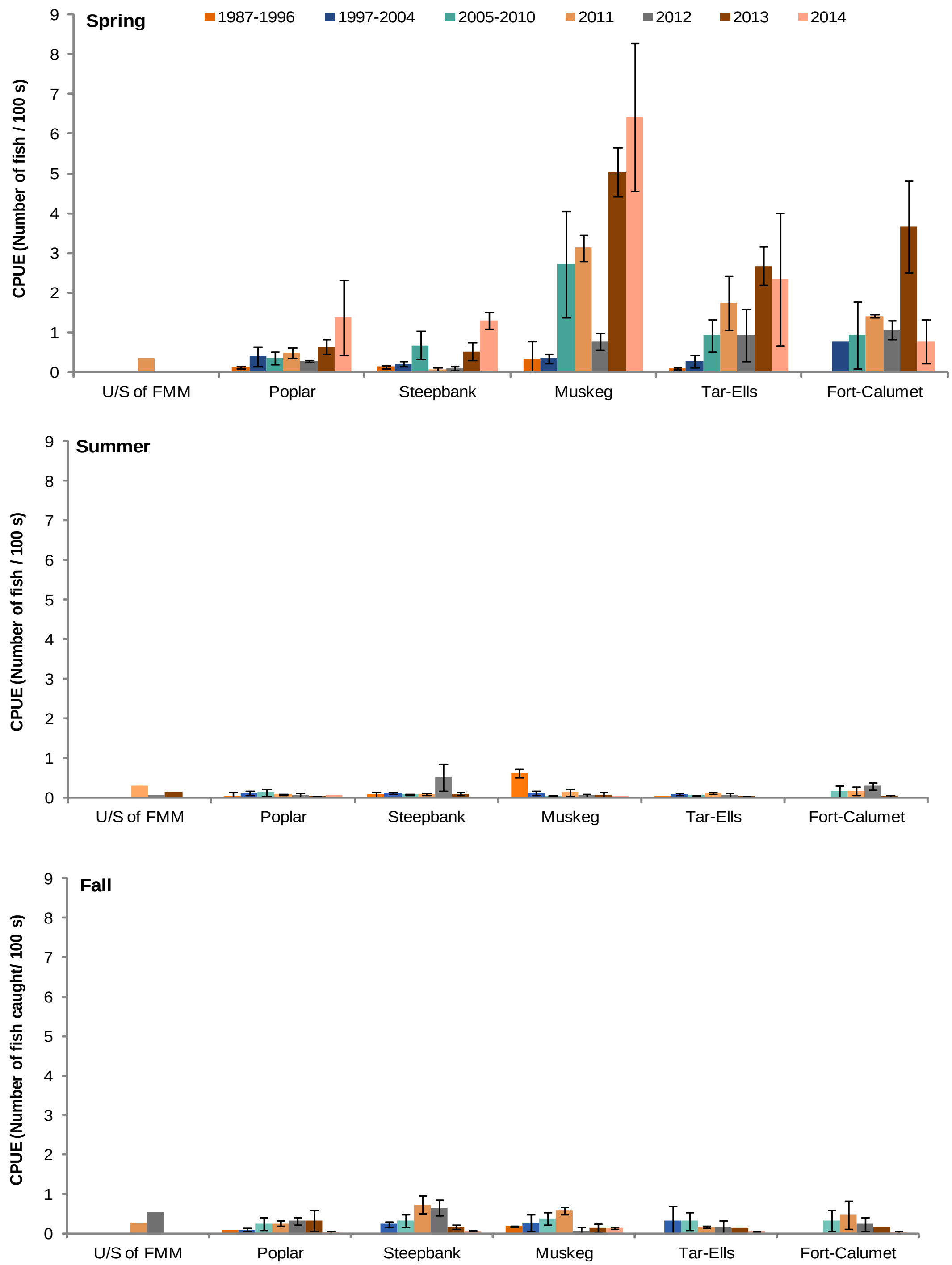
Figure 5.1-21 Mean CPUE (±1SD) of walleye captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

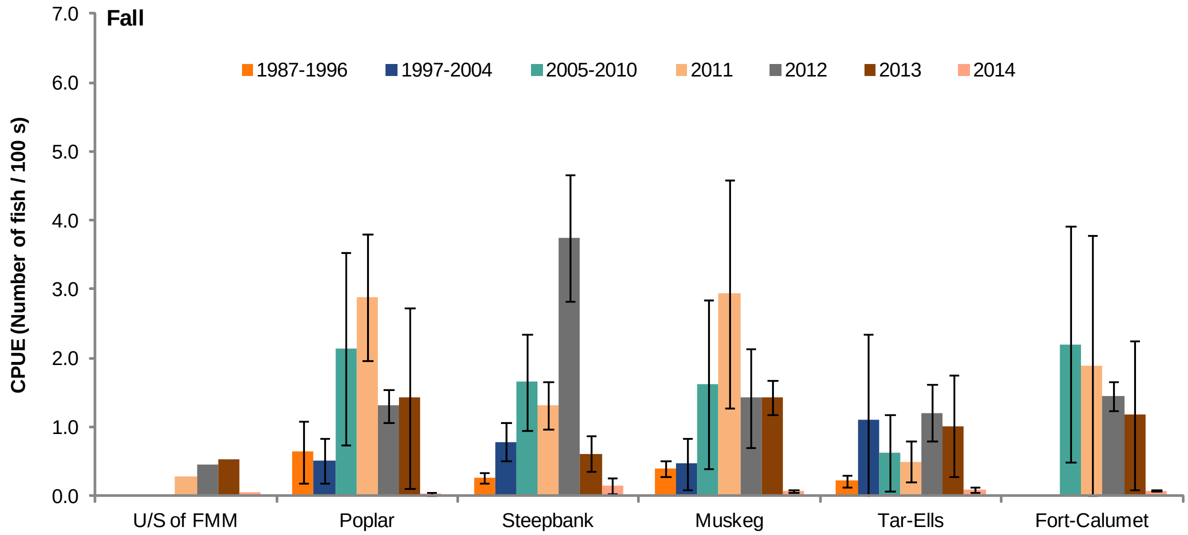
Figure 5.1-22 Mean CPUE (±1SD) of white sucker captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Note: The reach upstream of Fort McMurray was not completed in spring 2014 due to restrictions in the AESRD FRL regarding fishing during the sportfish spawning period.

Figure 5.1-23 Mean CPUE (±1SD) of lake whitefish captured from each area of the Athabasca River during spring, summer, and fall fish inventories, 1987 to 2014.



Note: Lake whitefish were not captured in spring or summer.

Note: The decrease in CPUE of lake whitefish in fall 2014 was due to a restriction outlined in the AESRD FRL, which did not allow fishing during the lake whitefish spawning period. Therefore, sampling was conducted earlier than in previous years.

Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Table 5.1-20 Results of temporal trend analyses of CPUE for KIR fish species in each sampled area of the Athabasca River, 1997 to 2014.

Area	Goldeye			Lake whitefish			Longnose sucker			Northern pike			Trout-perch			Walleye			White sucker		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Poplar	0.234	1.000	**+0.033**	0.504	0.944	0.099	0.086	0.014	**+0.007**	1.000	0.664	0.462	**+0.001**	0.625	**+0.002**	0.069	0.855	**+0.042**	**+0.025**	1.000	**+0.005**
Muskeg	0.069	0.250	0.069	0.857	0.864	**+0.001**	0.726	0.476	0.383	0.529	0.298	0.426	**+0.002**	0.207	**+0.002**	0.294	1.000	0.120	**+0.001**	1.000	0.069
Steepbank	0.417	0.945	0.151	0.352	1.000	**+0.009**	0.399	0.193	0.861	0.144	0.244	0.484	**+0.005**	**+0.019**	**+0.004**	0.496	0.451	0.050	0.846	0.492	**+0.032**
Tar-Ells	0.059	0.150	0.656	0.968	0.617	0.692	0.195	0.674	0.519	0.093	0.631	0.457	**+0.024**	0.241	**+0.026**	0.441	0.304	0.692	**+0.021**	0.721	0.767
Fort-Calumet	**-0.043**	1.000	0.474	0.122	0.180	**+0.032**	0.276	1.000	0.721	0.276	0.368	0.858	0.755	0.764	0.152	0.533	0.368	0.107	0.350	0.288	0.592

Bolded values denotes significant trend ($p<0.05$).

Note: All significant trends were assessed to be either increasing (+) or decreasing (-).

Note: A trend analysis could not be completed for the *baseline* area due to an insufficient number of sampling years.

Table 5.1-21 Number of ageing structures for each fish species used in age-frequency distributions and size-at-age relationships for large-bodied KIR species in the Athabasca River.

Year	Sample Size (n)					
	Goldeye	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
1997 to 2011	328	234	207	110	1,169	224
2012	353	99	88	56	353	150
2013	330	90	137	72	266	147
2014	232	29	88	25	145	146

Figure 5.1-24 Relative age-frequency distributions and size-at-age relationship for goldeye captured in the Athabasca River from 1997 to 2014.

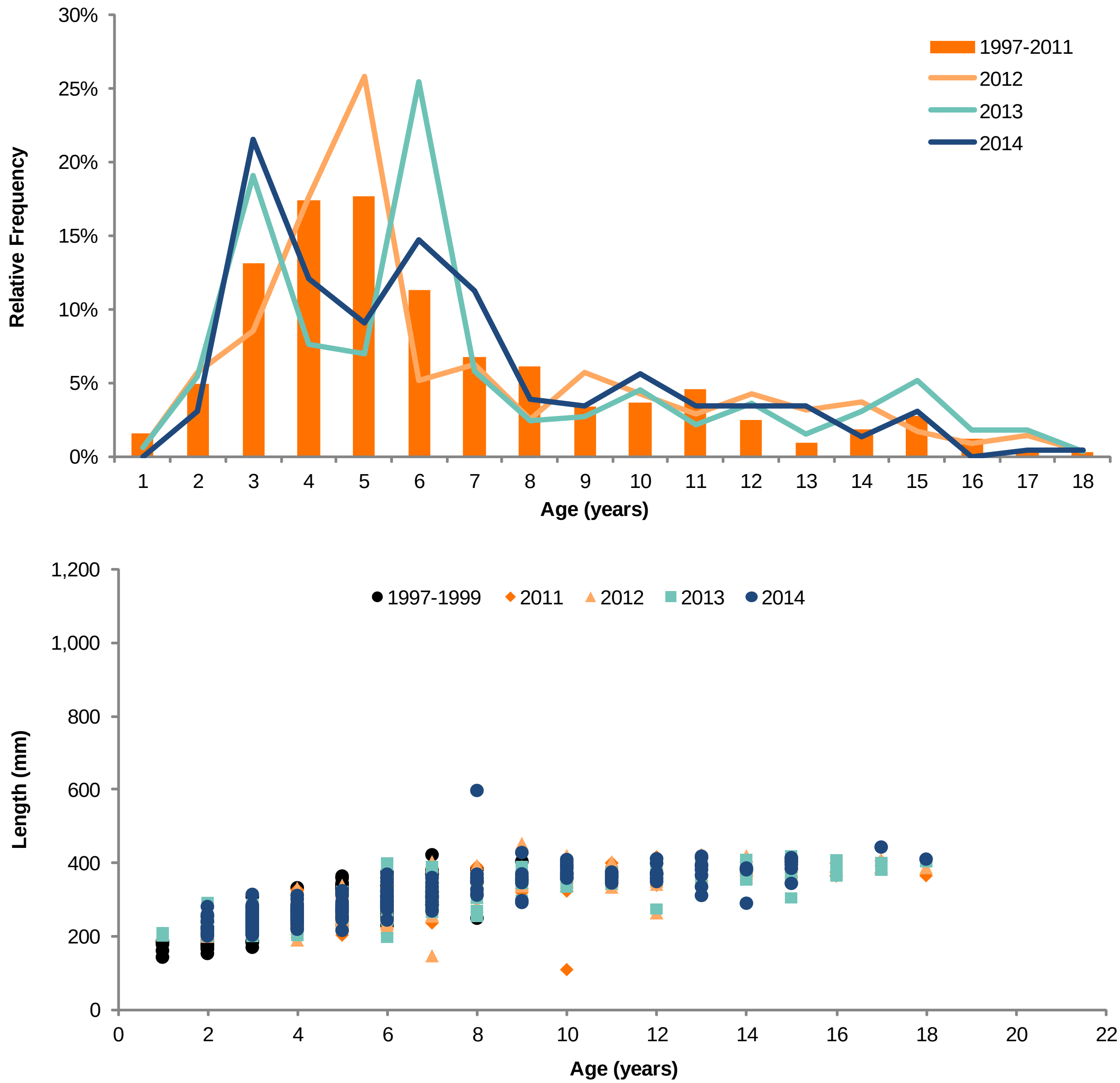


Figure 5.1-25 Relative age-frequency distributions and size-at-age relationship for longnose sucker captured in the Athabasca River from 1997 to 2014.

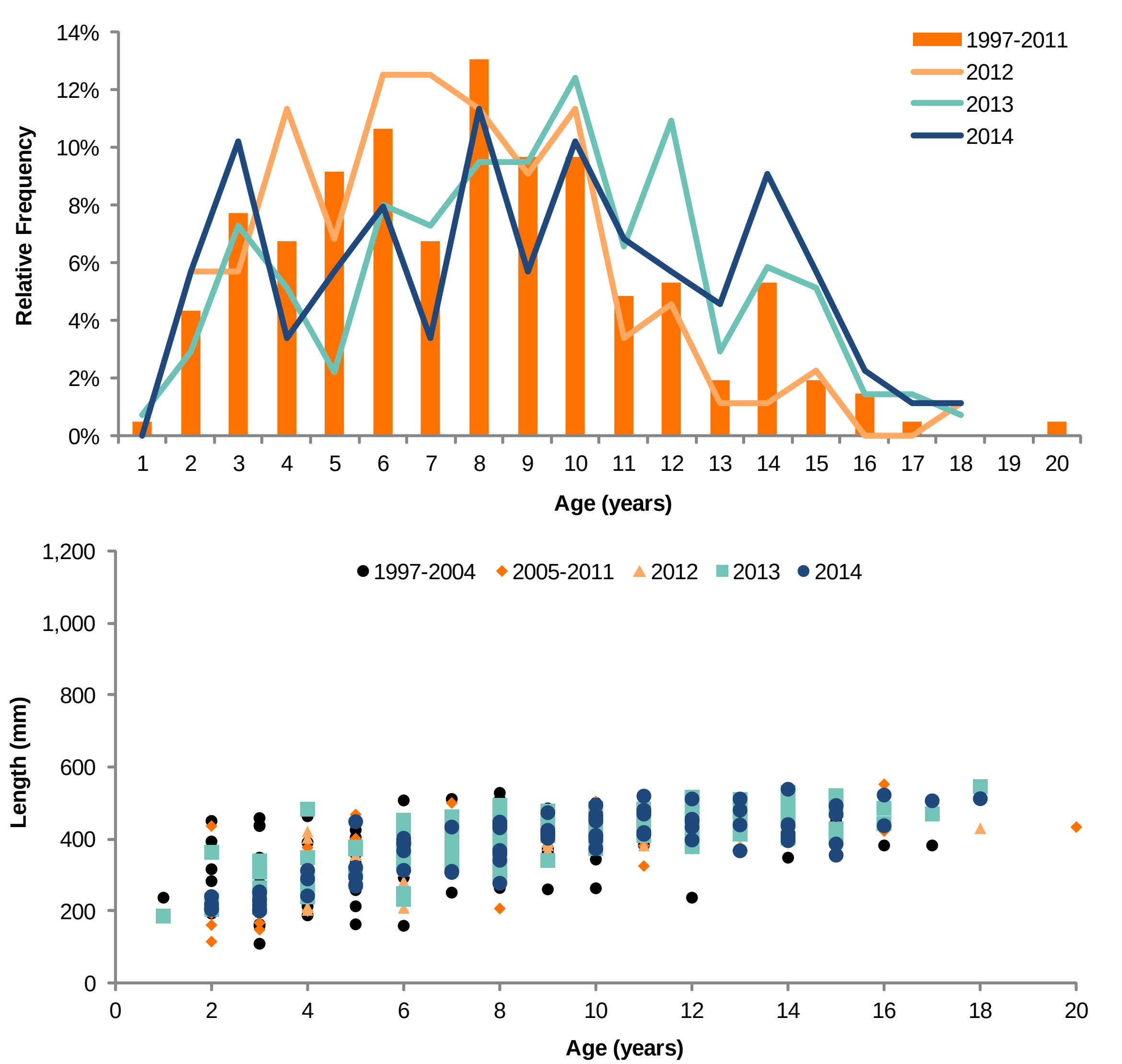


Figure 5.1-26 Relative age-frequency distributions and size-at-age relationship for northern pike captured in the Athabasca River from 1987 to 2014.

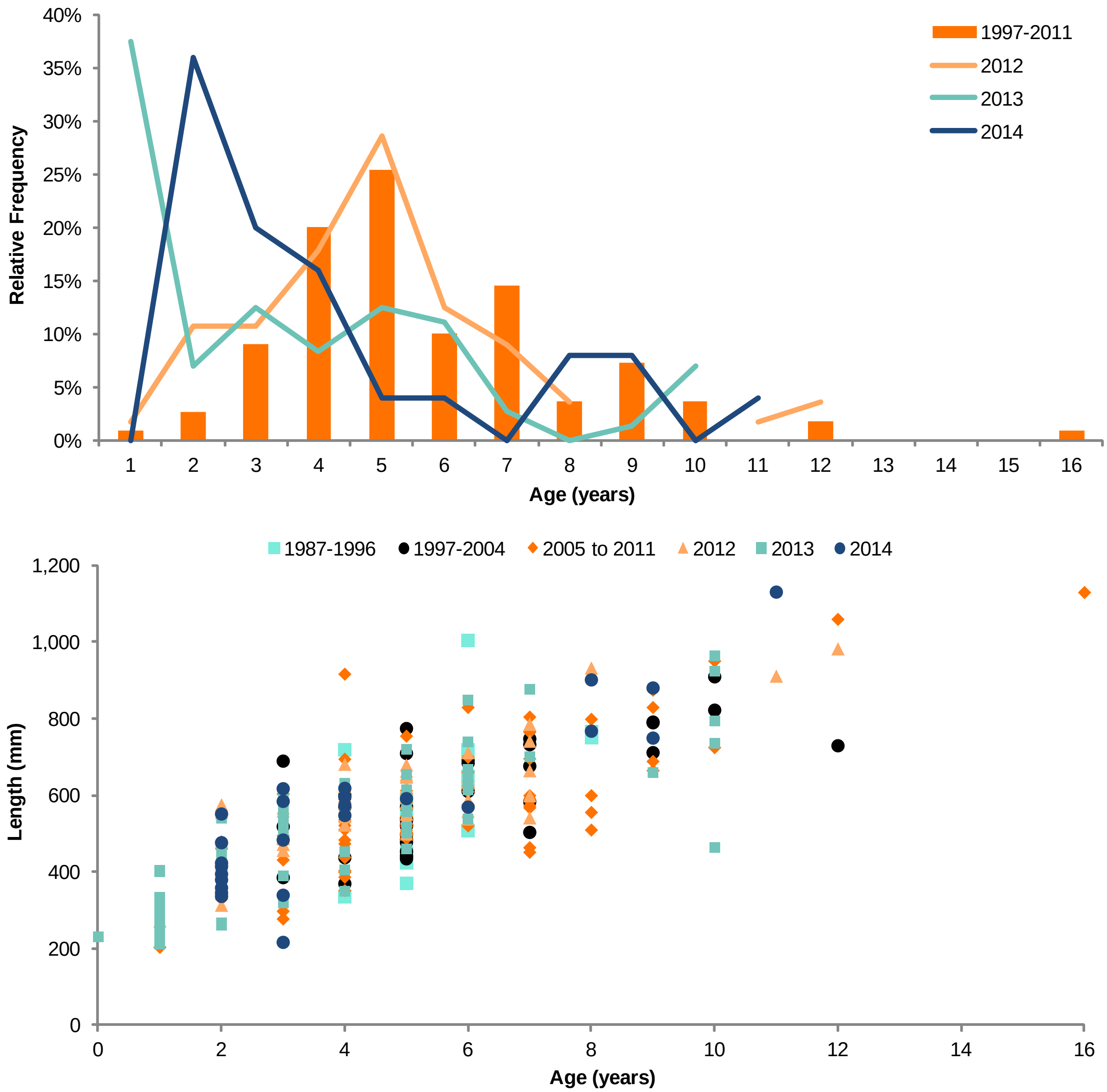


Figure 5.1-27 Relative age-frequency distributions and size-at-age relationship for walleye captured in the Athabasca River from 1987 to 2014.

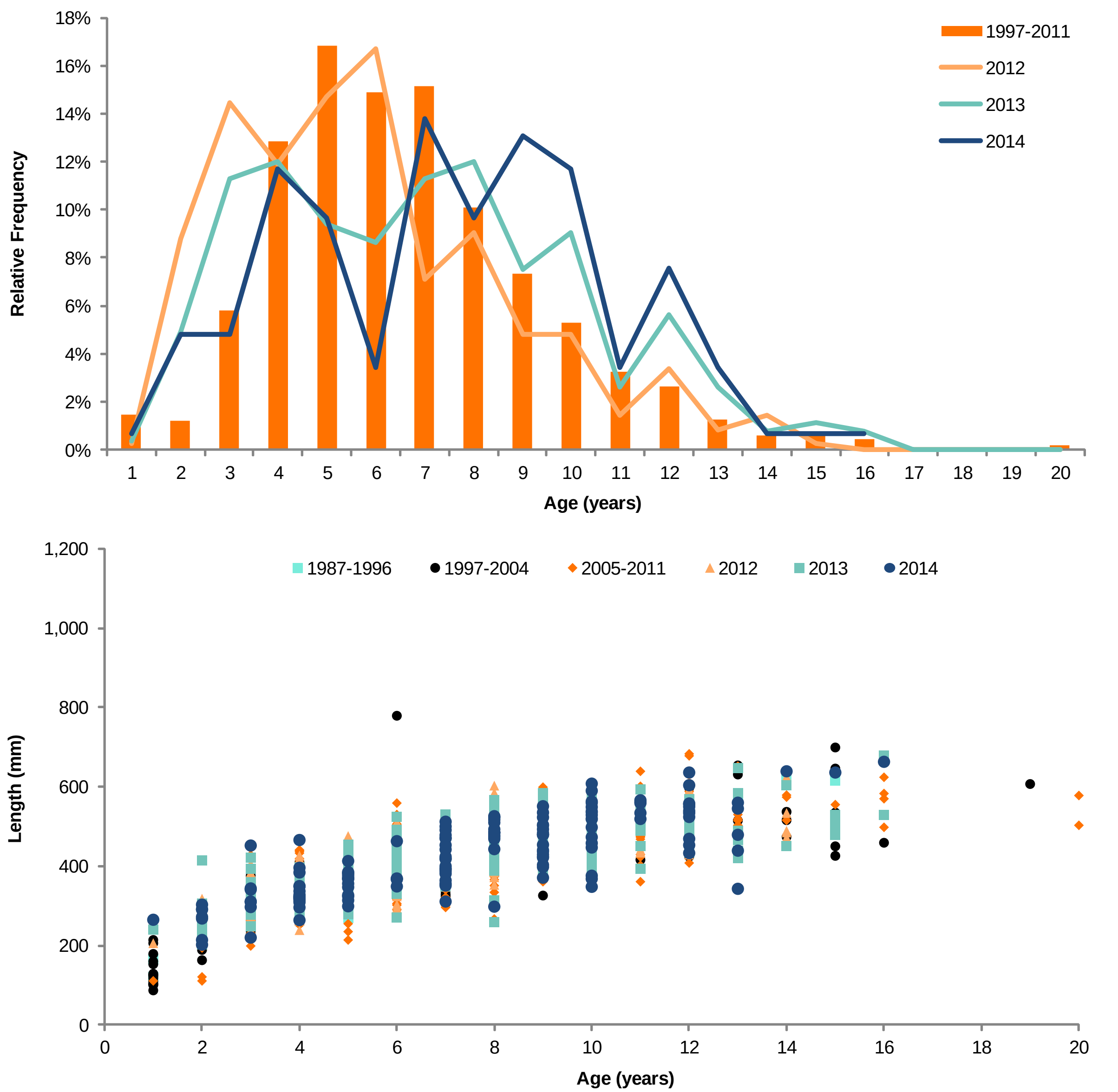


Figure 5.1-28 Relative age-frequency distributions and size-at-age relationship for white sucker captured in the Athabasca River from 1997 to 2014.

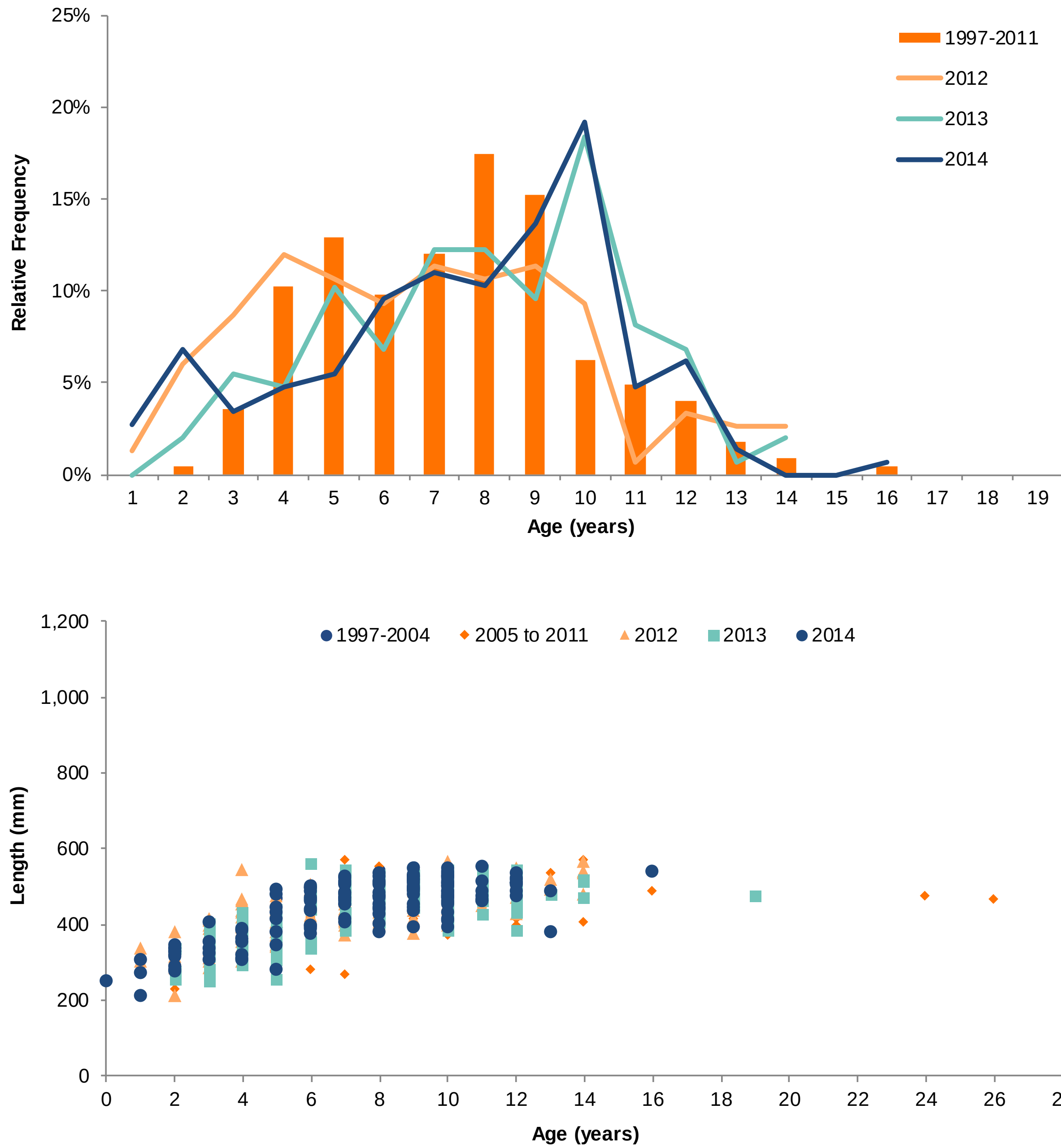
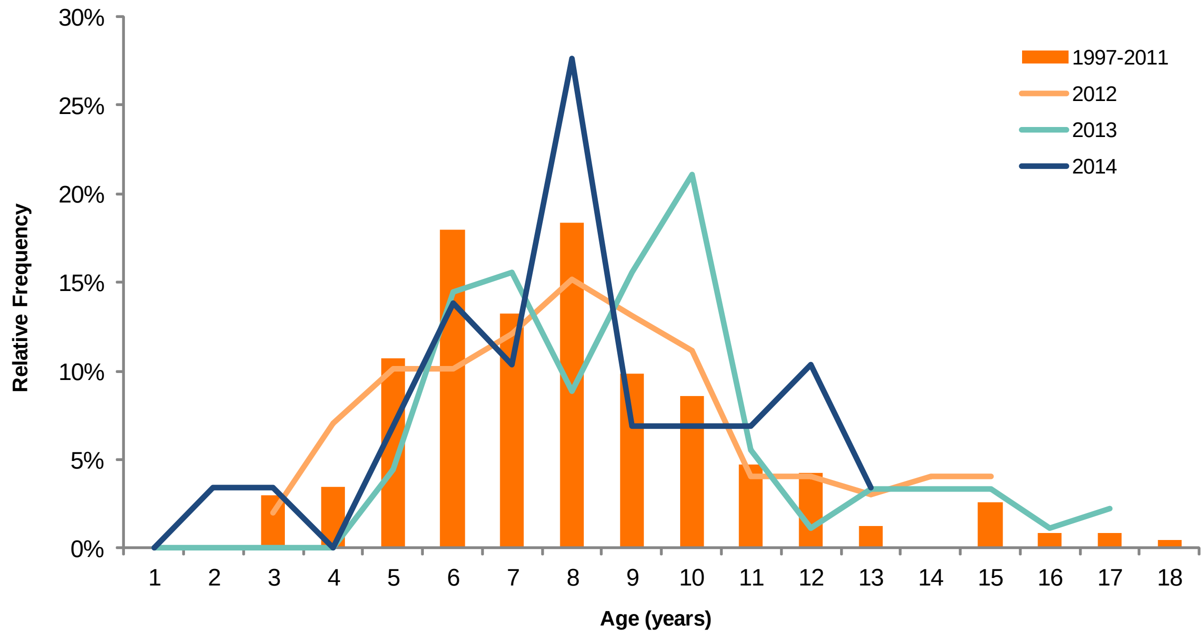


Figure 5.1-29 Relative age-frequency distributions and size-at-age relationship for lake whitefish captured in the Athabasca River from 1997 to 2014.



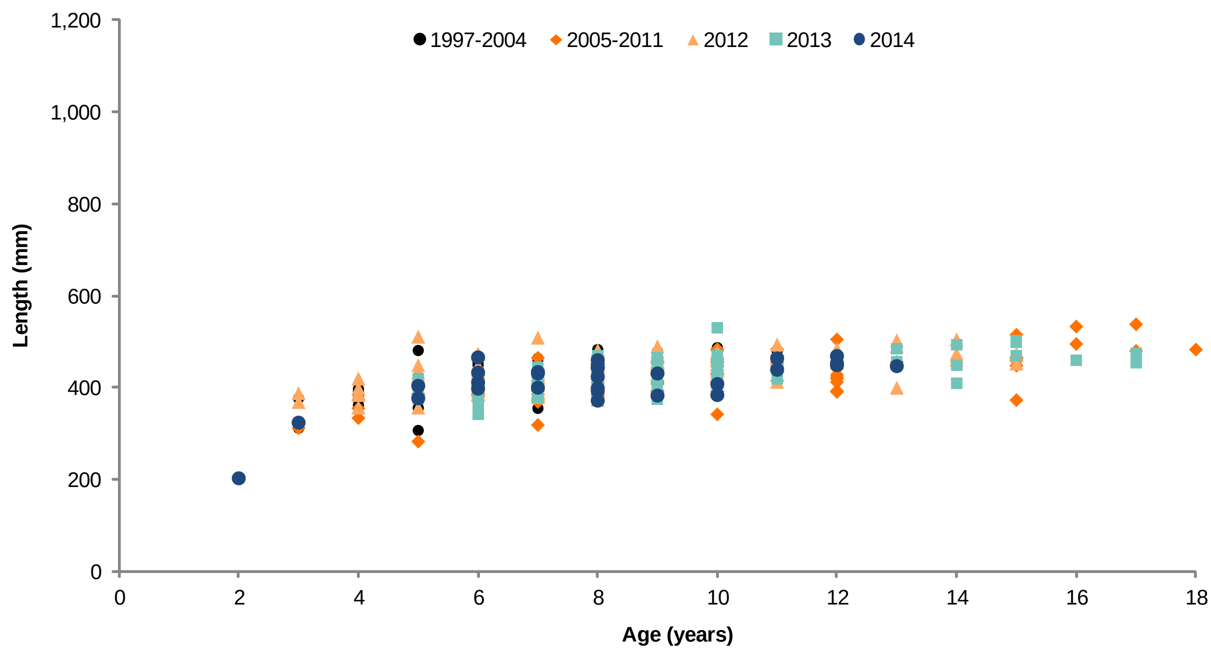


Figure 5.1-30 Mean condition (±1 SE) of goldeye captured in summer and fall from 1997 to 2014 in the Athabasca River, relative to a period prior to major oil sands development (1987 to 1996).

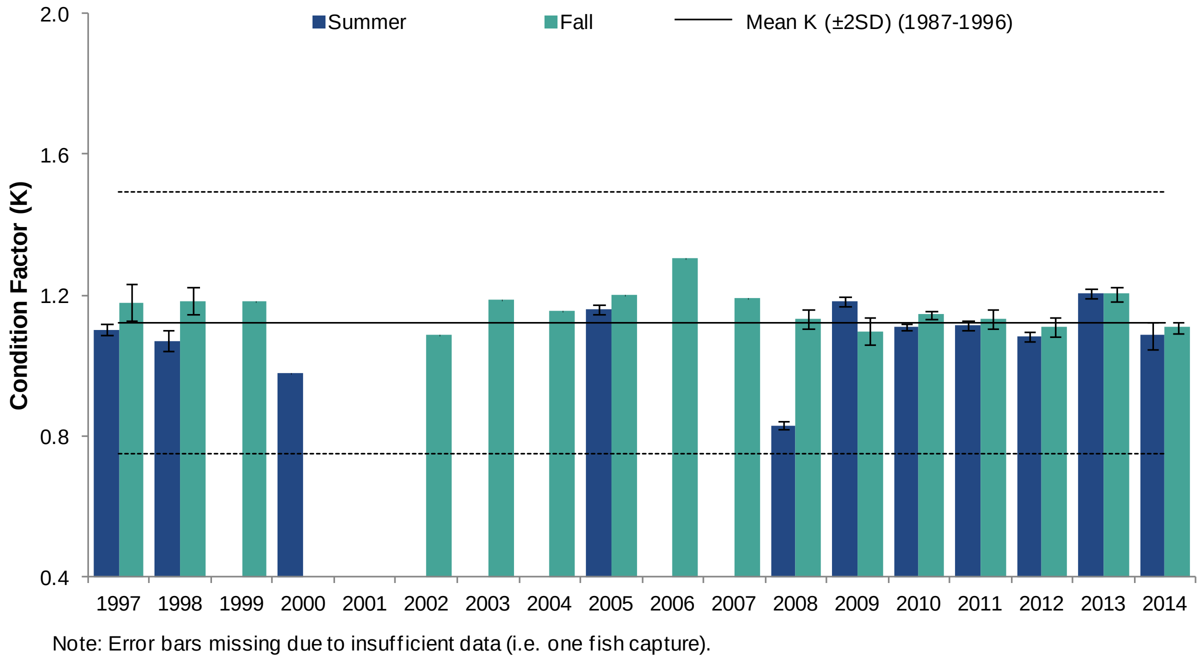


Figure 5.1-31 Mean condition (±1 SE) of longnose sucker captured in summer and fall from 1997 to 2014 in the Athabasca River, relative to a period prior to major oil sands development (1987 to 1996).

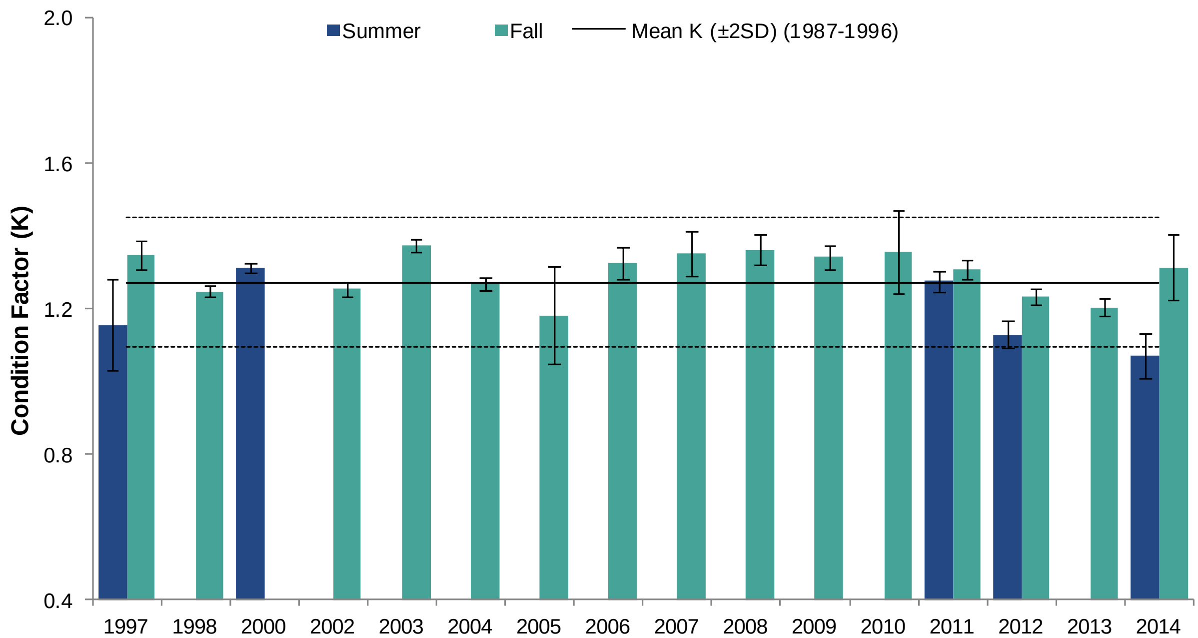


Figure 5.1-32 Mean condition (±1 SE) of northern pike captured in summer and fall from 1997 to 2014 in the Athabasca River, relative to a period prior to major oil sands development (1987 to 1996).

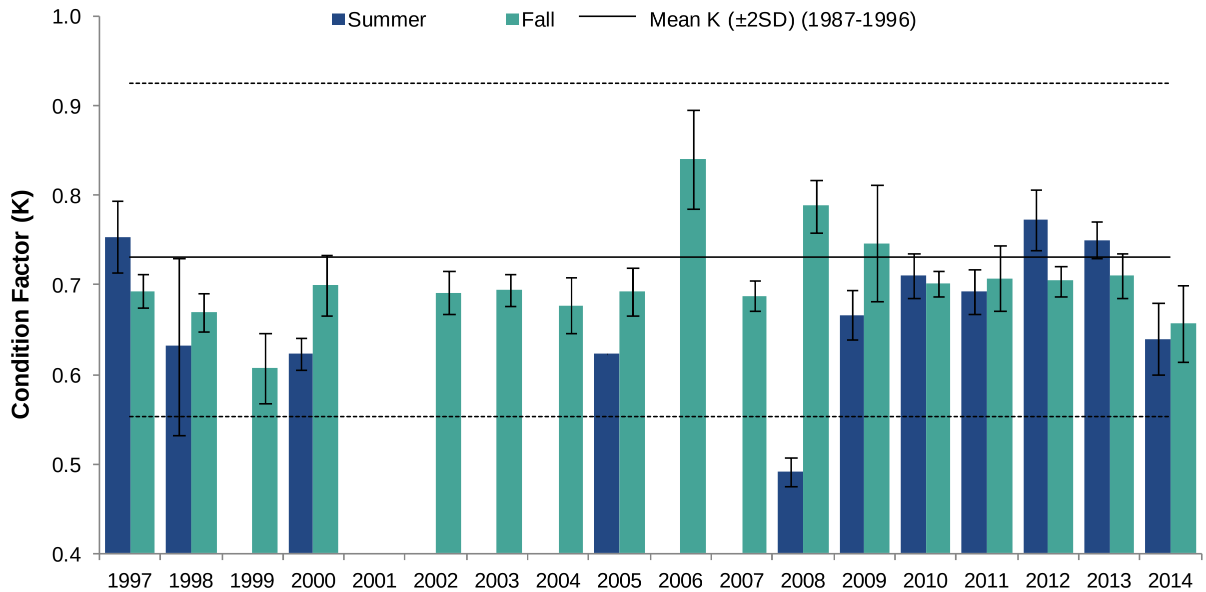
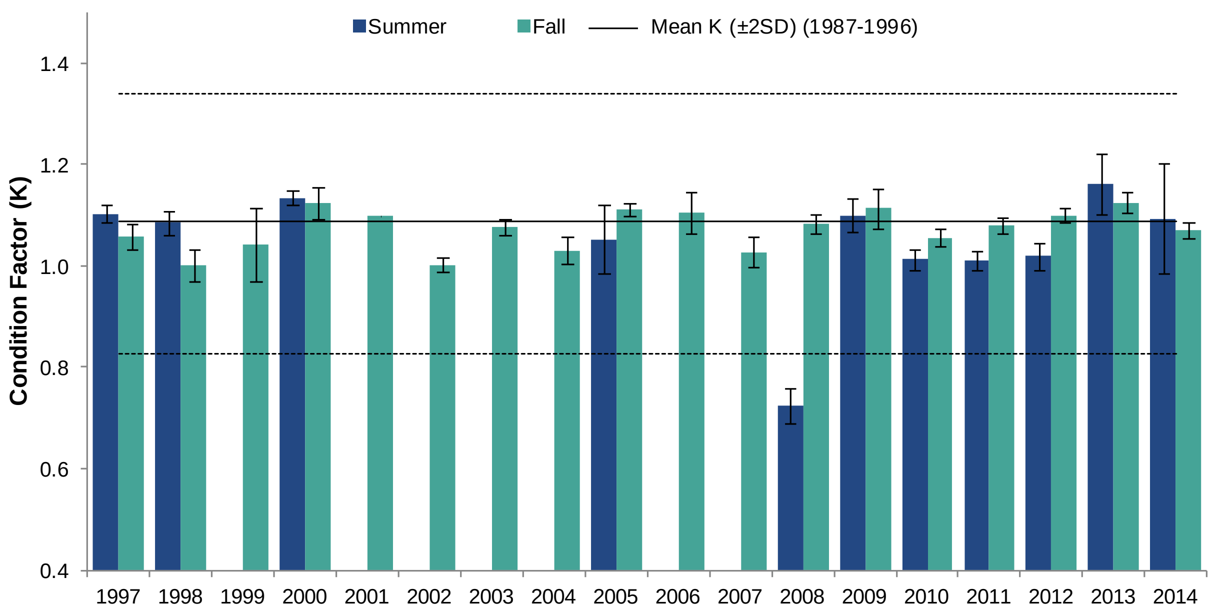


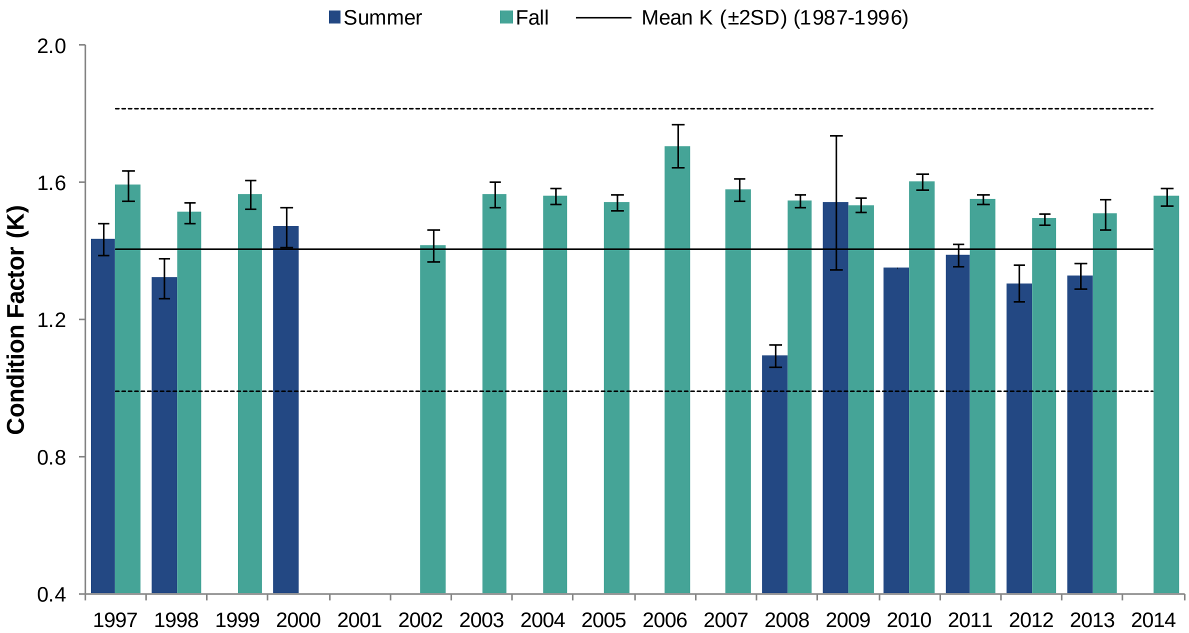
Figure 5.1-33 Mean condition (±1 SE) of walleye captured in summer and fall from 1997 to 2014 in the Athabasca River, relative to a period prior to major oil sands development (1987 to 1996).



Note: Error bars missing due to insufficient data (i.e. one fish capture).

Note: Seasons where condition is not shown was because no adult fish were captured.

Figure 5.1-34 Mean condition (±1 SE) of white sucker captured in summer and fall from 1997 to 2014 in the Athabasca River, relative to a period prior to major oil sands development (1987 to 1996).



Note: Error bars missing due to insufficient data (i.e. one fish capture).

Table 5.1-22 Number of fish in the adult size class to assess condition of large-bodied KIR species over time in the Athabasca River.

Year	Sample Size (n)										
	Goldeye (>300 mm)		Lake Whitefish (>350 mm)	Longnose Sucker (>350 mm)		Northern Pike (>400 mm)		Walleye (>400 mm)		White Sucker (>350 mm)	
	Fall	Summer	Fall	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer
1997	56	16	44	10	2	14	20	25	20	14	4
1998	12	8	168	83	-	11	5	36	11	40	2
1999	7	-	43	-	-	7	-	4	-	8	-
2000	-	29		-	2	7	13	5	2	-	5
2001	-	-		-	-	-	-	1	-	-	-
2002	1	-	24	12	-	6	-	4	-	3	-
2003	44	-	42	26	-	25	-	64	-	19	-
2004	177	-	54	5	-	23	-	33	-	35	-
2005	165	1	131	13	-	19	1	68	2	31	-
2006	25	-	118	14	-	31	-	16	-	37	-
2007	18	-	209	7	-	12	-	14	-	43	-
2008	145	27	530	13	-	14	12	39	12	91	12
2009	58	21	428	18	-	7	16	23	18	78	3
2010	148	47	398	2	-	31	23	32	10	27	1
2011	60	22	365	16	27	18	12	63	35	94	27
2012	181	68	275	20	20	28	11	53	27	63	21
2013	44	29	245	26	1	19	18	52	23	36	4
2014	26	23	18	20	2	5	2	16	3	12	1

Table 5.1-23 Percent of total fish captured in the Athabasca River with external pathology (growth/lesion, deformity, parasites), 1987 to 2014.

Year	% Growth/Lesion	% Deformity (body/fins)	% Parasites	% Total	Total # Fish
1987	0.33	0.00	0.00	0.33	1,823
1989	1.09	0.42	0.71	2.22	4,237
1990	0.65	0.43	0.22	1.30	921
1991	1.74	0.00	0.83	2.57	1,322
1996	2.65	1.58	2.29	6.51	1,965
1997	2.38	1.14	0.96	4.48	2,187
1998	1.39	0.67	0.88	2.94	2,381
1999	2.01	1.68	1.84	5.53	597
2000	2.43	0.41	0.81	3.65	493
2001	1.24	0.00	0.00	1.24	403
2002	0.45	0.17	0.22	0.84	1,793
2003	0.65	0.18	0.30	1.13	1,680
2004	0.37	0.05	0.69	1.12	1,883
2005	0.88	0.20	0.00	1.08	2,042
2006	0.63	0.05	0.27	0.95	2,222
2007	1.15	0.32	0.12	1.59	2,511
2008	1.43	0.42	0.32	2.18	4,951
2009	0.94	0.59	0.87	2.40	3,207
2010	0.53	0.21	0.64	1.39	5,284
2011	0.34	0.16	0.49	0.99	5,466
2012	0.30	0.21	0.11	0.62	5,656
2013	0.69	0.15	0.27	1.11	4,775
2014	1.11	0.33	0.44	1.88	2,704

Figure 5.1-35 Percent of total fish captured in the Athabasca River with some type of external pathology, 1987 to 2014.

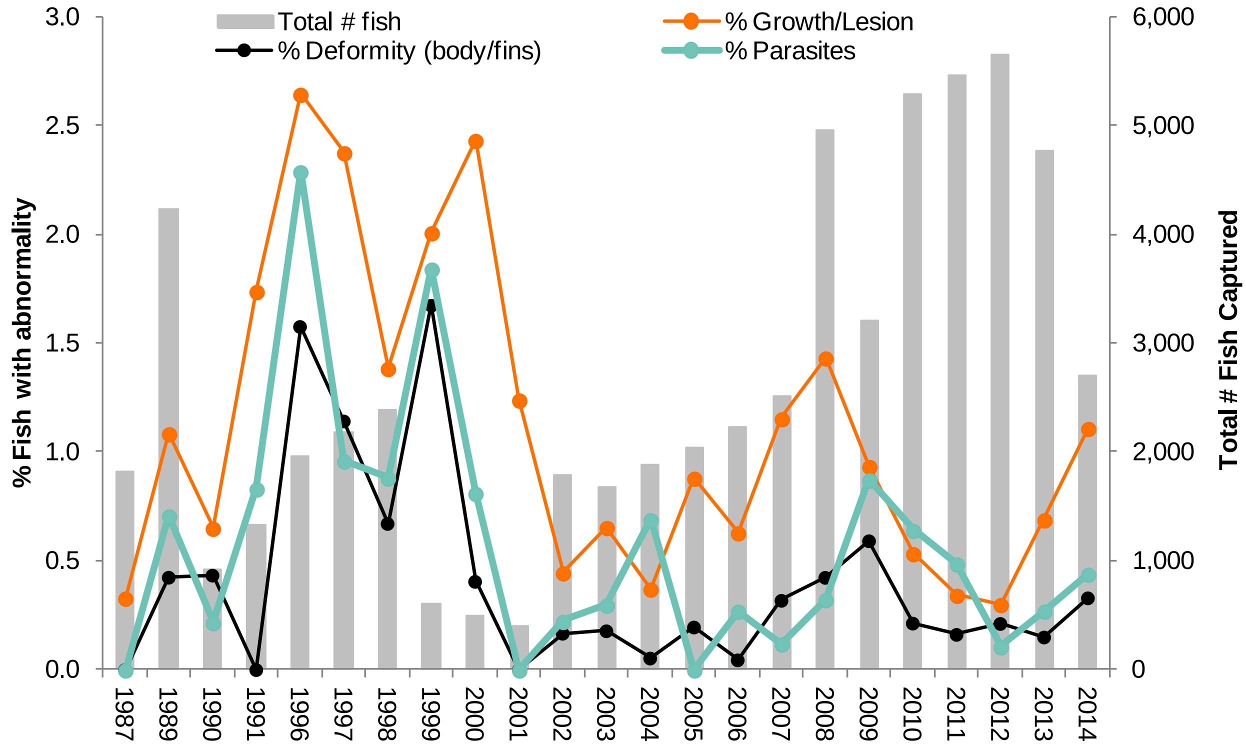


Figure 5.1-36 The location of a recaptured walleye by an angler in 2014.

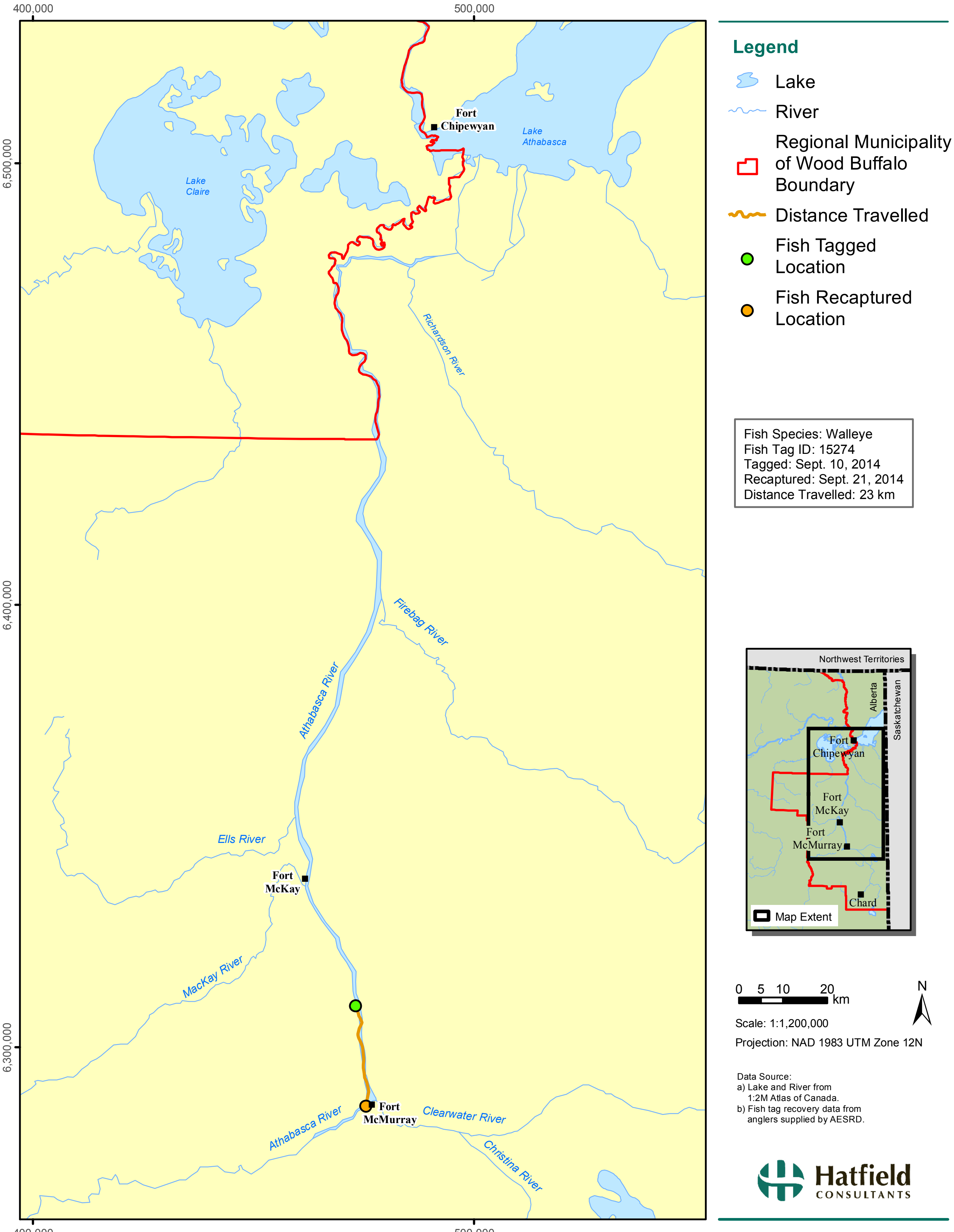


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Table 5.1-24 Number of fish tag returns by anglers and during the Athabasca River and Clearwater River fish inventory surveys in 2014.

Variable	Walleye	Northern Pike
No. of Fish Captured	2	1
Minimum Distance Travelled (km)	≥2	≥1
Maximum Distance Travelled (km)	23	≥1

Table 5.1-25 Number of fish tag returns by anglers, Athabasca and Clearwater rivers, 1999 to 2014.

Variable	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Captured	1	4	54	103	10
Minimum Distance Travelled (km)	271	5	≥1	≥1	≥1
Maximum Distance Travelled (km)	271	236	57	715	241

Table 5.1-26 Mercury concentrations (muscle) and whole-organisms metrics of lake whitefish and walleye collected from the Athabasca River, fall 2014, and screening of concentrations against criteria for fish consumption for the protection of human health.

Species	Sex	Length (mm)	Weight (g)	Age	Hg (mg/kg)
LKWH	F	415	1,184	7	0.09
LKWH	M	438	1,291	10	0.05
LKWH	F	444	1,562	7	0.05
LKWH	F	420	1,151	8	0.10
LKWH	F	402	1,057	7	0.11
LKWH	M	431	1,199	9	0.13
LKWH	F	414	1,240	5	0.10
LKWH	M	419	1,156	9	0.07
LKWH	F	445	1,408	8	0.10
LKWH	F	440	1,333	8	0.09
LKWH	F	401	1,097	8	0.04
LKWH	F	440	1,171	11	0.05
LKWH	M	450	1,593	8	0.10
LKWH	F	435	1,473	7	0.10
LKWH	F	444	1,360	8	0.06
LKWH	M	425	1,140	7	0.05
LKWH	U	461	1,502	8	0.06
LKWH	U	470	1,650	12	0.12
LKWH	U	501	1,826	10	0.15
LKWH	U	385	860	6	0.07
LKWH	U	465	1,594	10	0.12
LKWH	U	385	935	6	0.06
LKWH	U	460	1,240	12	0.47
LKWH	U	505	1,816	11	0.21
LKWH	U	493	1,932	11	0.06
LKWH	U	396	1,052	5	0.04
LKWH	U	465	1,377	11	0.09
LKWH	U	467	1,404	6	0.05
LKWH	U	385	831	10	0.11

LKWH – lake whitefish; WALL – walleye; M – Male; F – Female; U – Undetermined

* Refer to Table 3.4-9.

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Table 5.1-26 (Cont'd.)

Species	Sex	Length (mm)	Weight (g)	Age	Hg (mg/kg)
WALL	M	471	1,268	-	0.60
WALL	M	439	840	-	0.67
WALL	M	468	1,262	-	0.42
WALL	M	499	1,392	10	0.52
WALL	M	470	1,099	12	0.78
WALL	U	269	169	2	0.18
WALL	U	273	218	2	0.14
WALL	U	297	274	4	0.35
WALL	U	300	268	5	0.19
WALL	U	591	2,033	14	0.16
WALL	F	614	2,293	-	0.83
WALL	M	394	592	-	0.45
WALL	M	430	789	-	0.56
WALL	M	371	508	-	0.44
WALL	M	360	480	-	0.29
WALL	F	352	440	-	0.28
WALL	F	404	661	-	0.29

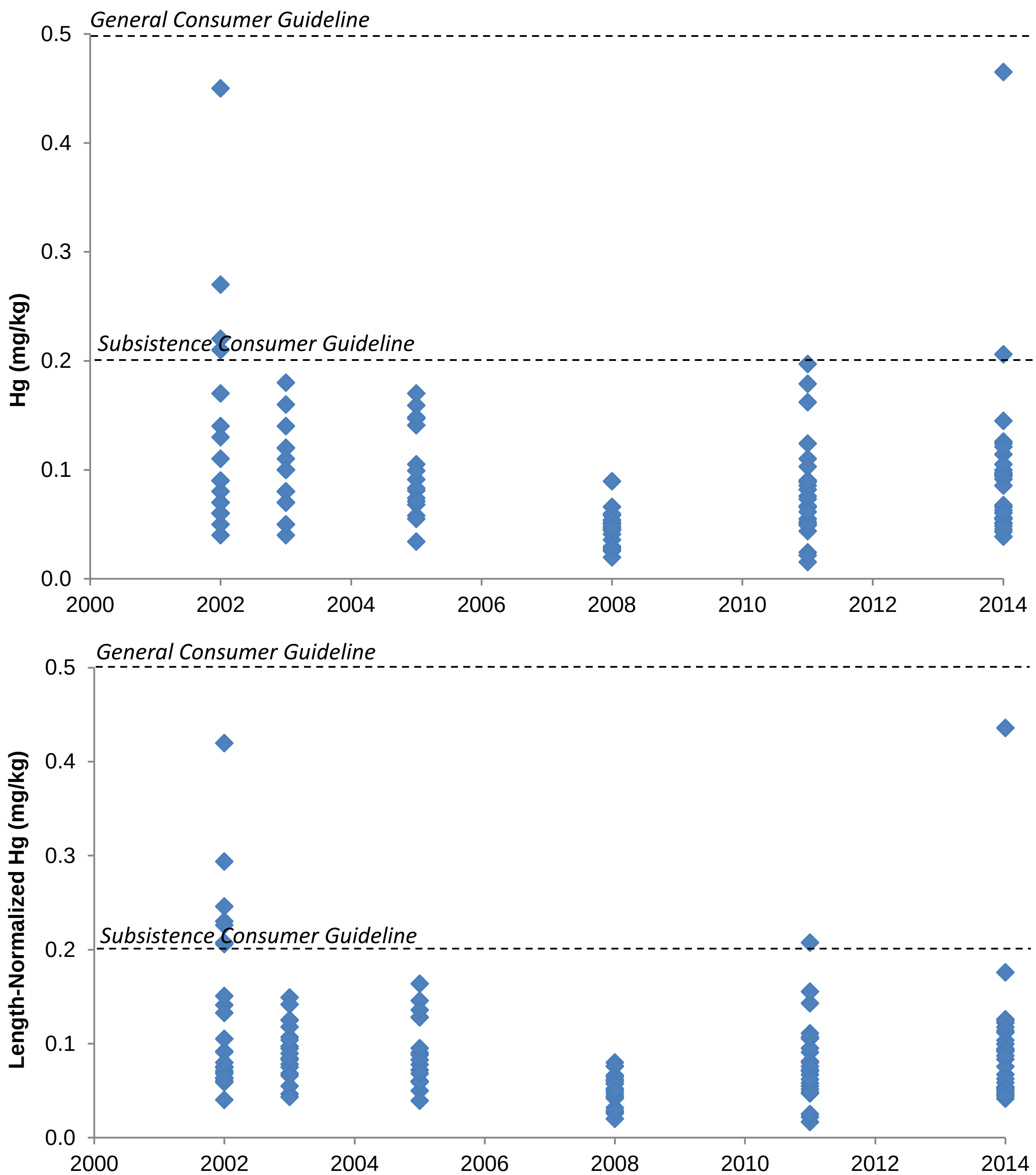
LKWH – lake whitefish; WALL – walleye; M – Male; F – Female; U – Undetermined

* Refer to Table 3.4-9.

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

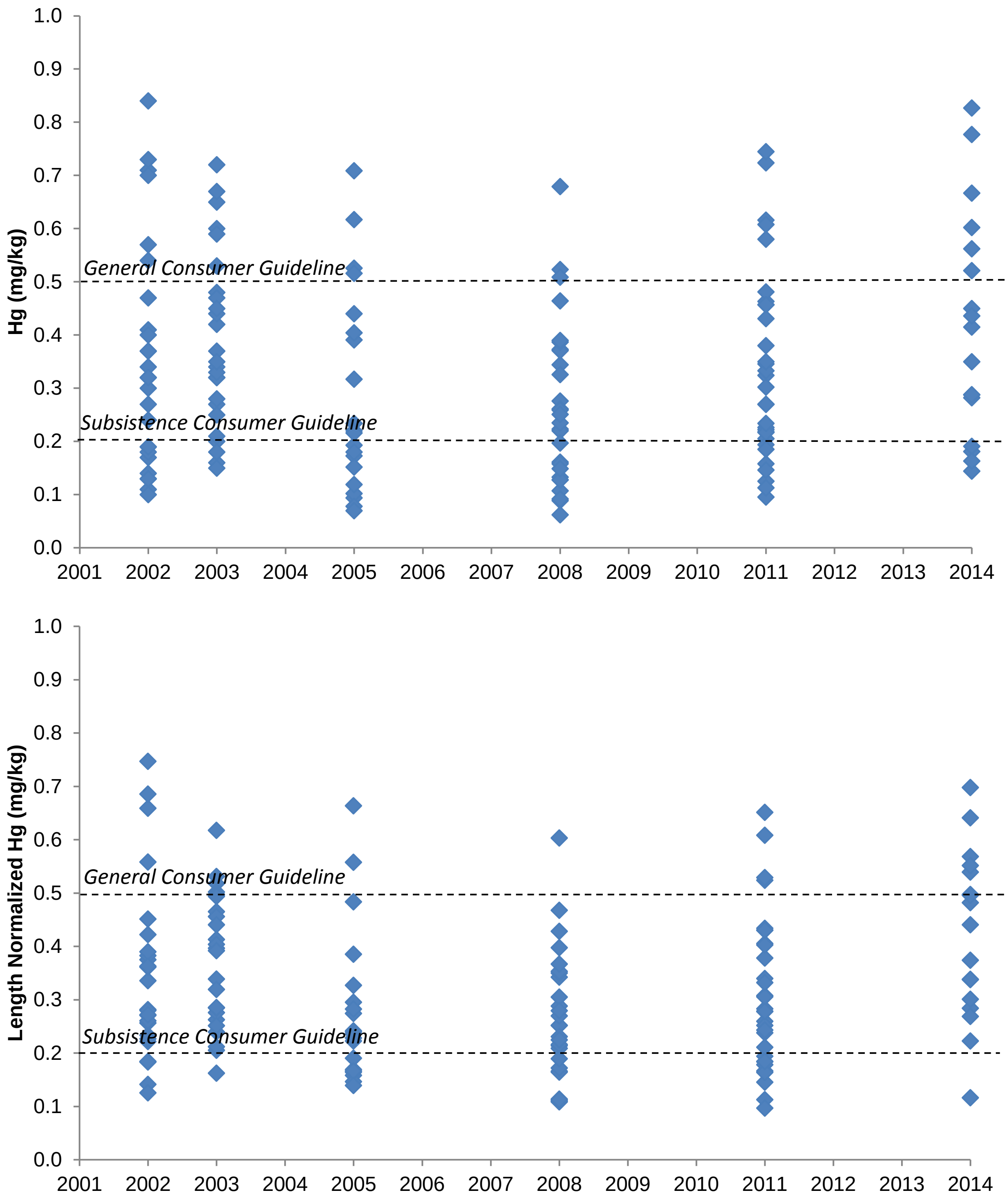
exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.1-37 Temporal comparison of mercury concentrations and length-normalized mercury concentrations in lake whitefish from the Athabasca River in 2002, 2003, 2005, 2008, 2011, and 2014.



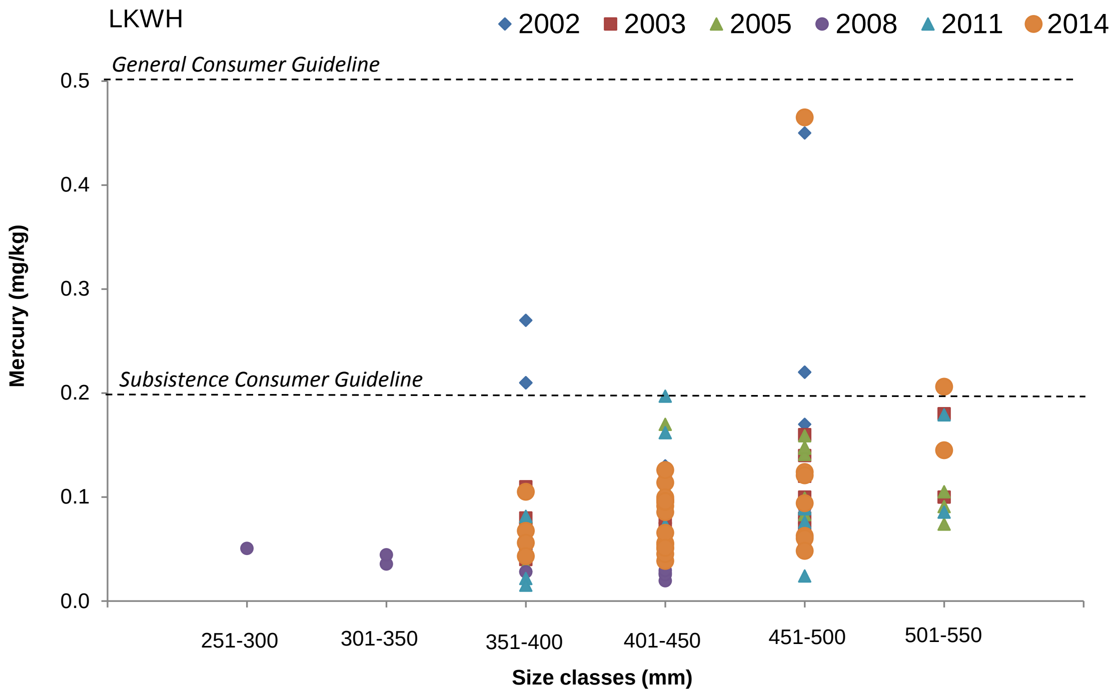
Note: length-normalized mercury concentrations are normalized to the mean length of lake whitefish captured.

Figure 5.1-38 Temporal comparison of mercury concentrations and length-normalized mercury concentrations in walleye from the Athabasca River in 2002, 2003, 2005, 2008, 2011, and 2014.



Note: length-normalized mercury concentrations are normalized to the mean length of walleye captured.

Figure 5.1-39 Temporal comparison of mercury concentrations by size class for lake whitefish (LKWH) and walleye (WALL) from the Athabasca River in 2002, 2003, 2005, 2008, 2011, and 2014.



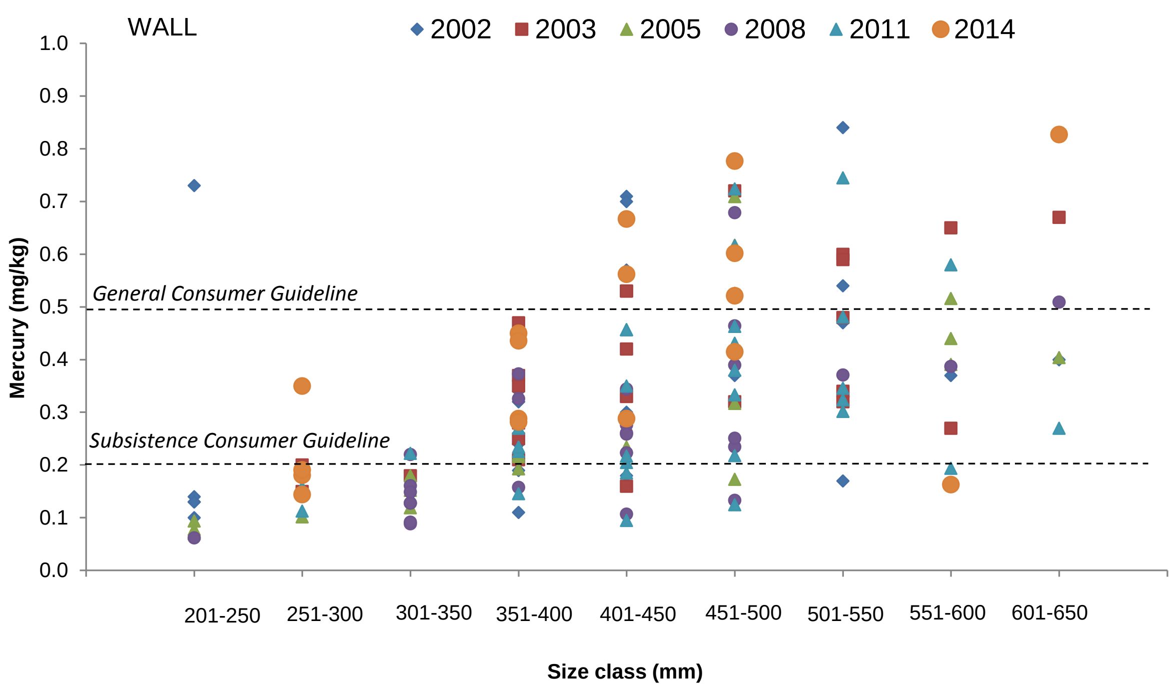


Figure 5.1-40 Mercury concentration in fish muscle versus length and age of lake whitefish (LKWH) and walleye (WALL) from the Athabasca River in 2014.

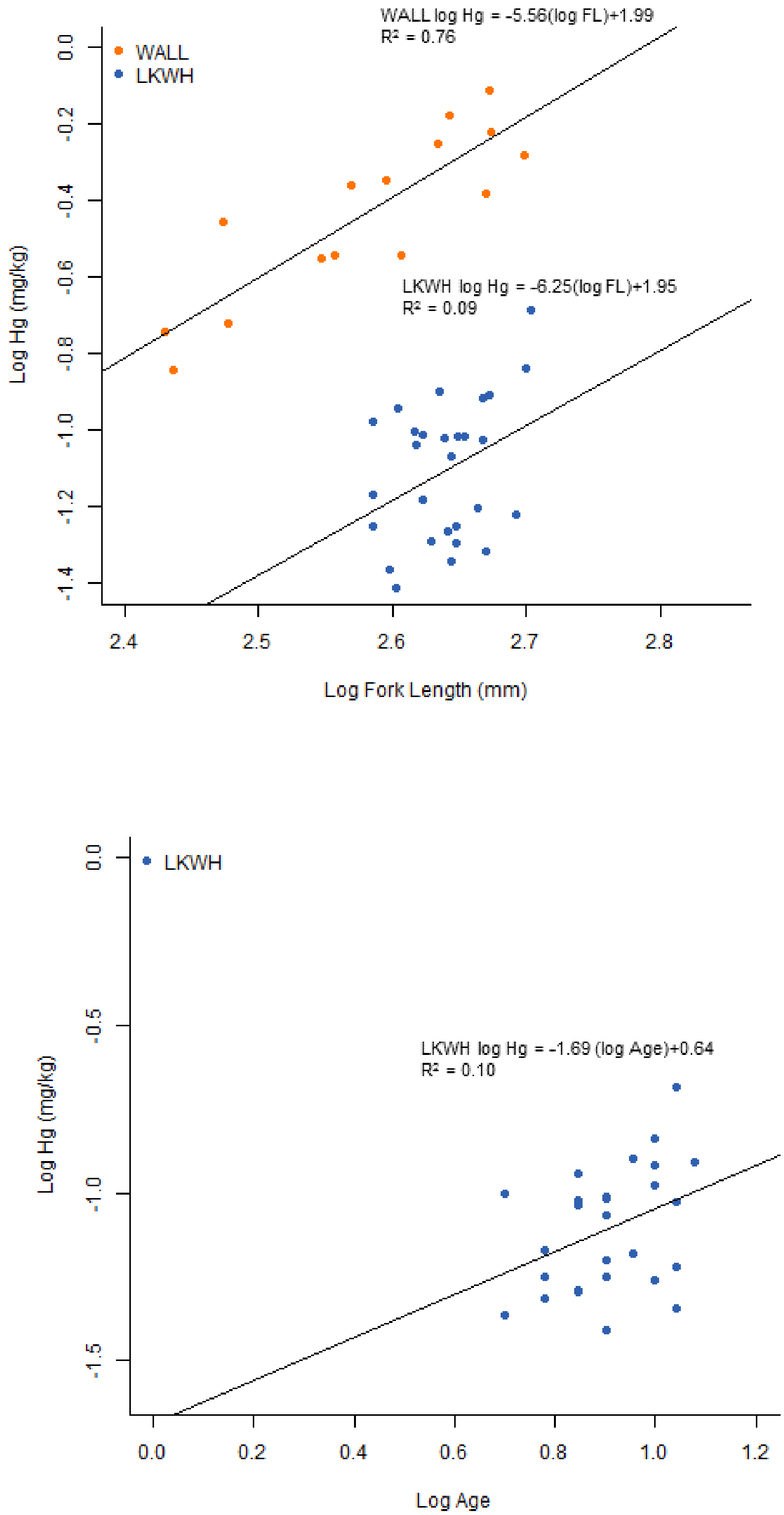


Table 5.1-27 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected in 2014 from the Athabasca River against fish consumption criteria for the protection of human health.

Variable	Units	DL	Results			Consumption Guideline		
			Composite LKWH[1]		Composite WALL[2]	National USEPA[3]		Region III USEPA[4]
			Male (400-450 mm)	Female (400-450 mm)	Male (450-500 mm)	Subsistence	Recreational	Risk-based Criteria
Total Metals								
Aluminum (Al)	mg/kg	2	<2	<2	<2	nc	nc	nc
Antimony (Sb)	mg/kg	0.01	<0.010	<0.01	<0.01	nc	nc	0.54
Arsenic (As)[5]	mg/kg	0.01	**<u>0.043</u>**	**<u>0.052</u>**	<u>0.019</u>	0.00327	0.026	0.0021
Inorganic Arsenic[6]	mg/kg		**<u>0.0043</u>**	**<u>0.0052</u>**	0.0019	0.00327	0.026	0.0021
Barium (Ba)	mg/kg	0.02	0.045	0.052	0.112	nc	nc	270
Beryllium (Be)	mg/kg	0.1	<0.10	<0.10	<0.10	nc	nc	2.7
Cadmium (Cd)	mg/kg	0.006	<.006	<0.006	<0.006	nc	nc	1.4
Calcium (Ca)	mg/kg	20	84.2	174	952	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	0.388	0.088	0.056	nc	nc	4.1
Cobalt (Co)	mg/kg	0.02	<0.02	<0.02	<0.020	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.171	0.197	0.173	nc	nc	54
Iron (Fe)	mg/kg	5	3.4	3.5	5	nc	nc	410
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	<0.02	nc	nc	nc
Magnesium (Mg)	mg/kg	5	298	289	315	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	0.141	0.211	0.145	nc	nc	190
Mercury (Hg)[8]	mg/kg	0.002	0.141	0.211	0.145	0.2[8]	0.5[8]	nc
Molybdenum (Mo)	mg/kg	0.01	<0.01	<0.01	<0.01	nc	nc	6.8
Nickel (Ni)	mg/kg	0.02	0.029	0.099	0.066	nc	nc	27

<u>Underline value</u> = exceeds Region III USEPA Risk-based Criteria

<u>bold value</u> = exceeds National USEPA Subsistence fishers

<u>shaded value</u> = exceeds National USEPA Recreational fisher guideline; nc = no criterion

[1] Composite sample taken from lake whitefish target size class (400-450 mm for males and females).

[2] Composite sampled taken from walleye target size class (450-500 mm for males; 450-500 mm and >500 mm for females).

[3] Last updated November 2000: http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

[4] Last updated June 2011: http://www.epa.gov/reg3hwmd/risk/human/pdf/JUNE_2011_FISH.pdf

[5] Guidelines refer to inorganic arsenic not total arsenic.

[6] Inorganic arsenic was estimated as 10% of total arsenic. This estimate was applied because inorganic arsenic concentrations were not actually evaluated. http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

[7] Naphthalene was tested for three target analytes: 1-Methylnaphthalene; 2,6-Dimethylnaphthalene; and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg.

[8] Health Canada Guideline.

Table 5.1-27 (Cont'd.)

Variable	Units	DL	Results			Consumption Guideline		
			Composite LKWH[1]		Composite WALL[2]	National USEPA[3]		Region III USEPA[4]
			Male (400-450 mm)	Female (400-450 mm)	Male (450-500 mm)	Subsistence	Recreational	Risk-based Criteria
Total Metals (Cont'd.)								
Phosphorus (P)	mg/kg	20	2,420	2,350	2,910	nc	nc	nc
Potassium (K)	mg/kg	20	4,740	4,800	5,520	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.25	0.246	0.212	2.457	20	6.8
Silver (Ag)	mg/kg	0.05	<0.05	<0.05	<0.05	nc	nc	6.8
Sodium (Na)	mg/kg	20	279	315	316	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.073	0.343	0.749	nc	nc	810
Thallium (Tl)	mg/kg	0.01	<0.01	<0.01	<0.01	nc	nc	0.095
Tin (Sn)	mg/kg	0.05	<0.05	<0.05	<0.05	nc	nc	810
Titanium (Ti)	mg/kg	0.1	0.12	<0.10	<0.10	nc	nc	nc
Vanadium (V)	mg/kg	0.1	<0.10	<0.10	<0.10	nc	nc	1.4
Zinc (Zn)	mg/kg	0.5	3.20	2.56	3.93	nc	nc	410
Tainting Compounds								
Thiophene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	110
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc
Naphthalene[7]	mg/kg	0.05	<0.05	<0.05	<0.05	nc	nc	nc

Underline value = exceeds Region III USEPA Risk-based Criteria

bold value = exceeds National USEPA Subsistence fishers

shaded value = exceeds National USEPA Recreational fisher guideline; nc = no criterion

1 Composite sample taken from lake whitefish target size class (400-450 mm for males and females).

2 Composite sampled taken from walleye target size class (450-500 mm for males; 450-500 mm and >500 mm for females).

3 Last updated November 2000: http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

4 Last updated June 2011: http://www.epa.gov/reg3hwmd/risk/human/pdf/JUNE_2011_FISH.pdf

5 Guidelines refer to inorganic arsenic not total arsenic.

6 Inorganic arsenic was estimated as 10% of total arsenic. This estimate was applied because inorganic arsenic concentrations were not actually evaluated. http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

7 Naphthalene was tested for three target analytes: 1-Methylnaphthalene; 2,6-Dimethylnaphthalene; and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg.

8 Health Canada guideline.

Table 5.1-28 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected in 2014 from the Athabasca River against criteria for the protection of fish health.

Variable	Units	DL	Results			Thresholds for the Protection of Fish[3]			
			Composite LKWH[1]		Composite WALL[2]	Lowest no-effects thresholds		Lowest effects Thresholds	
			Male (400-450 mm)	Female (400-450 mm)	Male (450-500 mm)	Lethal	Sublethal	Lethal	Sublethal
Total Metals									
Aluminum (Al)	mg/kg	2	<2	<2	<2	1	nc	20	nc
Antimony (Sb)	mg/kg	0.01	<0.010	<0.01	<0.01	5	nc	9	nc
Arsenic (As)	mg/kg	0.01	0.043	0.052	0.019	2.6	0.9	11.2	3.1
Barium (Ba)	mg/kg	0.1	0.0043	0.0052	0.0019	nc	nc	nc	nc
Beryllium (Be)	mg/kg	0.1	0.045	0.052	0.112	nc	nc	nc	nc
Cadmium (Cd)	mg/kg	0.006	<0.10	<0.10	<0.10	0.02	0.09	0.14	0.12
Calcium (Ca)	mg/kg	20	<.006	<0.006	<0.006	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	84.2	174	952	nc	nc	nc	nc
Cobalt (Co)	mg/kg	0.02	0.388	0.088	0.056	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	<0.02	<0.02	<0.020	0.5	3.4	0.5	0.3
Iron (Fe)	mg/kg	5	0.171	0.197	0.173	nc	nc	nc	nc
Lead (Pb)	mg/kg	0.02	3.4	3.5	**5**	4	nc	nc	nc
Magnesium (Mg)	mg/kg	5	<0.02	<0.02	<0.02	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	298	289	315	nc	nc	nc	nc
Mercury (Hg)[4,5]	mg/kg	0.002	0.141	0.211	0.145	1.91	2.28	3.7	8.6
Molybdenum (Mo)	mg/kg	0.05	<0.01	<0.01	<0.01	nc	nc	nc	nc

[1] Composite sample taken from lake whitefish target size class (400-450 mm for males and females).

[2] Composite sampled taken from walleye target size class (450-500 mm for males).

[3] Threshold values were derived from effects data for fish muscle tissue presented in Jarvinen and Ankley (1999).

[4] Threshold values were derived from methylated forms of mercury (Jarvinen and Ankley 1999).

[5] Mercury results are average values from individual samples.

[6] Threshold values are presented for carcass and not muscle tissue (Jarvinen and Ankley 1999).

value = exceeds sublethal lowest no-effects threshold

bold value = exceeds sublethal lowest effects threshold

underline value = exceeds lethal lowest no-effects threshold

shaded value = exceeds lethal lowest effects threshold

nc = no criteria

Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.1-28 (Cont'd.)

Variable	Units	DL	Results			Thresholds for the Protection of Fish[3]			
			Composite LKWH[1]		Composite WALL[2]	Lowest no-effects thresholds		Lowest effects Thresholds	
			Male (400-450 mm)	Female (400-450 mm)	Male (450-500 mm)	Lethal	Sublethal	Lethal	Sublethal
Nickel (Ni)	mg/kg	0.02	0.029	0.099	0.066	0.82	nc	118.1	nc
Phosphorus (P)	mg/kg	20	2,420	2,350	2,910	nc	nc	nc	nc
Potassium (K)	mg/kg	20	4,740	4,800	5,520	nc	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.25	0.246	0.212	0.28	0.08	0.92	0.32
Silver (Ag)[6]	mg/kg	0.05	<0.05	<0.05	<0.05	0.003	0.003	nc	nc
Sodium (Na)	mg/kg	20	279	315	316	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.073	0.343	0.749	nc	nc	nc	nc
Thallium (Tl)	mg/kg	0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
Tin (Sn)	mg/kg	0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc
Titanium (Ti)	mg/kg	0.1	0.12	<0.10	<0.10	nc	nc	nc	nc
Vanadium (V)[6]	mg/kg	0.1	<0.10	<0.10	<0.10	5.33	0.02	nc	0.41
Zinc (Zn)	mg/kg	0.5	3.20	2.56	3.93	60	60	nc	nc
Tainting Compounds									
Thiophene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc	nc
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	<0.10	nc	nc	nc	nc
Naphthalene[7]	mg/kg	0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc

[1] Composite sample taken from lake whitefish target size class (400-450 mm for males and females).

[2] Composite sampled taken from walleye target size class (450-500 mm for males).

[3] Threshold values were derived from effects data for fish muscle tissue presented in Jarvinen and Ankley (1999).

[4] Threshold values were derived from methylated forms of mercury (Jarvinen and Ankley 1999).

[5] Mercury results are average values from individual samples.

[6] Threshold values are presented for carcass and not muscle tissue (Jarvinen and Ankley 1999).

value = exceeds sublethal lowest no-effects threshold

bold value = exceeds sublethal lowest effects threshold

underline value = exceeds lethal lowest no-effects threshold

shaded value = exceeds lethal lowest effects threshold

nc = no criteria

Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.1-29 Average habitat characteristics of fish assemblage monitoring reaches of the Athabasca River Delta, August 2014.

Variable	Units	BPC-F1 *Test* Reach of Big Point Channel	GIC-F1 *Test* Reach of Goose Island Channel	FLC-F1 *Test* Reach of Fletcher Channel	EMR-F2 *Test* Reach of the Embarras River
Sample date	-	Aug 21, 2014	Aug 22, 2014	Aug 19, 2014	Aug 19, 2014
Habitat type	-	run	run	run	run
Reach length	m	5,783	5,613	4,433	4,291
Maximum depth	m	4.5	8.3	2.9	2.0
Bankfull channel width	m	115	154	67	64.5
Wetted channel width	m	115	150	67	63
Substrate					
Dominant	-	fines	fines	fines	fines
Subdominant	-	-	-	-	-
Instream cover					
Dominant	-	small woody debris, overhanging vegetation	small woody debris, live trees/roots, overhanging vegetation	small and large woody debris, macrophytes	small woody debris, macrophytes, overhanging vegetation
Subdominant	-	-	-	-	-
Field water quality					
Dissolved oxygen	mg/L	6.2	8.2	8.0	7.0
Conductivity	µS/cm	259	249	244	262
pH	pH units	7.07	7.70	7.50	8.00
Water temperature	^{0}C	20.4	21.5	23.2	23.4
Riparian cover – understory (<5 m)					
Dominant	-	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation	-	overhanging vegetation

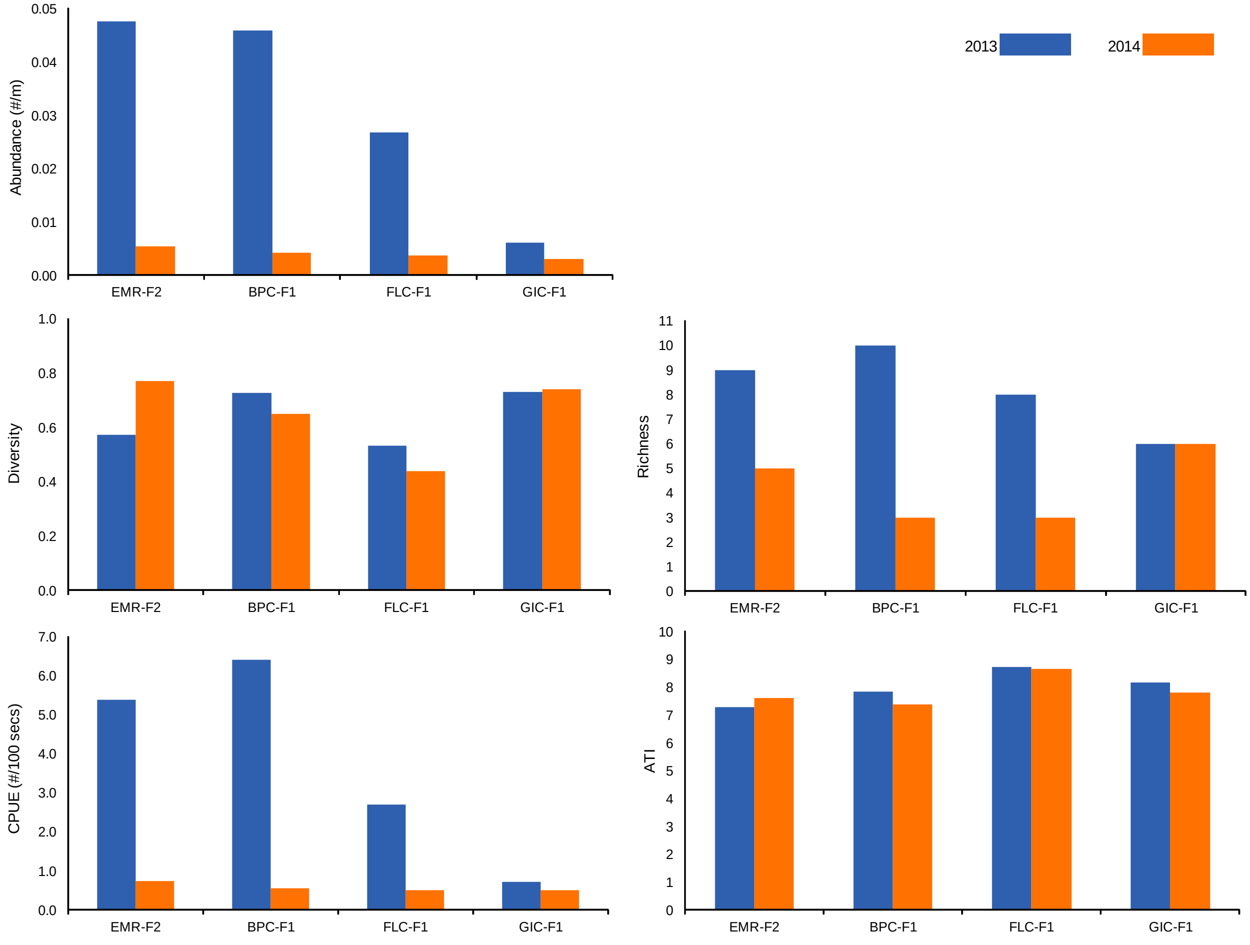
Table 5.1-30 Total number and percent composition of fish species captured in channels of the Athabasca River Delta, August 2014.

Common Name	Code	Total Species				Percent of Total Catch			
		EMR-F2	BPC-F1	FLC-F1	GIC-F1	EMR-F2	BPC-F1	FLC-F1	GIC-F1
emerald shiner	EMSH	8	10	4	7	44.4	31.3	23.5	41.2
goldeye	GOLD	-	4	12	4	-	12.5	70.6	23.5
northern pike	NRPK	5	3	1	2	27.8	9.4	5.9	11.8
spottail shiner	SPSH	5	8	-	1	27.8	25.0	-	5.9
walleye	WALL	-	-	-	1	-	-	-	5.9
white sucker	WHSC	-	-	-	2	-	-	-	11.8
yellow perch	YLPR	-	7	-	-	-	21.9	-	-
Total Count		18	32	17	17	100	100	100	100
Total Species Richness		3	5	3	6	-	-	-	-
Electrofishing Effort (secs)		3,289	4,360	3,400	4,470	-	-	-	-

Table 5.1-31 Summary of fish assemblage measurement endpoints for reaches of the Athabasca River Delta, 2014.

Reach	Abundance (#/m)	Total Richness	Diversity	Assemblage Tolerance Index	CPUE (#/100 secs)
EMR-F2	0.006	5	0.77	7.59	0.73
BPC-F1	0.004	3	0.65	7.37	0.55
FLC-F1	0.004	3	0.44	8.65	0.50
GIC-F1	0.003	6	0.74	7.81	0.50

Figure 5.1-41 Variations in fish assemblage measurement endpoints for *test* reaches of the Athabasca River Delta, 2013 and 2014.



Note: Fish assemblage monitoring was also conducted in 2012 in these channels of the ARD but using different sampling methods; therefore, the data were not displayed.

5.2 MUSKEG RIVER WATERSHED

Table 5.2-1 Summary of results for the Muskeg River watershed.

Muskeg River Watershed	Summary of 2014 Conditions										
	Muskeg River			*Jackpine Creek*		*Other Creeks*				*Lakes*	
Climate and Hydrology											
Criteria	no station	**07DA008** near Fort McKay	**S5, S5A, S20A, S33***	**S2** at Canterra Road	**S37** east Jackpine Creek near the 1,300 ft. contour	**S22** Muskeg Creek near the mouth	**S65** North Greenstock-ings Creek Tributary	**S10A** Wapasu Creek near the mouth	**S3** Iyinimin Creek above Kearl Lake	**L2** Kearl Lake	**S9** Kearl Lake Outlet
Mean open-water season discharge		🟠	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Mean winter discharge		🟡	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Annual maximum daily discharge		🟠	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Minimum open-water season discharge		🟤	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Water Quality											
Criteria	**MUR-1** at the mouth	no station sampled	**MUR-6A** upstream of Wapasu Creek	**JAC-1** at the mouth	**JAC-2** upper station	**MUC-1** Muskeg Creek at the mouth	**STC-1** Stanley Creek at the mouth	**WAC-1** Wapasu Creek at Canterra Road	**IYC-1** Iyinimin Creek	**KEL-1** Kearl Lake	no station
Water Quality Index	🟡		🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	
Benthic Invertebrate Communities and Sediment Quality											
Criteria	**MUR-E1** lower reach	**MUR-D2** middle reach	**MUR-D3** upper reach	**JAC-D1** lower reach	**JAC-D2** upper reach	no reach	no reach	no reach	no reach	**KEL-1** Kearl Lake	no reach
Benthic Invertebrate Communities	🟡	🟡	🟡	🟡	n/a					🟡	
Sediment Quality Index	n/a	🟡	🟡	🟡	🟡					n/a	
Fish Populations											
Criteria	**MUR-F1** lower reach	**MUR-F2** middle reach	**MUR-F3** upper reach	**JAC-F1** lower reach	**JAC-F2** upper reach	no reach	no reach	no reach	no reach	no reach	no reach
Fish Assemblages	🟠	🟡	🟤	🟤	n/a						

Legend and Notes

🟡 Negligible-Low

🟠 Moderate

🟤 High

baseline (green)

test (blue)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with *baseline* reaches.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

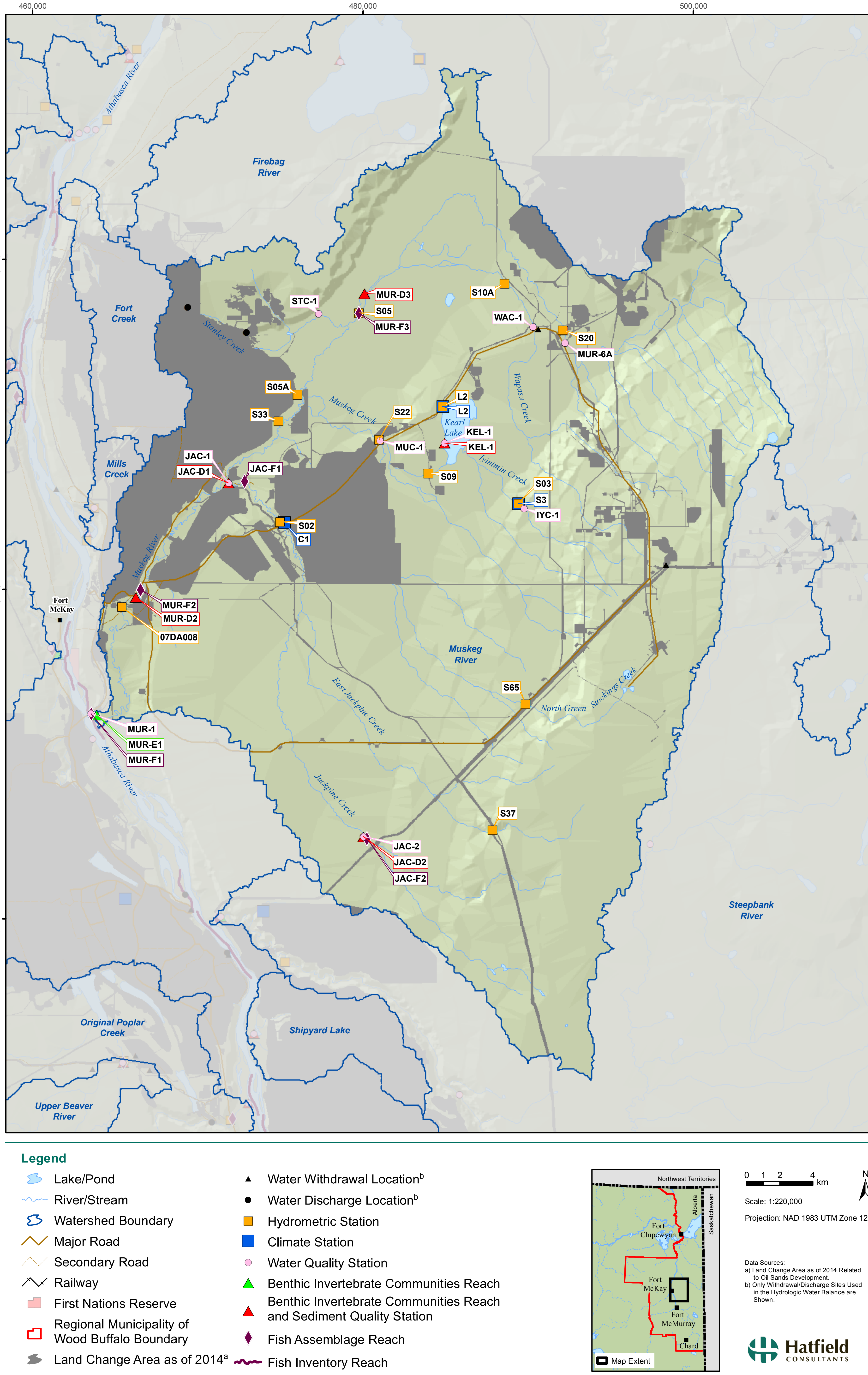
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baselines*; see Section 3.3.1.10 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.3 for a description of the classification methodology.

* Station S5 located on Muskeg River above Stanley Creek, S5A located on Muskeg River above Muskeg Creek, S20A located on Muskeg River Upland, and S33 located on Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary.

Figure 5.2-1 Muskeg River watershed.



K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_K02_Muskeg_20150331_ss.mxd

Figure 5.2-2 Representative monitoring stations of the Muskeg River watershed, 2014.

Benthic Invertebrate Reach MUR-E1 (Muskeg River): facing downstream

Water Quality Station MUC-1 (Muskeg Creek): facing upstream

Benthic and Sediment Quality Reach MUR-D2 (Muskeg River): facing downstream

Benthic and Sediment Quality Reach JAC-D2 (Jackpine Creek): facing upstream

Benthic and Sediment Quality Reach JAC-D1 (Jackpine Creek): facing upstream

Water Quality Station WAC-1 (Wapasu Creek)

Hydrology Station S5 (Muskeg River)

Water Quality Station KEL-1: Kearl Lake

5.2.1 Summary of 2014 Conditions

As of 2014, approximately 16% (23,330 ha) of the Muskeg River watershed had undergone land change from oil sands development (Table 2.3-1). The designations of specific areas of the Muskeg River watershed are as follows:

1. The Muskeg River from upstream of Wapasu Creek to the mouth, as well as the lower part of Stanley Creek, Muskeg Creek (including Kearl Lake), Jackpine Creek, and Wapasu Creek drainages in the Husky Sunrise, Shell Muskeg River Mine and Expansion, and Shell Jackpine Mine and Expansion leases are designated as *test*.

2. The remainder of the watershed, including the upper portion of Jackpine Creek, is designated as *baseline*.

Monitoring programs were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in the Muskeg River watershed in 2014. Table 5.2-1 is a summary of the 2014 assessment of the Muskeg River watershed, and Figure 5.2-1 denotes the location of the monitoring stations for each component, reported water withdrawal and discharge locations, and the area of land change as of 2014 in the Muskeg River watershed. Figure 5.2-2 contains fall 2014 photos of representative monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -4.9%, -5.5%, -8.3%, and 35.6%, respectively, in the observed *test* hydrograph compared to the estimated *baseline* hydrograph. The difference in mean open-water discharge was classified as **Negligible-Low.** The difference in annual maximum daily discharge and mean winter discharge were classified as **Moderate**, and the difference in open-water minimum daily discharge was classified as **High**. The results of the longitudinal assessment of the Muskeg River suggested that the extent of the **High** hydrologic changes was limited to a length of the Muskeg River between Stanley Creek and Muskeg Creek.

In the 2014 WY, the water level of Kearl Lake declined from November until mid-April and then increased from early April to early June and then decreased steadily until early September. The maximum lake level was 0.05 m higher than the historical mean annual maximum daily level. From early September until the end of the water year, the lake level remained relatively stable. The lake level was within the historical interquartile range for most of the WY, and did not exceed or drop below historical maxima or minima.

Water Quality In fall 2014, concentrations of most water quality measurement endpoints were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2014 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most water quality measurement endpoints at *test* station MUR-1 were within the range of regional *baseline* fall concentrations, with monthly variability generally showing higher concentrations of ions and metals in winter and early spring when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at *test* station MUR-1 remained consistent.

Benthic Invertebrate Communities and Sediment Quality Differences in values of measurement endpoints at *test* reach MUR-E1 were classified as **Negligible-Low** because the significant changes in CA Axis 1 and 2 scores were a result of higher relative abundances of benthic invertebrates at this reach. Higher relative abundances of chironomids, mayflies, and caddisflies, and the presence of stoneflies were indicative of good water quality and habitat conditions and higher habitat quality relative to 2013. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. The percentage of EPT taxa was slightly higher than the inner tolerance limit for the 95^{th} percentile, indicating a positive change at *test* reach MUR-E1.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because there were no significant changes detected at this reach, with high diversity and a high percentage of EPT taxa in 2014, and habitat quality was higher relative to 2013.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because the significant increase over time in the percentage of EPT taxa and the higher percentage of EPT taxa in 2014 compared to the mean of *baseline* years or the mean of all years combined were indicative of a positive change in the benthic invertebrate community. Four measurement endpoints were outside of the tolerance limits for the historical range of variation, but were also indicative of improving water quality and benthic community health. The relative abundance of tubificid worms was high in 2014, but consistent with previous years, and habitat quality was higher relative to 2013.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach JAC-D1 were classified as **Negligible-Low** because equitability was lower than previous years, indicating improving conditions, and the benthic community was diverse, including clams, snails, mayflies, and stoneflies.

Differences in measurement endpoints of benthic invertebrate communities of Kearl Lake were classified as **Negligible-Low** because the statistically large changes observed for richness, equitability, and CA Axis 1 and 2 scores were not indicative of degraded conditions. Additionally, the benthic invertebrate community of Kearl Lake contained a diverse fauna and included several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves).

Concentrations of sediment quality measurement endpoints at all Muskeg River watershed stations sampled in fall 2014 were within previously-measured concentrations, with the exception of naphthalene at *baseline* station JAC-D2, and *test* stations MUR-D3 and KEL-1, and total dibenzothiophenes, total PAHs, and total alkylated PAHs at *test* station KEL-1, which were below previously-measured minimum concentrations. Concentrations of F3 hydrocarbons exceeded the relevant CCME guideline at *test* stations JAC-D1 and MUR-D2, and F1, F2, and F3 hydrocarbons exceeded guidelines at *test* station KEL-1. Concentrations of metals in 2014 were below CCME guidelines. Differences in sediment quality in fall 2014 at all applicable stations of the Muskeg River watershed were classified as **Negligible-Low** relative to regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at *test* reach MUR-F1 were classified as **Moderate**. Although values of all measurement endpoints were within the range of regional *baseline* variability, there were significant decreases in abundance and CPUE, which were indicative of a potential negative change in the fish assemblage over time. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and regional *baseline* conditions were classified as **Negligible-Low** given there were no significant differences implying a negative change in the fish assemblage and only abundance and diversity were at the outer tolerance limit of the 5th percentile of variation of baseline conditions. Differences in measurement endpoints for test reach MUR-F3 were classified as **High** because although there were no significant differences over time, abundance, diversity, and CPUE have been below the range of baseline variability for three consecutive years.

Differences in measurement endpoints of the fish assemblage at *test* reach JAC-F1 were classified as **High** given abundance and CPUE were low and near the outer tolerance limit of the 5th percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints that were indicative of a negative change in the fish assemblage over time. It should be noted; however, that although there has been decreases in measurement endpoints since 2009, abundance, CPUE, richness, and diversity were higher in 2014 compared to 2013, which could indicate improving conditions.

5.2.2 Hydrologic Conditions: 2014 Water Year

Muskeg River

Hydrometric monitoring for the Muskeg River watershed in the 2014 WY was conducted at the following locations:

- WSC Station 07DA008 (formerly JOSMP Station S7), Muskeg River near Fort McKay;
- JOSMP Station L2 Kearl Lake;
- JOSMP Station S2 Jackpine Creek at Canterra Road;
- JOSMP Station S3 Iyinimin Creek above Kearl Lake;
- JOSMP Station S5 Muskeg River above Stanley Creek;
- JOSMP Station S5A Muskeg River above Muskeg Creek;
- JOSMP Station S9 Kearl Lake Outlet;
- JOSMP Station S10A Wapasu Creek near the mouth;
- JOSMP Station S20A Muskeg River Upland;
- JOSMP Station S22 Muskeg Creek near the mouth;
- JOSMP Station S33 Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary;
- JOSMP Station S37 East Jackpine Creek near the 1,300 ft. contour; and
- JOSMP Station S65 Greenstockings Creek at the East Athabasca Hwy.

Data from WSC Station 07DA008 (formerly JOSMP Station S7) were used for the water balance analysis and presented below. The data from JOSMP Station L2 are also presented below. Data from each JOSMP station can be found in Appendix C.

Seasonal data from March to October have been collected every year since 1974 at WSC Station 07DA008 (formerly JOSMP Station S7). Data during the winter months (November to February) were also collected from 1974 to 1986 and from 1999 to 2014; therefore, the data record was annual and continuous during these years.

The historical flow record for WSC Station 07DA008 is summarized in Figure 5.2-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Muskeg River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs between late March and late April. Monthly flows are most often highest in May, at the peak of freshet, and often remain elevated in June and July when total monthly rainfall are highest (Figure 4.2-2). Flows then generally decrease in fall; however, slight increases in discharge are common late in the water year in response to fall precipitation events.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above. Flows steadily decreased from November 2013 to March 2014, and generally remained close to historical median values for much of this period (Figure 5.2-3). The main rising limb associated with the spring thaw started in the third week of April, later than usual, and flows were lower than historical minima recorded from April 16 to April 22. Discharge increased rapidly to an initial peak in early May, and the peak annual flow (41.1 m^3/s) was reached on June 5 following rainfall accumulations. This peak was 70% higher than the historical mean annual maximum daily flow (24.2 m^3/s), and all flows from June 2 to June 11 were above historical maxima recorded on these dates. Flows then decreased until the minimum open-water daily flow of 0.687 m^3/s on September 25, which was 35% lower than the historical mean minimum daily flow of 1.052 m^3/s calculated for the open-water period. All flows from early August until the end of October were lower than historical median values.

Overall, the annual runoff volume in the 2014 WY was 148 million m^3. This value was 30% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Muskeg River watershed, at WSC Station 07DA008 (formerly JOSMP Station S7) is summarized in Table 5.2-2. Key changes in flows included:

1. The closed-circuited land change area as of 2014 was estimated to be 147.6 km^2 (Table 2.3-1). The loss of flow to the Muskeg River that would have otherwise occurred from this land area was estimated at 15.674 million m^3.

3. As of 2014, the area of land change in the Muskeg River watershed that was not closed-circuited was estimated to be 85.8 km^2 (Table 2.3-1). The increase in flow to the Muskeg River that would not have otherwise occurred from this land area was estimated at 1.821 million m^3.

4. Syncrude discharged 6.423 million m^3 of water into Stanley Creek via the Aurora Clean Water Diversion (CWD). As in previous water balance calculations involving the CWD (e.g., RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012; RAMP 2013), the assumption was made that none of the water released from the CWD would have reached the Muskeg River through other sources. Given that some of the CWD flows were diverted surface water, some proportion of this water likely would have contributed to the Muskeg River naturally; however, this was undefined.

5. Shell withdrew 0.385 million m^3 from the Athabasca River. This was released into Jackpine Creek to augment or maintain flows from October to May.

6. Imperial withdrew approximately 0.003 million m^3 (3,347 m^3) of water from Wapasu Creek for dust suppression.

7. Suncor Firebag withdrew approximately 0.004 million m^3 (3,564 m^3) of water from Wapasu Creek for dust suppression.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2014 WY was a loss of flow of 7.049 million m^3 at WSC Station 07DA008 (JOSMP Station S7). The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -4.9%, -5.5%, -8.3%, and 35.6% difference, respectively, for the observed *test* hydrograph compared to the estimated *baseline* hydrograph (Table 5.2-3). The mean open-water difference was classified as **Negligible-Low**; the mean winter and annual maximum differences were classified as **Moderate**, and the open-water minimum difference was classified as **High** (Table 5.2-1). This category of results required an additional, longitudinal classification of effects to be completed along the length of Muskeg River, using the methods outlined in Section 3.2.1.5.

The results of this analysis are presented in Figure 5.2-4, which shows a map of classified hydrologic changes along the length of the Muskeg River. Assessed changes for the Muskeg River above Stanley Creek (upstream of JOSMP Station S5), where land disturbance and water withdrawals and discharges were limited, were classified as **Negligible-Low**. Stanley Creek flows into the Muskeg River downstream of JOSMP Station S5, but upstream of JOSMP Station S5A, Muskeg River above Muskeg Creek, and impacts on this tributary included both large net releases of water and additional land disturbance. The hydrological change on the Muskeg River between the confluences of Stanley Creek and Muskeg Creek were classified as **High**. Downstream of Station S5A, until the confluence with Jackpine Creek, there was additional change from nearby land disturbance; therefore, the hydrologic changes were classified as **Moderate.** For the lowest 15 km of the Muskeg River (downstream of Jackpine Creek), including WSC Station 07DA008, the large contributing areas (e.g., from Jackpine Creek) were not impacted by either land disturbance or water withdrawals or releases; therefore, hydrologic changes for this reach were classified as **Negligible-Low**. The results from this longitudinal assessment suggested that the extent of **High** hydrologic changes was limited to a length of the Muskeg River between Stanley Creek and Muskeg Creek.

Kearl Lake

Continuous lake level data have been collected at Station L2 since 1999, with partial records for 1999 to 2001, and 2008. In the 2014 WY, the lake level declined from November until mid-April and then increased from early April to early June. The maximum lake level of 332.170 masl was reached on June 9 before decreasing steadily until early September. The maximum level was 0.05 m higher than the historical mean annual maximum daily lake level. From early September until the end of the water year, the lake level remained relatively stable. The lowest lake level of the water year was reached on May 1 (331.761 masl) and was 0.01 m higher than the historical mean minimum daily lake level of 331.750 masl. calculated for the open-water period. The lake level was within the historical interquartile range for most of the WY, and did not exceed or drop below historical maxima or minima. The difference between annual maximum and minimum lake level in the 2014 WY was 0.521 m. The mean historical difference was 0.415 m.

5.2.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Muskeg River near its mouth (*test* station MUR-1), sampled from 1997 to 2014 in fall and on a monthly basis starting in 2013;
- the Muskeg River upstream of Wapasu Creek (*test* station MUR-6A), initiated in 2013 when access issues required moving station MUR-6 further upstream (less than a kilometre). MUR-6 was designated as *baseline* from 1998 to 2007 and *test* from 2008 to 2012. When moved slightly upstream in 2013 and renamed, MUR-6A, it remained designated as a *test* station;
- Jackpine Creek near its mouth (*test* station JAC-1), designated as *baseline* from 1998 to 2005 and *test* from 2006 to 2014;
- upper Jackpine Creek (*baseline* station JAC-2), sampled since 2008;
- Muskeg Creek near its mouth (*test* station MUC-1), sampled intermittently from 1998 to 2014, designated as *baseline* from 1998 to 2007 and *test* from 2008 to 2014;
- Stanley Creek near its mouth (*test* station STC-1), designated as *baseline* from 2001 to 2002 and *test* from 2003 to 2014;
- Iyinimin Creek near its mouth (*test* station IYC-1), sampled in 2007, 2008, and from 2010 to 2014, designated as *baseline* from 2007 to 2008 and *test* from 2010 to 2014;
- Wapasu Creek near its mouth (*test* station WAC-1), sampled in 1998 and 1999 and from 2004 to 2014, designated as *baseline* from 1998 to 2006 and *test* from 2007 to 2014; and
- Kearl Lake (*test* station KEL-1), designated as *baseline* from 1998 to 2008 and *test* from 2009 to 2014.

Temporal Trends The following significant (α=0.05) trends over time in fall concentrations of water quality measurement endpoints were observed:

- An increasing concentration of total boron and decreasing concentrations of chloride, total suspended solids, and sulphate at *test* station MUR-6A (using data from *test* station MUR-6 for years prior to 2013);
- Decreasing concentrations of chloride, total suspended solids, and sulphate at *test* station MUC-1;
- An increasing concentration of total boron at *test* station JAC-1;
- Increasing concentrations of total boron, total arsenic, and dissolved phosphorus, and a decreasing concentration of sulphate at *test* station STC-1;
- A decreasing concentration of sulphate at *test* station WAC-1; and
- A decreasing concentration of sulphate, and an increasing concentration of dissolved phosphorus and total arsenic at *test* station KEL-1.

2014 Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2014 had concentrations within the range of previously-measured concentrations at each station, with the following exceptions (Table 5.2-4 to Table 5.2-12):

- At *test* station MUR-1, concentrations of total dissolved phosphorus, total aluminum, dissolved aluminum, retene, total PAHs, total parent PAHs, and total alkylated PAHS were below previously-measured minimum concentrations, and naphthenic acids and oilsands extractable acids exceeded previously-measured maximum concentrations (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- At *test* station MUR-6A, the concentration of naphthenic acids exceeded the previously-measured maximum concentration, and total dissolved phosphorus, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;
- At *test* station MUC-1, concentrations of total dissolved phosphorus, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, were below previously-measured minimum concentrations, and naphthenic acids and oilsands extractable acids exceeded previously-measured maximum concentrations;
- At *test* station JAC-1, pH and the concentration of naphthenic acids exceeded previously-measured maximum concentrations, and retene, total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;
- At *baseline* station JAC-2, pH and concentrations of naphthenic acids and oilsands extractable acids exceeded previously-measured maximum concentrations, and total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;
- At *test* station STC-1, concentrations of naphthenic acids and oilsands extractable acids exceeded previously-measured maximum concentrations and total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;
- At *test* station WAC-1, concentrations of calcium, chloride, and naphthenic acids exceeded previously-measured maximum concentrations, and total aluminum, total molybdenum, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;
- At *test* station IYC-1, concentrations of dissolved phosphorus, naphthenic acids, and oilsands extractable acids exceeded previously-measured maximum concentrations, and concentrations of total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs was below previously-measured minimum concentration; and
- At *test* station KEL-1, concentrations of calcium, naphthenic acids and oilsands extractable acids exceeded previously-measured maximum concentrations, and total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were below previously-measured minimum concentration.

Ion balance The ionic composition of water at stations in the Muskeg River watershed was similar to previous years and dominated by calcium and bicarbonate (Figure 5.2-6 and Figure 5.2-7). The ionic composition of water in Stanley Creek (*test* station STC-1) has historically shown the greatest variability of all stations (Figure 5.2-7), reflecting the influence of site drainage water from Syncrude's Aurora North project (i.e., the Clean Water Discharge). In the last six years; however, the ionic balance at *test* station STC-1 has been consistently dominated by calcium and bicarbonate, with low concentrations of sulphate and chloride.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines In fall 2014, concentrations of water quality measurement endpoints at stations in the Muskeg River watershed were below water quality guidelines with the exception of total aluminum at *baseline* station JAC-2.

Other Fall Water Quality Guideline Exceedances The following other water quality variables exceeded water quality guidelines in the Muskeg River watershed in fall 2014 (Table 5.2-13):

- Sulphide at *test* stations MUR-6A, WAC-1, JAC-1, IYC-1, KEL-1, and MUC-1;
- Total iron at *test* stations MUR-1, MUR-6A, JAC-1, IYC-1, WAC-1, and MUC-1, and *baseline* station JAC-2;
- Dissolved iron at *test* stations JAC-1 and IYC-1, and *baseline* station JAC-2;
- Total phenols at *test* stations JAC-1 and IYC-1; and
- Total chromium at *baseline* station JAC-2.

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of water quality measurement endpoints at *test* stations MUR-1, MUR-6A, MUC-1, JAC-1, STC-1, IYC-1, and WAC-1, and *baseline* station JAC-2 were within regional *baseline* concentrations, with the exception of (Figure 5.2-8 and Figure 5.2-9):

- Total dissolved phosphorus with concentrations below the 5^{th} percentile of regional *baseline* concentrations at *test* stations MUR-1 and MUC-1;
- Total nitrogen, total arsenic, and total mercury (ultra-trace), with concentrations below the 5^{th} percentile of regional *baseline* concentrations at *test* station STC-1; and
- Sulphate, with concentrations below the 5^{th} percentile of regional *baseline* concentrations at *test* stations MUR-6A, STC-1, and WAC-1.

Concentrations of water quality measurement endpoints in Kearl Lake (*test* station KEL-1) (Figure 5.2-10) were not compared to regional *baseline* concentrations because lakes were not included in the calculation of regional *baseline* conditions given ecological differences between lakes and rivers. A range of regional *baseline* conditions was not calculated for lakes sampled by JOSMP due to the limited *baseline* data available.

Water Quality Index WQI values for all Muskeg River watershed stations in fall 2014 indicated **Negligible-Low** differences from regional *baseline* water quality conditions. WQI values were 98.2 at *test* station WAC-1, 98.7 at *test* station JAC-1 and 100 at all remaining stations (Table 5.2-14).

Monthly Water Quality Results Water quality samples were collected monthly at *test* station MUR-1 in 2014 (Table 5.2-15).

Monthly Water Quality Guideline Exceedances Water quality variables that exceeded guidelines at *test* station MUR-1 in 2014 included (Table 5.2-16):

- Sulphide in all months except September and April;
- Total phenols from March to July;
- Total aluminum in April, May, June, and July and dissolved aluminum in April;
- Total iron in all months, and dissolved iron in January, May, July, August, November, and December;
- Total mercury (ultra-trace) in April; and
- Total chromium in April and June.

2014 Monthly Results Relative to Regional Fall *Baseline* Concentrations In 2014, most monthly data collected at *test* station MUR-1 were within the range of fall regional *baseline* concentrations (Figure 5.2-11), with the exception of:

- Total dissolved solids, with a concentration below the 5th percentile of regional *baseline* fall concentrations in May (annual minimum);
- Dissolved phosphorus, with concentrations below the 5th percentile of regional *baseline* fall concentrations in January, February, March, April, September (annual minimum), and December;
- Total strontium, with concentrations below the 5th percentile of regional *baseline* fall concentrations in May (annual minimum) and June;
- Total mercury (ultra-trace), with concentrations below the 5th percentile of regional *baseline* fall concentrations in January, March, and December (annual minimum), and concentrations that exceeded the 95th percentile in April (annual maximum);
- Calcium, with a concentration that exceeded the 95th percentile of regional *baseline* fall concentrations in March;
- Magnesium and total alkalinity, with concentrations below the 5th percentile of regional *baseline* fall concentrations in June;
- pH, with a value that exceeded the 95th percentile of regional *baseline* fall concentrations in October; and
- Hardness, with a concentration that exceeded the 95th percentile of regional fall *baseline* concentrations in March and was below the 5th percentile in June.

Monthly Ionic Balance In 2014, the ionic composition at *test* station MUR-1 was dominated by bicarbonate and calcium ions and remained consistent throughout the year (Figure 5.2-12).

Classification of Fall Results In fall 2014, concentrations of most water quality measurement endpoints were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2014 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints at *test* station MUR-1 were within the range of regional *baseline* fall concentrations, with monthly variability generally showing higher concentrations of ions and metals in winter and early spring when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at *test* station MUR-1 remained consistent.

5.2.4 Benthic Invertebrate Communities and Sediment Quality

5.2.4.1 Benthic Invertebrate Communities

Muskeg River Mainstem

Benthic invertebrate communities were sampled in fall 2014 at:

- erosional *test* reach MUR-E1, near the mouth of the Muskeg River, sampled since 2000;
- depositional *test* reach MUR-D2, near the Canterra Road crossing, sampled since 2000; and
- depositional *test* reach MUR-D3, designated as *baseline* from 2002 to 2007 and *test* from 2008 to 2014.

2014 Habitat Conditions Water at *test* reach MUR-E1 in fall 2014 was shallow (0.2 m in sampled locations), fast flowing (1.0 m/s), alkaline (pH: 8.5), with high conductivity (420 µS/cm) (Table 5.2-17). The substrate was dominated by small cobble (42%) and gravel (54%). Periphyton chlorophyll *a* biomass averaged 25.6 mg/m^2, which was within the inner tolerance limits for regional *baseline* variability (Figure 5.2-13).

Water at *test* reach MUR-D2 in fall 2014 was deep (1.5 m), slightly alkaline (pH=7.4), with high conductivity (419 µS/cm), and high dissolved oxygen (7.8 mg/L) (Table 5.2-17). The substrate was dominated almost completely by sand (94%) with a small amount of silt (4%) and clay (2%), and low total organic carbon content (<1%) (Table 5.2-17).

Water at *test* reach MUR-D3 in fall 2014 was relatively deep (1.4 m), slow moving (0.16 m/s), with a pH of 6.9, and high conductivity (403 µS/cm) (Table 5.2-17). The substrate was primarily composed of sand (41%) and silt (53%), with a small amount of clay (6%), and high total organic carbon content (26%) (Table 5.2-17).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach MUR-E1 in fall 2014 was dominated by Ephemeroptera (46%), and chironomids (26%) with subdominant taxa consisting of Trichoptera (9%) and naidid worms (6%) (Table 5.2-18). Chironomids were diverse, consisting of many common forms (Wiederholm 1983) including *Polypedilum, Lopesocladius, Rheotanytarsus,* and *Tvetenia.* Mayflies were represented by the genera *Baetis, Acerpenna, Ephemerella,* and *Heptagenia* among others. Other flying insects such as stoneflies (*Chloroperlidae, Isoperla,* and *Pteronarcys*), caddisflies (*Hydropsyche, Glossosoma, and Lepidostoma),* and dragonflies (*Ophiogomphus*) were found in low relative abundances. Fingernail and pea clams (*Pisidium* and *Sphaerium*) were also present.

The benthic invertebrate community of *test* reach MUR-D2 was dominated by chironomids (68%) with subdominant taxa consisting of ceratopogonids (9%), Ephemeroptera (5%), and naidid worms (5%) (Table 5.2-18). Chironomids primarily consisted of the common genera *Polypedilum*, *Saetheria*, *Paralauterborniella*, *Cladotanytarsus*, and *Stempellinella.* Six kinds of Ephemeroptera were found, the most common being from the genus *Caenis* and *Acerpenna pygmaea.* Trichoptera larvae primarily consisted of *Oxyethira,* but also included *Lepidostoma* and *Ceraclea.* Bivalves *(Pisidium/Sphaerium)* and *Gastropods (Ferrissia rivularis, Gyraulus,* and Lymnaeidae*)* were present but in low relative abundances and a single stonefly (*Isoperla*) was found at one replicate station in fall 2014 (Table 5.2-18).

The benthic invertebrate community of *test* reach MUR-D3 was dominated by chironomids (42%) with subdominant taxa consisting of Bivalvia (16%), Ephemeroptera (15%), and tubificid worms (12%) (Table 5.2-18). Dominant chironomids included the common genera *Polypedilum, Procladius,* and *Cladotanytarsus.* Mayfly larvae (Leptophlebia and Callibaetis) and caddisflies (*Mystacides*, *Ptilostomis,* and Molannidae) were found in low relative abundances. Permanent aquatic forms such as bivalves (*Pisidium/Sphaerium*), gastropods (*Gyraulus* and *Menetus cooperi*), and amphipods (*Gammarus lacustris* and *Hyalella azteca*) were found at *test* reach MUR-D3.

Temporal Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of the Muskeg River. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach MUR-E1 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2014 values and all previous years of sampling.

Temporal comparisons of measurement endpoints for *test* reach MUR-D2 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2014 values and the mean of all previous years of sampling.

Temporal comparisons of measurement endpoints for *test* reach MUR-D3 included testing for:

- changes from before (2002 to 2007) to after (2008 to present) the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- changes over time during the *test* period (Hypothesis 7, Section 3.2.3.1);
- changes between 2014 values and the mean of all *baseline* years; and
- changes between 2014 values and the mean of all previous years of sampling.

CA Axis 1 scores were lower in 2014 than the mean of previous sampling years at *test* reach MUR-E1 (Table 5.2-19). A shift in composition of the benthic invertebrate community to a greater relative abundance of EPT taxa (i.e., mayflies, caddisflies, and stoneflies) and the absence of tubificids at *test* reach MUR-E1 accounted for a large portion of the variance in annual means (Figure 5.2-14). CA Axis 2 scores were higher in 2014 than the mean of previous sampling years at *test* reach MUR-E1, accounting for 20% of the variance in annual means (Table 5.2-19).

There were no significant changes in measurement endpoints for benthic invertebrate communities at middle *test* reach MUR-D2 in 2014 (Table 5.2-20).

The percentage of the fauna as EPT taxa was significantly higher in 2014 than the mean of all previous years of sampling (2002 to 2013) at *test* reach MUR-D3, accounting for 25% of the variance in annual means (Table 5.2-21).

Comparison to Published Literature The benthic invertebrate community at *test* reach MUR-E1 was diverse, with a mean of 58 taxa per replicate sample and contained a number of taxa that are considered sensitive including the mayfly *Acerpenna pygmaea*, caddisfly *Hydropsyche*, and the stonefly *Isoperla* (Hynes 1960; Mandeville 2001; Griffiths 1998). Tubificidae, which is generally considered a group of tolerant worms (Mandeville 2001), were not present in fall 2014.

The benthic invertebrate community at *test* reach MUR-D2 was diverse, with a mean of 27 taxa per sample and included a number of taxa that are considered relatively sensitive including flying insects (mayflies: *Caenis* and *Acerpenna*) and permanent aquatic forms (bivalves: *Pisidium/Sphaerium* and gastropods: *Gyraulus* and *Menetus cooperi*). The percentage of the fauna as worms was low (<10%; Table 5.2-18), indicating good overall water quality (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at *test* reach MUR-D3 reflected typical depositional habitat conditions that have improved slightly compared to conditions observed in 2013. The community was dominated numerically by chironomids (42%), but also contained a high relative abundance of tubificid worms (~15%), fingernail clams (*Pisidium/Sphaerium*, 17%), and other sensitive forms such as mayfly larvae (Mandeville 2001) (Table 5.2-18).

2014 Results Relative to Historical or Regional *Baseline* Conditions *Test* reaches of the Muskeg River have more than eight years of data; therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for each reach. If there were exceedances of the tolerance limits for a reach, in a direction of a negative change, comparisons to the tolerance limits for regional *baseline* variability (depositional or erosional) were evaluated.

Mean values of all measurement endpoints in fall 2014 at *test* reach MUR-E1 were within the inner tolerance limits of the historical range of variation for MUR-E1; however, equitability and richness were near the inner tolerance limit of the 5th percentile (Figure 5.2-14, Figure 5.2-15). The decrease in equitability was not a cause for concern as it indicated an increase in diversity at this reach. The percentage of fauna as EPT taxa was slightly higher than the inner tolerance limit for the 95th percentile in 2014, which was not indicative of a negative change. CA Axis 1 and 2 scores were outside of the inner tolerance limits of the historical range of variation for the lower *test* reach (Figure 5.2-14).

Mean values of abundance, richness, and CA Axis 1 and 2 scores in fall 2014 at *test* reach MUR-D2 were within the inner tolerance limits of the historical range of variation for this reach (Figure 5.2-16, Figure 5.2-17). Equitability was below the inner tolerance limit of the 5th percentile and the percentage of fauna as EPT taxa was higher than the inner tolerance limit for the 95th percentile in 2014; neither result was indicative of a negative change at this reach. When compared to the range of variability from regional *baseline* depositional reaches, equitability and the percentage of EPT taxa were still outside of the inner tolerance limits, but neither result was indicative of a negative change.

Mean values of CA Axis 1 and 2 scores in fall 2014 at upper *test* reach MUR-D3 were within the inner tolerance limits of the historical range of variation for this reach (Figure 5.2-17, Figure 5.2-18). Abundance and richness were slightly higher than the inner tolerance limit, but not yet approaching the outer tolerance limit. The percentage of EPT taxa was near the outer tolerance limit of the 95th percentile. Equitability was relatively consistent to 2013 and still below the inner tolerance limit of the 5th percentile. Although these four measurement endpoints were outside the range of historical variation, the changes were indicative of improving water quality and benthic community health. When compared to the range of variability from regional *baseline* depositional reaches, abundance and equitability were within the inner tolerance limits; however, the percentage of EPT taxa was still higher than the inner tolerance limit for the 95th percentile, indicating a greater percentage of sensitive EPT taxa compared to *baseline* reaches.

Classification of Results Differences in values of measurement endpoints at *test* reach MUR-E1 were classified as **Negligible-Low** because the significant changes in CA Axis 1 and 2 scores were a result of higher relative abundances of benthic invertebrates at this reach. Higher relative abundances of chironomids, mayflies, and caddisflies, and the presence of stoneflies were indicative of good water quality and habitat conditions and higher habitat quality relative to 2013. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. The percentage of EPT taxa was slightly higher than the inner tolerance limit for the 95th percentile, indicating a positive change at *test* reach MUR-E1.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because there were no significant changes detected at this reach, with high diversity and a high percentage of EPT taxa in 2014, and habitat quality was higher relative to 2013.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because the significant increase over time in the percentage of EPT taxa and the higher percentage of EPT taxa in 2014 compared to the mean of *baseline* years or the mean of all years combined were indicative of a positive change in the benthic invertebrate community. Four measurement endpoints were outside of the tolerance limits for the historical range of variation, but were also indicative of improving water quality and benthic community health. The relative abundance of tubificid worms was high in 2014, but consistent with previous years, and habitat quality was higher relative to 2013.

Jackpine Creek

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *test* reach JAC-D1 sampled since 2002 and designated as *test* since 2006; and
- depositional *baseline* reach JAC-D2 sampled since 2003.

2014 Habitat Conditions Water at *test* reach JAC-D1 in fall 2014 was moderately deep (0.37 m), with slow velocity (0.17 m/s), a pH of 7.0, with moderate conductivity (308 µS/cm), and high dissolved oxygen (Table 5.2-22). The substrate was dominated almost entirely by sand (82%) with some silt (16%) and small amounts of clay (2%), and low total organic carbon content (<1 %) (Table 5.2-22).

Water at *baseline* reach JAC-D2 was the same depth as the lower reach (0.37 m), alkaline (pH: 8.3), with moderate conductivity (282 µS/cm). Similar to the lower *test* reach, the substrate at *baseline* reach JAC-D2 was dominated by sand (87%), and the total organic carbon content was low (~1%) (Table 5.2-22).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach JAC-D1 in fall 2014 was dominated by chironomids (50%) with subdominant taxa consisting of Ceratopogonidae (13%), and naidid (10%) and tubificid (9%) worms (Table 5.2-23). The most common chironomid taxa at *test* reach JAC-D1 included genera such as *Polypedilum*, *Larsia,* and *Saetheria.* Mayflies (*Caenis* and *Leptophlebia*) and stoneflies (*Zapada*) were sparse. Permanent aquatic forms such as gastropods (*Gyraulus* and *Ferrissia rivularis*), bivalves (*Pisidium/Sphaerium*), and amphipods (*Hyalella azteca)* were found in low relative abundances (Table 5.2-23).

The benthic invertebrate community at *baseline* reach JAC-D2 in fall 2014 was dominated by chironomids (36%) with subdominant taxa consisting of miscellaneous Diptera (17%), Oligochaeta (10%), and Hydracarina (8%) (Table 5.2-24). Chironomid taxa were dominated by *Micropsectra*/*Tanytarsus*, *Stempellinella,* and *Paracladopelma*. Miscellaneous Diptera included Empididae, Tabanidae, Muscidae, and Tipulidae. Mayflies, including *Caenis* and Leptophlebiidae were present in low abundances. Stoneflies, including *Oxyethira, Oecetis,* and *Lepidostoma* were present at *baseline* reach JAC-D2 in 2014 (Table 5.2-24). Permanent aquatic forms such as gastropods (*Gyraulus*) and bivalves (*Pisidium/Sphaerium*) were found in low relative abundances.

Temporal and Spatial Comparisons Below are the temporal and spatial comparisons of benthic communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of Jackpine Creek.

Temporal comparisons of measurement endpoints for *test* reach JAC-D1 included testing for:

- changes over time during the *test* period (i.e., since 2006, Hypothesis 4, Section 3.2.3.1);
- changes between 2014 values and the mean of all available *baseline* data for Jackpine Creek; and
- changes between 2014 values and the mean of all previous years of sampling (2002 to 2013).

Spatial comparisons of measurement endpoints for *test* reach JAC-D1 included testing for:

- differences from *baseline* reach JAC-D2 over time;
- differences from *baseline* reach JAC-D2 from before (2003 to 2005) to after (2006 to present) the lower reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- differences from *baseline* reach JAC-D2 from before to after the lower reach was designated as *test* (i.e., BACI contrast, Hypothesis 3, Section 3.2.3.1); and
- differences from *baseline* reach JAC-D2 over time during the *test* period for the lower reach (2006 to present).

Abundance and richness were significantly higher at both the *test* and *baseline* reaches during the *test* period (2006 to 2014) at reach JAC-D1. These changes explained a relatively large amount of variance in the annual means (>20%) (Table 5.2-25). Equitability was significantly higher at both the *test* and *baseline* reaches during the *baseline* period (2003 to 2005) at JAC-D1, accounting for 28% of the variance in annual means.

Comparison to Published Literature The benthic invertebrate community at *test* reach JAC-D1 in fall 2014 was typical of what would be expected in depositional habitat. The benthic invertebrate community was dominated by chironomids; however, the percentage of worms was higher relative to 2013 (Table 5.2-23). Representative taxa of Ephemeroptera, Plecoptera, and Trichoptera, and permanent aquatic forms were all present in 2014 indicating stable, cold-water habitat conditions (Hynes 1960; Griffiths 1998).

The upper reach of Jackpine Creek (*baseline* reach JAC-D2) was similar to the lower reach and supported a benthic invertebrate community reflecting a typical depositional river. Similar to *test* reach JAC-D1, the upper reach supported a benthic invertebrate community with EPT taxa, bivalves, and gastropods, and a high richness in chironomids (Figure 5.2-21).

2014 Results Relative to Historical or Regional *Baseline* Conditions *Test* reach JAC-D1 has more than eight years of data (2002 to 2014); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for *baseline* reach JAC-D2 were evaluated. All measurement endpoints for *test* reach JAC-D1, with the exception of equitability, were within the inner tolerance limits of the normal range of variation for this reach in previous years (Figure 5.2-19, Figure 5.2-20). A decrease in equitability was consistent with improving conditions. When compared to regional *baseline* data, equitability was within the tolerance limits for regional *baseline* depositional reaches.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach JAC-D1 were classified as **Negligible-Low** because equitability was lower than previous years, indicating improving conditions, and the benthic community was diverse, including clams, snails, mayflies, and stoneflies.

Kearl Lake

Benthic invertebrate communities were sampled in fall 2014 in Kearl Lake (*test* station KEL-1), which was classified as *baseline* from 2001 to 2008, and *test* from 2009 to 2014.

2014 Habitat Conditions Water in Kearl Lake in fall 2014 had a pH of 6.7, moderate conductivity (185 µS/cm), and high dissolved oxygen (9.8 mg/L). The substrate was primarily comprised of silt (88%) with small amounts of sand (3%) and clay (9%) and high organic carbon content (37%) (Table 5.2-26).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate taxa of Kearl Lake in fall 2014 were dominated by chironomids (41%), and naidid worms (36%) with subdominant taxa consisting of bivalves (10%) and tubificids (8%) (Table 5.2-27). Dominant chironomids included *Polypedilum, Cladopelma, Tanytarsus,* and *Chironomus*, which are commonly distributed in holarctic lakes. Bivalves were abundant and mainly from the two genera *Pisidium*/*Sphaerium*. Gastropods were represented by five genera species (*Ferrissia rivularis*, *Lymnaea, Gyraulus, Promenetus exacuous* and *Valvata sincera*). Trichoptera (Phryganeidae), Ephemeroptera (*Caenis*), and Odonata (*Cordulia shurtleffi*) were present but in low relative abundances (~1% each).

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Kearl Lake. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

The temporal comparisons of measurement endpoints included testing for:

- A difference between *baseline* (2001 to 2008) and *test* (2009 to present) periods;
- A time trend in the *test* period (i.e., since 2009);
- A difference between 2014 and the mean of all *baseline* years; and
- A difference between 2014 and all previous years.

Richness increased over time during the *test* period and was higher in 2014 than the mean of *baseline* years or the mean of all previous years (Table 5.2-28). These changes accounted for 36%, 33%, and 30% of the variance in annual means, respectively. Equitability decreased over time during the *test* period and was lower in 2014 than the mean of *baseline* years or the mean of all previous years (Table 5.2-28). These changes accounted for 31%, 38%, and 45% of the variance in annual means, respectively.

CA Axis 1 and 2 scores were higher in 2014 than the mean of the *baseline* years or the mean of all previous years (Table 5.2-28). The changes in axis scores was likely due to a shift in taxa composition in Kearl Lake with fewer amphipods and bivalves present in 2014 compared to historical years.

Comparison to Published Guidelines The benthic fauna of Kearl Lake was not overly unusual and contained fauna that would be considered relatively typical of benthos from a shallow lake. The percent of the fauna as worms was higher in 2014 than 2013, possibly indicating degraded water and sediment quality conditions (O'Toole et al. 2008). Chironomids accounted for 41% of the total benthic fauna, and species present tended to be a mix of tolerant (e.g., *Chironomus*) and ubiquitous (*Polypedilum, Tanytarsus*) taxa (Broderson and Lindegaard 1999). The benthic invertebrate community; however, also contained a mixture of permanent aquatic forms such as amphipods and bivalves, as well as larvae of flying insects (Ephemeroptera, Trichoptera), which indicated favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990).

2014 Results Relative to Historical Conditions Richness, equitability, and CA Axis 1 and 2 scores exceeded the tolerance limits of the normal range of variation for all previous years of sampling Kearl Lake (Figure 5.2-22 and Figure 5.2-23). Those results; however, were not indicative of negative changes given the increase in richness and diversity, and a modest change in taxa composition could all indicate improving conditions over time.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities of Kearl Lake were classified as **Negligible-Low** because the statistically large changes observed for richness, equitability, and CA Axis 1 and 2 scores were not indicative of degraded conditions. Additionally, the benthic invertebrate community of Kearl Lake contained a diverse fauna and included several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves).

5.2.4.2 Sediment Quality

Sediment quality was sampled in depositional reaches and lakes of the Muskeg River watershed in the same locations as benthic invertebrate community sampling in fall 2014, including:

- *test* station MUR-D2 of the Muskeg River (sampled in 2000, and 2003 to 2014);
- *test* station MUR-D3 of the Muskeg River (designated as *baseline* from 2002 to 2007 and *test* from 2008 to 2014);
- *test* station JAC-D1 of Jackpine Creek near its mouth (designated as *baseline* in 1997 and *test* from 2006 to 2014);
- *baseline* station JAC-D2 of Jackpine Creek (sampled since 2006); and
- *test* station KEL-1 in Kearl Lake (designated as *baseline* from 2001 to 2008 and as *test* from 2009 to 2014).

Temporal Trends The following significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected:

- Decreasing concentrations of total PAHs, total parent PAHs, total alkylated PAHs and PAH Hazard Index at *test* station MUR-D2; and
- Decreasing concentrations of total PAHs, total alkylated PAHs, and total arsenic at *test* station KEL-1.

No significant trends were observed in sediment quality at *test* stations MUR-D3 and JAC-D1 and *baseline* station JAC-D2.

2014 Results Relative to Historical Concentrations Sediments sampled in 2014 from all stations in the Muskeg River watershed were taken from the same locations as those reaches sampled from 2006 to 2014. Prior to the integration of the Sediment Quality component with the Benthic Invertebrate Communities component in 2006, *test* reaches MUR-D2 and MUR-D3 corresponded to pre-2006 sediment-quality *test* stations MUR-2 and MUR-D2 respectively, and *test* reach JAC-D1 corresponded with pre-2006 sediment quality station JAC-1; *baseline* reach JAC-D2 was established in 2006 (Table 5.2-29 to Table 5.2-33).

Similar with previous years, sediments at all Muskeg River and Jackpine Creek stations sampled in fall 2014 were dominated by sand, while Kearl Lake (KEL-1) was dominated by silt. In general, concentrations of sediment quality measurement endpoints were within previously-measured concentrations at each station with the following exceptions:

- Naphthalene was below the previously-measured minimum concentration at *baseline* station JAC-D2, and *test* stations MUR-D3 and KEL-1; and
- Total dibenzothiophenes, total PAHs, and total alkylated PAHs were below previously-measured minimum concentrations at *test* station KEL-1 (Table 5.2-29).

Most sediment toxicity results were within previous-measured concentrations for each station, except *Chironomus* survival at *test* stations MUR-D2 and MUR-D3, survival and growth of *Hyalella* at *test* station MUR-D3, and growth of *Hyalella* at *test* station JAC-D1, where historical highs were observed, and survival of *Hyalella*, which was below the previously-measured minimum value at *test* station KEL-1.

Spatial Comparisons The following comparisons of sediment quality measurement endpoints among stations in the Muskeg River watershed in fall 2014 were noted:

- Percent sand at *test* station MUR-D3 (83%) was lower than percent sand at *test* station MUR-D2 (88%), which was consistent with 2013. Percent sand was higher at *baseline* JAC-D2 (90.1%) than *test* station JAC-D1 (83.9%);
- Total organic carbon was higher at *test* station MUR-D3 (5.81%) than *test* station MUR-D2 (1.11%), which was consistent with 2013. Total organic carbon was higher at *test* JAC-D1 (1.81%) than *baseline* station JAC-D2 (0.59%);
- Concentrations of hydrocarbons (including PAHs) were generally higher at the lower *test* station (MUR-D2) than the upper *test* station (MUR-D3) of the Muskeg River (except for BTEX, F1 hydrocarbons, naphthalene, and retene, where higher concentrations were observed at *test* station at MUR-D3). *Baseline* station JAC-D2 exhibited the lowest concentrations of hydrocarbons across all sampling stations in the watershed; and
- Sediment toxicity results were similar at *test* and *baseline* stations of Jackpine Creek, although C*hironomus* survival was slightly higher at *test* station JAC-D1 (82%) than *baseline* station JAC-D2 (70%). Toxicity results also were similar between Muskeg River *test* stations, except for *Chironomus* survival, which was lower at *test* station MUR-D2 (88%) than *test* station MUR-D3 (95%).

2014 Results Relative to Regional *Baseline* Conditions Concentrations of all sediment quality measurement endpoints at all stations of the Muskeg River watershed in fall 2014 were within the range of regional *baseline* concentrations (Figure 5.2-24 to Figure 5.2-27), with the exception of total metals normalized to percent fines at *test* station JAC-D1, which was below the 5th percentile of regional *baseline* concentrations (Figure 5.2-26).

Concentrations of sediment quality measurement endpoints at Kearl Lake (Figure 5.2-28) were not compared to regional *baseline* concentrations because lakes were not included in the calculation of the *baseline* concentrations given the ecological differences between lakes and rivers.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of CCME hydrocarbons (BTEX and F1 to F4 hydrocarbons) at each station in fall 2014 were generally below relevant CCME guidelines, with the exception of F3 hydrocarbons at *test* stations JAC-D1 and MUR-D2, and F1, F2, and F3 hydrocarbons at *test* station KEL-1. No metal concentrations in 2014 exceeded CCME guidelines at any station.

Sediment Quality Index The SQI values for all stations in the Muskeg River watershed in fall 2014 indicated **Negligible-Low** differences in sediment quality conditions from regional *baseline* conditions (Table 5.2-34). A SQI was not calculated for *test* station KEL-1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Classification of Results Concentrations of sediment quality measurement endpoints at all Muskeg River watershed stations sampled in fall 2014 were within previously-measured concentrations, with the exception of naphthalene at *baseline* station JAC-D2, and *test* stations MUR-D3 and KEL-1, and total dibenzothiophenes, total PAHs, and total alkylated PAHs at *test* station KEL-1, which were below previously-measured minimum concentrations. Concentrations of F3 hydrocarbons exceeded the relevant CCME guideline at *test* stations JAC-D1 and MUR-D2, and F1, F2, and F3 hydrocarbons exceeded guidelines at *test* station KEL-1. Concentrations of metals in 2014 were below CCME guidelines. Differences in sediment quality in fall 2014 at all applicable stations of the Muskeg River watershed were classified as **Negligible-Low** relative to regional *baseline* conditions.

5.2.5 Fish Populations

Muskeg River Mainstem

Fish assemblages were sampled in fall 2014 at:

- *test* reach MUR-F1, near the mouth of the Muskeg River, sampled since 2009 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-E1);
- *test* reach MUR-F2, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D2); and
- *test* reach MUR-F3, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D3).

2014 Habitat Conditions *Test* reach MUR-F1 was comprised of run and shallow riffle habitat with a wetted width of 16.6 m and a bankfull width of 24.1 m. The substrate was comprised of fine gravel with small amounts of sand and cobble. Water at *test* reach MUR-F1 had a mean depth of 0.65 m, with slow velocity (mean=0.31 m/s), a pH of 8.25, high conductivity (393 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 11.9˚C. Instream cover consisted primarily of boulders and algae with small amounts of small woody debris (Table 5.2-35).

Test reach MUR-F2 was comprised entirely of deep run habitat with a wetted width of 11.5 m and a bankfull width of 15.8 m. The substrate was comprised of cobble with small amounts of sand. Water at *test* reach MUR-F2 had a mean depth of 0.66 m, with slow velocity (mean=0.31 m/s), a pH of 7.80, high conductivity (392 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 9.4˚C. Instream cover consisted of small woody debris and boulders with small proportions of macrophytes (Table 5.2-35).

Test reach MUR-F3 was comprised entirely of deep run habitat with a wetted and bankfull width of 9.2 m and substrate was comprised of sand and fine material. Water at *test* reach MUR-F3 had a mean depth of 1.92 m with negligible velocity, a pH of 7.85, high conductivity (404 µs/cm), moderately low dissolved oxygen (6.1 mg/L), and a temperature of 11.4˚C. Instream cover consisted of large and small woody debris, overhanging vegetation, and undercut banks (Table 5.2-35).

Relative Abundance of Fish Species The total catch of fish species at *test* reach MUR-F1 in 2014 was slightly higher than 2013; however, catch from 2012 to 2014 has remained below the range from 2009 to 2011. Slimy sculpin was the dominant species and accounted for 54.8% of the total catch, with burbot as the subdominant species (21.4%). The overall species composition has been relatively consistent across sampling years (Table 5.2-36).

The total catch of fish species at *test* reach MUR-F2 in 2014 was lower than 2013, with only five fish captured. Similarly, only four fish were captured at *test* reach MUR-F3, which was an increase from one fish caught in both 2012 and 2013 (Table 5.2-36). The low capture success was likely due to greater water depths, which decreased capture efficiency as well as lower dissolved oxygen at the upper *test* reach (MUR-F3).

Temporal and Spatial Comparisons Sampling was initiated at *test* reach MUR-F1 in 2009; therefore, temporal comparisons were conducted from 2009 to 2014 and included testing for changes in measurement endpoints over time (Hypothesis 1, Section 3.2.4.4). Temporal comparisons were also conducted for *test* reaches MUR-F2 and MUR-F3, although the low sample numbers in each year and only four years of data resulted in weak statistical strength. Spatial comparisons were not conducted for any of the *test* reaches of the Muskeg River due to the absence of an upstream *baseline* reach.

There were significant decreases in CPUE ($p=0.001$) and abundance ($p<0.001$) over time at *test* reach MUR-F1, indicating a negative change in the fish assemblage. However, there was also a significant decrease in the assemblage tolerance index (ATI) ($p=0.006$), indicating a greater proportion of more sensitive species at this reach. The ATI value in 2014 was the lowest recorded since 2009; all significant differences explained greater than 20% of the variance in the annual means (Table 5.2-37, Table 5.2-38).

Test reaches MUR-F2 and MUR-F3 were first sampled in 2011; therefore, temporal comparisons were conducted from 2011 to 2014. There was a significant increase in abundance ($p=0.02$) at *test* reach MUR-F2 (Table 5.2-39); however the change over time explained less than 20% of the variance in annual means. There were no significant differences observed over time at *test* reach MUR-F3 (Table 5.2-40).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on previous studies, 21 species have been documented in the Muskeg River; whereas JOSMP has found only fourteen fish species from 2009 to 2014. Past fish inventory studies in the Muskeg River used a variety of capture techniques (e.g., fish fence, trapping, electrofishing) targeting a broad range of life stages. Conversely, the JOSMP fish assemblage monitoring program has collected fish by means of a standardized protocol using backpack or boat electrofishing, which targeted small-bodied fish species and juvenile large-bodied fish species. These differences in fishing techniques may explain some of the observed variation in species richness reported by JOSMP for the FAM program versus historical studies. In addition, Golder (2004) documented fish inventory studies throughout the entire Muskeg River, whereas smaller, defined reach lengths were sampled by JOSMP.

Golder (2004) has documented similar habitat conditions in the portion of the Muskeg River where *test* reach MUR-F1 was located, consisting of slow riffle habitat, and infrequent pools dominated by cobble and gravel substrate with some boulder and fine sediment. Golder (2004) reported that this area of the river had low spawning potential, but provided excellent rearing habitat for young fish moving down from upstream spawning areas, as well as excellent resting areas for migratory fish coming from the Athabasca River (Bond and Machniak 1979). The low species richness observed at *test* reaches MUR-F2 and MUR-F3 could be attributed to the habitat conditions in these portions of the Muskeg River. Golder (2004) documented similar habitat conditions consisting of deep slow pools and runs, with substrate of primarily fines with very small amounts of gravel, cobble, and boulders. This portion of the river has low habitat diversity and limited spawning habitat and food supply for most fish species (Golder 2004).

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reach MUR-F1, with the exception of ATI, were within the inner tolerance limits of the normal *baseline* range (Figure 5.2-29). The mean ATI value was between the inner and outer tolerance limits of the 5th percentile. Abundance, CPUE and diversity at *test* reaches MUR-F2 and MUR-F3 were at the inner and outer tolerance limits of the lower 5th percentile for the normal range of *baseline* conditions while ATI and species richness were within the inner tolerance limits (Figure 5.2-30).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach MUR-F1 were classified as **Moderate.** Although values of all measurement endpoints were within the range of regional *baseline* variability, there were significant decreases in abundance and CPUE, which were indicative of a potential negative change in the fish assemblage over time. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and regional *baseline* conditions were classified as **Negligible-Low** given there were no significant differences implying a negative change in the fish assemblage and only abundance and diversity were at the outer tolerance limit of the 5th percentile of variation of *baseline* conditions. Differences in measurement endpoints for *test* reach MUR-F3 were classified as **High** because although there were no significant differences over time, abundance, diversity, and CPUE have been below the range of baseline variability for three consecutive years.

Jackpine Creek

Fish assemblages were sampled in fall 2014 at:

- *test* reach JAC-F1, near the mouth of Jackpine Creek, sampled since 2009 (this reach is at the same location as the benthic invertebrate community *test* reach JAC-D1); and
- *baseline* reach JAC-F2, sampled since 2009 (this reach is at the same location as the benthic invertebrate community *baseline* reach JAC-D2).

2014 Habitat Conditions *Test* reach JAC-F1 was comprised of run habitat with backwater pools and a wetted width of 8.2 m and bankfull width of 11.7 m. The substrate was comprised of sand with small amounts of cobble and fines. Water at *test* reach JAC-F1 had a mean depth of 0.89 m, with slow velocity (mean=0.04 m/s); a pH of 7.83, moderate conductivity (300 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 8.0 ºC. Instream cover consisted primarily of small woody debris with small amounts of algae (Table 5.2-41).

Baseline reach JAC-F2 was comprised of run habitat and a wetted width of 4.0 m and bankfull width of 7.0 m. The substrate was comprised of sand with some cobble and fine material. Water at *baseline* reach JAC-F2 had a mean depth of 0.56 m, with almost negligible velocity (mean=0.04 m/s), a pH of 8.28, moderate conductivity (291 µS/cm), high dissolved oxygen (9.1 mg/L), and a temperature of 13.6ºC. Instream cover consisted primarily of large and small woody debris with some macrophytes and overhanging vegetation (Table 5.2-41).

Relative Abundance of Fish Species The total catch of fish species in 2014 at *test* reach JAC-F1 was slightly higher than 2013 but lower compared to previous years (2010 and 2011). Only three species were captured in fall 2014, and consisting primarily of slimy sculpin. The total catch of fish species was much higher in 2014 at *baseline* reach JAC-F2 compared to 2013; with the second highest catch since sampling began in 2009 (2011 had a higher catch). Species composition in 2014 at *baseline* reach JAC-F2 was comparable to previous sampling years (Table 5.2-42).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach JAC-F1 included testing for changes over time in measurement endpoints from 2009 to 2014 (Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach JAC-F1 included testing for differences from *baseline* reach JAC-F2 in measurement endpoints over time (Hypothesis 2, Section 3.2.4.4).

Values of all measurement endpoints at *test* reach JAC-F1 exhibited a positive change (i.e., increase in abundance, diversity, richness, and CPUE; decrease in ATI) in 2014 compared to 2013, with the exception of abundance, which was negligibly lower. Similarly, all measurement endpoints showed a positive change at *baseline* reach JAC-F2 in 2014 compared to 2013 (Table 5.2-37, Table 5.2-43).

There were significant decreases in abundance (p=0.01), richness (p=0.004), diversity (p=0.03), ATI ($p<0.001$), and CPUE (p=0.04) over time at *test* reach JAC-F1, explaining greater than 20% of the variance in annual means (Table 5.2-43). There were no significant differences in measurement endpoints between *test* reach JAC-F1 and *baseline* reach JAC-F2 over time ($p>0.05$) (Table 5.2-43).

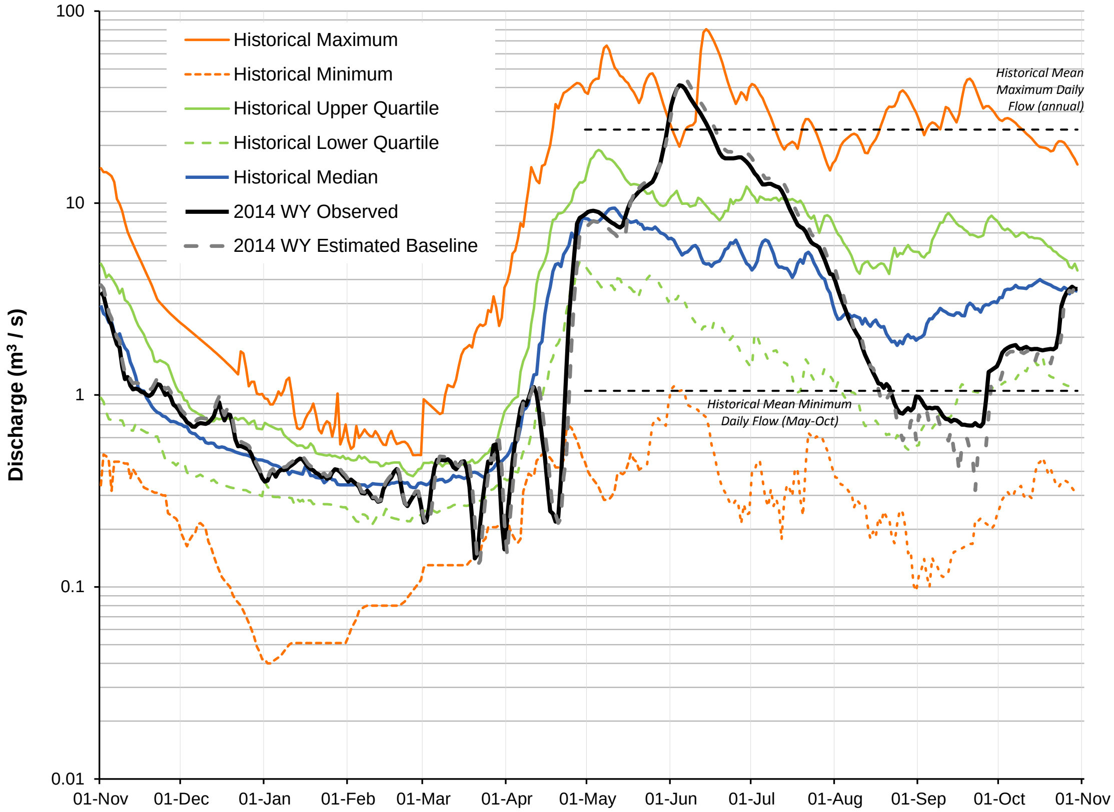
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important baseline data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of 15 fish species were recorded in Jackpine Creek; whereas JOSMP found only ten species from 2009 to 2014. Two additional fish species were observed by JOSMP from 2009 to 2014, including finescale dace and trout-perch that have not been previously documented (Table 5.2-42). Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., JOSMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder [2004]).

Golder (2004) documented similar habitat conditions to what have been observed by JOSMP, consisting of runs and small pools with sand/fine substrate and slow flowing water. This habitat is likely not suitable for most fish species in the region that require harder substrate and faster flowing water for spawning and rearing (e.g., sculpin sp., Arctic grayling, and sucker sp.) (Bond and Machniak 1977).

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints, with the exception of abundance and CPUE were between the inner tolerance limits of regional *baseline* conditions at *test* reach JAC-F1 (Figure 5.2-31).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach JAC-F1 were classified as **High** given abundance and CPUE were low and near the outer tolerance limit of the 5^{th} percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints that were indicative of a negative change in the fish assemblage over time. It should be noted; however, that although there has been decreases in measurement endpoints since 2009, abundance, CPUE, richness, and diversity were higher in 2014 compared to 2013, which could indicate improving conditions.

Figure 5.2-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Muskeg River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Muskeg River near Fort McKay, WSC Station 07DA008 (JOSMP Station S7). The upstream drainage area is 1,457 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1974 to 2013, and historical daily values from November 1 to February 28 calculated from data collected from 1974 to 1986 and from 1999 to 2013.

Note: For more realistic winter simulation of estimated *baseline* flows, the Clean Water Diversion releases reported by Syncrude were assumed to accumulate (be stored as ice) during mid-winter freezing conditions, then be released proportionally to observed flows during spring thaw.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.2-2 Estimated water balance at WSC Station 07DA008 (formerly JOSMP Station S7), Muskeg River near Fort McKay, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**147.667**	**Observed discharge, obtained from Muskeg River near Fort McKay, WSC Station 07DA008 (formerly JOSMP Station S7)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-15.674	Estimated 147.6 km^2 of the Muskeg River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	1.821	Estimated 85.8 km^2 of the Muskeg River watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Muskeg River watershed, relative to the estimated *baseline* hydrograph	-0.007	Water withdrawn by Shell, Imperial, and Suncor for flow augmentation and dust suppression (all values provided daily)
Water releases into the Muskeg River watershed, relative to the estimated *baseline* hydrograph	0	All released water is counted as a diversion in the Muskeg River watershed
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	6.808	Syncrude Aurora Clean Water Diversion discharges to Stanley Creek, and Shell Jackpine Mine diversion for Jackpine creek augmentation
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**154.740**	**Estimated *baseline* discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (formerly JOSMP Station S7)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-7.049	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-4.556**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Baseline values shown in the table were likely underestimated, because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: For more realistic winter simulation of estimated *baseline* flows, the Clean Water Diversion releases reported by Syncrude were assumed to accumulate (be stored as ice) during mid-winter freezing conditions, then be released proportionally to observed flows during spring thaw.

Note: All values in this table were presented to three decimal places.

Table 5.2-3 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed, 2014 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	8.486	8.926	-4.928%
Mean winter discharge	0.639	0.677	-5.520%
Annual maximum daily discharge	41.100	44.843	-8.346%
Open-water season minimum daily discharge	0.687	0.507	35.590%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from provisional data from WSC Station 07DA008.

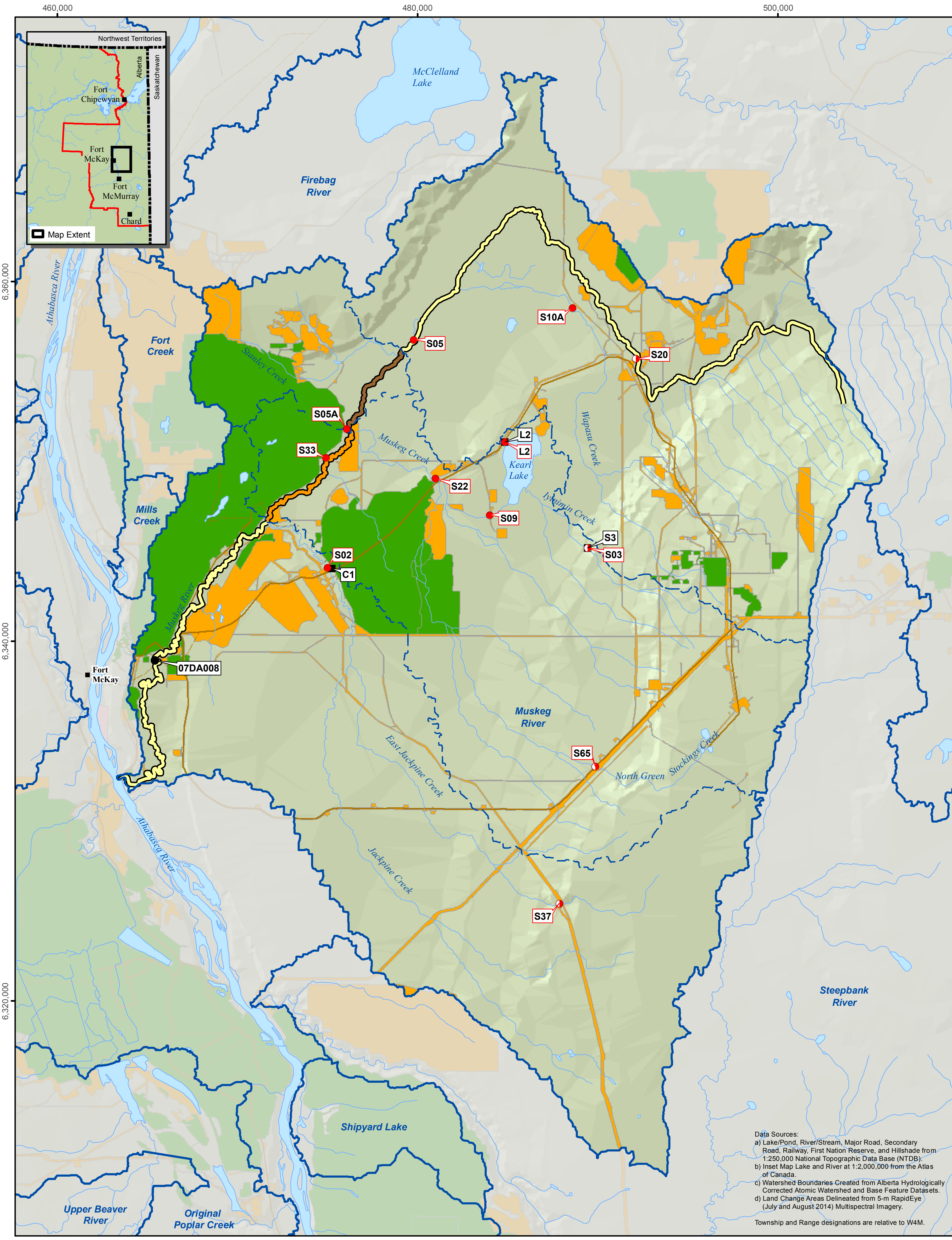
Note: Baseline values shown in the table were likely underestimated, because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: For more realistic winter simulation of estimated *baseline* flows, the Clean Water Diversion releases reported by Syncrude were assumed to accumulate (be stored as ice) during mid-winter freezing conditions, then be released proportionally to observed flows during spring thaw.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.2-4 Hydrologic change classification of the Muskeg River, 2014 WY.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Sub-Watershed Boundary
- Major Road
- Secondary Road
- First Nations Reserve

Land Change Area as of 2014[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Hydrometric Station

- JOSMP Seasonal
- JOSMP Year-Round
- Water Survey of Canada

Climate Station

- Year-Round Climate Station
- Seasonal Rainfall Monitoring Station

Hydrologic Change Classification

- Negligible-Low
- Moderate
- High

0 1 2 4 km

Scale: 1:220,000

Projection: NAD 1983 UTM Zone 12N

N

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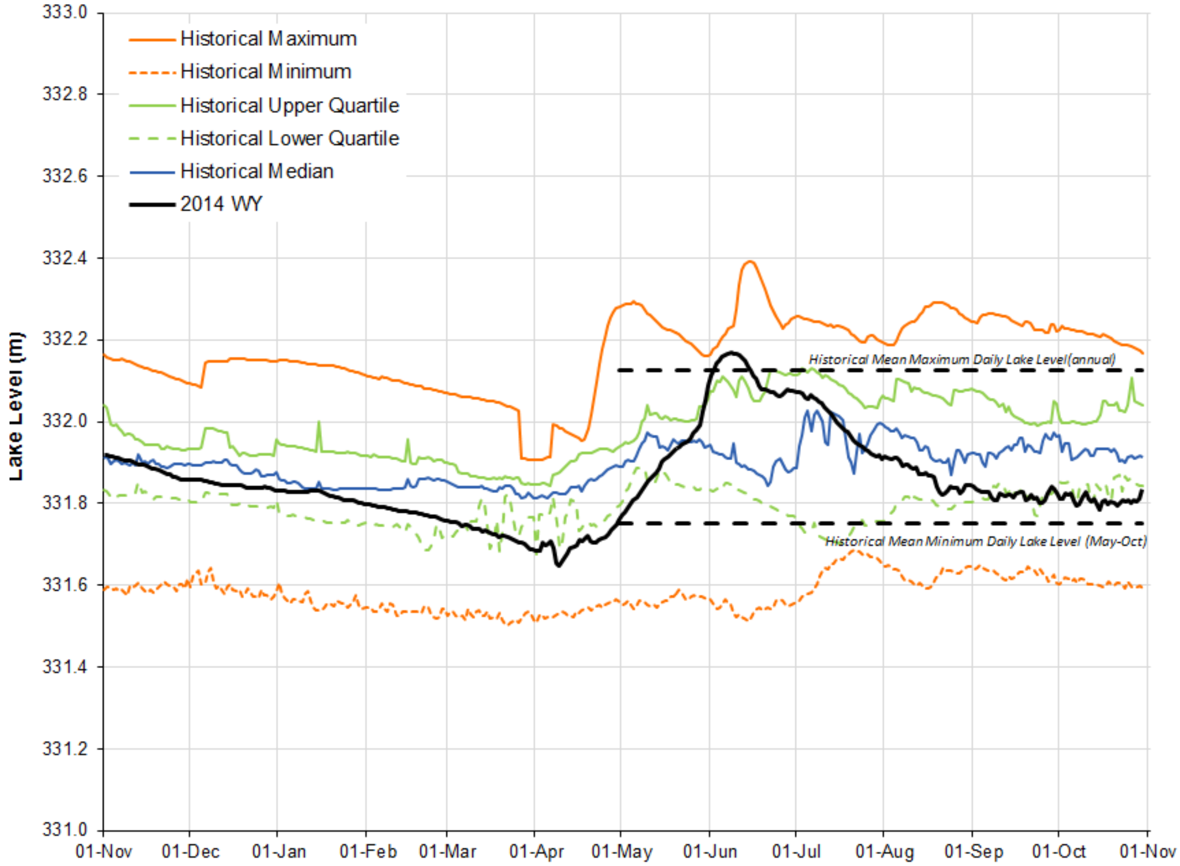
K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_M1_Muskeg_20150330_ss.mxd

Figure 5.2-5 Observed lake levels for Kearl Lake in the 2014 WY, compared to historical values.



Note: Based on provisional 2014 WY data recorded at Kearl Lake, JOSMP Station L2. Historical values were calculated for the period from 1999 to 2013, with periods of missing data present in most years.

Note: The historical mean minimum daily lake level was calculated for open-water months only (May to October). The historical mean maximum daily lake level was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.2-4 Concentrations of selected water quality measurement endpoints, mouth of Muskeg River (*test* station MUR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.36	17	7.40	8.24	8.61
Total suspended solids	mg/L	-	<3.0	17	<3.0	3.0	70
Conductivity	µS/cm	-	479	17	220	338	671
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.003</u>	17	0.004	0.013	0.030
Total nitrogen	mg/L	-	0.574	17	0.400	0.900	1.62
Nitrate+nitrite	mg/L	3	<0.054	17	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	16.1	17	15.0	22.0	29.0
Ions							
Sodium	mg/L	-	15.6	17	8.0	13.0	64.0
Calcium	mg/L	-	71.7	17	28.8	46.8	108
Magnesium	mg/L	-	17.3	17	7.1	12.3	18.9
Chloride	mg/L	120	7.4	17	1.0	3.0	36.0
Sulphate	mg/L	429	17.8	17	0.60	5.20	91.0
Total dissolved solids	mg/L	-	318	17	170	280	405
Total alkalinity	mg/L	-	231	17	105	177	313
Selected metals							
Total aluminum	mg/L	0.1	<u>0.021</u>	17	0.026	0.076	**1.20**
Dissolved aluminum	mg/L	0.05	<u>0.0013</u>	17	0.0016	0.0041	0.0300
Total arsenic	mg/L	0.005	0.0003	17	0.0003	0.0005	0.0010
Total boron	mg/L	1.2	0.052	17	0.032	0.048	0.150
Total molybdenum	mg/L	0.073	0.00007	17	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	0.79	11	0.60	1.20	3.00
Total strontium	mg/L	-	0.176	17	0.086	0.127	0.296
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>1.80</u>	3	0.210	0.430	0.880
Oilsands Extractable	mg/L	-	<u>2.40</u>	3	0.480	0.880	1.990
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<u>0.472</u>	3	0.894	1.13	2.15
Total dibenzothiophenes	ng/L	-	13.69	3	10.17	22.39	40.16
Total PAHs	ng/L	-	<u>101.3</u>	3	150.4	181.5	239.3
Total Parent PAHs	ng/L	-	<u>13.90</u>	3	17.18	20.69	23.74
Total Alkylated PAHs	ng/L	-	<u>87.4</u>	3	126.6	160.8	222.2
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.43**	17	0.29	**0.66**	**1.81**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-5 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (*test* station MUR-6A), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)[b]			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.15	16	7.20	8.10	8.40
Total suspended solids	mg/L	-	<3.0	16	<3.0	<3.0	25.0
Conductivity	µS/cm	-	440	16	225	312	524
Nutrients							
Total dissolved phosphorus	mg/L	-	0.011	16	0.011	0.014	0.0305
Total nitrogen	mg/L	-	0.724	16	0.300	0.886	1.93
Nitrate+nitrite	mg/L	3	<0.054	16	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	27.5	16	13.0	20.0	36.3
Ions							
Sodium	mg/L	-	3.60	16	2.90	3.40	7.00
Calcium	mg/L	-	65.1	16	28.1	44.3	67.4
Magnesium	mg/L	-	20.7	16	10.0	15.9	24.0
Chloride	mg/L	120	0.57	16	<0.50	1.00	3.00
Sulphate	mg/L	429	1.12	16	0.52	2.95	6.30
Total dissolved solids	mg/L	-	313	16	180	233	320
Total alkalinity	mg/L	-	235	16	99	175	292
Selected metals							
Total aluminum	mg/L	0.1	0.009	16	<0.003	0.021	**0.110**
Dissolved aluminum	mg/L	0.05	0.0016	16	0.0015	0.0053	<0.0100
Total arsenic	mg/L	0.005	0.0005	16	0.0003	0.0004	<0.0010
Total boron	mg/L	1.2	0.015	16	0.006	0.012	0.025
Total molybdenum	mg/L	0.073	0.00012	16	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	0.98	11	0.60	1.20	1.80
Total strontium	mg/L	-	0.121	16	0.053	0.085	0.164
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.90	3	0.20	0.26	0.42
Oilsands Extractable	mg/L	-	1.50	3	0.73	0.75	1.50
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.41	3	0.692	1.260	<2.071
Total dibenzothiophenes	ng/L	-	4.69	3	6.67	7.09	35.30
Total PAHs	ng/L	-	77.2	3	102.5	154.9	203.7
Total Parent PAHs	ng/L	-	13.31	3	16.48	19.84	22.44
Total Alkylated PAHs	ng/L	-	63.9	3	80.05	135.0	187.2
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.004**	16	<0.002	**0.007**	**0.014**
Total iron	mg/L	0.3	**0.466**	16	0.070	0.259	**13.9**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

Table 5.2-6 Concentrations of selected water quality measurement endpoints, Muskeg Creek (*test* station MUC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.93	14	7.40	8.04	8.34
Total suspended solids	mg/L	-	<3.0	14	<3.0	3.0	9.0
Conductivity	µS/cm	-	296	14	184	286	671
Nutrients							
Total dissolved phosphorus	mg/L	-	0.008	14	0.012	0.016	0.034
Total nitrogen	mg/L	-	0.78	14	0.40	1.02	1.20
Nitrate+nitrite	mg/L	3	<0.054	14	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	31.0	14	12.0	25.0	31.9
Ions							
Sodium	mg/L	-	15.7	14	7.0	17.0	64.0
Calcium	mg/L	-	39.2	14	20.8	32.1	71.1
Magnesium	mg/L	-	10.7	14	6.5	10.1	17.3
Chloride	mg/L	120	0.87	14	0.59	2.00	36.0
Sulphate	mg/L	309	4.52	14	1.18	3.20	8.00
Total dissolved solids	mg/L	-	237	14	140	221	378
Total alkalinity	mg/L	-	147	14	93.0	146	313
Selected metals							
Total aluminum	mg/L	0.1	0.048	14	0.021	0.050	**0.142**
Dissolved aluminum	mg/L	0.05	0.005	14	0.003	0.008	0.030
Total arsenic	mg/L	0.005	0.0005	14	0.0002	0.0006	0.0010
Total boron	mg/L	1.2	0.061	14	0.024	0.055	0.150
Total molybdenum	mg/L	0.073	0.00016	14	0.00004	0.00010	0.00640
Total mercury (ultra-trace)	ng/L	5, 13	1.42	9	0.60	1.20	2.30
Total strontium	mg/L	-	0.118	14	0.069	0.105	0.296
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.90	3	0.03	0.30	0.54
Oilsands Extractable	mg/L	-	2.50	3	0.24	0.94	1.58
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.548	3	<0.669	0.789	<2.071
Total dibenzothiophenes	ng/L	-	8.19	3	9.61	14.00	36.93
Total PAHs	ng/L	-	86.6	3	122.4	160.3	210.7
Total Parent PAHs	ng/L	-	15.48	3	16.73	19.32	23.44
Total Alkylated PAHs	ng/L	-	71.1	3	98.9	141.0	194.0
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.008**	14	0.002	**0.010**	**0.068**
Total iron	mg/L	0.3	**0.41**	14	0.29	**0.64**	**1.81**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

Table 5.2-7 Concentrations of selected water quality measurement endpoints, Jackpine Creek (*test* station JAC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.33</u>	15	7.80	8.10	8.32
Total suspended solids	mg/L	-	5.0	15	<3.0	3.0	50.0
Conductivity	µS/cm	-	362	15	183	237	483
Nutrients							
Total dissolved phosphorus	mg/L	-	0.024	15	0.006	0.014	0.030
Total nitrogen	mg/L	-	0.804	15	0.700	0.900	1.621
Nitrate+nitrite	mg/L	3	<0.054	15	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	27.1	15	18.6	24.0	31.8
Ions							
Sodium	mg/L	-	13.8	15	10.0	12.0	18.8
Calcium	mg/L	-	50.3	15	20.0	29.2	65.6
Magnesium	mg/L	-	13.3	15	6.1	8.5	16.3
Chloride	mg/L	120	3.77	15	0.89	2.00	5.60
Sulphate	mg/L	429	2.93	15	0.50	2.70	9.76
Total dissolved solids	mg/L	-	271	15	110	206	322
Total alkalinity	mg/L	-	188	15	89	122	249
Selected metals							
Total aluminum	mg/L	0.1	0.060	15	0.016	0.062	**0.658**
Dissolved aluminum	mg/L	0.05	0.005	15	0.002	0.009	**0.170**
Total arsenic	mg/L	0.005	0.0005	15	0.0003	0.0006	0.0010
Total boron	mg/L	1.2	0.051	15	0.033	0.046	0.071
Total molybdenum	mg/L	0.073	0.00013	15	0.00007	0.00010	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	1.15	11	0.600	1.20	2.90
Total strontium	mg/L	-	0.164	15	0.077	0.108	0.212
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>1.40</u>	3	0.08	0.31	0.41
Oilsands Extractable	mg/L	-	2.00	3	0.38	1.84	2.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<u>1.370</u>	3	3.070	3.380	13.80
Total dibenzothiophenes	ng/L	-	21.16	3	15.26	48.25	136.1
Total PAHs	ng/L	-	<u>122.8</u>	3	180.1	228.7	596.2
Total Parent PAHs	ng/L	-	<u>14.39</u>	3	20.37	24.02	24.59
Total Alkylated PAHs	ng/L	-	<u>108.4</u>	3	159.8	204.1	572.2
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.86**	15	**0.38**	**0.60**	**1.57**
Total phenols	mg/L	0.004	**0.005**	15	0.001	**0.007**	**0.019**
Dissolved iron	mg/L	0.3	**0.486**	15	0.136	**0.321**	**0.832**
Sulphide	mg/L	0.002	**0.007**	15	0.002	**0.008**	**0.103**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-8 Concentrations of selected water quality measurement endpoints, upper Jackpine Creek (*baseline* station JAC-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2008-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.33</u>	6	7.98	8.09	8.30
Total suspended solids	mg/L	-	10.0	6	<3.0	9.5	243
Conductivity	µS/cm	-	299	6	202	222	346
Nutrients							
Total dissolved phosphorus	mg/L	-	0.014	6	0.007	0.016	0.023
Total nitrogen	mg/L	-	0.744	6	0.721	0.981	2.63
Nitrate+nitrite	mg/L	3	<0.054	6	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	21.1	6	21.1	26.2	29.1
Ions							
Sodium	mg/L	-	20.4	6	10.0	11.5	25.5
Calcium	mg/L	-	32.4	6	22.1	28.7	36.9
Magnesium	mg/L	-	10.2	6	7.2	8.6	11.5
Chloride	mg/L	120	1.16	6	<0.50	1.09	1.63
Sulphate	mg/L	309	2.73	6	0.67	1.78	4.33
Total dissolved solids	mg/L	-	216	6	150	178	264
Total alkalinity	mg/L	-	155	6	103	112	187
Selected metals							
Total aluminum	mg/L	0.1	**0.676**	6	**0.142**	**0.489**	**2.84**
Dissolved aluminum	mg/L	0.05	0.011	6	0.006	0.012	0.029
Total arsenic	mg/L	0.005	0.0009	6	0.0007	0.0009	0.0016
Total boron	mg/L	1.2	0.119	6	0.045	0.067	0.137
Total molybdenum	mg/L	0.073	0.00017	6	0.00011	0.00014	0.00024
Total mercury (ultra-trace)	ng/L	5, 13	2.06	6	1.00	1.20	**8.80**
Total strontium	mg/L	-	0.142	6	0.096	0.113	0.201
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.64</u>	3	0.05	0.05	0.31
Oilsands Extractable	mg/L	-	<u>1.10</u>	3	0.42	0.43	1.08
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.874	3	1.220	<2.071	11.10
Total dibenzothiophenes	ng/L	-	10.83	3	7.091	7.446	45.44
Total PAHs	ng/L	-	<u>86.12</u>	3	104.5	154.1	299.1
Total Parent PAHs	ng/L	-	<u>13.34</u>	3	19.55	20.00	22.44
Total Alkylated PAHs	ng/L	-	<u>72.78</u>	3	82.03	134.5	279.1
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.606**	6	0.238	**0.467**	**0.709**
Total iron	mg/L	0.3	**1.450**	6	**0.689**	**0.943**	**4.360**
Total chromium	mg/L	0.001	**0.0010**	6	0.0003	0.0006	**0.0039**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-9 Concentrations of selected water quality measurement endpoints, Stanley Creek (*test* station STC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.38	13	7.60	8.00	8.46
Total suspended solids	mg/L	-	<3.0	13	<3.0	<3.0	6.0
Conductivity	µS/cm	-	337	13	271	392	760
Nutrients							
Total dissolved phosphorus	mg/L	-	0.014	14	0.010	0.021	0.039
Total nitrogen	mg/L	-	0.314	14	0.300	0.451	2.10
Nitrate+nitrite	mg/L	3	<0.054	14	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	8.10	13	6.00	9.00	13.10
Ions							
Sodium	mg/L	-	4.4	13	2.0	5.0	26.0
Calcium	mg/L	-	50.2	13	45.4	61.1	112.0
Magnesium	mg/L	-	11.2	13	11.1	12.9	20.5
Chloride	mg/L	120	0.54	13	<0.50	1.40	14.0
Sulphate	mg/L	309	1.44	13	<0.50	2.4	126
Total dissolved solids	mg/L	-	208	13	200	244	480
Total alkalinity	mg/L	-	180	13	157	206	260
Selected metals							
Total aluminum	mg/L	0.1	0.007	14	<0.002	0.007	0.020
Dissolved aluminum	mg/L	0.05	0.0003	14	<0.0010	0.0010	0.0200
Total arsenic	mg/L	0.005	0.00006	14	<0.00010	0.00014	<0.00100
Total boron	mg/L	1.2	0.0326	14	0.0180	0.0267	0.0871
Total molybdenum	mg/L	0.073	0.000023	14	0.000008	0.000100	0.000200
Total mercury (ultra-trace)	ng/L	5, 13	0.25	11	<0.6	<1.2	<1.4
Total strontium	mg/L	-	0.103	14	0.075	0.127	0.248
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.30	3	0.51	0.54	1.00
Oilsands Extractable	mg/L	-	2.20	3	0.91	1.29	1.48
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.41	3	0.554	<2.071	2.760
Total dibenzothiophenes	ng/L	-	4.162	3	8.250	8.607	35.72
Total PAHs	ng/L	-	74.12	3	113.1	173.6	206.9
Total Parent PAHs	ng/L	-	13.26	3	16.52	19.62	22.55
Total Alkylated PAHs	ng/L	-	60.87	3	90.53	153.98	190.34

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; underlined values are outside of historical range.

Table 5.2-10 Concentrations of selected water quality measurement endpoints, Wapasu Creek (*test* station WAC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.00	12	7.40	7.99	8.22
Total suspended solids	mg/L	-	<3.0	12	<3.0	<3.0	23.0
Conductivity	µS/cm	-	295	12	207	266	524
Nutrients							
Total dissolved phosphorus	mg/L	-	0.011	12	0.009	0.014	0.027
Total nitrogen	mg/L	-	0.67	12	0.50	1.00	1.84
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	26.3	12	5.7	22.0	33.2
Ions							
Sodium	mg/L	-	8.60	12	6.00	7.25	9.00
Calcium	mg/L	-	<u>181</u>	12	26.7	38.6	71.7
Magnesium	mg/L	-	13.8	12	8.6	13.0	25.1
Chloride	mg/L	120	<u>4.02</u>	12	0.79	2.00	4.00
Sulphate	mg/L	309	0.59	12	<0.50	2.03	7.60
Total dissolved solids	mg/L	-	217	12	160	218	312
Total alkalinity	mg/L	-	149	12	99.1	146	292
Selected metals							
Total aluminum	mg/L	0.1	<u>0.010</u>	12	0.014	0.019	0.074
Dissolved aluminum	mg/L	0.05	0.0035	12	0.0025	0.0063	0.0500
Total arsenic	mg/L	0.005	0.0003	12	0.0002	0.0004	<0.0010
Total boron	mg/L	1.2	0.025	12	0.014	0.024	0.081
Total molybdenum	mg/L	0.073	<u>0.00002</u>	12	0.00003	0.00008	0.00040
Total mercury (ultra-trace)	ng/L	5, 13	0.95	10	<0.60	<1.2	3.3
Total strontium	mg/L	-	0.090	12	0.063	0.089	0.149
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.81</u>	3	0.14	0.35	0.41
Oilsands Extractable	mg/L	-	1.30	3	0.13	1.34	1.42
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.429	3	<0.509	<1.780	<2.071
Total dibenzothiophenes	ng/L	-	<u>4.229</u>	3	6.672	20.36	35.35
Total PAHs	ng/L	-	<u>75.38</u>	3	105.1	207.9	228.9
Total Parent PAHs	ng/L	-	<u>13.99</u>	3	16.64	20.39	22.91
Total Alkylated PAHs	ng/L	-	<u>61.39</u>	3	82.17	191.2	208.5
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.462**	12	0.177	**0.482**	**2.070**
Sulphide	mg/L	0.002	**0.010**	12	<0.002	**0.008**	**0.019**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-11 Concentrations of selected water quality measurement endpoints, Iyinimin Creek (*baseline* station IYC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.39	6	7.94	8.10	8.48
Total suspended solids	mg/L	-	<3.0	6	<3.0	12.0	122.0
Conductivity	µS/cm	-	298	6	134	196.5	535
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.037</u>	6	0.017	0.019	0.034
Total nitrogen	mg/L	-	0.654	6	0.581	0.900	1.931
Nitrate+nitrite	mg/L	3	<0.054	6	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	21.2	6	21.2	28.7	33.9
Ions							
Sodium	mg/L	-	14.8	6	4.9	8.0	40.1
Calcium	mg/L	-	36.2	6	18.0	22.9	51.0
Magnesium	mg/L	-	10.8	6	6.2	7.9	18.0
Chloride	mg/L	120	1.28	6	<0.50	1.40	3.33
Sulphate	mg/L	309	2.99	6	2.24	3.30	12.3
Total dissolved solids	mg/L	-	219	6	134	170	359
Total alkalinity	mg/L	-	156	6	64.4	96.4	284
Selected metals							
Total aluminum	mg/L	0.1	0.092	6	0.055	**0.896**	**1.93**
Dissolved aluminum	mg/L	0.05	0.009	6	0.008	0.030	**0.051**
Total arsenic	mg/L	0.005	0.0008	6	0.0007	0.0008	0.0013
Total boron	mg/L	1.2	0.072	6	0.025	0.043	0.228
Total molybdenum	mg/L	0.073	0.00035	6	0.00011	0.00017	0.00047
Total mercury (ultra-trace)	ng/L	5, 13	1.32	6	<0.60	2.35	8.10
Total strontium	mg/L	-	0.099	6	0.046	0.071	0.193
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.68</u>	3	0.02	0.27	0.37
Oilsands Extractable	mg/L	-	<u>1.30</u>	3	0.20	0.79	1.08
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.489	3	<1.58	2.14	19.60
Total dibenzothiophenes	ng/L	-	<u>4.232</u>	3	6.672	27.29	35.72
Total PAHs	ng/L	-	<u>65.05</u>	3	104.0	221.2	234.7
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	17.00	22.44	22.87
Total Alkylated PAHs	ng/L	-	<u>51.79</u>	3	81.6	198.3	217.7
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.819**	6	0.280	**0.421**	**0.883**
Total iron	mg/L	0.3	**1.17**	6	**0.84**	**1.10**	**3.06**
Total phenols	mg/L	0.004	**<u>0.0045</u>**	6	**0.0047**	**0.0087**	**0.0160**
Sulphide	mg/L	0.002	**0.0023**	6	<0.002	**0.006**	**0.013**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-12 Concentrations of selected water quality measurement endpoints, Kearl Lake (*test* station KEL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.13	15	7.60	8.06	8.30
Total suspended solids	mg/L	-	3.0	15	<3.0	4.0	19.0
Conductivity	µS/cm	-	180	15	133	176	207
Nutrients							
Total dissolved phosphorus	mg/L	-	0.002	15	0.002	0.007	0.013
Total nitrogen	mg/L	-	1.03	15	0.45	1.32	1.92
Nitrate+nitrite	mg/L	3	<0.054	15	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	23.3	15	9.8	21.9	28.2
Ions							
Sodium	mg/L	-	9.8	15	8.0	10.0	11.3
Calcium	mg/L	-	<u>20.9</u>	15	16.5	19.6	20.6
Magnesium	mg/L	-	6.91	15	5.70	6.90	7.60
Chloride	mg/L	120	2.54	15	<0.50	<1.00	3.00
Sulphate	mg/L	309	3.21	15	1.38	4.20	5.70
Total dissolved solids	mg/L	-	145	15	94.0	156	220
Total alkalinity	mg/L	-	88.6	15	72.0	88.0	105
Selected metals							
Total aluminum	mg/L	0.1	0.007	15	0.007	0.018	**0.130**
Dissolved aluminum	mg/L	0.05	0.001	15	<0.001	0.001	0.030
Total arsenic	mg/L	0.005	0.00031	15	0.00029	0.00036	<0.00100
Total boron	mg/L	1.2	0.049	15	0.012	0.047	0.052
Total molybdenum	mg/L	0.073	0.00003	15	0.00003	0.00010	0.00090
Total mercury (ultra-trace)	ng/L	5, 13	0.74	11	<0.600	<1.200	<1.300
Total strontium	mg/L	-	0.065	15	0.056	0.066	0.215
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>1.20</u>	3	0.19	0.43	0.49
Oilsands Extractable	mg/L	-	<u>2.10</u>	3	0.42	1.08	1.25
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	10.90	14.13	<15.16
Retene	ng/L	-	<0.407	3	<0.509	<0.669	<2.071
Total dibenzothiophenes	ng/L	-	<u>5.399</u>	3	7.027	7.682	35.35
Total PAHs	ng/L	-	<u>76.58</u>	3	104.5	161.2	206.9
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	18.81	20.73	22.57
Total Alkylated PAHs	ng/L	-	<u>63.33</u>	3	81.89	140.5	188.1
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.005**	15	<0.002	**0.005**	**0.010**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Figure 5.2-6 Piper diagram of fall ion concentrations in the Muskeg River.

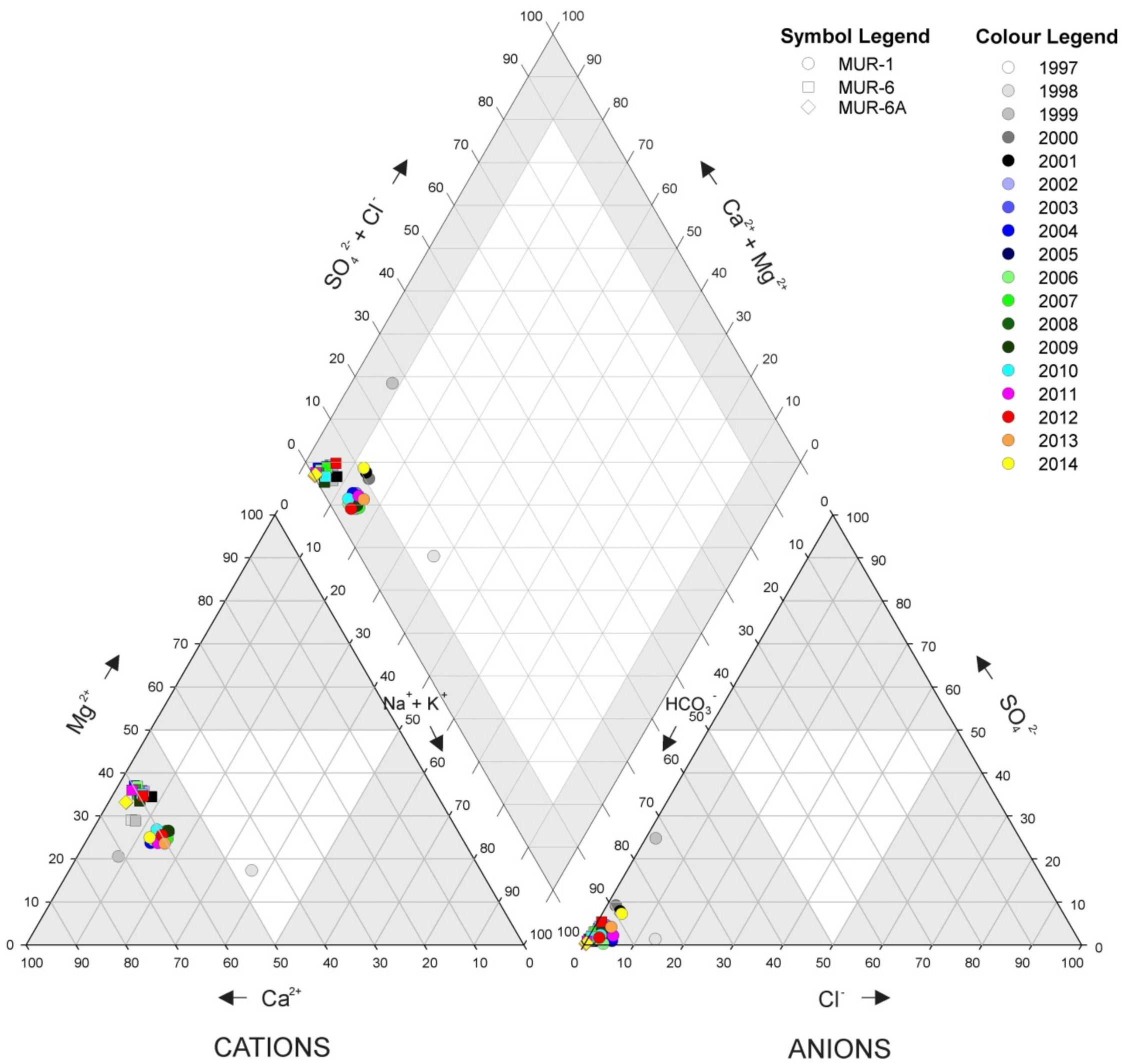


Figure 5.2-7 Piper diagram of fall ion concentrations in tributaries to the Muskeg River and Kearl Lake.

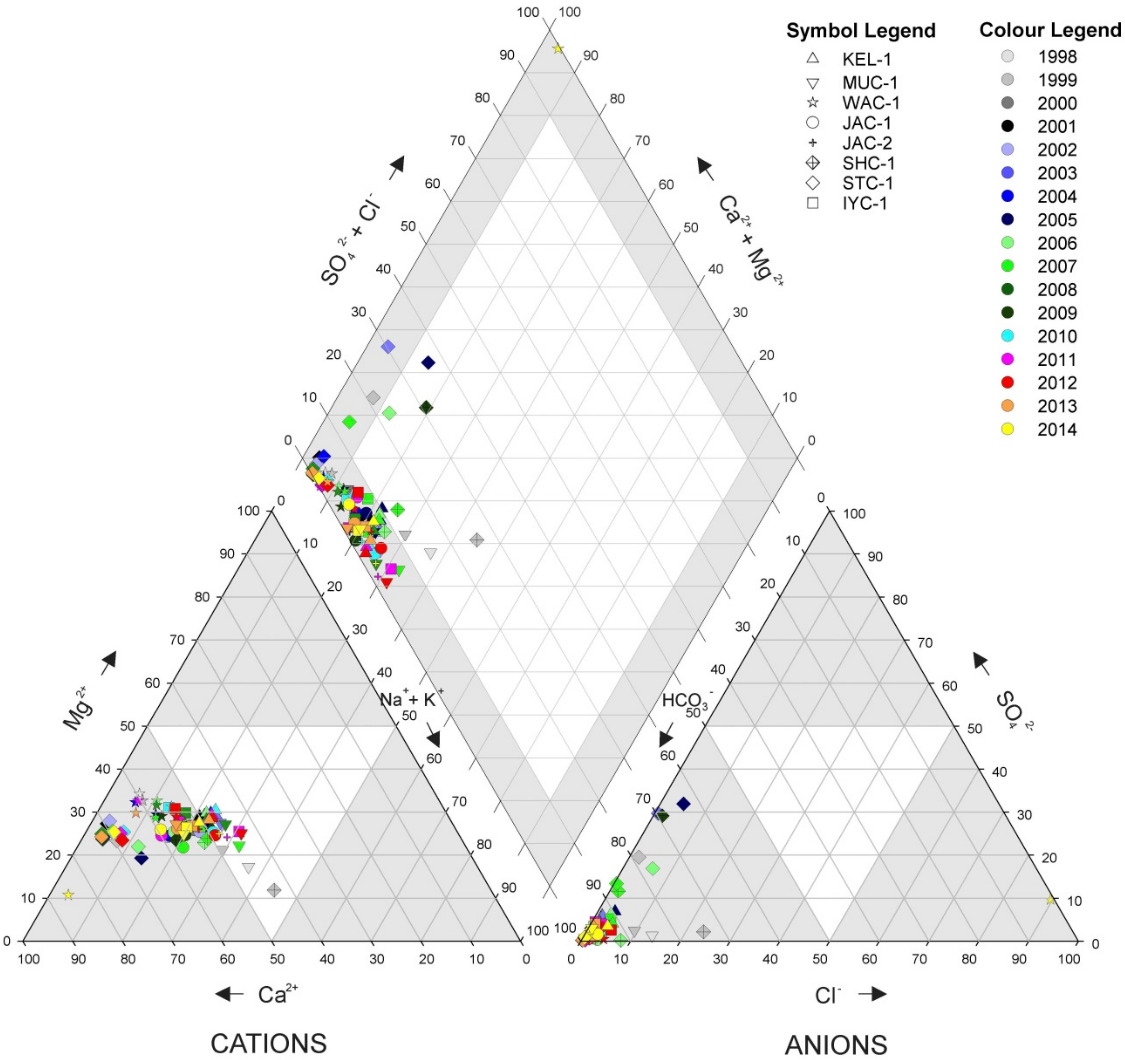


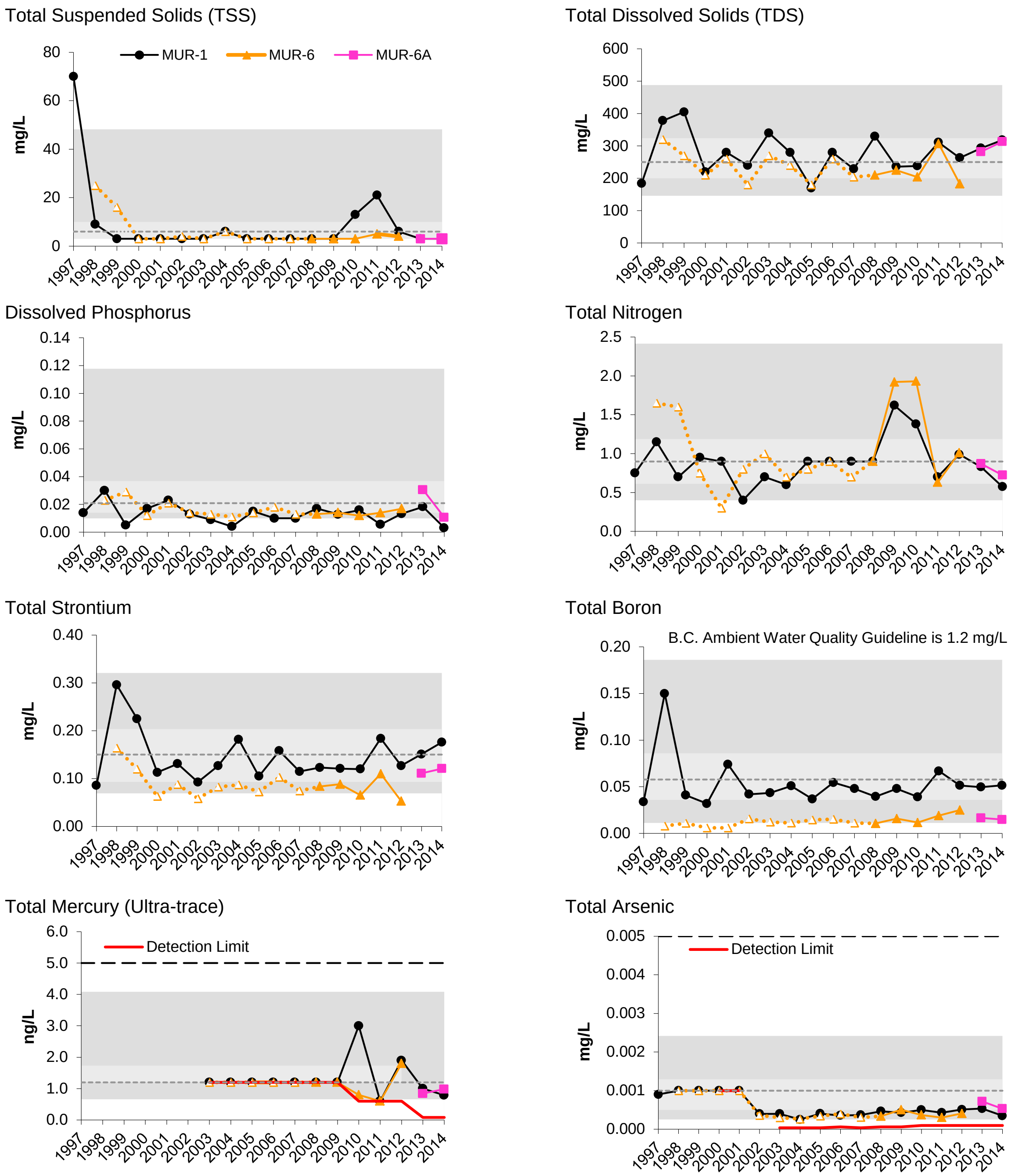
Table 5.2-13 Water quality guideline exceedances, Muskeg River watershed, fall 2014.

Variable	Units	Guideline[a]	MUR-1	MUR-6A	MUC-1	JAC-1	JAC-2	STC-1	WAC-1	IYC-1	KEL-1
Dissolved iron	mg/L	0.3	-	-	-	0.486	0.606	-	-	0.819	-
Sulphide	mg/L	0.002	-	0.0041	0.0076	0.007	-	-	0.0096	0.0023	0.0047
Total aluminum	mg/L	0.1	-	-	-	-	0.676	-	-	-	-
Total chromium	mg/L	0.001	-	-	-	-	0.00103	-	-	-	-
Total iron	mg/L	0.3	0.428	0.466	0.410	0.862	1.450	-	0.462	1.170	-
Total phenols	mg/L	0.004	-	-	-	0.0048	-	-	-	0.0045	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Underline denotes *baseline* station.

Figure 5.2-8 Selected water quality measurement endpoints in the Muskeg River at the mouth (*test* station MUR-1) and upstream of Wapasu Creek (*test* station MUR-6A) (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

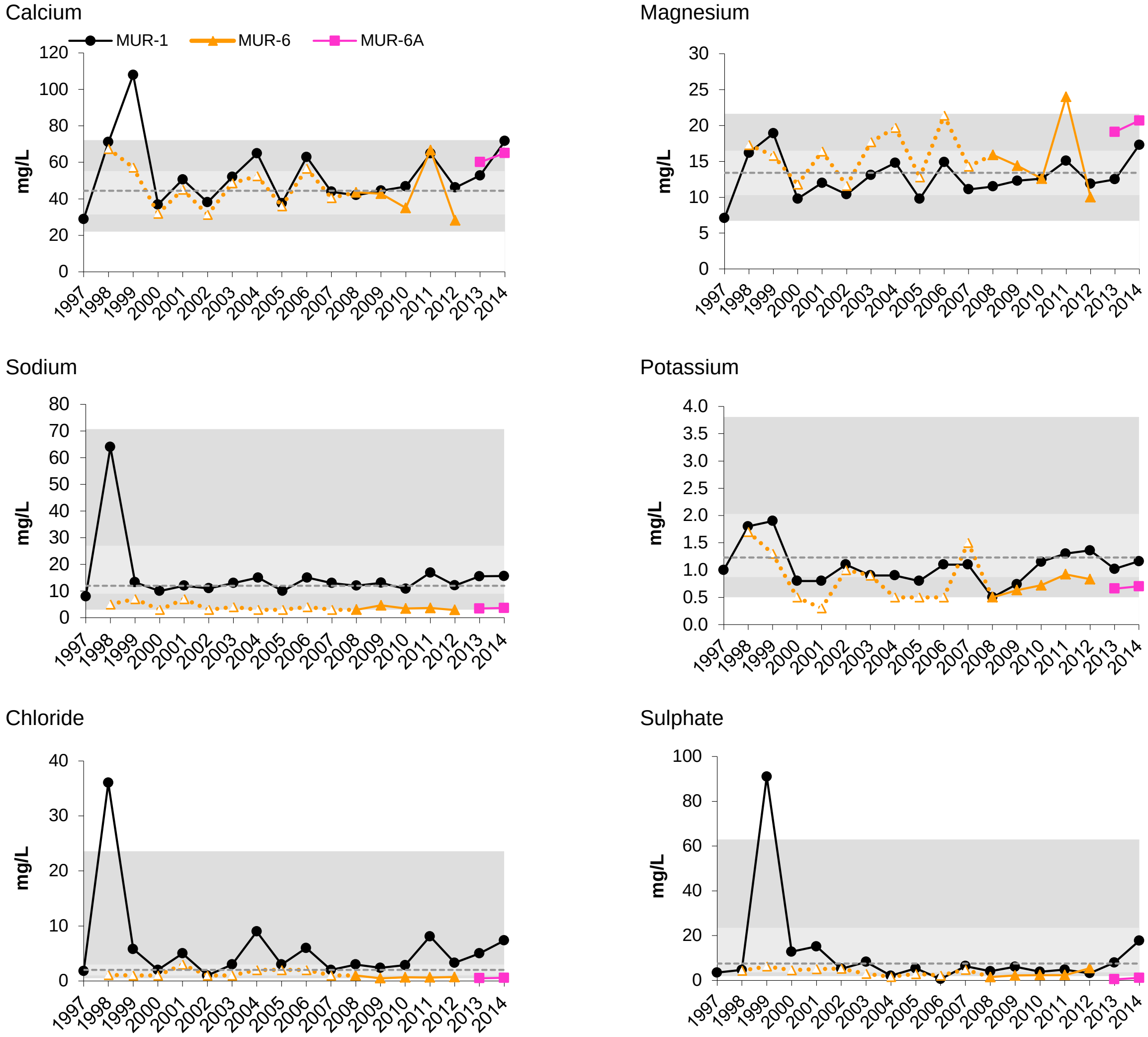
- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Note: Historical *test* station MUR-6 was moved approximately one kilometer upstream in 2013 due to station access issues and renamed as *test* station MUR-6A.

Figure 5.2-8 (Cont'd.)



Non-detectable values are shown at the detection limit.

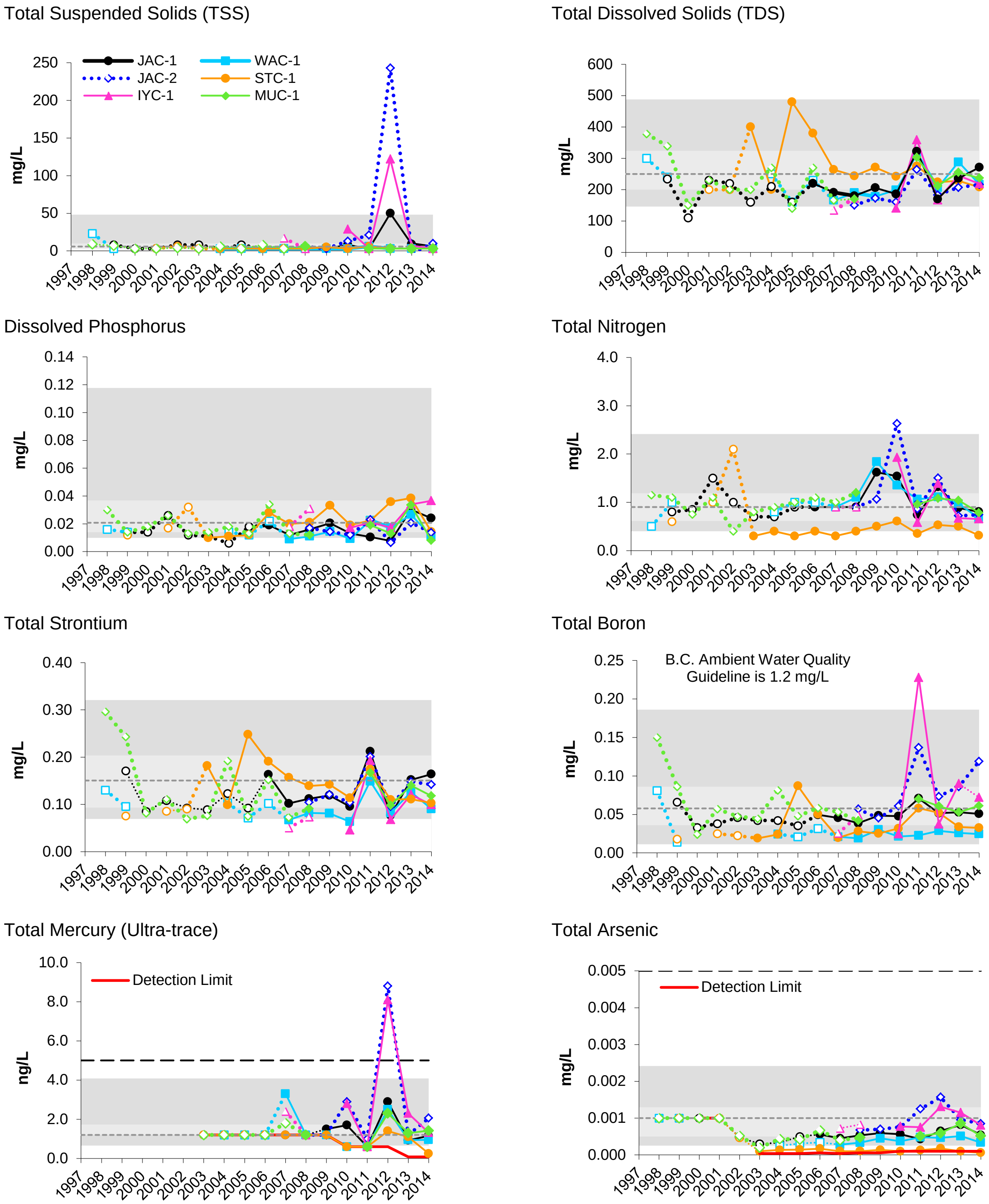
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Note: Historical *test* station MUR-6 was moved approximately one kilometer upstream in 2013 due to station access issues and renamed as *test* station MUR-6A.

Figure 5.2-9 Selected water quality measurement endpoints in Muskeg River tributaries (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



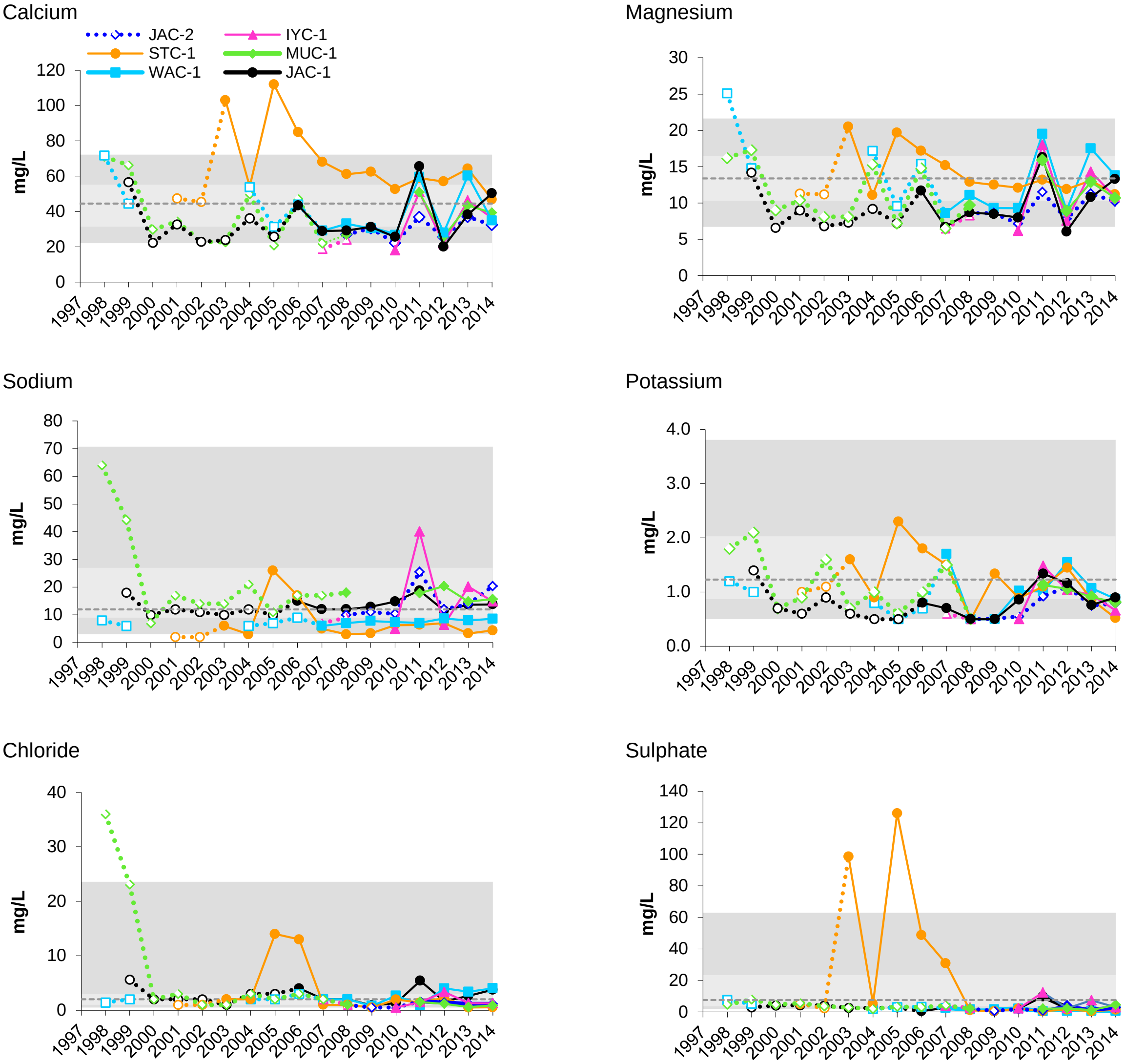
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●━━━● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-9 (Cont'd.)



Non-detectable values are shown at the detection limit.

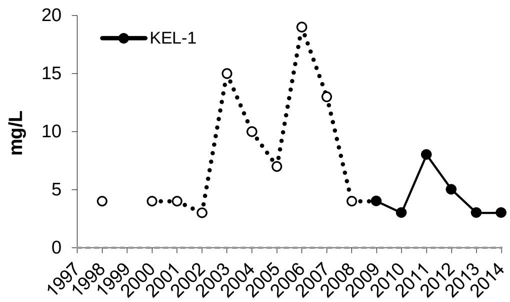
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O••••••O Sampled as a *baseline* station ●——● Sampled as a *test* station

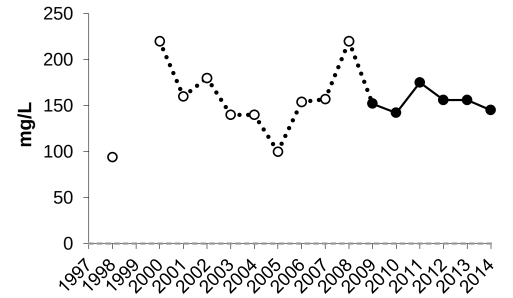
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-10 Selected water quality measurement endpoints in Kearl Lake (fall data) relative to historical concentrations.

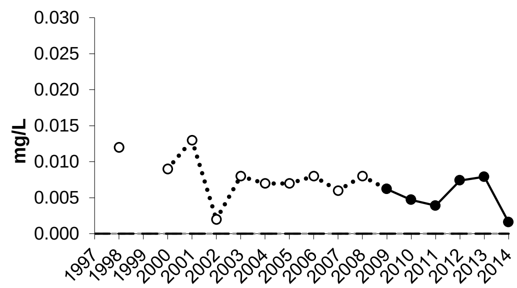
Total Suspended Solids (TSS)



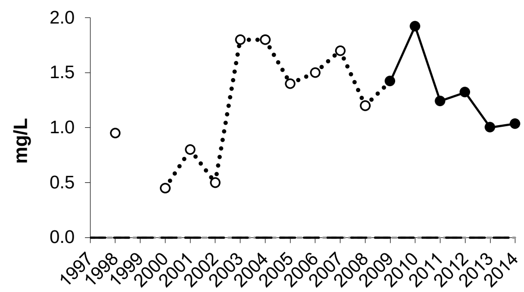
Total Dissolved Solids (TDS)



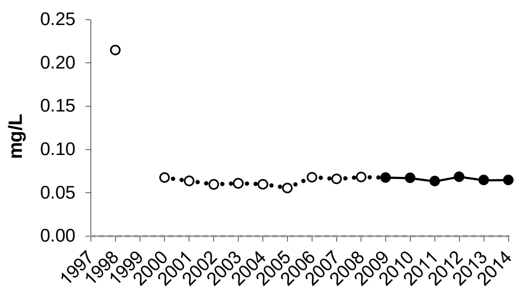
Dissolved Phosphorus



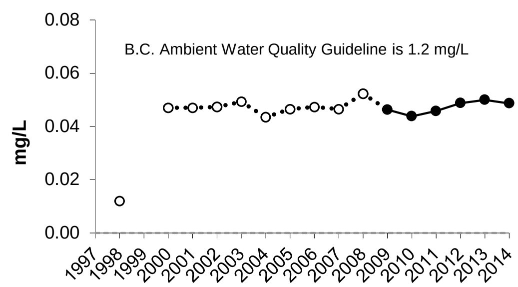
Total Nitrogen



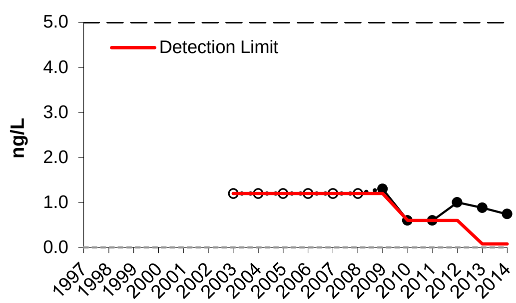
Total Strontium



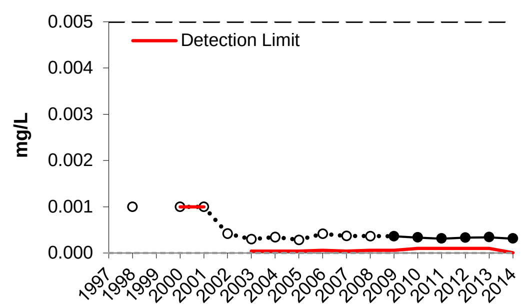
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic

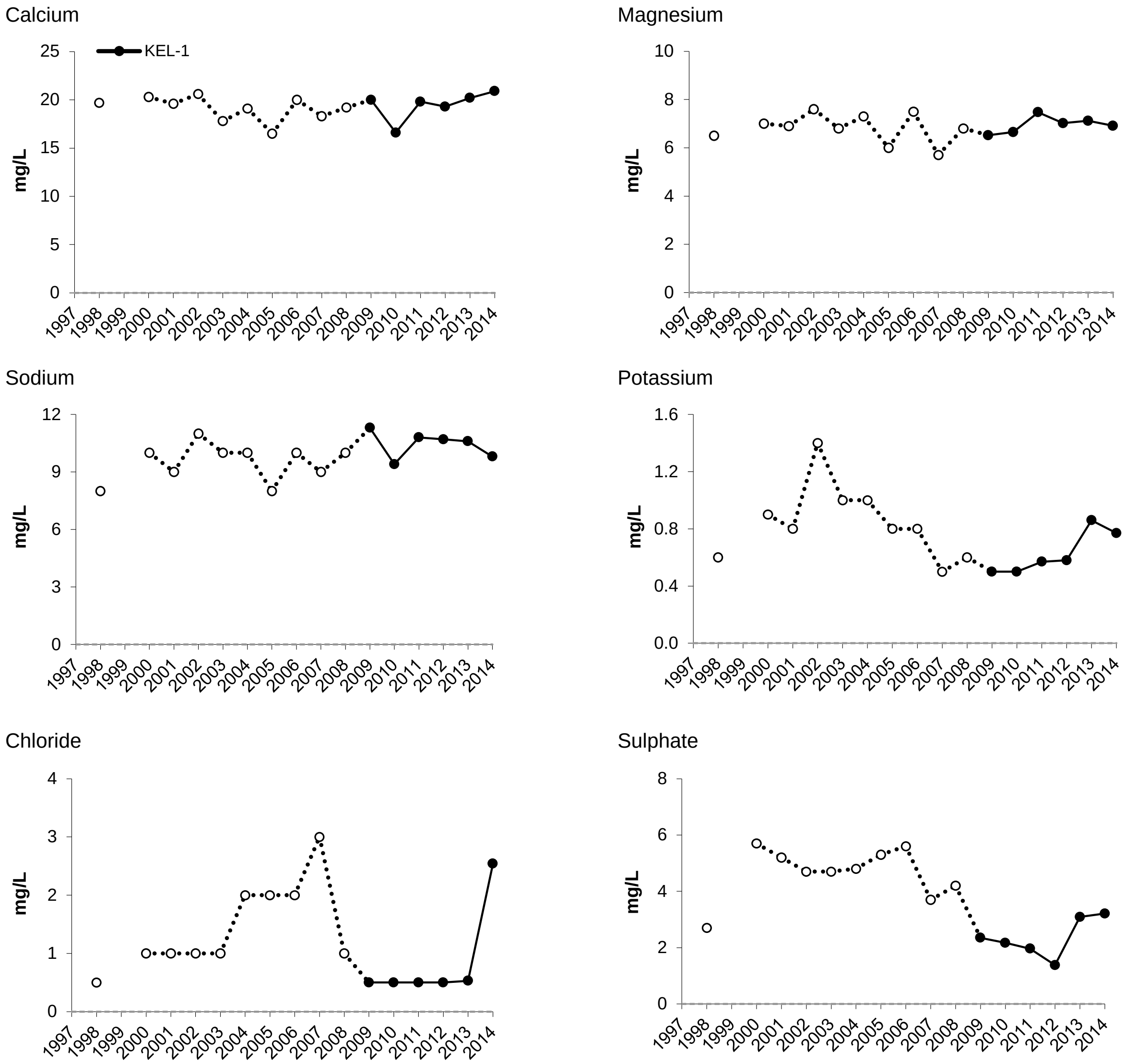


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.2-10 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O••••••O Sampled as a *baseline* station ●——● Sampled as a *test* station

Table 5.2-14 Water quality index (fall 2014) for Muskeg River watershed stations.

Station Identifier	Location	2014 Designation	Water Quality Index	Classification
MUR-1	lower Muskeg River	*test*	100	Negligible-Low
MUR-6A	upstream of Wapasu Creek	*test*	100	Negligible-Low
IYC-1	near mouth of Iyinimin Creek	*test*	100	Negligible-Low
JAC-1	near mouth of Jackpine Creek	*test*	98.7	Negligible-Low
JAC-2	upper Jackpine Creek	*baseline*	100	Negligible-Low
MUC-1	near mouth of Muskeg Creek	*test*	100	Negligible-Low
STC-1	near mouth of Stanley Creek	*test*	100	Negligible-Low
WAC-1	near mouth of Wapasu Creek	*test*	98.2	Negligible-Low

Table 5.2-15 Monthly water quality measurement endpoints at the mouth of the Muskeg River (*test* station MUR-1), January to December 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence						2013 Range (n=12)	
			n	Min		Median	Max		Min	Max
Physical variables										
pH	pH units	6.5-9.0	12	7.63	(May)	7.91	8.51	(October)	7.61	8.41
Total suspended solids	mg/L	-	12	14.9	(May)	20	30	(July)	<3	17
Conductivity	µS/cm	-	12	183	(June)	428	538	(March)	207	480
Nutrients										
Total dissolved phosphorus	mg/L	-	12	0.003	(September)	0.010	0.020	(June)	0.004	0.020
Total nitrogen	mg/L	-	12	0.504	(May)	0.837	1.038	(March)	0.691	1.341
Nitrate+nitrite	mg/L	3	12	<0.054	(May-Nov)	<0.054	0.200	(April)	<0.070	0.185
Dissolved organic carbon	mg/L	-	12	16.1	(September)	20.9	32.4	(July)	20.9	31.2
Ions										
Sodium	mg/L	-	12	7.3	(May)	13.8	19.4	(March)	7.6	16.9
Calcium	mg/L	-	12	22.6	(June)	54.7	80.8	(March)	32.6	66.0
Magnesium	mg/L	-	12	5.5	(June)	13.9	18.1	(March)	8.3	17.0
Chloride	mg/L	120	12	2.09	(July)	6.44	10.20	(March)	1.57	7.10
Sulphate	mg/L	429	12	5.0	(July)	12.9	20.0	(November)	2.9	15.4
Total dissolved solids	mg/L	-	12	133.0	(May)	269.5	358.0	(March)	184.0	317.0
Total alkalinity	mg/L	-	12	84.7	(June)	195.5	294	(February)	102	252
Selected metals										
Total aluminum	mg/L	0.1	12	0.021	(September)	0.045	**5.480**	(April)	0.027	**1.350**
Dissolved aluminum	mg/L	0.05	12	<0.0005	(July)	0.003	0.058	(April)	0.004	0.015
Total arsenic	mg/L	0.005	12	0.0003	(March)	0.0004	0.0007	(April)	0.0003	0.0008
Total boron	mg/L	1.2	12	0.036	(May)	0.052	0.062	(February)	0.034	0.053
Total molybdenum	mg/L	0.073	12	<0.00010	(Feb, Mar)	0.00011	0.00030	(April)	<0.00010	0.00022
Total mercury (ultra-trace)	ng/L	5, 13	12	0.56	(December)	0.98	**5.83**	(April)	0.70	2.20
Total strontium	mg/L	-	12	0.066	(May)	0.151	0.196	(March)	0.083	0.169
Total hydrocarbons										
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	12	<0.02	(Jul,Aug)	0.63	1.80	(September)	0.22	0.75
Oilsands Extractable	mg/L	-	12	0.45	(May)	1.63	3.50	(August)	0.35	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	12	<7.21	-	<7.21	67	(March)	<15.16	68.30
Retene	ng/L	-	12	0.46	(March)	0.822	6.23	(July)	<0.669	8.920
Total dibenzothiophenes	ng/L	-	12	10.72	(January)	18.82	336.79	(April)	12.64	305.99
Total PAHs	ng/L	-	12	101.3	(September)	128.2	1297.1	(April)	133.4	986.2
Total Parent PAHs	ng/L	-	12	13.90	(September)	17.78	81.63	(April)	22.78	96.19
Total Alkylated PAHs	ng/L	-	12	86.7	(December)	111.8	1215.5	(April)	107.4	949.5
Other variables that exceeded CCME/AESRD guidelines in 2014[1]										
Total phenols	mg/L	0.004	5	<0.001	(December)	0.004	**0.007**	(April)	0.003	**0.009**
Sulphide	mg/L	0.002	10	<0.0015	(September)	**0.003**	**0.012**	(July)	**<0.003**	**0.012**
Total iron	mg/L	0.3	12	**0.428**	(September)	**0.843**	**2.340**	(April)	**0.740**	**3.990**
Dissolved iron	mg/L	0.3	6	0.0923	(September)	0.295	**0.494**	(May)	0.269	1.290
Total chromium	mg/L	0.001	2	<0.0003	(Feb,Mar)	0.00021	**0.00426**	(April)	<0.00030	0.00166

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

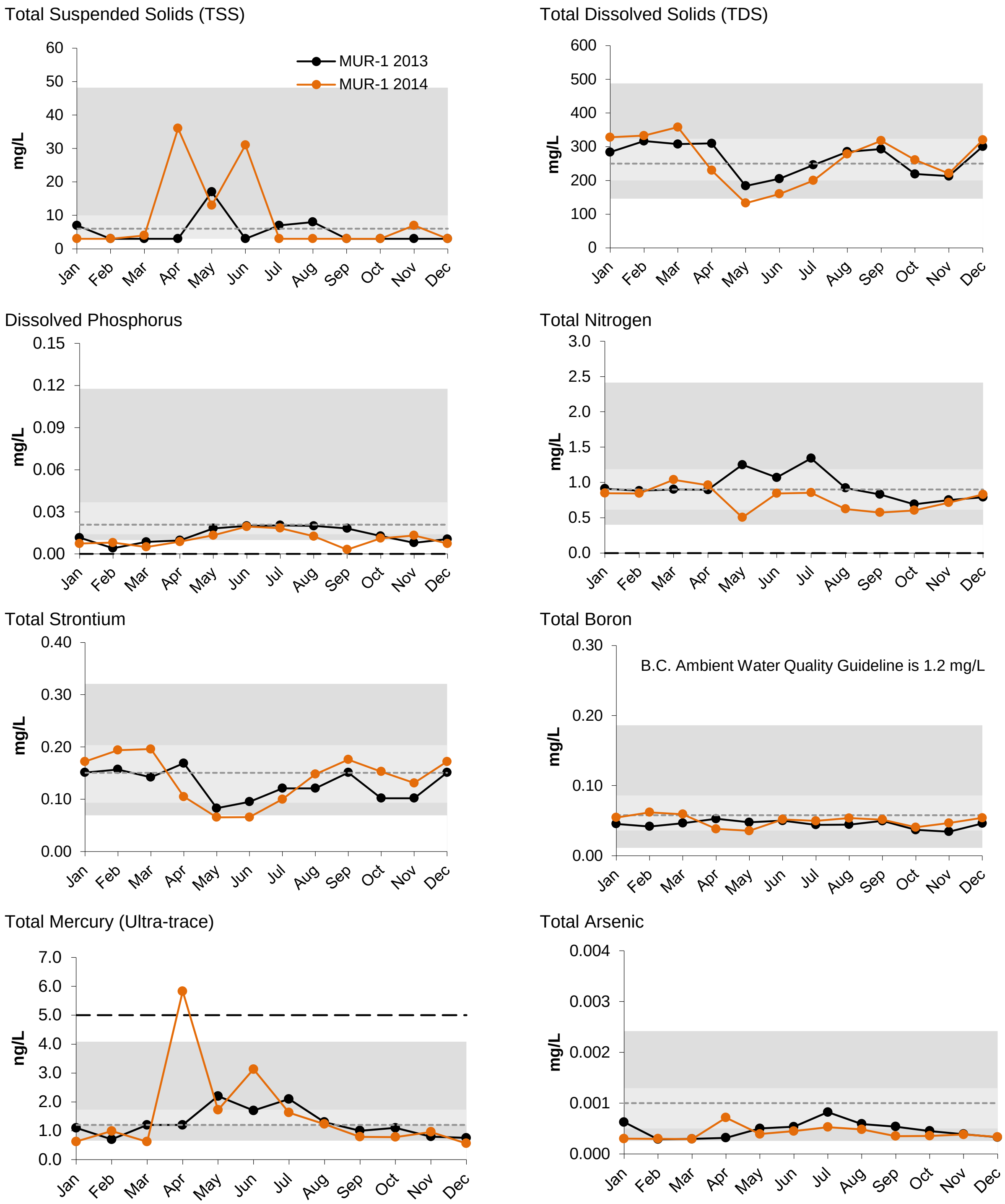
[1] n refers to number of exceedances in 2014.

Table 5.2-16 Monthly water quality guideline exceedances at the mouth of the Muskeg River (*test* station MUR-1), January to December 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	-	-	0.0048	0.0067	0.0051	0.0052	0.0058	-	-	-	-	-
Sulphide	mg/L	0.002	0.0025	0.0025	0.0034	-	0.0035	0.0074	0.0120	0.0041	-	0.0043	0.0049	0.0029
Total aluminum	mg/L	0.1	-	-	-	5.480	0.311	1.430	0.228	-	-	-	-	-
Dissolved aluminum	mg/L	0.05	-	-	-	0.058	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	0.85	0.84	0.67	2.34	1.30	1.10	0.78	0.69	0.43	0.84	0.95	1.19
Dissolved iron	mg/L	0.3000	0.37	-	-	-	0.49	-	0.37	0.33	-	-	0.43	0.38
Total chromium	mg/L	0.001	-	-	-	0.0043	-	0.0014	-	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5,13	-	-	-	5.83	-	-	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.2-11 Concentrations of selected water quality measurement endpoints in the Muskeg River (monthly data) relative to regional *baseline* fall concentrations.

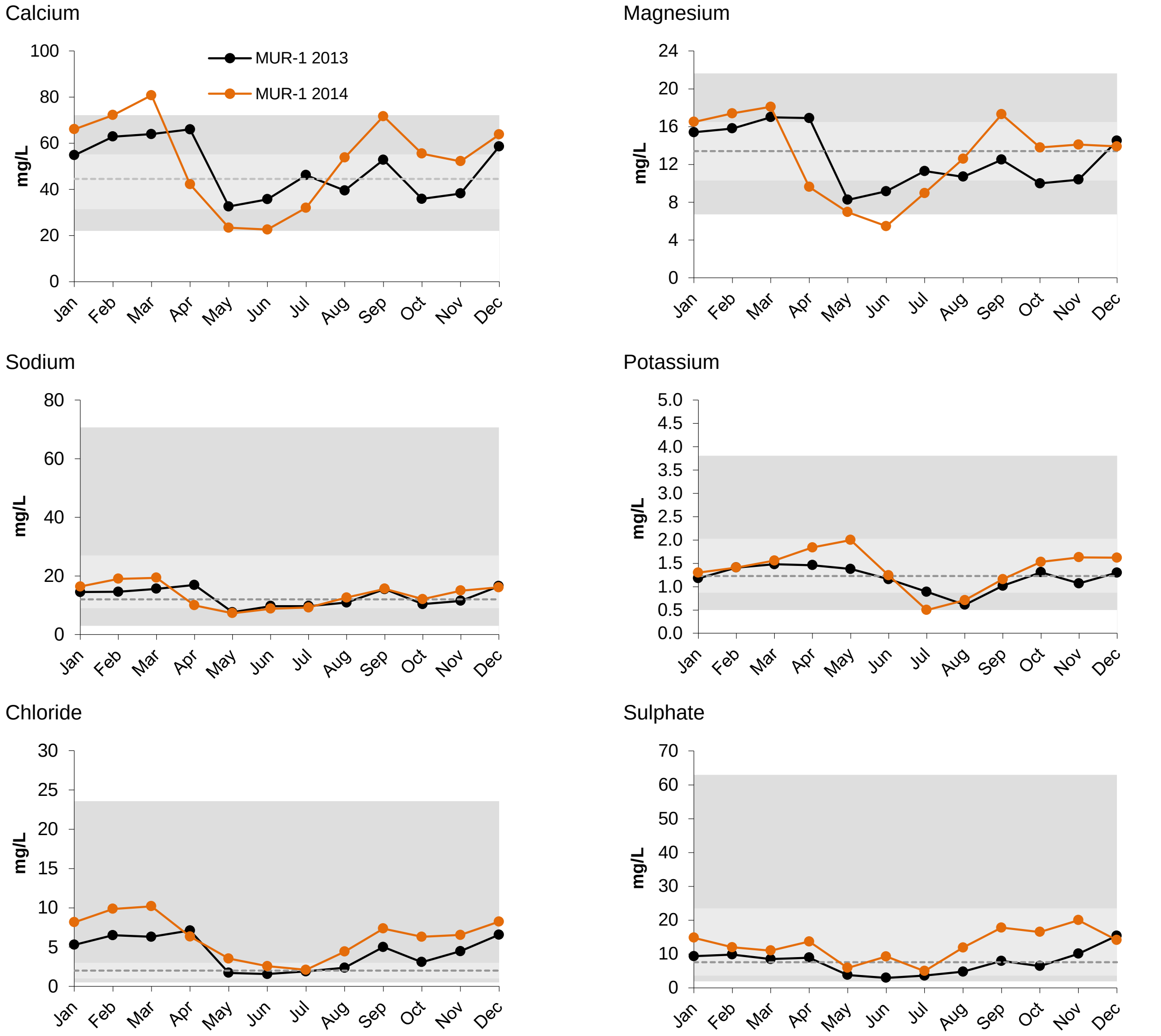


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-11 (Cont'd.)



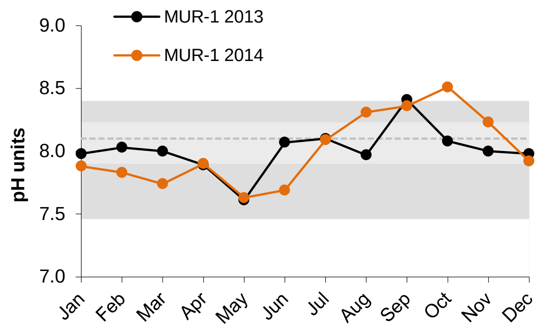
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

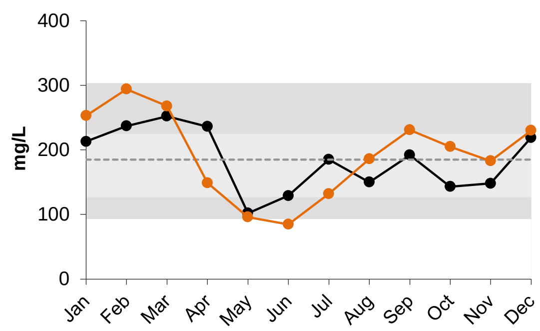
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-11 (Cont'd.)

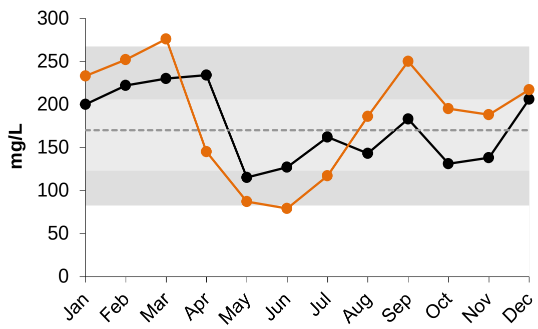
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-12 Piper diagram of monthly ion concentrations in the lower Muskeg River (*test* station MUR-1).

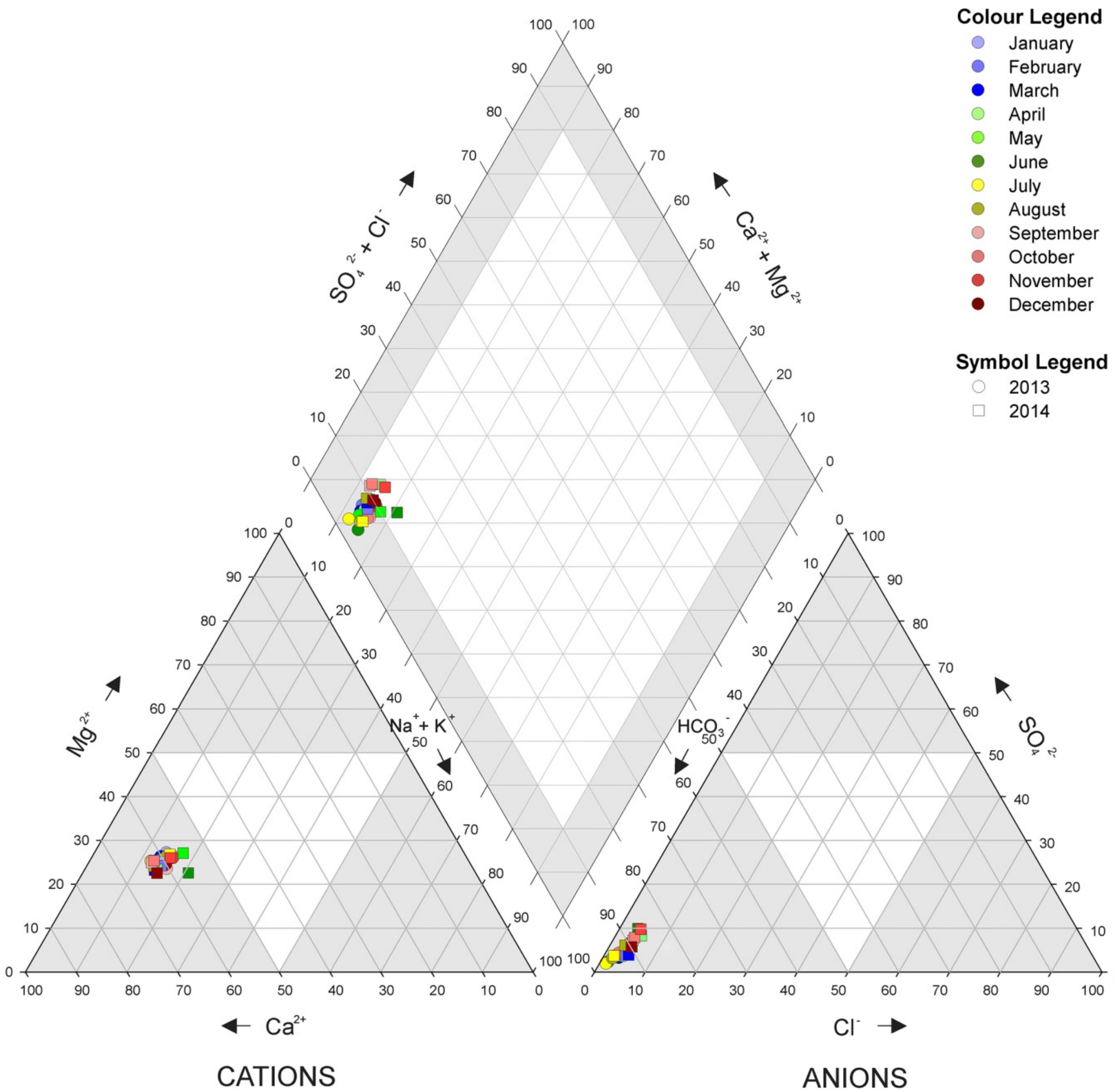
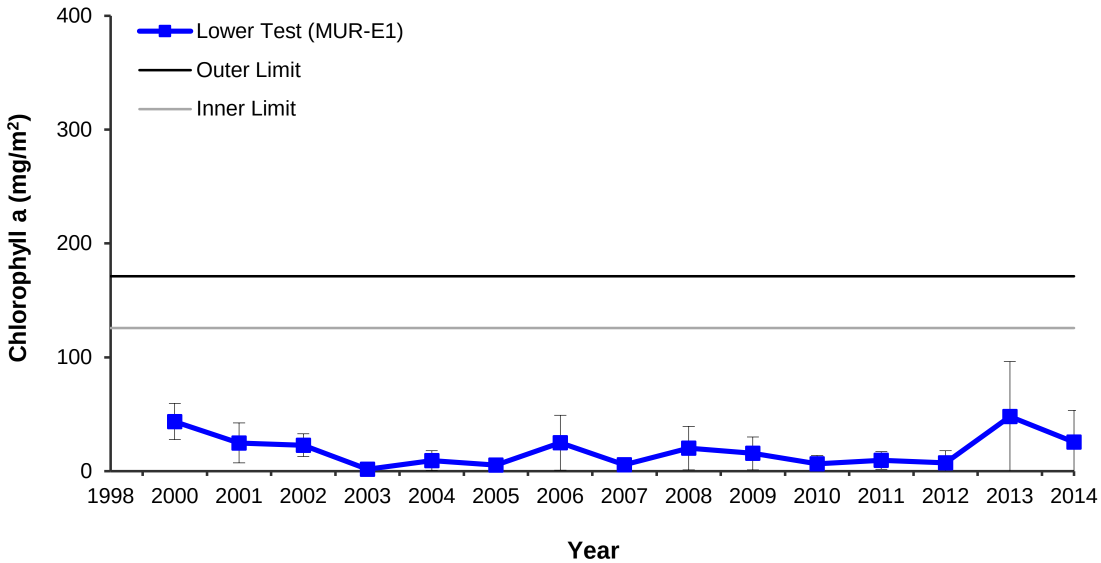


Table 5.2-17 Average habitat characteristics of benthic invertebrate sampling locations of the Muskeg River, fall 2014.

Variable	Units	MUR-E1 Lower *Test* Reach	MUR-D2 Middle *Test* Reach	MUR-D3 Upper *Test* Reach
Sample date	-	Sept 6, 2014	Sept 4, 2014	Sept 5, 2014
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	1.5	1.4
Current velocity	m/s	1.01	0.20	0.16
Field Water Quality				
Dissolved oxygen	mg/L	10	7.8	6.8
Conductivity	µS/cm	420	419	403
pH	pH units	8.5	7.4	6.9
Water temperature	°C	15.6	13.6	11.1
Sediment Composition (mean ± 1SD)				
Sand	%		94±4	41±40
Silt	%		4±2	53±39
Clay	%		2±2	6±3
Sand/Silt/Clay	%	-		
Small Gravel	%	19±11		
Large Gravel	%	36±15		
Small Cobble	%	42±16		
Large Cobble	%	4±13		
Boulder	%	-		
Bedrock	%	-		
Total Organic Carbon	%		0.5±0.4	26±14

Figure 5.2-13 Periphyton chlorophyll *a* biomass at *test* reach MUR-E1 of the Muskeg River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for all years up to and including 2013.

Table 5.2-18 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in the Muskeg River.

Taxon	Percent Major Taxa Enumerated in Each Year								
	Reach MUR-E1			Reach MUR-D2			Reach MUR-D3		
	1998	2000-2013	2014	2000	2001-2013	2014	2002	2003-2013	2014
Hydra	-	0 to <1	-	<1	0 to 4	1	-	0 to 1	3
Nematoda	2	<1 to 5	1	2	1 to 6	1	1	0 to 6	4
Naididae	5	1 to 30	6	2	<1 to 11	5	<1	<1 to 7	1
Tubificidae	5	0 to 26	-	10	<1 to 31	2	<1	2 to 26	12
Enchytraeidae	<1	0 to 1	<1	<1	0 to 6	<1	-	-	-
Lumbriculidae	-	0 to <1	-	1	0 to 7	-	-	0 to 2	2
Erpobdellidae	-	0 to <1	-	<1	0 to <1	-	<1	0 to <1	-
Hirudinea	-	0 to <1	-	<1	0 to 1	<1	<1	0 to 3	<1
Hydracarina	14	0 to 17	7	1	<1 to 3	4	<1	0 to 17	1
Amphipoda	-	0 to <1	-	-	0 to 2	-	<1	<1 to 5	2
Gastropoda	3	0 to 7	-	<1	0 to 4	<1	<1	0 to 2	<1
Bivalvia	6	0 to 9	<1	4	0 to 5	1	28	0 to 18	16
Ceratopogonidae	1	0 to 26	<1	1	1 to 28	9	<1	0 to 2	1
Chironomidae	32	15 to 58	26	75	32 to 84	68	66	27 to 79	42
Dolichopodidae	-	<1	-	-	-	-	-	-	-
Diptera (misc.)	4	<1 to 22	1	<1	0 to 4	3	<1	0 to 2	<1
Ephydridae	-	<1	-	-	-	-	-	-	-
Coleoptera	5	<1 to 10	<1	<1	0 to 1	-	-	0 to 1	<1
Ephemeroptera	12	5 to 50	46	<1	<1 to 6	5	-	<1 to 9	15
Odonata	<1	<1 to 2	2	<1	0 to <1	<1	-	0 to <1	<1
Plecoptera	4	<1 to 8	2	<1	0 to <1	<1	-	0 to 1	-
Trichoptera	2	1 to16	9	<1	0 to <1	<1	<1	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints									
Total abundance per sample	1,487	258 to 3,183	1,790	1321	137 to 1,300	263	218	133 to 389	383
Richness	60	29 to 43	31	26	10 to 32	27	12	9 to 17	17
Equitability	0.25	0.13 to 0.38	0.15	0.2	0.18 to 0.42	0.16	0.26	0.39 to 0.52	0.29
% EPT	18	14 to 57	58	<1	<1 to 6	5	<1	<1 to 12	16

Table 5.2-19 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River, *test* reach MUR-E1.

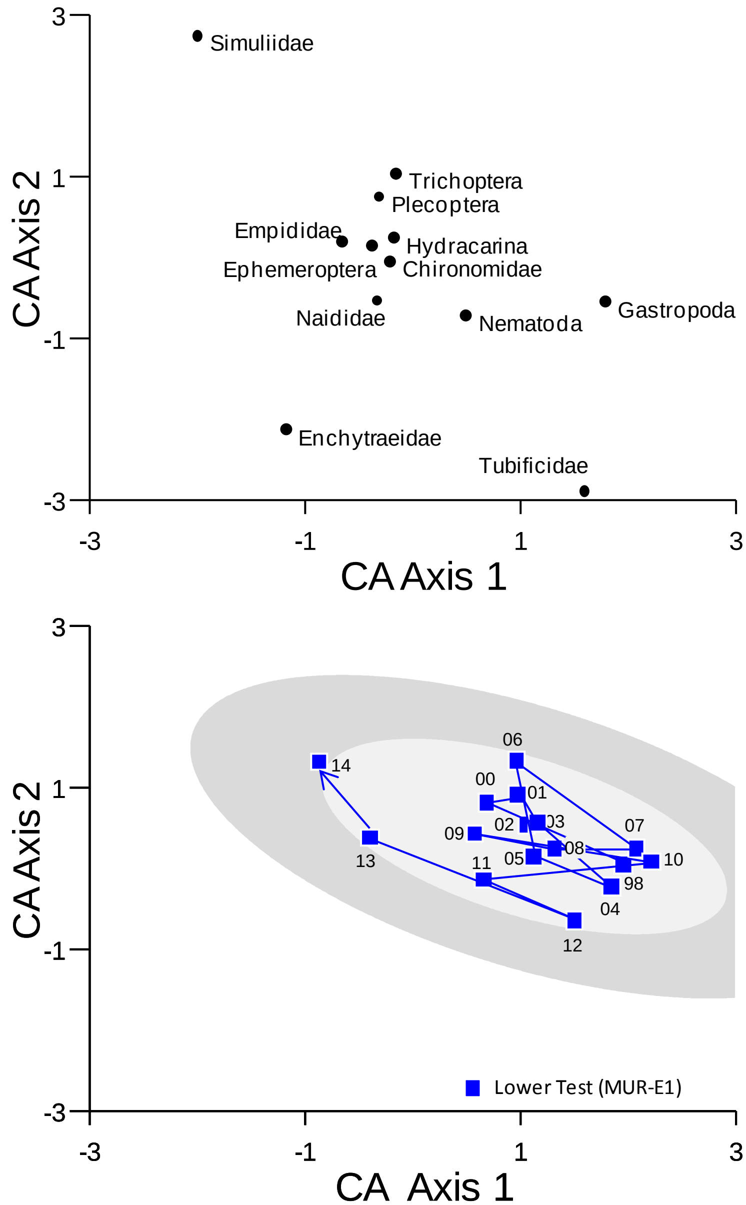
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Period)	2014 vs. Previous Years	Time Trend (*Test* Period)	2014 vs. Previous Years	
Log of Abundance	**<0.001**	**0.023**	16	4	Increasing over time; higher in 2014 than mean of previous years.
Log of Richness	0.766	0.286	0	2	No change.
Equitability	**<0.001**	**0.001**	13	10	Decreasing over time; higher in 2014 than mean of previous years.
Log of EPT	0.050	**<0.001**	3	13	Increasing over time; higher in 2014 than mean of previous years.
CA Axis 1	**<0.001**	**<0.001**	15	38	Decreasing over time; lower in 2014 than mean of previous years.
CA Axis 2	0.200	**<0.001**	1	20	Higher in 2014 than mean of previous years.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-14 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the lower reach of the Muskeg River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-E1 (1998 to 2013).

Table 5.2-20 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D2).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Period)	2014 vs. Previous Years	Time Trend (*Test* Period)	2014 vs. Previous Years	
Log of Abundance	0.214	0.800	14	5	No change.
Log of Richness	**0.050**	0.842	10	6	Increasing over time.
Equitability	0.752	0.208	21	21	No change.
Log of EPT	**0.002**	0.912	4	12	Increasing over time.
CA Axis 1	0.116	0.117	4	4	No change.
CA Axis 2	**0.026**	**0.001**	6	12	Decreasing over time.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.2-21 Results of analysis of variance (ANOVA) testing differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D3).

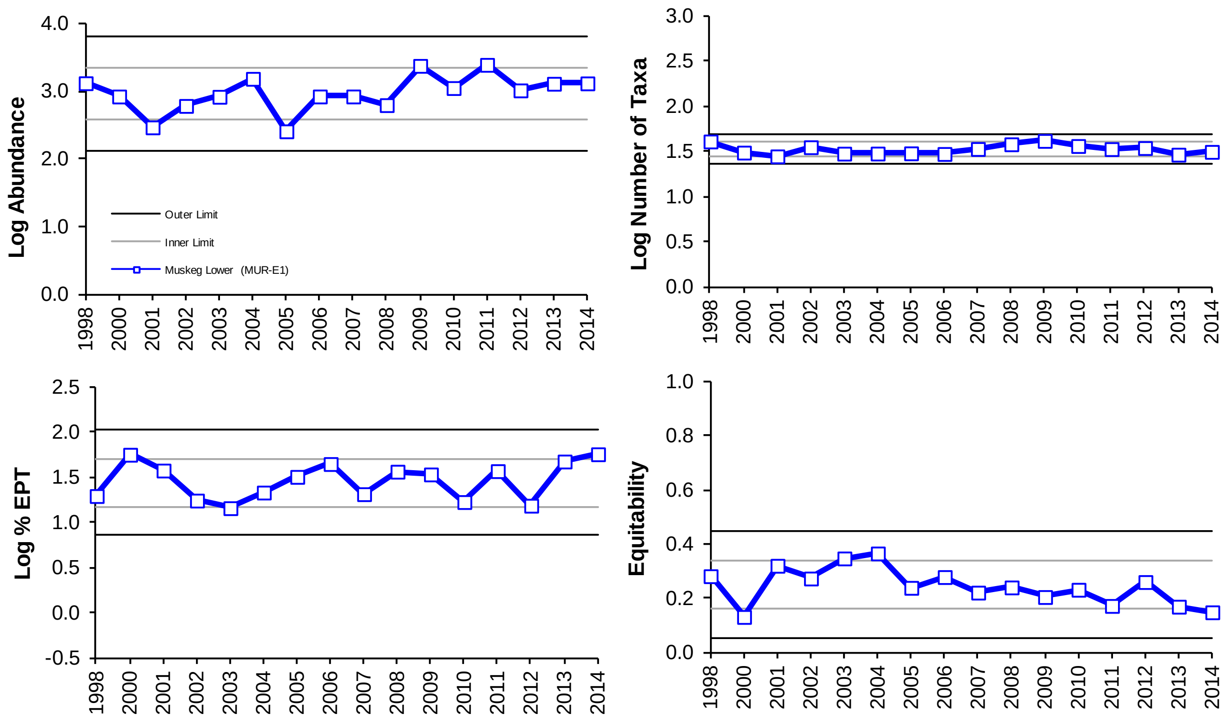
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	0.842	0.072	0.051	**0.033**	1	14	10	10	Higher in 2014 than the mean of previous years.
Log of Richness	0.103	0.220	0.373	0.148	1	18	10	15	No change.
Equitability	0.447	0.447	0.500	0.319	1	6	19	21	No change.
Log of EPT	**0.027**	**0.012**	**0.022**	**0.035**	0	3	19	25	Higher in *test* period; increasing over time in *test* period; higher in 2014 than mean of *baseline* years and mean of all previous years.
CA Axis 1	**0.042**	0.693	0.641	0.939	8	0	0	0	Higher in *test* period.
CA Axis 2	0.185	0.925	0.262	0.385	3	0	2	1	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

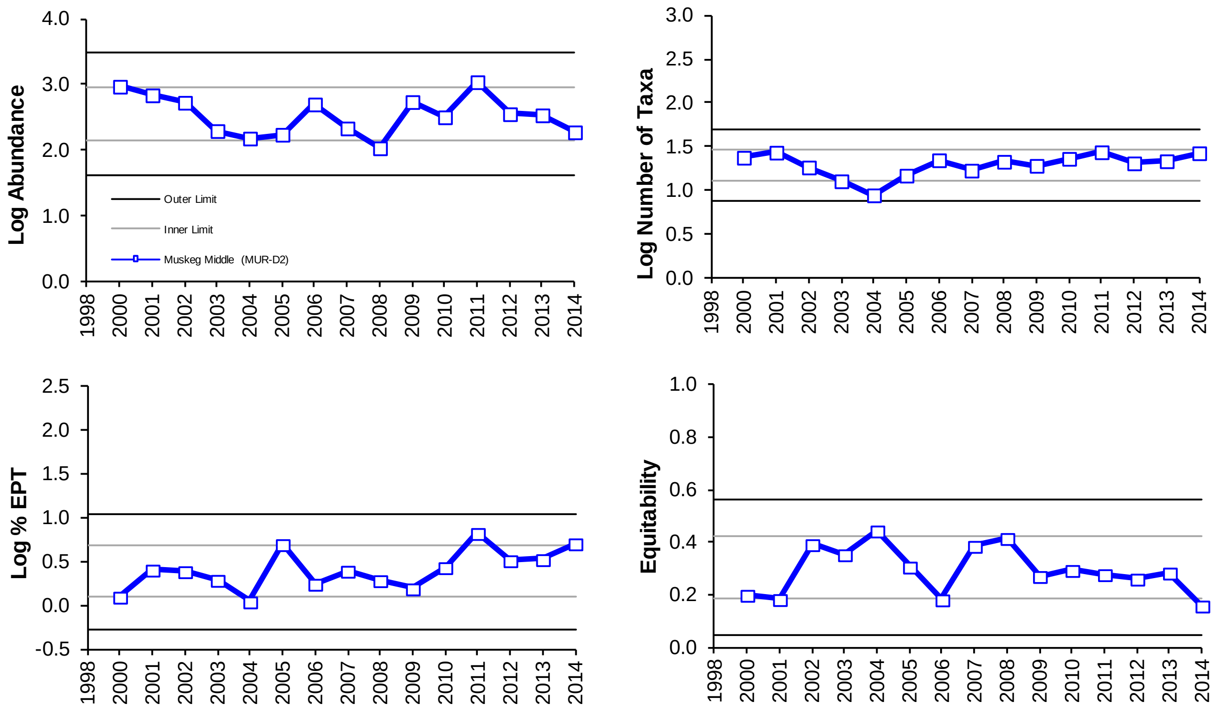
Figure 5.2-15 Variation in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-E1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-E1 (1998 to 2013).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

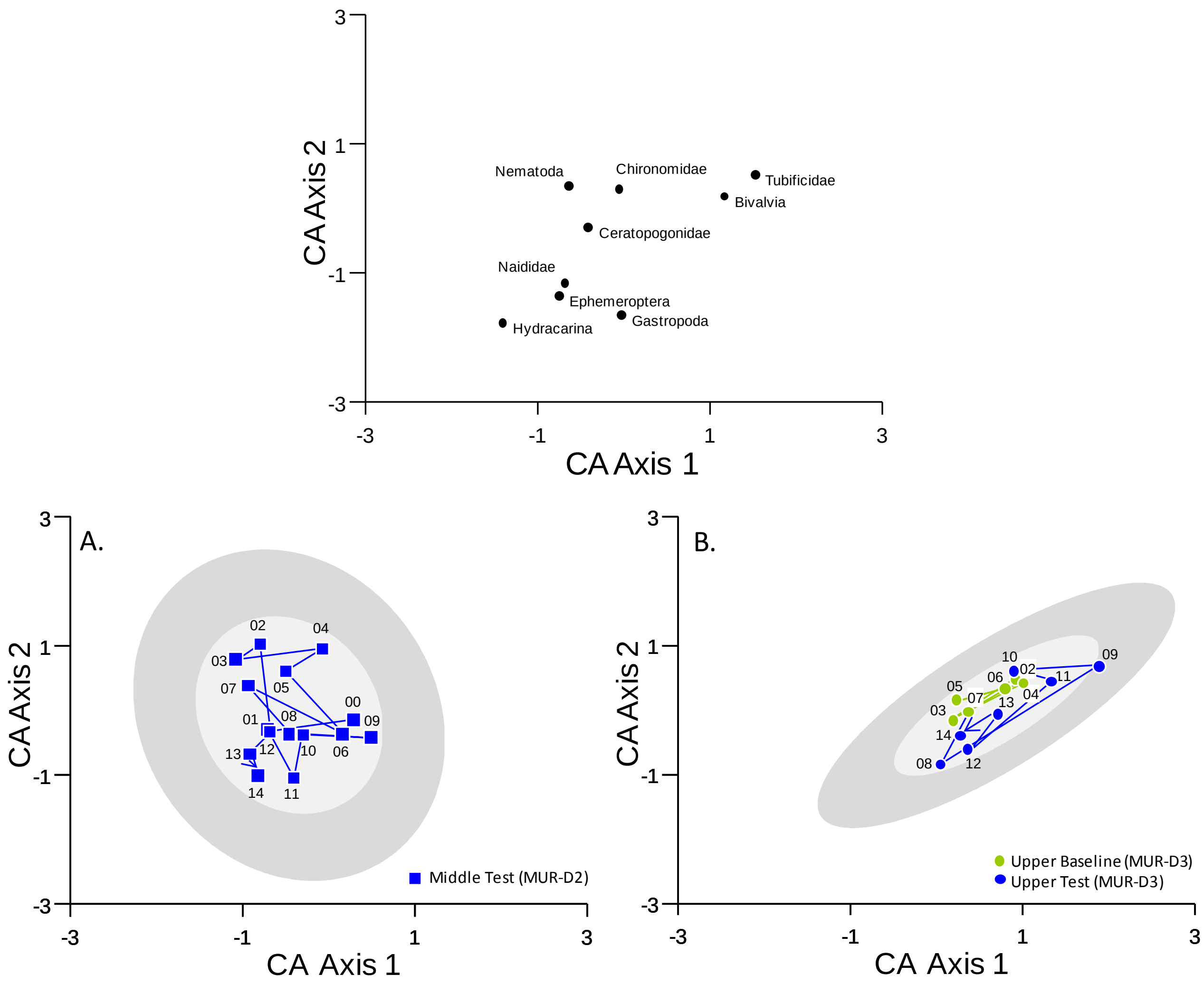
Figure 5.2-16 Variation in benthic invertebrate community measurement endpoints in the middle *test* reach of the Muskeg River (MUR-D2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-D2 (2000 to 2013).

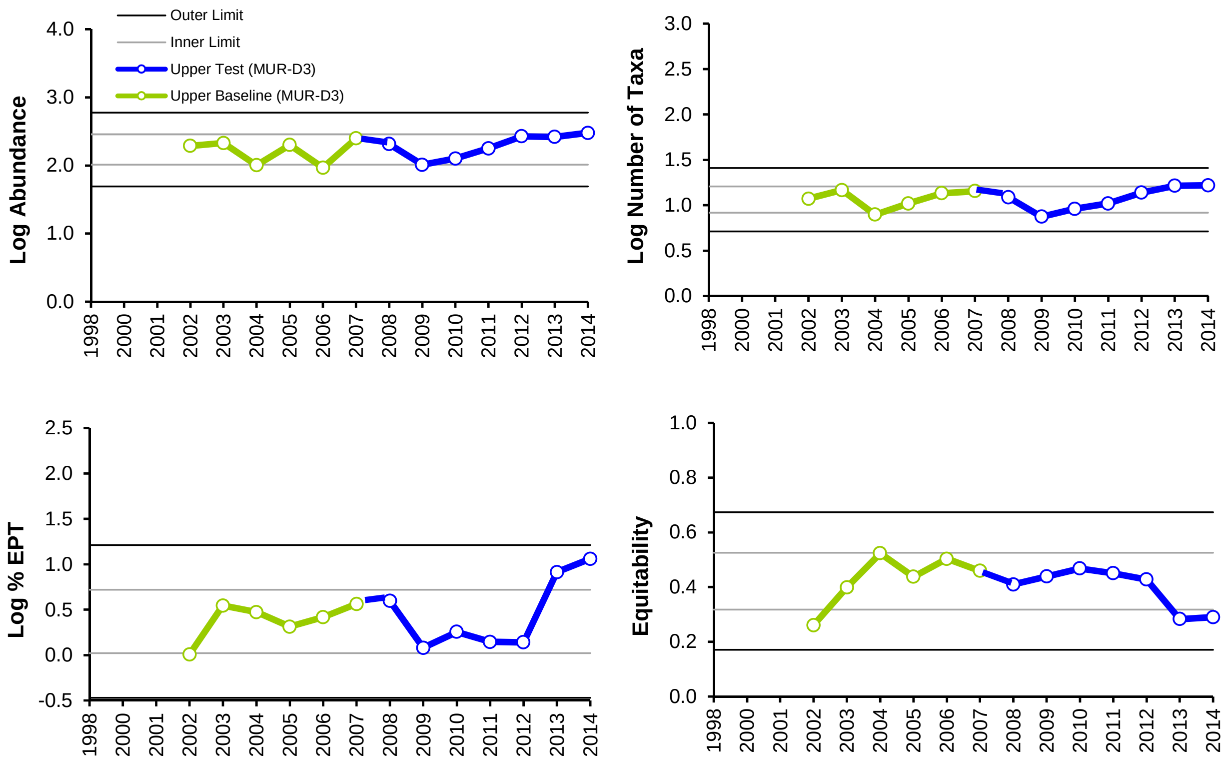
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.2-17 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the middle and upper reaches of the Muskeg River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at each reach.

Figure 5.2-18 Variation in benthic invertebrate community measurement endpoints at the upper *test* reach of the Muskeg River (MUR-D3).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-D3 (2002 to 2013).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.2-22 Average habitat characteristics of benthic invertebrate sampling locations in Jackpine Creek, fall 2014.

Variable	Units	JAC-D1 Lower *Test* Reach	JAC-D2 Upper *Baseline* Reach
Sample date	-	Sept 10, 2014	Sept 11, 2014
Habitat	-	Depositional	Depositional
Water depth	m	0.37	0.37
Current velocity	m/s	0.17	0.37
Field Water Quality			
Dissolved oxygen	mg/L	10.4	12.4
Conductivity	µS/cm	308	282
pH	pH units	7.0	8.3
Water temperature	°C	7.5	6.1
Sediment Composition (mean ± 1SD)			
Sand	%	82±30	87±19
Silt	%	16±30	8±16
Clay	%	2±2	5±4
Total Organic Carbon	%	1.0±0.7	1.1±2.2

Table 5.2-23 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in lower Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach JAC-D1		
	2002	2003-2013	2014
Hydra	-	0 to 1	-
Nematoda	5	1 to 11	4
Naididae	<1	0 to 8	10
Tubificidae	<1	<1 to 17	9
Enchytraeidae	<1	0 to 18	1
Hirudinea	-	0 to <1	-
Hydracarina	1	1 to 8	6
Amphipoda	-	0 to <1	<1
Gastropoda	<1	0 to 4	2
Bivalvia	1	0 to 3	<1
Ceratopogonidae	2	0 to 16	13
Chironomidae	88	38 to 86	50
Dolichopodidae	-	<1	-
Diptera (misc.)	<1	<1 to 4	2
Coleoptera	-	0 to <1	-
Ephemeroptera	<1	0 to 7	1
Odonata	<1	0 to <1	<1
Plecoptera	-	0 to 1	<1
Trichoptera	<1	<1 to 3	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	619	79 to 2,053	188
Richness	15	7 to 31	13
Equitability	0.38	0.34 to 0.56	0.29
% EPT	<1	<1 to 4	1

Table 5.2-24 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in upper Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach JAC-D2		
	2003	2004-2013	2014
Hydra	-	0 to <1	<1
Nematoda	6	<1 to 5	6
Oligochaeta	-	<1	10
Naididae	3	0 to 9	1
Tubificidae	2	1 to 13	1
Enchytraeidae	1	<1 to 5	<1
Hydracarina	<1	0 to 18	8
Gastropoda	-	0 to 1	<1
Bivalvia	<1	0 to 13	<1
Ceratopogonidae	1	2 to 31	6
Chironomidae	67	3 to 82	36
Diptera (misc.)	1	0 to 13	17
Coleoptera	6	1 to 7	5
Ephemeroptera	<1	1 to 19	2
Odonata	-	0 to <1	-
Plecoptera	<1	0 to <1	-
Trichoptera	<1	1 to 7	6
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	105	61 to 521	152
Richness	12	10 to 25	18
Equitability	0.59	0.42 to 0.61	0.50
% EPT	2	<1 to 21	9

Table 5.2-25 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints between *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.

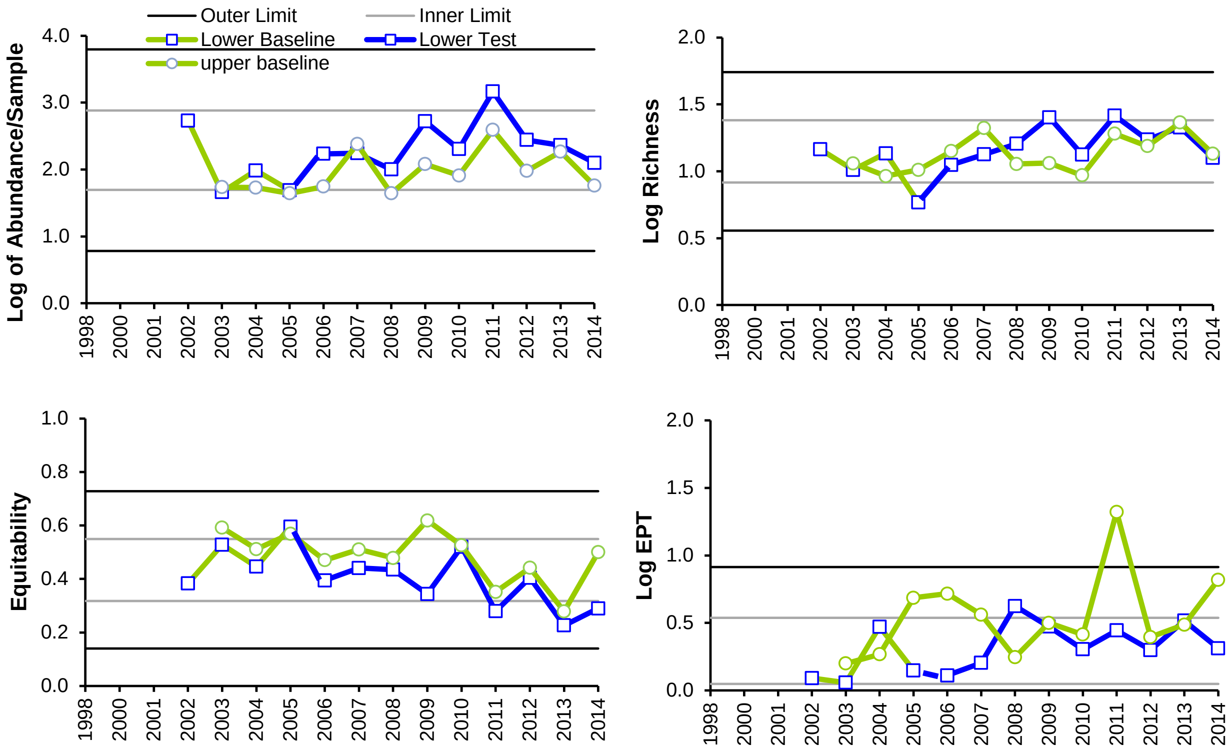
Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	Test Reach vs. *Baseline* Reach	*Test* Period vs. *Baseline* Period	Differences Between *Baseline* and *Test* Reaches from Before to After Lower Reach Was Designated as *Test*	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	*Test* Period vs. *Baseline* Period	Differences Between *Baseline* and *Test* Reaches from Before to After Lower Reach Was Designated as *Test*	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**<0.001**	**<0.001**	0.052	0.273	0.908	0.485	0.237	12	28	2	1	0	0	1	Higher at *test* reach; higher during *test* period at both reaches.
Log of Richness	0.330	**<0.001**	0.153	0.088	0.641	0.967	0.455	1	38	2	3	0	0	1	Higher in *test* period at both reaches.
Equitability	**0.001**	**0.002**	0.256	**0.002**	0.707	**0.002**	0.051	13	28	2	12	0	12	5	Lower at *test* reach; higher in *baseline* period at both reaches; decreasing over time at *test* reach; lower in 2014 than mean of previous years.
Log of EPT	**<0.001**	**0.001**	0.447	0.090	0.853	0.253	1.000	16	9	0	2	0	1	0	Lower at *test* reach; higher in *test* period at both reaches.
CA Axis 1	0.533	0.220	0.105	**0.009**	**0.027**	0.971	0.835	1	2	4	11	8	0	0	Increasing over time at *baseline* reach; decreasing over time at *test* reach.
CA Axis 2	0.962	**<0.001**	0.571	0.325	0.327	0.320	0.430	0	19	0	1	1	1	0	Higher during *baseline* period at both reaches.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.2-19 Variations in benthic invertebrate community measurement endpoints in *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.

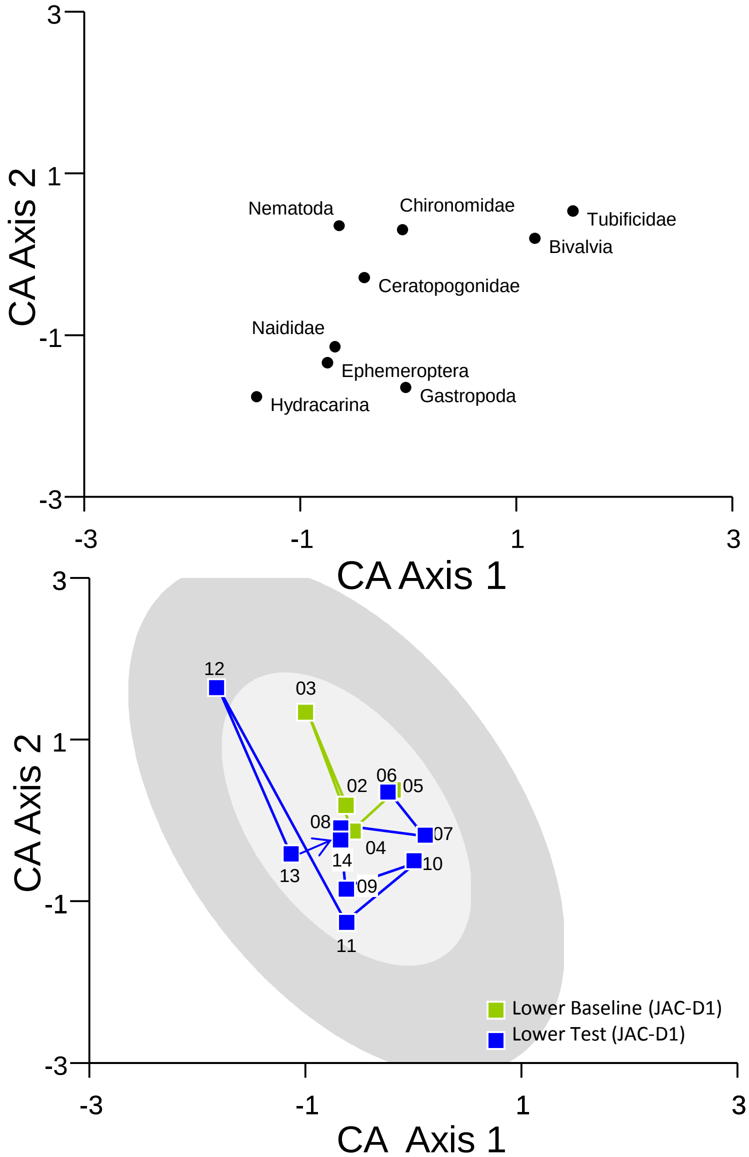


Note: *Test* reach JAC-D1 was designated as *baseline* from 2002 to 2005.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at JAC-D1 (2002 to 2013).

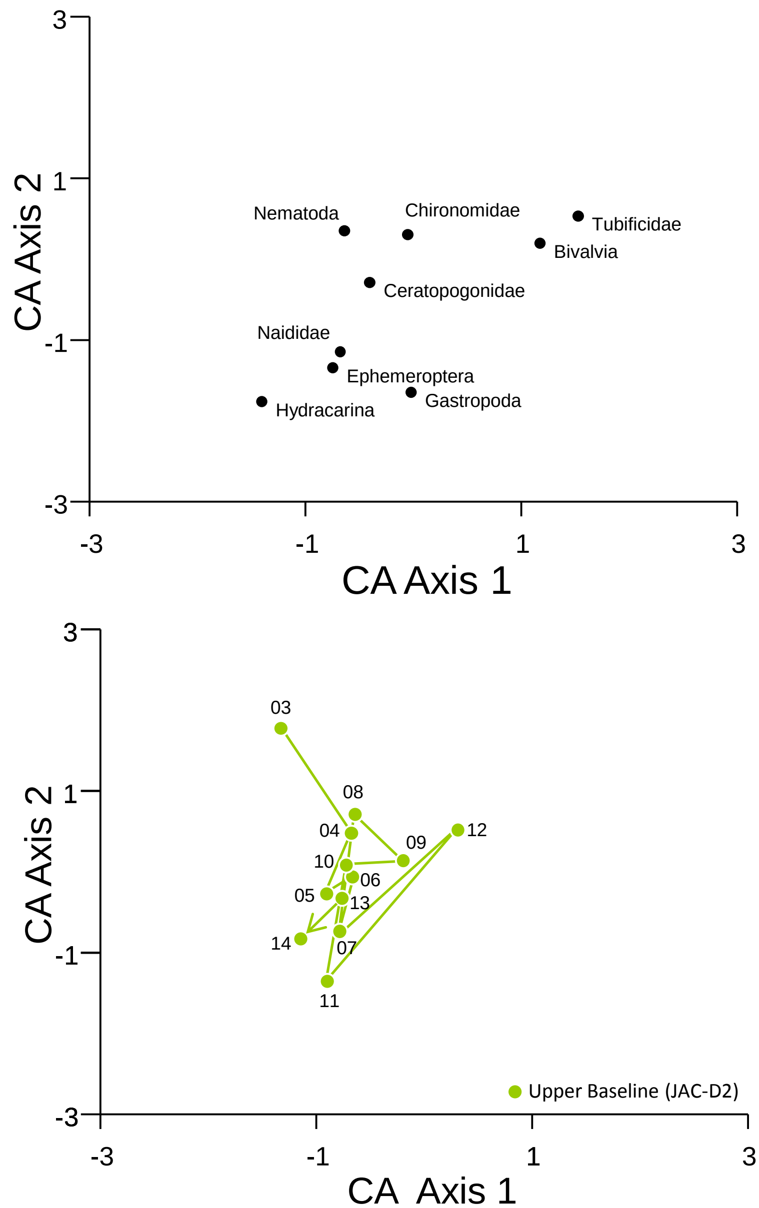
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.2-20 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Jackpine Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.2-21 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the upper reach of Jackpine Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.2-26 Average habitat characteristics of benthic invertebrate community sampling locations in Kearl Lake, fall 2014.

Variable	Units	Kearl Lake
Sample date	-	Sept 11, 2014
Habitat	-	Depositional
Water depth	m	2
Field Water Quality		
Dissolved oxygen	mg/L	9.8
Conductivity	µS/cm	185
pH	pH units	6.7
Water temperature	°C	9
Sediment Composition (mean ± 1SD)		
Sand	%	3±1
Silt	%	88±3
Clay	%	9±2
Total Organic Carbon	%	36.7±1.5

Table 5.2-27 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Kearl Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Kearl Lake		
	2001	2002-2013	2014
Hydra	-	-	<1
Nematoda	-	0 to 5	1
Naididae	-	<1 to 20	36
Tubificidae	-	0 to 2	8
Enchytraeidae	-	<1	<1
Lumbriculidae	-	0 to <1	<1
Hirudinea	0 to <1	0 to <1	<1
Hydracarina	<1	0 to 16	<1
Amphipoda	13	2 to 58	<1
Gastropoda	1	0 to 1	2
Bivalvia	4	4 to 31	10
Ceratopogonidae	-	0 to 1	<1
Chironomidae	6	13 to 46	41
Diptera (misc)	1	0 to <1	<1
Ephemeroptera	<1	0 to 2	<1
Odonata	-	0 to <1	<1
Trichoptera	2	0 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	18	41 to 401	331
Richness	7	7 to 17	18
Equitability	0.92	0.29 to 0.77	0.13
% EPT	3	<1 to 2	<1

Table 5.2-28 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Kearl Lake.

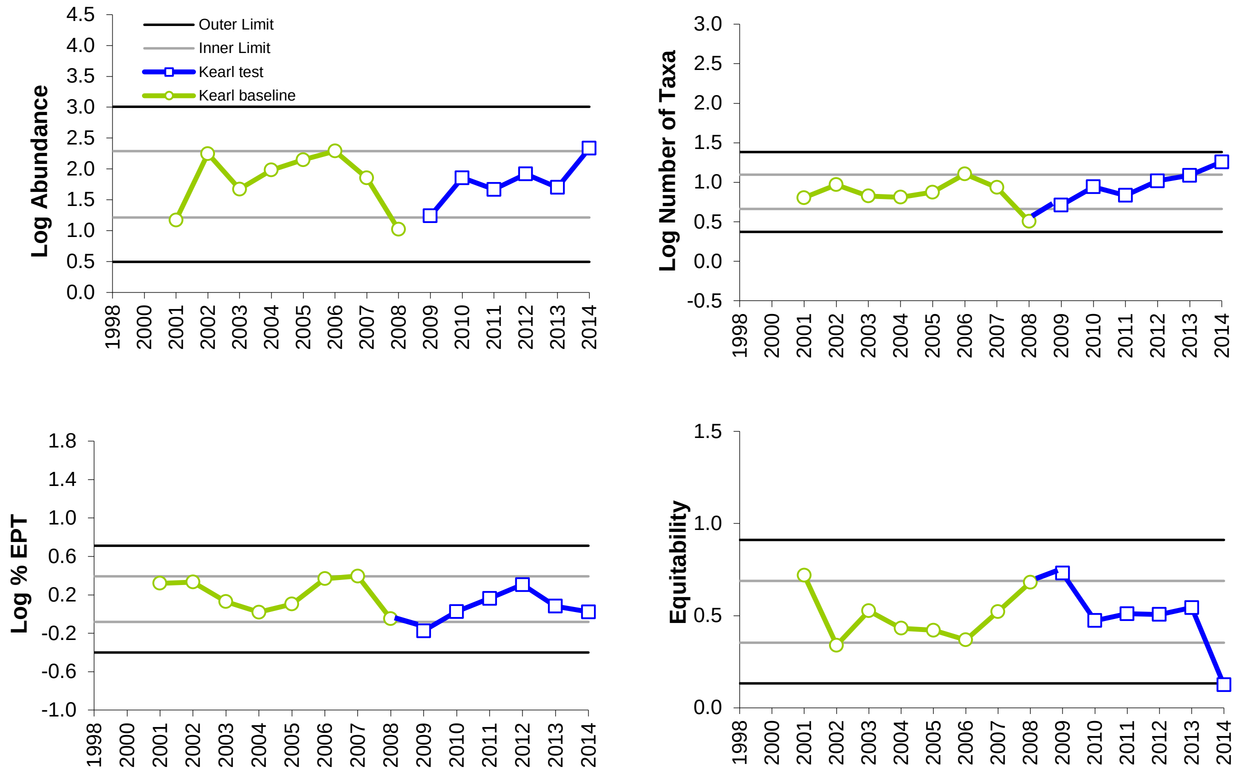
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	***Test* Period vs. *Baseline* Period**	**Time Trend (*Test* Period)**	**2014 vs. *Baseline* Years**	**2014 vs. Previous Years**	***Test* Period vs. *Baseline* Period**	**Time Trend (*Test* Period)**	**2014 vs. *Baseline* Years**	**2014 vs. Previous Years**	
Log of Abundance	0.861	**<0.001**	**<0.001**	**<0.001**	0	17	11	14	Increasing over time in *test* period; higher in 2014 than the mean of *baseline* years and mean of all previous years.
Log of Richness	**0.003**	**<0.001**	**<0.001**	**<0.001**	11	36	33	30	Higher in *test* period; increasing over time in *test* period; higher in 2014 than the mean of *baseline* years and mean of all previous years.
Equitability	0.529	**<0.001**	**<0.001**	**<0.001**	0	31	38	45	Decreased over time in *test* period; lower in 2014 than mean of *baseline* years and mean of all previous years.
Log of EPT	**0.008**	0.081	0.062	0.157	15	6	7	4	Lower in *test* period.
CA Axis 1	**0.012**	**0.020**	**<0.001**	**<0.001**	10	9	33	31	Higher in *test* period; increasing over time in *test* period; higher in 2014 than mean of *baseline* years and mean of all previous years.
CA Axis 2	**0.001**	**0.002**	**<0.001**	**<0.001**	13	12	35	32	Higher in *test* period; increasing over time; higher in 2014 than mean of *baseline* years and mean of all previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparisons to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-22 Variations in benthic invertebrate community measurement endpoints in Kearl Lake (KEL-1).

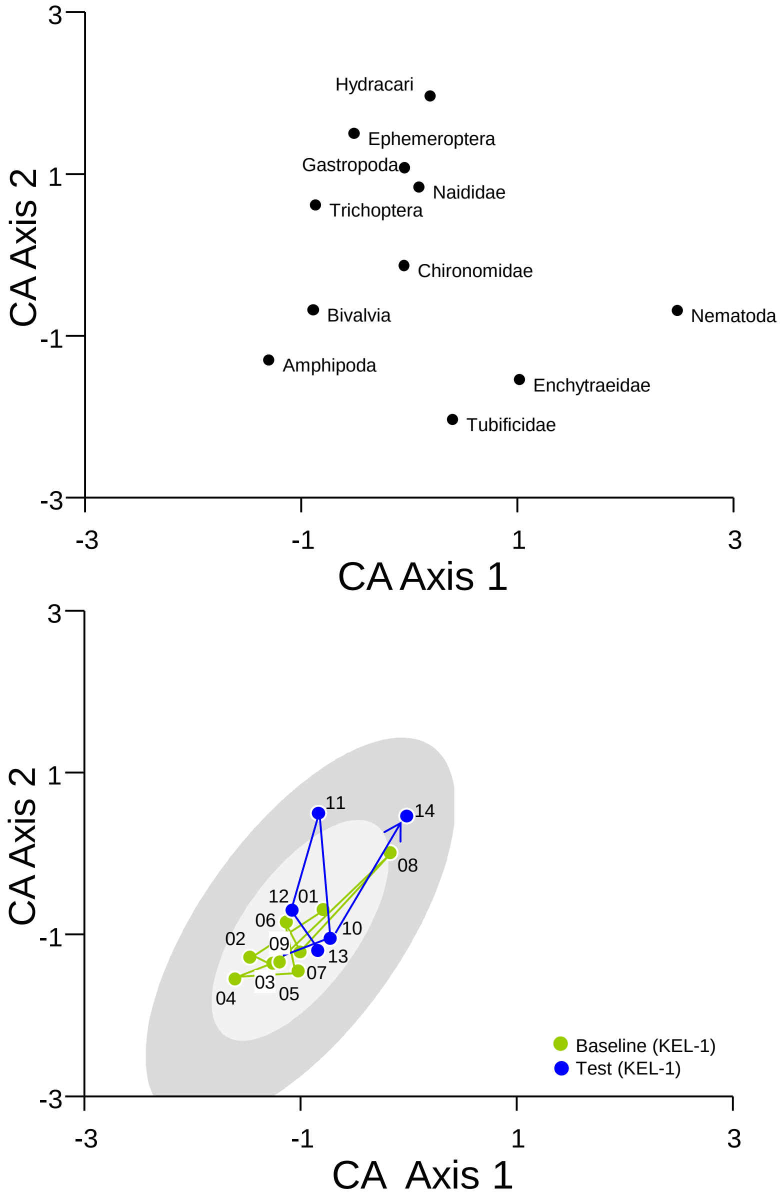


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2001 to 2013.

Note: Values have been adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-23 Ordination (Correspondence Analysis) of benthic invertebrate communities of lakes in the oil sands region, showing Kearl Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.2-29 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D2), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.6	10	1	5.1	12
Silt	%	-	6.4	10	1	17.5	32
Sand	%	-	88	10	60	76.5	98.6
Total organic carbon	%	-	1.11	11	0.13	2.8	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	10	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	10	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	67	10	<5	56	**180**
Fraction 3 (C16-C34)	mg/kg	300[1]	**644**	10	50	**968**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	558	10	43	922	2,100
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	12	0.0004	0.002	0.02
Retene	mg/kg	-	0.046	12	0.002	0.145	0.314
Total dibenzothiophenes	mg/kg	-	1.242	12	0.053	3.061	11.04
Total PAHs	mg/kg	-	3.707	12	0.404	11.14	30.44
Total Parent PAHs	mg/kg	-	0.089	12	0.014	0.281	0.676
Total Alkylated PAHs	mg/kg	-	3.618	12	0.389	10.862	29.764
Predicted PAH toxicity[3]	H.I.	1.0	0.849	12	0.731	1.396	3.997
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>8.8</u>	8	2.6	6.8	8.6
Chironomus growth - 10d	mg/organism	-	1.9	8	0.7	2.2	4.3
Hyalella survival - 14d	# surviving	-	9.6	8	8	8.3	10
Hyalella growth - 14d	mg/organism	-	0.3	8	0.1	0.3	0.4

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.2-30 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D3), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7.5	10	4.5	6.3	47
Silt	%	-	9.5	10	6	12.8	29
Sand	%	-	83	10	26	79.5	85.1
Total organic carbon	%	-	5.81	11	1.7	22.2	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<30	10	<5	<7.5	<80
Fraction 1 (C6-C10)	mg/kg	30[1]	<30	10	<5	<7.5	<80
Fraction 2 (C10-C16)	mg/kg	150[1]	<24	10	<5	37	130
Fraction 3 (C16-C34)	mg/kg	300[1]	225	10	52	**726**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	131	10	56	315.5	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.00043</u>	11	0.00085	0.00652	0.0145
Retene	mg/kg	-	0.0919	11	0.0155	0.349	2.33
Total dibenzothiophenes	mg/kg	-	0.0562	11	0.0419	0.1229	0.1899
Total PAHs	mg/kg	-	0.4214	11	0.3786	1.124	3.1058
Total Parent PAHs	mg/kg	-	0.0198	11	0.0179	0.048	0.3397
Total Alkylated PAHs	mg/kg	-	0.4016	11	0.3486	0.9682	3.0537
Predicted PAH toxicity[3]	H.I.	1.0	0.3274	11	0.0253	0.303	**1.2248**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>9.5</u>	7	3	6.4	8.8
Chironomus growth - 10d	mg/organism	-	1.9	7	1.28	1.8	2.95
Hyalella survival - 14d	# surviving	-	<u>9.5</u>	7	7	8.2	9.2
Hyalella growth - 14d	mg/organism	-	<u>0.36</u>	7	0.11	0.21	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.2-31 Concentrations of selected sediment quality measurement endpoints in Jackpine Creek (*test* station JAC-D1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2.4	10	0.1	3.5	18.7
Silt	%	-	13.7	10	0.3	7.8	19.9
Sand	%	-	83.9	10	74.5	85.5	99.3
Total organic carbon	%	-	1.81	10	0.2	1.1	3.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	9	13	<20	71
Fraction 3 (C16-C34)	mg/kg	300[1]	**365**	9	101	**450**	**790**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	472	9	137	530	820
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0007	10	0.0003	0.0011	0.003
Retene	mg/kg	-	0.019	9	0.007	0.025	0.951
Total dibenzothiophenes	mg/kg	-	0.235	10	0.105	0.448	1.639
Total PAHs	mg/kg	-	0.968	10	0.413	1.451	4.492
Total Parent PAHs	mg/kg	-	0.039	10	0.015	0.046	0.136
Total Alkylated PAHs	mg/kg	-	0.929	10	0.391	1.406	4.375
Predicted PAH toxicity[3]	H.I.	1.0	0.316	10	0.214	0.462	**1.596**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.2	8	5.6	7.5	9.6
Chironomus growth - 10d	mg/organism	-	2.26	8	1.15	2.47	3.4
Hyalella survival - 14d	# surviving	-	9.3	8	7.0	9.5	10.0
Hyalella growth - 14d	mg/organism	-	<u>0.4</u>	8	0.14	0.27	0.31

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.2-32 Concentrations of selected sediment quality measurement endpoints in Jackpine Creek (*baseline* station JAC-D2), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.06	7	<1	6.8	13
Silt	%	-	4.85	7	<1	14	23.1
Sand	%	-	90.1	7	66	78	99
Total organic carbon	%	-	0.59	8	0.1	1.2	2.1
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	8	<5	<20	<27
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	8	10	56	190
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	8	<5	50.5	160
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0003</u>	7	0.0005	0.0008	0.0041
Retene	mg/kg	-	0.0036	7	0.001	0.0152	0.0331
Total dibenzothiophenes	mg/kg	-	0.005	7	0.0019	0.0069	0.0164
Total PAHs	mg/kg	-	0.032	7	0.0143	0.0973	0.2002
Total Parent PAHs	mg/kg	-	0.0037	7	0.0037	0.0091	0.0203
Total Alkylated PAHs	mg/kg	-	0.028	7	0.0106	0.0899	0.1803
Predicted PAH toxicity[3]	H.I.	1.0	0.148	7	0.1351	0.2261	0.3563
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	7	4.6	8.2	9.6
Chironomus growth - 10d	mg/organism	-	2.8	7	0.8	2.3	4.2
Hyalella survival - 14d	# surviving	-	9.2	7	8	9.2	9.8
Hyalella growth - 14d	mg/organism	-	0.3	7	0.3	0.3	0.6

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.2-33 Concentrations of selected sediment quality measurement endpoints in Kearl Lake (*test* station KEL-1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8.9	8	1	12.3	58
Silt	%	-	87.6	8	4	38.9	69.9
Sand	%	-	3.5	8	9	38	93
Total organic carbon	%	-	35.7	10	5	34	38.1
Total hydrocarbons							
BTEX	mg/kg	-	<160	9	<5	<80	<1000
Fraction 1 (C6-C10)	mg/kg	30[1]	**<160**	9	<5	**<80**	**<1000**
Fraction 2 (C10-C16)	mg/kg	150[1]	**<216**	9	<5	<146	**530**
Fraction 3 (C16-C34)	mg/kg	300[1]	**681**	9	230	**487**	**3,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	486	9	81	366	2,500
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0065	6	0.0083	0.0168	0.0361
Retene	mg/kg	-	0.035	10	0.0156	0.0452	0.1130
Total dibenzothiophenes	mg/kg	-	0.026	10	0.0281	0.0470	0.0866
Total PAHs	mg/kg	-	0.509	10	0.7229	0.8904	1.4596
Total Parent PAHs	mg/kg	-	0.089	10	0.0783	0.1209	0.3449
Total Alkylated PAHs	mg/kg	-	0.42	10	0.6345	0.7144	1.3436
Predicted PAH toxicity[3]	H.I.	1.0	0.1014	10	0.0311	0.1926	0.9241
Metals that exceeded CCME guidelines in 2014							
none				-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.8	6	7	8.8	9
Chironomus growth - 10d	mg/organism	-	1.91	6	1.2	1.4	2.3
Hyalella survival - 14d	# surviving	-	7.4	6	7.6	9.1	9.6
Hyalella growth - 14d	mg/organism	-	0.26	6	0.1	0.2	0.3

Values in **bold** indicate concentrations exceeding guidelines.

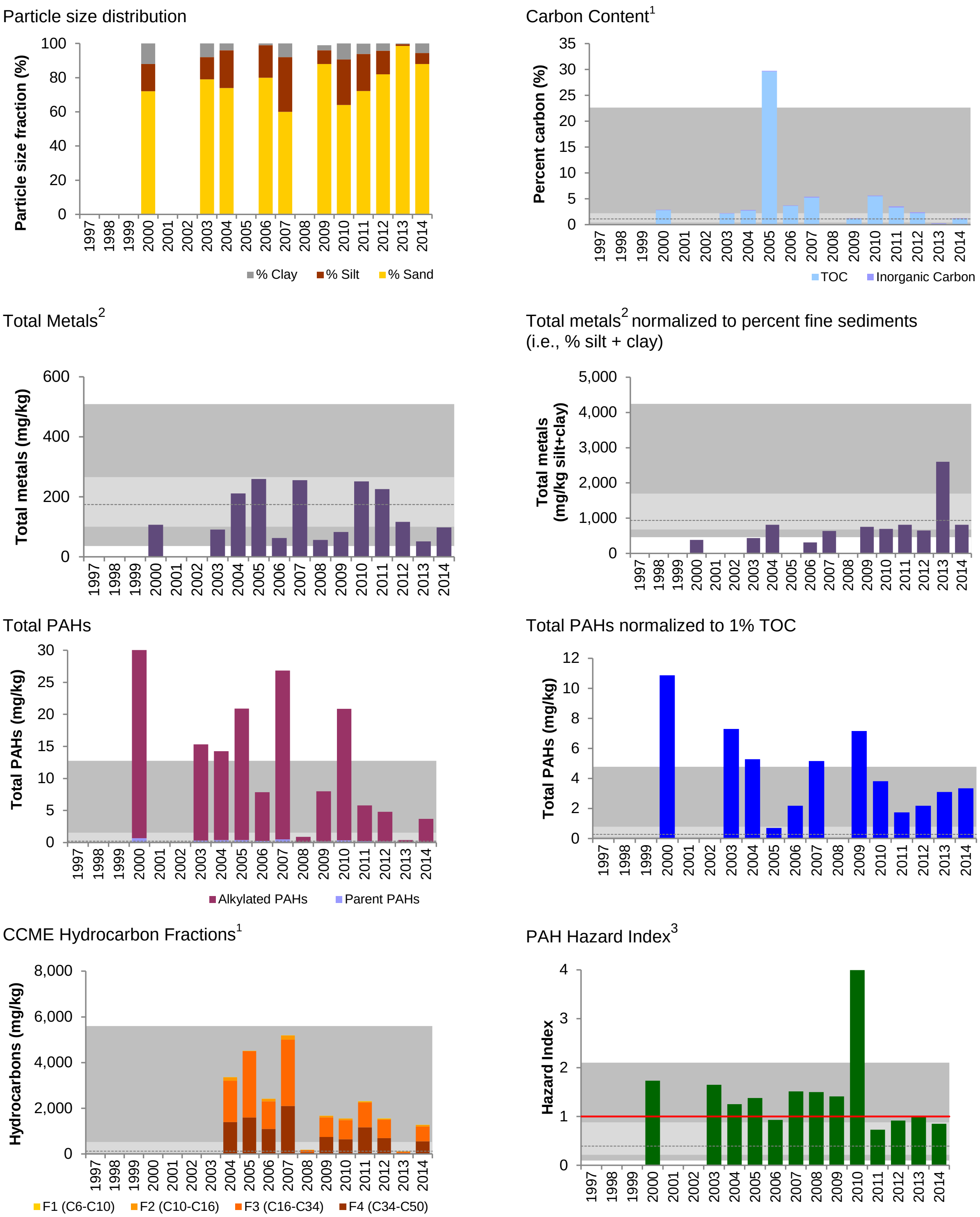
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-24 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D2.



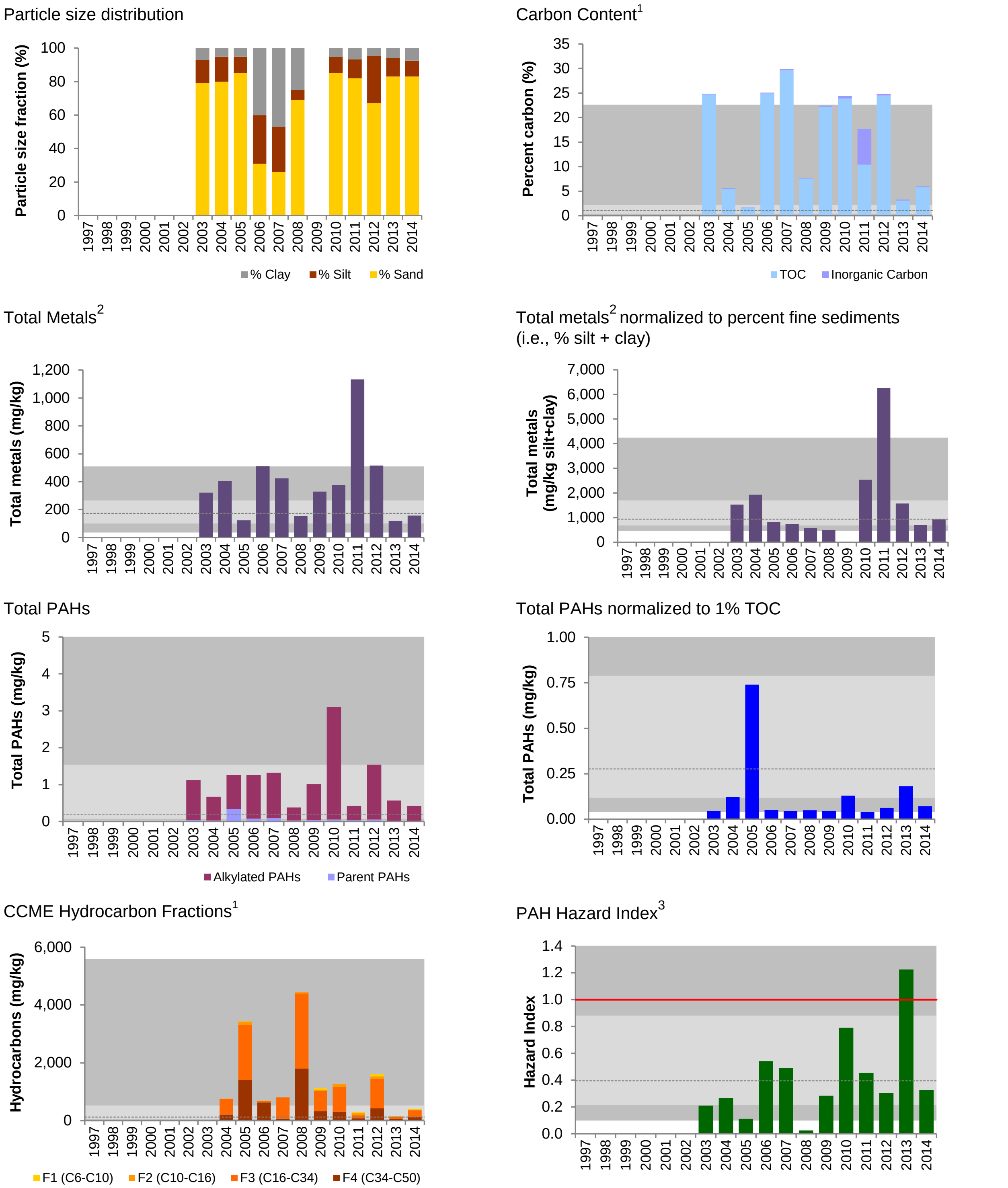
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-25 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D3.



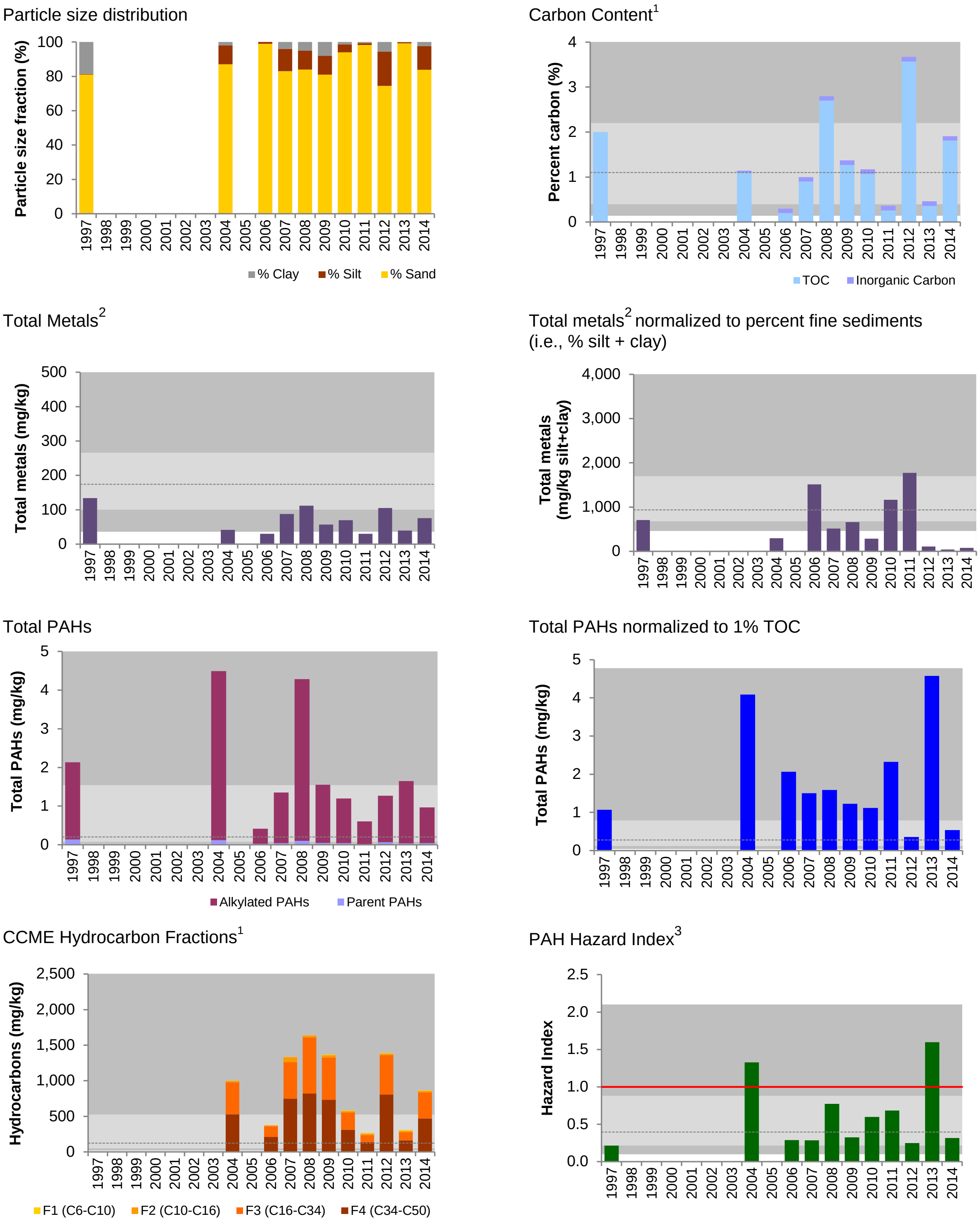
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-26 Variation in sediment quality measurement endpoints in Jackpine Creek, *test* station JAC-D1.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

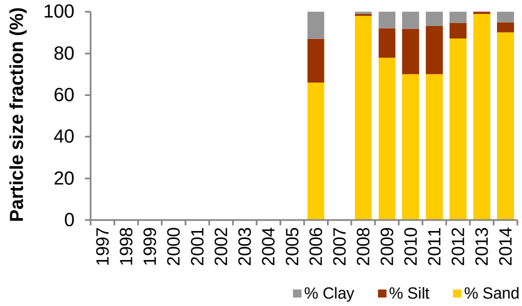
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

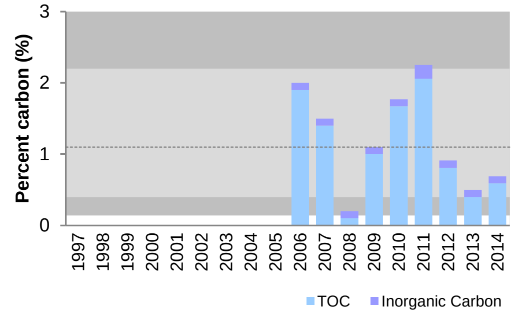
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-27 Variation in sediment quality measurement endpoints in Jackpine Creek, *baseline* station JAC-D2.

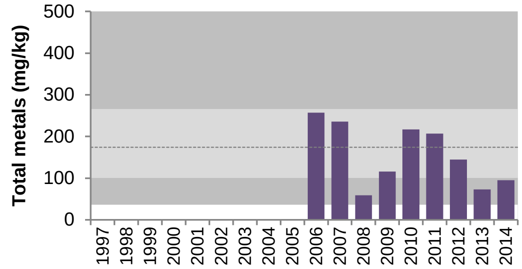
Particle size distribution



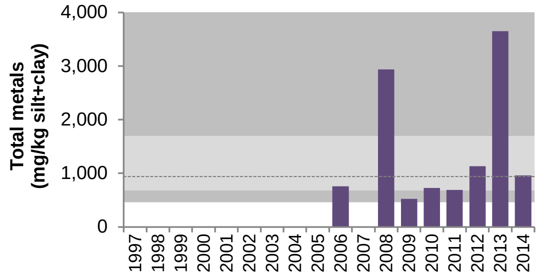
Carbon Content[1]



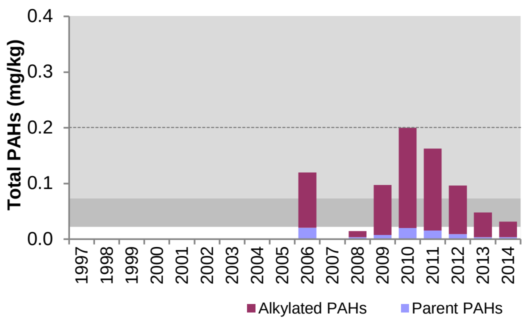
Total Metals[2]



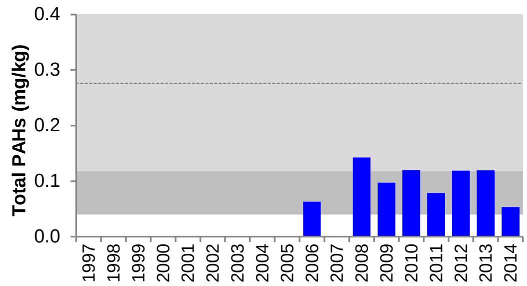
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



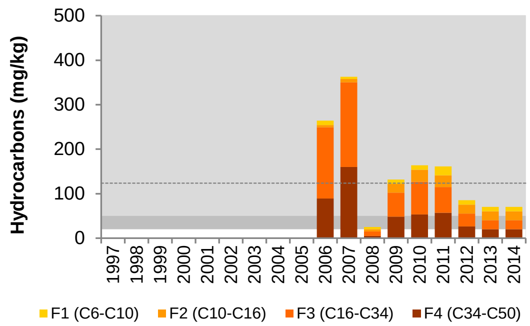
Total PAHs



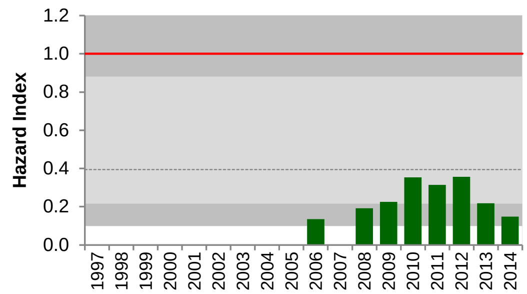
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

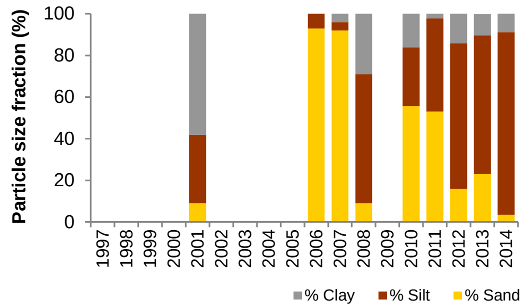
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

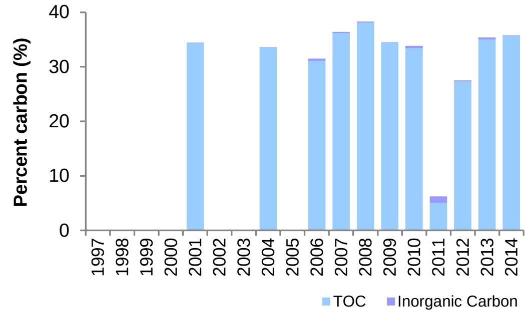
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-28 Variation in sediment quality measurement endpoints in Kearl Lake, *test* station KEL-1.

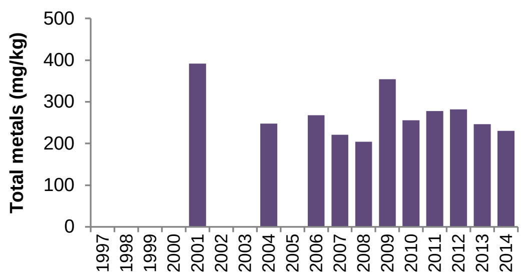
Particle size distribution



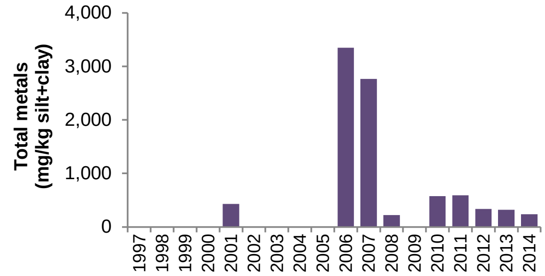
Carbon Content[1]



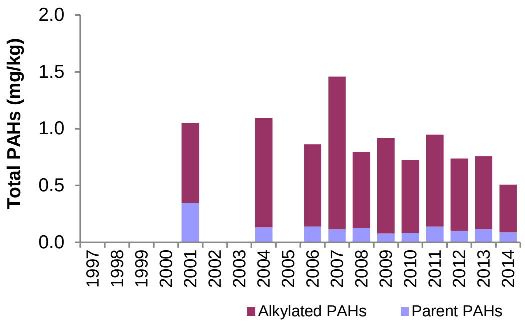
Total Metals[2]



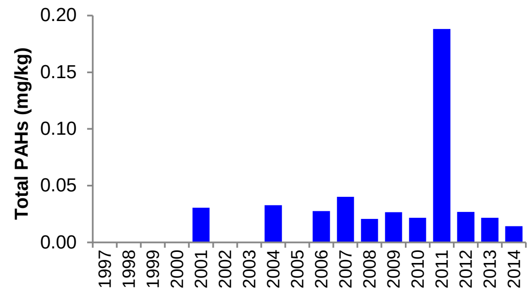
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



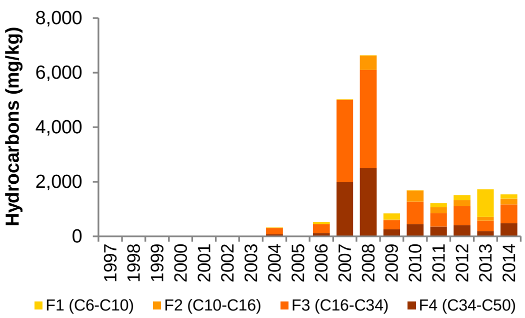
Total PAHs



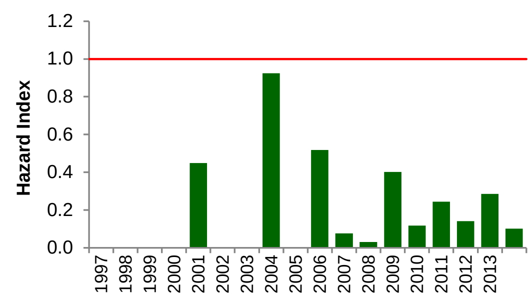
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-34 Sediment quality index (fall 2014) for Muskeg River watershed stations.

Station Identifier	Location	2014 Designation	Sediment Quality Index	Classification
MUR-D2	Muskeg River at Canterra Road	*test*	100.00	Negligible-Low
MUR-D3	upper Muskeg River	*test*	98.91	Negligible-Low
JAC-D1	mouth of Jackpine Creek	*test*	100.00	Negligible-Low
JAC-D2	upper Jackpine Creek	*baseline*	100.00	Negligible-Low

Table 5.2-35 Average habitat characteristics of fish assemblage monitoring locations of the Muskeg River, fall 2014.

Variable	Units	MUR-F1 Lower *Test* Reach	MUR-F2 Middle *Test* Reach	MUR-F3 Upper *Test* Reach
Sample date		Sept 3, 2014	Sept 9, 2014	Sept 4, 2014
Habitat type	-	run/riffle	riffle/run	run
Maximum depth	m	0.70	1.07	1.92
Mean depth	m	0.65	0.66	1.92
Bankfull channel width	m	24.1	15.8	9.2
Wetted channel width	m	16.6	11.5	9.2
Substrate				
Dominant	-	fine gravel	cobble	sand
Subdominant	-	sand/cobble	sand/fines	fines
Instream cover				
Dominant	-	boulders, filamentous algae	small woody debris, boulders	large and small woody debris, overhanging vegetation, undercut banks
Subdominant	-	small woody debris	macrophytes	live trees, macrophytes
Field water quality				
Dissolved oxygen	mg/L	9.2	9.6	6.1
Conductivity	µS/cm	393	392	404
pH	pH units	8.25	7.80	7.85
Water temperature	^{o}C	11.9	9.4	11.4
Water velocity				
Left bank velocity	m/s	0.29	0.35	0.00
Left bank water depth	m	0.65	0.53	1.45
Centre of channel velocity	m/s	0.29	0.27	0.00
Centre of channel water depth	m	0.60	0.60	1.53
Right bank velocity	m/s	0.35	0.30	0.00
Right bank water depth	m	0.40	0.43	1.50
Riparian cover – understory (<5 m)				
Dominant	-	woody shrubs and samplings	-	woody shrubs and samplings
Subdominant	-	overhanging vegetation	-	overhanging vegetation

Table 5.2-36 Total number and percent composition of fish species captured at reaches of the Muskeg River, 2009 to 2014.

Common Name	Code	Total Species Catch														Percent of Total Catch													
		MUR-F1						MUR-F2				MUR-F3				MUR-F1						MUR-F2				MUR-F3			
		2009	2010	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
brook stickleback	BRST	3	5	1	-	-	-	-	-	-	-	33	1	-	-	5.2	5.4	1.4	0	0	0	0	0	0	0	84.6	100	0	0
burbot	BURB	1	-	-	-	8	9	-	-	-	-	-	-	-	-	1.7	0	0	0	29.6	21.4	0	0	0	0	0	0	0	0
finescale dace	FNDC	-	15	-	-	-	-	-	-	-	-	-	-	-	-	0	16.1	0	0	0	0	0	0	0	0	0	0	0	0
lake chub	LKCH	4	8	1	-	2	-	-	-	2	3	-	-	-	-	6.9	8.6	1.4	0	7.4	0	0	0	20.0	60.0	0	0	0	0
longnose dace	LNDC	-	10	7	1	-	-	-	-	-	-	-	-	-	-	0	10.8	9.9	16.7	0	0	0	0	0	0	0	0	0	0
longnose sucker	LNSC	5	4	49	-	3	6	-	-	1	-	-	-	-	-	8.6	4.3	69.0	0	11.1	14.3	0	0	10.0	0	0	0	0	0
northern pike	NRPK	-	-	-	1	1	-	2	-	1	1	-	-	-	1	0	0	0	16.7	3.7	0	66.7	0	10.0	20.0	0	0	0	25.0
pearl dace	PRDC	-	35	2	-	-	-	-	-	2	-	2	-	-	-	0	37.6	2.8	0	0	0	0	0	20.0	0	5.1	0	0	0
slimy sculpin	SLSC	43	11	5	1	7	23	-	-	-	-	-	-	-	-	74.1	11.8	7.0	16.7	25.9	54.8	0	0	0	0	0	0	0	0
spoonhead sculpin	SPSC	1	3	-	1	1	1	-	-	-	-	-	-	-	-	1.7	3.2	0	16.7	3.7	2.4	0	0	0	0	0	0	0	0
walleye	WALL	-	-	1	-	-	-	-	-	-	-	-	-	-	-	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	-	2	5	-	3	2	1	-	4	1	-	-	1	3	0	2.2	7.0	0	11.1	4.8	33.3	0	40.0	20.0	0	0	100	75.0
yellow perch	YLPR	-	-	-	2	2	1	-	-	-	-	-	-	-	-	0	0.0	0	33.3	7.4	2.4	0	0	0	0	0	0	0	0
sucker sp. *		1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0
unknown sp. *		-	-	-	-	-	-	-	-	-	-	4	-	-	-	0	0	0	0	0	0	0	0	0	0	10.3	0	0	0
Total Count		**58**	**93**	**71**	**6**	**27**	**42**	**3**	**0**	**10**	**5**	**39**	**1**	**1**	**4**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**-**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**7**	**9**	**8**	**5**	**8**	**6**	**2**	**0**	**5**	**3**	**3**	**1**	**1**	**2**	**7**	**9**	**8**	**5**	**8**	**6**	**2**	**0**	**5**	**3**	**3**	**1**	**1**	**2**
Electrofishing effort (secs)		**2,051**	**4,623**	**1,267**	**1,526**	**2,274**	**2,296**	**1,178**	**1,841**	**1,853**	**1,765**	**1,297**	**1,763**	**1,551**	**1,310**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	-	**-**	**-**	**-**	**-**

* Unknown species not included in the calculation of species richness.

Table 5.2-37 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of the Muskeg River and Jackpine Creek, 2009 to 2014.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MUR-F1	2009	0.15	-	7	-	-	0.43	-	3.65	-	2.78	-
	2010	0.19	0.08	9	4.10	2.38	0.64	0.29	6.10	0.51	3.89	2.01
	2011	0.28	0.09	8	3.80	1.10	0.47	0.13	5.15	0.39	5.64	1.87
	2012	0.03	0.02	5	1.20	0.84	0.20	0.27	6.05	2.13	0.40	0.27
	2013	0.05	0.04	8	3.40	2.07	0.53	0.32	5.07	1.89	1.19	0.97
	2014	0.09	0.04	6	3.00	0.71	0.54	0.16	3.29	0.46	1.83	0.89
MUR-F2	2009	0.00	-	1	-	-	0.00	-	2.00	-	0.11	-
	2011	0.01	0.02	2	0.60	0.89	0.10	0.22	7.75	0.07	0.23	0.35
	2012	0.00	-	0	0.00	-	0.00	-	0.00	-	0.00	-
	2013	0.01	0.01	5	2.00	1.22	0.30	0.27	6.90	1.14	0.54	0.31
	2014	0.01	0.00	3	0.80	0.45	0.00	-	6.60	1.27	0.38	0.27
MUR-F3	2011	0.16	0.10	3	1.40	0.55	0.14	0.22	9.06	0.58	2.99	1.84
	2012	0.00	0.01	1	0.20	0.45	0.00	-	9.40	-	0.06	0.14
	2013	0.00	0.01	1	0.20	0.45	0.00	-	7.60	-	0.06	0.14
	2014	0.01	0.01	2	0.60	0.55	0.00	-	7.67	0.12	0.23	0.24
JAC-F1	2009	0.02	-	3	-	-	0.57	-	6.41	-	0.32	-
	2010	0.65	0.59	8	3.90	2.38	0.53	0.29	7.72	0.51	4.31	4.01
	2011	1.03	1.04	6	2.80	0.84	0.20	0.20	5.74	0.35	17.15	21.14
	2012	0.01	0.01	1	0.40	0.55	0.00	-	3.00	-	0.13	0.17
	2013	0.05	0.02	2	1.40	0.55	0.18	0.24	3.24	0.36	0.76	0.34
	2014	0.05	0.02	3	1.60	0.55	0.29	0.26	3.97	1.14	0.91	0.46
JAC-F2	2009	0.42	-	4	-	-	0.48	-	6.56	-	4.36	-
	2010	0.10	-	5	-	-	0.69	-	7.85	-	4.51	-
	2011	0.69	0.62	4	2.80	0.84	0.50	0.16	8.18	0.61	10.43	10.88
	2012	0.02	0.02	2	0.60	0.55	0.00	-	6.80	2.25	0.30	0.33
	2013	0.12	0.10	3	1.80	0.84	0.19	0.21	8.26	1.72	2.25	1.72
	2014	0.21	0.10	4	2.60	1.14	0.35	0.26	6.19	0.58	5.01	2.42

* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

Table 5.2-38 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for the lower Muskeg River (*test* reach MUR-F1).

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**<0.001***	36	Decreasing over time.
Richness	0.100*	9	No change.
Diversity	0.250*	5	No change.
ATI	**0.006***	24	Decreasing over time.
CPUE (No./100 sec)*	**0.001**	32	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

* denotes data were rank transformed to meet assumptions of ANOVA.

Table 5.2-39 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for the middle Muskeg River (*test* reach MUR-F2).

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**0.020***	9	Increasing over time.
Richness	0.110*	14	No change.
Diversity	0.340*	5	No change.
ATI	0.810*	1	No change.
CPUE (No./100 sec)	0.120*	<1	No change.

Bold values indicate significant difference (p<0.05).

* denotes data were rank transformed to meet assumptions of ANOVA.

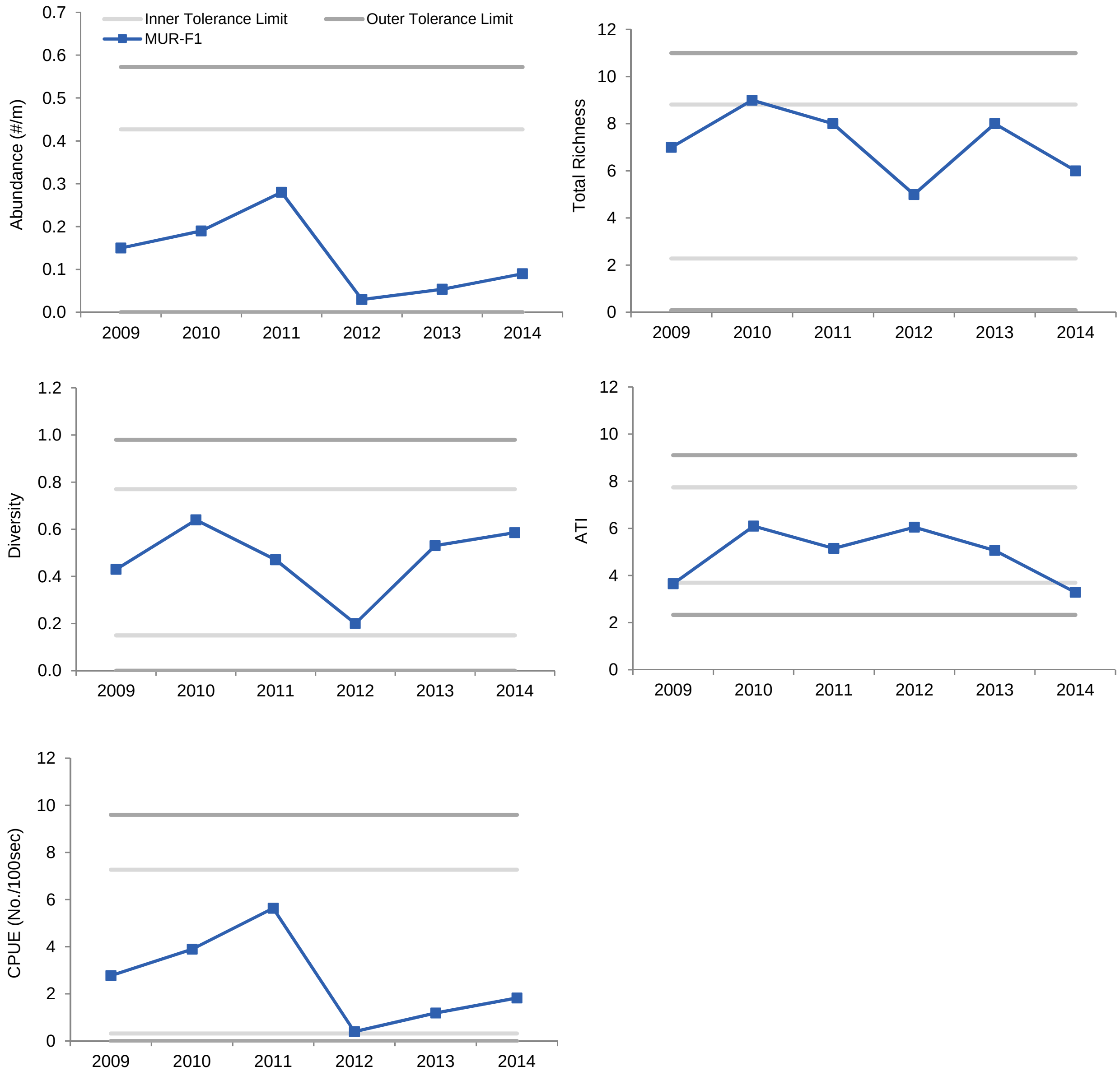
Table 5.2-40 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for the upper Muskeg River (*test* reach MUR-F3).

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance*	0.120	14	No change.
Richness	0.100	16	No change.
Diversity*	0.310	6	No change.
ATI*	0.670	1	No change.
CPUE (No./100 sec)*	0.120	14	No change.

Bold values indicate significant difference (p<0.05).

* denotes data were rank transformed to meet assumptions of ANOVA.

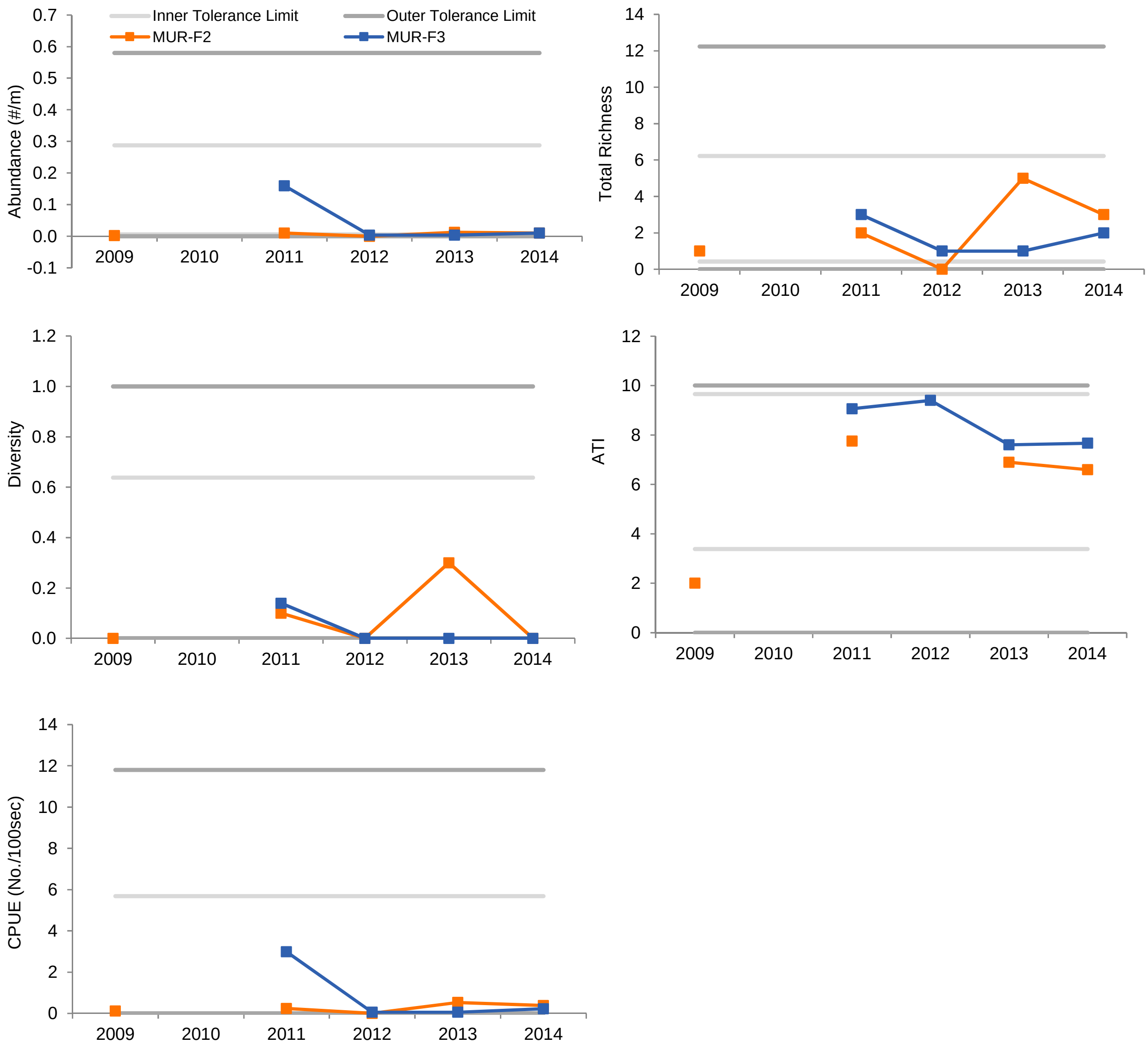
Figure 5.2-29 Variation in fish assemblage measurement endpoints for the lower *test* reach (MUR-F1) of the Muskeg River from 2009 to 2014 relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using baseline data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A solid line denotes a *test* reach.

Figure 5.2-30 Variation in fish assemblage measurement endpoints for the middle and upper *test* reaches (MUR-F2 and MUR-F3) of the Muskeg River from 2009 to 2014 relative to regional *baseline* conditions (cluster 1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 1 (see Table 3.2-14 and Table 3.2-15).

Note: A solid line denotes a *test* reach.

Table 5.2-41 Average habitat characteristics of fish assemblage monitoring locations of Jackpine Creek, fall 2014.

Variable	Units	JAC-F1 Lower *Test* Reach	JAC-F2 Upper *Baseline* Reach
Sample date	-	Sept 9, 2014	Sept 4, 2014
Habitat type	-	run	run
Maximum depth	m	1.10	0.71
Mean depth	m	0.89	0.56
Bankfull channel width	m	11.7	7.0
Wetted channel width	m	8.2	4.0
Substrate			
Dominant	-	sand	sand
Subdominant	-	fines/cobble	fines/cobble
Instream cover			
Dominant	-	small woody debris	large and small woody debris
Subdominant	-	filamentous algae	overhanging vegetation, macrophytes
Field water quality			
Dissolved oxygen	mg/L	9.2	9.1
Conductivity	µS/cm	300	291
pH	pH units	7.83	8.28
Water temperature	^{0}C	8.0	13.6
Water velocity			
Left bank velocity	m/s	0.08	-0.01
Left bank water depth	m	0.17	0.39
Centre of channel velocity	m/s	0.02	0.08
Centre of channel water depth	m	0.42	0.52
Right bank velocity	m/s	0.01	0.04
Right bank water depth	m	0.76	0.41
Riparian cover – understory (<5 m)			
Dominant	-	-	woody shrubs and saplings
Subdominant	-	-	overhanging vegetation

Table 5.2-42 Total number and percent composition of fish species captured at reaches of Jackpine Creek, 2009 to 2014.

Common Name	Code	Total Species Catch												Percent of Total Catch											
		JAC-F1						JAC-F2						JAC-F1						JAC-F2					
		2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014
brook stickleback	BRST	-	19	2	-	-	-	14	29	36	1	16	7	0	11.4	1.3	0	0	0	23.7	47.5	35.0	25.0	44.4	10.9
finescale dace	FNDC	-	75	-	-	-	-	-	12	-	-	-	1	0	44.9	0	0	0	0	0	19.7	0	0	0	1.6
lake chub	LKCH	1	-	138	-	-	2	40	10	-	3	18	50	14.3	0	89.6	0	0	14.3	67.8	16.4	0	75.0	50.0	78.1
longnose sucker	LNSC	2	3	5	-	2	-	-	-	-	-	-	-	28.6	1.8	3.2	0	16.7	0	0	0	0	0	0	0
northern pike	NRPK	-	1	-	-	-	-	-	-	-	-	-	-	0	0.6	0	0	0	0	0	0	0	0	0	0
northern redbelly dace	NRDC	-	-	-	-	-	-	-	-	2	-	-	-	0	0	0	0	0	0	0	0	1.9	0	0	0
pearl dace	PRDC	-	21	-	-	-	-	3	9	50	-	-	-	0	12.6	0	0	0	0	5.1	14.8	48.5	0	0	0
slimy sculpin	SLSC	-	23	2	2	10	9	-	-	-	-	-	-	0	13.8	1.3	100.0	83.3	64.3	0	0	0	0	0	0
trout-perch	TRPR	-	9	5	-	-	-	-	-	-	-	-	-	0	5.4	3.2	0	0	0	0	0	0	0	0	0
white sucker	WHSC	4	16	2	-	-	3	2	1	15	-	2	6	57.1	9.6	1.3	0	0	21.4	3.4	1.6	14.6	0	5.6	9.4
Total Count		**7**	**167**	**154**	**2**	**12**	**14**	**59**	**61**	**103**	**4**	**36**	**64**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**3**	**8**	**6**	**1**	**2**	**3**	**4**	**5**	**4**	**2**	**3**	**4**	**3**	**8**	**6**	**1**	**2**	**3**	**4**	**5**	**4**	**2**	**3**	**4**
Electrofishing effort (secs)		**2,221**	**3,863**	**1,052**	**1,590**	**1,564**		**1,352**	**4,183**	**973**	**1,316**	**1,564**		**-**	**-**	**-**	**-**	**-**	-	**-**	**-**	**-**	**-**	**-**	**-**

Table 5.2-43 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for lower Jackpine Creek.

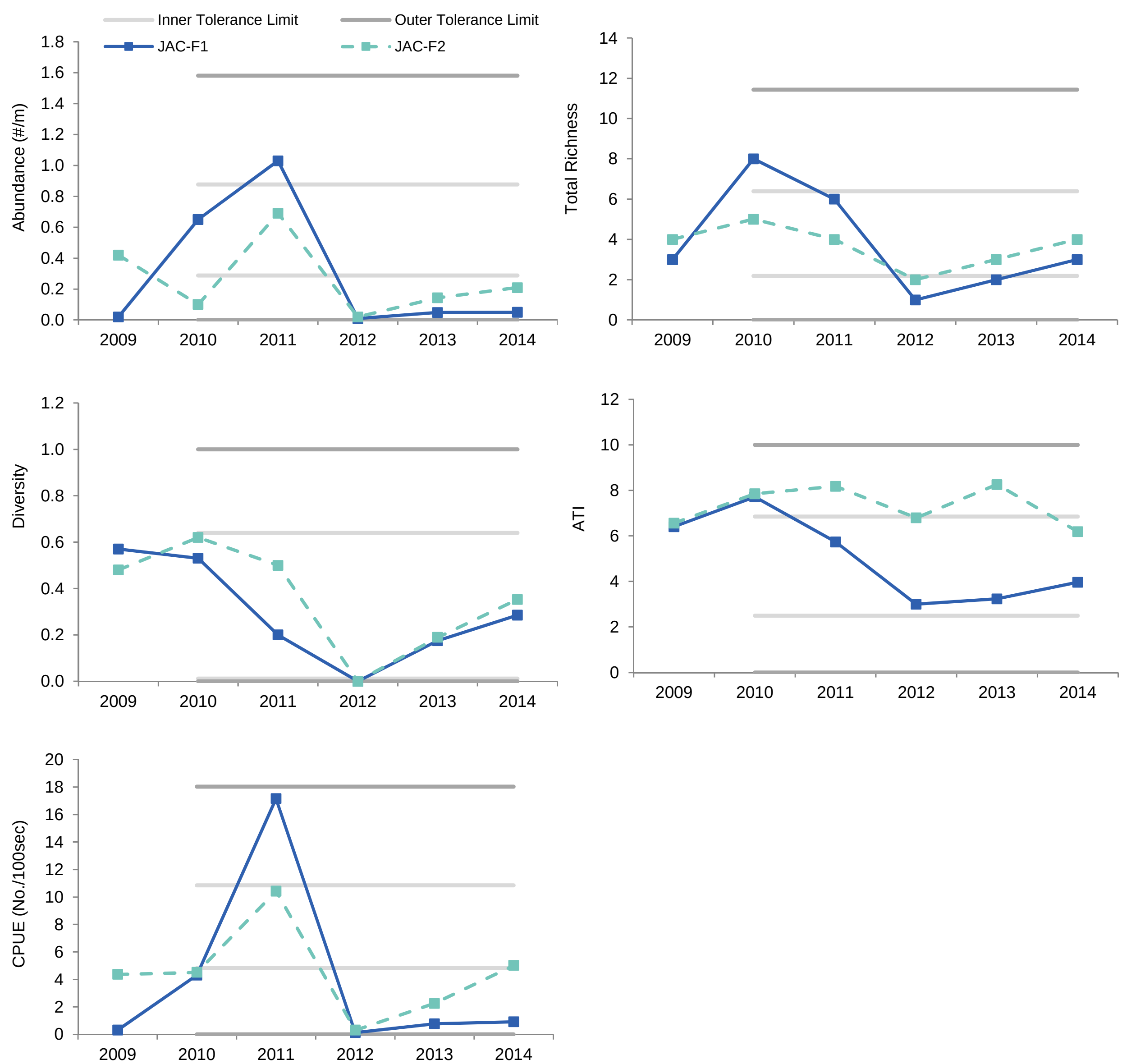
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	
Abundance	**0.010***	0.180*	21.5	4.8	Decreasing over time at *test* reach.
Richness	**0.004**	0.370	26.4	2.1	Decreasing over time at *test* reach.
Diversity	**0.030**	0.200*	15.0	4.3	Decreasing over time at *test* reach.
ATI	**<0.001**	0.580*	71.3	1.0	Decreasing over time at *test* reach.
CPUE (No./100 sec)	**0.040***	0.120*	13.5	6.2	Decreasing over time at *test* reach.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

* denotes data were rank transformed to meet assumptions of ANOVA.

Figure 5.2-31 Variation in fish assemblage measurement endpoints for reaches of Jackpine Creek from 2009 to 2014 relative to regional *baseline* conditions (cluster 3).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data for cluster 3 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: No *baseline* data for cluster 3 prior to 2010.

Note: Although *baseline* reach JAC-F2 is not part of *baseline* cluster 3, the data were graphed to provide comparison to *test* reach JAC-F1.

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5.3 STEEPBANK RIVER WATERSHED

Table 5.3-1 Summary of results for the Steepbank River watershed.

Steepbank River Watershed	Summary of 2014 Conditions			
	Steepbank River			*North Steepbank River*
Climate and Hydrology				
Criteria	**07DA006** near Fort McMurray	**S66** downstream of North Steepbank River	no station	no station
Mean open-water season discharge	🟡	not measured		
Mean winter discharge	🟡	not measured		
Annual maximum daily discharge	🟡	not measured		
Minimum open-water season discharge	🟡	not measured		
Water Quality				
Criteria	**STR-1** at the mouth	**STR-2** downstream of North Steepbank River	**STR-3** upstream of North Steepbank River	**NSR-1** North Steepbank River
Water Quality Index	🟠	🟡	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality				
Criteria	**STR-E1** lower reach	no reach	**STR-E2** upper reach	no reach
Benthic Invertebrate Communities	🟠		n/a	
No Sediment Quality component activities conducted in 2014				
Fish Populations				
Criteria	**STR-F1** lower reach	no reach	**STR-F2** upper reach	no reach
Fish Assemblages	🟤		n/a	

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline (green shading)

test (blue shading)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

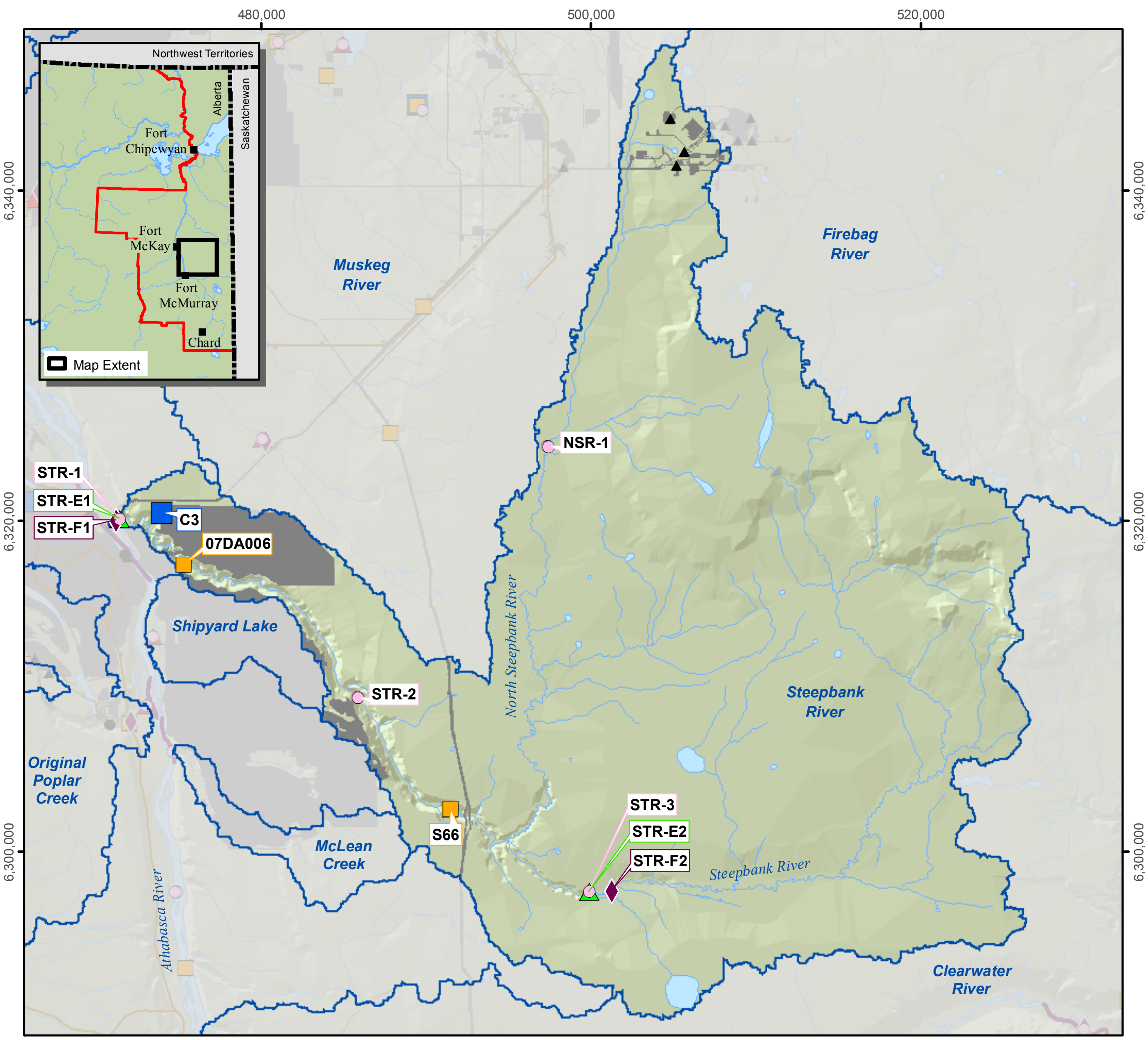
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.3-1 Steepbank River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach

0 2.5 5 10 km

N

Scale: 1:380,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.3-2 Representative monitoring stations of the Steepbank River watershed, fall 2014.

Water Quality Station STR-1: Left Downstream Bank

Benthic Invertebrate and Fish Assemblage Reach STR-E2/STR-F2: Centre Channel, facing upstream

Hydrology Station S66: facing downstream

Water Quality Station NSR-1: North Steepbank River, facing upstream.

5.3.1 Summary of 2014 Conditions

Approximately 4% (5,451 ha) of the Steepbank River watershed had undergone land change as of 2014 from oil sands development (Table 2.3-1); much of this land change is concentrated in the lower portion of the watershed. The designations of specific areas of the watershed for 2014 are as follows:

1. The Steepbank River watershed downstream of the Suncor oil sands developments, including the North Steepbank River, is designated as *test* (Figure 5.3-1).
2. The remainder of the watershed is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Populations components in the Steepbank River watershed in 2014. Table 5.3-1 is a summary of the 2014 assessment for the Steepbank River watershed, while Figure 5.3-1 is a detailed map of the Steepbank River watershed, indicating the location of the monitoring stations for each component, reported water withdrawal and discharge locations, and the area of land change as of 2014. Figure 5.3-2 contains photos of representative monitoring stations in the watershed taken in fall 2014.

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.33%, 0.34%, 0.34%, and 0.01% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of most water quality measurement endpoints in the Steepbank River watershed in fall 2014 were within previously-measured concentrations, with the exception of many ions at *test* station STR-2, which showed concentrations higher than previously measured in fall 2014. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2014 was similar to previous years. Concentrations of water quality measurement endpoints were also generally within the range of regional *baseline* conditions. Differences in water quality in fall 2014 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed, with the exception of *test* station STR-1, which was classified as **Moderate** due to exceedances of concentrations of total metals, ions, and physical variables from the 95th percentile of the regional *baseline* conditions.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* station STR-2. Typically the maximum concentration of ions was reached in April, while the minimum concentrations were reached in June. Despite the observed changes in ion concentrations from previous years in fall, the ionic composition remained consistent throughout the year.

Benthic Invertebrate Communities Differences in measurement endpoints of the benthic invertebrate community at *test* reach STR-E1 were classified as **Moderate** because abundance, richness, CA Axis 1 and 2 scores, and the percentage of EPT taxa were significantly lower than *baseline* reach STR-E2. The benthic invertebrate community at *test* reach STR-E1; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach and generally good water quality conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at *test* reach STR-F1 were classified as **High** given that three of the five measurement endpoints (abundance, richness, and catch per unit effort [CPUE]) significantly decreased over time and CPUE and abundance were lower than the range of regional *baseline* variability, indicating a potential negative change to the fish assemblage.

5.3.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Steepbank River watershed in the 2014 WY was conducted at WSC Station 07DA006 (formerly JOSMP Station S38), Steepbank River near Fort McMurray and JOSMP Station S66, Steepbank River below North Steepbank River. The data from the WSC Station were used for the water balance analysis presented below. Details for each of these stations can be found in Appendix C.

Seasonal data from March to October have been collected every year at WSC Station 07DA006 (JOSMP Station S38) since 1974, with some data for 1972 and 1973. Continuous annual hydrometric data have been collected from 1974 to 1986 and from 2009 to 2014.

The historical flow record for WSC Station 07DA006 (JOSMP Station S38) is summarized in Figure 5.3-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Steepbank River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in late March and April. Monthly flows are highest during May, at the peak of freshet, and remain elevated in June and July when total monthly rainfall are highest (Figure 4.2-2). Flows then generally recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

In the 2014 WY, flows were similar to the historical seasonal pattern described above (Figure 5.3-3). Flows generally decreased from November to early January, but then fluctuated until early March, occasionally exceeding the range of previously-recorded flows during this period. Flows rapidly increased in late April due to spring thaw, and again following rainfall accumulations in late May. The peak annual flow of 66 m^3/s occurred on June 4 and was 84% higher than the historical mean annual maximum flow (36 m^3/s). Flows then decreased following this peak until the lowest open-water daily flow of 0.97 m^3/s on August 29. This value was 42% lower than the historical mean open-water minimum daily flow. Flows then increased after mid-September, and remained near the historical median for the remainder of the water year.

Overall, the annual runoff volume in the 2014 WY was 200 million m^3. This was 27% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Steepbank River watershed at WSC Station 07DA006 (JOSMP Station S38) is summarized in Table 5.3-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2014 in the Steepbank River watershed was estimated to be 5.4 km^2 (Table 2.3-1). The loss of flow to the Steepbank River that would have otherwise occurred from this land area was estimated at 0.814 million m^3.

3. As of 2014, the area of land change in the Steepbank River watershed that was not closed-circuited was estimated to be 49.1 km^2 (Table 2.3-1). The increase in flow to the Steepbank River that would not have otherwise occurred from this land area was estimated at 1.487 million m^3.

4. In the 2014 WY, Suncor Firebag withdrew approximately 0.015 million m^3 (14,576 m^3) of water from three locations in the Steepbank River watershed to support dust control activities.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was an increase in flow of 0.658 million m^3 at WSC Station 07DA006 (JOSMP Station S38). The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.33%, 0.34%, 0.34%, and 0.01% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.3-3). These differences were classified as **Negligible-Low** (Table 5.3-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.3.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Steepbank River near its mouth (*test* station STR-1), sampled from 1997 to 2014;
- the Steepbank River downstream of the confluence with the North Steepbank River (*test* station STR-2), designated as *baseline* from 2002 to 2007 and *test* from 2008 to 2014;
- the Steepbank River upstream of the confluence with the North Steepbank River (*baseline* station STR-3), sampled from 2004 to 2014; and
- the North Steepbank River (*test* station NSR-1), designated as *baseline* from 2002 to 2008 and *test* from 2009 to 2014.

In addition to fall water quality sampling, *test* station STR-1 was sampled in winter (March) 2014 and *test* station STR-2 was sampled monthly beginning in April 2014.

Temporal Trends The following significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- A decreasing concentration of chloride at *test* station STR-2;
- Decreasing concentrations of chloride and sulphate at *baseline* station STR-3; and
- A decreasing concentration of sulphate and an increasing concentration of total arsenic at *test* station NSR-1.

2014 Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2014 had similar concentrations to historical results, with the following exceptions (Table 5.3-4 to Table 5.3-7):

- Sulphate, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station STR-1;
- Total nitrogen, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station STR-2 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- pH, total suspended solids, conductivity, sodium, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, total strontium, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station STR-2;

- Naphthenic acids and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station STR-3;

- Retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station STR-3;

- Naphthenic acids, with a concentration that exceeded the previously-measured maximum concentration at *test* station NSR-1; and

- Total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station NSR-1.

Ion Balance In fall 2014, the ionic composition of all stations in the Steepbank River watershed was dominated by calcium and bicarbonate ions. The North Steepbank River (*test* station NSR-1) was slightly more calcium dominated than the Steepbank River stations. The ion balance for all stations in 2014 was comparable with previous years (Figure 5.3-4).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints measured in the Steepbank River in fall 2014 were below water quality guidelines, with the exception of total aluminum at *test* stations STR-1 and STR-2 (Table 5.3-8).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Steepbank River watershed in fall 2014 (Table 5.3-8):

- Total iron at *test* stations STR-1, STR-2, and NSR-1, and *baseline* station STR-3;

- Total chromium and total phenols at *test* stations STR-1;

- Dissolved iron at *test* stations STR-2 and NSR-1, and *baseline* station STR-3;

- Sulphide at *baseline* station STR-3; and

- Total phenols at *test* station NSR-1.

In addition, concentrations of total aluminum and total iron exceeded water quality guidelines at *test* station STR-1 during the winter sampling period (Table 5.3-8).

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints in fall 2014 at *test* stations STR-1, STR-2, and NSR-1 and *baseline* station STR-3 were within regional *baseline* concentrations, with the following exceptions (Figure 5.3-5):

- Sodium, with a concentration that exceeded the 95th percentile of the regional *baseline* at *test* station STR- 1;

- Total dissolved solids, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-2;

- Total boron and calcium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations STR-1 and STR-2;

- Total strontium, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station NSR-1; and

- Sulphate, with a concentration below the 5th percentile of regional *baseline* concentrations at *test* station NSR-1.

Water Quality Index The WQI values for all stations in the Steepbank River watershed indicated **Negligible-Low** differences from regional *baseline* conditions in fall 2014, with the exception of *test* station STR-1. *Test* station STR-1 indicated a **Moderate** difference from regional *baseline* conditions, with a WQI value of 75.9. The **Moderate** difference at *test* station STR-1 was the result of exceedances of concentrations of total metals, ions, and physical variables from the 95th percentile of regional *baseline* conditions. WQI values for the remaining stations ranged from 83.6 (*test* station STR-2) to 98.7 (*baseline* station STR-3) (Table 5.3-9).

Monthly Water Quality Results Water quality samples were collected on a monthly basis at *test* station STR-2 beginning in April 2014. All monthly results for 2014 are summarized in Table 5.3-10.

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances at *test* station STR-2 in 2014 included (Table 5.3-11):

- total phenols in May and June;

- sulphide from May to August and October to December;

- total aluminum from April to July and September;

- total iron from April to December, and dissolved iron in May and from July to December; and

- total chromium and total mercury (ultra-trace) in June.

2014 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2014, monthly water quality data collected at *test* station STR-2 were within the range of the regional *baseline* concentrations observed in fall (Figure 5.3-6), with the exception of:

- total suspended solids in June, with a concentration that exceeded the 95th percentile of fall regional *baseline* concentrations;

- total dissolved solids, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations in April, September and December, and was below the 5th percentile in June;

- total strontium, with concentrations that exceeded the 95th percentile in April and December, and were below the 5th percentile of fall regional *baseline* concentrations in May and June;

- total boron, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations in April, September, and December;

- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile in May and June, and was below the 5th percentile of the fall regional *baseline* concentrations in December;

- calcium, with concentrations that exceeded the 95th percentile in April, September and December, and was below the 5th percentile in June of fall regional *baseline* concentrations;

- magnesium, with concentrations that exceeded the 95th percentile in April and were below the 5th percentile of the fall regional *baseline* concentrations in May and June;

- sodium, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations in April and December;

- pH, with levels below the 5th percentile in May and June and that exceeded the 95th percentile of the fall regional *baseline* concentrations in September; and

- total alkalinity and hardness with concentrations that exceeded the 95th percentile in April, September, and December, and were below the 5th percentile of the fall regional *baseline* concentrations in June.

Monthly Ion Balance In 2014, the ionic composition of *test* station STR-2 was dominated by bicarbonate and calcium ions and remained consistent throughout the year (Figure 5.3-7).

Classification of Results Concentrations of most water quality measurement endpoints in the Steepbank River watershed in fall 2014 were within previously-measured concentrations, with the exception of many ions at *test* station STR-2, which showed concentrations higher than previously measured in fall 2014. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2014 was similar to previous years. Concentrations of water quality measurement endpoints were also generally within the range of regional *baseline* conditions. Differences in water quality in fall 2014 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed, with the exception of *test* station STR-1, which was classified as **Moderate** due to exceedances of concentrations of total metals, ions, and physical variables from the 95th percentile of the regional *baseline* conditions.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* station STR-2. Typically the maximum concentration of ions was reached in April, while the minimum concentrations were reached in June. Despite the observed changes in ion concentrations from previous years in fall, the ionic composition remained consistent throughout the year.

5.3.4 Benthic Invertebrate Communities and Sediment Quality

5.3.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- erosional *test* reach (STR-E1), sampled since 1998; and

- erosional *baseline* reach (STR-E2), sampled since 2004.

2014 Habitat Conditions Water at *test* reach STR-E1 in fall 2014 was shallow (0.22 m in sampled areas) with moderate velocity (0.92 m/s), a pH of 7.6, moderate conductivity (371 µS/cm), and high dissolved oxygen (9.4 mg/L) (Table 5.3-12). The substrate at *test* reach MAR-E2 was dominated by small (25%) and large (36%) cobble. Periphyton chlorophyll *a* biomass at *test* reach STR-E1 averaged 31.2 mg/m^2, which was within the normal range of regional *baseline* variability (Figure 5.3-8).

Water at *baseline* reach STR-E2 was shallow (0.24 m in sampled areas), with relatively fast velocity (0.8 m/s), a pH of 7.7, moderate conductivity (270 µS/cm) and high dissolved oxygen (10.4 mg/L) (Table 5.3-12). The substrate was dominated by small cobble (28%) and large gravel (29%). Periphyton chlorophyll *a* biomass at *baseline* reach STR-E2 averaged 57.4 mg/m^2, which was within the normal range of regional *baseline* variability (Figure 5.3-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach STR-E1 was dominated by Ephemeroptera (41%) and chironomids (29%) with subdominant taxa consisting of naidid worms (17%) (Table 5.3-13). Chironomids included *Rheotanytarsus*, *Cricotopus*/*Orthocladius*, *Synorthocladius*, and *Polypedilum*, as well as other forms that are more restricted to clean cold water such as *Tvetenia* (Mandeville 2001). Ephemeroptera were diverse with 11 kinds and included the widely distributed *Baetis*, as well as *Ephemerella*, *Rhithrogena*, *Heptagenia*, and *Acentrella*. Bivalves and gastropods were absent at the lower test reach of the Steepbank River in 2014; however, other sensitive taxa such as stoneflies (*Isoperla*, *Skwala*, *Zapada*), caddisflies (*Hydropsyche*, *Lepidostoma*, and *Myatrichia*), and dragonflies (*Ophiogomphus*) were present.

The benthic invertebrate community at *baseline* reach STR-E2 was dominated by Ephemeroptera (32%), Trichoptera (28%), and Chironomidae (26%) with subdominant taxa consisting of Hydracarina (5%) and Plecoptera (3%) (Table 5.3-14). Mayflies were diverse with nine types, the most abundant of which were the ubiquitous *Baetis* and *Acerpenna pygmaea* and the sensitive *Ephemerella*. Trichoptera were also diverse and included *Hydropsyche*, *Lepidostoma*, *Psychomia*, *Micrasema*, and *Brachycentrus*. Other flying insects were present in lower relative abundances (Plecoptera: *Zapada*, *Claassenia sabulosa*, *Pteronarcys* and Anisoptera: *Ophiogomphus*). Chironomids were primarily comprised of *Rheotanytarsus*, *Tvetenia*, *Micropsectra*/*Tanytarsus*, *Cricotopus*/*Orthocladius*, and *Thienemannimyia* gr. Permanent aquatic forms such as gastropods (*Ferrissia rivularis* and *Gyraulus*) and *Pisidium*/*Sphaerium* bivalves were also present at *baseline* reach STR-E2 in 2014.

Temporal and Spatial Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the Steepbank River watershed. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

The spatial and temporal comparisons of measurement endpoints included testing for:

- A difference in mean values between the upper *baseline* and lower *test* reaches;
- Changes over time at the lower *test* reach (1998 to 2014) (Hypothesis 1, Section 3.2.3.1);
- Differences between 2014 values and the mean of all previous years of sampling (1998 to 2013) for the lower *test* reach;

- Changes over time between the upper and lower reaches from 2004 to 2014 (Hypothesis 2, Section 3.2.3.1); and
- Difference between 2014 values for the lower *test* reach and the mean of all *baseline* years (2004 to 2014) from the upper reach.

Abundance and richness were significantly lower at *test* reach STR-E1 compared to *baseline* reach STR-E2, accounting for 32% and 25% of the variance in annual means, respectively (Table 5.3-15).

The percentage of EPT taxa was significantly lower at *test* reach STR-E1 accounting for 33% of the variance in annual means (Table 5.3-15).

CA Axis 1 scores increased over time at *test* reach STR-E1 accounting for 26% of the variance in annual means and CA Axis 2 scores were significantly lower at the *test* reach compared to the *baseline* reach accounting for 48% of the variation in annual means (Table 5.3-15). The benthic invertebrate community composition was different between the upper and lower reaches of the Steepbank River, which resulted in the difference in CA Axis scores (Figure 5.3-9). *Test* reach STR-E1 had a higher relative abundances of tubificid worms and the *baseline* reach STR-E1 typically had a higher relative abundance of EPT taxa (Figure 5.3-10).

Comparison to Published Literature The benthic invertebrate community at *test* reach STR-E1 was diverse with a mean of 30 taxa per sample, and contained genera that require colder and cleaner water such as the chironomid *Tvetenia* and the mayfly *Ephemerella* (Mandeville 2001). Mayflies were diverse and abundant at the lower reach as well as larvae of other flying insects in lower relative abundances. The presence of these taxa at the *test* reach (STR-E1) indicated good overall water quality.

The benthic invertebrate community at *baseline* reach STR-E2 was diverse and contained a benthic fauna that reflected high water and substrate quality. The percentage of the community as worms was low (~5%), while chironomids accounted for 26% of the fauna. The percentage of the fauna as EPT taxa was higher than previously documented (64%), indicating the presence of a robust community, reflecting high water and sediment quality (Hynes 1960; Griffiths 1998).

2014 Results Relative to Historical Conditions Given there are more than eight years of data for the lower test reach, values of all measurement endpoints in 2014 were compared to the range of variability for all previous years. Values of all measurement endpoints for the lower *test* reach were within the inner tolerance limits of the normal range of variation for this reach (Figure 5.3-9 and Figure 5.3-10).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* reach STR-E1 were classified as **Moderate** because abundance, richness, CA Axis 1 and 2 scores, and the percentage of EPT taxa were significantly lower than *baseline* reach STR-E2. The benthic invertebrate community at *test* reach STR-E1; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach and generally good water quality conditions.

5.3.4.2 Sediment Quality

No sediment quality sampling was conducted in the Steepbank River in 2014. Sediment quality is only sampled in combination with benthic community samples at depositional reaches, and all reaches of the Steepbank River were erosional.

5.3.5 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- *test* reach STR-F1, near the mouth of the Steepbank River, sampled since 2009 (this reach is in the same location as benthic invertebrate community *test* reach STR-E1); and
- *baseline* reach STR-F2, sampled since 2011 (this reach is in the same location as benthic invertebrate community *baseline* reach STR-E2).

2014 Habitat Conditions *Test* reach STR-F1 was comprised of run and riffle habitat with a wetted width of 11.9 m and a bankfull width of 25.4 m. The substrate consisted of coarse gravel with embedded fine material. Water at *test* reach STR-F1 had a mean depth of 0.47 m, with moderate velocity (mean=0.48 m/s), a pH of 5.86, moderate conductivity (345 µS/cm), high dissolved oxygen (9.1 mg/L), and a temperature of 9.2ºC. Instream cover consisted primarily of small woody debris and algae with small amounts of macrophytes, boulders, and large woody debris (Table 5.3-16).

Baseline reach STR-F2 was comprised of riffle and run habitat, with a wetted width of 15.0 m and a bankfull width of 17.7 m. The substrate consisted of cobble with small proportions of fine material. Water at *baseline* reach STR-F2 had a mean depth of 0.98 m, with slow velocity (mean=0.16 m/s), a pH of 8.27, moderate conductivity (295 µS/cm), high dissolved oxygen (11.4 mg/L), and a temperature of 4.5˚C. Instream cover consisted primarily of boulders with some small woody debris (Table 5.3-16).

Relative Abundance of Fish Species The total catch of fish species at *test* reach STR-F1 increased slightly from 2013 and was dominated by slimy sculpin (59%) with burbot as the subdominant species (Table 5.3-17). The total catch of fish species at *baseline* reach STR-F2 increased in 2014 compared to 2013, but exhibited a similar species composition. The fish assemblage at *baseline* reach STR-F2 was dominated by slimy sculpin (50%) (Table 5.3-17).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach STR-F1 included testing for changes over time (2009 to 2014, Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach STR-F1 included testing for differences from *baseline* reach STR-F2 over time (Hypothesis 2, Section 3.2.4.4).

There were significant decreases over time in abundance ($p<0.001$), richness ($p=0.01$), assemblage tolerance index (ATI) ($p=0.002$), and total CPUE ($p<0.001$) at *test* reach STR-F1, explaining greater than 21% in the variance of annual means (Table 5.3-18, Table 5.3-19). The decrease in the ATI value was a result of the dominance of burbot and slimy sculpin in the fish assemblage, which are both considered sensitive species (Whittier et al. 2007). There were no significant differences between *test* reach STR-F1 and *baseline* reach STR-F2 (Table 5.3-19).

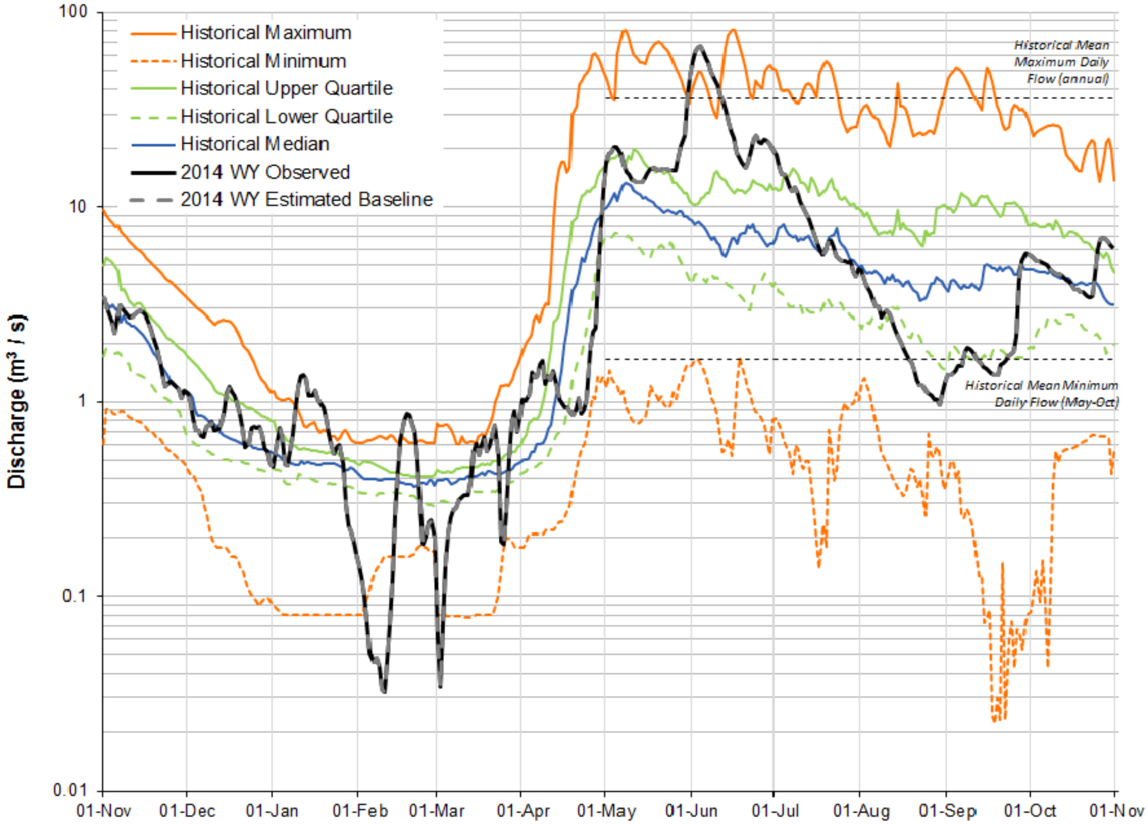
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of 24 fish species were recorded in the Steepbank River; whereas JOSMP found only 16 species from 2009 to 2014. Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., JOSMP sampled a smaller, defined reach length relative to multiple locations/reaches documented in Golder [2004]).

Habitat conditions documented in Golder (2004) were different than what has been observed by JOSMP from 2009 to 2014. Historically, habitat conditions in the lower Steepbank River were poor due to beaver activity, low habitat heterogeneity and predominance of fine substrate (Golder 2004). In more recent years, including 2014, JOSMP has documented habitat conditions at *test* reach STR-F1 consisting of riffles and runs, with an increasing amount of embedded substrate over time and run and riffle habitat with cobble and smaller proportions of small boulders at *baseline* reach STR-F2. Beaver impoundments have not been documented during fish assemblage monitoring by JOSMP in the Steepbank River.

2014 Results Relative to Regional *Baseline* Conditions With the exception of CPUE and abundance, mean values of all measurement endpoints in 2014 at *test* reach STR-F1 were within the inner tolerance limits for the normal range of *baseline* conditions (Figure 5.3-11). Mean CPUE and abundance were near the outer tolerance limit of the 5^{th} percentile in 2014.

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach STR-F1 were classified as **High** given that three of the five measurement endpoints (abundance, richness, and CPUE) significantly decreased over time and CPUE and abundance were lower than the range of regional *baseline* variability, indicating a potential negative change to the fish assemblage.

Figure 5.3-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Steepbank River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Steepbank River near Fort McMurray, WSC Station 07DA006 (JOSMP Station S38) provisional data. The upstream drainage area is 1,320 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1972 to 2013, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1986 and from 2009 to 2013.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.3-2 Estimated water balance at WSC Station 07DA006 (formerly JOSMP Station S38), Steepbank River near Fort McMurray, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**200.476**	**Observed discharge from Steepbank River near Fort McMurray, WSC Station 07DA006 (formerly JOSMP Station S38)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.814	Estimated 5.4 km^2 of the Steepbank River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	+1.487	Estimated 49.1 km^2 of the Steepbank River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Steepbank River watershed, relative to the estimated *baseline* hydrograph	-0.015	Water withdrawals by Suncor Firebag (daily values provided)
Water releases into the Steepbank River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**199.817**	**Estimated *baseline* discharge at Steepbank River near Fort McMurray, WSC Station 07DA006 (formerly JOSMP Station S38)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	+0.658	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**0.330**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Table 5.3-3 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed, 2014 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	11.518	11.556	0.330%
Mean winter discharge	0.893	0.896	0.340%
Annual maximum daily discharge	65.778	66.000	0.340%
Open-water season minimum daily discharge	0.968	0.968	0.020%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data from WSC Station 07DA006.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.3-4 Concentrations of water quality measurement endpoints in the Steepbank River (*test* station STR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.36	16	7.70	8.20	8.60
Total suspended solids	mg/L	-	3.4	16	<3.0	8.0	60.0
Conductivity	µS/cm	-	374	16	141	222	516
Nutrients							
Total dissolved phosphorus	mg/L	-	0.010	16	0.006	0.020	0.039
Total nitrogen	mg/L	-	0.504	16	0.250	0.850	2.40
Nitrate+nitrite	mg/L	3	<0.054	16	<0.050	<0.086	<0.100
Dissolved organic carbon	mg/L	-	19.4	16	10.0	22.8	30.0
Ions							
Sodium	mg/L	-	29.1	16	6.00	10.5	38.0
Calcium	mg/L	-	47.4	16	17.2	28.8	50.3
Magnesium	mg/L	-	14.1	16	5.40	8.45	16.2
Chloride	mg/L	120	5.58	16	<0.70	2.00	8.40
Sulphate	mg/L	309	<u>18.4</u>	16	2.45	4.65	12.3
Total dissolved solids	mg/L	-	218	16	120	181	320
Total alkalinity	mg/L	-	193	16	63.0	113	263
Selected metals							
Total aluminum	mg/L	0.1	**0.952**	16	0.040	**0.176**	**2.79**
Dissolved aluminum	mg/L	0.05	0.0077	16	<0.0044	0.0142	**0.0987**
Total arsenic	mg/L	0.005	0.0008	16	<0.0005	0.0008	0.0013
Total boron	mg/L	1.2	0.164	16	0.025	0.054	0.200
Total molybdenum	mg/L	0.073	0.00043	16	0.00015	0.00022	0.00050
Total mercury (ultra-trace)	ng/L	5, 13	2.28	11	<1.20	<1.40	5.00
Total strontium	mg/L	-	0.174	16	0.063	0.108	0.252
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.88</u>	3	0.19	0.26	0.60
Oilsands Extractable	mg/L	-	<u>2.20</u>	3	0.52	1.08	1.27
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<14.13	<15.16
Retene	ng/L	-	7.30	3	1.540	9.42	53.70
Total dibenzothiophenes	ng/L	-	413.1	3	89.17	114.1	1,678
Total PAHs	ng/L	-	1,176	3	325.4	529.8	4,775
Total Parent PAHs	ng/L	-	35.39	3	27.69	32.26	97.42
Total Alkylated PAHs	ng/L	-	1,140	3	297.7	497.5	4,677
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total chromium	mg/L	0.001	**0.0014**	16	0.0003	0.0007	**0.0083**
Total iron	mg/L	0.3	**1.28**	16	**0.470**	**0.925**	**2.48**
Total phenols	mg/L	0.004	**0.0043**	16	<0.001	**0.0065**	**0.0130**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.3-5 Concentrations of water quality measurement endpoints in the Steepbank River (*test* station STR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.47	12	7.80	8.11	8.42
Total suspended solids	mg/L	-	29.1	12	<3.0	4.5	28.0
Conductivity	µS/cm	-	436	12	121	196	329
Nutrients							
Total dissolved phosphorus	mg/L	-	0.018	12	0.014	0.026	0.048
Total nitrogen	mg/L	-	0.494	12	0.600	0.800	1.99
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	0.100
Dissolved organic carbon	mg/L	-	19.8	12	14.0	24.0	30.1
Ions							
Sodium	mg/L	-	20.6	12	5.00	8.55	18.5
Calcium	mg/L	-	45.3	12	16.8	26.0	41.4
Magnesium	mg/L	-	12.7	12	5.30	7.77	11.6
Chloride	mg/L	120	1.12	12	<0.50	1.00	3.00
Sulphate	mg/L	309	11.5	12	<0.50	2.75	5.50
Total dissolved solids	mg/L	-	292	12	139	168	249
Total alkalinity	mg/L	-	201	12	61.0	101	178
Selected metals							
Total aluminum	mg/L	0.1	**0.250**	12	0.018	**0.123**	**0.536**
Dissolved aluminum	mg/L	0.05	0.0038	12	0.0023	0.0137	0.0294
Total arsenic	mg/L	0.005	0.00063	12	0.00050	0.00069	0.00091
Total boron	mg/L	1.2	0.150	12	0.023	0.051	0.157
Total molybdenum	mg/L	0.073	0.00029	12	0.00010	0.00017	0.00032
Total mercury (ultra-trace)	ng/L	5, 13	1.34	11	0.60	1.40	3.40
Total strontium	mg/L	-	0.174	12	0.053	0.098	0.167
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.51	3	0.15	0.18	0.19
Oilsands Extractable	mg/L	-	1.70	3	0.31	0.67	1.14
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.756	<14.13	<15.16
Retene	ng/L	-	0.725	3	1.300	3.990	27.50
Total dibenzothiophenes	ng/L	-	4.134	3	6.372	7.060	35.60
Total PAHs	ng/L	-	75.26	3	103.3	188.0	221.9
Total Parent PAHs	ng/L	-	13.49	3	16.61	20.63	22.59
Total Alkylated PAHs	ng/L	-	61.78	3	80.74	167.4	205.3
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.397**	12	0.273	**0.470**	**0.846**
Total iron	mg/L	0.3	**0.878**	12	**0.733**	**0.825**	**1.40**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.3-6 Concentrations of water quality measurement endpoints in the Steepbank River (*baseline* station STR-3), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.34	10	7.88	8.16	8.46
Total suspended solids	mg/L	-	<3.0	10	<3.0	<3.0	15
Conductivity	µS/cm	-	304	10	128	253	357
Nutrients							
Total dissolved phosphorus	mg/L	-	0.039	10	0.024	0.040	0.070
Total nitrogen	mg/L	-	0.664	10	0.571	0.750	1.85
Nitrate+nitrite	mg/L	3	<0.054	10	<0.071	<0.086	<0.100
Dissolved organic carbon	mg/L	-	21.1	10	14.0	22.9	32.4
Ions							
Sodium	mg/L	-	16.1	10	5.40	13.0	22.8
Calcium	mg/L	-	37.7	10	17.1	34.0	45.4
Magnesium	mg/L	-	10.6	10	5.24	10.10	13.2
Chloride	mg/L	120	<0.50	10	<0.50	0.84	2.00
Sulphate	mg/L	309	1.39	10	0.83	1.99	3.40
Total dissolved solids	mg/L	-	225	10	140	193	247
Total alkalinity	mg/L	-	161	10	63.6	143	194
Selected metals							
Total aluminum	mg/L	0.1	0.026	10	0.015	0.040	**0.240**
Dissolved aluminum	mg/L	0.05	0.006	10	0.004	0.011	0.030
Total arsenic	mg/L	0.005	0.00062	10	0.00046	0.00067	0.00083
Total boron	mg/L	1.2	0.100	10	0.025	0.065	0.134
Total molybdenum	mg/L	0.073	0.00021	10	0.00014	0.00019	0.00032
Total mercury (ultra-trace)	ng/L	5, 13	1.10	10	0.60	1.20	3.50
Total strontium	mg/L	-	0.134	10	0.057	0.108	0.158
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.85</u>	3	0.03	0.26	0.28
Oilsands Extractable	mg/L	-	<u>1.80</u>	3	0.25	0.84	1.12
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<14.13	<15.16
Retene	ng/L	-	<u>2.290</u>	3	2.590	3.500	12.20
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	5.936	6.672	35.30
Total PAHs	ng/L	-	<u>77.36</u>	3	106.3	171.7	217.0
Total Parent PAHs	ng/L	-	<u>13.69</u>	3	16.41	19.98	22.96
Total Alkylated PAHs	ng/L	-	<u>63.66</u>	3	83.32	151.7	200.6
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.584**	10	**0.336**	**0.572**	**0.975**
Sulphide	mg/L	0.002	**<u>0.0022</u>**	10	**0.0031**	**0.0052**	**0.0110**
Total iron	mg/L	0.3	**1.00**	10	**0.698**	**0.934**	**1.41**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.3-7 Concentrations of water quality measurement endpoints in the North Steepbank River (*test* station NSR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.37	12	7.50	8.00	8.42
Total suspended solids	mg/L	-	<3.0	12	<3.0	<3.0	20.0
Conductivity	µS/cm	-	295	12	110	164	311
Nutrients							
Total dissolved phosphorus	mg/L	-	0.037	12	0.015	0.024	0.050
Total nitrogen	mg/L	-	0.594	12	0.400	0.700	1.27
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	0.403
Dissolved organic carbon	mg/L	-	18.3	12	13.0	20.0	23.1
Ions							
Sodium	mg/L	-	5.20	12	2.00	3.00	6.10
Calcium	mg/L	-	42.2	12	16.5	23.2	42.9
Magnesium	mg/L	-	11.0	12	4.90	6.60	12.5
Chloride	mg/L	120	0.55	12	<0.50	1.00	4.79
Sulphate	mg/L	309	<0.50	12	<0.50	<1.05	<6.50
Total dissolved solids	mg/L	-	202	12	102	145	219
Total alkalinity	mg/L	-	158	12	55.0	84.0	169
Selected metals							
Total aluminum	mg/L	0.1	0.021	12	0.018	0.052	**0.241**
Dissolved aluminum	mg/L	0.05	0.0041	12	0.0030	0.0106	0.0148
Total arsenic	mg/L	0.005	0.0013	12	0.0005	0.0009	0.0014
Total boron	mg/L	1.2	0.037	12	0.010	0.015	0.050
Total molybdenum	mg/L	0.073	0.00073	12	0.00013	0.00020	0.00080
Total mercury (ultra-trace)	ng/L	5, 13	0.90	11	<0.60	<1.20	3.30
Total strontium	mg/L	-	0.186	12	0.049	0.084	0.245
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.51</u>	3	0.25	0.25	0.27
Oilsands Extractable	mg/L	-	0.50	3	0.24	0.89	1.11
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.756	<14.13	<15.16
Retene	ng/L	-	<0.407	3	<0.732	2.071	6.740
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	5.922	6.672	35.30
Total PAHs	ng/L	-	<u>74.10</u>	3	102.6	178.5	207.1
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	16.42	19.51	22.57
Total Alkylated PAHs	ng/L	-	<u>60.84</u>	3	80.05	159.0	190.7
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.65**	12	0.226	**0.524**	**1.08**
Total iron	mg/L	0.3	**1.28**	12	**0.507**	**0.918**	**1.92**
Total phenols	mg/L	0.004	**0.005**	12	<0.001	**0.006**	**0.010**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Figure 5.3-4 Piper diagram of fall ion concentrations in the Steepbank River, fall 2014.

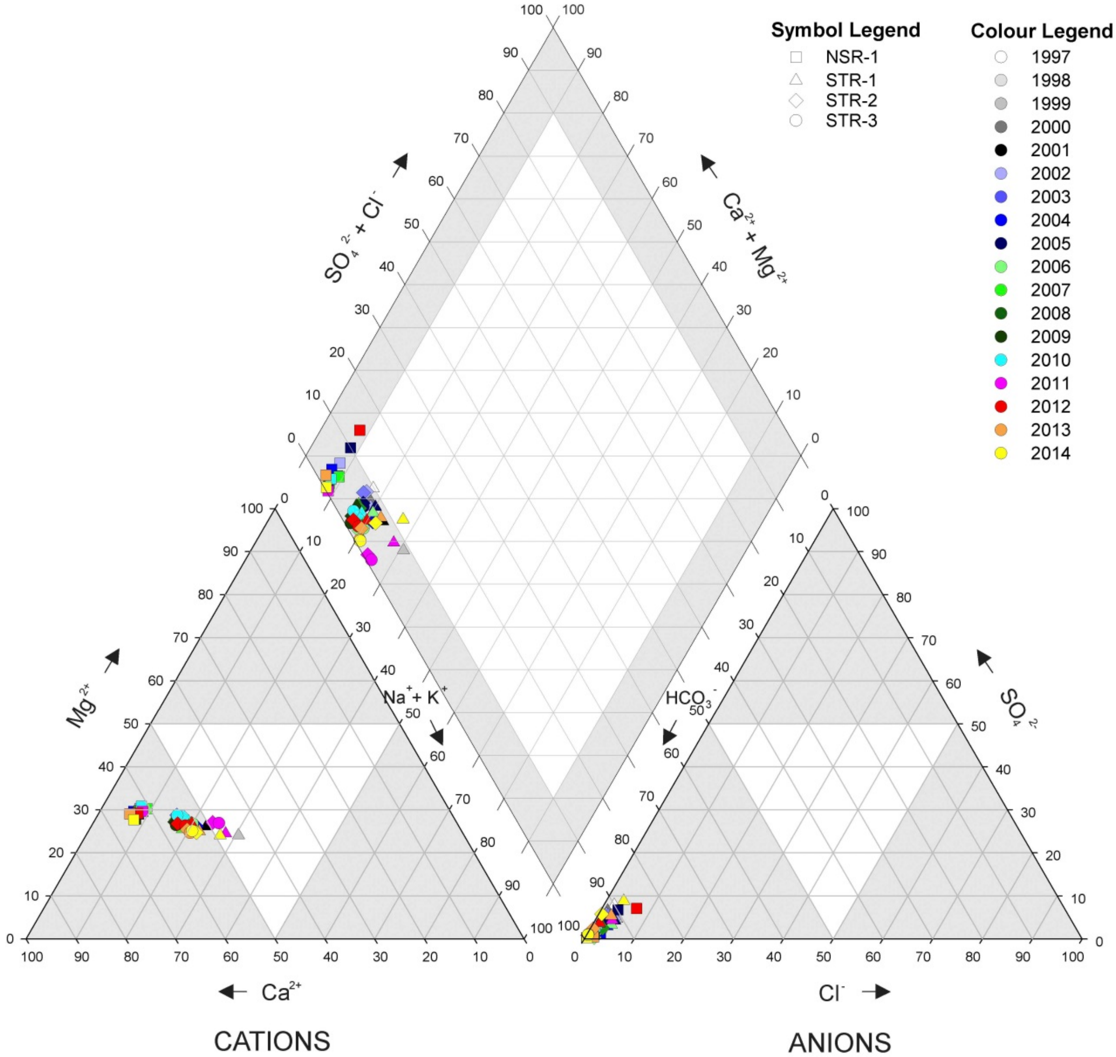


Table 5.3-8 Water quality guideline exceedances, Steepbank River watershed, fall 2014.

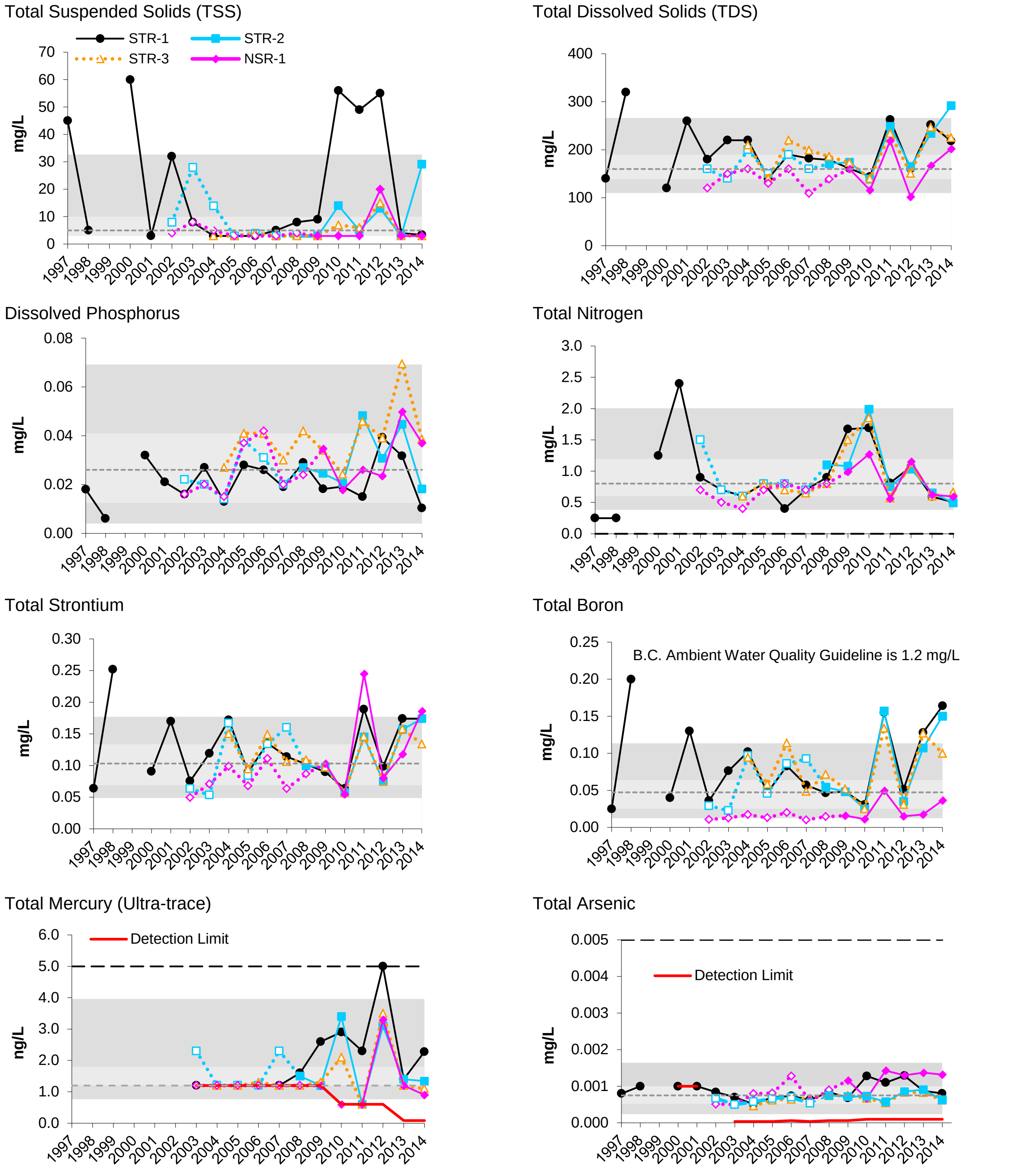
Variable	Units	Guideline[a]	STR-1	STR-2	STR-3	NSR-1
Winter						
Total aluminum	mg/L	0.1	0.115	ns	ns	ns
Total iron	mg/L	0.3	0.656	ns	ns	ns
Fall						
Dissolved iron	mg/L	0.3	-	0.397	0.584	0.654
Sulphide	mg/L	0.002	-	-	0.0022	-
Total aluminum	mg/L	0.1	0.952	0.250	-	-
Total chromium	mg/L	0.001	0.0014	-	-	-
Total iron	mg/L	0.3	1.28	0.878	1.00	1.28
Total phenols	mg/L	0.004	0.0043	-	-	0.0053

[a] Sources for all guidelines are outlined in Table 3.2-5.

Underline denotes baseline station.

ns=not sampled.

Figure 5.3-5 Concentrations of selected water quality measurement endpoints in the Steepbank River (fall data) relative to historical data and regional *baseline* fall concentrations.



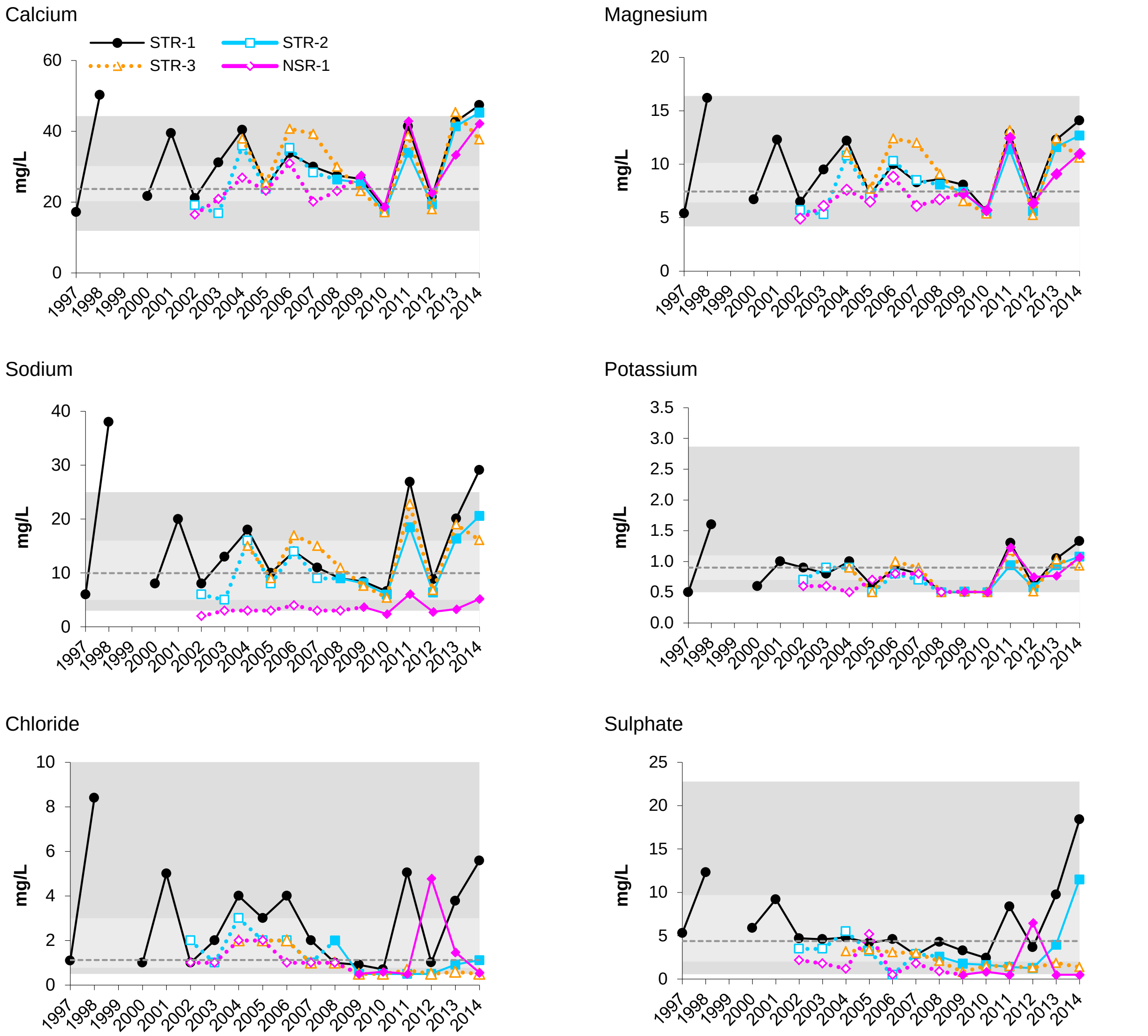
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.3-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.3-9 Water quality index (fall 2014) for Steepbank River watershed stations.

Station Identifier	Location	2014 Designation	Water Quality Index	Classification
NSR-1	North Steepbank River	*test*	95.0	Negligible-Low
STR-1	Lower Steepbank River	*test*	75.9	Moderate
STR-2	Upstream of Suncor Millennium Project	*test*	83.6	Negligible-Low
STR-3	Upstream of North Steepbank River	*baseline*	98.7	Negligible-Low

Note: see Section 3.2.2.3 for a description of the Water Quality Index.

Table 5.3-10 Monthly water quality measurement endpoints at the mouth of the Steepbank River (*test* station STR-1), April to December 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Data and Month of Occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	9	7.41	(May)	8.00	8.47	(September)
Total suspended solids	mg/L	-	9	9.4	(April)	22	26.9	(November)
Conductivity	µS/cm	-	9	85.3	(June)	272	610	(April)
Nutrients								
Total dissolved phosphorus	mg/L	-	9	0.017	(June)	0.030	0.038	(December)
Total nitrogen	mg/L	-	9	0.494	(September)	0.754	0.824	(August)
Nitrate+nitrite	mg/L	3	9	<0.054	(May-Nov)	<0.054	0.321	(April)
Dissolved organic carbon	mg/L	-	9	9.5	(April)	23.2	29.2	(July)
Ions								
Sodium	mg/L	-	9	3.5	(June)	13.7	40.3	(April)
Calcium	mg/L	-	9	11.0	(June)	34.2	67.7	(April)
Magnesium	mg/L	-	9	3.4	(June)	9.7	19.7	(April)
Chloride	mg/L	120	9	<0.5	(May-Jul)	0.74	2.43	(April)
Sulphate	mg/L	429	9	1.2	(July)	3.6	11.5	(September)
Total dissolved solids	mg/L	-	9	93	(June)	188	386	(April)
Total alkalinity	mg/L	-	9	41	(June)	142	355	(April)
Selected metals								
Total aluminum	mg/L	0.1	9	0.03	(November)	**0.25**	**3.54**	(June)
Dissolved aluminum	mg/L	0.05	9	0.001	(April)	0.008	0.040	(June)
Total arsenic	mg/L	0.005	9	0.0005	(October)	0.0006	0.0010	(June)
Total boron	mg/L	1.2	9	0.026	(June)	0.082	0.252	(April)
Total molybdenum	mg/L	0.073	9	0.00015	(June)	0.00027	0.003	(November)
Total mercury (ultra-trace)	ng/L	5, 13	9	0.61	(December)	1.56	**5.26**	(June)
Total strontium	mg/L	-	9	0.041	(June)	0.119	0.312	(April)
Total hydrocarbons								
BTEX	mg/L	-	9	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	9	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	9	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	9	<0.25	-	<0.25	0.43	(July)
Fraction 4 (C34-C50)	mg/L	-	9	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	9	<0.02	(December)	0.28	0.51	(September)
Oilsands Extractable	mg/L	-	9	0.32	(April)	1.00	3.2	(August)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	9	<7.21	-	<7.21	885	(April)
Retene	ng/L	-	9	0.7250	(September)	1.50	23.2	(June)
Total dibenzothiophenes	ng/L	-	9	4.13	-	5.51	33.18	(April)
Total PAHs	ng/L	-	9	75.3	(September)	80.5	2345.7	(April)
Total Parent PAHs	ng/L	-	9	13.30	(May)	13.67	925.6	(April)
Total Alkylated PAHs	ng/L	-	9	61.8	(September)	66	1420.1	(April)
Other variables that exceeded CCME/AESRD guidelines in 2014[1]								
Total phenols	mg/L	0.004	2	<0.001	(December)	0.004	**0.011**	(May)
Sulphide	mg/L	0.002	7	<0.002	(September)	**0.003**	**0.007**	(July)
Total iron	mg/L	0.3	9	**0.612**	(October)	**0.891**	**2.510**	(June)
Dissolved iron	mg/L	0.3	7	<0.004	(April)	**0.433**	**0.76**	(December)
Total chromium	mg/L	0.001	1	0.0001	(November)	0.0003	**0.0027**	(June)

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

[1] n value refers to number of exceedances in 2014.

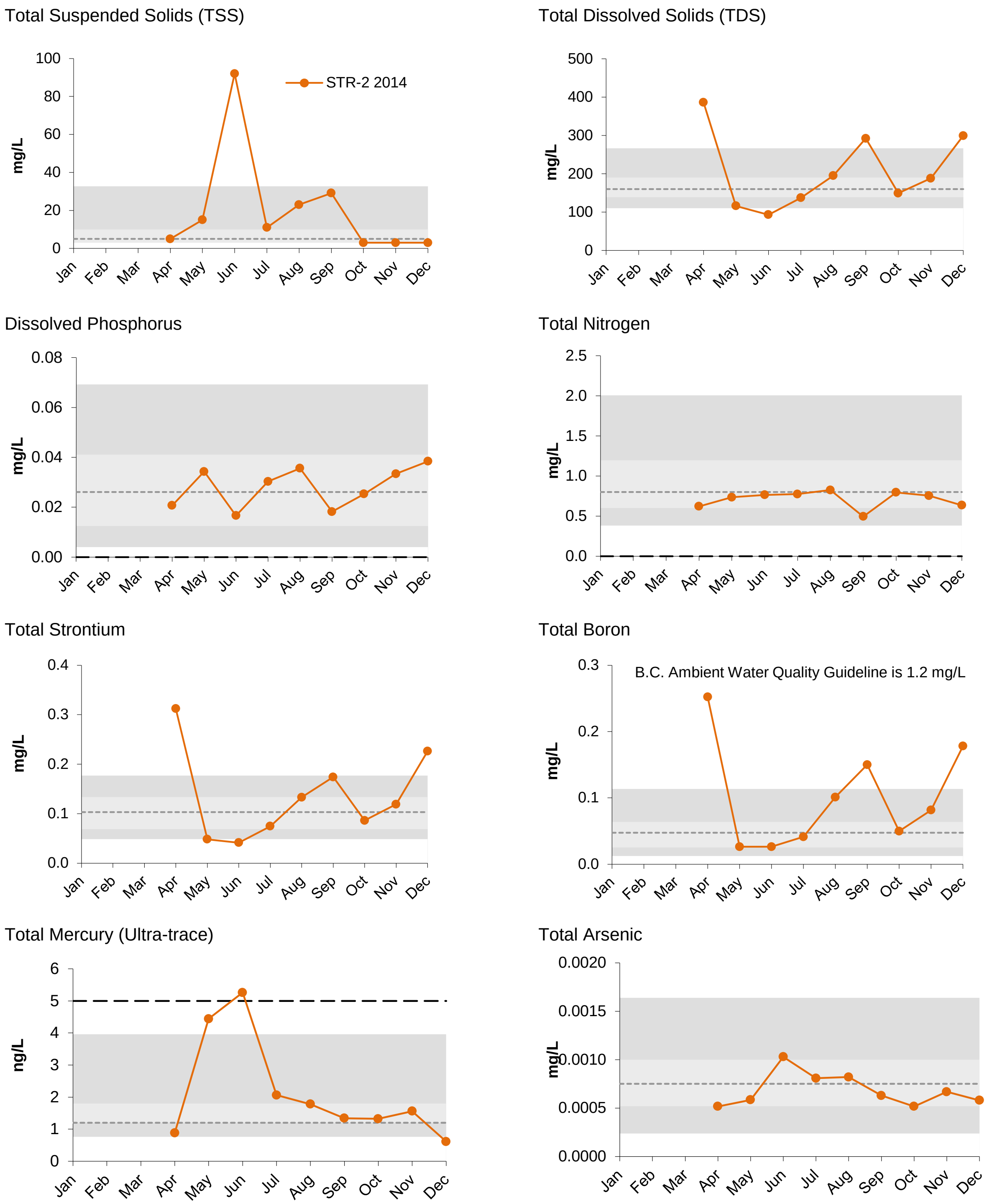
Table 5.3-11 Monthly water quality guideline exceedances at *test* station STR-2 of the Steepbank River, April to December 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	ns	ns	ns	-	0.0112	0.0055	-	-	-	-	-	-
Sulphide	mg/L	0.002	ns	ns	ns	-	0.0030	0.0061	0.0071	0.0030	-	0.0049	0.0048	0.0022
Total aluminum	mg/L	0.1	ns	ns	ns	0.2540	0.595	3.540	0.254	-	0.2500	-	-	-
Total iron	mg/L	0.3	ns	ns	ns	0.978	1.390	2.510	0.856	0.891	0.878	0.612	0.676	1.700
Dissolved iron	mg/L	0.30	ns	ns	ns	-	0.4960	-	0.4330	0.5650	0.3970	0.3420	0.6690	0.7630
Total chromium	mg/L	0.001	ns	ns	ns	-	-	0.0027	-	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5,13	ns	ns	ns	-	-	5.26	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

ns = not sampled.

Figure 5.3-6 Concentrations of selected water quality measurement endpoints in the Steepbank River (*test* station STR-2) relative to regional *baseline* fall concentrations.



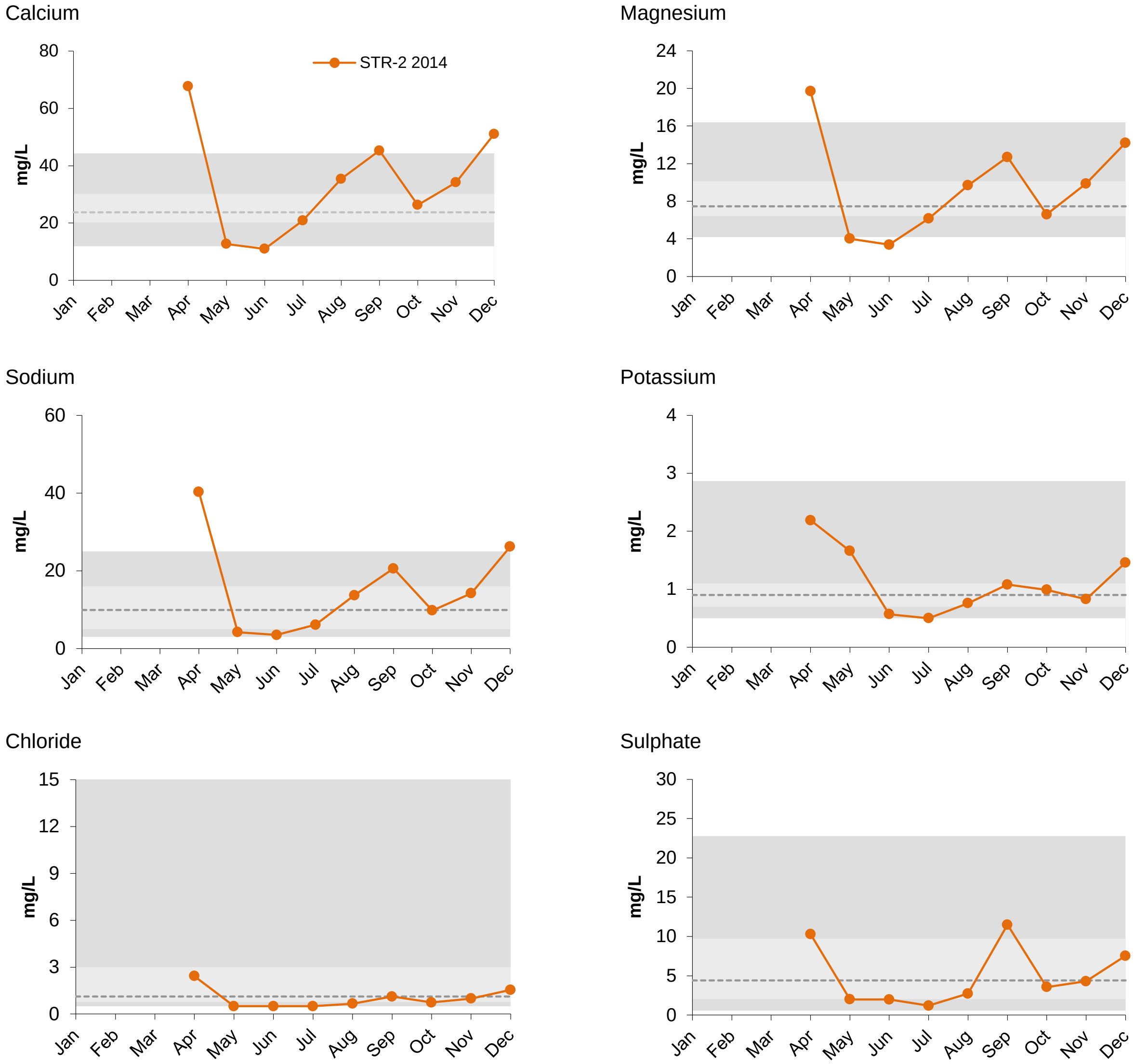
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.3-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

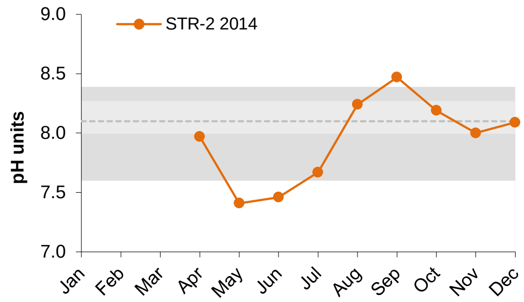
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

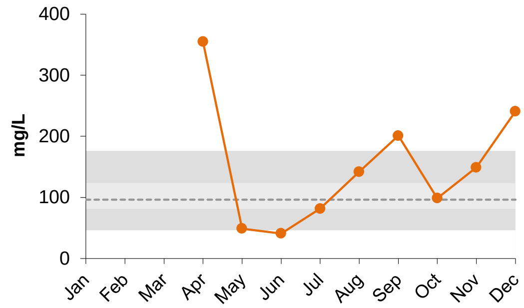
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.3-6 (Cont'd.)

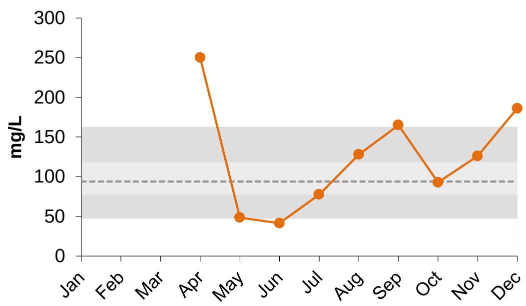
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.3-7 Piper diagram of monthly ion concentrations at *test* station STR-2 of the Steepbank River.

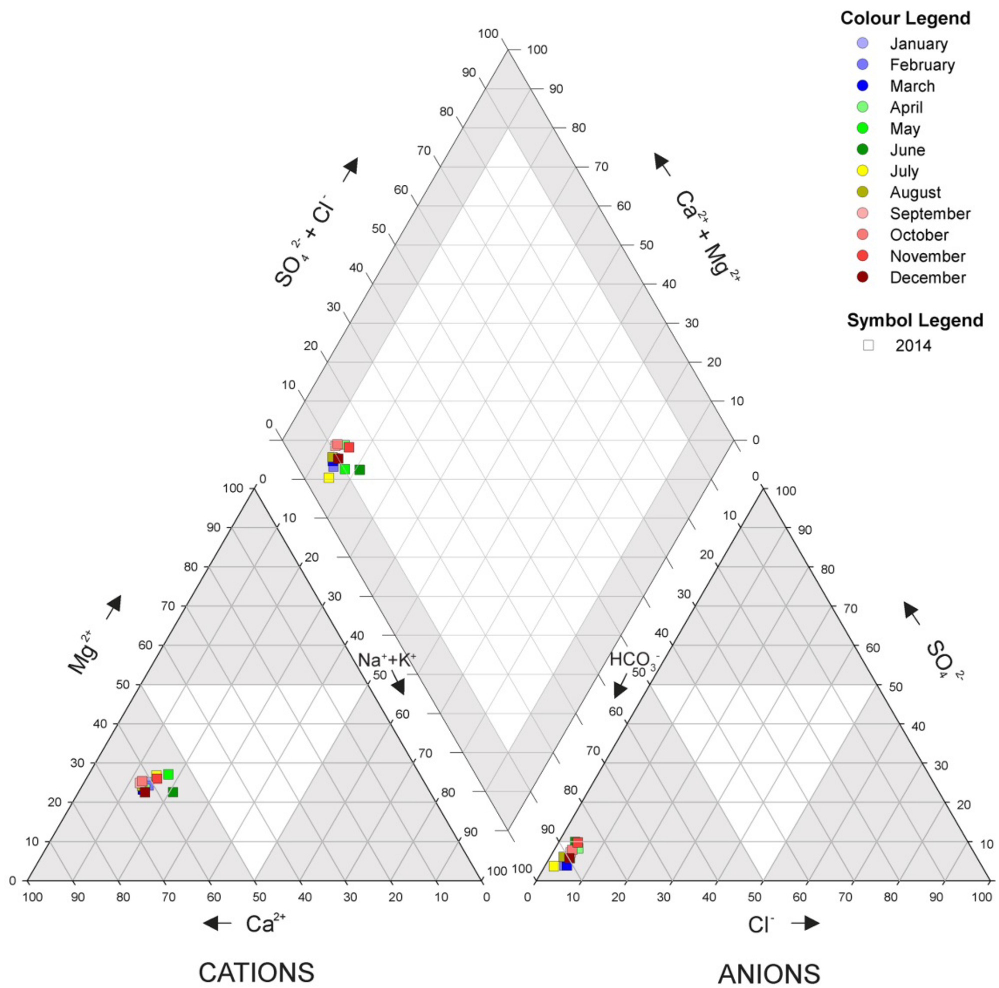
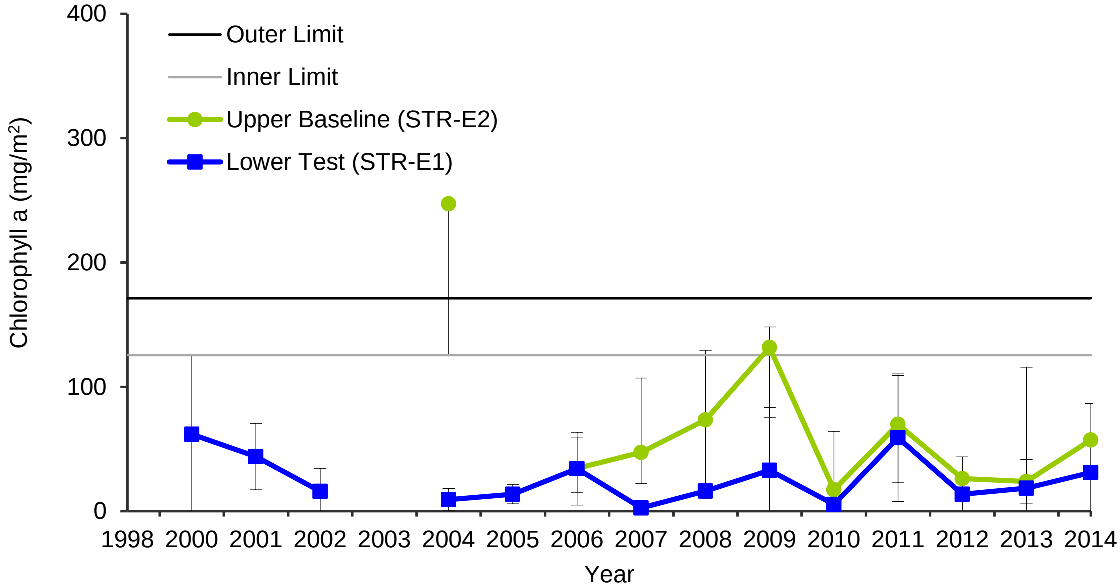


Table 5.3-12 Average habitat characteristics of benthic invertebrate sampling locations in the Steepbank River, fall 2014.

Variable	Units	STR-E1 Lower *Test* Reach	STR-E2 Upper *Baseline* Reach
Sample date	-	Sept 5, 2014	Sept 11, 2014
Habitat	-	Erosional	Erosional
Water depth	m	0.22	0.24
Current velocity	m/s	0.92	0.84
Field Water Quality			
Dissolved oxygen	mg/L	9.4	10.4
Conductivity	µS/cm	371	270
pH	pH units	7.6	7.7
Water temperature	°C	12.4	4.8
Sediment Composition (mean ± 1SD)			
Sand/Silt/Clay	%	-	5±3
Small Gravel	%	12±18	16±9
Large Gravel	%	10±12	29±13
Small Cobble	%	36±25	28±15
Large Cobble	%	25±18	14±9
Boulder	%	9±28	7±5
Bedrock	%	6±19	-

Figure 5.3-8 Periphyton chlorophyll *a* biomass at the upper *baseline* (STR-E2) and lower *test* (STR-E1) reaches of the Steepbank River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years up to and including 2013.

Table 5.3-13 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the lower Steepbank River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach STR-E1		
	1998	2000-2013	2014
Nematoda	1	<1 to 3	1
Oligochaeta	-	0 to <1	-
Naididae	2	2 to 41	17
Tubificidae	2	<1 to 23	<1
Enchytraeidae	1	1 to 15	2
Hydracarina	6	3 to 20	4
Gastropoda	<1	0 to 6	-
Bivalvia	-	0 to <1	-
Ceratopogonidae	<1	0 to 3	<1
Chironomidae	31	15 to 43	29
Diptera (misc.)	<1	<1 to 9	5
Dolichopodidae	-	0 to <1	-
Coleoptera	-	0 to <1	<1
Lepidoptera	-	-	<1
Ephemeroptera	51	1 to 51	41
Odonata	<1	<1 to 1	<1
Plecoptera	<1	<1 to 1	1
Trichoptera	1	<1 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	679	156 to 2,326	664
Richness	41	17 to 41	30
Equitability	0.11	0.13 to 0.42	0.25
% EPT	47	10 to 47	43

Table 5.3-14 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the upper Steepbank River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach STR-E2		
	2004	2005-2013	2014
Hydra	-	0 to <1	-
Nematoda	3	1 to 6	2
Naididae	2	1 to 24	2
Tubificidae	<1	0 to 1	-
Enchytraeidae	<1	0 to 1	<1
Lumbriculidae	-	0 to <1	-
Hydracarina	7	3 to 12	5
Gastropoda	-	0 to <1	<1
Bivalvia	-	0 to 4	<1
Ceratopogonidae	-	0 to 7	-
Chironomidae	46	24 to 52	26
Diptera (misc.)	<1	<1 to 8	2
Coleoptera	-	0 to <1	<1
Ephemeroptera	18	6 to 35	32
Odonata	<1	0 to <1	<1
Plecoptera	2	1 to 4	3
Trichoptera	9	6 to 34	28
Heteroptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	3,443	919 to 5,857	2,512
Richness	34	29 to 46	38
Equitability	0.28	0.11 to 0.32	0.19
% EPT	29	26 to 56	64

Table 5.3-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Steepbank River.

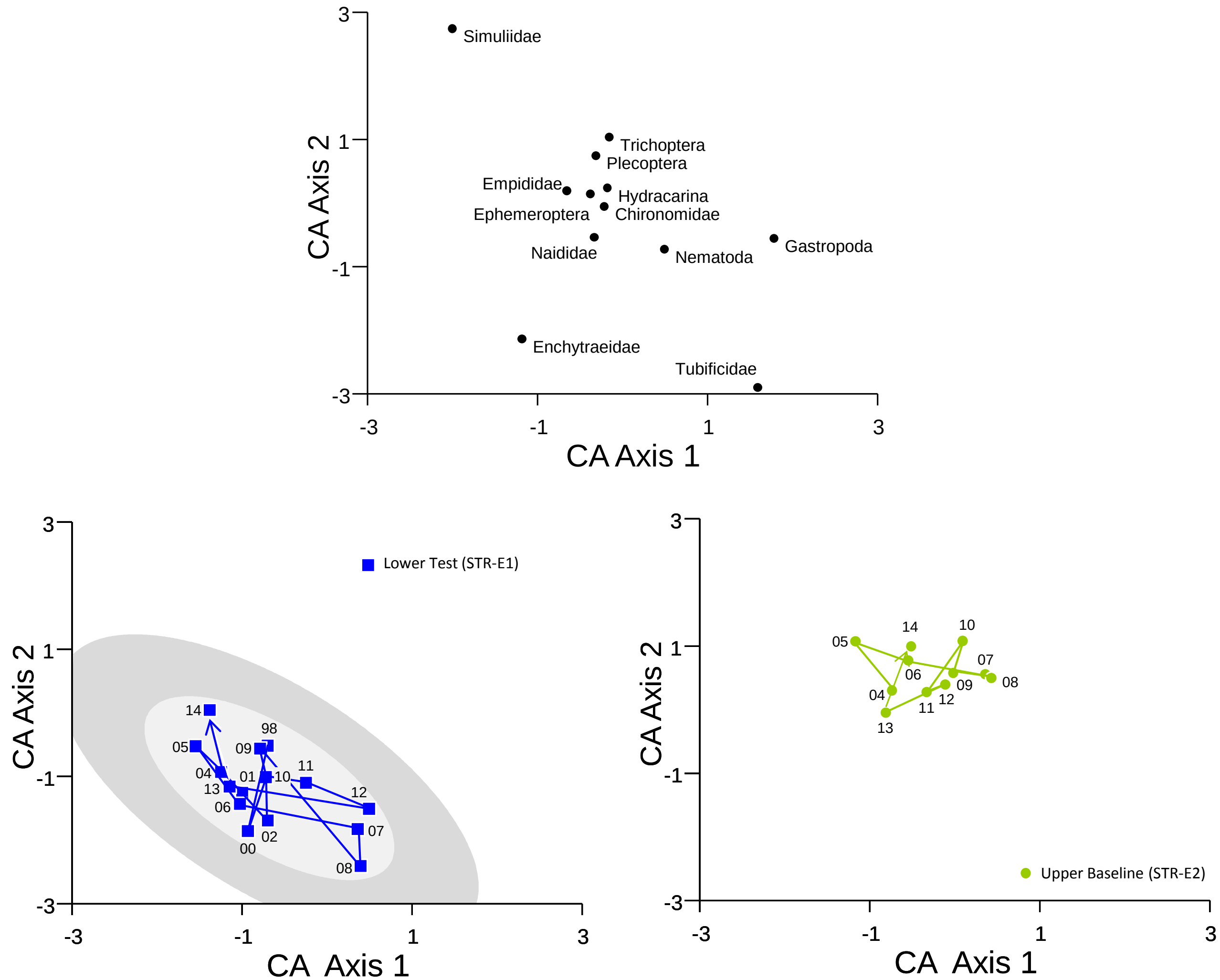
Measurement Endpoint	P-value					Variance Explained (%)					Nature of Change(s)
	Test Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.155	32	3	2	5	0	Lower at *test* reach; decreasing over time at *baseline* reach while increasing over time at *test* reach; lower in 2014 at *test* reach than the mean of all years at *baseline* reach.
Log of Richness	**<0.001**	**<0.001**	**0.004**	**0.024**	0.112	25	11	2	1	1	Lower at *test* reach; increasing at both reaches but at a greater rate at *test* reach; lower in 2014 at *test* reach than mean of all years at *baseline* reach.
Equitability	**<0.001**	0.094	**<0.001**	0.378	0.861	19	2	8	0	0	Higher at *test* reach; increasing at *baseline* reach while decreasing at *test* reach.
Log of EPT	**<0.001**	0.353	**0.020**	0.831	0.626	33	0	2	0	0	Lower at *test* reach; increasing over time at a greater rate at *test* reach.
CA Axis 1	**<0.001**	**0.012**	0.646	**<0.001**	**<0.001**	6	26	0	12	3	Lower at *test* reach; increasing over time at both reaches; lower in 2014 at *test* reach than the mean of previous years and the mean of all years at the *baseline* reach.
CA Axis 2	**<0.001**	0.081	**0.034**	**0.016**	0.296	48	0	1	1	0	Lower at *test* reach; decreasing at *baseline* reach while increasing at *test* reach; lower in 2014 than the mean of all years at the *baseline* reach.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

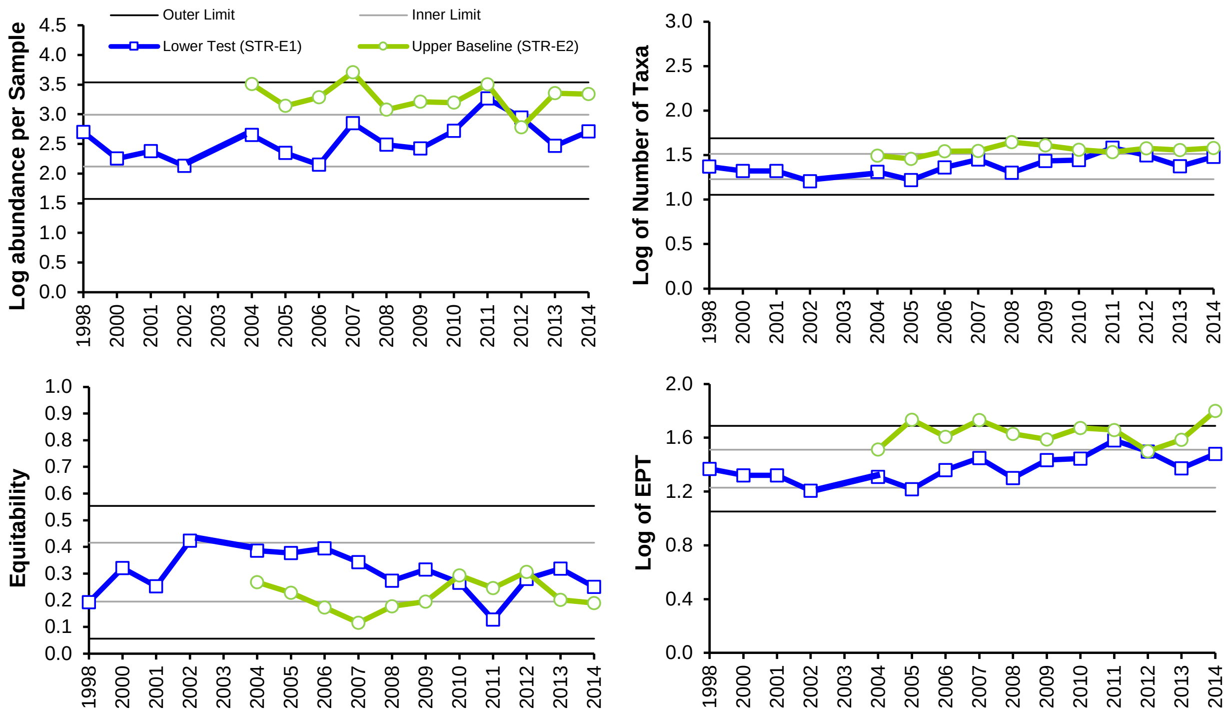
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.3-9 Ordination (Correspondence Analysis) of benthic invertebrate communities in erosional reaches, showing the lower *test* reach (STR-E1) and upper *baseline* reach (STR-E2) of the Steepbank River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach STR-E1 (1998 to 2013).

Figure 5.3-10 Variation in benthic invertebrate community measurement endpoints in the Steepbank River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years for *test* reach STR-E1 (1998 to 2013).

Note: 2014 was compared to the within-reach variability from previous years if there were eight or more years of data. If exceedances were observed, comparisons were made to the regional *baseline* dataset (depositional or erosional). If there were less than eight years of previous data for a *test* reach, it was only compared to the regional *baseline* dataset.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.3-16 Average habitat characteristics of fish assemblage monitoring locations of the Steepbank River, fall 2014.

Variable	Units	STR-F1 Lower *Test* Reach	STR-F2 Upper *Baseline* Reach
Sample date	-	Sept 17, 2014	Sept 14, 2014
Habitat type	-	run/riffle	riffle/run
Maximum depth	m	0.48	1.25
Mean depth	m	0.47	0.98
Bankfull channel width	m	25.4	17.7
Wetted channel width	m	11.9	15.0
Substrate			
Dominant	-	coarse gravel	cobble
Subdominant	-	cobble	fines
Instream cover			
Dominant	-	small woody debris, filamentous algae	boulders
Subdominant	-	macrophytes, boulders, large woody debris	small woody debris
Field water quality			
Dissolved oxygen	mg/L	9.1	11.4
Conductivity	µS/cm	345	295
pH	pH units	5.86	8.27
Water temperature	^{0}C	9.2	4.5
Water velocity			
Left bank velocity	m/s	0.59	0.20
Left bank water depth	m	0.36	0.79
Centre of channel velocity	m/s	0.62	0.12
Centre of channel water depth	m	0.45	0.56
Right bank velocity	m/s	0.24	0.15
Right bank water depth	m	0.31	0.38
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	-	-

Table 5.3-17 Total number and percent composition of fish species captured in reaches of the Steepbank River, 2009 to 2014.

Common Name	Code	Total Species Catch										Percent of Total Catch									
		Reach STR-F1						Reach STR-F2				Reach STR-F1						Reach STR-F2			
		2009	2010	2011	2012	2013	2014	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2011	2012	2013	2014
Arctic grayling	ARGR	-	-	-	-	-	-	-	-	1	6	0	0	0	0	0	0	0	0	2.2	3.5
brook stickleback	BRST	-	-	-	-	-	-	5	1	-	-	0	0	0	0	0	0	6.3	50.0	0	0
burbot	BURB	-	8	-	-	6	3	-	-	-	-	0	3.8	0	0	42.9	17.6	0	0	0	0
lake chub	LKCH	2	-	-	3	-	-	5	1	3	8	6.1	0	0	30.0	0	0	6.3	50.0	6.5	4.6
lake whitefish	LKWH	-	-	-	-	-	-	1	-	-	-	0	0	0	0	0	0	1.3	0	0	0
longnose dace	LNDC	1	63	2	2	1	-	9	-	3	13	3.0	30.0	7.7	20.0	7.1	0	11.4	0	6.5	7.5
longnose sucker	LNSC	2	-	1	1	2	3	3	-	3	25	6	0	3.8	10.0	14.3	17.6	3.8	0	6.5	14.5
northern pike	NRPK	-	-	-	1	-	1	-	-	-	-	0	0	0	10.0	0	5.9	0	0	0	0
northern redbelly dace	NRDC	16	-	-	-	-	-	1	-	-	-	48.5	0	0	0	0	0	1.3	0	0	0
pearl dace	PRDC	2	64	-	-	-	-	-	-	-	-	6.1	30.5	0	0	0	0	0	0	0	0
slimy sculpin	SLSC	2	60	8	2	2	10	35	-	29	87	6.1	28.6	30.8	20.0	14.3	58.8	44.3	0	63.0	50.3
spoonhead sculpin	SPSC	-	3	3	-	-	-	-	-	-	-	0	1.4	11.5	0	0	0	0	0	0	0
trout-perch	TRPR	1	7	-	-	1	-	20	-	7	22	3.0	3.3	0	0	7.1	0	25.3	0	15.2	12.7
walleye	WALL	1	-	-	-	1	-	-	-	-	5	3.0	0	0	0	7.1	0	0	0	0	2.9
white sucker	WHSC	1	4	12	1	-	-	-	-	-	7	3.0	1.9	46.2	10.0	0	0	0	0	0	4.0
yellow perch	YLPR	-	1	-	-	1	-	-	-	-	-	0	0.5	0	0	7.1	0	0	0	0	0
unknown sp. *		5	-	-	-	-	-	-	-	-	-	15.2	0	0	0	0	0	0	0	0	0
Total Count		**33**	**210**	**26**	**10**	**14**	**17**	**79**	**2**	**46**	**173**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**9**	**8**	**5**	**6**	**7**	**4**	**8**	**2**	**6**	**8**	**9**	**8**	**5**	**6**	**7**	**4**	**8**	**2**	**6**	**8**
Electrofishing effort (secs)		**3,652**	**4,977**	**1,326**	**1,948**	**1,772**	**1,765**	**1,309**	**1,712**	**2,269**	**2,606**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* not included in total species richness count.

Underline denotes *baseline* reach.

Table 5.3-18 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of the Steepbank River, 2009 to 2014.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
STR-F1	2009	0.25	-	10	9.00	-	0.13	-	6.92	-	0.90	-
	2010	0.42	0.23	8	3.70	0.95	0.57	0.13	5.42	0.81	4.38	2.60
	2011	0.10	0.07	5	2.60	1.14	0.43	0.29	5.07	1.46	1.96	1.32
	2012	0.04	0.03	6	2.00	1.58	0.38	0.36	5.44	1.28	0.51	0.40
	2013	0.02	0.02	7	2.20	1.30	0.37	0.35	4.25	1.45	0.90	0.83
	2014	0.05	0.02	4	2.20	1.10	0.39	0.35	3.37	0.53	0.96	0.33
STR-F2	2011	0.32	0.18	8	4.20	1.30	0.59	0.09	6.02	2.08	5.80	2.82
	2012	0.01	0.01	2	0.40	0.55	0.00	0.00	7.45	2.76	0.12	0.16
	2013	0.18	0.04	6	3.40	1.14	0.51	0.16	4.32	0.64	2.03	0.50
	2014	0.38	0.16	8	4.40	0.89	0.60	0.10	5.10	1.82	4.48	1.93

* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

Underline denotes *baseline* reach.

Table 5.3-19 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for reaches of the Steepbank River.

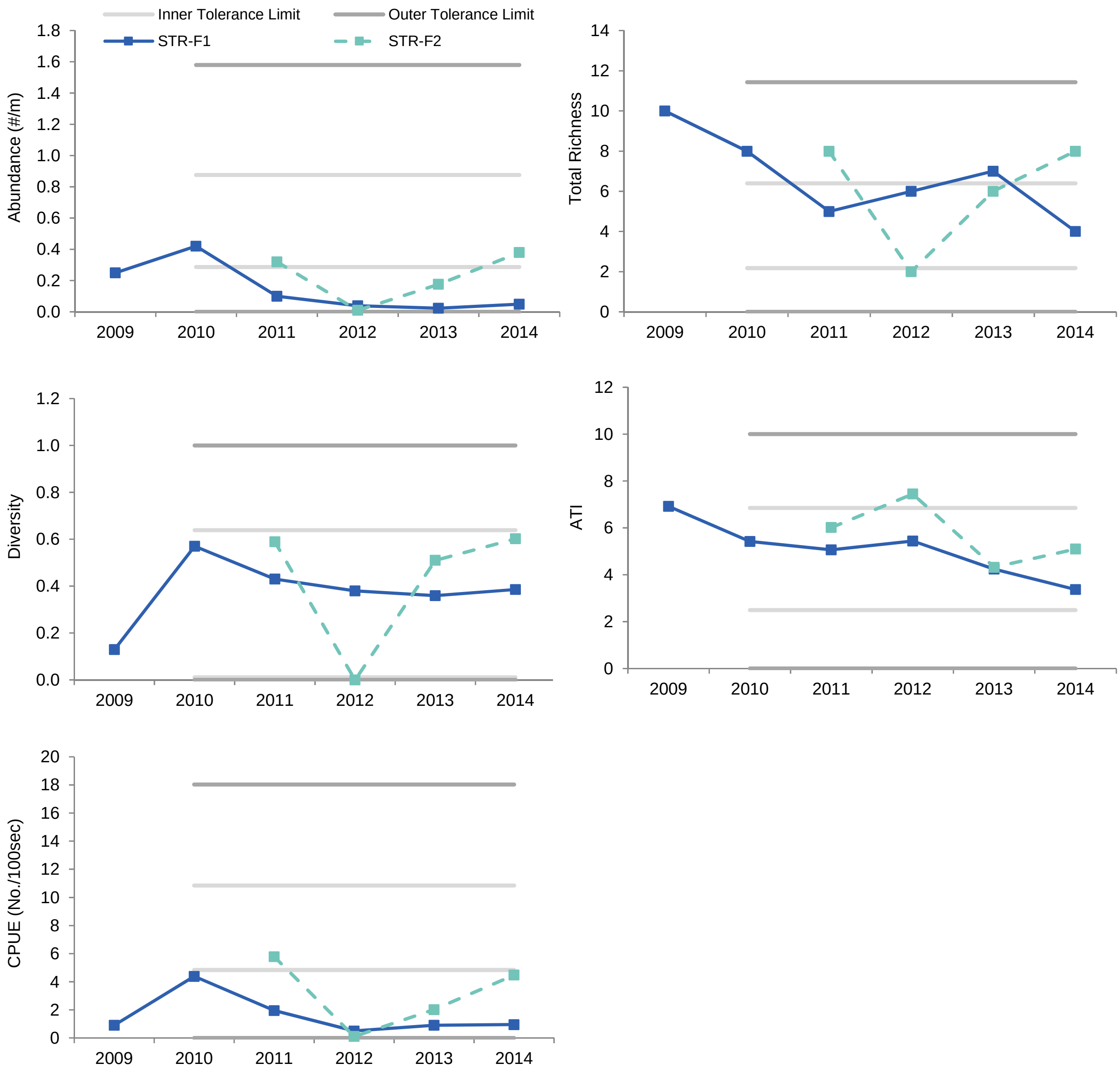
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	
Abundance	**<0.001***	0.150*	51.7	5.5	Decreasing over time at *test* reach.
Richness	**0.010**	0.320	21.4	2.6	Decreasing over time at *test* reach.
Diversity	0.420*	0.480*	2.4	1.3	No change.
ATI	0.002	0.670*	30.4	1.0	Decreasing over time at *test* reach.
CPUE (No./100 sec)	**<0.001***	0.390*	38.1	1.9	Decreasing over time at *test* reach.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

* Denotes data were rank transformed to meet assumptions of ANOVA.

Figure 5.3-11 Variation in fish assemblage measurement endpoints for the Steepbank River from 2009 to 2014 relative to regional *baseline* conditions (cluster 3).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 3 (see Table 3.2-14 and Table 3.2-15).

Note: No *baseline* data for cluster 3 prior to 2010.

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: Although *baseline* reach STR-F2 was not part of *baseline* cluster 3, the data were graphed to provide comparison to *test* reach STR-F1.

5.4 TAR RIVER WATERSHED

Table 5.4-1 Summary of results for the Tar River watershed.

Tar River Watershed	Summary of 2014 Conditions	
Climate and Hydrology		
Criteria	**S15A** near the mouth	**S34** above Horizon Lake
Mean open-water season discharge	🟤	not measured
Mean winter discharge	not measured	not measured
Annual maximum daily discharge	🟤	not measured
Minimum open-water season discharge	🟤	not measured
Water Quality		
Criteria	**TAR-1** at the mouth	**TAR-2** upstream of Canadian Natural Horizon
Water Quality Index	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality		
Criteria	**TAR-D1** lower reach	**TAR-E2** upper reach
Benthic Invertebrate Communities	🟤	n/a
Sediment Quality Index	🟡	no station
Fish Populations		
Criteria	**TAR-F1** lower reach	**TAR-F2** upper reach
Fish Assemblages	🟡	n/a

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline

test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches and/or regional *baseline* conditions.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

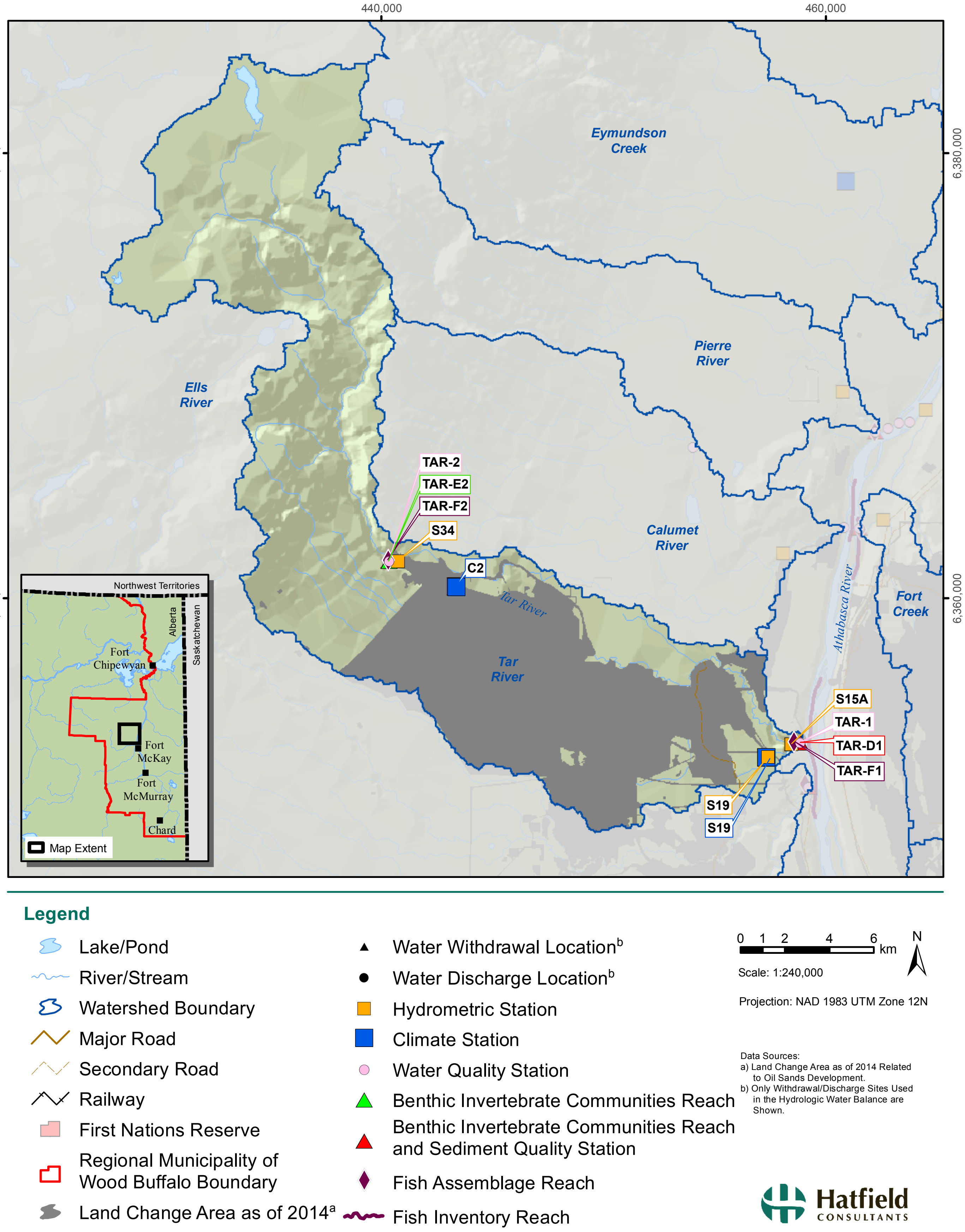
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Figure 5.4-1 Tar River watershed.



K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_K04_Tar_20150330_ss.mxd

Figure 5.4-2 Representative monitoring stations of the Tar River watershed, fall 2014.

Benthic Invertebrate and Fish Assemblage Reach TAR-D1/TAR-F1: facing upstream

Hydrology Station S15A: facing downstream

Hydrology Station S34 (above Horizon Lake): facing downstream

Benthic Invertebrate and Fish Assemblage Reach TAR-E2/TAR-F2: facing downstream

5.1.1 Summary of 2014 Conditions

As of 2014, approximately 33.5% (11,172 ha) of the Tar River watershed had undergone land change from oil sands development (Table 2.3-1). The designations of specific areas of the watershed are as follows (Figure 5.4-1):

1. The Tar River watershed downstream of the Canadian Natural Horizon Project operations is designated as *test*.
2. The remainder of the watershed is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in the Tar River watershed in 2014. Table 5.4-1 is a summary of the 2014 assessment for the Tar River watershed, while Figure 5.4-1 denotes the location of the monitoring stations for each component, reported project water withdrawal and discharge locations, and the area of land change as of 2014. Figure 5.4-2 contains fall 2014 photos of representative monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 28.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**. While the overall classification of watershed changes was classified as **High**, the results from the longitudinal assessment suggested that the extent of **High** hydrologic changes was limited to the lowest 7 km of the Tar River, which were approved changes as part of the development of the Canadian Natural Horizon project.

Water Quality In fall 2014, water quality at stations of the Tar River indicated **Negligible-Low** differences from regional *baseline* conditions. Most water quality measurement endpoints at *baseline* station TAR-2 and *test* station TAR-1 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities at *test* reach TAR-D1 were classified as **High** because of the significant decreases in abundance and richness, and increase in equitability (i.e., lower diversity) from the *baseline* period at this reach. A significant time trend was noted for CA Axis 1 scores suggesting a change in taxa composition over time with fewer water mites and mayflies found in more recent years at the lower *test* reach. Abundance and richness were below the normal range of variation for regional *baseline* depositional reaches. Overall diversity and the percentage of EPT taxa has been steadily decreasing since 2009 and mayflies and caddisflies, which were present during the *baseline* period and in previous *test* years, were absent in both 2013 and 2014.

Concentrations of all sediment quality measurement endpoints at *test* station TAR-D1 in fall 2014 were within previously-measured concentrations except naphthalene, which was below historical observations. The concentration of F3 hydrocarbons and the predicted PAH toxicity exceeded relevant thresholds, but were within the range of historical observations. Differences in sediment quality observed in fall 2014 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low**.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the *baseline* range of variability and there were no significant changes in measurement endpoints over time.

5.1.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Tar River watershed in the 2014 WY was conducted at the following locations:

- JOSMP Station S15A, Tar River near the mouth;
- JOSMP Station S19A, Tar River Lowland Tributary near the mouth; and
- JOSMP Station S34, Tar River above Horizon Lake.

Data from the JOSMP Station S15A were used for the water balance analysis and are presented below. Data from the other JOSMP stations can be found in Appendix C.

Hydrometric data from the open-water period (May to October) have been collected every year at JOSMP Station S15A since 2007. Data were also collected annually at WSC Station 07DA015, Tar River near Fort MacKay from 1975 to 1977, and during the open-water period at JOSMP Station S15 from 2001 to 2006. The combination of these data records provides the historical context for JOSMP Station S15A.

The historical flow record for JOSMP Station S15A is summarized in Figure 5.4-3 and includes the median, interquartile range, and range of flows recorded daily through the open-water period. Flows of the Tar River are typical for a northern environment; the available historical data indicated that flows are typically highest during spring freshet in May and lower for the other open-water months. Winter flows have not historically been monitored for a sufficiently long period to present summary statistics.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above. Flows were above historical median values for most dates in May, and the peak open-water flow of 11.0 m^3/s occurred on May 31 shortly after rainfall events. This was 50% higher than the historical mean open-water maximum daily flow (7.3 m^3/s). Flows from May 27 to June 9 exceeded historical maxima flows recorded on these dates. Flows then decreased sharply, and fell below historical median values in mid-July. The minimum open-water daily flow of 0.091 m^3/s was recorded on August 29, and was 49% lower than the historical mean minimum daily flow of 0.179 m^3/s calculated for the open-water period. Flows then remained relatively constant, and close to historical median values, throughout September and October.

Overall, the runoff volume in the 2014 WY open-water period was 24.531 million m^3. This value was 75% higher than the mean historical open-water runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Tar River watershed at JOSMP Station S15A is summarized in Table 5.4-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2014 was estimated to be 98.4 km^2 (Table 2.3-1). The loss of flow to the Tar River that would have otherwise occurred from this land area was estimated at 10.220 million m^3.
2. As of 2014, the area of land change in the Tar River watershed that was not closed-circuited was estimated to be 13.3 km^2 (Table 2.3-1). The increase in flow to the Tar River that would not have otherwise occurred from this land area was estimated at 0.276 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the open-water period of the 2014 WY was a loss of flow of 9.944 million m^3 in the Tar River near the mouth (JOSMP Station S15A). The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 28.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.4-3). These differences were classified as **High** (Table 5.4-1).

The **High** classification of results required an additional longitudinal classification of changes that was completed for the length of the Tar River, using the methods outlined in Section 3.2.1.5. The results of this analysis are presented in Figure 5.4-4, which shows a map of classified hydrologic changes along the length of the Tar River. Assessed changes to the hydrology upstream of JOSMP Station S34, Tar River above Horizon Lake, were classified as **Negligible-Low** (Table 5.4-1). Between JOSMP Station S34 and approximately 7 km upstream of Station S15A, Tar River near the mouth, changes to the hydrology were classified as **Moderate,** and changes to the portion of the river from approximately 7 km upstream of Station S15A, Tar River near the mouth, to the mouth of the river were classified as **High**. While the overall classification of watershed changes was classified as **High**, the results from this longitudinal assessment suggested that the extent of **High** hydrologic changes was limited to the lowest 7 km of the Tar River, which were approved changes as part of the development of the Canadian Natural Horizon project.

5.1.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Tar River near its mouth (*test* station TAR-1), designated as *baseline* from 1998 to 2003, and *test* from summer 2004 to 2014; and
- the upper Tar River (*baseline* station TAR-2), sampled since 2004.

Temporal Trends There were no significant (α=0.05) trends in fall concentrations of water quality measurement endpoints, with the exception of decreasing trends in concentrations of chloride and dissolved phosphorus at *baseline* station TAR-2.

2014 Results Relative to Historical Concentrations Concentrations of most water quality measurement endpoints in fall 2014 were within previously-measured concentrations (Table 5.4-4 and Table 5.4-5) with the following exceptions:

- CCME Fraction 3 (C16-C34) hydrocarbons, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station TAR-1;
- Retene, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station TAR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- Naphthenic acids and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station TAR-2; and
- Total nitrogen, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station TAR-2.

Ion Balance In fall 2014, the ionic composition of water at *test* station TAR-1 was generally consistent with previous years, but has shown high variability since sampling was initiated in 1998. The ionic composition of water at *test* station TAR-1 in fall 2014 was similar to results in fall 2013, 2010, 2007, and 2006 (Figure 5.4-5). In 2012 and 2008 the anion contributions were much less dominated by bicarbonate then was observed in the current data. The ionic composition of water at *baseline* station TAR-2 was similar to previous years and has been relatively stable over time.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum exceeded water quality guidelines at *test* station TAR-1 and *baseline* station TAR-2 in the fall of 2014 (Table 5.4-4 and Table 5.4-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Tar River in fall 2014 (Table 5.4-6):

- Total iron at *test* station TAR-1 and *baseline* station TAR-2; and
- Dissolved iron, sulphide, and total chromium at *test* station TAR-1.

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of all water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2 were within regional *baseline* concentrations, with the exception of total nitrogen at *baseline* station TAR-2, which was below the 5^{th} percentile of regional *baseline* concentrations (Figure 5.4-6).

Water Quality Index The WQI value for *test* station TAR-1 (100) and *baseline* station TAR-2 (100) indicated **Negligible-Low** differences from regional *baseline* conditions.

Classification of Results In fall 2014, water quality at stations of the Tar River indicated **Negligible-Low** differences from regional *baseline* conditions. Most water quality measurement endpoints at *baseline* station TAR-2 and *test* station TAR-1 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *test* reach TAR-D1, designated as *baseline* from 2002 to 2003 and as *test* from 2004 to 2014 (the reach was not sampled in 2007 and 2008); and
- erosional *baseline* reach TAR-E2, sampled since 2009. The *baseline* reach in the upper watershed was situated at TAR-E1 from 2003 to 2006. The study reach was "moved" further upstream due to increased oil sands development in the watershed.

2014 Habitat Conditions Water at *test* reach TAR-D1 was shallow (0.26 m in sampled areas), with moderate velocity (0.4 m/s), a pH of 8.0, and moderate conductivity (320 μS/cm) (Table 5.4-7). The substrate was primarily comprised of sand (92%), with low total organic carbon (<1%).

Water at *baseline* reach TAR-E2 was shallow (0.2 m in sampled areas), with relatively fast velocity (0.89 m/s), a pH of 8.1, and somewhat higher conductivity (377 μS/cm) than the lower reach (Table 5.4-7). The substrate was primarily a mixture of large cobble (24%), small cobble (28%), and large gravel (23%). Periphyton chlorophyll *a* biomass averaged 8.1 mg/m^2, which was within the range of variability for *baseline* erosional reaches in previous years (Figure 5.4-7).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of the lower *test* reach (TAR-D1) was dominated by chironomids (61%) and tubificid worms (28%) (Table 5.4-8). The chironomids were primarily comprised of *Saetheria*, and *Lopesocladius/Rheosmittia*.

EPT taxa were not present at *test* reach TAR-D1 in 2014. Permanent aquatic forms were represented by a single Lymnaeidae gastropod and a single indeterminate gastropod.

The benthic invertertebrate community of *baseline* reach TAR-E2 was dominated by mayflies (Ephemeroptera, 22%), chironomids (18%), Trichoptera (16%), miscellaneous Diptera (14%), and Plecoptera (13%) (Table 5.4-8). A variety of worms including enchytraeids, nematodes, and tubificids were present in low relative abundances (~1% each). Chironomids were mainly *Rheotanytarsus* and *Cricotopus/*Orthocladius; however, *Eukiefferiella*, *Krenosmittia, Polypedilum, Saetheria, Thienemanniella,* and *Tvetenia* were also present. Mayflies were comprised primarily of members of the Heptageniidae (*Heptagenia*) and Baetidae (*Baetis* and *Acerpenna pygmaea*) families, although the sensitive taxa *Ephemerella* was present as well. The dominant caddisflies included the net spinner *Hydropsyche*, and the scraper *Glossosoma*, both of which are very common in north-temperate locales (Wiggins 1977). Nine kinds of stoneflies were present including members of the Capniidae and Chloroperlidae families as well as the genera *Zapada, Isogenoides, Skwala,* and *Pteronarcella.*

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the Tar River watershed. Spatial comparisons were not conducted for *test* reach TAR-D1 given that there was no upstream *baseline* reach of similar habitat. For the purpose of this report, a comparison was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the variation in annual means.

Temporal comparisons in measurement endpoints for *test* reach TAR-D1 included testing for:

- changes from before (2002 to 2003) to after (2004 to present) the reach was designated *test* (Hypothesis 1, Section 3.2.3.1);
- changes over time for the period that the reach was designated as *test* (Hypothesis 2, Section 3.2.3.1);
- changes between 2014 values and the mean of all previous sampling years; and
- changes between 2014 values and the mean of all *baseline* years (2002 and 2003).

Abundance and richness were lower during the *test* period than during *baseline* years at *test* reach TAR-D1, accounting for a large amount of the variance in annual means (>20%) (Table 5.4-9). Abundance and richness were also lower in 2014 than the mean of *baseline* years, accounting for 45% and 39%, respectively, of the variance in annual means (Table 5.4-9).

Equitability was higher in 2014 than the mean of *baseline* years accounting for 20% of the variance in annual means (Table 5.4-9).

CA Axis 1 scores increased over time at the *test* reach, accounting for 50% of the variance in annual means (Table 5.4-9). The increase in CA axis 1 scores over time reflected lower relative abundances of water mites (Hydracarina) and mayflies (Ephemeroptera) during the *test* years (Figure 5.4-8).

Comparison to Published Literature The percentage of the benthic invertebrate community as worms at *test* reach TAR-D1 was high in 2014 (>25%) but not as high as in 2013 (>69%). The high relative abundance of worms suggested that the habitat at *test* reach TAR-D1 was in poor condition (Hynes 1960; Griffiths 1998). Larger permanent aquatic forms (e.g., gastropods) were present but in very low relative abundances. EPT taxa, which have been present in the past, were absent in 2014, which was consistent with 2013. The decrease in abundance and taxa richness, the high relative abundance of worms (28%), and the absence of EPT taxa in 2014 was consistent potential degradation of habitat at this reach.

2014 Results Relative to Historical or Regional *Baseline* Conditions Equitability, the percentage of EPT taxa, and CA Axis 1 and 2 scores were within the normal range of variation for regional *baseline* depositional reaches; however, abundance and richness were below the inner tolerance limits and near the outer tolerance lower limit (Figure 5.4-8, Figure 5.4-9), indicating a good probability that the observed values in 2014 were unusual.

The variability of measurement endpoints at *baseline* reach TAR-E2 was contributing to the characterization of regional *baseline* erosional conditions. Therefore, no comparisons to the regional data were conducted (Figure 5.4-10, Figure 5.4-11). Abundance decreased and equitability increased from 2013 at *baseline* reach TAR-E2, while richness and percent EPT have remained fairly consistent (Figure 5.4-11).

Classification of Results Differences in benthic invertebrate communities at *test* reach TAR-D1 were classified as **High** because of the significant decreases in abundance and richness, and increase in equitability (i.e., lower diversity) from the *baseline* period at this reach. A significant time trend was noted for CA Axis 1 scores suggesting a change in taxa composition over time with fewer water mites and mayflies found in more recent years at the lower *test* reach. Abundance and richness were below the normal range of variation for regional *baseline* depositional reaches. Overall diversity and the percentage of EPT taxa has been steadily decreasing since 2009 and mayflies and caddisflies, which were present during the *baseline* period and in previous *test* years, were absent in both 2013 and 2014.

5.1.4.2 Sediment Quality

Sediment quality of the Tar River was assessed in fall 2014 near its mouth (*test* station TAR-D1) in the same location where benthic invertebrate communities were sampled. This station was designated as *baseline* from 1998 to 2003 and as *test* from 2004 to 2014.

Temporal Trends Significant (α=0.05) increasing trends were detected in concentrations of F1, F2 F3, and F4 hydrocarbons at *test* station TAR-D1 in fall 2014.

2014 Results Relative to Historical Conditions Sediment quality data from *test* station TAR-D1 in 2014 were compared directly with data collected from this station in 2006 and 2009 to 2013. Prior to integration of the Sediment Quality component with the Benthic Invertebrate Communities component of RAMP in 2006, *test* station TAR-D1 corresponded to pre-2006 sediment quality station TAR-1.

Sediment at *test* station TAR-D1 in fall 2014 was dominated by sand (93.6%), with small amounts of silt and clay (Table 5.4-10). The substrate composition was similar to previously-measured observations, with the exception of 2013 when sediment at this station was dominated by silt (Table 5.4-10). Concentrations of all sediment quality measurement endpoints at *test* station TAR-D1 were within previously-measured concentrations, with the exception naphthalene, which was below the previously-measured minimum concentration (Table 5.4-10 and Figure 5.4-12).

Sediment toxicity tests at test station TAR-D1 in fall 2014 showed high survival of *Chironomus* (87%) and *Hyalella* (98%), with all test results within previously-measured values (Table 5.4-10).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines In fall 2014, the concentration of F3 hydrocarbons (340 mg/kg) exceeded the CCME guideline of 300 mg/kg and the PAH Hazard Index (1.306) exceeded the potential-toxicity threshold value of 1.0 (Table 5.4-10).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station TAR-D1 (Figure 5.4-12).

Sediment Quality Index The SQI for *test* station TAR-D1 in fall 2014 was 100, indicating **Negligible-Low** differences from regional *baseline* conditions. In previous years, a lower SQI indicating **Moderate** differences from regional *baseline* conditions has periodically been observed at this station.

Classification of Results Concentrations of all sediment quality measurement endpoints at *test* station TAR-D1 in fall 2014 were within previously-measured concentrations except naphthalene, which was below historical observations. The concentration of F3 hydrocarbons and the predicted PAH toxicity exceeded relevant thresholds, but were within the range of historical observations. Differences in sediment quality observed in fall 2014 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low**.

5.1.5 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- *test* reach TAR-F1, sampled in 2009 as part of the Fish Assemblage Pilot Study and since 2011 (this reach is in the same location as the benthic invertebrate community *test* reach TAR-D1); and
- *baseline* reach TAR-F2, sampled since 2011 (this reach is in the same location as the benthic invertebrate community *baseline* reach TAR-E2).

2014 Habitat Conditions *Test* reach TAR-F1 was comprised of run habitat with a wetted width of 6.0 m and a bankfull width of 18.7 m. The substrate was comprised entirely of sand where sampling occurrred. Water at *test* reach TAR-F1 was shallow with a mean depth of 0.24 m, slow velocity (mean=0.26 m/s); was slightly acidic (pH: 6.53), with high conductivity (596 µS/cm), high dissolved oxygen (10.2 mg/L), and a temperature of 7.3˚C. Instream cover consisted of boulders, with some small woody debris (Table 5.4-11).

Baseline reach TAR-F2 was comprised of run and riffle habitat, with a wetted width of 5.3 m and a bankfull width of 6.7 m. The substrate was comprised primarily of cobble, with small amounts of coarse gravel. Water at *baseline* reach TAR-F2 was shallow with a mean depth of 0.22 m and slow velocity (mean=0.30 m/s), a pH of 8.00, moderate conductivity (326 µS/cm), high dissolved oxygen (10.2 mg/L), and a temperature of 6.8 ˚C. Instream cover consisted primarily of boulders and overhanging vegetation, with some small woody debris, undercut banks, and live trees (Table 5.4-11).

Relative Abundance of Fish Species The total catch of fish species at *test* reach TAR-F1 decreased from 2013 and was dominated by lake chub (57%) with walleye as the subdominant species (14%). The abundance of burbot was slightly lower in 2014 compared to 2013 when it was common near the confluence of many of the tributaries to the Athabasca River and caught in numbers not previously observed during JOSMP surveys. In general, fish species composition in fall 2014 at *test* reach TAR-F1 was comparable to previous years (Table 5.4-12).

The total catch of fish species at *baseline* reach TAR-F2 was slightly lower than 2013 and was comprised entirely of slimy sculpin. Slimy sculpin was the dominant species in the previous year, comprising at least 86% of the total catch since the start of sampling in 2011 (Table 5.4-12).

Temporal and Spatial Comparisons Temporal comparisons were conducted at *test* reach TAR-F1 between 2009 and 2014 to test for changes over time in measurement endpoints (Hypothesis 1, Section 3.2.4.4). Spatial comparisons were not conducted between *test* reach TAR-F1 and *baseline* reach TAR-F2 given the differences in habitat conditions (i.e., erosional versus depositional habitat).

There were no significant changes over time in abundance (p=0.45), richness (p=0.96), diversity (p=0.92), ATI (p=0.15), or total CPUE (p=0.77) at *test* reach TAR-F1 (Table 5.4-13; Table 5.4-14). Mean values of all measurement endpoints were lower at *baseline* reach TAR-F2 in 2014 compared to previous years (Table 5.4-13).

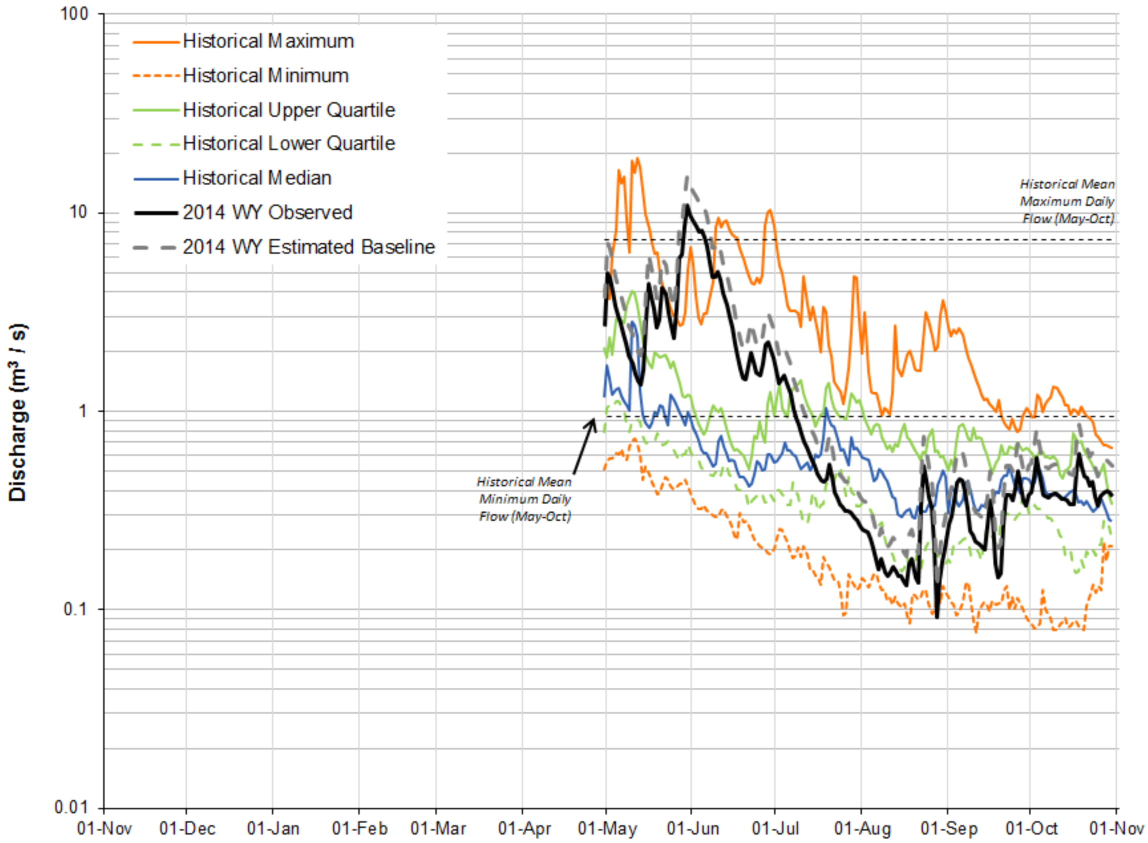
Comparison to Published Literature A summary of fish sampling activities within watersheds in the Athabasca oil sands region was prepared in Golder (2004). This document provides a thorough assessment of fish species presence in watersheds prior to major oil sands development to capture historical *baseline* fish assemblages for comparison to results reported by JOSMP for the FAM program. Historically, 11 fish species have been documented along the entire length of the Tar River (Golder 2004). JOSMP has observed eight of these fish species at *test* reach TAR-F1 and *baseline* reach TAR-F2 from 2009 to 2014, as well as seven additional species that were not previously documented including walleye, finescale dace, longnose dace, northern redbelly dace, and northern pike at test reach TAR-F1 and brassy minnow and fathead minnow at *baseline* reach TAR-F2 (Table 5.4-12). All of the new species captured have been small-bodied species, or juvenile large-bodied species, which are specifically targeted by backpack electrofishing methods used for this fish assemblage monitoring program.

Habitat conditions documented by Golder (2004) were similar to conditions observed from 2009 to 2014 at *test* reach TAR-F1. Golder (2004) documented low habitat diversity and relatively homogenous substrate (90% sand) in the location of *test* reach TAR-F1 and better fish habitat with a combination of riffles, runs, and pools and a higher proportion of coarser substrate in the location of *baseline* reach TAR-F2.

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for test reach TAR-F1 were within the inner tolerance limits of the normal range of variability for *baseline* conditions (Figure 5.4-13).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the *baseline* range of variability and there were no significant changes in measurement endpoints over time.

Figure 5.4-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Tar River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph is based on Tar River near the mouth (JOSMP Station S15A) daily mean open-water data. The upstream drainage area is 332 km^2. Historical values were calculated for the open-water period at WSC Station 07DA015 (1975 to 1977), JOSMP Station S15 (2001 to 2006), and JOSMP Station S15A (2007 to 2013).

Note: The historical mean minimum and maximum daily flow were calculated for open-water months only (May to October).

Table 5.4-2 Estimated water balance at JOSMP Station S15A, Tar River near the mouth, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**24.531**	**Observed discharge, obtained from Tar River near the mouth, Station S15A**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-10.220	Estimated 98.4 km^2 of the Tar River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.276	Estimated 13.3 km^2 of the Tar River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Tar River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Water releases into the Tar River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**34.475**	**Estimated *baseline* discharge at Tar River near the mouth, JOSMP Station S15A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	-9.944	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-28.840**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table were presented to three decimal places.

Note: Observed volume of water discharged was calculated using data for May 1 to October 31, 2014 for Tar River near the mouth, JOSMP Station S15A.

Table 5.4-3 Calculated change in hydrologic measurement endpoints for the Tar River watershed, 2014 WY.

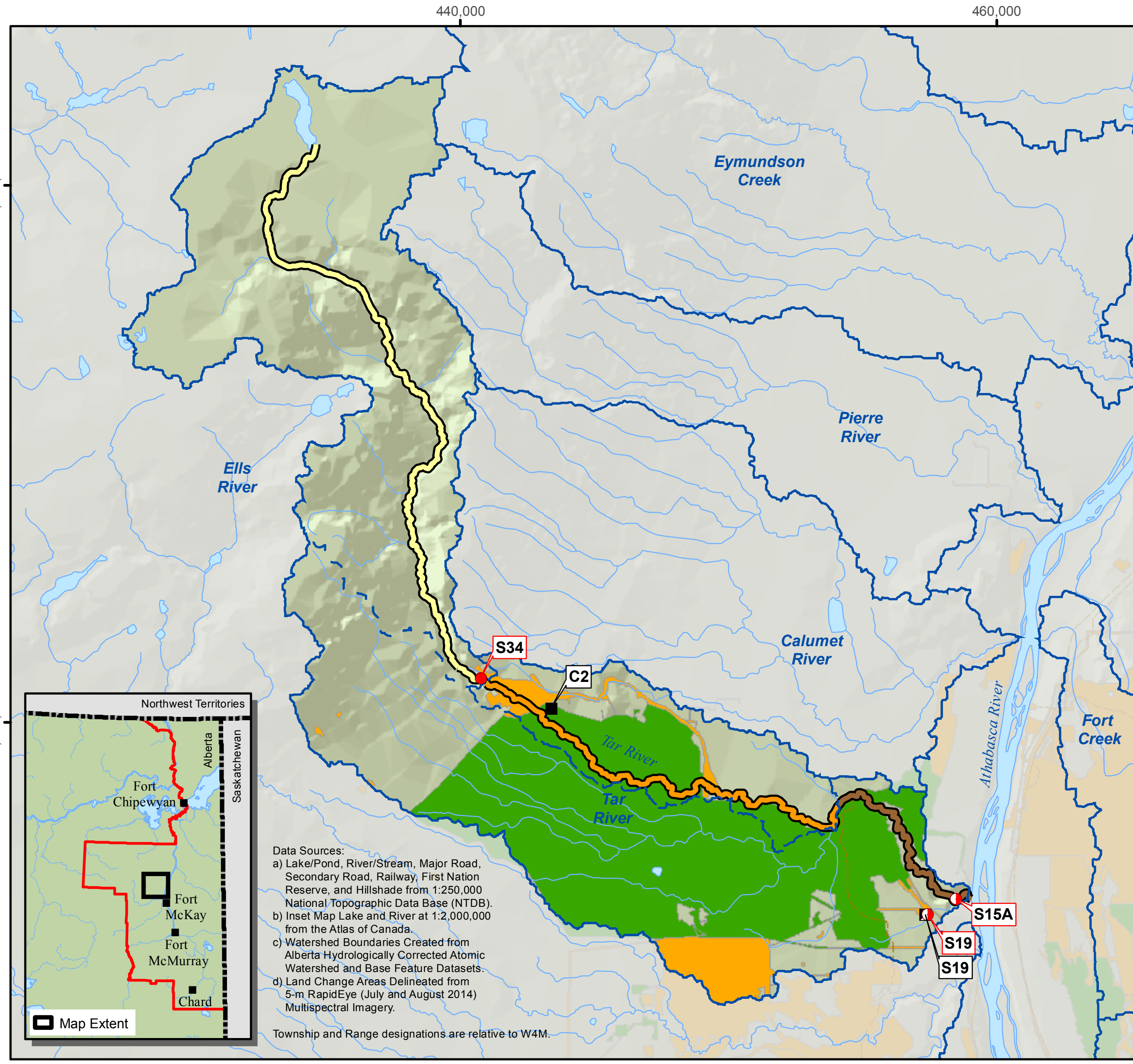
Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	2.169	1.543	-28.84%
Mean winter discharge	not measured	not measured	not measured
Open-water maximum daily discharge	15.464	11.004	-28.84%
Open-water season minimum daily discharge	0.128	0.091	-28.84%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and two decimal places, respectively.

Note: Discharge statistics were calculated using data for May 1 to October 31, 2014 for Tar River near the mouth, JOSMP Station S15A.

Figure 5.4-4 Hydrologic change classification of the Tar River, 2014 WY.



Legend

Lake/Pond
River/Stream
Watershed Boundary
Sub-Watershed Boundary
Secondary Road

Land Change Area as of 2014[d]

Not Hydrologically Closed-Circuited
Hydrologically Closed-Circuited

Hydrometric Station

JOSMP Seasonal
JOSMP Year-Round

Climate Station

Year-Round Climate Station
Seasonal Rainfall Monitoring Station

Hydrologic Change Classification

Negligible-Low
Moderate
High

0 1 2 4 6 km
N
Scale: 1:240,000
Projection: NAD 1983 UTM Zone 12N

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Table 5.4-4 Concentrations of water quality measurement endpoints, mouth of the Tar River (*test* station TAR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.20	13	8.09	8.20	8.50
Total suspended solids	mg/L	-	26.0	13	6.0	15.0	372
Conductivity	µS/cm	-	366	13	302	437	875
Nutrients							
Total dissolved phosphorus	mg/L	-	0.015	13	0.012	0.017	0.125
Total nitrogen	mg/L	-	0.67	13	0.50	1.00	4.30
Nitrate+nitrite	mg/L	3	<0.054	13	<0.050	<0.10	**3.50**
Dissolved organic carbon	mg/L	-	20.3	13	12.0	17.0	22.6
Ions							
Sodium	mg/L	-	18.9	13	14.6	24.7	50.0
Calcium	mg/L	-	40.5	13	38.0	49.2	88.5
Magnesium	mg/L	-	11.6	13	11.3	15.4	24.3
Chloride	mg/L	120	5.55	13	1.70	5.00	50.0
Sulphate	mg/L	309	55.1	13	20.4	45.6	173
Total dissolved solids	mg/L	-	258	13	170	330	590
Total alkalinity	mg/L	-	122	13	121	153	221
Selected metals							
Total aluminum	mg/L	0.1	**0.882**	13	**0.167**	**0.668**	**16.6**
Dissolved aluminum	mg/L	0.05	0.024	13	0.005	0.015	**0.057**
Total arsenic	mg/L	0.005	0.0020	13	0.0009	0.0017	0.0037
Total boron	mg/L	1.2	0.076	13	0.053	0.078	0.145
Total molybdenum	mg/L	0.073	0.00097	13	0.00037	0.00096	0.00200
Total mercury (ultra-trace)	ng/L	5, 13	3.5	11	<1.20	1.70	**27.00**
Total strontium	mg/L	-	0.172	13	0.143	0.194	0.442
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	0.40	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.78	3	0.06	0.36	0.63
Oilsands Extractable	mg/L	-	2.00	3	0.47	1.33	1.49
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	2.210	3	2.470	3.660	18.50
Total dibenzothiophenes	ng/L	-	105.5	3	68.28	98.00	419.3
Total PAHs	ng/L	-	363.9	3	440.4	599.5	1,664
Total Parent PAHs	ng/L	-	23.04	3	36.77	43.79	100.4
Total Alkylated PAHs	ng/L	-	340.9	3	403.6	555.8	1,564
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.671**	13	0.004	**0.335**	**0.947**
Sulphide	mg/L	0.002	**0.009**	13	<0.002	**0.007**	**0.023**
Total chromium	mg/L	0.001	**0.0014**	13	0.0006	0.0010	**0.0113**
Total iron	mg/L	0.3	**2.56**	13	**1.38**	**1.70**	**13.10**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.4-5 Concentrations of water quality measurement endpoints, upper Tar River (*baseline* station TAR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.23	9	8.00	8.29	8.40
Total suspended solids	mg/L	-	3.1	9	<3.0	5.0	8.0
Conductivity	µS/cm	-	390	9	233	332	393
Nutrients							
Total dissolved phosphorus	mg/L	-	0.017	9	0.005	0.035	0.058
Total nitrogen	mg/L	-	<u>0.26</u>	9	0.40	0.50	1.43
Nitrate+nitrite	mg/L	3	<0.054	9	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	11.3	9	8.0	13.0	15.8
Ions							
Sodium	mg/L	-	12.4	9	6.0	12.0	16.0
Calcium	mg/L	-	49.6	9	31.4	44.0	53.0
Magnesium	mg/L	-	13.2	9	8.8	13.2	14.3
Chloride	mg/L	120	<0.5	9	<0.5	1.0	2.0
Sulphate	mg/L	309	43.8	9	20.0	37.2	49.0
Total dissolved solids	mg/L	-	241	9	160	233	280
Total alkalinity	mg/L	-	158	9	100	157	162
Selected metals							
Total aluminum	mg/L	0.1	**0.158**	10	0.073	**0.160**	**0.708**
Dissolved aluminum	mg/L	0.05	0.036	10	0.008	0.022	**0.052**
Total arsenic	mg/L	0.005	0.0012	10	0.0008	0.0012	0.0014
Total boron	mg/L	1.2	0.065	10	0.035	0.062	0.109
Total molybdenum	mg/L	0.073	0.0014	10	0.0008	0.0014	0.0016
Total mercury (ultra-trace)	ng/L	5, 13	1.14	10	0.80	<1.20	3.40
Total strontium	mg/L	-	0.17	10	0.10	0.16	0.20
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.26</u>	3	0.02	0.04	0.16
Oilsands Extractable	mg/L	-	<u>1.20</u>	3	0.34	0.67	0.83
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.407	3	0.609	0.669	<2.071
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	5.844	6.880	35.30
Total PAHs	ng/L	-	<u>74.10</u>	3	110.2	157.0	203.4
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	16.51	19.23	25.76
Total Alkylated PAHs	ng/L	-	<u>60.84</u>	3	84.40	137.8	186.9
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**1.26**	10	**0.65**	**1.00**	**1.59**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Figure 5.4-5 Piper diagram of fall ion concentrations, Tar River.

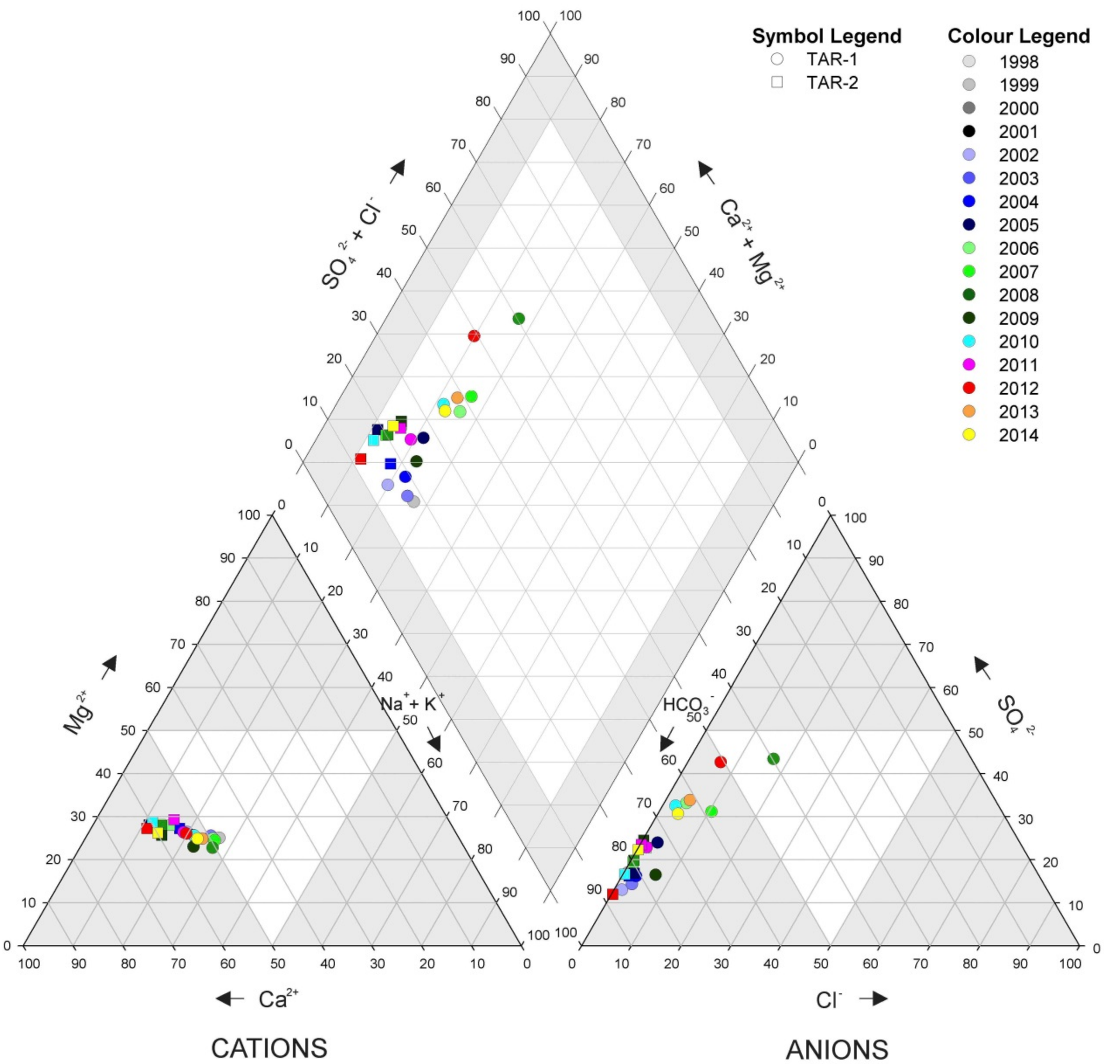
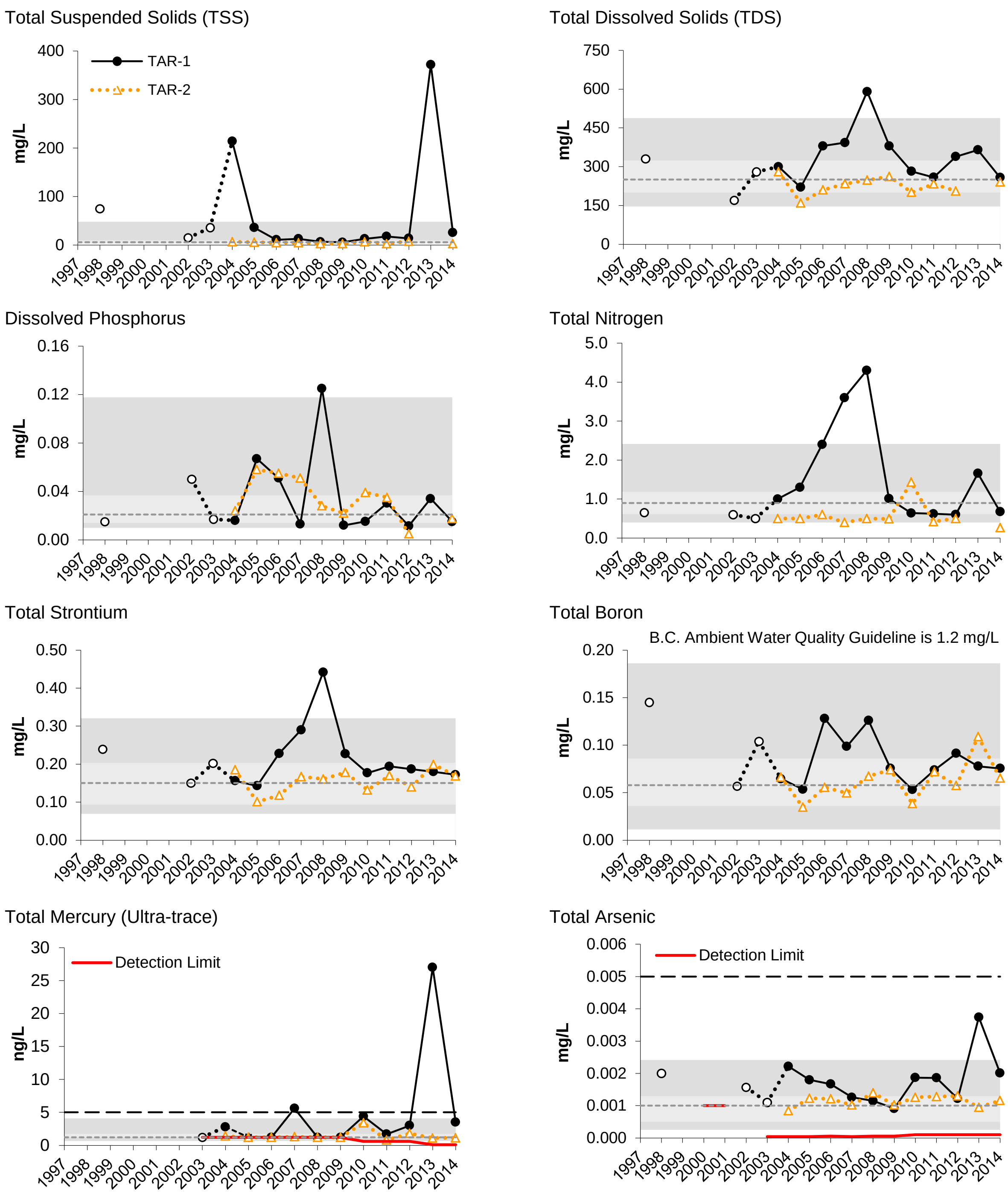


Table 5.4-6 Water quality guideline exceedances, Tar River, fall 2014.

Variable	Units	Guideline[a]	TAR-1	TAR-2
Dissolved iron	mg/L	0.3	0.671	-
Sulphide	mg/L	0.002	0.009	-
Total aluminum	mg/L	0.1	0.882	0.158
Total chromium	mg/L	0.001	0.0014	-
Total iron	mg/L	0.3	2.56	1.26

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.4-6 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

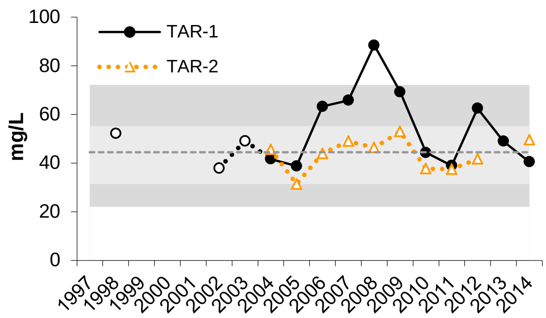
- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

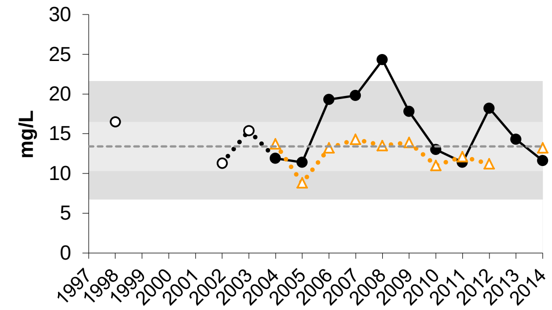
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.4-6 (Cont'd.)

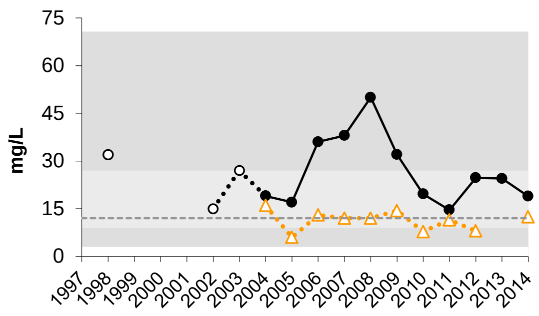
Calcium



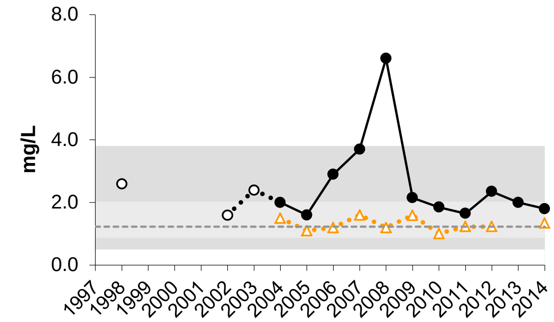
Magnesium



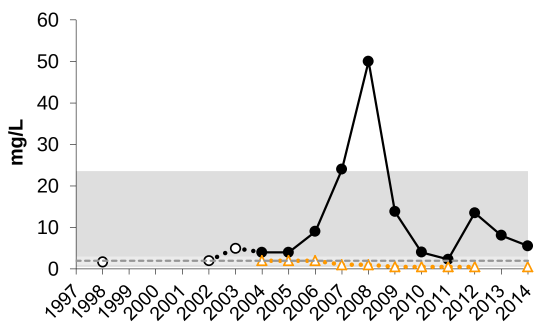
Sodium



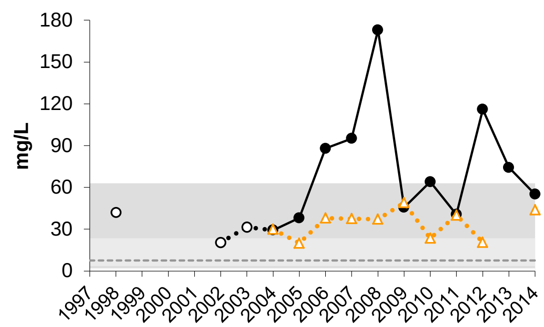
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

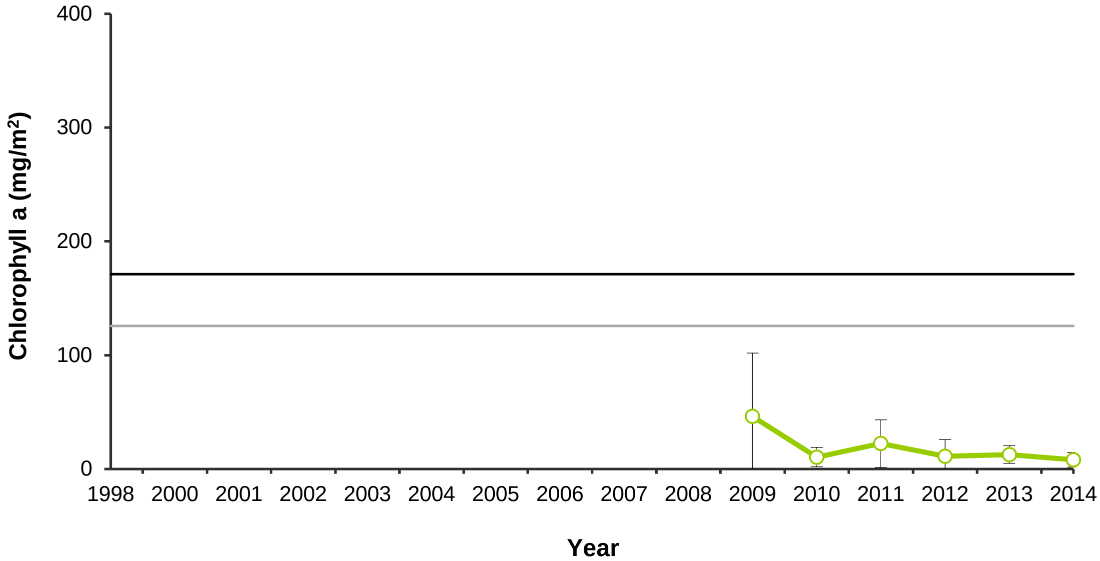
O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.4-7 Average habitat characteristics of benthic invertebrate community sampling locations in the Tar River, fall 2014.

Variable	Units	TAR-D1 Lower *Test* Reach	TAR-E2 Upper *Baseline* Reach
Sample date	-	Sept 11, 2014	Sept 9, 2014
Habitat	-	Depositional	Erosional
Water depth	m	0.26	0.17
Current velocity	m/s	0.38	0.89
Field Water Quality			
Dissolved oxygen	mg/L	11.4	11.2
Conductivity	µS/cm	320	377
pH	pH units	6.8	8.1
Water temperature	°C	8.0	4.9
Sediment Composition (mean ± 1SD)			
Sand	%	92±3	
Silt	%	4±2	
Clay	%	4±2	
Total Organic Carbon	%	0.55±0.14	
Sand/Silt/Clay	%		7±5
Small Gravel	%		11±6
Large Gravel	%		23±8
Small Cobble	%		28±7
Large Cobble	%		24±11
Boulder	%		9±7
Bedrock	%		-

Figure 5.4-7 Periphyton chlorophyll *a* biomass at *baseline* reach TAR-E2 of the Tar River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using regional *baseline* erosional data from years up to and including 2013.

Table 5.4-8 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at reaches of the Tar River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Reach TAR-D1			Reach TAR-E2		
	2002	2003-2013	2014	2009	2010-2013	2014
Nematoda	2	0 to 4	1	<1	<1 to 2	<1
Oligochaeta	-	-	-	-	<1	-
Naididae	<1	0 to 4	1	<1	<1 to 2	-
Tubificidae	7	1 to 69	28	<1	1 to 2	1
Enchytraeidae	-	0 to 5	-	6	1 to 4	2
Lumbriculidae		-	-	-	0 to <1	-
Erpobdellidae	<1	0 to <1	-	-	-	-
Hirudinea	-	-	-	-	-	-
Hydracarina	<1	0 to 2	-	4	8 to 13	15
Amphipoda	<1	-	-	-	-	-
Gastropoda	<1	0 to 2	1	-	-	-
Bivalvia	1	0 to 2	-	-	-	-
Ceratopogonidae	1	0 to 16	-	-	0 to <1	-
Chironomidae	86	<1 to 90	61	28	26 to 50	18
Diptera (misc.)	1	0 to 37	-	27	0 to 5	14
Coleoptera	<1	0 to <1	-	-	<1	-
Ephemeroptera	<1	0 to 1	-	1	18 to 40	22
Odonata	<1	0 to <1	-	-	-	-
Plecoptera	<1	0 to <1	-	15	3 to 21	13
Trichoptera	<1	0 to <1	-	16	8 to 17	16
Collembola	-	0 to <1	-	-	-	-
Lepidoptera	-	-	-	-	<1	-
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	1562	9 to 559	15	187	415 to 921	368
Richness	22	4 to 18	3	25	23 to 32	26
Equitability	0.27	0.27 to 0.73	0.6	0.33	0.29 to 0.37	0.36
% EPT	<1	0 to 2	0	56	5 to 52	51

Table 5.4-9 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach TAR-D1.

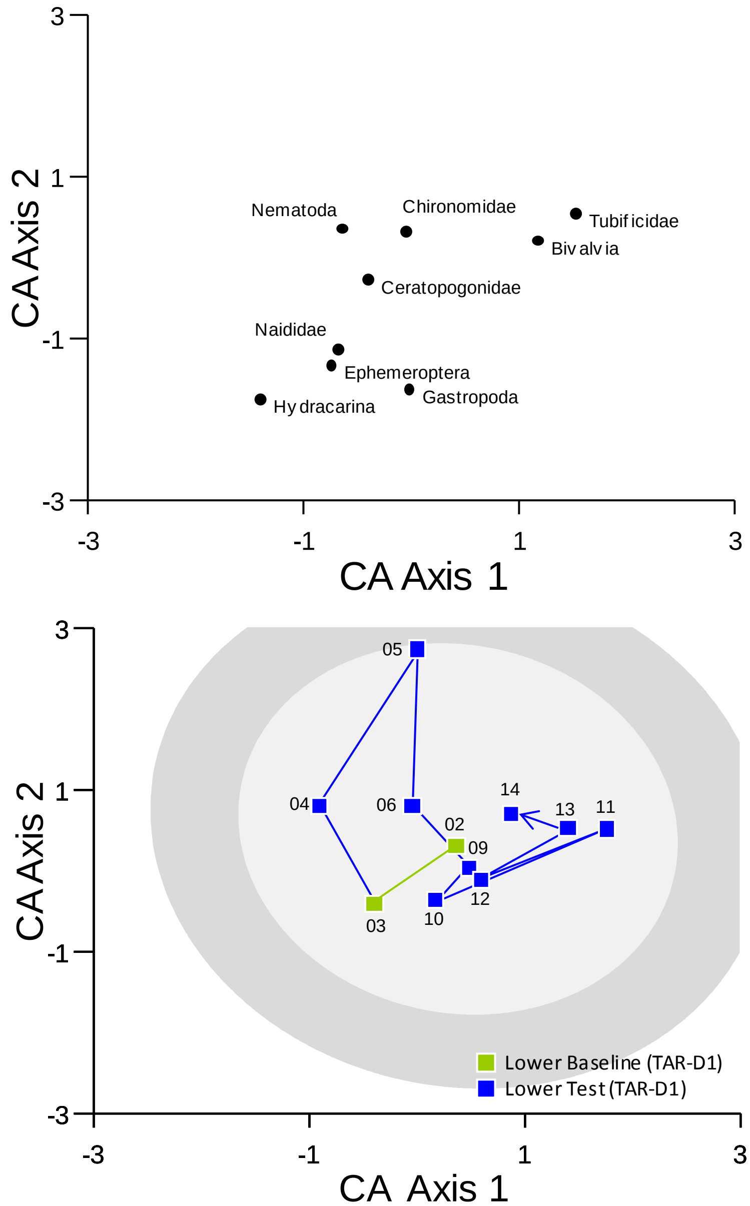
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**<0.001**	0.148	**<0.001**	**<0.001**	39	1	45	14	Lower in *test* period; lower in 2014 than mean of *baseline* years and previous *test* years.
Log of Richness	**<0.001**	**0.002**	0.510	**0.011**	39	0	39	11	Lower in *test* period; increasing over time in *test* period; lower in 2014 than mean of previous *test* years.
Equitability	**0.033**	0.107	**0.003**	**0.029**	10	6	20	11	Higher in *test* period; higher in 2014 than mean of *baseline* years and mean of previous *test* years.
Log of EPT	0.508	0.225	0.302	0.084	2	6	5	13	No change.
CA Axis 1	0.056	**<0.001**	**0.049**	0.280	8	50	9	3	Increasing over time in *test* period; higher in 2014 than mean of *baseline* years.
CA Axis 2	**0.014**	**0.007**	0.116	0.855	14	17	6	0	Higher in *test* period; increasing over time in *test* period.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

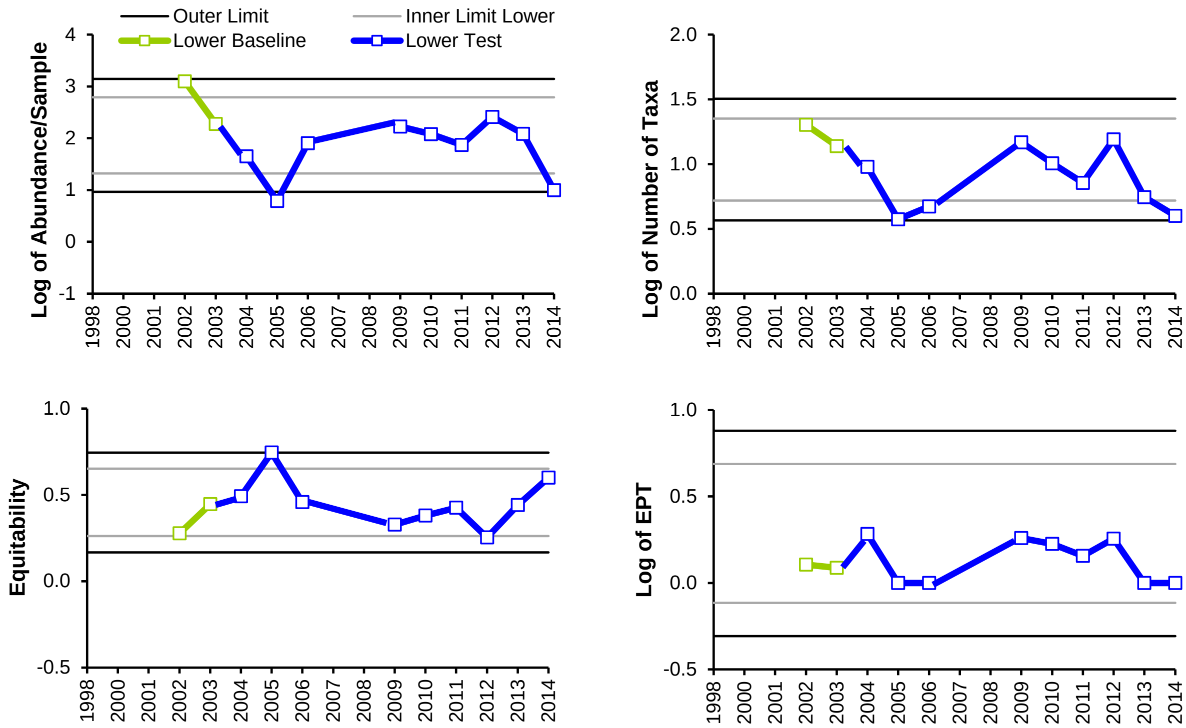
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.4-8 Ordination (Correspondence Analysis) of benthic invertebrate communities in the lower Tar River (*test* reach TAR-D1).



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipses in the lower panel are the 5^{th} and 95^{th} tolerance limits for previous years in the lower Tar River.

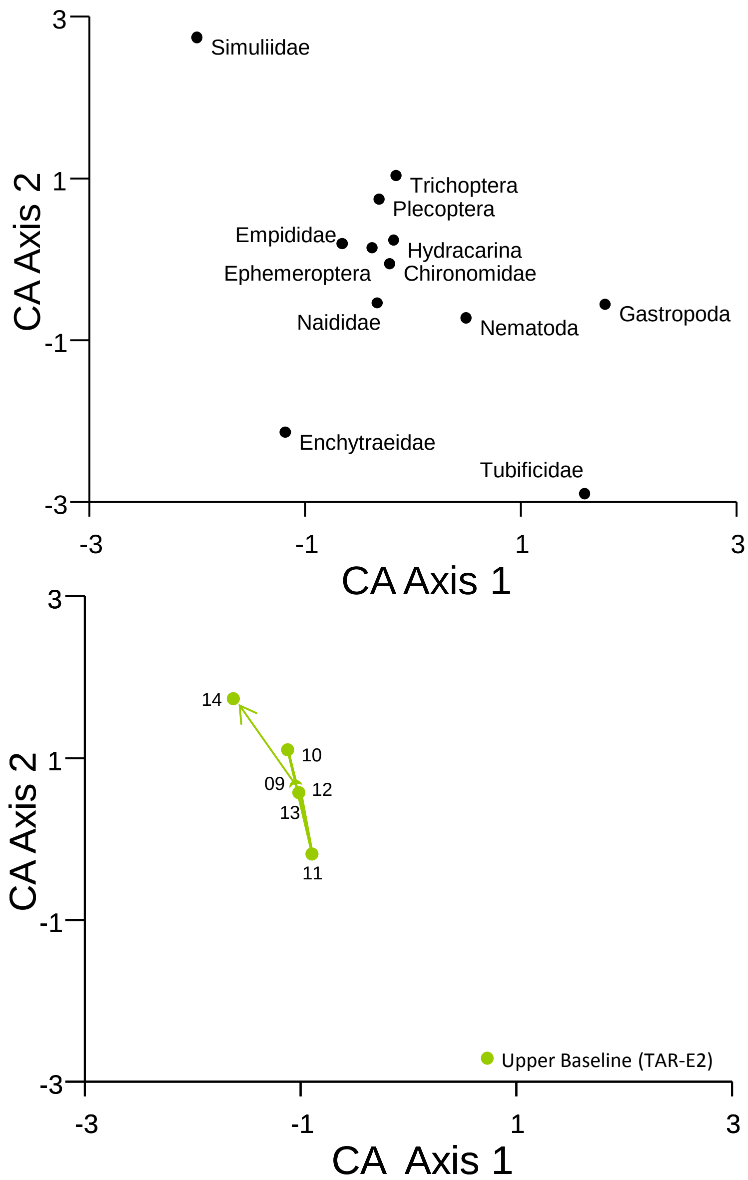
Figure 5.4-9 Variation in benthic invertebrate community measurement endpoints in the Tar River (*test* reach TAR-D1).



Note: Tolerance limits for the 5th and 95th percentiles were calculate using data from previous years (2002 to 2013).

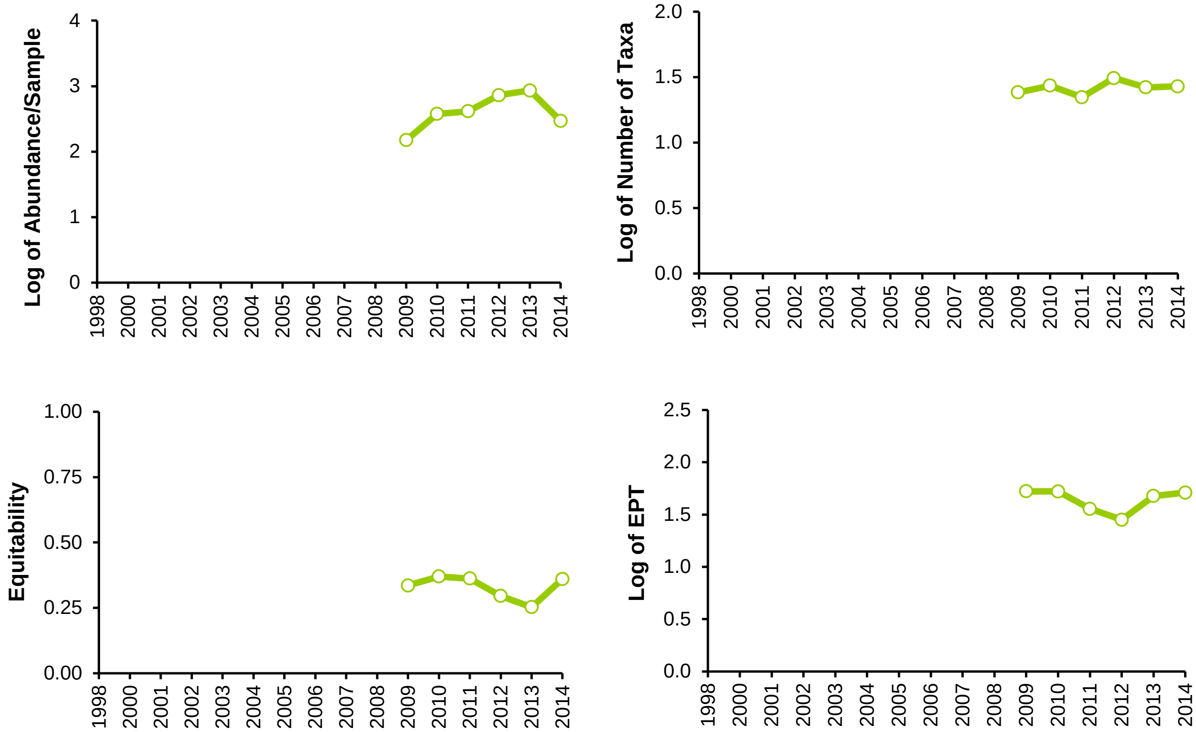
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.4-10 Ordination (Correspondence Analysis) of benthic invertebrate communities in the upper Tar River (*baseline* reach TAR-E2).



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores.

Figure 5.4-11 Variation in benthic invertebrate community measurement endpoints in the Tar River (*baseline* reach TAR-E2).



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.4-10 Concentrations of selected sediment measurement endpoints, Tar River (test station TAR-D1), fall 2014.

Variables	Units	Guideline	September 2014	1998-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.18	11	3	15	29
Silt	%	-	3.21	11	3	20	67
Sand	%	-	93.6	11	12	65	94
Total organic carbon	%	-	0.58	11	0.3	1.5	6.3
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<10	<30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<10	<30
Fraction 2 (C10-C16)	mg/kg	150[1]	25	8	13	36	105
Fraction 3 (C16-C34)	mg/kg	300[1]	**340**	8	220	**467**	**860**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	256	8	119	288	483
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.00068</u>	11	0.00125	0.00436	0.015
Retene	mg/kg	-	0.0291	10	0.0116	0.0714	2.19
Total dibenzothiophenes	mg/kg	-	0.9422	11	0.1521	0.9443	6.2555
Total PAHs	mg/kg	-	2.7815	11	0.6243	3.9378	19.1394
Total Parent PAHs	mg/kg	-	0.0692	11	0.0473	0.1179	0.4486
Total Alkylated PAHs	mg/kg	-	2.712	11	0.522	3.668	18.691
Predicted PAH toxicity[3]	H.I.	1.0	1.306	11	0.2063	**2.205**	**4.404**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.7	8	1	6.8	9.8
Chironomus growth - 10d	mg/organism	-	2.11	8	0.9	1.96	4
Hyalella survival - 14d	# surviving	-	9.8	8	6.6	8.8	10
Hyalella growth - 14d	mg/organism	-	0.29	8	0.1	0.2	0.56

Values in **bold** indicate concentrations exceeding guidelines.

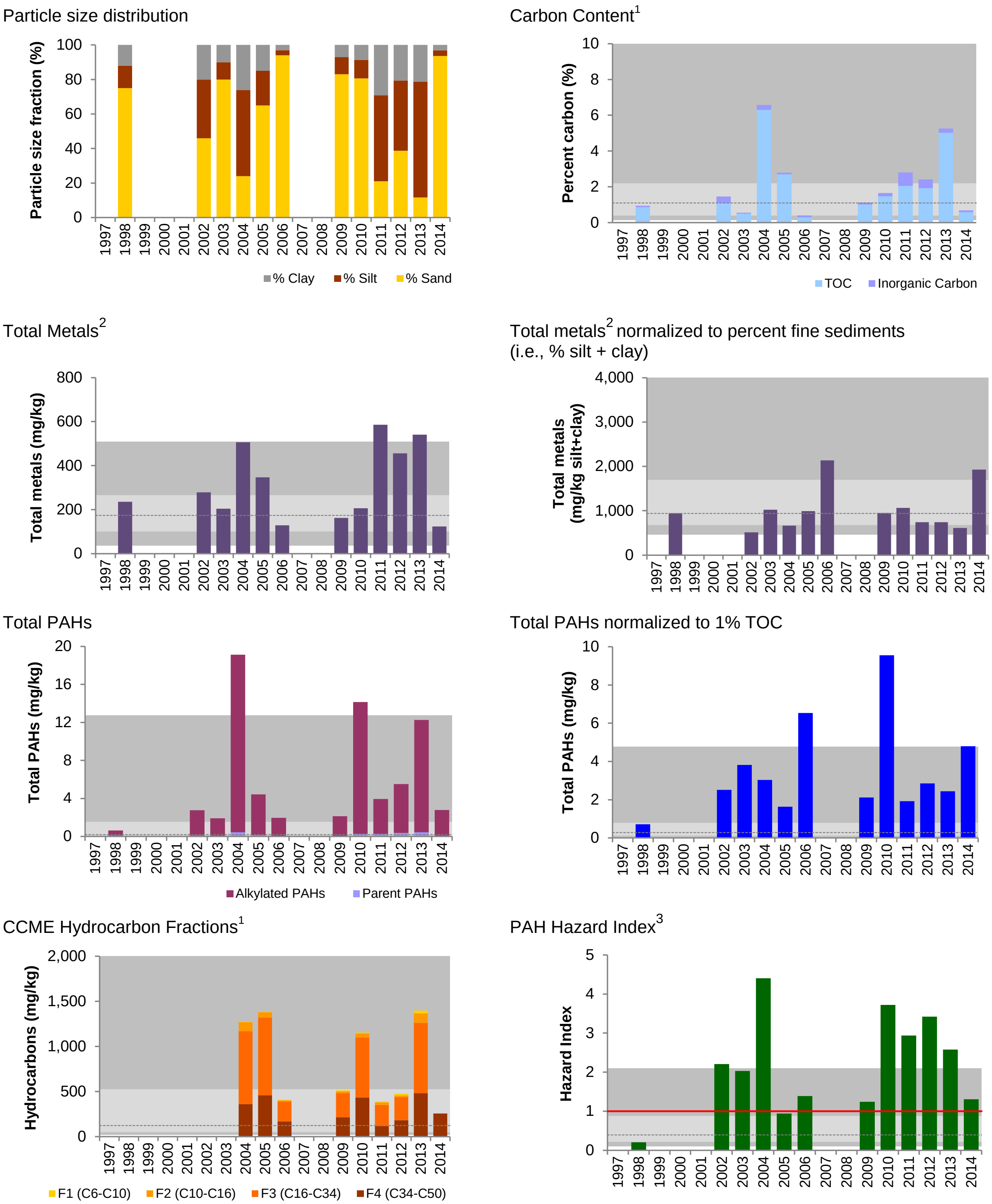
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.4-12 Variation in sediment quality measurement endpoints in the Tar River, *test* station TAR-D1.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.4-11 Average habitat characteristics of fish assemblage monitoring locations at *test* reach TAR-F1 and *baseline* reach TAR-F2 of the Tar River, fall 2014.

Variable	Units	TAR-F1 Lower *Test* Reach	TAR-F2 Upper *Baseline* Reach
Sample date	-	Sept 9, 2014	Sept 14, 2014
Habitat type	-	run	run/riffle
Maximum depth	m	0.46	0.30
Mean depth	m	0.24	0.22
Bankfull channel width	m	18.7	6.7
Wetted channel width	m	6.0	5.3
Substrate			
Dominant	-	sand	cobble
Subdominant	-	-	coarse gravel
Instream cover			
Dominant	-	macrophytes, large woody debris, small woody debris, overhanging vegetation	boulders, overhanging vegetation
Subdominant	-	-	small woody debris, live trees and roots, undercut banks
Field water quality			
Dissolved oxygen	mg/L	10.2	10.2
Conductivity	µS/cm	596	326
pH	pH units	6.5	8.0
Water temperature	^{0}C	7.3	6.8
Water velocity			
Left bank velocity	m/s	0.24	0.20
Left bank water depth	m	0.32	0.23
Centre of channel velocity	m/s	0.30	0.57
Centre of channel water depth	m	0.20	0.30
Right bank velocity	m/s	0.23	0.14
Right bank water depth	m	0.20	0.13
Riparian cover – understory (<5 m)			
Dominant	-	overhanging vegetation	woody shrubs and saplings, overhanging vegetation
Subdominant	-	woody shrubs and saplings	-

Table 5.4-12 Total number and percent composition of fish species captured at reaches of the Tar River, 2009 to 2014.

Common Name	Code	Total Species Catch									Percent of Total Catch								
		Reach TAR-F1					Reach TAR-F2				Reach TAR-F1					Reach TAR-F2			
		2009	2011	2012	2013	2014	2011	2012	2013	2014	2009	2011	2012	2013	2014	2011	2012	2013	2014
arctic grayling	ARGR	-	-	-	-	-	1	2	1	-	0	0	0	0	0	0.9	1.6	0.9	0
brook stickleback	BRST	2	2	-	-	-	-	-	-	-	18.2	3.9	0	0	0	0	0	0	0
brassy minnow	BRMN	-	-	-	-	-	-	1	-	-	0	0	0	0	0	0	0.8	0	0
burbot	BURB	-	-	-	10	3	-	-	-	-	0	0	0	13.5	10.7	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	-	7	-	0	0	0	0	0	0	0	6.3	0
finescale dace	FNDC	-	5	1	-	-	-	-	-	-	0	9.8	7.1	0	0	0	0	0	0
lake chub	LKCH	4	26	-	33	16	5	-	8	-	36.4	51.0	0	44.6	57.1	4.7	0	7.1	0
lake whitefish	LKWH	-	-	-	-	1	-	-	-	-	0	0	0	0	3.6	0	0	0	0
longnose dace	LNDC	-	1	-	-	-	-	-	-	-	0	2.0	0	0	0	0	0	0	0
longnose sucker	LNSC	-	4	3	5	-	-	7	-	-	0	7.8	21.4	6.8	0	0	5.7	0	0
northern pike	NRPK	1	1	-	5	1	-	-	-	-	9.1	2.0	0	6.8	3.6	0	0	0	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	-	-	0	0	0	1.4	0	0	0	0	0
slimy sculpin	SLSC	-	-	2	1	-	101	113	96	85	0	0	14.3	1.4	0	94.4	92.6	85.7	100
trout-perch	TRPR	-	8	1	2	-	-	-	-	-	0	15.7	7.1	2.7	0	0	0	0	0
walleye	WALL	-	-	-	-	4	-	-	-	-	0	0	0	0	14.3	0	0	0	0
white sucker	WHSC	4	4	7	17	3	-	-	-	-	36.4	7.8	50.0	23.0	10.7	0	0	0	0
Total Count		**11**	**51**	**14**	**74**	**28**	**107**	**122**	**112**	**85**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**4**	**8**	**5**	**8**	**6**	**3**	**4**	**4**	**1**	**4**	**8**	**5**	**8**	**6**	**3**	**4**	**4**	**1**
Electrofishing effort (secs)		**1,552**	**743**	**1,905**	**1,786**	**1,529**	**1,043**	**1,526**	**1,347**	**1,270**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Underline denotes *baseline* reach.

Table 5.4-13 Summary of fish assemblage measurement endpoints (±1SD) for reaches of the Tar River, 2009 to 2014.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TAR-F1	2009	0.06	-	4	4.00	-	0.69	-	7.18	-	0.39	-
	2011	0.26	0.28	8	3.80	2.59	0.53	0.32	6.43	0.65	5.56	6.56
	2012	0.07	0.09	5	1.80	1.30	0.22	0.31	5.33	2.19	0.75	0.95
	2013	0.30	0.35	8	4.80	1.92	0.64	0.17	5.08	1.32	4.20	5.07
	2014	0.09	0.04	6	2.80	1.30	0.43	0.32	6.23	1.42	1.83	0.83
TAR-F2	2011	0.71	0.24	3	1.60	0.55	0.10	0.13	3.13	0.22	10.36	3.94
	2012	0.83	0.20	5	2.20	0.84	0.15	0.11	3.16	0.20	7.98	2.05
	2013	0.45	0.08	4	2.80	0.45	0.24	0.11	3.46	0.34	8.33	1.59
	2014	0.28	0.09	1	1.00	0.00	0.00	-	3.00	0.00	6.68	2.17

SD=standard deviation across sub-reaches within a reach.

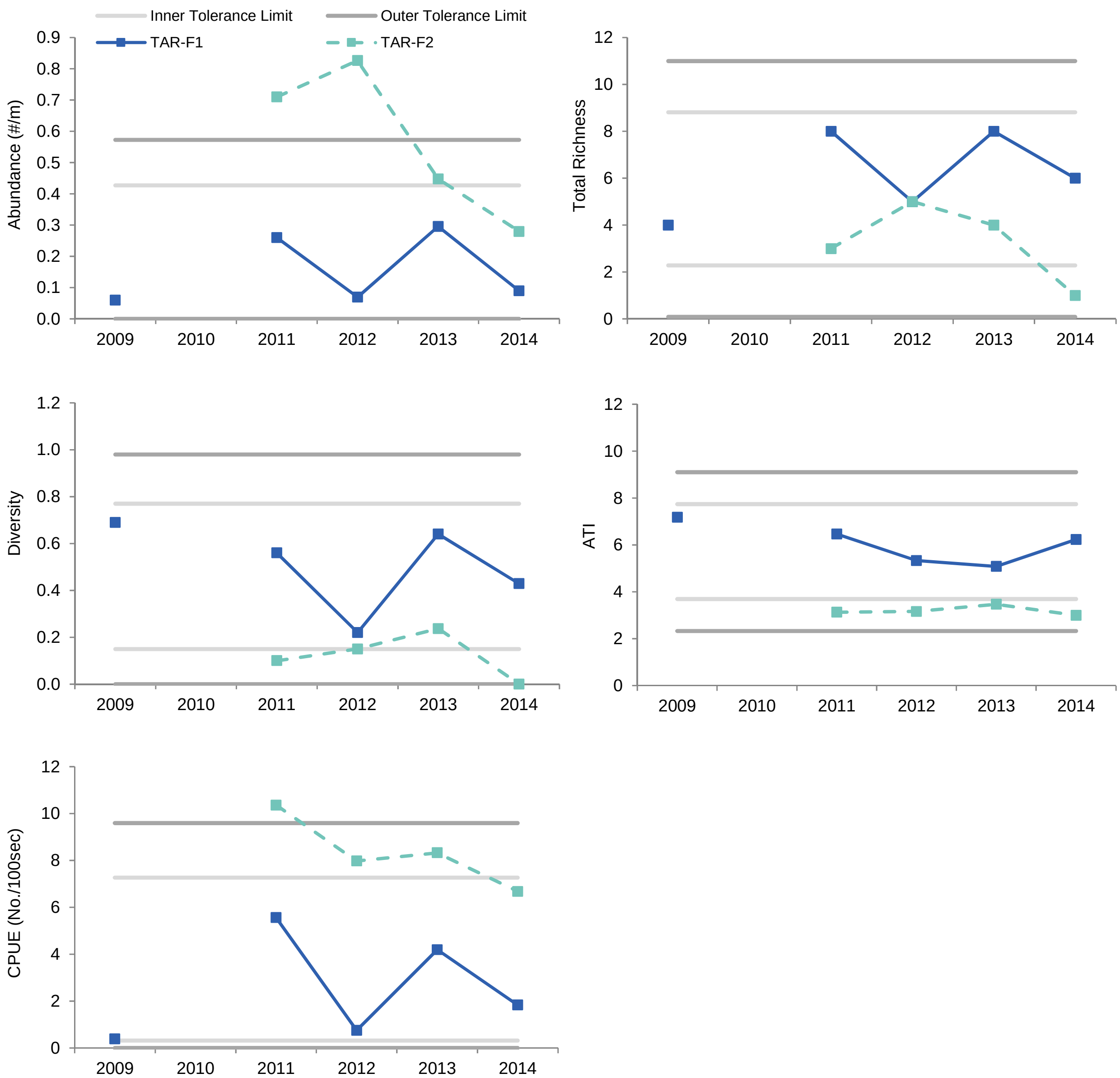
Underline denotes *baseline* reach.

Table 5.4-14 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for reaches of the Tar River.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*test* reach)	*Test* Reach vs. *Baseline* Reach	Time Trend (*test* reach)	*Test* Reach vs. *Baseline* Reach	
Abundance	0.450*	0.460*	3.2	1.4	No change.
Richness	0.960	0.530*	1.0	1.0	No change.
Diversity	0.920*	0.520*	1.0	1.0	No change.
ATI	0.150*	0.770*	1.0	1.0	No change.
CPUE	0.770*	0.850*	1.0	1.0	No change.

* Denotes data were rank transformed to meet assumptions of ANOVA.

Figure 5.4-13 Variation in fish assemblage measurement endpoints for reaches of the Tar River from 2009 to 2014 relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: Although *baseline* reach TAR-F2 was not part of *baseline* cluster 2, the data were graphed to provide comparison to *test* reach TAR-F1.

5.5 MACKAY RIVER WATERSHED

Table 5.5-1 Summary of results for the MacKay River watershed.

MacKay River Watershed	Summary of 2014 Conditions				
	MacKay River			Tributaries to MacKay River	
Climate and Hydrology					
Criteria	**07DB001** near Fort McKay	**S40** at Petro-Canada Bridge	no station	**S53** Dover River near the mouth	**S54** Dunkirk River near Fort McKay
Mean open-water season discharge	🟡	not measured		not measured	not measured
Mean winter discharge	🟡	not measured		not measured	not measured
Annual maximum daily discharge	🟡	not measured		not measured	not measured
Minimum open-water season discharge	🟡	not measured		not measured	not measured
Water Quality					
Criteria	**MAR-1** at the mouth	**MAR-2A** upstream of Suncor MacKay	**MAR-2** upstream of Suncor Dover	no station	no station
Water Quality Index	🟡	🟡	🟡		
Benthic Invertebrate Communities and Sediment Quality					
Criteria	**MAR-E1** at the mouth	**MAR-E2** upstream of Suncor MacKay	**MAR-E3** upstream of Suncor Dover	no reach	no reach
Benthic Invertebrate Communities	🟡	🟡	n/a		
No Sediment Quality component activities conducted in 2014					
Fish Populations					
Criteria	**MAR-F1** at the mouth	**MAR-F2** upstream of Suncor MacKay	**MAR-F3** upstream of Suncor Dover	no reach	no reach
Fish Assemblages	🟠	🟡	n/a		

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline

test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches or regional *baseline* conditions.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Figure 5.5-1 MacKay River watershed.

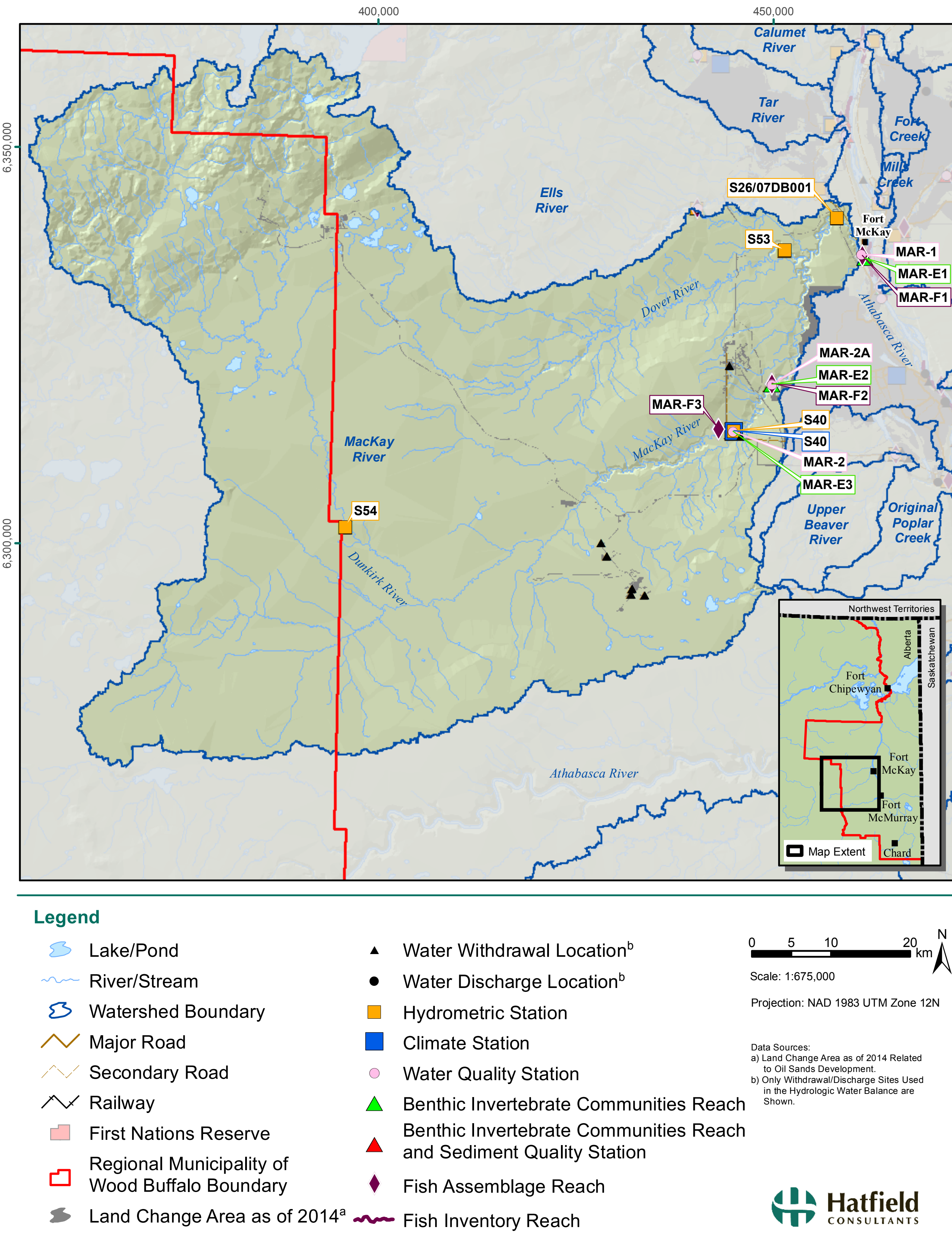


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Figure 5.5-2 Representative monitoring stations of the MacKay River watershed, fall 2014.

Fish Assemblage Reach MAR-F1:
facing upstream

Benthic Invertebrate Reach MAR-E2:
facing upstream

Hydrology Station S54:
Dunkirk River near Fort McKay

Benthic Invertebrate Reach MAR-E3:
facing downstream

5.5.1 Summary of 2014 Conditions

As of 2014, approximately 1% (4,712 ha) of the MacKay River watershed had undergone land change as a result of oil sands development (Table 2.3-1). The designations of specific areas of the watershed are as follows:

1. The MacKay River watershed downstream of the Suncor MacKay River in situ operations and the part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 5.5-1) are designated as *test*.

2. The remainder of the watershed is designated as *baseline*, although the Southern Pacific in situ operation has some minor land change near the headwaters of the watershed.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Populations components in the MacKay River watershed in 2014. Table 5.5-1 is a summary of the 2014 assessment of the MacKay River watershed, while Figure 5.5-1 denotes the location of the monitoring stations for each component, locations of reported project water withdrawal and discharge locations from oil sands operations, and the area of land change as of 2014. Figure 5.5-2 contains fall 2014 photos of monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, and open-water minimum daily discharge were 0.004%, 0.069%, 0.045% lower, respectively, and the annual maximum daily discharge was 0.007% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints in the MacKay River watershed were within the range of previously-measured concentrations and were within the range of regional *baseline* concentrations in fall 2014. Differences between water quality at *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 and regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *baseline* station MAR-2. Typically, the maximum concentration of ions occurred in March and the minimum concentrations occurred in May, consistent with expected seasonal influences of surface-water runoff (i.e., greatest during freshet and weakest during winter low-flow conditions). The decrease in alkalinity in spring likely resulted from base-cation dilution by snowmelt rather than consumption of alkalinity by acidic compounds in snow, given consistent seasonal trends also were observed in other ions. Despite the observed changes in ion concentrations, the ionic composition remained relatively consistent throughout the year but was slightly less dominated by calcium in winter months.

Benthic Invertebrate Communities Differences in measurement endpoints for benthic invertebrate communities at *test* reach MAR-E1 were classified as **Negligible-Low** because, although richness was significantly lower than *baseline* reach MAR-E3, richness was higher in 2014 than the mean of all *baseline* years for the lower and upper reaches. Differences in CA Axis 2 scores were due to slight difference in taxa composition between the lower *test* and upper *baseline* reaches. Additionally, the taxa composition at *test* reach MAR-E1 has remained stable and diverse over the past two years with the presence of EPT taxa and a low overall abundance of worms.

Differences in measurement endpoints for the benthic invertebrate community at *test* reach MAR-E2 were classified as **Negligible-Low** because the only significant change was an increasing trend over time for the percentage of the fauna as EPT taxa and differences in CA Axis 2 scores, which did not imply a negative change in the benthic invertebrate community. The benthic fauna at *test* reach MAR-E2 was representative of good overall water quality with a high percentage of EPT taxa and a low relative abundance of worms.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at *test* reach MAR-F1 were classified as **Moderate** because of significant decreases in abundance and CPUE over time and differences compared to *baseline* reach MAR-F3. In addition, abundance and CPUE were also lower than regional *baseline* conditions. Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F2 were classified as **Negligible-Low** given there was only a significant decrease in abundance over time and all measurement endpoints were within regional *baseline* variability.

5.5.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the MacKay River watershed in the 2014 WY was conducted at the following locations:

- WSC Station 07DB001 (formerly JOSMP Station S26), MacKay River near Fort McKay;
- JOSMP Station S40, MacKay River at the Petro-Canada Bridge;
- JOSMP Station S53, Dover River near the mouth; and
- JOSMP Station S54, Dunkirk River near Fort McKay.

Data from the WSC Station were used for the water balance analysis and presented below; data from each JOSMP station can be found in Appendix C.

Seasonal data from March to October have been collected every year since 1973 at WSC Station 07DB001 (formerly JOSMP Station S26), with some data for 1972. Additional winter data (November to February) were collected from 1973 to 1986 and more recently from 2002 to 2014; therefore, the record was annual and continuous during these years.

The historical flow record for WSC Station 07DB001 is summarized in Figure 5.5-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the MacKay River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in late March and April. Monthly flows are highest during May, at the peak of freshet, and often remain elevated in June and July when total monthly rainfall are highest (Figure 4.2-4). Flows then generally recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above. Flows steadily decreased from November 2013 to March 2014, and generally remained close to historical median values for much of this period (Figure 5.5-3). The increase in flow due to spring thaw occurred later than usual resulting in a seven-day period in late April when flows were lower than the historical minima for this period. The freshet and annual peak of 120 m^3/s was recorded on May 31; this was 10% higher than the historical mean annual maximum daily flow (109 m^3/s). Flows then decreased through the summer until early September, and were below the historical median values after mid-July. The minimum open-water daily flow of 3.18 m^3/s was recorded on September 2 and was 12% lower than the historical mean minimum daily flow of 3.62 m^3/s calculated for the open-water period.

Overall, the annual runoff volume in the 2014 WY was 417 million m^3. This value was 3% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the MacKay River watershed, at WSC Station 07DB001 (formerly JOSMP Station S26) is summarized in Table 5.5-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2014 was estimated to be 7.3 km^2 (Table 2.3-1). The loss of flow to the MacKay River that would have otherwise occurred from this land area was estimated at 0.550 million m^3.
2. As of 2014, the area of land change in the MacKay River watershed that was not closed-circuited was estimated to be 39.8 km^2 (Table 2.3-1). The increase in flow to the MacKay River that would not have otherwise occurred from this land area was estimated at 0.596 million m^3.
3. In the 2014 WY, Suncor withdrew approximately 0.007 million m^3 (7,451 m^3) of water for dust suppression activities.
4. In the 2014 WY, Brion Energy withdrew approximately 0.072 million m^3 (71,942 m^3) for dust suppression and drilling activities.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2014 WY was a loss of flow of 0.033 million m^3 at WSC Station 07DB001. The 2014 WY mean open-water discharge, mean winter discharge, and open-water minimum daily discharge were 0.004%, 0.069%, 0.045% lower, respectively, and the annual maximum daily discharge was 0.007% higher in the observed *test* hydrograph than in the estimated baseline hydrograph (Table 5.5-3). These differences were classified as **Negligible-Low** (Table 5.5-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.5.3 Water Quality

In fall 2014, water quality samples were taken from:

- the MacKay River near its mouth (*test* station MAR-1), first sampled in 1998, fall sampling every year from 2000 to 2014;
- the MacKay River upstream of the Suncor Dover development (*test* station MAR-2A), sampled since 2009; and
- the MacKay River upstream of the Suncor MacKay River Dover in situ development (*baseline* station MAR-2), sampled since 2002 (note that this station was excluded from the 2014 regional *baseline* calculations because of pilot-scale in situ oil sands activities undertaken further upstream in this watershed).

Monthly water quality sampling was also conducted at *baseline* station MAR-2 in 2013 and 2014.

Temporal Trends Significant (α=0.05) decreasing trends in fall concentrations of sulphate were observed over time at *test* station MAR-1 (1998 to 2014). A decreasing trend in chloride and an increasing trend in total arsenic were observed at *baseline* station MAR-2 (2002 to 2014). Trend analysis was not conducted for *test* station MAR-2A given that there were only five years of data available.

2014 Results Relative to Historical Concentrations In fall 2014, concentrations of water quality measurement endpoints were within previously-measured concentrations (Table 5.5-4 to Table 5.5-6) with the following exceptions:

- Naphthenic acids and oilsands extractable acids, with concentration that exceeded previously-measured maximum concentrations, and total dibenzothiophenes, total PAHs, total parent PAHs, and total Alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station MAR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);

- Conductivity, sodium, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations, and total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station MAR-2; and

- Sodium, chloride, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations, and total dissolved phosphorus, total nitrogen, total arsenic, total mercury (ultra-trace), retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station MAR-2A.

Ion Balance In fall 2014, the ionic composition of water at all stations of the MacKay River was consistent with previous sampling years and dominated by bicarbonate and calcium (Figure 5.5-7).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2 in fall 2014 exceeded the published guideline (Table 5.5-4 to Table 5.5-6).

Other Fall Water Quality Guideline Exceedances Other water quality guideline exceedances in fall 2014 included dissolved iron, total iron, and sulphide at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2. Total phenols also exceeded the water quality guideline at *test* station MAR-2A (Table 5.5-7).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, all water quality measurement endpoints were within the range of regional *baseline* concentrations, with the exception of the following (Figure 5.5-5):

- Total strontium, with a concentration that exceeded the 95^{th} percentile of regional *baseline* concentrations at *test* station MAR-1; and

- Total mercury (ultra-trace), with a concentration below the 5^{th} percentile of regional *baseline* concentrations at *test* station MAR-2A.

Water Quality Index The WQI for *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 were 91.2, 97.5, and 92.5, respectively. These values indicate **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2014.

Monthly Water Quality Results Water quality in 2014 was collected monthly at *baseline* station MAR-2 (Table 5.5-8). The maximum concentrations of most ions occurred in March and minimum concentrations occurred most frequently in May. Concentrations of PAHs were generally highest in May and lowest in September. Concentrations of metals did not follow an apparent monthly pattern.

Monthly Water Quality Guideline Exceedances Water quality exceedances measured at *baseline* station MAR-2 in 2014 included (Table 5.5-9):

- total mercury (ultra-trace) in April, May, and June;
- total chromium from April to July;
- total phenols from January to August;
- sulphide in all months, with the exception of March;
- total aluminum in all months, with the exception of January;
- dissolved aluminum in June; and
- total iron in all months and dissolved iron in all months, with the exception of June.

2014 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2014, monthly data collected at *baseline* station MAR-2 were generally within regional *baseline* conditions for fall, with the exception of (Figure 5.5-6):

- total suspended solids, with concentrations that exceeded the 95^{th} percentile of regional *baseline* fall concentrations in May and June (annual maximum);
- total dissolved solids in May and June, with concentrations below the 5^{th} percentile of regional *baseline* fall concentrations;
- dissolved phosphorus, with the maximum concentration in April exceeding the 95^{th} percentile of regional *baseline* fall concentrations;
- total strontium, with the maximum concentration in March exceeding the 95^{th} percentile of regional *baseline* fall concentrations;
- total mercury (ultra-trace), with concentrations that exceeded the 95^{th} percentile of regional *baseline* fall concentrations in April, May, and June;
- calcium, magnesium, alkalinity, and hardness, with concentrations below the 5^{th} percentile of regional *baseline* fall concentrations in May (annual minimum), June, and July;
- magnesium, with the maximum concentration in March exceeding the 95^{th} percentile of regional *baseline* fall concentrations;
- potassium, with the maximum concentration in April exceeding the 95^{th} percentile of the regional *baseline* fall concentrations; and
- pH, with a value below the 5^{th} percentile of regional *baseline* values in May and June.

Monthly Ion Balance The ionic composition of water at *baseline* station MAR-2 was consistently dominated by bicarbonate and calcium throughout the year and remained fairly consistent across months in 2014. Generally *baseline* station MAR-2 showed slightly less dominance in calcium in winter months and showed the lowest proportion of calcium in April 2014 (Figure 5.5-7).

Classification of Fall Results Concentrations of most water quality measurement endpoints in the MacKay River watershed were within the range of previously-measured concentrations and were within the range of regional *baseline* concentrations in fall 2014. Differences between water quality at *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 and regional *baseline* water quality conditions were classified as **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *baseline* station MAR-2. Typically, the maximum concentration of ions occurred in March and the minimum concentrations occurred in May, consistent with expected seasonal influences of surface-water runoff (i.e., greatest during freshet and weakest during winter low-flow conditions). The decrease in alkalinity in spring likely resulted from base-cation dilution by snowmelt rather than consumption of alkalinity by acidic compounds in snow, given consistent seasonal trends also were observed in other ions. Despite the observed changes in ion concentrations, the ionic composition remained relatively consistent throughout the year but was slightly less dominated by calcium in winter months.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- erosional *test* reach MAR-E1 near the mouth of the river, sampled since 1998 and designated *baseline* from 1998 to 2001, and *test* since 2002;
- erosional *test* reach MAR-E2 located upstream of the Suncor Dover development, sampled since 2002 and designated as *test* since 2005; and
- erosional *baseline* reach MAR-E3 located upstream of all Suncor in situ developments, sampled since 2010.

2014 Habitat Conditions Water at *test* reach MAR-E1 in fall 2014 was shallow (0.21 m in sampled areas), with moderate velocity (0.26 m/s), a pH of 7.9, moderate conductivity (290 µS/cm), and high dissolved oxygen (10.3 mg/L) (Table 5.5-10). Although this reach was classified as erosional, the substrate was dominated by sand/silt/clay (62%) with some gravel (small, 14% and large, 9%). Periphyton chlorophyll *a* biomass averaged 11 mg/m^2 and was within the normal range of *baseline* variability (Figure 5.5-8).

Water at *test* reach MAR-E2 was shallow (0.18 m in sampled areas) with high velocity (0.8 m/s), a pH of 7.8, moderate conductivity (242 µS/cm), and high dissolved oxygen (11.0 mg/L). The substrate at *test* reach MAR-E2 was dominated by large cobble (38%) and boulders (35%) (Table 5.5-10). Periphyton chlorophyll *a* biomass averaged 79 mg/m^2, which was within the normal range of *baseline* variability (Figure 5.5-8).

Water at *baseline* reach MAR-E3 was also shallow (0.24 m in sampled areas) with high velocity (0.74 m/s), a pH of 7.2, moderate conductivity (210 µS/cm) and high dissolved oxygen (9.3 mg/L) (Table 5.5-10). The substrate at *baseline* reach MAR-E3 was dominated by large cobble (46%) and large gravel (22%). Periphyton chlorophyll *a* biomass averaged 30 mg/m^2, which was within the normal range of regional *baseline* variability (Figure 5.5-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach MAR-E1 in fall 2014 was dominated by chironomids (62%) and mayflies (11%) with subdominant taxa consisting of water mites (Hydracarina: 7%) (Table 5.5-11). The most common chironomid taxa at *test* reach MAR-E1 included genera such as *Polypedilum*, *Stempellinella,* and *Chironomus.* Mayflies (Ephemeroptera) were diverse (15 types) and included the common, *Baetis*, *Acerpenna pygmaea*, *Ephemerella, Heptagenia*, and *Tricorythodes*. Other flying insects included stoneflies (*Isoperla, Taeniopteryx*, and Chloroperlidae) and caddisflies (*Hydropsyche* and *Oecetis)*. Permanent aquatic forms were represented by the limpet *Ferrissia rivularis*, which were found at only one replicate station at *test* reach MAR-E1.

The benthic invertebrate community at *test* reach MAR-E2 in fall 2014 was dominated by Ephemeroptera (40%) and chironomids (34%) with subdominant taxa consisting of naidid worms (13%) and water mites (Hydracarina: 4%) (Table 5.5-12). Chironomid taxa were diverse and dominated by *Polypedilum*, *Rheotanytarsus, Cricotopus/Orthocladius, Lopesocladius,* and *Tvetenia*. Similarly to the lower *test* reach, mayflies were diverse and were primarily *Acerpenna pygmaea, Baetis, Tricorythodes, Ephemerella, and Heptagenia,* but *Rhithrogena* were also abundant. Stoneflies (Plecoptera) were represented by *Isoperla, Claassenia sabulosa, Pteronarcys, Taeniopteryx, and Skwala*. Caddisflies were primarily *Lepidostoma*, *Cheumatopsyche*, and *Hydropsyche*. *Ophiogomphus* dragonflies were also present at most replicate stations. Permanent aquatic forms included the limpet *Ferrissia rivularis*, and *Pisidium/Sphaerium* bivalves.

The benthic invertebrate community at *baseline* reach MAR-E3 in fall 2014 was dominated by Ephemeroptera (42%) and Chironomidae (31%) with subdominant taxa consisting of naidid worms (6%), Hydracarina (6%) and Trichoptera (5%) (Table 5.5-12). Dominant chironomids included *Tvetenia, Rheotanytarsus, Polypedilum, Cricotopus/Orthocladius,* and *Lopesocladius.* Mayflies were abundant and diverse, represented primarily by the genera *Baetis, Acerpenna pygmaea, Tricorythodes*, *Heptagenia, Rhithrogena,* and *Ephemerella*. Plecoptera (Chloroperlidae, *Claassenia sabulosa, Skwala*, and *Isoperla*) and Trichoptera (*Brachycentrus, Hydropsyche, Cheumatopsyche*, *Glossosoma*, and *Lepidostoma*) were also present at *baseline* reach MAR-E3. Gastropods (*Ferrissia rivularis)* were present in low relative abundances at *baseline* reach MAR-E3.

Temporal and Spatial Comparisons Below are the temporal and spatial comparisons of benthic communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of the MacKay River. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach MAR-E1 included testing for:

- changes from before (1998, 2000, 2001) to after (2002 to present) the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);

- changes over time for the period that reach MAR-E1 has been designated as *test* (i.e., since 2002, Hypothesis 2, Section 3.2.3.1);
- changes between 2014 values and the mean of all *baseline* years; and
- changes between 2014 values and the mean of all previous years of sampling (1998 to 2013).

Temporal comparisons of measurement endpoints for *test* reach MAR-E2 included testing for:

- changes over time (Hypothesis 2, Section 3.2.3.1);
- changes between 2014 values and the mean of all *baseline* years; and
- changes between 2014 values and the mean of all previous years of sampling (2002 to 2013).

Spatial comparisons of measurement endpoints for *test* reaches MAR-E1 and MAR-E2 included testing for:

- differences from *baseline* reach MAR-E3 from 2010 to 2014 (Hypothesis 4, Section 3.2.3.1); and
- differences in 2014 values from all years at *baseline* reach MAR-E3.

Richness was lower at *test* reach MAR-1 compared to *baseline* reach MAR-E3, but was higher in 2014 at *test* reach MAR-E1 than the mean of all *baseline* years for the lower and upper reaches. These changes accounted for 22% and 20% of the variance in annual means, respectively (Table 5.5-13). Equitability was higher at *test* reach MAR-E1 compared to *baseline* reach MAR-E3, accounting for 24% of the variance in annual means (Table 5.5-13). CA Axis 2 scores were lower at *test* reach MAR-E1 compared to *baseline* reach MAR-E3, which accounted for 32% of the variance in annual means and was due to the historically low abundance of worms at the *baseline* reach.

The percentage of EPT taxa increased over time at *test* reach MAR-E2, accounting for 39% of the variance in annual means (Table 5.5-14). The CA Axis 2 scores were lower at *test* reach MAR-E2 than *baseline* reach MAR-E3 and were higher in 2014 at *test* reach MAR-E2 than all previous years at this reach. These changes accounted for 20% and 21% of the variance in annual means (Table 5.5-14). The higher CA Axis 2 scores in 2014 were likely due to the increase in the presence of Ephemeroptera at *test* reach MAR-E2.

Comparison to Published Literature The benthic invertebrate community at lower *test* reach MAR-E1 has remained in good condition and consistent to 2013. The percentage of the community as worms was lower (~5%) in 2014 than in recent years (Table 5.5-11). Ephemeroptera were prevalent in 2014 with the sensitive *Ephemerella* being one of the more dominant species. Other sensitive taxa such as Plecoptera and Trichoptera were also noted indicating a stable, cold-water habitat (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at middle *test* reach MAR-E2 was similar to the lower reach and reflected somewhat favourable conditions with high relative abundances of chironomids and Ephemeroptera, and with the presence of Plecoptera and Trichoptera (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at upper *baseline* reach MAR-E3 reflected good water quality conditions based on the relative abundance of chironomids and Ephemeroptera and the presence of Plecoptera and low relative abundances of worms (Griffiths 1998).

2014 Results Relative to Historical Conditions Values of measurement endpoints for *test* reach MAR-E1 were within the inner tolerance limits of the normal range of variation for the reach in previous years, with the exception of richness (Figure 5.5-9 and Figure 5.5-10). Richness was near the lower inner tolerance limit for the 5th percentile of previous years (Figure 5.5-10).

Values of measurement endpoints for *test* reach MAR-E2 were within the inner tolerance limits of the normal range of variation for all previous years at this reach, with the exception of the percentage of EPT taxa (Figure 5.5-9 and Figure 5.5-11). The percentage of EPT taxa exceeded the inner tolerance limit for the 95th percentile but was still within the outer tolerance limit.

2014 Results Relative to Regional *Baseline* Conditions Given that the percentage of EPT taxa at *test* reach MAR-E2 was outside of the inner tolerance limits from all previous years, it was compared to the tolerance limits of the normal range of variation for regional *baseline* erosional reaches. When compared against the regional *baseline* variability, the percentage of EPT taxa was within the inner tolerance limits.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach MAR-E1 were classified as **Negligible-Low** because although richness was significantly lower than *baseline* reach MAR-E3, richness was higher in 2014 than the mean of all *baseline* years for the lower and upper reaches. Differences in CA Axis 2 scores were due to slight differences in taxa composition between the lower *test* and upper *baseline* reaches. Additionally, the taxa composition at *test* reach MAR-E1 has remained stable and diverse over the past two years with the presence of EPT taxa and a low overall abundance of worms.

Differences in measurement endpoints for the benthic invertebrate community at *test* reach MAR-E2 were classified as **Negligible-Low** because the only significant change was an increasing trend over time for the percentage of the fauna as EPT taxa and differences in CA Axis 2 scores, which did not imply a negative change in the benthic invertebrate community. The benthic fauna at *test* reach MAR-E2 was representative of good overall water quality with a high percentage of EPT taxa and a low relative abundance of worms.

5.5.4.2 Sediment Quality

No sediment quality sampling was conducted in the MacKay River in 2014 because the reaches of the MacKay River where benthic invertebrate communities were sampled are erosional and sediment quality is only sampled in depositional reaches.

5.5.5 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- *test* reach MAR-F1, first sampled in 2009 and since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MAR-E1);
- *test* reach MAR-F2, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MAR-E2); and
- *baseline* reach MAR-F3, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *baseline* reach MAR-E3).

2014 Habitat Conditions *Test* reach MAR-F1 was comprised entirely of run habitat with a wetted width of 38.0 m and a bankfull width of 44.1 m. The substrate was primarily comprised of sand with some gravel. Water at *test* reach MAR-F1 had a mean depth of 0.58 m, moderate velocity (mean=0.31 m/s), a pH of 8.48, moderate conductivity (295 µS/cm), moderate dissolved oxygen (8.8 mg/L), and a temperature of 15.9˚C. Instream cover consisted primarily of algae with some small woody debris and overhanging vegetation (Table 5.5-15).

Test reach MAR-F2 was comprised of riffle habitat with a wetted width of 32.0 m and a bankfull width of 42.9 m. The substrate consisted of cobble with a few small boulders. Water at *test* reach MAR-F2 had a mean depth of 0.57 m, moderate velocity (mean=0.32 m/s), a pH or 8.75, moderate conductivity (227 µS/cm), high dissolved oxygen (11.2 mg/L), and a temperature of 10.4˚C. Instream cover consisted primarily of boulders with small amounts of algae, macrophytes, and small woody debris (Table 5.5-15).

Baseline reach MAR-F3 was comprised of run and riffle habitat with a wetted width of 34.0 m and a bankfull width of 40.0 m. The substrate was comprised of cobble with some coarse gravel. Water at *baseline* reach MAR-F3 had a mean depth of 0.92 m, moderate velocity (mean=0.37 m/s), a pH of 7.31, low conductivity (247 µS/cm), high dissolved oxygen (10.4 mg/L), and a temperature of 8.1˚C. Instream cover consisted primarily of boulders covered in algae with some macrophytes and small woody debris (Table 5.5-15).

Relative Abundance of Fish Species The total catch of fish species at *test* reach MAR-F1 was slightly higher in 2014 compared to 2013, with four more species captured in 2014 and burbot as the dominant species (30%) (Table 5.5-16). The total catch of fish species was higher in 2014 compared to 2013 at *test* reach MAR-F2 and *baseline* reach MAR-F3 and dominated by longnose dace (54% and 42%, respectively) (Table 5.5-16).

Temporal and Spatial Comparisons Temporal comparisons for *test* reaches MAR-F1 and MAR-F2 included testing for changes over time in measurement endpoints (Table 5.5-17) (Hypothesis 1, Section 3.2.4.4). Spatial comparisons included testing for differences in measurement endpoints between *baseline* reach MAR-F3 and the two *test* reaches (MAR-F1 and MAR-F2) over time (Hypothesis 2, Section 3.2.4.4).

There were significant decreases in abundance (p=0.004) and CPUE (p=0.01) over time at *test* reach MAR-F1, explaining greater than 21% of the variance in annual means (Table 5.5-18). There was also a decrease in the assemblage tolerance index (ATI) (p=0.003) at *test* reach MAR-F1 as a result of the high proportion of burbot and slimy sculpin, which are considered sensitive species (Whittier et al. 2007).

There were significant differences over time in ATI (p=0.04) and CPUE (p=0.02) between *test* reach MAR-F1 and *baseline* reach MAR-F3, explaining greater than 20% of the variation in annual means (Table 5.5-18). All other measurement endpoints for fish assemblages were relatively consistent between *test* reach MAR-F1 and *baseline* reach MAR-F3 (p>0.05).

There was a significant decrease in mean abundance (p<0.001) from 2009 to 2014 at *test* reach MAR-F2, explaining 38% of the variance in annual means (Table 5.5-18). There were no significant differences in measurement endpoints over time between *test* reach MAR-F2 and *baseline* reach MAR-F3 (p>0.05) (Table 5.5-18).

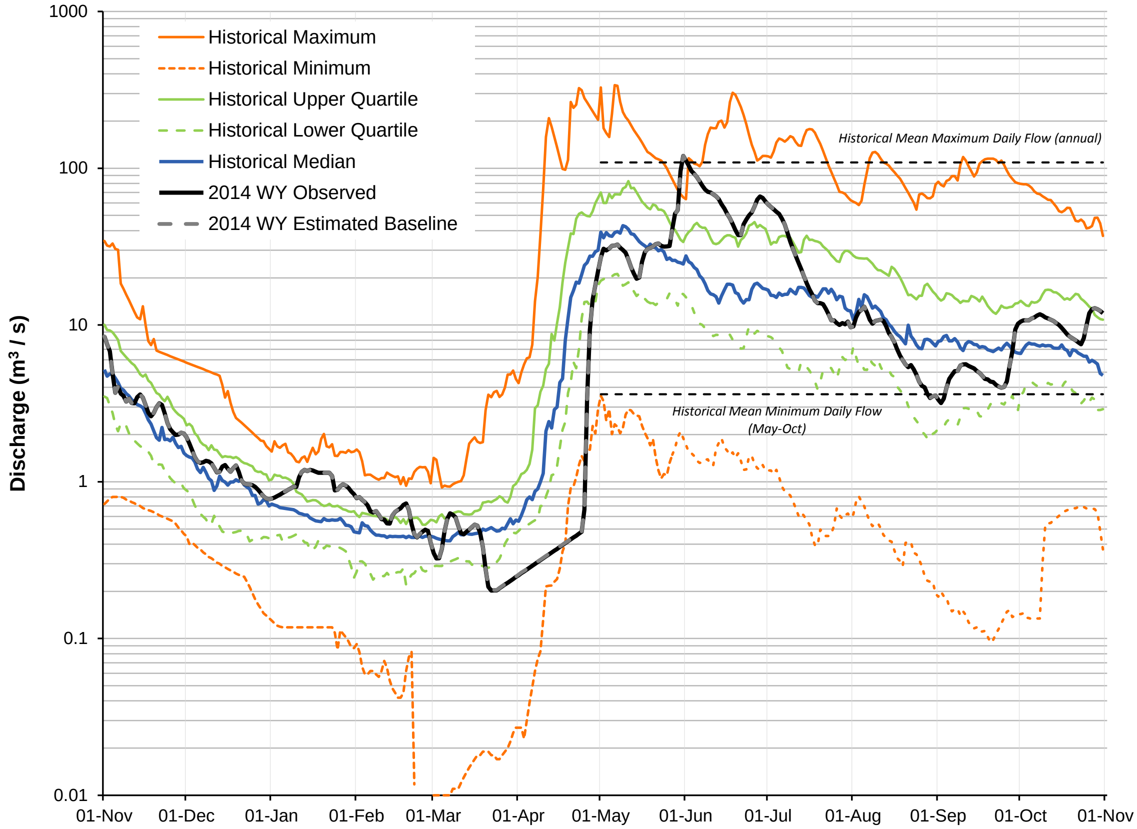
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of 23 fish species were recorded in the MacKay River watershed; whereas JOSMP found only 17 species from 2009 to 2014. Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., JOSMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder (2004).

Golder (2004) documented similar riffle and run habitat, with substrate consisting of sand, gravel, cobble, and boulders in the area of the river where both *test* reaches (MAR-F1 and MAR-F2), and the *baseline* reach (MAR-F3) are located (i.e., 1 km to 112 km from the mouth of the river), which was consistent with habitat conditions documented in fall 2014 (Table 5.5-15). This section of the river provides moderate to high fisheries potential (Golder 2004).

2014 Results Relative to Regional *Baseline* Conditions Mean values of diversity and ATI for *test* reach MAR-F1 were between the inner tolerance limits of regional *baseline* variability (Figure 5.5-12). Species richness exceeded the inner tolerance limit of the 95th percentile of *baseline* variability, indicating a positive change while CPUE and abundance were below the 5th percentile indicating a negative change at *test* reach MAR-F1. All measurement endpoints for *test* reach MAR-F2 and *baseline* reach MAR-F3 were between the inner tolerance limits of regional *baseline* variability (Figure 5.5-12).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach MAR-F1 were classified as **Moderate** because of significant decreases in abundance and CPUE over time and differences compared to *baseline* reach MAR-F3. In addition, abundance and CPUE were also lower than regional *baseline* conditions. Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F2 were classified as **Negligible-Low** given there was only a significant decrease in abundance over time and all measurement endpoints were within regional *baseline* variability.

Figure 5.5-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the MacKay River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26) provisional data. The upstream drainage area is 5,569.3 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1972 to 2013, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1987, and from 2002 to 2013.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.5-2 Estimated water balance at WSC Station 07DB001 (formerly JOSMP Station S26), MacKay River near Fort McKay, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**417.377**	**Observed discharge, obtained from MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.550	Estimated 7.34 km^2 of the MacKay River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	+0.596	Estimated 34.3 km^2 and 39.8 km^2 of the MacKay River watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the MacKay River watershed, relative to the estimated *baseline* hydrograph	-0.079	Water withdrawals by Suncor and Brion Energy (daily values provided)
Water releases into the MacKay River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**417.410**	**Estimated *baseline* discharge at MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-0.033	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-0.008**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Table 5.5-3 Calculated change in hydrologic measurement endpoints for the MacKay River watershed, 2014 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	24.750	24.751	-0.004%
Mean winter discharge	1.327	1.327	-0.069%
Annual maximum daily discharge	120.000	119.992	0.007%
Open-water season minimum daily discharge	3.180	3.181	-0.045%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from provisional data from WSC Station 07DB001.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.5-4 Concentrations of water quality measurement endpoints, mouth of MacKay River (*test* station MAR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	15	7.6	8.2	8.6
Total suspended solids	mg/L	-	<3.0	15	<2.0	7.0	41
Conductivity	µS/cm	-	334	15	183	268	576
Nutrients							
Total dissolved phosphorus	mg/L	-	0.023	15	0.004	0.027	0.048
Total nitrogen	mg/L	-	0.964	15	0.400	1.07	3.20
Nitrate+nitrite	mg/L	3	<0.054	15	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	29.2	15	20.0	28.3	40.0
Ions							
Sodium	mg/L	-	24.1	15	15.0	20.0	60.0
Calcium	mg/L	-	33.9	15	20.8	27.3	44.7
Magnesium	mg/L	-	11.50	15	7.26	9.00	15.90
Chloride	mg/L	120	4.19	15	1.20	4.00	41.2
Sulphate	mg/L	309	15.9	15	9.3	16.1	35.5
Total dissolved solids	mg/L	-	248	15	170	213	342
Total alkalinity	mg/L	-	148	15	80	124	202
Selected metals							
Total aluminum	mg/L	0.1	**0.163**	15	0.050	**0.238**	**1.740**
Dissolved aluminum	mg/L	0.05	0.022	15	0.007	0.024	0.046
Total arsenic	mg/L	0.005	0.0009	15	0.0007	0.0010	0.0013
Total boron	mg/L	1.2	0.100	15	0.051	0.080	0.140
Total molybdenum	mg/L	0.073	0.00031	15	0.00015	0.00036	0.00060
Total mercury (ultra-trace)	ng/L	5, 13	2.0	11	<1.2	<1.2	**6.3**
Total strontium	mg/L	-	0.191	15	0.108	0.158	0.287
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.77</u>	3	0.06	0.17	0.30
Oilsands Extractable	mg/L	-	<u>1.20</u>	3	0.56	0.80	1.18
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.905	3	<2.05	2.07	5.55
Total dibenzothiophenes	ng/L	-	<u>23.95</u>	3	49.94	68.53	289.1
Total PAHs	ng/L	-	<u>131.6</u>	3	266.5	271.9	1,028
Total Parent PAHs	ng/L	-	<u>14.76</u>	3	21.87	25.57	30.37
Total Alkylated PAHs	ng/L	-	<u>116.9</u>	3	241.0	250.0	997.8
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.690**	15	0.230	**0.480**	**1.110**
Sulphide	mg/L	0.002	**0.010**	15	**0.003**	**0.012**	**0.032**
Total iron	mg/L	0.3	**1.11**	15	**0.31**	**1.00**	**23.30**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.5-5 Concentrations of water quality measurement endpoints, middle MacKay River (*test* station MAR-2A), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2009-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	4	8.0	8.3	8.4
Total suspended solids	mg/L	-	3.0	4	<3	4.0	376
Conductivity	µS/cm	-	260	4	196	237	268
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.020</u>	4	0.027	0.036	0.046
Total nitrogen	mg/L	-	<u>0.91</u>	4	1.11	1.41	1.75
Nitrate+nitrite	mg/L	3	<0.054	4	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	30.8	4	24.7	33.3	39.6
Ions							
Sodium	mg/L	-	<u>17.6</u>	4	12.9	14.6	15.6
Calcium	mg/L	-	30.9	4	19.4	28.0	31.3
Magnesium	mg/L	-	9.76	4	6.77	8.45	10.00
Chloride	mg/L	120	<u>1.14</u>	4	0.53	0.64	0.74
Sulphate	mg/L	309	14.7	4	7.6	10.6	18.4
Total dissolved solids	mg/L	-	215	4	198	216	244
Total alkalinity	mg/L	-	115	4	91.9	112	122
Selected metals							
Total aluminum	mg/L	0.1	**0.170**	4	**0.116**	**0.145**	**9.650**
Dissolved aluminum	mg/L	0.05	0.026	4	0.017	0.025	**0.147**
Total arsenic	mg/L	0.005	<u>0.0010</u>	4	0.0011	0.0011	0.0023
Total boron	mg/L	1.2	0.074	4	0.056	0.065	0.080
Total molybdenum	mg/L	0.073	0.0004	4	<0.0001	0.0003	0.0006
Total mercury (ultra-trace)	ng/L	5, 13	<u>0.23</u>	4	0.60	2.2	**10.6**
Total strontium	mg/L	-	0.150	4	0.109	0.144	0.168
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.89</u>	3	0.06	0.36	0.39
Oilsands Extractable	mg/L	-	<u>1.60</u>	3	0.42	0.91	1.12
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<u>0.592</u>	3	1.000	4.150	28.60
Total dibenzothiophenes	ng/L	-	<u>4.606</u>	3	6.672	8.454	75.43
Total PAHs	ng/L	-	<u>75.44</u>	3	102.5	171.4	717.3
Total Parent PAHs	ng/L	-	<u>13.27</u>	3	19.82	22.44	56.72
Total Alkylated PAHs	ng/L	-	<u>62.17</u>	3	80.05	151.5	660.6
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.740**	4	**0.521**	**0.792**	**1.160**
Sulphide	mg/L	0.002	**0.012**	4	**0.005**	**0.012**	**0.018**
Total iron	mg/L	0.3	**1.22**	4	**1.05**	**1.36**	**6.44**
Total phenols	mg/L	0.004	**<u>0.005</u>**	4	**0.008**	**0.010**	**0.011**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.5-6 Concentrations of water quality measurement endpoints, upper MacKay River (*baseline* station MAR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	12	7.8	8.2	8.3
Total suspended solids	mg/L	-	4.1	12	<3.0	<3.0	23.0
Conductivity	µS/cm	-	<u>284</u>	12	164	224	264
Nutrients							
Total dissolved phosphorus	mg/L	-	0.032	12	0.008	0.036	0.052
Total nitrogen	mg/L	-	0.974	12	0.800	1.25	3.10
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	0.100
Dissolved organic carbon	mg/L	-	30.8	12	22.0	31.5	41.0
Ions							
Sodium	mg/L	-	<u>20.1</u>	12	11.0	14.7	19.0
Calcium	mg/L	-	30.5	12	17.8	25.0	34.5
Magnesium	mg/L	-	10.2	12	6.3	8.5	11.0
Chloride	mg/L	120	0.83	12	<0.5	1.5	3.0
Sulphate	mg/L	309	14.0	12	6.58	9.98	23.7
Total dissolved solids	mg/L	-	211	12	160	195	240
Total alkalinity	mg/L	-	128	12	75	104	128
Selected metals							
Total aluminum	mg/L	0.1	**0.201**	12	0.020	**0.167**	**1.080**
Dissolved aluminum	mg/L	0.05	0.021	12	<0.001	0.025	0.044
Total arsenic	mg/L	0.005	0.0011	12	0.0006	0.0010	0.0013
Total boron	mg/L	1.2	0.100	12	0.043	0.057	0.105
Total molybdenum	mg/L	0.073	0.00038	12	0.00013	0.00030	0.00055
Total mercury (ultra-trace)	ng/L	5, 13	2.32	11	0.60	1.60	5.00
Total strontium	mg/L	-	0.171	12	0.105	0.133	0.197
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.25	3	0.15	0.25	0.25
Oilsands Extractable	mg/L	-	<u>1.70</u>	3	0.18	0.79	1.21
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.743	3	0.983	1.19	<2.07
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	6.672	16.11	35.33
Total PAHs	ng/L	-	<u>74.13</u>	3	102.6	193.4	205.1
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	16.73	20.01	22.44
Total Alkylated PAHs	ng/L	-	<u>60.88</u>	3	80.19	173.4	188.3
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.834**	12	0.289	**0.593**	**1.240**
Sulphide	mg/L	0.002	**0.014**	12	**0.005**	**0.018**	**0.030**
Total iron	mg/L	0.3	**1.30**	12	**0.386**	**1.06**	**1.66**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Figure 5.5-4 Piper diagram of fall ion concentrations in the MacKay River watershed.

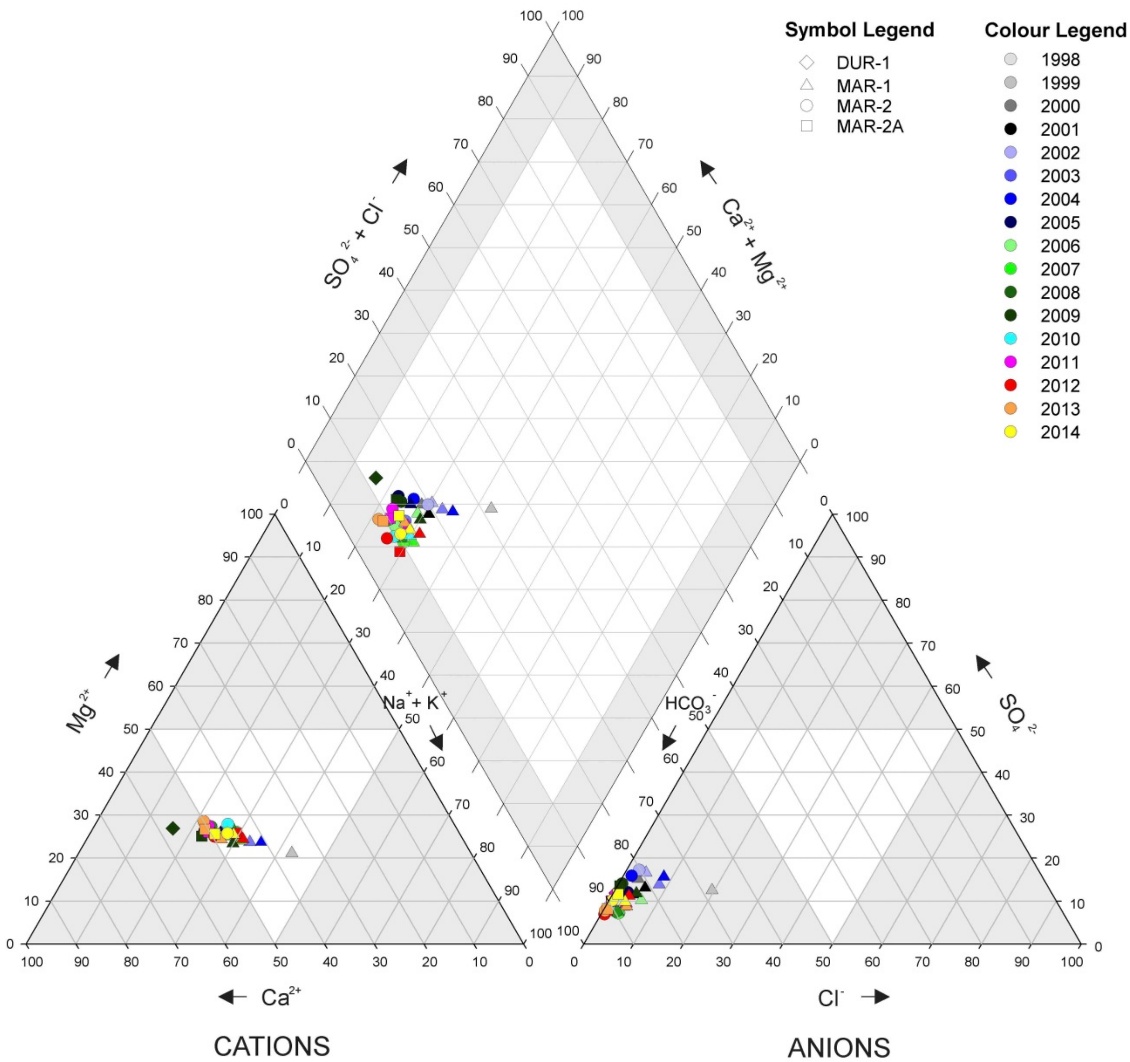
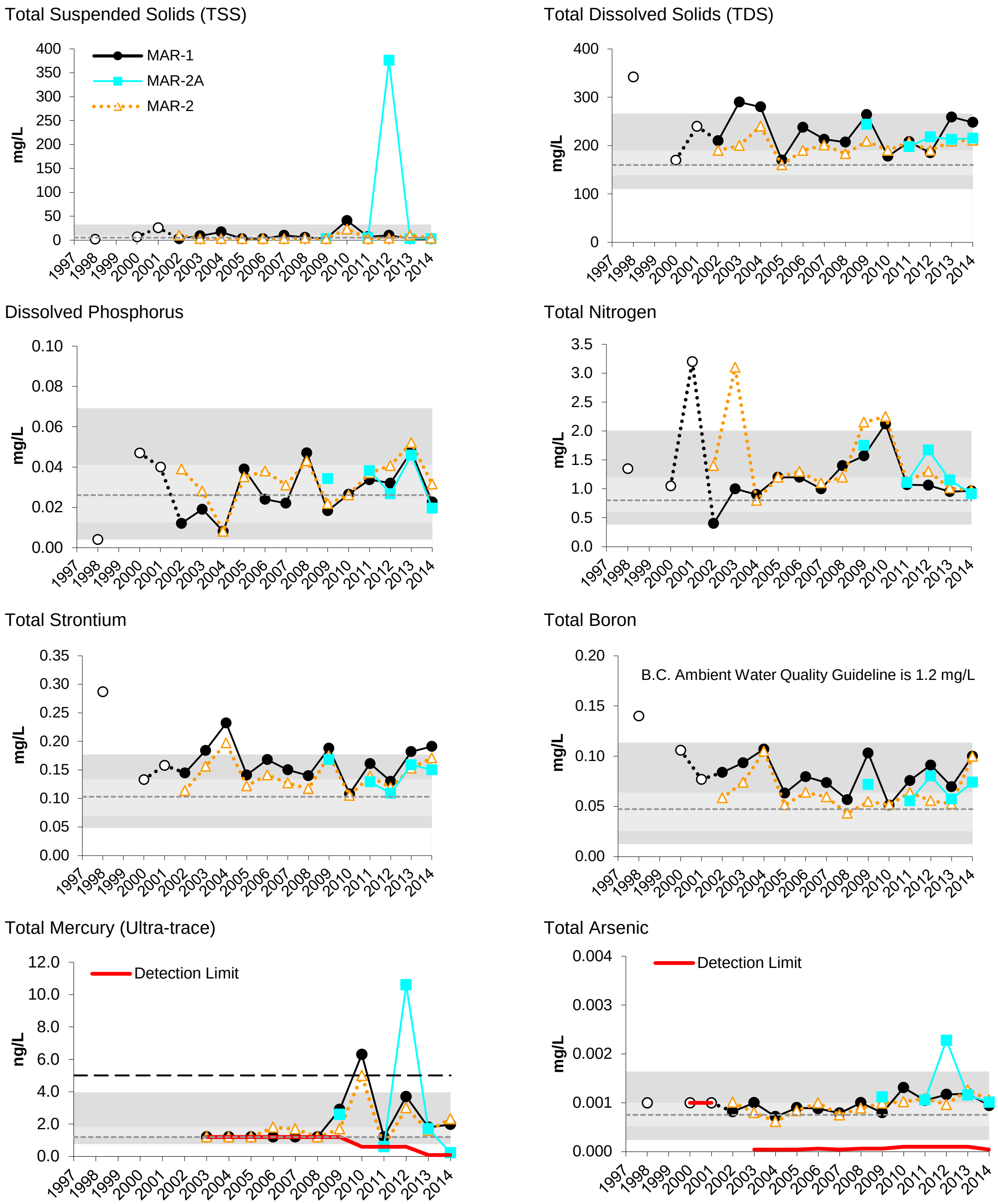


Table 5.5-7 Water quality guideline exceedances, MacKay River watershed, fall 2014.

Variable	Units	Guideline[a]	MAR-1	MAR-2	MAR-2A
Dissolved iron	mg/L	0.3	0.69	0.83	0.74
Sulphide	mg/L	0.002	0.010	0.014	0.012
Total aluminum	mg/L	0.1	0.16	0.20	0.17
Total iron	mg/L	0.3	1.11	1.30	1.22
Total phenols	mg/L	0.004	-	-	0.005

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.5-5 Concentrations of selected water quality measurement endpoints in the MacKay River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

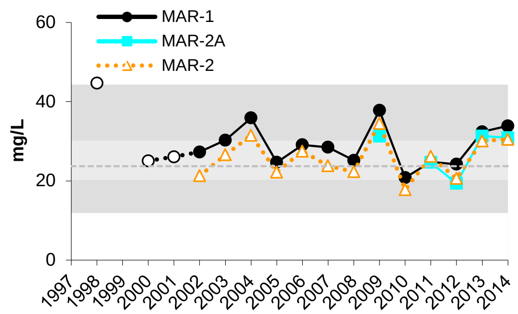
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

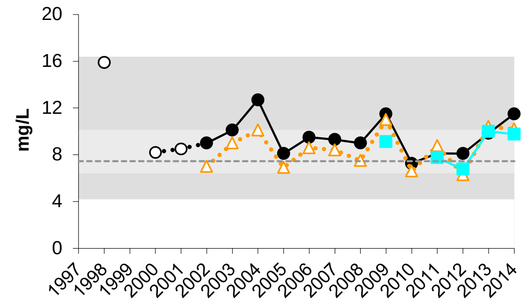
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.5-5 (Cont'd.)

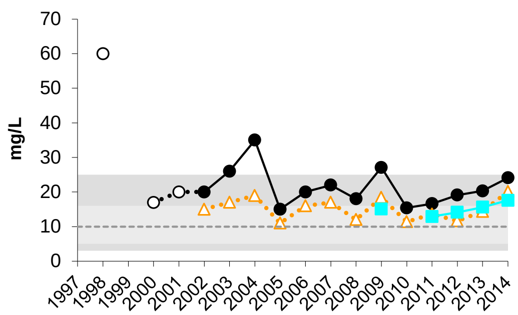
Calcium



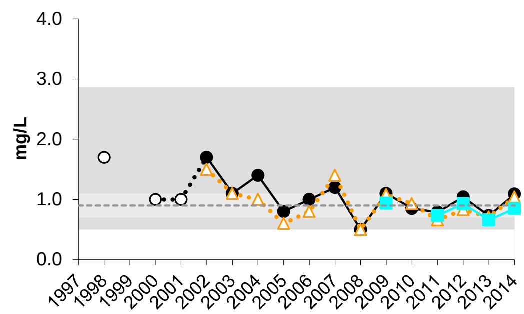
Magnesium



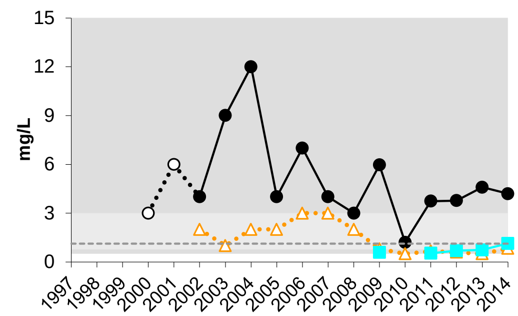
Sodium



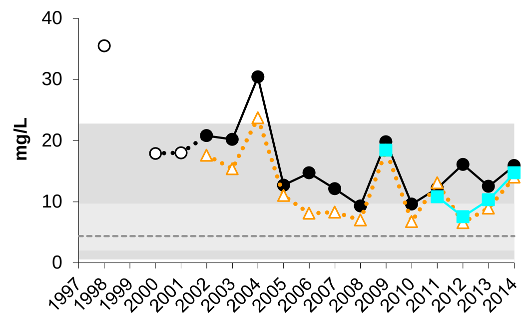
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.5-8 Monthly water quality measurement endpoints, upper MacKay River (*baseline* station MAR-2), January to December 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence						2013 Range (n=12)	
			n	Min		Median	Max		Min	Max
Physical variables										
pH	pH units	6.5-9.0	12	7.38	(May)	7.89	8.16	(August)	7.78	8.18
Total suspended solids	mg/L	-	12	<20.6	(April)	31	43.1	(November)	<3	201
Conductivity	µS/cm	-	12	120	(June)	273.5	635	(March)	93	532
Nutrients										
Total dissolved phosphorus	mg/L	-	12	0.023	(June)	0.043	0.122	(April)	0.030	0.085
Total nitrogen	mg/L	-	12	0.934	(June)	1.109	1.357	(March)	1.001	1.591
Nitrate+nitrite	mg/L	3	12	<0.054	(May-Nov)	<0.054	0.507	(March)	<0.070	0.447
Dissolved organic carbon	mg/L	-	12	21.8	(April)	30.6	43.4	(November)	6.7	38.5
Ions										
Sodium	mg/L	-	12	7.3	(May)	19.9	49.1	(March)	6.8	42.4
Calcium	mg/L	-	12	12.9	(May)	27.8	67.8	(March)	9.4	55.0
Magnesium	mg/L	-	12	4.3	(May)	9.4	22.6	(March)	3.2	17.2
Chloride	mg/L	120	12	<0.50	(Jun, Jul)	1.09	3.98	(March)	<0.50	6.33
Sulphate	mg/L	429	12	5.86	(July)	14.2	61	(March)	4.6	47.8
Total dissolved solids	mg/L	-	12	132	(May)	203.5	444	(March)	138	370
Total alkalinity	mg/L	-	12	53	(June)	117	296	(March)	40	230
Selected metals										
Total aluminum	mg/L	0.1	12	0.055	(January)	**0.313**	**4.57**	(June)	0.076	**9.57**
Dissolved aluminum	mg/L	0.05	12	0.010	(March)	0.031	**0.068**	(June)	0.014	**0.116**
Total arsenic	mg/L	0.005	12	0.0008	(October)	0.0010	0.0014	(May)	0.0008	0.0023
Total boron	mg/L	1.2	12	0.041	(May)	0.083	0.164	(March)	0.048	0.173
Total molybdenum	mg/L	0.073	12	0.00017	(October)	0.00039	0.00064	(March)	0.00013	0.00054
Total mercury (ultra-trace)	ng/L	5, 13	12	1.32	(January)	2.37	**6.76**	(May)	<1.20	**6.20**
Total strontium	mg/L	-	12	0.072	(May)	0.153	0.365	(March)	0.067	0.319
Total hydrocarbons										
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	12	<0.02	(July)	0.37	0.61	(November)	0.05	0.60
Oilsands Extractable	mg/L	-	12	0.35	(April)	1.18	2.80	(August)	0.27	1.21
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	12	<7.21	-	<7.21	10.60	(January)	<15.16	29.10
Retene	ng/L	-	12	0.74	(September)	1.18	15.30	(May)	0.90	52.00
Total dibenzothiophenes	ng/L	-	12	4.13	-	5.20	22.28	(May)	6.67	28.14
Total PAHs	ng/L	-	12	74.1	(September)	83.9	177.5	(May)	102.6	362.4
Total Parent PAHs	ng/L	-	12	13.3	(September)	13.9	16.7	(January)	22.4	45.3
Total Alkylated PAHs	ng/L	-	12	60.9	(September)	68.6	161.4	(May)	80.2	336.5
Other variables that exceeded CCME/AESRD guidelines in 2014[1]										
Total phenols	mg/L	0.004	8	<0.001	(December)	**0.005**	**0.011**	(April)	<0.001	**0.011**
Sulphide	mg/L	0.002	11	<0.002	(March)	0.0103	**0.0272**	(July)	**0.0446**	**0.2700**
Total iron	mg/L	0.3	12	**1.010**	(October)	**1.915**	**2.940**	(May)	**1.080**	**7.160**
Dissolved iron	mg/L	0.3	1	0.299	(June)	**0.797**	**1.4**	(January)	**0.445**	**1.680**
Total chromium	mg/L	0.001	4	<0.0003	(Jan, Mar)	0.0004	**0.0037**	(June)	<0.0003	**0.0092**

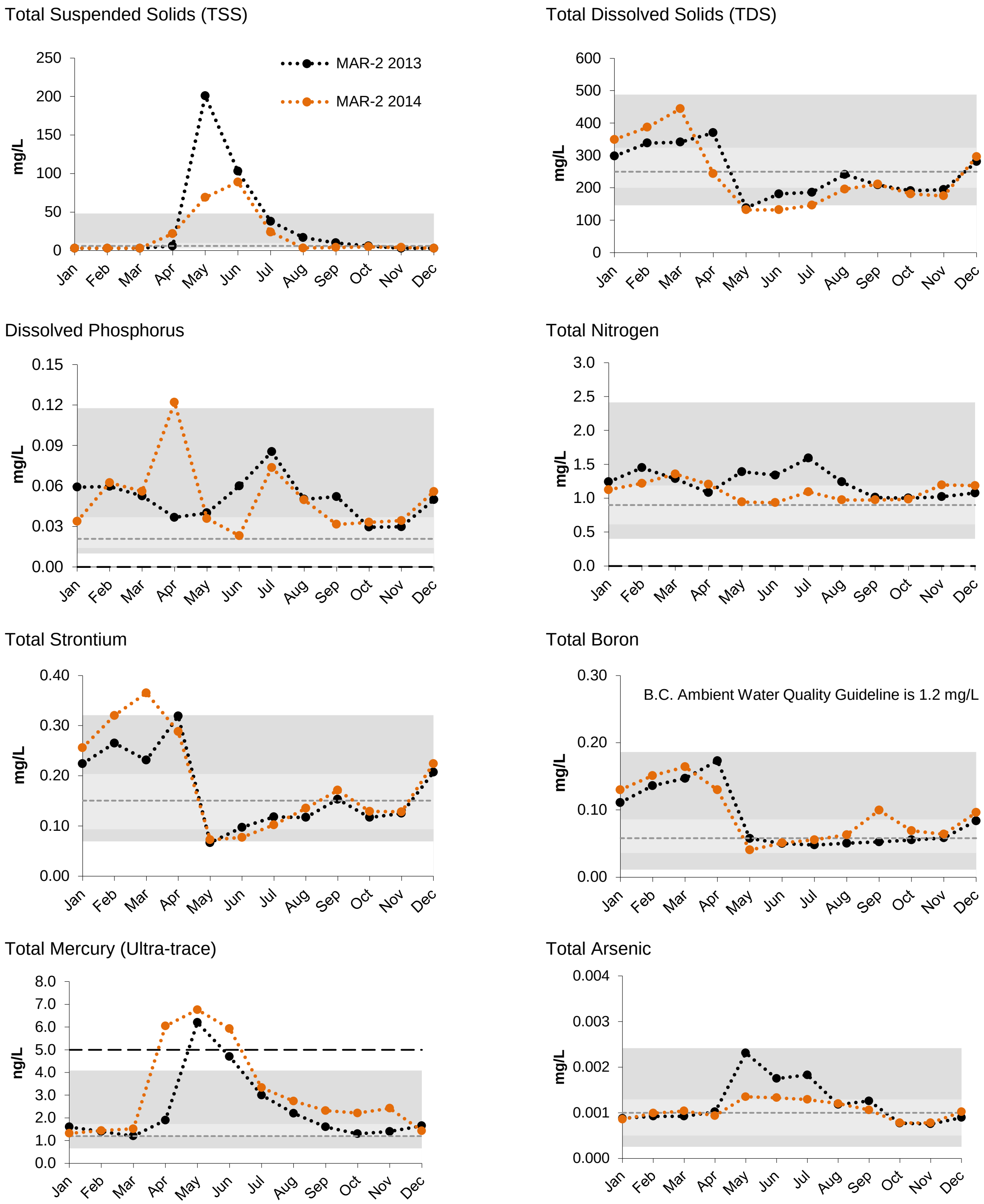
[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.
[1] n value refers to number of exceedances in 2014.

Table 5.5-9 Monthly water quality guideline exceedances, upper MacKay River (*baseline* station MAR-2), January to December 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0076	0.0076	0.005	0.0109	0.0097	<0.005	0.005	0.0052	-	-	-	-
Sulphide	mg/L	0.002	0.0104	0.0092	-	0.0033	0.0044	0.0034	0.0272	0.0121	0.0139	0.0153	0.0203	0.0102
Total aluminum	mg/L	0.1	-	0.395	0.166	2.22	3.17	4.57	1.37	0.199	0.201	0.29	0.336	0.248
Dissolved aluminum	mg/L	0.05	-	-	-	-	-	0.0676	-	-	-	-	-	-
Total iron	mg/L	0.3	1.82	1.95	1.97	2.04	2.94	2.83	1.94	1.23	1.3	1.01	1.56	1.89
Dissolved iron	mg/L	0.3	1.4	1.02	0.754	0.445	0.759	-	0.882	0.709	0.834	0.524	0.922	1.39
Total chromium	mg/L	0.001	-	-	-	0.00183	0.00252	0.0037	0.00125	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.5-6 Concentrations of selected water quality measurement endpoints in the upper MacKay River (monthly data) relative to regional *baseline* fall concentrations.



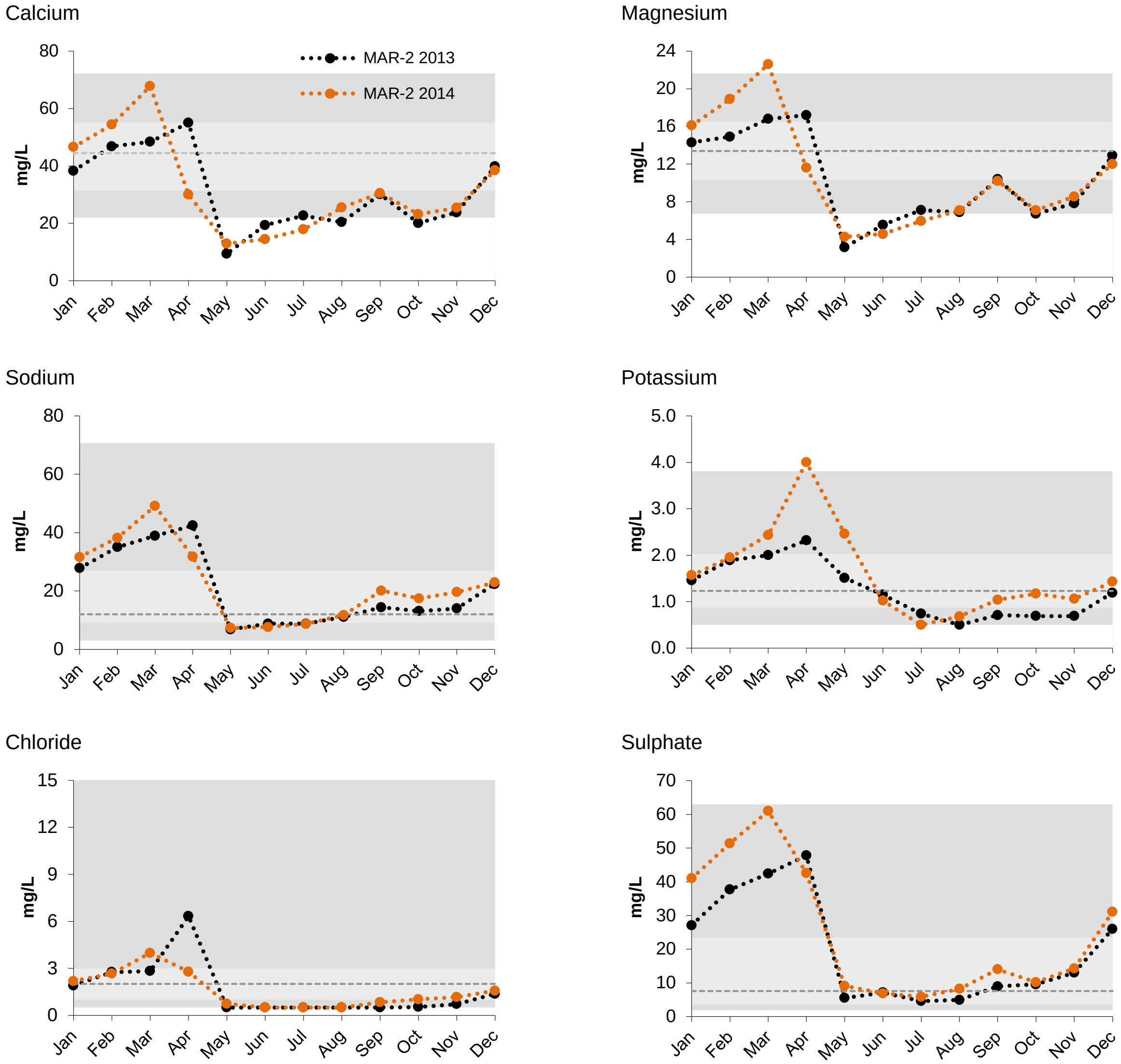
Non-detectable values are shown at the detection limit.

– – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.5-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

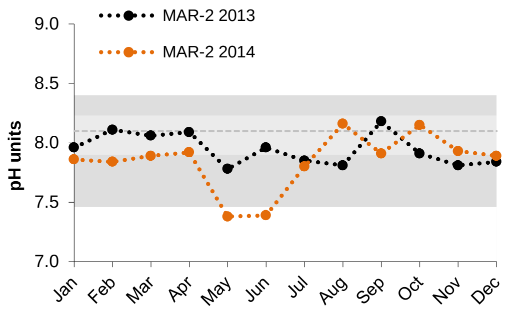
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

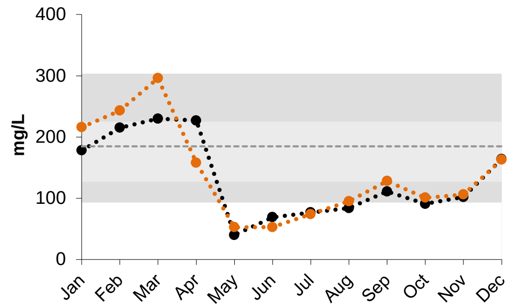
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.5-6 (Cont'd.)

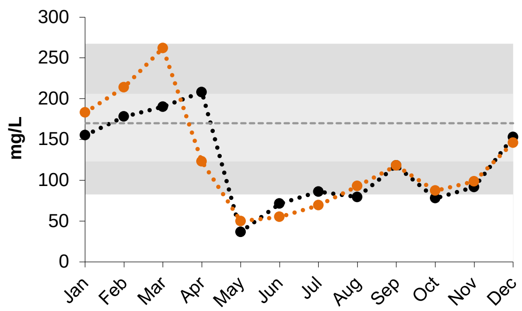
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.5-7 Piper diagram of monthly ion concentrations in the upper MacKay River (*baseline* station MAR-2).

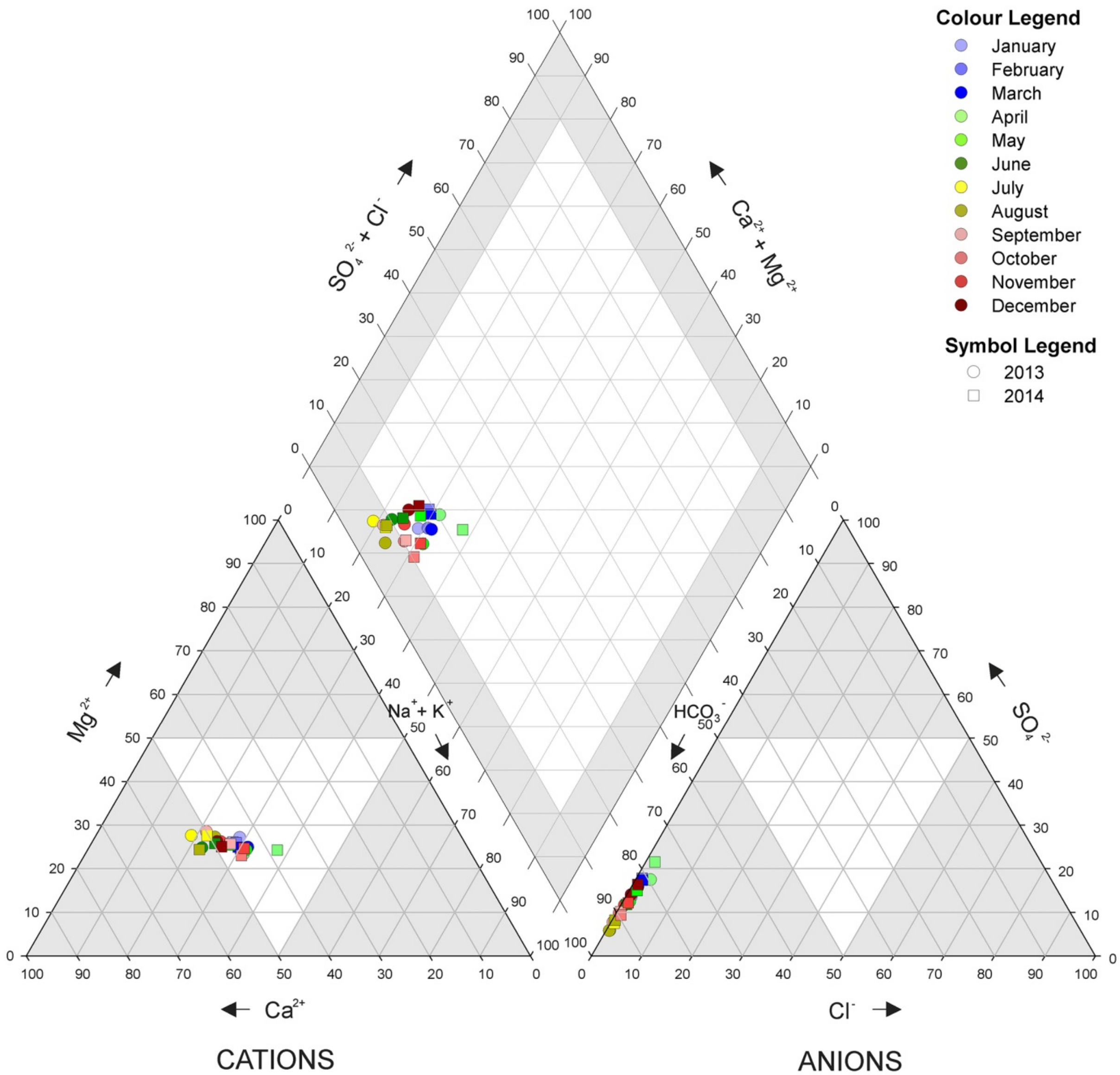
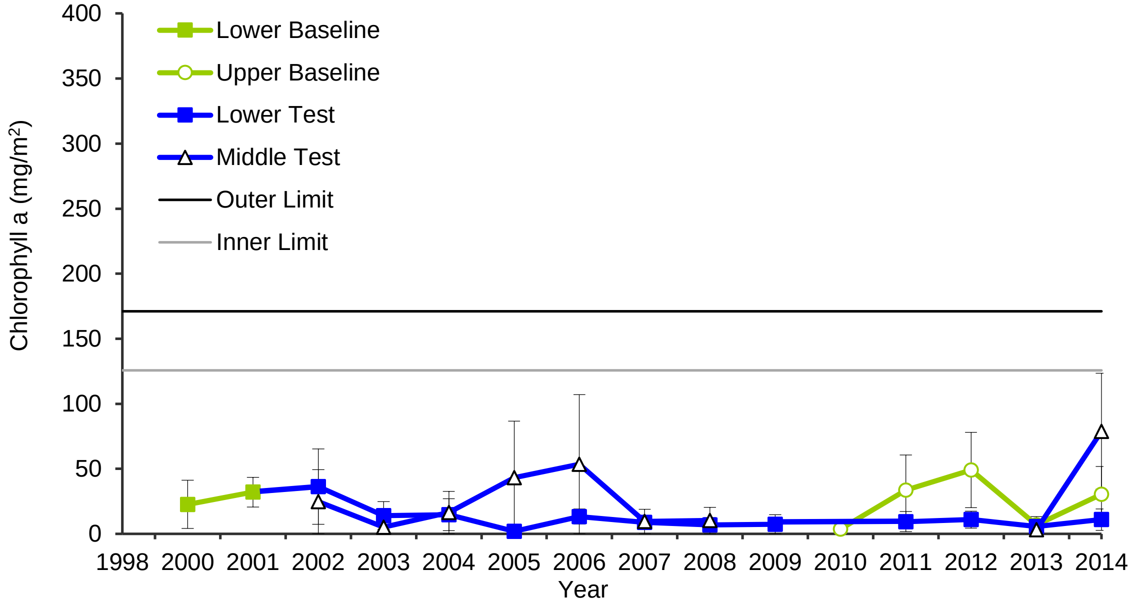


Table 5.5-10 Average habitat characteristics of benthic invertebrate sampling locations in the MacKay River, fall 2014.

Variable	Units	MAR-E1 Lower *Test* Reach	MAR-E2 Middle *Test* Reach	MAR-E3 Upper *Baseline* Reach
Sample date	-	Sept 10, 2014	Sept 8 2014	Sept 3, 2014
Habitat	-	Erosional	Erosional	Erosional
Water depth	m	0.21	0.18	0.24
Current velocity	m/s	0.26	0.77	0.74
Field Water Quality				
Dissolved oxygen	mg/L	10.3	11.0	9.3
Conductivity	µS/cm	290.0	241.5	210.0
pH	pH units	7.9	7.9	7.2
Water temperature	°C	7.5	8.8	16
Sediment Composition (mean ± 1SD)				
Sand/Silt/Clay	%	62±5	-	9±14
Small Gravel	%	14±8	<1±2	4±8
Large Gravel	%	9±3	3±4	22±16
Small Cobble	%	7±3	13±16	13±14
Large Cobble	%	8±3	38±16	46±30
Boulder	%	1±2	35±23	6±13
Bedrock	%	<1±2	11±19	-

Figure 5.5-8 Periphyton chlorophyll *a* biomass in *test* (MAR-E1 and MAR-E2) and *baseline* (MAR-E3) reaches of the MacKay River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* reaches for years up to and including 2013.

Table 5.5-11 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community in the lower MacKay River.

Taxon	Percent Major Taxa Enumerated in Each Year *Test* Reach MAR-E1		
	1998	2000-2013	2014
Hydra	<1	0 to <1	-
Nematoda	2	1 to 8	<1
Naididae	2	2 to 30	3
Tubificidae	2	<1 to 23	1
Enchytraeidae	4	1 to 12	1
Lumbriculidae	-	0 to <1	-
Erpobdellidae	-	0 to <1	-
Hydracarina	1	<1 to 18	7
Gastropoda	<1	0 to 3	1
Bivalvia	-	0 to 4	-
Ceratopogonidae	1	<1 to 5	1
Chironomidae	57	2 to 69	62
Diptera (misc.)	1	0 to 12	5
Coleoptera	<1	0 to <1	-
Ephemeroptera	26	6 to 29	11
Odonata	1	<1 to 5	3
Plecoptera	2	<1 to 8	4
Trichoptera	<1	<1 to 5	<1
Heteroptera	<1	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	1,276	221 to 1,200	494
Richness	49	23 to 38	32
Equitability	0.16	0.23 to 0.38	0.34
% EPT	26	7 to 42	16

Table 5.5-12 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in the middle and upper reaches of the MacKay River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach MAR-E2			*Baseline* Reach MAR-E3		
	2002	2003-2013	2014	2010	2011-2013	2014
Hydra	<1	-	-	-	-	-
Nematoda	3	1 to 4	1	1	<1 to 3	1
Naididae	48	2 to 32	13	41	15 to 18	6
Tubificidae	<1	<1 to 8	-	<1	<1 to <1	<1
Enchytraeidae	1	<1 to 4	<1	2	<1 to 3	1
Lumbriculidae	-	0 to 3	-	-	-	-
Erpobdellidae	-	0 to <1	-	-	-	-
Hydracarina	7	4 to 21	4	5	8 to 13	6
Gastropoda	<1	0 to 2	<1	1	<1 to <1	2
Bivalvia	<1	0 to 4	<1	1	<1 to 1	-
Ceratopogonidae	<1	<1 to 3	<1	1	<1 to <1	<1
Chironomidae	31	3 to 63	34	25	35 to 64	31
Diptera (misc.)	1	<1 to 5	1	<1	<1 to 2	1
Coleoptera	-	0 to <1	<1	<1	<1 to 1	<1
Ephemeroptera	2	1 to 31	40	9	14 to 18	42
Odonata	<1	<1 to 1	1	<1	<1 to 1	1
Plecoptera	<1	1 to 3	2	3	2 to 4	3
Neuroptera	-	-	-	-	<1	-
Trichoptera	6	1 to 12	3	8	7 to 10	5
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	2,524	320 to 1,662	811	618	533 to 1,206	1,205
Richness	40	27 to 41	34	35	31 to 43	40
Equitability	0.11	0.16 to 0.40	0.25	0.24	0.26 to 0.32	0.25
% EPT	8	16 to 36	45	22	26 to 29	50

Table 5.5-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E1 of the MacKay River.

Measurement Endpoint	P-value					Variance Explained (%)					Nature of Change(s)
	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Time Trend (*Test* Period)**	**2014 vs. *Baseline* Years**	**2014 vs. Previous Years**	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Time Trend (*Test* Period)**	**2014 vs. *Baseline* Years**	**2014 vs. Previous Years**	
Log of Abundance	0.055	0.761	**<0.001**	**0.002**	0.111	3	0	12	7	2	Decreasing over time in *test* period at *test* reach; lower in 2014 at lower *test* reach than mean of all *baseline* years at the lower and upper reaches.
Log of Richness	**<0.001**	0.980	0.246	**<0.001**	**0.031**	22	0	2	20	5	Lower at *test* reach; decreasing over time at *test* reach; higher in 2014 at lower *test* reach than mean of all *baseline* years at the lower and upper reaches.
Equitability	**<0.001**	0.469	0.482	0.068	0.351	24	1	1	6	2	Higher at *test* reach.
Log of EPT	**<0.001**	**0.037**	**<0.001**	0.437	**0.032**	13	4	13	1	4	Lower at *test* reach; lower during *test* period at *test* reach; decreasing over time at *test* reach and was lower in 2014 than mean of previous years.
CA Axis 1	**0.014**	**<0.001**	**0.001**	0.280	0.797	3	12	6	1	5	Higher at *test* reach; higher at *test* reach during *test* period; increasing over time at *test* reach.
CA Axis 2	**<0.001**	0.072	**<0.001**	**<0.001**	**0.019**	32	2	16	11	3	Lower at *test* reach; decreasing over time during *test* period; lower in 2014 at lower *test* reach than mean of all previous years at *test* reach and mean of all *baseline* years at the upper and lower reaches.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of spatial and temporal trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.5-14 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E2 of the MacKay River.

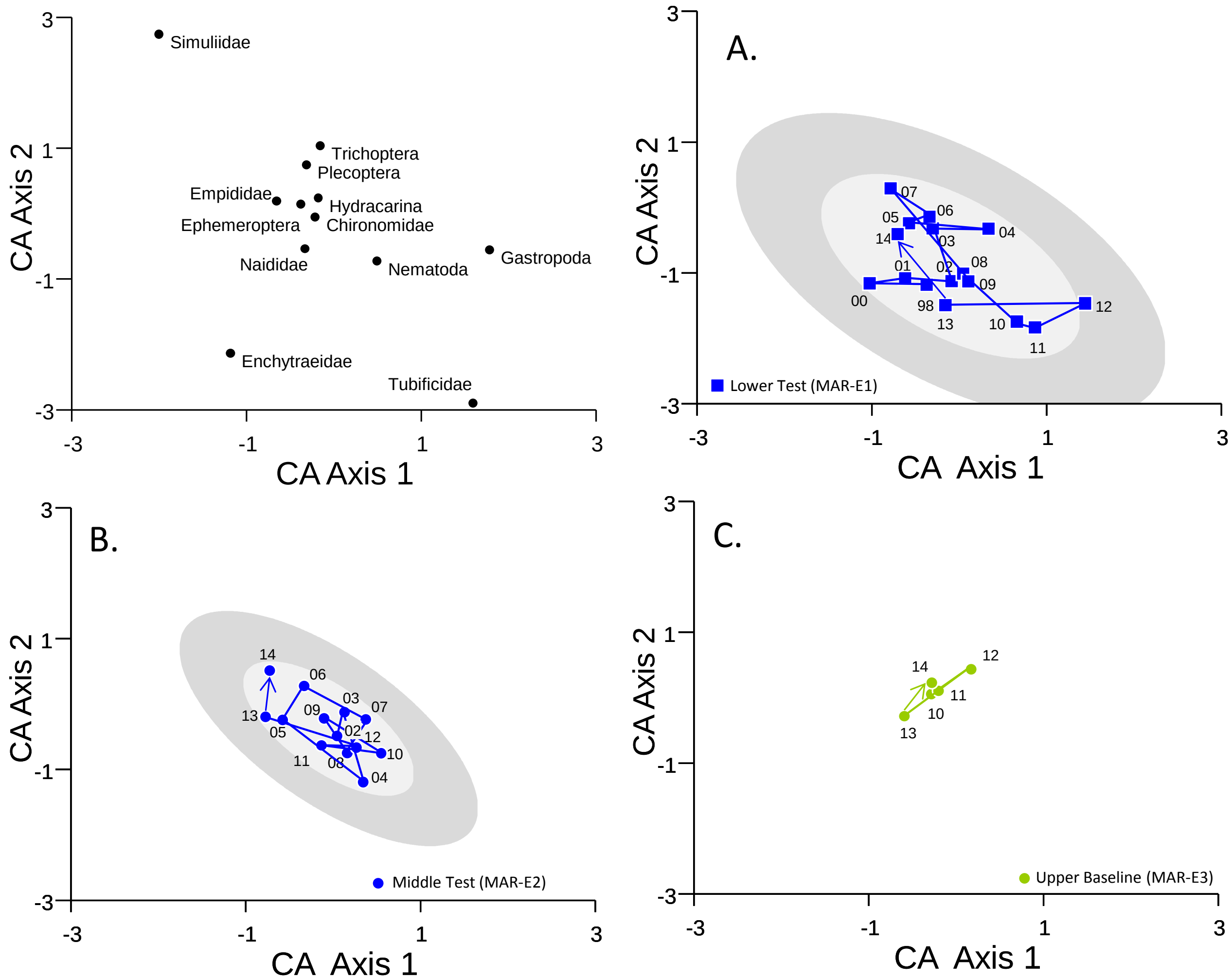
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	0.260	**<0.001**	0.861	0.409	1	12	0	0	Decreasing over time at *test* reach.
Log of Richness	0.546	0.448	0.742	0.477	0	1	0	1	No change.
Equitability	0.398	0.073	0.922	0.723	1	3	0	0	No change.
Log of EPT	0.072	**<0.001**	**0.003**	**<0.001**	3	39	7	15	Increasing over time at *test* reach; higher in 2014 than mean of all previous years and all years at upper *baseline* reach.
CA Axis 1	**<0.001**	0.054	**0.002**	**0.011**	4	11	7	18	Lower at *test* reach; lower in 2014 than mean of all previous years and all years at upper *baseline* reach.
CA Axis 2	**<0.001**	0.073	0.071	**<0.001**	20	3	3	21	Lower at *test* reach; lower in 2014 than mean of all previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

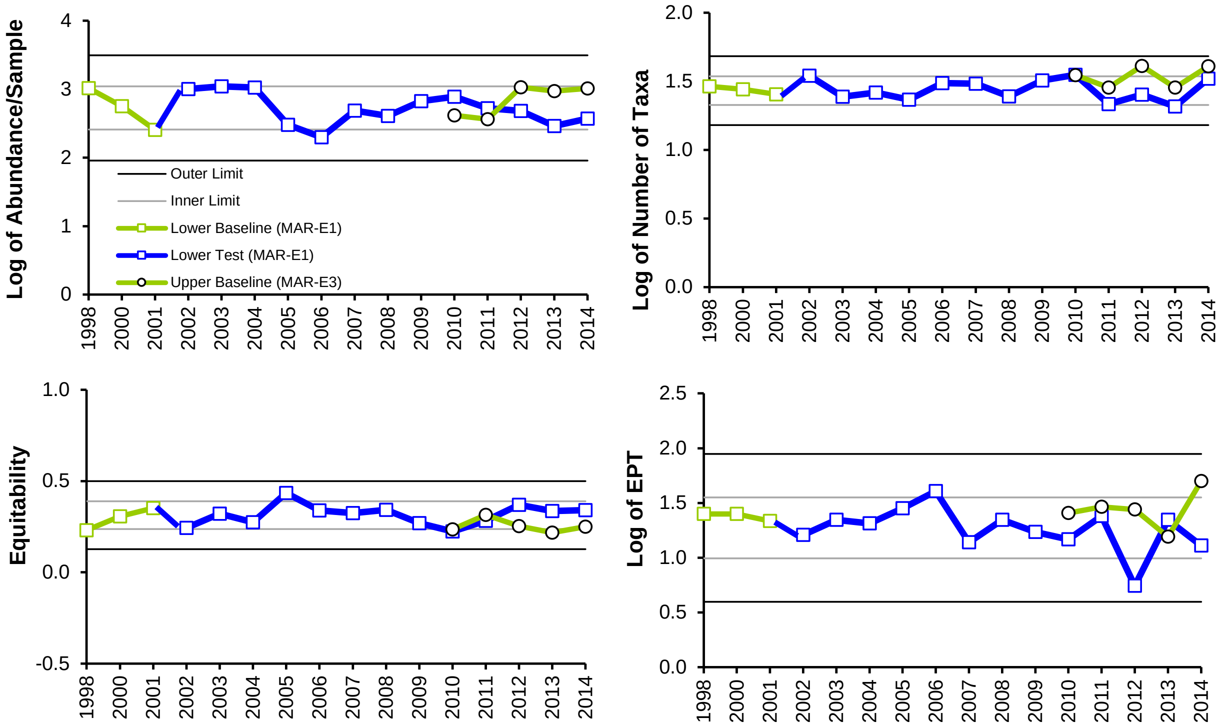
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.5-9 Ordination (Correspondence Analysis) of benthic invertebrate communities in erosional reaches, showing the lower *test* reach (MAR-E1), middle *test* reach (MAR-E2), and upper *baseline* reach (MAR-E3) of the MacKay River.



Note: Top left panel is the scatterplot of taxa scores, all other panels are scatterplots of sample scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at either *test* reach (1998 to 2013).

Figure 5.5-10 Variation in benthic invertebrate community measurement endpoints in the lower *test* reach (MAR-E1) and upper *baseline* reach (MAR-E3) of the MacKay River.

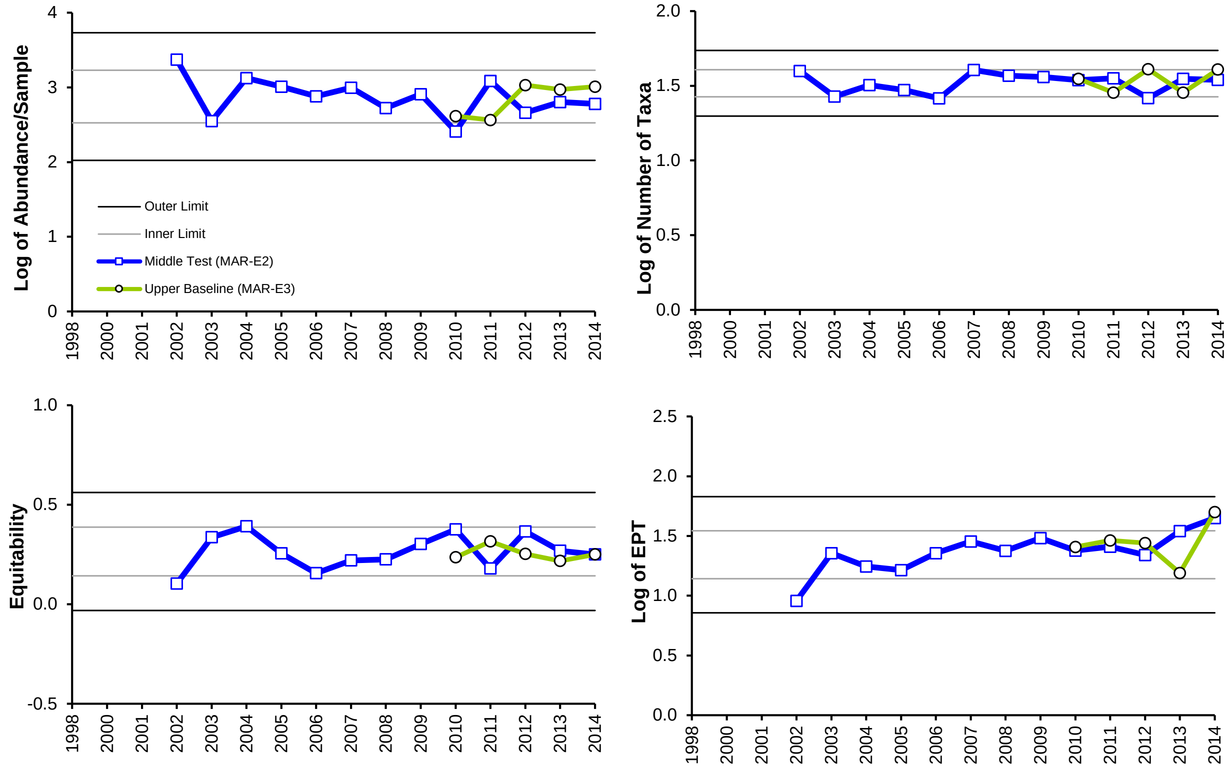


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at the lower *test* reach (1998 to 2013).

Note: 2014 was compared to the within-reach variability from previous years if there were eight or more years of data. If exceedances were observed, comparisons were made to the regional *baseline* dataset (depositional or erosional). If there were less than eight years of previous data for a *test* reach, it was only compared to the regional *baseline* dataset.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.5-11 Variation in benthic invertebrate community measurement endpoints in the middle *test* reach (MAR-E2) and upper *baseline* reach (MAR-E3) of the MacKay River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at the middle *test* reach (2002 to 2013).

Note: 2014 was compared to the within-reach variability from previous years if there were eight or more years of data. If exceedances were observed, comparisons were made to the regional *baseline* dataset (depositional or erosional). If there were less than eight years of previous data for a *test* reach, it is only compared to the regional *baseline* dataset.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.5-15 Average habitat characteristics of fish assemblage monitoring locations of the MacKay River, fall 2014.

Variable	Units	MAR-F1 Lower *Test* Reach	MAR-F2 Middle *Test* Reach	MAR-F3 Upper *Baseline* Reach
Sample date	-	Sept 3, 2014	Sept 7, 2014	Sept 9, 2014
Habitat type	-	run	riffle	riffle/run
Maximum depth	m	0.70	0.65	1.16
Mean depth	m	0.58	0.57	0.92
Bankfull channel width	m	44.1	42.9	40.0
Wetted channel width	m	38.0	32.0	34.0
Substrate				
Dominant	-	sand	cobble	cobble
Subdominant	-	gravel	small boulder	coarse gravel
Instream cover				
Dominant	-	filamentous algae	boulders	boulders, filamentous algae
Subdominant	-	small woody debris, overhanging vegetation	filamentous algae, macrophytes, small woody debris	macrophytes, small woody debris
Field water quality				
Dissolved oxygen	mg/L	8.80	11.2	10.4
Conductivity	µS/cm	295	227	247
pH	pH units	8.48	8.75	7.31
Water temperature	^{0}C	15.9	10.4	8.1
Water velocity				
Left bank velocity	m/s	0.35	0.29	0.49
Left bank water depth	m	0.36	0.25	0.66
Centre of channel velocity	m/s	0.33	0.48	0.24
Centre of channel water depth	m	0.43	0.57	0.50
Right bank velocity	m/s	0.26	0.19	0.37
Right bank water depth	m	0.45	0.35	0.45
Riparian cover – understory (<5 m)				
Dominant	-	-	woody shrubs and saplings	-
Subdominant	-	-	-	-

Table 5.5-16 Total number and percent composition of fish species captured at reaches of the MacKay River, 2009 to 2014.

Common Name	Code	Total Species Catch													Percent of Total Catch												
		MAR-F1					MAR-F2				MAR-F3				MAR-F1					MAR-F2				MAR-F3			
		2009	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2009	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
brook stickleback	BRST	1	-	1	-	-	-	-	-	-	-	-	-	-	5.6	0	0.7	0	0	0	0	0	0	0	0	0	0
burbot	BURB	-	-	-	5	7	-	-	-	-	-	-	-	-	0	0	0	50.0	30.4	0	0	0	0	0	0	0	0
flathead chub	FLCH	-	-	1	-	-	-	-	-	-	-	-	-	-	0	0	0.7	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	-	1	-	-	-	-	1	-	-	-	-	-	-	0	3.4	0	0	0	0	2.4	0	0	0	0	0	0
goldeye	GOLD	-	-	1	-	-	-	-	-	-	-	-	-	-	0	0	0.7	0	0	0	0	0	0	0	0	0	0
lake chub	LKCH	1	3	-	-	-	22	30	12	17	6	3	1	30	5.6	10.3	0	0	0	40.7	71.4	21.4	20.5	15.8	7.3	4.5	29.1
longnose dace	LNDC	-	4	-	-	2	21	3	36	45	1	1	11	43	0	13.8	0	0	8.7	38.9	7.1	64.3	54.2	2.6	2.4	50.0	41.7
longnose sucker	LNSC	-	1	-	-	-	2	1	3	1	1	1	2	-	0	3.4	0	0	0	3.7	2.4	5.4	1.2	2.6	2.4	9.1	0
northern pike	NRPK	1	-	-	-	-	-	-	1	-	-	1	-	-	5.6	0	0	0	0	0	0	1.8	0	0	2.4	0	0
pearl dace	PRDC	-	-	7	-	1	-	-	-	-	-	-	-	-	0	0	4.7	0	4.3	0	0	0	0	0	0	0	0
slimy sculpin	SLSC	-	1	-	3	3	1	2	4	3	21	12	7	20	0	3.4	0	30.0	13.0	1.9	4.8	7.1	3.6	55.3	29.3	31.8	19.4
spoonhead sculpin	SPSC	9	7	-	-	-	-	-	-	-	-	-	-	-	50	24.1	0	0	0	0	0	0	0	0	0	0	0
spottail shiner	SPSH	-	-	2	-	2	-	-	-	-	-	-	-	-	0	0	1.3	0	8.7	0	0	0	0	0	0	0	0
trout-perch	TRPR	6	10	133	-	4	8	5	-	11	9	23	1	1	33.3	34.5	88.7	0	17.4	14.8	11.9	0	13.3	23.7	56.1	4.5	1.0
walleye	WALL	-	-	2	1	2	-	-	-	-	-	-	-	-	0	0	1.3	10.0	8.7	0	0	0	0	0	0	0	0
white sucker	WHSC	-	2	3	-	-	-	-	-	6	-	-	-	9	0	6.9	2.0	0	0	0	0	0	7.2	0	0	0	8.7
yellow perch	YLPR	-	-	-	1	2	-	-	-	-	-	-	-	-	0	0	0	10.0	8.7	0	0	0	0	0	0	0	0
Total		**18**	**29**	**150**	**10**	**23**	**54**	**42**	**56**	**83**	**38**	**41**	**22**	**103**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**8**	**9**	**4**	**8**	**5**	**6**	**5**	**6**	**5**	**5**	**5**	**5**	**5**	**8**	**9**	**4**	**8**	**5**	**6**	**5**	**6**	**5**	**5**	**5**	**5**
Electrofishing effort (secs)		**2,980**	**1,372**	**2,920**	**3,015**	**2,982**	**1,480**	**2,017**	**2,529**	**2,548**	**1,375**	**1,977**	**2,509**	**2,521**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Underline denotes *baseline* reach.

Table 5.5-17 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of the MacKay River, 2009 to 2014.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MAR-F1	2009	0.04	-	4	4.00	-	0.58	-	5.57	-	3.89	-
	2011	0.12	0.05	7	3.80	0.84	0.69	0.06	5.93	0.95	2.09	0.87
	2012	0.50	0.30	8	3.00	1.87	0.17	0.19	8.34	0.16	5.19	3.21
	2013	0.03	0.04	4	1.40	1.52	0.14	0.31	2.54	1.08	0.33	0.46
	2014	0.02	0.01	7	3.00	1.22	0.54	0.31	4.63	1.58	0.71	0.36
MAR-F2	2011	0.22	0.05	5	3.20	1.10	0.52	0.21	6.17	0.32	3.66	0.81
	2012	0.14	0.03	6	2.80	0.84	0.41	0.19	5.77	0.56	2.09	0.54
	2013	0.07	0.01	5	3.40	0.89	0.50	0.07	5.76	0.23	2.21	0.35
	2014	0.10	0.02	6	4.20	1.30	0.62	0.06	6.32	0.08	3.26	0.84
<u>MAR-F3</u>	2011	0.15	0.05	5	2.80	1.30	0.44	0.28	4.66	1.51	2.74	0.88
	2012	0.11	0.08	6	2.60	1.34	0.42	0.25	6.25	1.48	2.08	1.49
	2013	0.03	0.01	5	2.40	0.55	0.48	0.13	5.13	0.36	0.96	0.16
	2014	0.14	0.03	5	3.80	0.45	0.66	0.08	5.51	0.20	4.09	1.05

SD = standard deviation across sub-reaches within a reach.

<u>Underline</u> denotes *baseline* reach.

Table 5.5-18 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for reaches of the MacKay River.

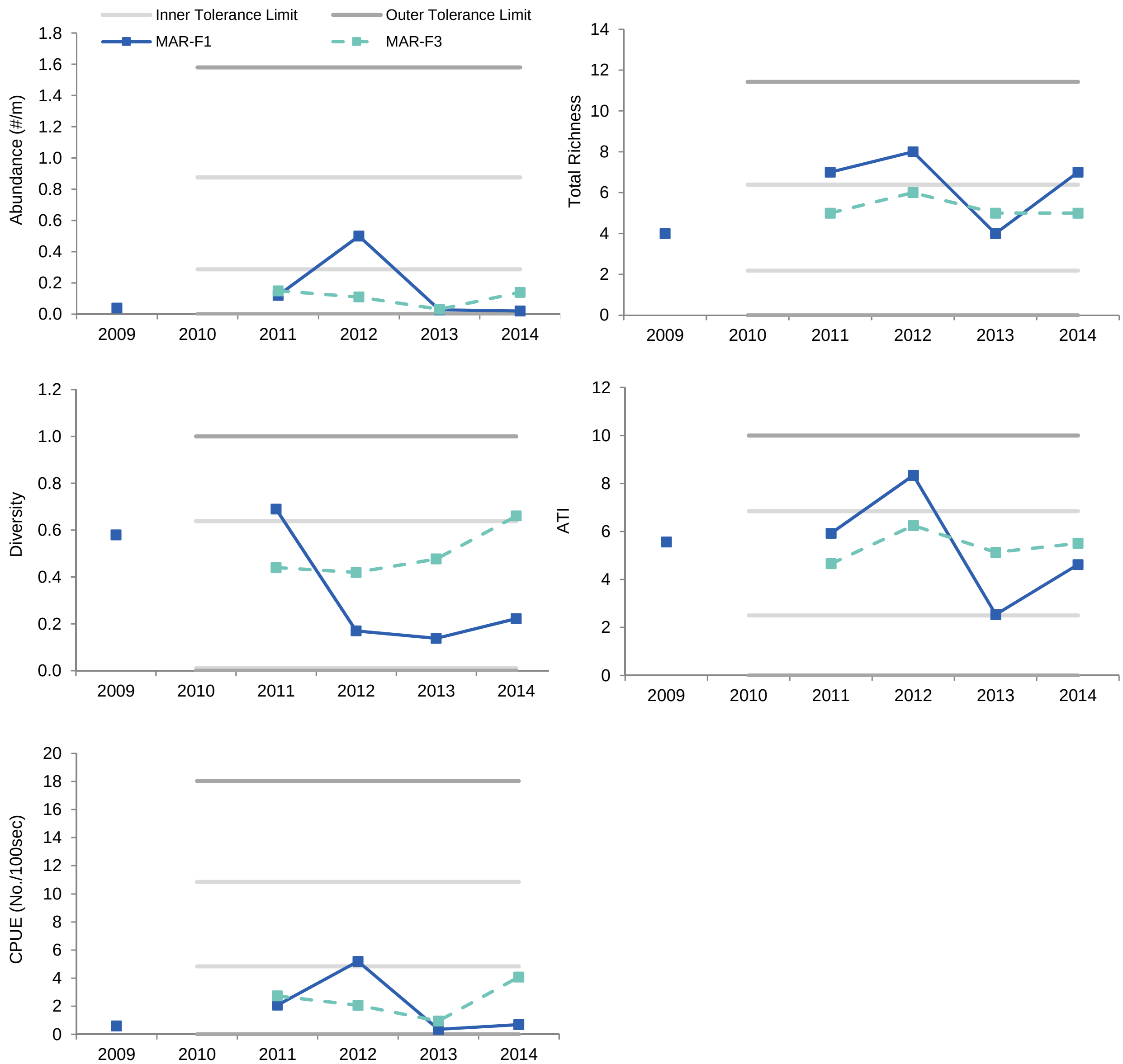
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Time Trend (*Test* Reach MAR-F1)	*Test* Reach MAR-F1 vs. *Baseline* Reach	Time Trend (*Test* Reach MAR-F2)	*Test* Reach MAR-F2 vs. *Baseline* Reach	Time Trend (*Test* Reach MAR-F1)	*Test* Reach MAR-F1 vs. *Baseline* Reach	Time Trend (*Test* Reach MAR-F2)	*Test* Reach MAR-F2 vs. *Baseline* Reach	
Abundance	**0.004**	0.060*	**<0.001**	0.110*	37.7	9.3	58.9	6.6	Decreasing over time at *test* reaches MAR-F1 and MAR-F2.
Richness	0.210	0.070	0.100	0.800	8.5	8.4	14.2	1.0	No change.
Diversity	0.520	0.120*	0.430*	0.550*	1.5	6.2	3.5	1.0	No change.
ATI	**0.003***	**0.040***	0.600	0.590*	26.8	11.4	1.6	1.0	Decreasing over time at *test* reach MAR-F1 while increasing over time at *baseline* reach MAR-F3.
CPUE (No./100 sec)	**0.010***	**0.020***	0.650	0.260	21.1	14.0	1.2	3.3	Decreasing over time at *test* reach MAR-F1 while increasing over time at *baseline* reach MAR-F3.

***** Denotes data were ranked transformed to meet assumptions of ANOVA.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in temporal and spatial comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Figure 5.5-12 Variation in fish assemblage measurement endpoints for the lower *test* reach of the MacKay River from 2009 to 2014, relative to regional *baseline* conditions (cluster 3).



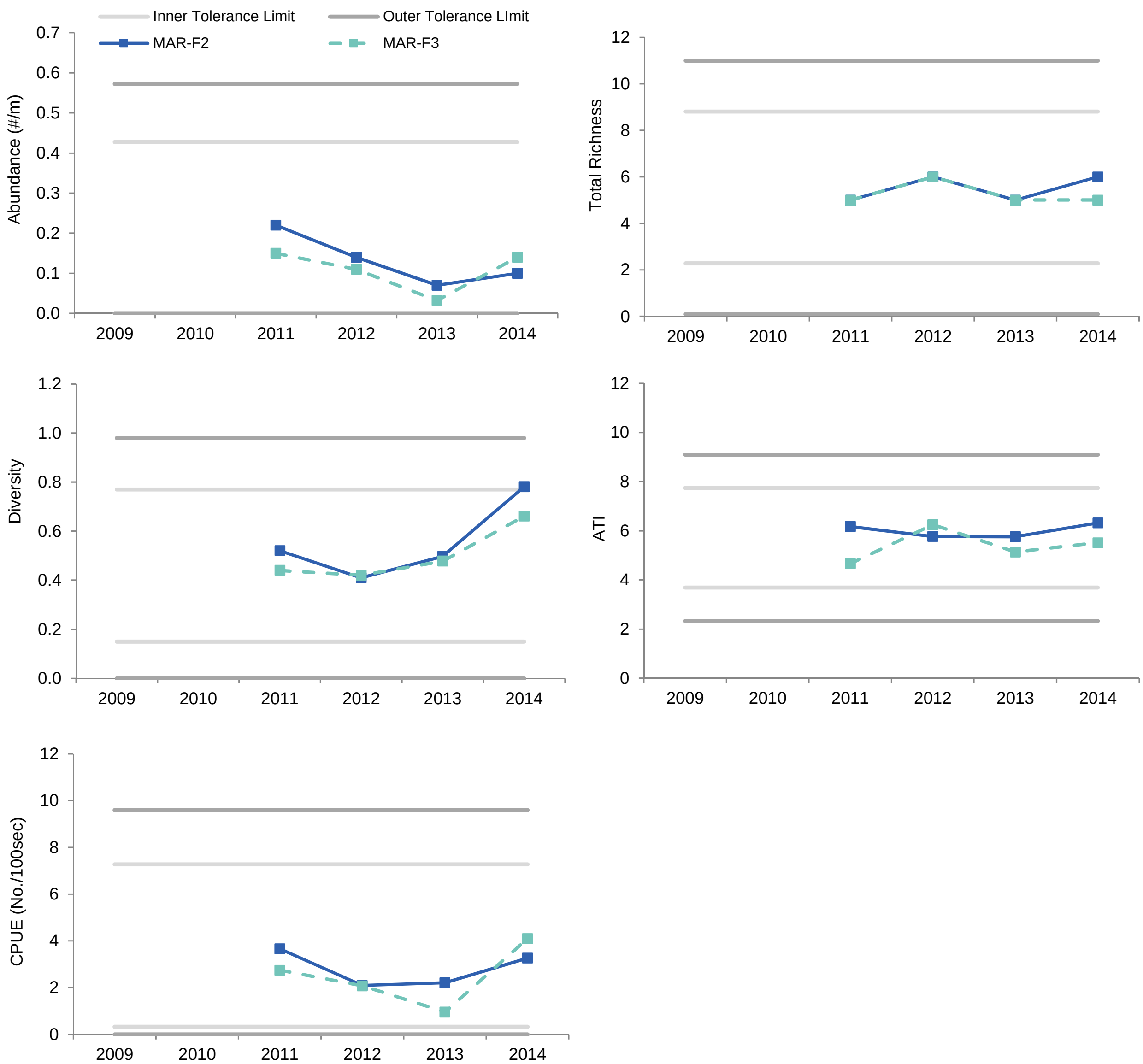
Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 3 (see Table 3.2-14 and Table 3.2-15).

Note: No *baseline* data for cluster 3 prior to 2010.

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: Although *baseline* reach MAR-F3 was not part of *baseline* cluster 3, the data were graphed to provide comparison to *test* reaches MAR-F1.

Figure 5.5-13 Variation in fish assemblage measurement endpoints for the middle *test* reach and upper *baseline* reach of the MacKay River from 2009 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

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5.6 CALUMET RIVER WATERSHED

Table 5.6-1 Summary of results for the Calumet River watershed.

Calumet River Watershed	Summary of 2014 Conditions	
Climate and Hydrology		
Criteria	**Station S16A** at the mouth	no station
Mean open-water season discharge	🟡	
Mean winter discharge	not measured	
Annual maximum daily discharge	🟡	
Minimum open-water season discharge	🟡	
Water Quality		
Criteria	**CAR-1** at the mouth	**CAR-2** upstream of Canadian Natural Horizon
Water Quality Index	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality		
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2014		
Fish Populations		
No Fish Populations component activities conducted in 2014		

Legend and Notes

🟡 Negligible - Low
🟠 Moderate
🟤 High

baseline (green shading)
test (blue shading)

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Figure 5.6-1 Calumet River watershed.

Legend

Lake/Pond
River/Stream
Watershed Boundary
Major Road
Secondary Road
Railway
First Nations Reserve
Regional Municipality of Wood Buffalo Boundary
Land Change Area as of 2014[a]
Water Withdrawal Location[b]
Water Discharge Location[b]
Hydrometric Station
Climate Station
Water Quality Station
Benthic Invertebrate Communities Reach
Benthic Invertebrate Communities Reach and Sediment Quality Station
Fish Assemblage Reach
Fish Inventory Reach

0 1 2 4 km N

Scale: 1:140,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.6-2 Representative monitoring stations of the Calumet River watershed, 2014.

Water Quality Station CAR-1:
Left Downstream Bank, facing downstream

Water Quality Station CAR-2:
Right Downstream Bank, facing upstream

Hydrology Station S16A (August):
Right downstream bank, facing downstream

Hydrology Station S16A (September):
Centre Channel, facing upstream

5.6.1 Summary of 2014 Conditions

As of 2014, 1.14% (199 ha) of the Calumet River watershed had undergone land change from oil sands development, with no change from the previous two years (Table 2.3-1). The designations of specific areas of the watershed are as follows:

1. The Calumet River watershed downstream of Canadian Natural Horizon Project operations is designated as *test*.

2. The remainder of the watershed is designated as *baseline* (Figure 5.6-1).

Monitoring activities were conducted for the Climate and Hydrology and Water Quality components in the Calumet River watershed in 2014. Table 5.6-1 is a summary of the 2014 assessment for the Calumet River watershed, while Figure 5.6-1 denotes the location of the monitoring stations for each component and the areas with land change as of 2014. Figure 5.6-2 contains summer and fall 2014 photos of water quality and hydrology monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were 0.26% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2014, water quality at *test* station CAR-1 and *baseline* station CAR-2 indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured concentrations for both stations, with the exception of concentrations of many hydrocarbons (CCME fractions and PAHs) in 2014 at *test* station CAR-1, which had concentrations substantially greater than historically observed at this station and compared to *baseline* station CAR-2 in 2014. Significantly higher flows in 2014 in the Calumet River in May and June 2014 contributed to bank erosion near the lower water quality station (*test* station CAR-1), which may have caused the increase in TSS and PAHs and hydrocarbons from bank sediments. The ionic composition of water at *test* station CAR-1 was consistent with previous years, while the ionic composition of water at *baseline* station CAR-2 was less dominated by bicarbonate ions in 2014 than most historical sampling years.

5.6.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Calumet River watershed in the 2014 WY was conducted at JOSMP Station S16A, Calumet River near the mouth. These data were used for the water balance analysis and presented below.

Continuous hydrometric data have been collected during the open-water period at Station S16A since April 2010. Prior to 2010, hydrometric data were collected from the mouth of the Calumet River at Station S16 for each open-water period from 2001 to 2004 and at the Canadian Natural CR-1 station from 2005 to 2009. Only partial records exist for most historical years; therefore, historical statistics should be interpreted with caution for this station.

The historical flow record for JOSMP Station S16A is summarized in Figure 5.6-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Calumet River are typical for a northern environment; the available historical data indicates that flows are typically highest during spring freshet and lower for the other open-water months. Winter flows have not historically been monitored for a sufficiently adequate period to present summary statistics.

In the 2014 WY, flows were also much higher in May, than the subsequent open-water months. The peak flow in the 2014 WY was recorded on May 30 (12.3 m^3/s) following rainfall events, and exceeded all previous recorded flows in the period of data record. This flow was over three times higher than the historical mean annual open-water peak flow of 3.6 m^3/s. Recorded flows ceased on May 31, and were much lower when data collection resumed on June 20; however, flows in late June generally continued to exceed previous historical maxima during this period. Flows then decreased sharply to below the historical median values in late July. The minimum open-water daily flow of 0.012 m^3/s was recorded on August 29, and was 31% lower than the historical mean minimum daily flow of 0.017 m^3/s calculated for the open-water period. Flows were close to historical minima throughout much of September, until rainfall events in late September increased flows to closer to historical median values.

Overall, the recorded open-water runoff volume in the 2014 WY was 6.605 million m^3. This value was 123% higher than the mean historical open-water runoff volume based on the available historical record.

The actual open-water runoff volume would be higher if the missing period of data from June 1 to June 19 was accounted. As noted previously, only partial records exist for most historical years, so historical statistics should be used with caution for this station.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Calumet River at JOSMP Station S16A is summarized in Table 5.6-2. Key changes in flows included:

1. The closed-circuited land change area as of 2014 was estimated to be 0.7 km^2 (Table 2.3-1). The loss of flow to the Calumet River that would have otherwise occurred from this land area was estimated at 0.028 million m^3.

2. As of 2014, the area of land change in the Calumet River watershed that was not closed-circuited was estimated to be 1.3 km^2 (Table 2.3-1). The increase in flow to the Calumet River that would not have otherwise occurred from this land area was estimated at 0.010 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was a loss of 0.017 million m^3 at JOSMP Station S16A. The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were 0.26% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.6-3). These differences were classified as **Negligible-Low** (Table 5.6-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.6.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Calumet River near its mouth (*test* station CAR-1), designated as *baseline* from 2002 to 2004 and *test* from 2005 to 2014; and

- the upper Calumet River (*baseline* station CAR-2), sampled since 2005.

Temporal Trends There were no significant trends in fall concentrations of water quality measurement endpoints at *test* station CAR-1. There was a significant (α=0.05) decreasing trend in dissolved phosphorus at *baseline* station CAR-2 in 2014.

2014 Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2014 were similar to historical results with the following exceptions (Table 5.6-4 and Table 5.6-5):

- Total suspended solids, sulphate, CCME Fraction 3 (C16-C34), CCME Fraction 4 (C34-C50), naphthenic acids, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations that exceeded previously-measured maximum concentrations at *test* station CAR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);

- Total arsenic, with a concentration below the previously-measured minimum concentration at *test* station CAR-1;
- Dissolved phosphorus, total nitrogen, chloride, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station CAR-2; and
- Naphthenic acids and sulphate, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station CAR-2.

Ion Balance The ionic composition of water at *test* station CAR-1 in fall 2014 has remained fairly consistent to previous sampling years, with the exception of fall 2007 when the cation composition was more calcium-dominated than in other years (Figure 5.6-4). In fall 2014, the ionic composition of water at *baseline* station CAR-2 was very similar to 2013 and 2010. These years had substantially higher concentrations of sulphate relative the other years, shifting the ionic composition to be less dominated by bicarbonate. Across sampling years, water at *baseline* station CAR-2 has had a lower relative concentration of bicarbonate than water at *test* station CAR-1 (Figure 5.6-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in fall 2014 were below water quality guidelines with the exception of total aluminum at *test* station CAR-1 (Table 5.6-4 and Table 5.6-5).

Other Water Quality Guideline Exceedances Additional guideline exceedances in fall 2014 at *test* station CAR-1 and *baseline* station CAR-2 included dissolved iron, total iron, sulphide, and total phenols (Table 5.6-6).

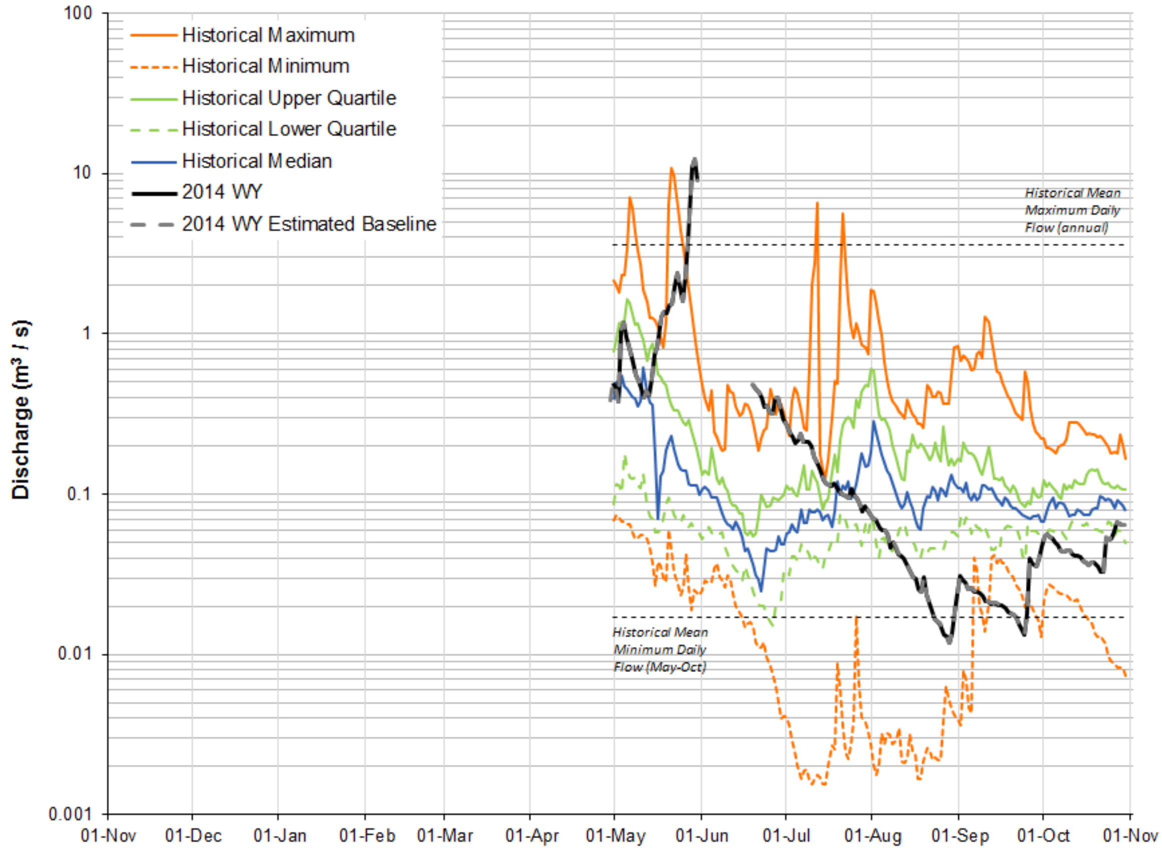
2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of some water quality variables were outside the range of regional *baseline* concentrations at *test* station CAR-1 and *baseline* station CAR-2 (Figure 5.6-5), including:

- total suspended solids, with a concentration that exceeded the 95^{th} percentile of the regional *baseline* concentrations at *test* station CAR-1; and
- total dissolved solids, magnesium, and sulphate with concentrations that exceeded the 95^{th} percentile of regional *baseline* concentrations at *baseline* station CAR-2.

Water Quality Index The WQI value for *test* station CAR-1 (98.7) and *baseline* station CAR-2 (91.2) indicated **Negligible-Low** differences from regional *baseline* conditions.

Classification of Results In fall 2014, water quality at *test* station CAR-1 and *baseline* station CAR-2 indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured concentrations for both stations, with the exception of concentrations of many hydrocarbons (CCME fractions and PAHs) in 2014 at *test* station CAR-1, which had concentrations substantially greater than historically observed at this station and compared to *baseline* station CAR-2 in 2014. Significantly higher flows in 2014 in the Calumet River in May and June 2014 (Figure 5.6-3) contributed to bank erosion near the lower water quality station (*test* station CAR-1), which may have caused the increase in TSS and PAHs and hydrocarbons from bank sediments. The ionic composition of water at *test* station CAR-1 was consistent with previous years, while the ionic composition of water at *baseline* station CAR-2 was less dominated by bicarbonate ions in 2014 than most historical sampling years.

Figure 5.6-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Calumet River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph is based on Calumet River near the mouth (JOSMP Station S16A) daily mean open-water data. Historical daily values from May 1 to October 31 calculated from data collected from 2001 to 2004, CR-1 from 2005 to 2009, and S16A from 2010 to 2013.

Note: The historical mean minimum and maximum daily flow were calculated for open-water months only (May to October).

Table 5.6-2 Estimated water balance at Station S16A, Calumet River near the mouth, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**6.637**	**Observed discharge from Calumet River near the mouth (JOSMP Station S16A)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.028	Estimated 0.7 km^2 of the Calumet River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.010	Estimated 1.3 km^2 of the Calumet River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Calumet River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Calumet River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**6.655**	**Estimated *baseline* discharge from Calumet River near the mouth, JOSMP Station S16A.**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	-0.017	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-0.260**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Note: Observed volume of water discharged was calculated using data for April 30 to October 31, 2014 for JOSMP Station S16A, Calumet River near the mouth.

Table 5.6-3 Calculated change in hydrologic measurement endpoints in the Calumet River watershed, 2014 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.464	0.463	-0.262%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	12.312	12.280	-0.262%
Open-water season minimum daily discharge	0.012	0.012	-0.262%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from JOSMP Station S16A.

Note: The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: Discharge statistics were calculated using data for April 30 to October 31, 2014 for JOSMP Station S16A, Calumet River near the mouth.

Table 5.6-4 Concentrations of water quality measurement endpoints, mouth of Calumet River (*test* station CAR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.6	12	8.1	8.2	8.6
Total suspended solids	mg/L	-	77.1	12	<3.0	10.5	66.0
Conductivity	µS/cm	-	565	12	188	583	702
Nutrients							
Total dissolved phosphorus	mg/L	-	0.045	12	0.025	0.055	0.122
Total nitrogen	mg/L	-	0.98	12	0.80	1.33	1.54
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	29.8	12	22.0	32.3	40.7
Ions							
Sodium	mg/L	-	39.0	12	7.00	49.4	71.0
Calcium	mg/L	-	63.8	12	25.3	55.5	74.2
Magnesium	mg/L	-	17.8	12	7.80	18.6	23.4
Chloride	mg/L	120	12.8	12	2.00	15.6	34.0
Sulphate	mg/L	429	30.7	12	3.60	12.45	23.5
Total dissolved solids	mg/L	-	390	12	151	397	480
Total alkalinity	mg/L	-	259	12	96	285	337
Selected metals							
Total aluminum	mg/L	0.1	**0.399**	12	0.040	**0.152**	**1.28**
Dissolved aluminum	mg/L	0.05	0.0025	12	0.0013	0.0038	0.0058
Total arsenic	mg/L	0.005	0.0008	12	0.0009	0.0011	0.0016
Total boron	mg/L	1.2	0.080	12	0.074	0.088	0.122
Total molybdenum	mg/L	0.073	0.00013	12	0.00011	0.00015	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	3.60	11	<0.94	<1.20	3.80
Total strontium	mg/L	-	0.23	12	0.16	0.25	0.32
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	0.45	3	<0.25	<0.25	0.26
Fraction 4 (C34-C50)	mg/L	-	0.34	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	2.50	3	0.05	0.55	1.16
Oilsands Extractable	mg/L	-	2.50	3	0.55	1.42	2.87
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	39.0	3	1.11	3.35	15.10
Total dibenzothiophenes	ng/L	-	1,437	3	54.72	67.13	105.0
Total PAHs	ng/L	-	3,716	3	245.2	387.1	493.6
Total Parent PAHs	ng/L	-	79.49	3	23.56	25.78	29.10
Total Alkylated PAHs	ng/L	-	3,636	3	219.4	363.6	464.5
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.30	**0.349**	12	0.273	**0.510**	**0.911**
Sulphide	mg/L	0.002	**0.012**	12	**0.005**	**0.013**	**0.028**
Total iron	mg/L	0.3	**1.70**	12	**0.535**	**1.47**	**3.14**
Total phenols	mg/L	0.004	**0.007**	11	<0.001	**0.009**	**0.016**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

Table 5.6-5 Concentrations of water quality measurement endpoints, upper Calumet River (*baseline* station CAR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	9	7.7	8.1	8.5
Total suspended solids	mg/L	-	<3.0	9	<3.0	5.0	208
Conductivity	µS/cm	-	676	9	494	610	772
Nutrients							
Total dissolved phosphorus	mg/L	-	0.067	9	0.068	0.119	0.305
Total nitrogen	mg/L	-	1.5	9	1.7	1.9	5.5
Nitrate+nitrite	mg/L	3	<0.054	9	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	49.4	9	36.1	47.4	54.4
Ions							
Sodium	mg/L	-	58.6	9	53.0	69.0	76.0
Calcium	mg/L	-	61.5	9	29.6	48.5	72.5
Magnesium	mg/L	-	21.7	9	12.3	20.5	26.6
Chloride	mg/L	120	8.8	9	12.3	15.3	24.3
Sulphate	mg/L	429	111.0	9	23.5	55.8	103.0
Total dissolved solids	mg/L	-	512	9	323	467	547
Total alkalinity	mg/L	-	225	9	188	238	315
Selected metals							
Total aluminum	mg/L	0.1	0.060	9	0.020	0.062	**4.10**
Dissolved aluminum	mg/L	0.05	0.022	9	0.004	0.010	0.024
Total arsenic	mg/L	0.005	0.0018	9	0.0009	0.0025	**0.0050**
Total boron	mg/L	1.2	0.110	9	0.076	0.094	0.128
Total molybdenum	mg/L	0.073	0.00087	9	0.00009	0.00055	0.00102
Total mercury (ultra-trace)	ng/L	5, 13	3.5	9	<1.2	1.3	4.4
Total strontium	mg/L	-	0.32	9	0.15	0.29	0.37
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	0.65
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	0.49
Naphthenic Acids	mg/L	-	1.60	3	0.11	0.45	0.50
Oilsands Extractable	mg/L	-	1.50	3	0.73	0.90	1.98
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.8	<14.1	<15.2
Retene	ng/L	-	0.637	3	0.972	3.730	10.80
Total dibenzothiophenes	ng/L	-	4.514	3	5.881	6.672	35.41
Total PAHs	ng/L	-	76.11	3	115.3	151.2	207.1
Total Parent PAHs	ng/L	-	13.26	3	17.37	19.26	22.55
Total Alkylated PAHs	ng/L	-	62.86	3	92.76	132.0	189.7
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.30	**0.846**	9	0.110	**0.404**	**1.500**
Sulphide	mg/L	0.002	**0.020**	9	**0.024**	**0.034**	**0.588**
Total iron	mg/L	0.30	**1.480**	9	0.167	**1.250**	**6.680**
Total phenols	mg/L	0.004	**0.012**	9	**0.008**	**0.014**	**0.041**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; underlined values are outside of historical range.

Figure 5.6-4 Piper diagram of fall ion concentrations in Calumet River watershed.

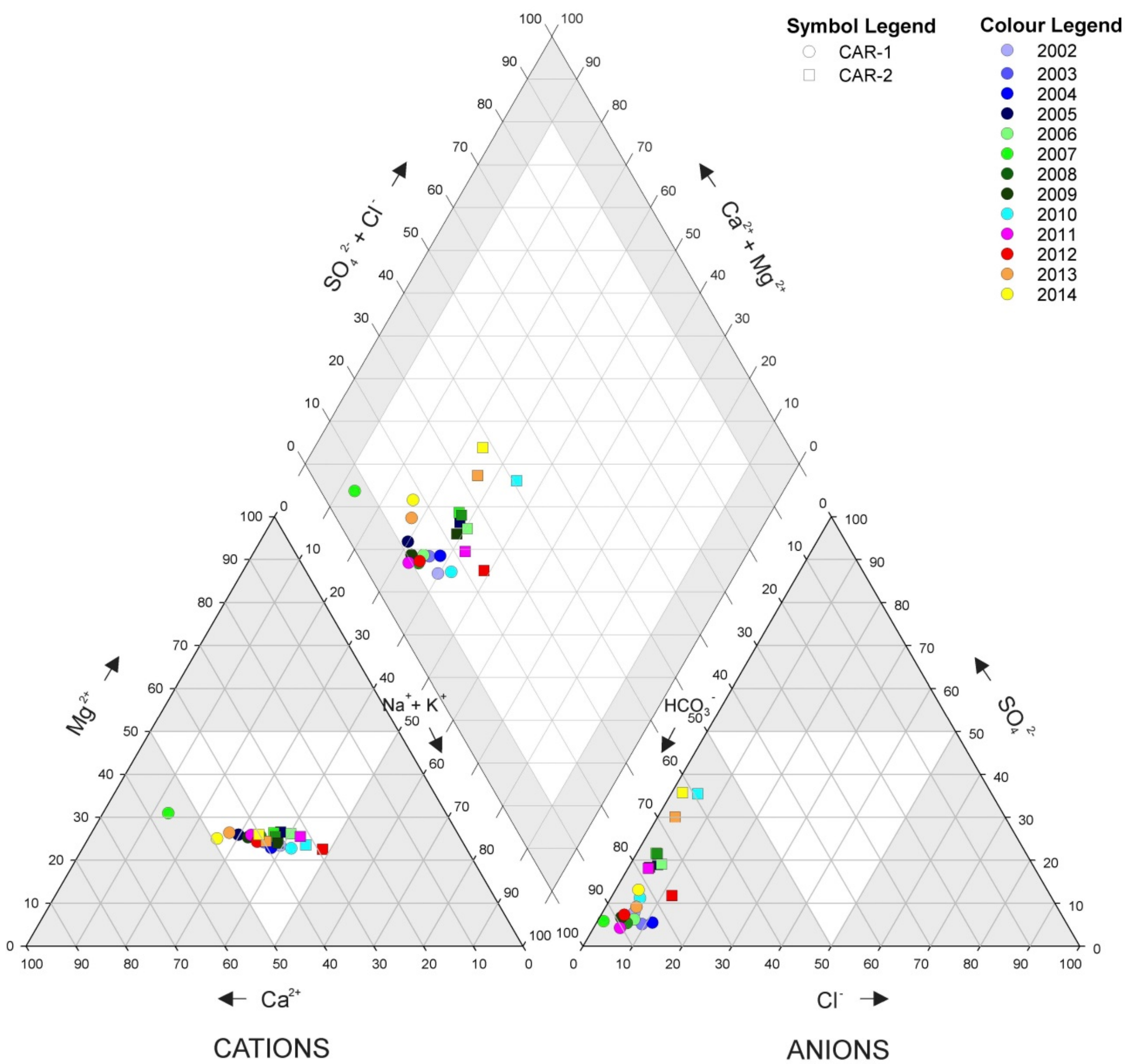
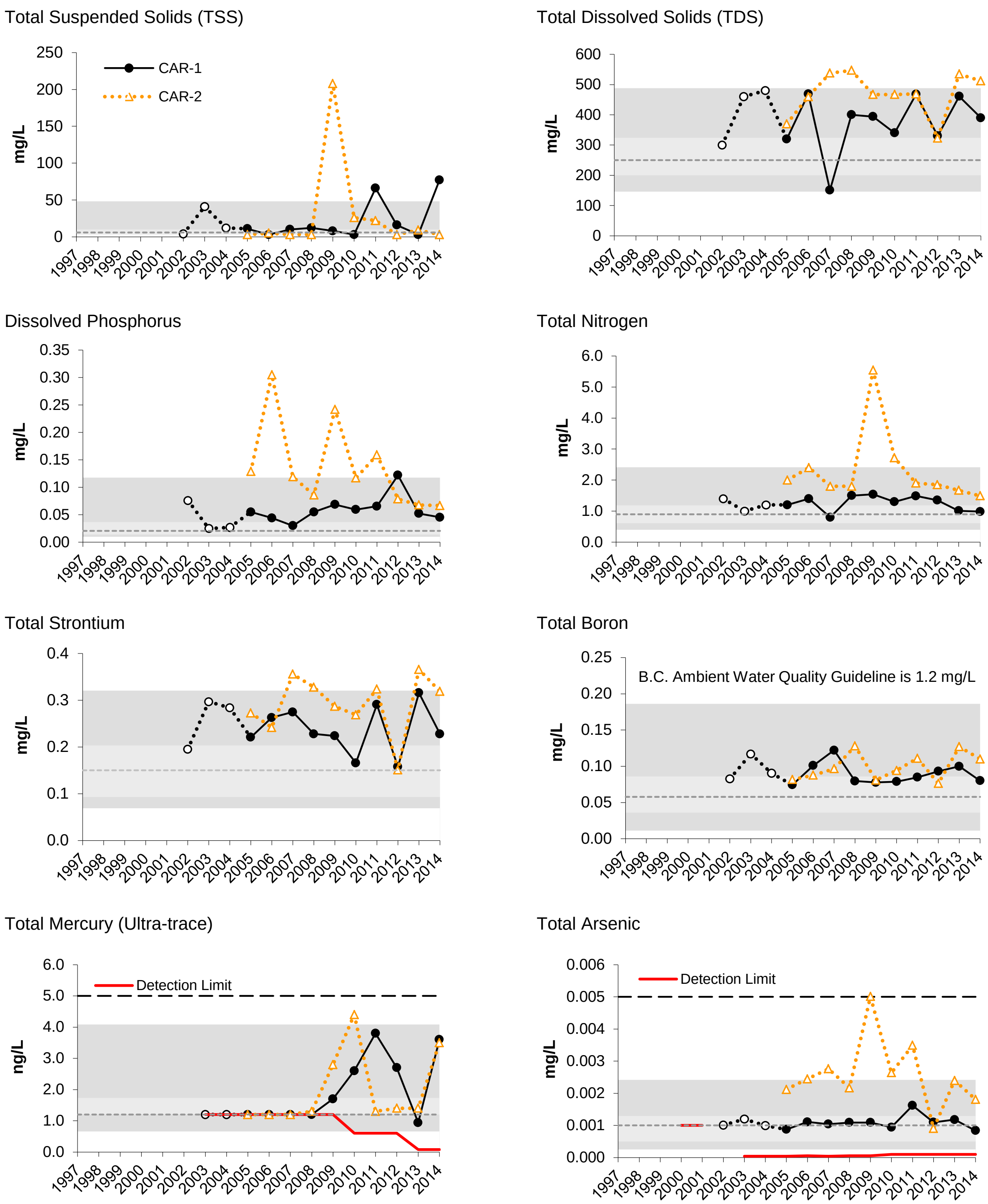


Table 5.6-6 Water quality guideline exceedances, Calumet River watershed, fall 2014.

Variable	Units	Guideline[a]	CAR-1	CAR-2
Dissolved iron	mg/L	0.3	0.349	0.846
Sulphide	mg/L	0.002	0.012	0.020
Total aluminum	mg/L	0.1	0.40	-
Total iron	mg/L	0.3	1.70	1.48
Total phenols	mg/L	0.004	0.007	0.012

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.6-5 Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

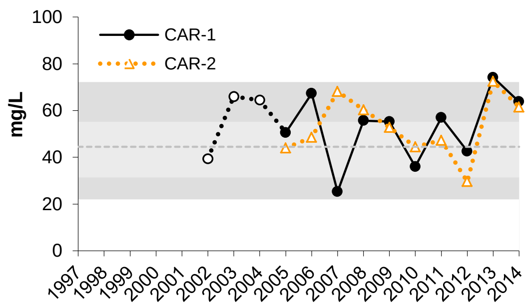
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

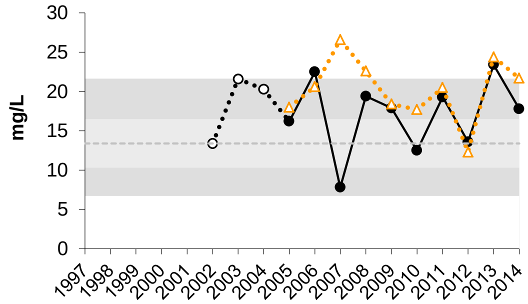
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.6-5 (Cont'd.)

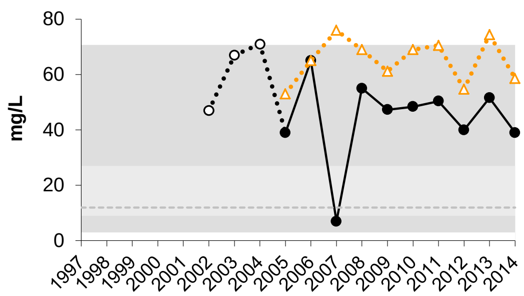
Calcium



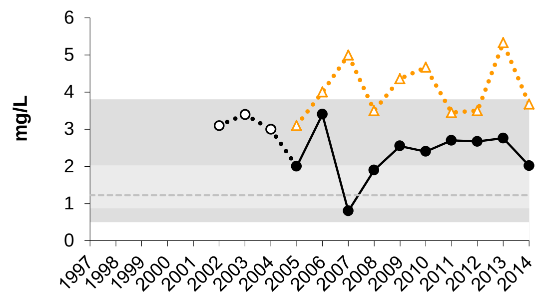
Magnesium



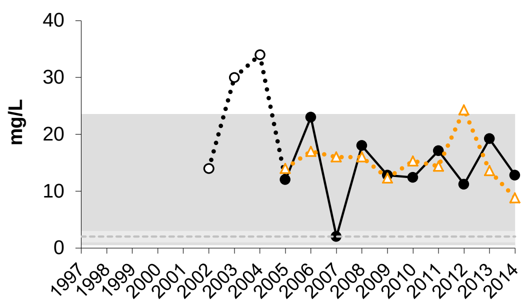
Sodium



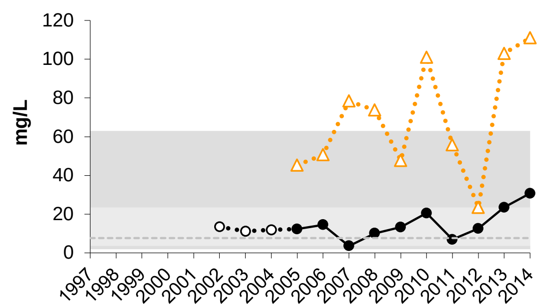
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●━━● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

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5.7 FIREBAG RIVER WATERSHED

Table 5.7-1 Summary of results for the Firebag River watershed.

Firebag River Watershed	Summary of 2014 Conditions			
	Firebag River		*Lakes*	
Climate and Hydrology				
Criteria	**WSC 07DC001** at the mouth	**S43** upstream of Suncor Firebag	**L1, S36** McClelland Lake and Outlet	no station
Mean open-water season discharge	○	not measured	not measured	
Mean winter discharge	○	not measured	not measured	
Annual maximum daily discharge	○	not measured	not measured	
Minimum open-water season discharge	○	not measured	not measured	
Water Quality				
Criteria	**FIR-1** at the mouth	**FIR-2** upstream of Suncor Firebag	**MCL-1** McClelland Lake	**JOL-1** Johnson Lake
Water Quality Index	○	○	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality				
Criteria	**FIR-D1** at the mouth	**FIR-E2** upstream of Suncor Firebag	**MCL-1** McClelland Lake	**JOL-1** Johnson Lake
Benthic Invertebrate Communities	not sampled in 2014	not sampled in 2014	○	n/a
Sediment Quality Index	not sampled in 2014	not sampled in 2014	n/a	n/a
Fish Populations				
No Fish Populations component activities conducted in 2014				

Legend and Notes

- ○ Negligible - Low
- ● Moderate
- ● High

baseline

test

n/a - not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions. The WQI/SQI was not calculated given the limited existing *baseline* data for lakes.

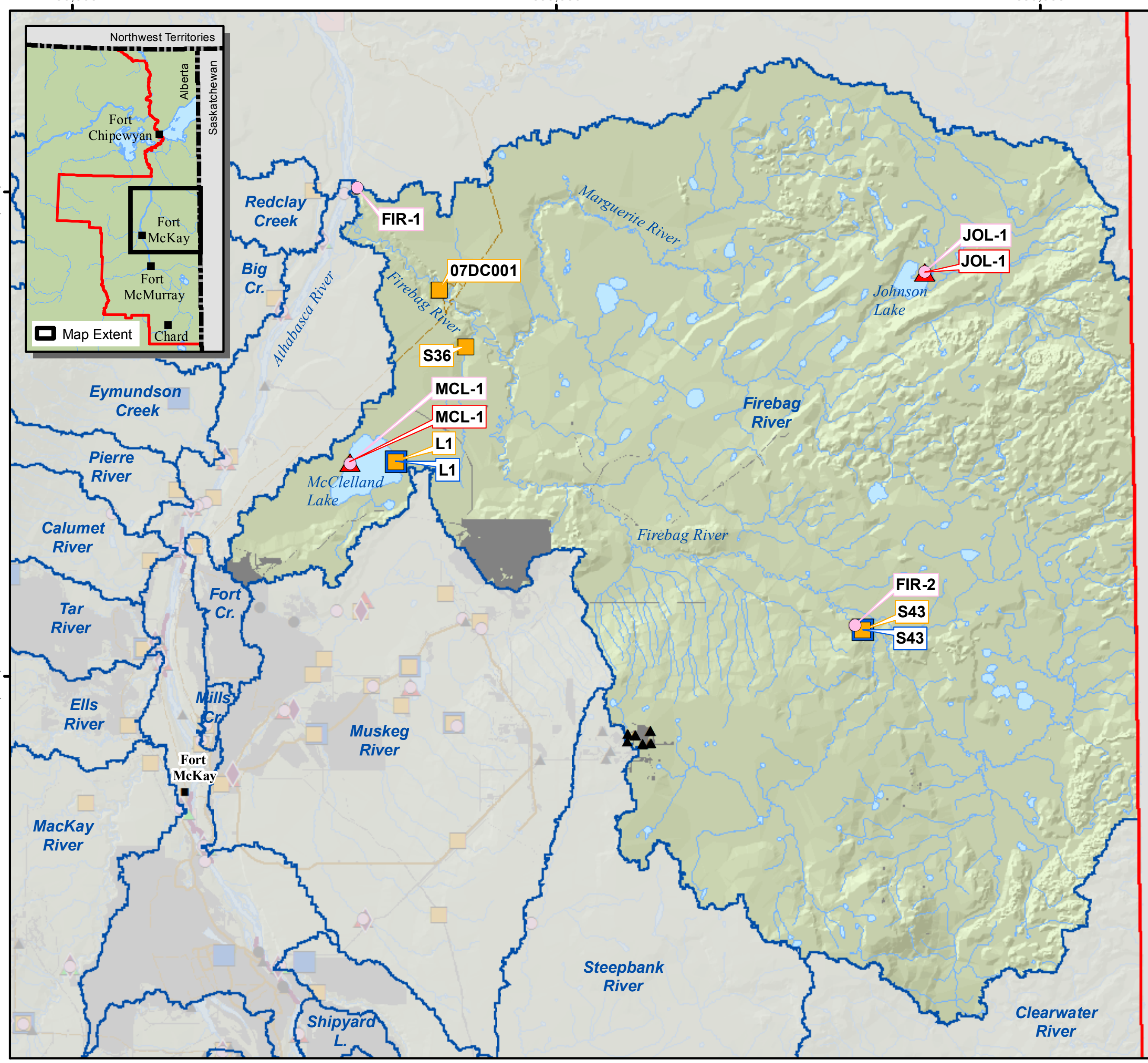
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Figure 5.7-1 Firebag River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach

0 5 10 20 km N

Scale: 1:675,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.7-2 Representative monitoring stations of the Firebag River watershed, fall 2014.

Water Quality Station FIR-1:
Left Downstream Bank, facing downstream

Water Quality Station FIR-2:
Right Downstream Bank, facing downstream

Hydrology Station S36:
McClelland Lake Outlet

Water Quality Station JOL-1:
Johnson Lake

Hydrology Station L1:
McClelland Lake

Water Quality Station MCL-1:
McClelland Lake

5.7.1 Summary of 2014 Conditions

Approximately 1.3% (7,138 ha) of the Firebag River watershed underwent land change as of 2014 from oil sands development (Table 2.3-1). The area downstream of the Suncor Firebag and Fort Hills, Imperial Kearl, and Husky Sunrise projects that are in the Firebag River watershed (Figure 5.7-1) is designated as *test*; the remainder of the watershed is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, and Benthic Invertebrate Communities and Sediment Quality components in the Firebag River watershed in 2014. Table 5.7-1 is a summary of the 2014 assessment of the Firebag River watershed, while Figure 5.7-1 denotes the location of the monitoring stations for each component, reported oil sands water withdrawal and discharge locations, and the area with land change as of 2014. Figure 5.7-2 contains spring and fall 2014 photos from monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.23% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

The water level recorded at Station L1, McClelland Lake, in winter of the 2014 WY was generally near the upper quartile and reached a peak in early June due to rainfall events. The lake level from June to October was above the historical median values.

Water Quality In fall 2014, water quality at *test* station FIR-1 and *baseline* station FIR-2 showed **Negligible-Low** differences from regional *baseline* water quality conditions. Concentrations of most water quality measurement endpoints at *test* station FIR-1 and *baseline* station FIR-2 were within the range of regional *baseline* concentrations and within the range of previously-measured concentrations in fall 2014. The ionic composition of water in fall 2014 at both Firebag River stations and Johnson Lake were consistent with previous sampling years and dominated by calcium and bicarbonate ions. The ionic composition at McClelland Lake was dominated by magnesium and bicarbonate and consistent with previous sampling years. Concentrations of water quality measurement endpoints for *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities of McClelland Lake were classified as **Negligible-Low** because although there was a significant increase in the percentage of fauna as EPT taxa and lower equitability in 2014 compared to previous years, these changes were indicative of good lake conditions. The general composition of the community in terms of relative abundances, presence of fully aquatic forms, and presence of generally sensitive taxa such as the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent to *baseline* conditions.

The benthic invertebrate community of Johnson Lake showed some improvement in 2014 compared to 2013, with the presence of EPT taxa, which were not observed in 2013. The abundance of worms (Tubificidae and Naididae) were lower in 2014 compared to 2013 and there were amphipods and gastropods present, indicating that Johnson Lake was generally in good condition.

Sediment at both *test* station MCL-1 and *baseline* station JOL-1 was predominantly composed of silt. The percentage of silt and the total organic carbon content exceeded previously-measured maximum values at *test* station MCL-1, while the percentage of sand was below the previously-measured minimum value. All physical variables at *baseline* station JOL-1 were within the range of previously-measured values. Concentrations of naphthalene, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs at *baseline* station JOL-1 were below the previously-measured minimum concentrations. All sediment quality measurement endpoints were below the relevant sediment quality guidelines, with the exception F3 hydrocarbons, which exceeded the CCME guideline at both stations. SQI values were not calculated for MCL-1 and JOL-1 given the absence of regional *baseline* concentrations for lakes.

5.7.2 Hydrologic Conditions: 2014 Water Year

Firebag River

Hydrometric monitoring for the Firebag River watershed in the 2014 WY was conducted at the following locations:

- WSC Station 07DC001 (formerly JOSMP Station S27), Firebag River near the mouth;
- JOSMP Station S43, Firebag River above Suncor Firebag;
- JOSMP Station L1, McClelland Lake; and
- JOSMP S36, McClelland Lake Outlet above Firebag River.

Data from the WSC Station were used for the water balance analysis and are presented below. Data from L1 are also presented below. Data from the other JOSMP stations can be found in Appendix C.

Seasonal data from March to October have been collected every year at WSC Station 07DC001 (formerly JOSMP Station S27) since 1972, with some partial data for 1971. Continuous annual hydrometric data have been collected from 1972 to 1986, and more recently in 2002, and from 2004 to 2014. The historical flow record for the station is summarized in Figure 5.7-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Firebag River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in April. Monthly flows are highest in May, at the peak of freshet. Flows then generally recede slowly through June and July, and remain similar from August to October.

In the 2014 WY, flows were similar to the historical seasonal pattern described above (Figure 5.7-3). Flows steadily decreased from November to late April, and remained above the historical median values for most of this period. The increase in flow due to spring thaw occurred rapidly in late April, which was later than usual, with flows from April 22 to 29 being lower than the historical minima for these dates. The freshet peak of 162 m^3/s occurred on May 1; flows then decreased but increased again in early June following rainfall events in late May. The annual peak flow of 166 m^3/s occurred on June 5 and was 30% higher than the historical mean annual maximum daily flow (128 m^3/s). All daily flows from May 30 to June 9 exceeded the historical maxima recorded on these dates. Flows then decreased through summer until late August, when the minimum open-water daily flow was recorded (15.9 m^3/s on August 29). This flow was 2% higher than the historical mean minimum daily flow of 15.7 m^3/s calculated for the open-water period. Flows increased slightly in late September due to rainfall, and were close to historical median values throughout October.

Overall, the annual runoff volume in the 2014 WY was 1,075 million m^3, which was 30% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Firebag River watershed, at WSC Station 07DC001 (formerly JOSMP Station S27) is summarized in Table 5.7-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2014 was estimated to be 23.4 km^2 (Table 2.3-1). The loss of flow to the Firebag River that would have otherwise occurred from this land area was estimated at 4,217 million m^3.

2. As of 2014, the area of land change in the Firebag River watershed that was not closed-circuited was estimated to be 48.0 km^2 (Table 2.3-1). The increase in flow to the Firebag River that would not have otherwise occurred from this land area was estimated at 1,726 million m^3.

3. In the 2014 WY, Suncor withdrew approximately 0.013 million m^3 (12,864 m^3) of water for dust suppression.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was a loss of flow of 2,504 million m^3 at WSC Station 07DC001 (formerly JOSMP Station S27). The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.23% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.7-3). These differences were classified as **Negligible-Low** (Table 5.7-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

McClelland Lake

Continuous lake level data have been collected at JOSMP Station L1, McClelland Lake, since 1997, with several periods of missing data over the data record. In the 2014 WY, the water level increased from November until early January, and then remained constant until the spring thaw in April (Figure 5.7-4). The lake level throughout this winter period was approximately equivalent to the historical upper quartile level. Lake level increased during freshet from late April, and reached the annual peak (294.787 m) on June 4 following some rainfall events. The annual peak occurred later than usual (annual peak in historical median level was on April 27), and all daily values recorded from May 27 to July 19 were higher than the previous maxima recorded on these dates. Following this peak, the lake level steadily decreased until early September, and then remained relatively constant until the end of October. Values from June to October remained between approximately 0.15 m to 0.20 m above historical median values during these months.

5.7.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Firebag River near its mouth (*test* station FIR-1), sampled since 2002;
- the Firebag River upstream of all oil sands development (*baseline* station FIR-2), sampled since 2003;
- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2000 to 2009 and *test* since 2010; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

Water quality samples were also collected at *baseline* station JOL-1 in winter, spring, and summer 2014.

Temporal Trends The following significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- Decreasing concentrations of total chloride at *test* station MCL-1 and *baseline* station FIR-2;
- A decreasing concentration of sulphate at *test* station MCL-1;
- An increasing concentration of total arsenic at *baseline* station FIR-2; and
- Increasing concentrations of total boron at *test* stations FIR-1 and MCL-1, and *baseline* station FIR-2.

Trend analysis could not be conducted for *baseline* station JOL-1 because only four years of data were available.

2014 Results Relative to Historical Concentrations Water quality measurement endpoints that were outside the range of previously-measured concentrations in fall 2014 included (Table 5.7-4 to Table 5.7-7):

- conductivity, calcium, total alkalinity, and naphthenic acids, with concentrations that exceeded previously-measured maximum concentrations, and retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station FIR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- total nitrogen, total aluminum, oilsands extractable acids, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station FIR-2;
- naphthenic acids and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations, and total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station MCL-1;

- pH, magnesium, total strontium, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station JOL-1; and

- conductivity, total dissolved phosphorus, total nitrogen, calcium, chloride, sulphate, total dissolved solids, total alkalinity, total and dissolved aluminum, total arsenic, total boron, total mercury (ultra-trace), retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station JOL-1.

Ion Balance The ionic composition of water in fall 2014 at *test* station FIR-1 and *baseline* station FIR-2 was similar to previous years and dominated primarily by calcium and bicarbonate (Figure 5.7-5). The ionic composition of water at these stations has remained consistent since monitoring began, with the exception of *baseline* station FIR-2 in 2007, when lower relative concentrations of calcium were measured. The ionic composition of McClelland Lake (*test* station MCL-1) in fall 2014 was consistent with previous years and dominated by magnesium and bicarbonate (Figure 5.7-5). *Baseline* station JOL-1 had an ionic composition similar to *test* station FIR-1 and *baseline* station FIR-2 (Figure 5.7-5).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in fall 2014 were below water quality guidelines at *test* stations FIR-1 and MCL-1 and at *baseline* stations FIR-2 and JOL-1 (Table 5.7-4 to Table 5.7-7).

Other Water Quality Guideline Exceedances Other water quality guideline exceedances that were measured in fall 2014 included total iron at *test* station FIR-1 and *baseline* station FIR-2 and total phenols at *baseline* station FIR-2 (Table 5.7-8).

Water quality guideline exceedances at *baseline* station JOL-1 in winter included sulphide, total iron, and total phenols (Table 5.7-8). During spring and summer, there were no guideline exceedances at *baseline* station JOL-1.

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *test* station FIR-1 and *baseline* station FIR-2 were within regional *baseline* concentrations, with the exception of (Figure 5.7-6):

- total mercury (ultra-trace), with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station FIR-1 and *baseline* station FIR-2; and

- total strontium, with a concentration that below the 5th percentile of regional *baseline* concentrations at *baseline* station FIR-2.

Concentrations of water quality measurement endpoints in McClelland Lake (*test* station MCL-1) and Johnson Lake (*baseline* station JOL-1) were not compared to regional *baseline* conditions because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers (Figure 5.7-7).

Water Quality Index The WQI values for *test* station FIR-1 (100) and *baseline* station FIR-2 (100) in the Firebag River watershed in fall 2014 indicated **Negligible-Low** differences from regional *baseline* conditions, and were similar to previous WQI values. WQI values were not calculated for McClelland Lake and Johnson Lake because lakes were not compared to regional *baseline* conditions.

Classification of Results In fall 2014, water quality at *test* station FIR-1 and *baseline* station FIR-2 showed **Negligible-Low** differences from regional *baseline* water quality conditions. Concentrations of most water quality measurement endpoints at *test* station FIR-1 and *baseline* station FIR-2 were within the range of regional *baseline* concentrations and within the range of previously-measured concentrations in fall 2014. The ionic composition of water in fall 2014 at both Firebag River stations and Johnson Lake were consistent with previous sampling years and dominated by calcium and bicarbonate ions. The ionic composition at McClelland Lake was dominated by magnesium and bicarbonate and consistent with previous sampling years. Concentrations of water quality measurement endpoints for *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2009 and *test* from 2010 to 2014; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

McClelland Lake

2014 Habitat Conditions Water in McClelland Lake had a pH of 8.6 and moderate conductivity (215 µS/cm), which was consistent with previous years (Table 5.7-9). Samples were taken at a depth of nearly 2 m. The lake substrate was primarily comprised of silt (87%) with small amounts of sand (6%) and clay (7%). The organic content of McClelland Lake sediments was very high in 2014 (33% TOC).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of McClelland Lake in 2014 was dominated by chironomids (38%) with subdominant taxa consisting of Ephemeroptera (13%) and naidid worms (11%) (Table 5.7-10). Dominant chironomids included *Dicrotendipes*, *Tanytarsus*, *Paratanytarsus*, and *Polypedilum,* all of which are very common in northern temperate lakes (Wiederholm 1983). Permanent aquatic forms such as bivalve clams (*Pisidium/Sphaerium*), gastropod snails (*Gyraulus, Promenetus exacuous,* and *Valvata sincera*), and amphipods (*Hyalella azteca*) were found in McClelland Lake indicating favorable long-term water quality. Mayflies (*Caenis*) and six types of caddisflies were also present (Table 5.7-10).

Temporal Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for McClelland Lake. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal comparisons of measurement endpoints included testing for:

- changes from the *baseline* (2002 to 2009) and *test* (2010 to present) periods (Hypothesis 2, Section 3.2.3.1);
- changes over time in the *test* period (i.e., 2010 to present);

- changes between 2014 and the mean of all *baseline* years; and
- changes between 2014 and all previous years of sampling.

Equitability was significantly lower in 2014 than the mean of the *baseline* period and the mean of all previous years at *test* station MCL-1, which accounted for 25% and 24% of the variation in annual means, respectively (Table 5.7-11). The percentage of the fauna as EPT taxa significantly increased over time during the *test* period, accounting for 30% of the variance in annual means (Table 5.7-11). The CA Axis 1 scores were higher during the *test* period, which explained 25% of the variation in annual means (Table 5.7-11). The higher CA Axis 1 scores during the *test* period reflected a shift in taxa composition to a higher relative abundance of worms present during the *test* period (Figure 5.7-8).

Comparison to Published Literature The benthic invertebrate community of McClelland Lake has had a fauna relatively typical of a shallow lake environment (Parsons et al. 2010; Pennak 1989). McClelland Lake contained several taxa considered to be permanent aquatic forms such as bivalves and gastropods in addition to larvae of flying insects (Ephemeroptera and Trichoptera) indicating favourable long-term water quality (Niemi et al. 1990).

2014 Results Relative to Historical Conditions Equitability and the percentage of EPT taxa in 2014 were above and below the inner tolerance limits of the normal range of variation, respectively, from all previous years for McClelland Lake (Figure 5.7-9). These exceedances were not indicative of a negative change in the lake as an increase in EPT taxa and diversity generally indicates favorable conditions.

Classification of Results Differences in benthic invertebrate communities of McClelland Lake were classified as **Negligible-Low** because although there was a significant increase in the percentage of fauna as EPT taxa and lower equitability in 2014 compared to previous years, these changes were indicative of good lake conditions. The general composition of the community in terms of relative abundances, presence of fully aquatic forms, and presence of generally sensitive taxa such as the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent to *baseline* conditions.

Johnson Lake

2014 Habitat Conditions Water in Johnson Lake in the fall of 2014 had a pH of 7.9 and moderate conductivity (259 µS/cm) (Table 5.7-9). Samples were taken at a depth of about 1 m. The substrate of Johnson Lake consisted primarily of silt (85%) with some clay (12%), and a small amount of sand (3%). The organic carbon content of the lake was high (24.5%) (Table 5.7-9).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Johnson Lake at *baseline* station JOL-1 in fall 2014 was dominated by chironomids (49%) and amphipods (25%) with subdominant taxa consisting of bivalves (9%) and naidid worms (Table 5.7-10). Chironomids were more diverse than 2013 with 24 genera in 2014. Dominant chironomids were the common forms of *Microtendipes*, *Polypedilum,* and *Procladius*. Amphipods included *Hyalella azteca* and *Gammarus lacustris*, both of which are commonly distributed in Canada (Väinölä et al. 2008). Bivalves (*Pisidium/Sphaerium*) were abundant and gastropods were well represented with eight kinds present. The most abundant gastropods were *Valvata sincera* and *Gyraulus.* A single *Caenis* mayfly was found at one of the replicate stations in Johnson Lake in 2014, as well as several *Enallagma* damselflies. Five kinds of caddisflies were present in the lake, with *Molanna* as the most abundant.

Comparison to Published Guidelines The benthic invertebrate community of Johnson Lake contained a fauna in 2014 that reflected generally good water quality and lentic conditions. The community contained several permanent aquatic forms such as Amphipoda (25%), fingernail clams (Bivalvia: Sphaeriidae), and gastropods, which are consistent with good long-term water quality (Niemi et al. 1990; Pennak 1989). The abundance of worms in Johnson Lake was lower compared to 2013. EPT taxa which were absent in 2013, were present in low relative abundances in 2014.

2014 Results Relative to Historical Conditions Johnson Lake is a *baseline* lake and has been since the beginning of sampling in 2011. In 2014, all measurement endpoints for benthic invertebrate community composition were similar to previous years (Figure 5.7-10 and Figure 5.7-11). There was a slight increase in richness and the percentage of fauna as EPT taxa compared to 2013 (Figure 5.7-11).

Classification of Results The benthic invertebrate community of Johnson Lake showed some improvement in 2014 compared to 2013, with the presence of EPT taxa, which were not observed in 2013. The abundance of worms (Tubificidae and Naididae) were lower in 2014 compared to 2013 and there were amphipods and gastropods present, indicating that Johnson Lake was generally in good condition.

5.7.4.2 Sediment Quality

In fall 2014, sediment quality samples were collected from:

- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2009 and *test* from 2010 to 2014; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

Temporal Trends A significant decreasing trend (α=0.05) over time in total arsenic was observed at *test* station MCL-1. A trend analysis was not completed for *baseline* station JOL-1 given the station has only been sampled for four years.

2014 Results Relative to Historical Concentrations Sediment at *test* station MCL-1 was composed predominantly of silt (90.6%) in fall 2014 (Table 5.7-13). The percentage of silt and the total organic carbon content in sediment exceeded previously-measured maximum values, while the percentage of sand was below the previously-measured minimum value. Concentrations of all hydrocarbons and PAHs at *test* station MCL-1 in fall 2014 were within previously-measured concentrations (Table 5.7-13 and Figure 5.7-12). Direct tests of sediment toxicity in fall 2014 indicated higher survival of the midge *Chironomus* (86%) than the amphipod *Hyalella* (58%), with survival of *Hyalella* below the previously-measured minimum value (Table 5.7-13).

Sediment collected at *baseline* station JOL-1 was dominated by silt (90.7%) with a small amount of clay (8.25%) in fall 2014 (Table 5.7-14). Concentrations of most sediment quality measurement endpoints were within the range of previously-measured concentrations, with the exception of naphthalene, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs, which were below previously-measured minimum concentrations (Table 5.7-14 and Figure 5.7-13). Direct tests of sediment toxicity indicated a higher survival rate of the midge *Chironomus* (96%) compared to survival rate of the amphipod *Hyalella*

(76%). The survival rate of *Chironomus* exceeded the previously-measured maximum value, while the survival rate of *Hyalella* was below the previously-measured minimum value at *baseline* station JOL-1 in fall 2014 (Table 5.7-14).

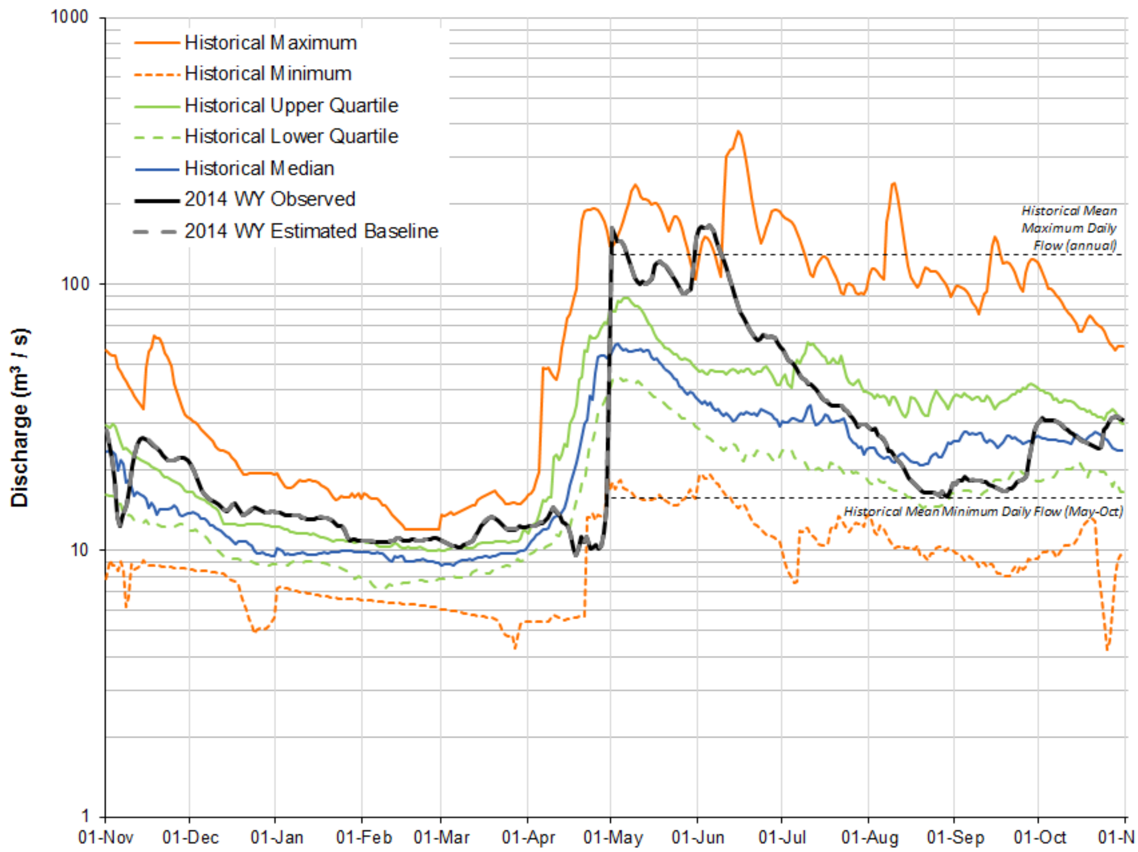
Comparison of Sediment Quality Measurement Endpoints to Published Guidelines All sediment quality measurement endpoints at *test* station MCL-1 and *baseline* station JOL-1 were below the relevant sediment quality guidelines, with the exception of F3 (C16-C34) hydrocarbons, which exceeded the CCME guideline at both stations (Table 5.7-13 and Table 5.7-14).

2014 Results Relative to Regional *Baseline* Concentrations Given the ecological differences between lakes and rivers, and because lakes were not included in the regional *baseline* calculations, *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* concentrations in fall 2014 (Figure 5.7-12 and Figure 5.7-13).

Sediment Quality Index SQI values were not calculated for *test* station MCL-1 or *baseline* station JOL-1 because lakes were not included in the regional *baseline* conditions, given the ecological differences between lakes and rivers and the limited *baseline*-lake data available for the oil sands region.

Classification of Results Sediment at both *test* station MCL-1 and *baseline* station JOL-1 was predominantly composed of silt. The percentage of silt and the total organic carbon content exceeded previously-measured maximum values at *test* station MCL-1, while the percentage of sand was below the previously-measured minimum value. All physical variables at *baseline* station JOL-1 were within the range of previously-measured values. Concentrations of naphthalene, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs at *baseline* station JOL-1 were below the previously-measured minimum concentrations. All sediment quality measurement endpoints were below the relevant sediment quality guidelines, with the exception F3 hydrocarbons, which exceeded the CCME guideline at both stations. SQI values were not calculated for MCL-1 and JOL-1 given the absence of regional *baseline* concentrations for lakes.

Figure 5.7-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Firebag River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on provisional data for Firebag River near the mouth, WSC Station 07DC001. The upstream drainage area is 5,988 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1972 to 2013, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1986, 2002, and from 2004 to 2013.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.7-2 Estimated water balance at WSC Station 07DC001 (formerly JOSMP Station S27), Firebag River near the mouth, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**1075.191**	**Observed discharge, obtained from Firebag River near the mouth, WSC Station 07DC001 (formerly JOSMP Station S27)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-4.217	Estimated 23.4 km^2 of the Firebag River watershed is closed-circuited as of 2014 (Table 2.3-1).
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	1.726	Estimated 48.0 km^2 of the Firebag River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1).
Water withdrawals from the Firebag River watershed, relative to the estimated *baseline* hydrograph	-0.013	Water withdrawals by Suncor for dust suppression
Water releases into the Firebag River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**1077.695**	**Estimated *baseline* discharge at Firebag River near the mouth, WSC Station 07DC001 (formerly JOSMP Station S27)**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	-2.504	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-0.230**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Table 5.7-3 Calculated change in hydrologic measurement endpoints for the Firebag River near the mouth, 2014 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	53.692	53.567	-0.230%
Mean winter discharge	14.563	14.530	-0.230%
Annual maximum daily discharge	166.385	166.000	-0.230%
Open-water season minimum daily discharge	15.937	15.900	-0.230%

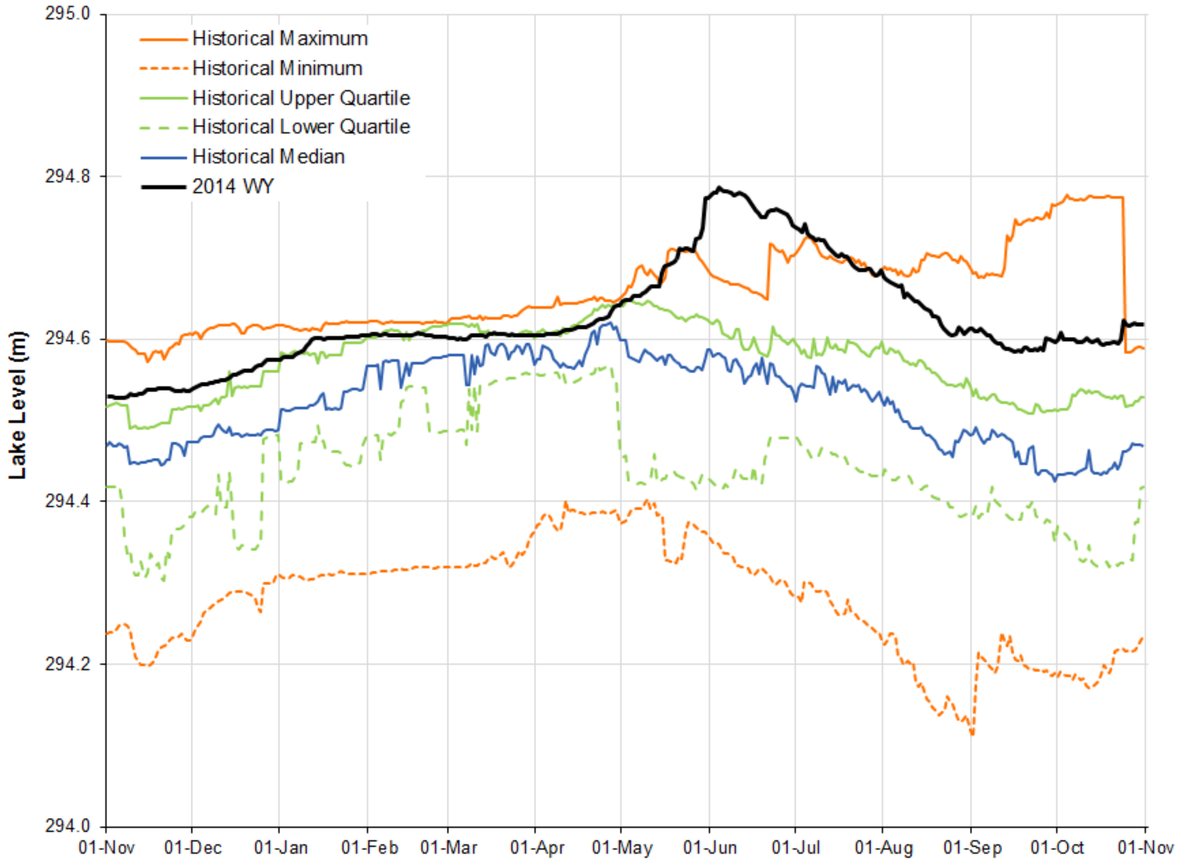
Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from provisional data from WSC Station 07DC001.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.7-4 Variation in the water level of McClelland Lake for the 2014 WY, compared to historical values.



Note: Observed 2014 WY record based on McClelland Lake, JOSMP Station L1. Historical statistics calculated for the period from 1997 to 2013 with numerous periods of missing data over the data record.

Table 5.7-4 Concentrations of water quality measurement endpoints, mouth of the Firebag River (*test* station FIR-1) in fall 2014, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	12	7.9	8.2	8.5
Total suspended solids	mg/L	-	<3.0	12	<3.0	6.0	23
Conductivity	µS/cm	-	<u>251</u>	12	171	217	248
Nutrients							
Total dissolved phosphorus	mg/L	-	0.022	12	0.012	0.031	0.057
Total nitrogen	mg/L	-	0.384	12	0.361	0.600	1.70
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	9.5	12	8.0	13.0	16.2
Ions							
Sodium	mg/L	-	4.0	12	2.0	4.0	4.6
Calcium	mg/L	-	<u>34.4</u>	12	22.6	30.5	33.2
Magnesium	mg/L	-	9.1	12	6.8	8.8	9.7
Chloride	mg/L	120	1.8	12	1.0	2.0	3.1
Sulphate	mg/L	309	3.2	12	1.7	2.6	10.3
Total dissolved solids	mg/L	-	149	12	60	142	170
Total alkalinity	mg/L	-	<u>125</u>	12	85	110	124
Selected metals							
Total aluminum	mg/L	0.1	0.035	12	0.033	0.098	**0.428**
Dissolved aluminum	mg/L	0.05	0.0016	12	0.0015	0.0052	0.0089
Total arsenic	mg/L	0.005	0.00034	12	0.00028	0.00047	0.00062
Total boron	mg/L	1.2	0.018	12	0.014	0.018	0.022
Total molybdenum	mg/L	0.073	0.00019	11	0.00011	0.00014	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	0.58	11	0.60	<1.20	4.40
Total strontium	mg/L	-	0.074	11	0.051	0.073	0.083
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.67</u>	3	0.29	0.34	0.44
Oilsands Extractable	mg/L	-	0.80	3	0.25	0.86	0.89
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.2
Retene	ng/L	-	<u>0.58</u>	3	2.07	3.43	3.43
Total dibenzothiophenes	ng/L	-	<u>7.724</u>	3	9.109	13.18	58.15
Total PAHs	ng/L	-	<u>85.14</u>	3	136.8	176.8	344.1
Total Parent PAHs	ng/L	-	<u>13.83</u>	3	22.27	23.48	24.07
Total Alkylated PAHs	ng/L	-	<u>71.31</u>	3	112.7	153.3	321.8
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.436**	12	**0.394**	**0.783**	**1.40**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.7-5 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (*baseline* station FIR-2) in fall 2014, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	12	7.4	8.1	8.3
Total suspended solids	mg/L	-	<3.0	12	<3.0	3.0	8.0
Conductivity	µS/cm	-	183	12	113	173	261
Nutrients							
Total dissolved phosphorus	mg/L	-	0.058	12	0.009	0.061	0.096
Total nitrogen	mg/L	-	<u>0.434</u>	12	0.500	0.716	1.28
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	8.50	12	8.00	13.6	17.4
Ions							
Sodium	mg/L	-	3.0	12	2.0	3.8	16
Calcium	mg/L	-	23.6	12	16.4	23.6	28.4
Magnesium	mg/L	-	6.9	12	5.1	6.4	8.7
Chloride	mg/L	120	<0.50	12	0.50	1.00	2.00
Sulphate	mg/L	309	1.20	12	0.810	1.60	22.6
Total dissolved solids	mg/L	-	124	12	110	127	158
Total alkalinity	mg/L	-	104	12	57.0	92.0	114
Selected metals							
Total aluminum	mg/L	0.1	<u>0.012</u>	12	0.015	0.036	0.082
Dissolved aluminum	mg/L	0.05	0.003	12	0.001	0.005	0.011
Total arsenic	mg/L	0.005	0.00043	12	0.00010	0.00058	0.00062
Total boron	mg/L	1.2	0.015	12	0.008	0.013	0.035
Total molybdenum	mg/L	0.073	0.00022	12	0.00004	0.00018	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	0.53	11	0.60	<1.2	2.2
Total strontium	mg/L	-	0.044	12	0.028	0.049	0.068
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.19	3	0.06	0.27	0.27
Oilsands Extractable	mg/L	-	<u>0.30</u>	3	0.91	0.99	0.99
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<8.76	<14.1
Retene	ng/L	-	0.791	3	1.210	1.210	<2.071
Total dibenzothiophenes	ng/L	-	<u>4.172</u>	3	5.844	35.30	35.30
Total PAHs	ng/L	-	<u>74.13</u>	3	151.2	206.3	206.3
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	16.49	16.49	19.21
Total Alkylated PAHs	ng/L	-	<u>60.88</u>	3	132.0	189.8	189.8
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.397**	12	0.240	**0.700**	**1.390**
Total phenols	mg/L	0.004	**0.0042**	12	<0.0010	**0.0046**	**0.0154**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.7-6 Concentrations of water quality measurement endpoints, McClelland Lake (*test* station MCL-1) in fall 2014, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	12	8.1	8.5	8.7
Total suspended solids	mg/L	-	<3.0	12	<3.0	3.0	9.0
Conductivity	µS/cm	-	249	12	224	243	267
Nutrients							
Total dissolved phosphorus	mg/L	-	0.002	12	0.002	0.004	0.013
Total nitrogen	mg/L	-	0.86	12	0.55	1.00	2.00
Nitrate+nitrite	mg/L	3	<0.054	12	<0.050	<0.086	<0.100
Dissolved organic carbon	mg/L	-	14.0	12	11.0	13.0	17.0
Ions							
Sodium	mg/L	-	4.8	12	4.0	4.9	6.0
Calcium	mg/L	-	22.1	12	19.3	21.7	25.8
Magnesium	mg/L	-	16.5	12	14.6	16.7	18.0
Chloride	mg/L	120	<0.50	12	<0.50	<1.0	1.0
Sulphate	mg/L	309	<0.50	12	<0.50	0.55	4.30
Total dissolved solids	mg/L	-	175	12	80.0	155	194
Total alkalinity	mg/L	-	134	12	122	130	145
Selected metals							
Total aluminum	mg/L	0.1	0.011	12	0.003	0.011	0.026
Dissolved aluminum	mg/L	0.05	0.0006	12	<0.001	<0.001	0.010
Total arsenic	mg/L	0.005	0.00020	12	0.00019	0.00021	<0.0010
Total boron	mg/L	1.2	0.073	12	0.051	0.065	0.089
Total molybdenum	mg/L	0.073	0.000003	12	<0.000008	<0.000065	<0.00010
Total mercury (ultra-trace)	ng/L	5, 13	0.42	9	<0.3	<1.2	2.4
Total strontium	mg/L	-	0.140	12	0.110	0.133	0.153
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.64	3	0.09	0.34	0.38
Oilsands Extractable	mg/L	-	1.70	3	0.45	0.54	1.14
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	12.50	14.13	<15.2
Retene	ng/L	-	<0.407	3	<0.509	<0.669	<2.07
Total dibenzothiophenes	ng/L	-	4.495	3	6.625	7.575	35.30
Total PAHs	ng/L	-	74.72	3	105.2	165.2	221.5
Total Parent PAHs	ng/L	-	13.26	3	20.47	20.63	23.46
Total Alkylated PAHs	ng/L	-	61.47	3	81.76	144.8	200.8

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.7-7 Concentrations of water quality measurement endpoints, Johnson Lake (*baseline* station JOL-1) in fall 2014, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.44	3	8.24	8.37	8.38
Total suspended solids	mg/L	-	<3.0	3	<3.0	5	61
Conductivity	µS/cm	-	249	3	294	323	341
Nutrients							
Total dissolved phosphorus	mg/L	-	0.002	3	0.004	0.013	0.019
Total nitrogen	mg/L	-	0.864	3	0.881	1.20	2.20
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	14.0	3	12.2	13.7	14.6
Ions							
Sodium	mg/L	-	4.8	3	3.9	5.8	6.6
Calcium	mg/L	-	22.1	3	37.8	41.6	44.0
Magnesium	mg/L	-	16.5	3	12.3	13.5	15.8
Chloride	mg/L	120	<0.50	3	2.64	4.75	6.07
Sulphate	mg/L	309	<0.50	3	1.02	1.29	1.49
Total dissolved solids	mg/L	-	175	3	190	199	236
Total alkalinity	mg/L	-	134	3	154	165	172
Selected metals							
Total aluminum	mg/L	0.1	0.011	3	0.012	0.017	**0.132**
Dissolved aluminum	mg/L	0.05	0.0006	3	0.0010	0.0046	0.0158
Total arsenic	mg/L	0.005	0.00020	3	0.00023	0.00030	0.00039
Total boron	mg/L	1.2	0.073	3	0.096	0.173	0.252
Total molybdenum	mg/L	0.073	0.000003	3	<0.00010	0.00010	0.00014
Total mercury (ultra-trace)	ng/L	5, 13	0.42	3	0.90	1.20	1.80
Total strontium	mg/L	-	0.140	3	0.107	0.109	0.138
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.64	3	0.11	0.22	0.51
Oilsands Extractable	mg/L	-	1.70	3	0.45	0.58	1.54
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	9.360	14.13	<15.16
Retene	ng/L	-	0.506	3	0.643	1.250	17.30
Total dibenzothiophenes	ng/L	-	4.134	3	6.664	6.672	35.30
Total PAHs	ng/L	-	75.33	3	104.5	168.5	212.0
Total Parent PAHs	ng/L	-	13.26	3	17.55	19.74	24.11
Total Alkylated PAHs	ng/L	-	62.08	3	80.40	148.7	194.4

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.7-5 Piper diagram of fall ion concentrations in the Firebag River watershed, fall 2014.

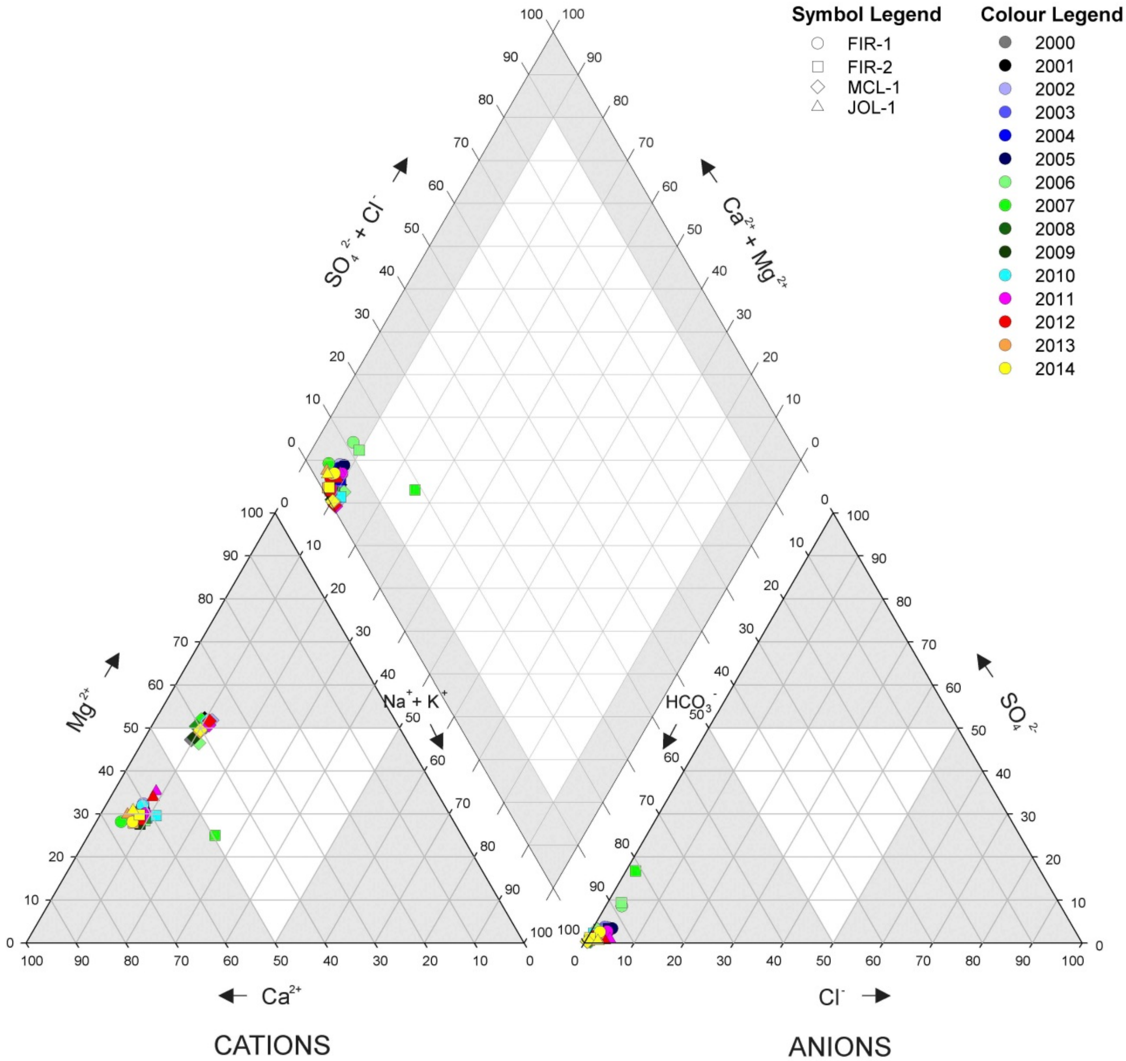


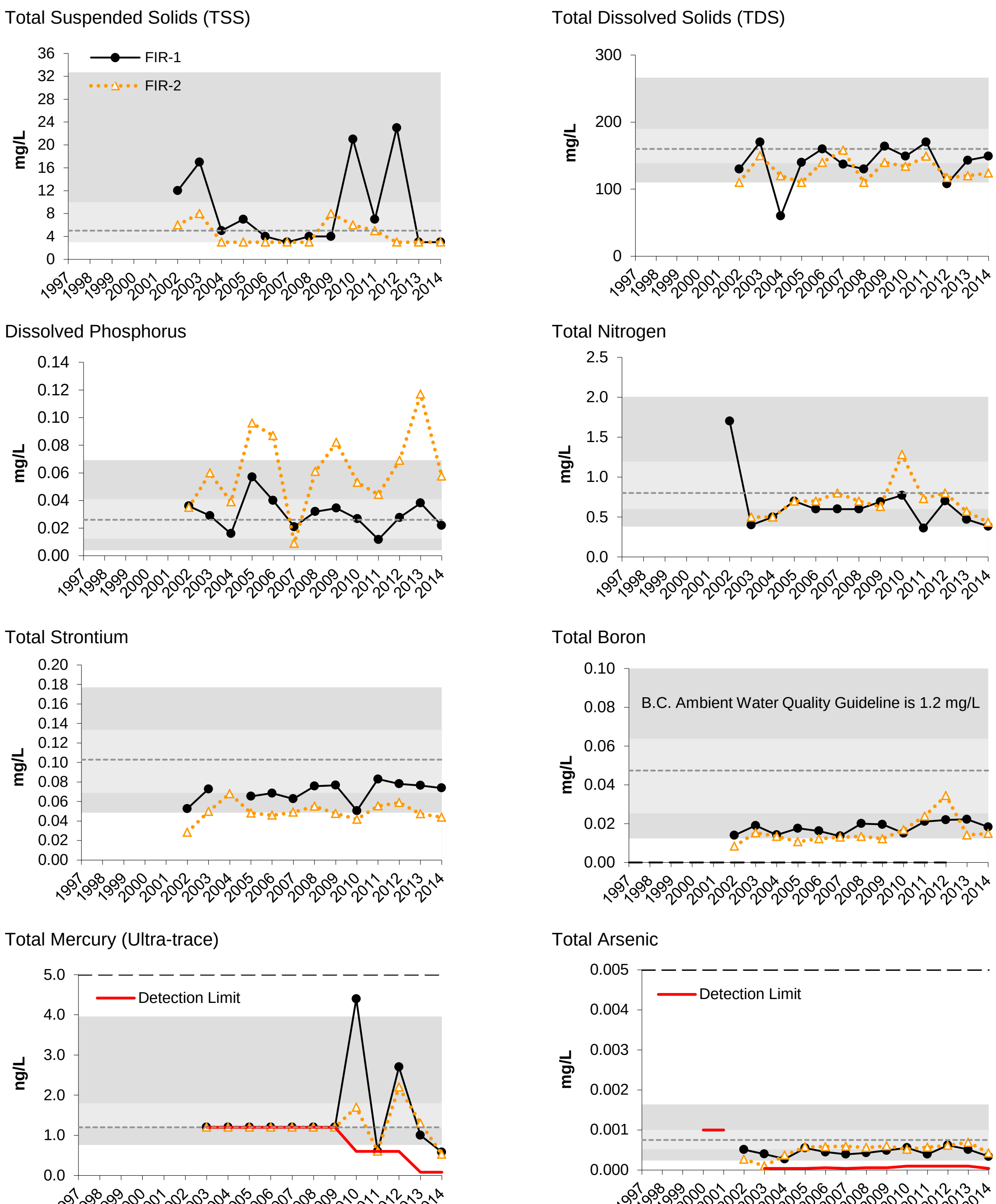
Table 5.7-8 Water quality guideline exceedances, Firebag River watershed, 2014.

Variable	Units	Guideline[a]	FIR-1	FIR-2	MCL-1	JOL-1[b]
Winter						
Sulphide	mg/L	0.002	ns	ns	ns	0.004
Total iron	mg/L	0.3	ns	ns	ns	0.646
Total phenols	mg/L	0.004	ns	ns	ns	0.005
Fall						
Total iron	mg/L	0.3	0.436	0.397	-	-
Total phenols	mg/L	0.004	-	0.004	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

ns = not sampled

Figure 5.7-6 Concentrations of selected water quality measurement endpoints in the Firebag River (fall 2014) relative to historical concentrations and regional *baseline* fall concentrations.



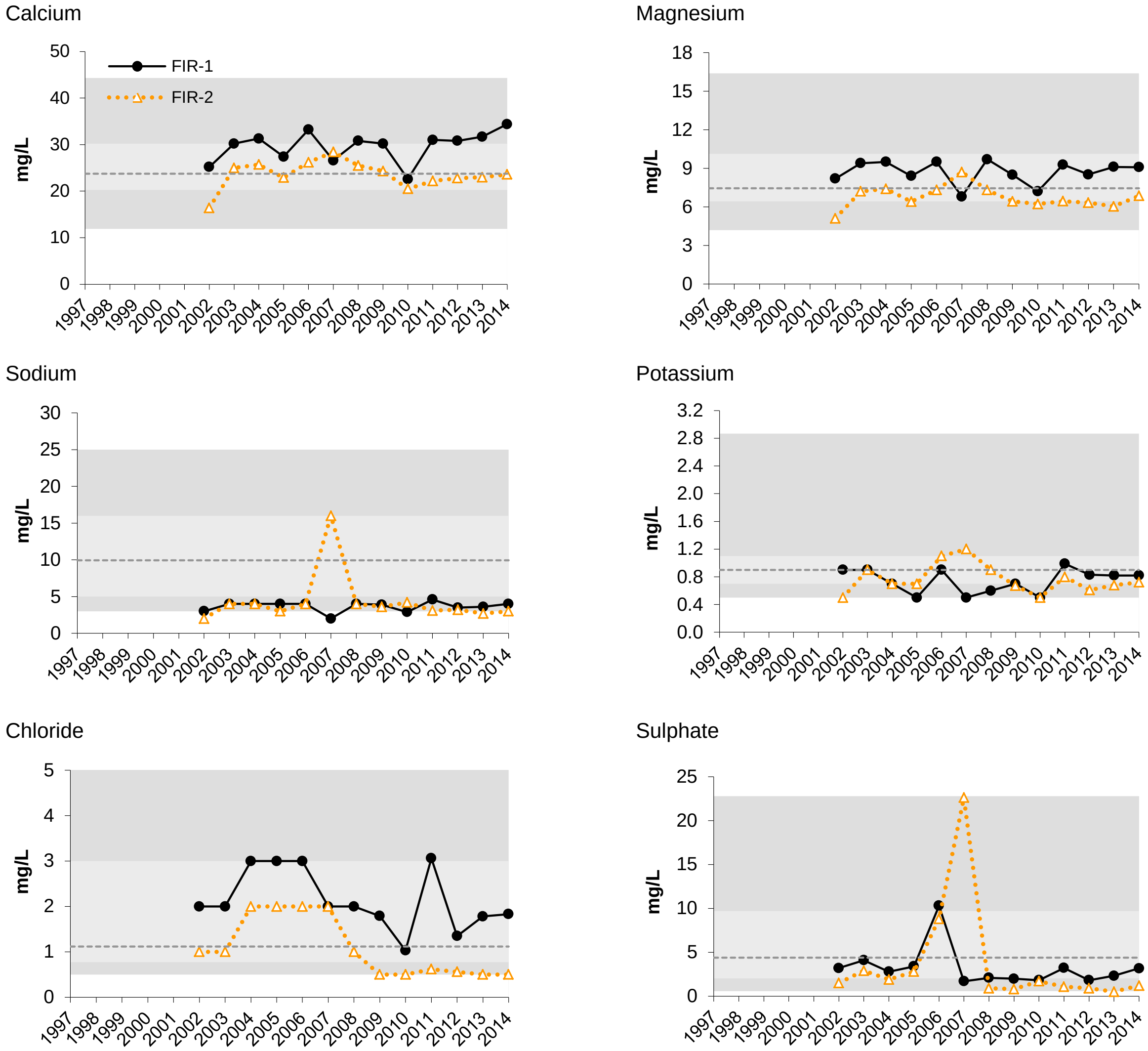
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.7-6 (Cont'd.)



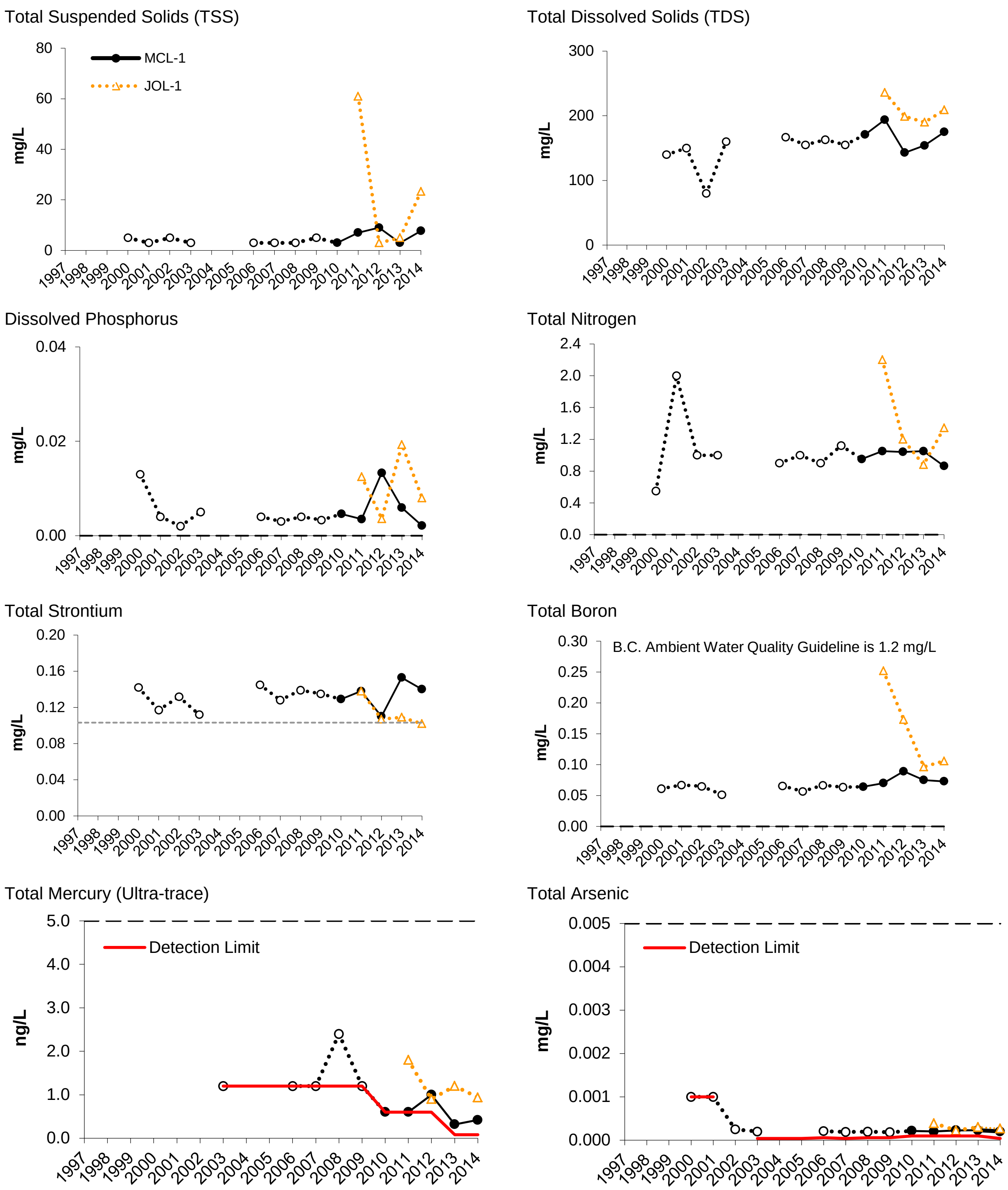
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.7-7 Concentrations of selected water quality measurement endpoints in McClelland Lake and Johnson Lake (fall 2014) relative to historical concentrations.

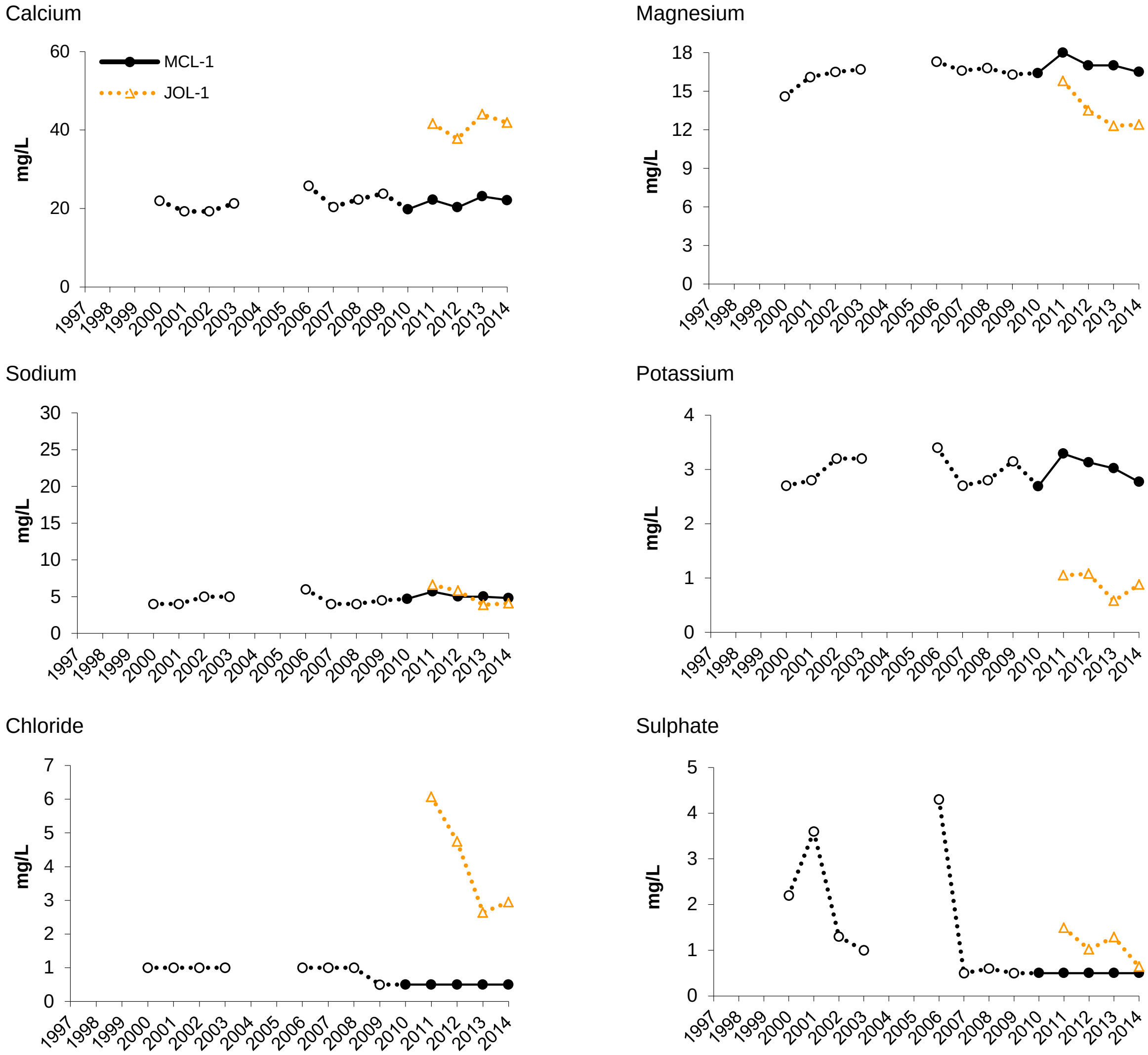


Non-detectable values are shown at the detection limit.

– – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.7-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Table 5.7-9 Average habitat characteristics of benthic invertebrate sampling locations in McClelland Lake and Johnson Lake, fall 2014.

Variable	Units	McClelland Lake	Johnson Lake
Sample date	-	Sept 5, 2014	Sept 5, 2014
Habitat	-	Depositional	Depositional
Water depth	m	1.7	0.6
Field Water Quality			
Dissolved oxygen	mg/L	8.8	7.2
Conductivity	µS/cm	215	259
pH	pH units	8.6	7.9
Water temperature	°C	14.8	13.1
Sediment Composition (mean ± 1SD)			
Sand	%	6±9	2 ±2
Silt	%	88±9	86±3
Clay	%	7±4	12±3
Total Organic Carbon	%	34±4	25±1

Table 5.7-10 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in McClelland Lake and Johnson Lake.

Taxon	Percent Major Taxa Enumerated in Each Year					
	McClelland Lake			Johnson Lake		
	2002	2003-2013	2014	2011	2012-2013	2014
Hydra	-	-	<1	-	-	-
Nematoda	1	0 to 5	<1	1	<1 to 13	1
Oligochaeta	-	-	<1	-	-	-
Naididae	14	2 to 17	11	<1	2 to 7	4
Tubificidae	-	0 to 6	7	3	4 to 18	1
Enchytraeidae	-	<1	-	-	-	-
Lumbriculidae	-	0 to 8	<1	-	<1	<1
Hirudinea	-	-	<1	1	<1 to 2	<1
Erpobdellidae	1	0 to <1	-	-	-	-
Hydracarina	1	0 to 12	1	<1	2	<1
Amphipoda	11	0 to 22	13	37	3 to 21	25
Gastropoda	<1	0 to 22	<1	<1	<1 to 2	3
Bivalvia	2	1 to 9	3	19	7 to 31	9
Ceratopogonidae	-	0 to 1	-	1	-	1
Chironomidae	58	24 to 91	38	33	23 to 53	49
Diptera (misc.)	-	<1	<1	<1	<1	-
Ephemeroptera	1	<1 to 20	13	-	<1	<1
Odonata	-	0 to 1	<1	-	-	<1
Trichoptera	1	0 to 3	2	<1	-	<1
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	129	763 to 2,409	469	230	170 to 397	279
Richness	11	6 to 24	18	11	10 to 11	20
Equitability	0.51	0.22 to 0.73	0.12	0.44	0.4 to 0.46	0.33
% EPT	2	1 to 24	15	<1	0 to <1	0.87

Table 5.7-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in McClelland Lake.

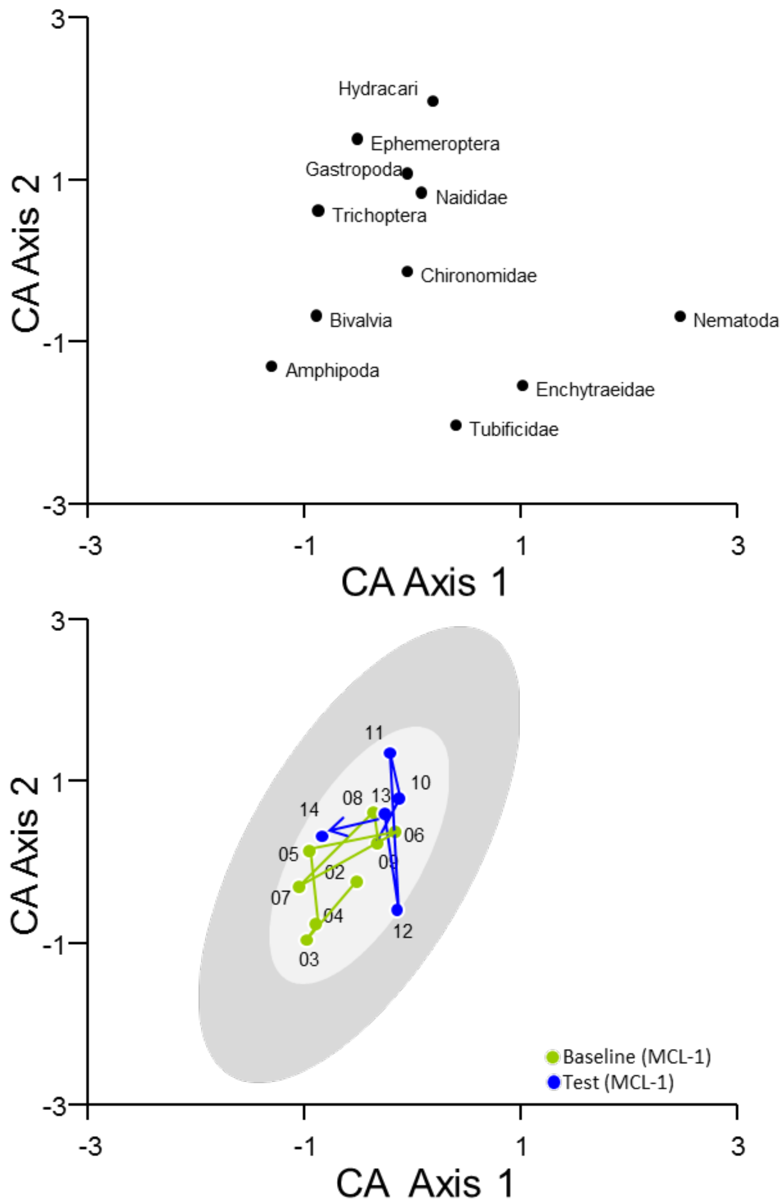
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Period vs. *Baseline* Period	Time Trend (*test* period)	2014 vs. *Baseline* Period	2014 vs. Previous Years	*Test* Period vs. *Baseline* Period	Time Trend (*test* period)	2014 vs. *Baseline* Period	2014 vs. Previous Years	
Log of Abundance	**0.005**	**0.002**	0.814	0.727	7	10	0	0	Higher during *test* period; decreasing over time in *test* period.
Log of Richness	**0.011**	0.624	0.273	0.530	8	0	2	1	Higher during *test* period.
Equitability	**0.003**	0.140	**<0.001**	**<0.001**	9	2	25	24	Lower during *test* period; lower in 2014 than *baseline* period and all previous years.
Log of EPT	**0.005**	**0.000**	**0.001**	**0.004**	14	30	18	15	Higher during *test* period; increasing over time in *test* period; higher in 2014 than the mean of *baseline* years and all previous years.
CA Axis 1	**0.004**	0.060	0.543	0.181	25	10	1	5	Higher during *test* period.
CA Axis 2	**0.006**	0.099	0.300	0.616	19	7	3	1	Higher during *test* period.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-8).

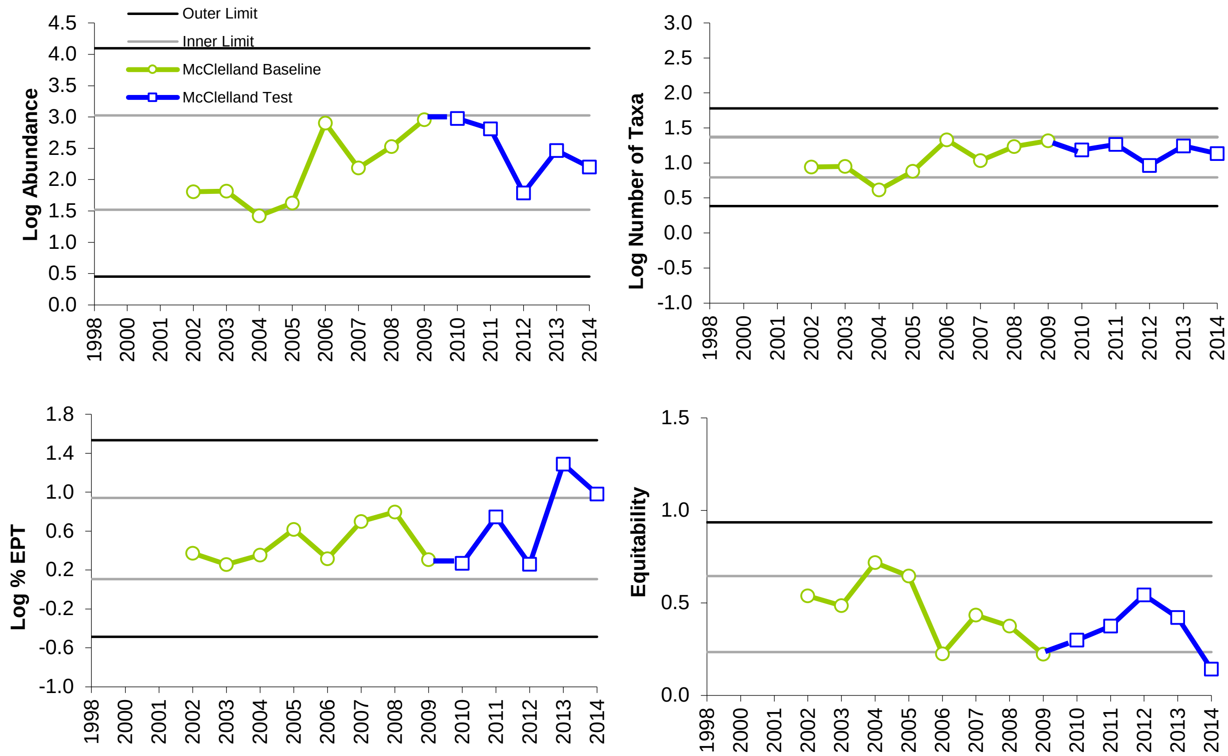
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.7-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of the study lakes, showing McClelland Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.7-9 Variation in benthic invertebrate community measurement endpoints in McClelland Lake relative to the historical range of variability.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years (2002 to 2013).

Note: Abundance, richness and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.7-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Johnson Lake.

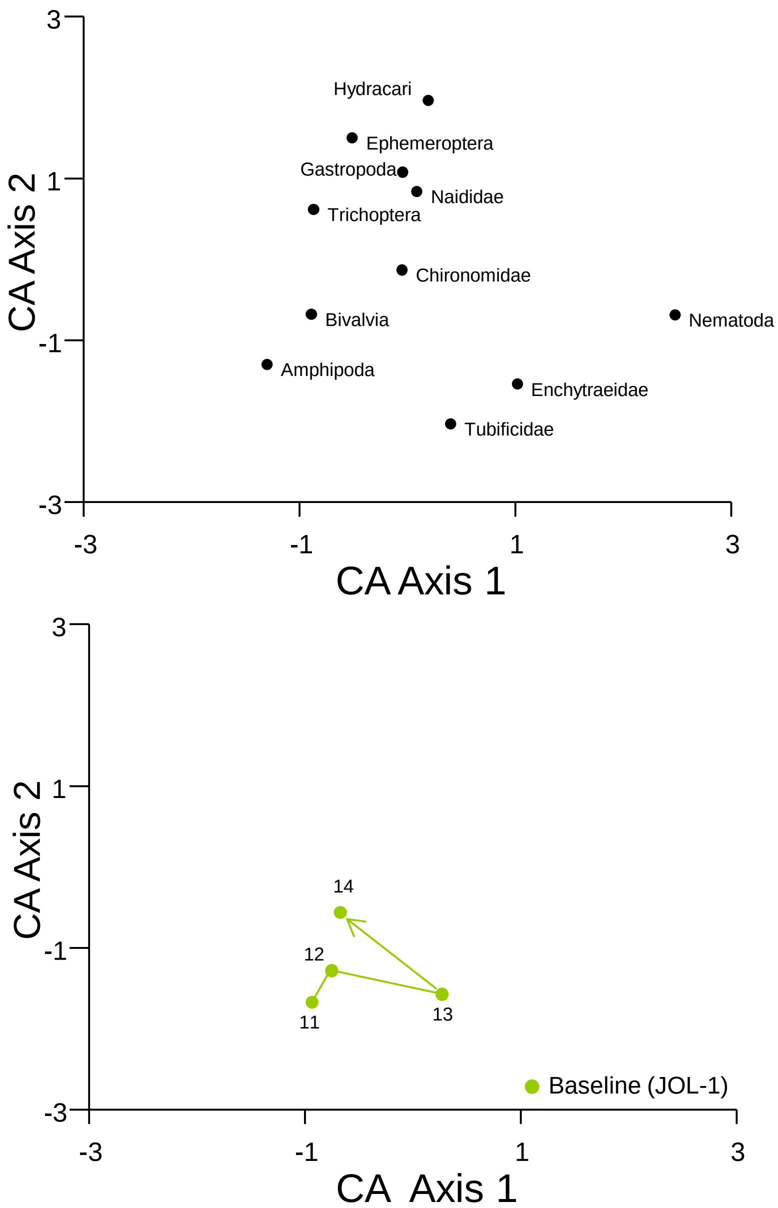
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. previous years	Time Trend	2014 vs. previous years	
Log of Abundance	0.692	0.738	68	48	No change.
Log of Richness	0.105	**0.039**	58	96	Higher in 2014 than mean of previous years.
Equitability	0.503	0.490	67	71	No change.
Log of EPT	0.971	**0.021**	0	46	Higher in 2014 than mean of previous years.
CA Axis 1	**0.006**	0.575	33	1	Increasing over time.
CA Axis 2	**0.010**	**0.001**	41	80	Increasing over time; higher in 2014 than mean of previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

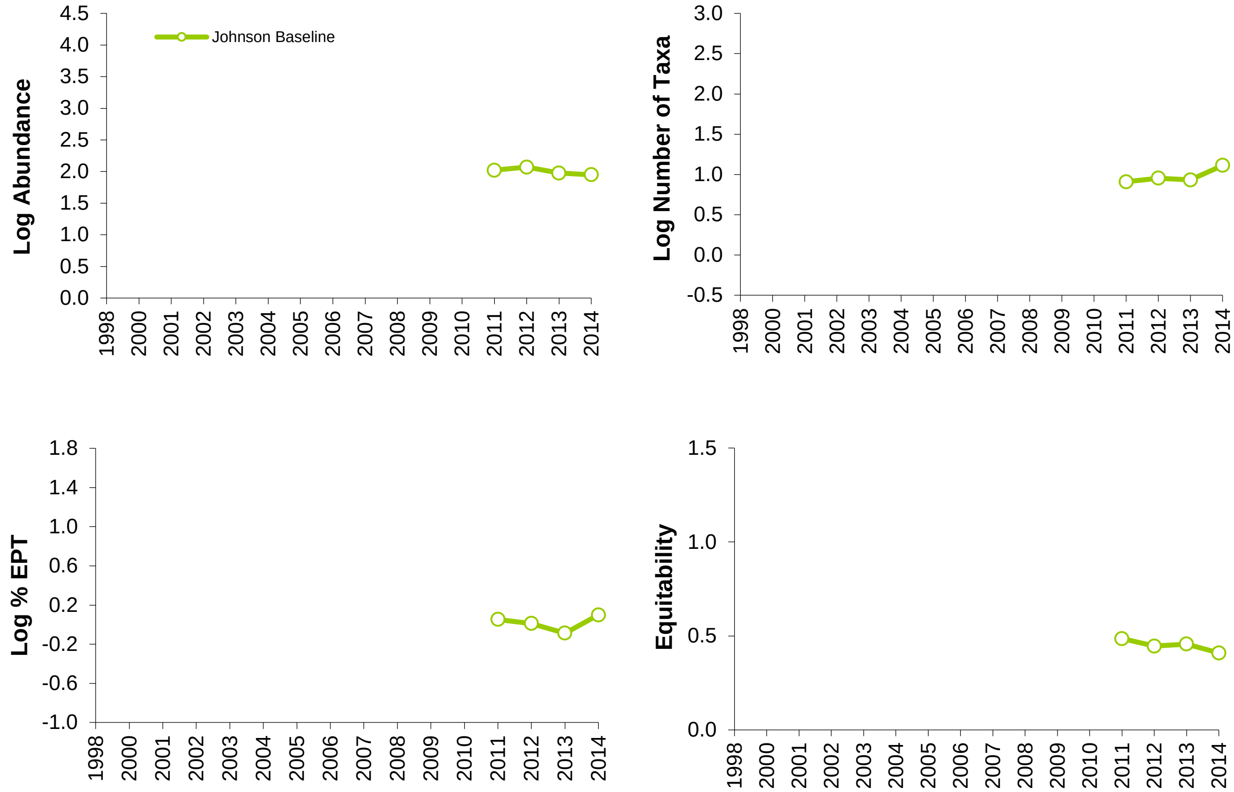
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-10 Ordination (Correspondence Analysis) of benthic invertebrate communities of the study lakes, showing Johnson Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Figure 5.7-11 Variation in benthic invertebrate community measurement endpoints in Johnson Lake.



Note: Abundance, richness and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.7-13 Concentrations of sediment quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2014.

Variables	Units	Guideline	September 2014	2002-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.4	10	0.46	11.05	49
Silt	%	-	<u>90.6</u>	10	0.19	22	80.1
Sand	%	-	<u>4</u>	10	9.76	51.4	99.4
Total organic carbon	%	-	<u>35</u>	10	0.4	28.2	33.9
Total hydrocarbons							
BTEX	mg/kg	-	<130	8	<5	<55	<150
Fraction 1 (C6-C10)	mg/kg	30[1]	<130	8	<5	<55	<150
Fraction 2 (C10-C16)	mg/kg	150[1]	<124	8	<5	<101	<288
Fraction 3 (C16-C34)	mg/kg	300[1]	**379**	8	20.0	**460**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	134	8	20	265	2,400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0044	7	0.0004	0.0095	0.0241
Retene	mg/kg	-	0.1560	10	0.0013	0.0852	0.161
Total dibenzothiophenes	mg/kg	-	0.0993	10	0.0020	0.0329	0.3091
Total PAHs	mg/kg	-	0.6811	10	0.034	0.5445	1.9466
Total Parent PAHs	mg/kg	-	0.0671	10	0.0027	0.0637	0.1389
Total Alkylated PAHs	mg/kg	-	0.6140	10	0.0313	0.4786	1.8077
Predicted PAH toxicity[3]	H.I.	1.0	0.3053	10	0.0387	0.1508	0.7789
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.6	6	7.4	9.1	9.6
Chironomus growth - 10d	mg/organism	-	2.11	6	1.4	1.7	2.12
Hyalella survival - 14d	# surviving	-	<u>5.8</u>	6	7.4	8.4	9.8
Hyalella growth - 14d	mg/organism	-	0.26	6	0.22	0.32	0.49

Values in **bold** indicate concentrations exceeding guidelines.

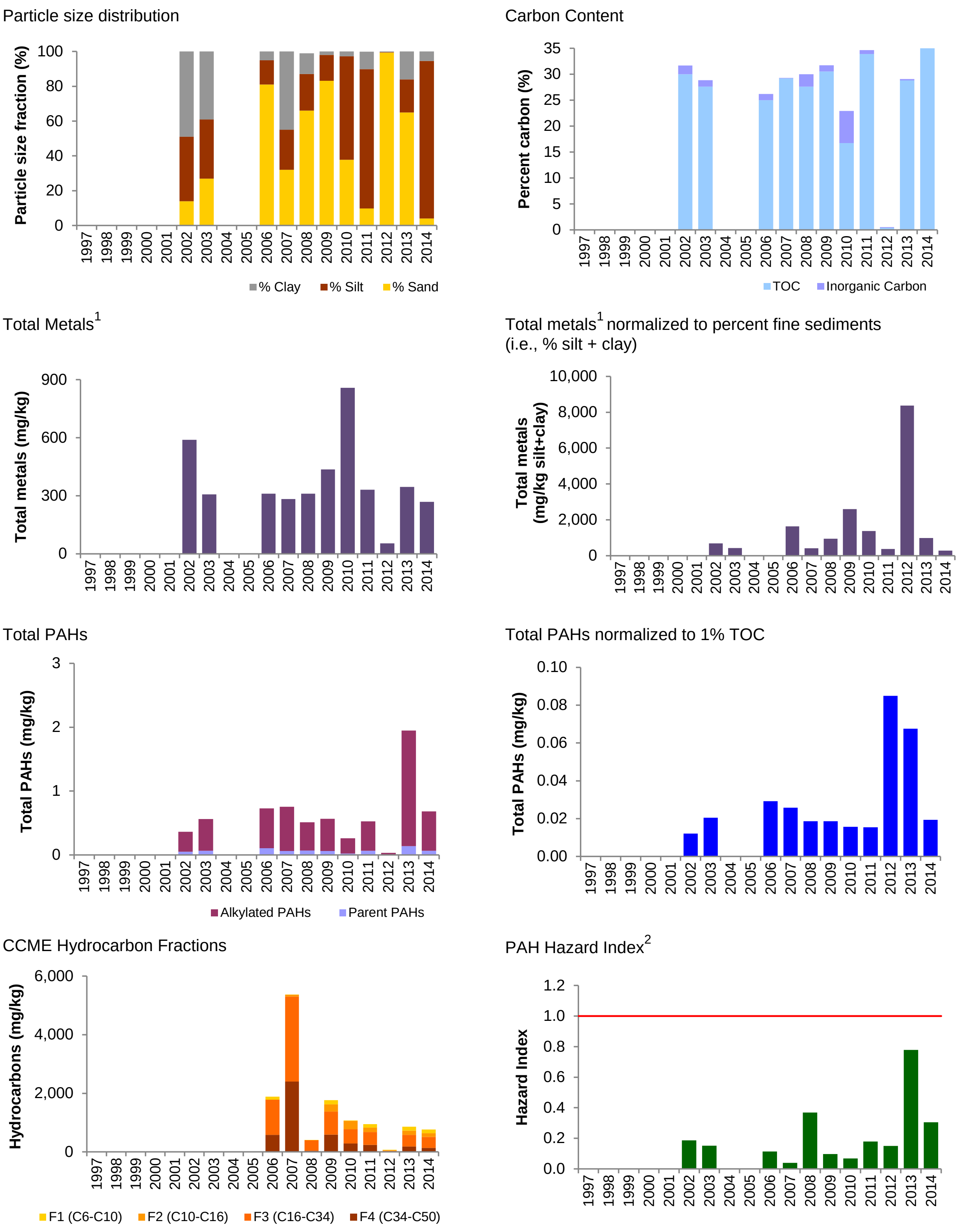
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-12 Variation in sediment quality measurement endpoints in McClelland Lake, *test* station MCL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.7-14 Concentrations of sediment quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2014.

Variables	Units	Guideline	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Med	Max
Physical variables							
Clay	%	-	8.25	3	4.95	8.00	18.1
Silt	%	-	90.7	3	34.1	63.6	94.3
Sand	%	-	1.07	3	0.80	28.4	47.7
Total organic carbon	%	-	25.8	3	19.0	26.2	38
Total hydrocarbons							
BTEX	mg/kg	-	<90	3	<90	<130	<160
Fraction 1 (C6-C10)	mg/kg	30[1]	<90	3	<90	<130	<160
Fraction 2 (C10-C16)	mg/kg	150[1]	<92	3	<107	<165	<187
Fraction 3 (C16-C34)	mg/kg	300[1]	**438**	3	**281**	**1,070**	**1,300**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	190	3	174	464	760
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0022	3	0.0042	0.0062	0.0062
Retene	mg/kg	-	0.0519	3	0.1080	0.1130	0.219
Total dibenzothiophenes	mg/kg	-	0.0160	3	0.0303	0.0374	0.0495
Total PAHs	mg/kg	-	0.3321	3	0.5471	0.5545	1.0291
Total Parent PAHs	mg/kg	-	0.0410	3	0.0299	0.0353	0.054
Total Alkylated PAHs	mg/kg	-	0.2910	3	0.5171	0.5192	0.975
Predicted PAH toxicity[3]	H.I.	1.0	0.1371	3	0.0937	0.1209	0.2951
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.6	3	8.6	9.0	9.4
Chironomus growth - 10d	mg/organism	-	1.90	3	1.17	1.90	1.93
Hyalella survival - 14d	# surviving	-	7.6	3	8.4	8.4	9.2
Hyalella growth - 14d	mg/organism	-	0.29	3	0.20	0.29	0.37

Values in **bold** indicate concentrations exceeding guidelines.

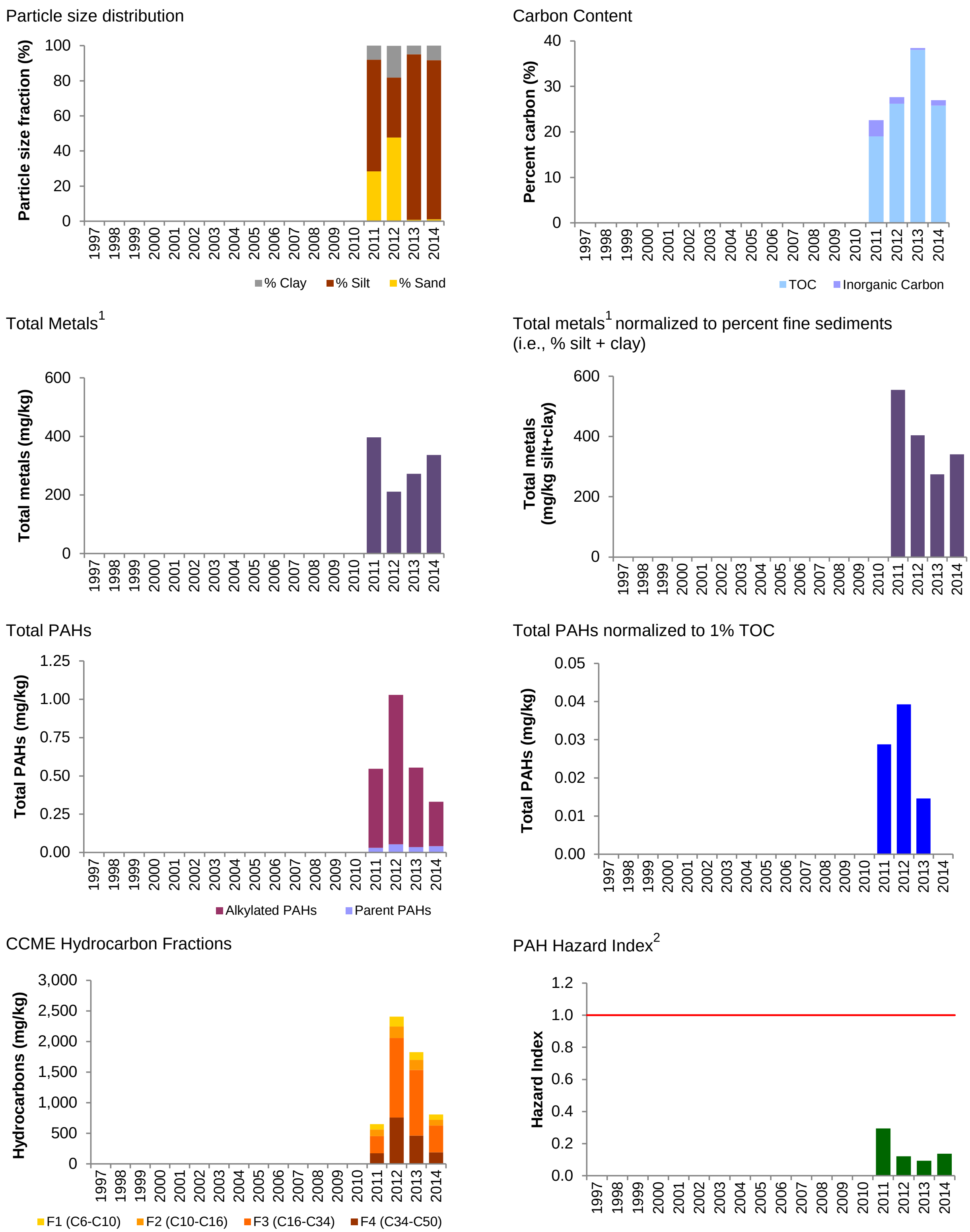
Underlined values indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-13 Variation in sediment quality measurement endpoints in Johnson Lake, *baseline* station JOL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

5.8 ELLS RIVER WATERSHED

Table 5.8-1 Summary of results for the Ells River watershed.

Ells River Watershed	Summary of 2014 Conditions			
	Ells River		Lakes	
Climate and Hydrology				
Criteria	**S14A** Canadian Natural Bridge	no station	**L4** Namur Lake near outlet	no station
Mean open-water season discharge	Negligible - Low			
Mean winter discharge	Negligible - Low			
Annual maximum daily discharge	Negligible - Low			
Minimum open-water season discharge	Negligible - Low			
Water Quality				
Criteria	**ELR-1** at the mouth	**ELR-3** upstream of development	**NAL-1** Namur Lake	**GAL-1** Gardiner Lake
Water Quality Index	Negligible - Low	Negligible - Low	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality				
Criteria	**ELR-D1** lower reach	**ELR-E3** upstream of development	**NAL-1** Namur Lake	**GAL-1** Gardiner Lake
Benthic Invertebrate Communities	Moderate	n/a	n/a	n/a
Sediment Quality Index	Negligible - Low	no station	n/a	n/a
Fish Populations				
Criteria	**ELR-F1** lower reach	**ELR-F3** upstream of development	no station	no station
Fish Assemblages	Moderate	n/a		

Legend and Notes

- ○ Negligible - Low
- ● Moderate
- ● High

baseline (ELR-3, ELR-E3, ELR-F3, S14A, L4, NAL-1, GAL-1)
test (ELR-1, ELR-D1, ELR-F1)

n/a - not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Figure 5.8-1 Ells River watershed.

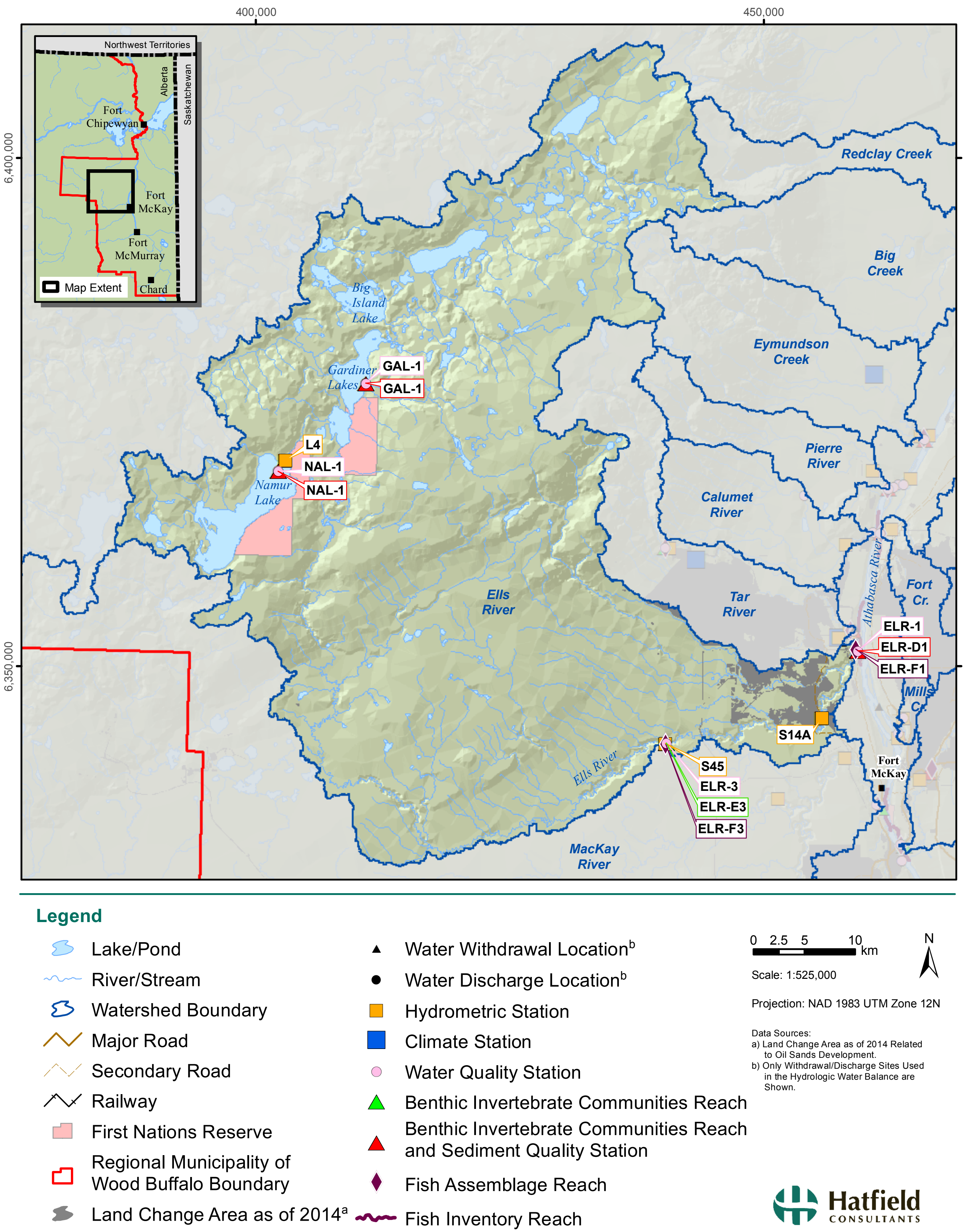


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Figure 5.8-2 Representative monitoring stations of the Ells River watershed, fall 2014.

Benthic Invertebrate Reach ELR-D1:
Right Downstream Bank, facing downstream

Benthic Invertebrate Reach ELR-E3:
Mid-Channel, facing downstream

Hydrology Station L4 (Namur Lake)

Hydrology Station S14A:
at the Canadian Natural Bridge, facing upstream

Gardiner Lake (aerial view)

Namur Lake (aerial view)

5.8.1 Summary of 2014 Conditions

Approximately 1.5% (3,370 ha) of the Ells River watershed had undergone land change as of 2014 from oil sands development (Table 2.3-1); much of this land change was located in the Joslyn Creek drainage. The designations of specific areas of the watershed are as follows:

1. The Ells River watershed downstream of the Total E&P Joslyn Project (now on hold) and the confluence of Joslyn Creek with the Ells River (Figure 5.8-1) is designated as *test*.
2. The remainder of the watershed is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in the Ells River watershed in 2014. Table 5.8-1 is a summary of the 2014 assessment for the Ells River watershed while Figure 5.8-1 denotes the location of the monitoring stations for each component, and the area with land change as of 2014. Figure 5.8-2 contains fall 2014 photos of a number of monitoring stations in the watershed.

Hydrology The 2014 WY mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

Water Quality Differences in water quality in fall 2014 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* station ELR-1 and were typically within the range of previously-measured concentrations and regional *baseline* conditions. *Baseline* station ELR-3, initiated in 2013, showed similar water quality to *test* station ELR-1, and was within regional *baseline* conditions in fall 2014 for all measurement endpoints with the exception of lower concentrations of total mercury (ultra-trace). Concentrations of water quality measurement endpoints from *baseline* stations GAL-1 and NAL-1 (Gardiner and Namur lakes) were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. The ionic composition of water in Namur and Gardiner lakes was similar to stations of the Ells River but showed a slightly lower and greater dominance of calcium and bicarbonate, respectively, compared to the stations on the Ells River. There were no water quality guideline exceedances at Namur Lake and very few at Gardiner Lake in 2014.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 were classified as **Moderate** because significant decreases in abundance, EPT, richness, and CA Axis 2 scores over time were indicative of potentially degrading conditions. Abundance in fall 2014 (111 organisms per sample) was higher than fall 2013 (48 organisms per sample), but still lower than previous years. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) were sparse in 2014 and EPT taxa were absent. All of the smaller and previously-abundant organisms remained abundant in 2014 and a decrease in tubificid worms has been occurring over time. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Similar to 2013, water velocity at the lower Ells River in 2014 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and could be an explanation for the absence of larger forms of benthic invertebrates at *test* reach ELR-D1 in recent years.

The benthic invertebrate communities of Gardiner and Namur lakes were sampled for the first time in 2014. The benthic invertebrate communities of both lakes were evident of good water quality conditions, with the presence of EPT taxa and permanent aquatic forms (e.g., bivalves, gastropods). The relative abundance of worms were high in both lakes in 2014.

Sediment quality in fall 2014 at *test* station ELR-D1 indicated **Negligible-Low** differences from regional *baseline* conditions, and most sediment quality measurement endpoints were within the range of the regional *baseline* concentrations, with the exception of total PAHs. Concentrations of F2 and F3 hydrocarbons, and chrysene exceeded CCME guidelines and the predicted PAH toxicity exceeded the potential chronic effect level at *test* station ELR-D1. SQI values were not calculated for *baseline* stations NAL-1 and GAL-1 because lakes were not included in the regional *baseline* calculations. Sampling at *baseline* stations GAL-1 and NAL-1 was initiated in 2014; therefore, no historical data were available for comparison. No sediment guidelines or threshold values were exceeded at either lake in 2014.

Fish Populations (fish assemblages) Differences in measurement endpoints for the fish assemblage at *test* reach ELR-F1 were classified as **Moderate** given that abundance and CPUE have decreased over time and all measurement endpoints were lower compared to *baseline* reach ELR-F3. It is noted; however, that there was a decrease in the ATI value, indicating a greater proportion of sensitive species in the assemblage, and all measurement endpoints were within regional *baseline* conditions.

5.8.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Ells River watershed in the 2014 WY was conducted at the following locations:

- JOSMP Station S14A, Ells River at the Canadian Natural Bridge;
- JOSMP Station L4, Namur Lake;
- WSC Station 07DA909, Namur Lake near the outlet; and
- JOSMP Station S45, Ells River above the Joslyn Creek Diversion.

Data from JOSMP Station S14A, Ells River at the Canadian Natural Bridge, were used for the water balance analysis and are presented below; data from the remaining stations are presented in Appendix C.

Continuous annual hydrometric data have been collected at JOSMP Station S14A every year since 2004. Data were also collected at this station during the open-water season from 2001 to 2004. Continuous annual data were also collected from 1975 to 1986 at WSC Station 07DA017, Ells River near the mouth; this station was located approximately 7.5 km downstream of JOSMP Station S14A. The difference in drainage areas was very small (30 km^2, or 1.2%).

The historical flow record for JOSMP Station S14A is summarized in Figure 5.8-3, and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Ells River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are often much lower than during the open-water season, and generally decreased from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in April. Monthly flows are highest during May, at the peak of freshet, and often remain elevated in June and July when total monthly rainfall is highest (Figure 4.2-2). Flows generally recede from late July until the end of October in response to declining rainfall inputs and, eventually, river freeze-up.

Flows of the Ells River in the 2014 WY were generally similar to the pattern described above, but with several key differences. In winter, flows decreased from November 2013 to March 2014, but were consistently above the historical upper quartile range and often above historical maxima for this period (Figure 5.8-3). Flows increased rapidly in late April due to spring thaw, slightly later than usual, to an initial peak flow of 30.5 m^3/s on May 2. Flows then decreased until about May 11 in response to near freezing air temperatures. The peak annual flow of 83.9 m^3/s occurred on June 5 following two weeks of rainfall accumulation. The magnitude of flow at this time was 54% higher than the historical mean annual maximum daily flow of 54.6 m^3/s. Flows from June until early July remained above the historical upper quartile, occasionally exceeding the historical maximum values during this period. Flows then decreased steadily from July until the lowest open-water daily flow of 2.1 m^3/s on September 24. This value was 15% lower than the historical mean open-water minimum daily flow. Flows remained within the historical lower quartile during September and October.

Overall, the annual runoff volume in the 2014 WY was 325 million m^3, which was 47% higher than the mean historical annual runoff volume based on the available period of record.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Ells River watershed at JOSMP Station S14A is summarized in Table 5.8-2. The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.8-3. Key changes in flows included:

1. The closed-circuited land change area as of 2014 in the Ells River watershed was estimated to be 3.6 km^2 (Table 2.3-1). The loss of flow to the Ells River that would have otherwise occurred from this land area was estimated at 0.475 million m^3.

2. As of 2014, the area of land change in the Ells River watershed that was not closed-circuited was estimated to be 36.2 km^2 (Table 2.3-1). The increase in flow to the Ells River that would not have otherwise occurred from this land area was estimated at 0.968 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The 2014 WY estimated water balance for the Ells River is based on recorded flows at JOSMP Station S14A, which is upstream of some of the oil sands development within the Ells River watershed. The station could not be located downstream of development because of backwater effects from the Athabasca River in the downstream reach of the Ells River. Consequently, the analysis was conservative, with differences between the observed *test* hydrograph and the estimated *baseline* hydrograph expected to be different at the mouth.

The estimated cumulative effect of oil sands development in the 2014 WY was an increase in flow of approximately 0.493 million m^3 at JOSMP Station S14A. The 2014 WY mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.8-3). These differences were classified as **Negligible-Low** (Table 5.8-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.8.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Ells River near its mouth (*test* station ELR-1), sampled in 1998, and from 2002 to 2014;
- the Ells River upstream of development (*baseline* station ELR-3), a new station established in 2013 to replace *baseline* station ELR-2A, as a result of increasing development;
- Gardiner Lake (*baseline* station GAL-1), a new station established in 2014; and
- Namur Lake (*baseline* station NAL-1), a new station established in 2014.

In addition to fall sampling, *baseline* station ELR-3 was also sampled in winter, spring, and summer and *baseline* stations GAL-1 and NAL-1 were sampled in spring and summer 2014.

Temporal Trends There were no significant trends (α=0.05) in fall concentrations of water quality measurement endpoints detected over time at *test* station ELR-1. A trend analysis could not be conducted for *baseline* stations ELR-3, GAL-1, or NAL-1 due to an insufficient number of sampling years available.

2014 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations in fall 2014 at *test* station ELR-1 with the exception of (Table 5.8-4):

- magnesium, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations; and
- dissolved organic carbon, dissolved aluminum, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only).

Water quality at *baseline* station ELR-3 was measured for the first time in 2013, and *baseline* stations GAL-1 and NAL-1 were sampled for the first time in 2014; therefore, historical comparisons were not possible at these stations (Table 5.8-5 to Table 5.8-7).

Ion Balance The ionic composition of water in fall 2014 was generally similar across stations of the Ells River, and Namur and Gardiner lakes and dominated by calcium and bicarbonate (Figure 5.8-4). *Baseline* stations NAL-1 and GAL-1 showed a slightly lower and greater dominance of calcium and bicarbonate, respectively, compared to the stations on the Ells River. The ionic composition of water at *test* station ELR-1 has remained consistent since monitoring began in 1998.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in the Ells River watershed in fall 2014 were below water quality guidelines (Table 5.8-4 to Table 5.8-7), with the exception of total aluminum at *test* station ELR-1 and *baseline* stations ELR-3 and GAL-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Ells River watershed in fall 2014 (Table 5.8-8):

- Total iron and sulphide at *test* station ELR-1 and *baseline* station ELR-3; and
- Total iron, sulphide, and total phenols at *baseline* station GAL-1.

The following water quality guideline exceedances were measured in other seasons (Table 5.8-8):

- Total iron, total phenols, and total aluminum in winter at *baseline* station ELR-3;
- Dissolved aluminum, dissolved iron, sulphide, total aluminum, total chromium, total copper, total iron, total lead, total phenols, and total mercury (ultra-trace) in spring at *baseline* station ELR-3;
- Total phenols in spring at *baseline* station GAL-1;
- Sulphide, total aluminum, total chromium, total copper, total iron, and total phenols in summer at *baseline* station ELR-3; and
- Total phenols and sulphide in summer at *baseline* station GAL-1.

There were no guideline exceedances at *baseline* station NAL-1 during spring, summer, or fall 2014.

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints in fall 2014 for *test* station ELR-1 were within the range of regional *baseline* concentrations (Figure 5.8-5). Concentrations of all water quality measurement endpoints, except total mercury (ultra-trace), were within the range of regional *baseline* concentrations at *baseline* station ELR-3. Total mercury (ultra-trace) was lower than the 5th percentile of regional *baseline* concentrations at *baseline* station ELR-3 in fall 2014 (Figure 5.8-5).

Concentrations of water quality measurement endpoints at Gardiner Lake (*baseline* station GAL-1) and Namur Lake (*baseline* station NAL-1) were not compared to regional *baseline* concentrations because lakes were not included in calculations of regional *baseline* conditions, given ecological differences between lakes and rivers. A range of regional *baseline* conditions was not calculated for lakes sampled by JOSMP due to limited *baseline* data available.

Water Quality Index The WQI value of 96.2 for *test* station ELR-1 and 100 for *baseline* station ELR-3 indicated **Negligible-Low** differences from regional *baseline* water quality conditions at both stations in fall 2014.

Classification of Results Differences in water quality in fall 2014 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* station ELR-1 and were typically within the range of previously-measured concentrations and regional *baseline* conditions. *Baseline* station ELR-3, initiated in 2013, showed similar water quality to *test* station ELR-1, and was within regional *baseline* conditions in fall 2014 for all measurement endpoints with the exception of lower concentrations of total mercury (ultra-trace). Concentrations of water quality measurement endpoints for *baseline* stations GAL-1 and NAL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. The ionic composition of water in Namur and Gardiner lakes was similar to station of the Ells River but showed a slightly lower and greater dominance of calcium and bicarbonate, respectively, compared to the stations on the Ells River. There were no water quality guideline exceedances for Namur Lake and very few for Gardiner Lake in 2014.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

Ells River

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *test* reach ELR-D1, sampled since 2003; and
- erosional *baseline* reach ELR-E3, sampled since 2013.

2014 Habitat Conditions Water at *test* reach ELR-D1 in fall 2014 was shallow (0.4 m) and slightly alkaline (pH: 7.6), with high dissolved oxygen (9.7 mg/L), and moderate conductivity (232 μS/cm) (Table 5.8-9). The substrate was primarily sand (87%), with low total organic carbon (<1%) (Table 5.8-9).

Water at *baseline* reach ELR-E3 in fall 2014 was relatively shallow (0.3 m), with fast velocity (0.6 m/s), was alkaline (pH: 8.6), with moderate conductivity (226 μS/cm) (Table 5.8-10). The substrate was dominated by gravel and cobble (Table 5.8-9). Periphyton biomass averaged 20.1 mg/m^2 at *baseline* reach ELR-E3, which was well within the inner tolerance limits for the range of variation for regional *baseline* conditions (Table 5.8-10).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach ELR-D1 in fall 2014 was dominated by chironomids (72%) and tubificid worms (14%) (Table 5.8-10). Chironomids were not diverse at this reach and were mostly comprised of *Rheosmittia*, *Saetheria*, and *Polypedilum,* all of which are relatively tolerant of pollution (Mandeville 2001). Permanent aquatic forms such as bivalves, gastropods, amphipods, and flying insects (Ephemeroptera, Plecoptera, Trichoptera) have not been present in the last two years.

The benthic invertebrate community of *baseline* reach ELR-E3 in fall 2014 was dominated by chironomids (38%) and Ephemeroptera (22%) with subdominant taxa consisting of Plecoptera (9%), Trichoptera (7%), and Hydracarina (6%) (Table 5.8-11). Chironomids were diverse and included the rheophilic *Rheotanytarsus,* and the common forms *Polypedilum, Tventia,* and *Cricotopus/Orthocladius.* Bivalves and gastropods were present in low relative abundances. Ephemeroptera were diverse and included 15 species from the families Baetidae, Ephemerellidae, Heptageniidae, and Leptophlebiidae. Stoneflies were well represented with 11 species, the most abundant of which were *Isoperla* and *Taeniopteryx*. Caddisflies (*Cheumatopsyche* and *Hydropsyche)* were also well represented and Gomphidae (dragonflies) were present in relatively large numbers at all replicate stations (Table 5.8-11).

Temporal and Spatial Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the Ells River watershed. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach ELR-D1 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2014 values and the mean of all previous years of sampling (2003 to 2013).

Abundance decreased over time at *test* reach ELR-D1 and was lower in 2014 than the mean of all previous years of sampling, accounting for 25% and 34% of the variance in annual means, respectively (Table 5.8-12).

Richness decreased over time at *test* reach ELR-D1 and was lower in 2014 than the mean of all previous years of sampling, accounting for 23% and 37% of the variance in annual means, respectively (Table 5.8-12).

The percentage of the fauna as EPT taxa decreased over time at *test* reach ELR-D1, accounting for 44% of the variance in annual means (Table 5.8-12).

CA Axis 2 scores significantly increased over time at *test* reach ELR-D1, accounting for 32% of the variance in annual means (Table 5.8-12). The decrease in CA Axis 2 scores over time was likely due to a decrease in the overall abundance of tubificid worms (Figure 5.8-8).

Comparison to Published Literature *Test* reach ELR-D1 had low diversity and a moderate percentage of the fauna as worms (~14%) in fall 2014. The benthic invertebrate community at *test* reach ELR-D1 also contained no EPT taxa and no permanent aquatic forms, which might indicate that dissolved oxygen levels may not have been consistently high in that area of the river.

2014 Results Relative to Historical or *Baseline* Conditions *Test* reach ELR-D1 has ten years of data (2003 to 2014); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* conditions were evaluated (there was no upstream depositional *baseline* reach on the Ells River to make a direct comparison to *test* reach ELR-D1).

Abundance and richness at *test* reach ELR-D1 in fall 2014 were below the inner tolerance limits for the range of variability for previous years (Figure 5.8-9). Equitability, %EPT taxa, and CA Axis 1 and 2 scores were within the inner tolerance limits for the range of variability for previous years (Figure 5.8-8, Figure 5.8-9).

When compared to the tolerance limits of the normal range of variation for means from regional *baseline* depositional reaches, abundance and richness were below the normal range of variability at *test* reach ELR-D1 in fall 2014.

The variability of measurement endpoints at *baseline* reach ELR-E3 was contributing to the characterization of regional *baseline* erosional conditions. No comparison to the regional data were conducted (Figure 5.8-10, Figure 5.8-11).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 were classified as **Moderate** because significant decreases in abundance, EPT, richness, and CA Axis 2 scores over time were indicative of potentially degrading conditions. Abundance in fall 2014 (111 organisms per sample) was higher than fall 2013 (48 organisms per sample), but still lower than previous years. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) were sparse in 2014 and EPT taxa were absent. All of the smaller and previously-abundant organisms remained abundant in 2014 and a decrease in tubificid worms has been occurring over time. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Similar to 2013, water velocity at the lower Ells River in 2014 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and could be an explanation for the absence of larger forms of benthic invertebrates at *test* reach ELR-D1 in recent years.

Namur and Gardiner Lakes

2014 Habitat Conditions Water in Gardiner Lake in fall 2014 had a pH of 7.98 and moderate conductivity (176 µS/cm) (Table 5.8-13). Benthic community samples were collected from a depth of just under 1 m. The substrate of Gardiner Lake consisted primarily of sand (96%), with low organic carbon content (<1%) (Table 5.8-13).

Water in Namur Lake in fall 2014 had a pH of 7.3 and low conductivity (69 µS/cm) (Table 5.8-13). Benthic community samples were collected from a depth of 1 m. The substrate of Namur Lake consisted primarily of sand (94%) with small amounts of silt (4%) and clay (2%), with low organic carbon content (<1%) (Table 5.8-13).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Gardiner Lake at *baseline* station GAL-1 in fall 2014 was dominated by chironomids (61%), Nematoda (14%), and enchytraeid worms (10%) (Table 5.8-14). Chironomids were diverse and consisting primarily of *Stichtochironomus, Tanytarsus, Cladotanytarsus,* and *Cricotopus/Orthocladius.* Amphipods were present and consisted mostly of *Hyalella azteca* though a few *Gammarus lacustris* were also present. Other permanent aquatic forms such as bivalves (*Pisidium/Sphaerium*) and gastropods (*Lymnaea, Physa, Gyraulus*, and *Helisoma*) were found at *baseline* station GAL-1. EPT taxa (Ephemeroptera: *Callibaetis, Caenis, Ephemera, Leptophlebia*; Trichoptera: *Mystacides* and *Oecetis*) were present but in low relative abundances.

The benthic invertebrate community of Namur Lake at *baseline* station NAL-1 in fall 2014 was dominated by Nematoda (29%), Hydracarina (22%) and Chironomidae (17%) with subdominant taxa consisting of gastropods (7%), bivalves (6%), and naidid worms (6%) (Table 5.8-14). Chironomids were primarily *Cladotanytarsus*, though *Paratendipes*, *Stichtochironomus*, and *Cricotopus/Orthocladius* were also relatively abundant. Bivalves were represented by *Pisidium/Sphaerium* and gastropods were mainly *Gyraulus, Valvata sincera*. Flying insects such as mayflies (*Callibaetis, Caenis, Ephemera, Leptophlebia*) and caddisflies (*Lepidostoma, Mystacides, Oecetis, Molanna* and Limnephilidae) were found but in relatively low abundances (Table 5.8-14).

Comparison to Published Guidelines The benthic invertebrate community of Gardiner Lake reflected generally good water quality in 2014. The abundance of worms was relatively high; however, the presence of EPT taxa and several permanent aquatic forms such as Amphipoda, fingernail clams (Bivalvia: Sphaeriidae), and gastropods were consistent with good long-term water quality (Niemi et al. 1990; Pennak 1989).

The benthic invertebrate community of Namur Lake was typical of a shallow lake environment (Parsons et al. 2010; Pennak 1989) in 2014. The relative abundance of "tolerant" nematodes was high, possibly indicating poor water quality (Pennak 1989); however, there was a healthy presence of permanent aquatic forms such as bivalves and gastropods. Larvae of several flying insect groups were found in Namur Lake including several types of mayflies and caddisflies, suggesting that conditions were at least fair.

Summary of Results The benthic invertebrate communities of Gardiner and Namur Lakes were sampled for the first time in 2014. The benthic invertebrate communities of both lakes were evident of good water quality conditions, with the presence of EPT taxa and permanent aquatic forms (e.g., bivalves, gastropods). The relative abundance of worms were high in both lakes in 2014.

5.8.4.2 Sediment Quality

Sediment quality was sampled in fall 2014 at:

- the Ells River near its mouth (*test* reach ELR-D1), designated as *baseline* in 1998 and *test* from 2002 to 2014, and in the same location as the benthic invertebrate community reach;
- Namur Lake (*baseline* station NAL-1), sampled for the first time in 2014; and
- Gardiner Lake (*baseline* station GAL-1), sampled for the first time in 2014.

Temporal Trends Significant increasing (α=0.05) trends over time in concentrations of F2, F3, and F4 hydrocarbons were observed at *test* station ELR-D1. Trend analysis was not performed on *baseline* stations GAL-1 and NAL-1, as there was only one year of data.

2014 Results Relative to Historical Concentrations Prior to the integration of the Sediment Quality component with the Benthic Invertebrate Communities component in 2006 (RAMP 2007), *test* reach ELR-D1 corresponded to pre-2006 sediment quality station ELR-1. Sediment quality data from *test* station ELR-D1 sampled in 2014 were compared to all available data collected at this location (including pre-2006 results).

Sediments at *test* station ELR-D1 continued to be dominated by sand (95.2%), with the proportion of sand exceeding the previously-measured maximum value and the proportion of clay below the previously-measured minimum value in fall 2014 (Table 5.8-15). Concentrations of hydrocarbons and PAHs were all within the range of previously-measured concentrations. The concentration of total metals was also within the range of previously-measured concentrations; however, when normalized to percent fines, the concentration exceeded the previously-measured maximum concentration (Figure 5.8-12). As in previous years, concentrations of hydrocarbons at *test* station ELR-D1 were dominated by fractions 3 and 4, which likely indicated the presence of bitumen in sediments (Table 5.8-15).

Sediments at *baseline* stations GAL-1 and NAL-1 were dominated by sand (95.2% and 98.2% respectively), with the remaining composition equally composed of clay and silt (Table 5.8-16 and Table 5.8-17). Concentrations of all hydrocarbon fractions at *baseline* station GAL-1 were below detection limits, while heavier hydrocarbons (F3 and F4) were measurable, but still relatively low at *baseline* station NAL-1. Concentrations of PAHs were generally low at both stations, resulting in a low predicted PAH toxicity value (Figure 5.8-13 and Figure 5.8-14). No historical data were available for comparison to 2014 data for these lakes.

Direct tests of sediment toxicity to invertebrates at *test* station ELR-D1 showed 90% survival in the amphipod *Hyalella* and a 40% survival of the midge *Chironomus,* which were both within the range of previously measured values (Table 5.8-15. Sediment toxicity at *baseline* stations GAL-1 and NAL-1 indicated high survival rate for both the midge *Chironomus* (87% and 83%, respectively) and the amphipod *Hyalella* (92% and 98%, respectively) (Table 5.8-16 and Table 5.8-17).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines At *test* station ELR-D1, concentrations of F2 and F3 hydrocarbons and chrysene exceeded CCME sediment quality guidelines, and the predicted PAH toxicity value exceeded the potential chronic toxicity threshold value. No sediment guideline or threshold exceedances occurred at *baseline* stations GAL-1 and NAL-1 in 2014.

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of total PAHs (absolute and carbon-normalized) at *test* station ELR-D1 in fall 2014 exceeded the 95th percentile of regional *baseline* concentrations (Figure 5.8-12). Given the ecological differences between lakes and rivers, and because lakes were not included in the regional *baseline* calculations, sediments quality measurements at *baseline* stations GAL-1 and NAL-1 were not compared to the regional *baseline* concentrations.

Sediment Quality Index In fall 2014, the SQI value of 82.1 at *test* station ELR-D1 indicated **Negligible-Low** differences from regional *baseline* conditions. Since 1998, the SQI at *test* station ELR-D1 has most commonly shown a **Moderate** (i.e., SQI<80) difference from regional *baseline* conditions, due primarily to regionally high concentrations of hydrocarbons and PAHs at this station. A SQI was not calculated for *baseline* stations GAL-1 and NAL-1 because lakes were not included in the regional *baseline* conditions, given the ecological differences between lakes and rivers; there are not enough *baseline*-lake data to calculate lake-specific SQI values.

Classification of Results Sediment quality in fall 2014 at *test* station ELR-D1 indicated **Negligible-Low** differences from regional *baseline* conditions, and most sediment quality measurement endpoints were within the range of the regional *baseline* concentrations, with the exception of total PAHs. Concentrations of F2 and F3 hydrocarbons, and chrysene exceeded CCME guidelines and predicted PAH toxicity exceeded the potential chronic effect level at *test* station ELR-D1. SQI values were not calculated for *baseline* stations NAL-1 and GAL-1 because lakes are not included in the regional *baseline* calculations. Sampling at *baseline* stations GAL-1 and NAL-1 was initiated in 2014; therefore, no historical data were available for comparison. No sediment guidelines or threshold values were exceeded at either lake station in 2014.

5.8.5 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- *test* reach ELR-F1, sampled since 2010 (this reach is at the same location as the benthic invertebrate community *test* reach ELR-D1); and
- *baseline* reach ELR-F3, this reach was sampled for the first time in 2013 and is upstream from reach ELR-F2A, which was sampled from 2010 to 2012. The *baseline* reach was moved further upstream in 2013 due to expanding development in the watershed (this reach is at the same location as the benthic invertebrate community *baseline* reach ELR-E3).

2014 Habitat Conditions *Test* reach ELR-F1 was comprised entirely of run habitat with a wetted width of 18.0 m and a bankfull width of 37.0 m. The substrate consisted of sand with some fine material. Water at *test* reach ELR-F1 had a mean depth of 1.21 m, high velocity (mean=1.40 m/s), a pH of 6.45, low conductivity (221 µS/cm), high dissolved oxygen (9.0 mg/L), and a temperature of 12.7˚C. Instream cover primarily consisted of large and small woody debris with some macrophytes and algae (Table 5.8-18).

Baseline reach ELR-F3 was comprised of riffle and run habitat with a wetted width of 32.8 m and a bankfull width of 39.8 m. The substrate was comprised of sand with small amounts of cobble. Water at *baseline* reach ELR-F3 had a mean depth of 0.70 m, moderate velocity (mean=0.37 m/s); a pH of 7.92, low conductivity (196 µs/cm), high dissolved oxygen (10 mg/L), and a temperature of 10.1˚C. Instream cover was comprised of large woody debris and macrophytes with some small woody debris and overhanging vegetation (Table 5.8-18).

Relative Abundance of Fish Species The total catch of fish species at *test* reach ELR-F1 decreased from 2013 and was dominated by juvenile burbot (47%) and slimy sculpin (27%) (Table 5.8-19). The total catch of fish species at *baseline* reach ELR-F3 was lower compared to 2013, with 121 fewer individuals and four fewer species in 2014. Species composition at *baseline* reach ELR-F3 was dominated by juvenile walleye (39%) and lake chub (32%) (Table 5.8-19).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach ELR-F1 included testing for changes over time in measurement endpoints (2010 to 2014, Hypothesis 1, Section 3.2.4.4). Spatial comparisons between *test* reach ELR-F1 and *baseline* reach ELR-F3 were conducted for 2013 and 2014 given the similar habitat conditions between these reaches (see Table 5.8-18).

With the exception of diversity, all measurement endpoints were lower at *test* reach ELR-F1 compared to *baseline* reach ELR-F3 in 2013 and 2014 (Table 5.8-20).There were significant decreases in abundance ($p<0.001$), CPUE ($p<0.01$), and the assemblage tolerance index (ATI; $p=0.003$) over time at *test* reach ELR-F1, explaining greater than 20% of the variance in annual means (Table 5.8-21). The decrease in ATI was due to the catch of longnose dace in 2014, which were absent in 2012 and 2013 (Table 5.8-20).

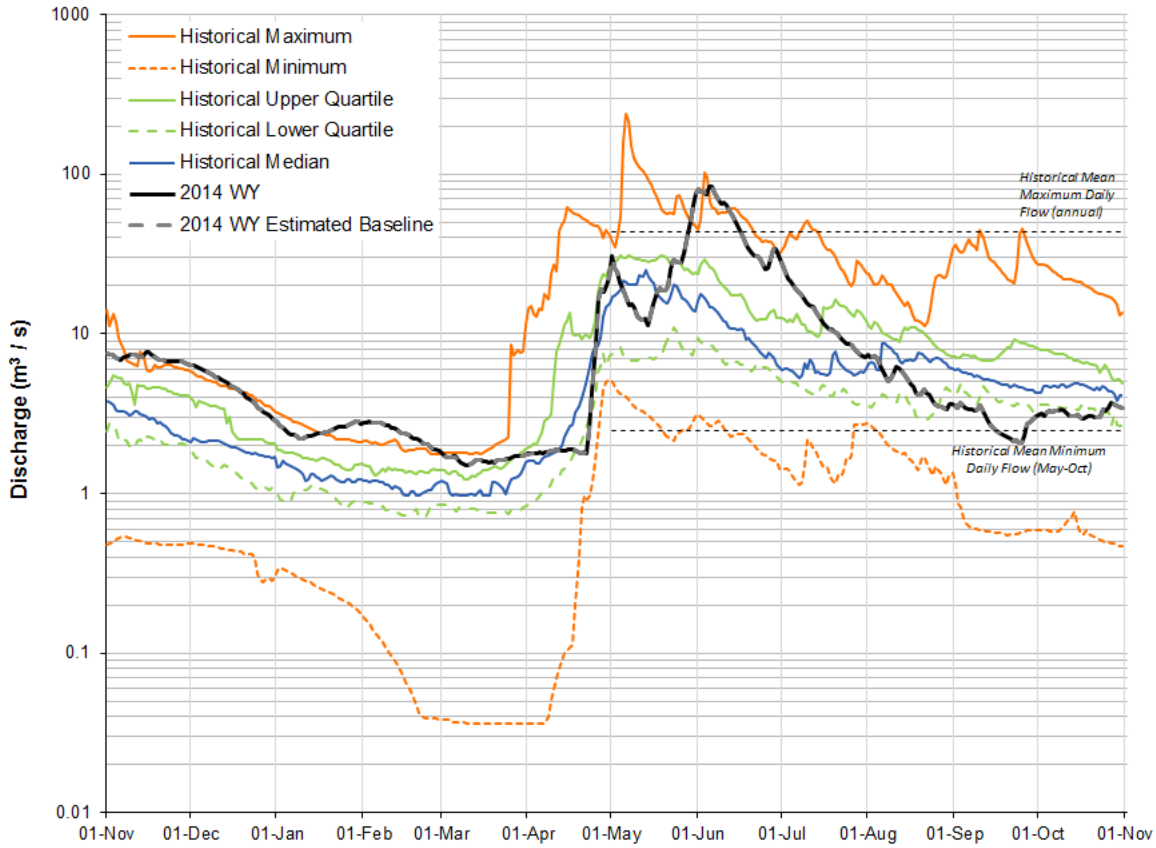
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of 19 fish species were recorded in the Ells River watershed (Golder 2004). An additional species, finescale dace, which was not recorded by Golder (2004), was found by JOSMP in 2012. In 2013, northern redbelly dace were also found, which have not previously been documented in the Ells River. Two species (burbot and spoonhead sculpin) were found in 2013 that are known to occur in the Ells River but have not been captured during the JOSMP Fish Assemblage Monitoring program. This brings the total number of fish species to 15 that RAMP/JOSMP has observed between 2010 and 2014. Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., JOSMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder (2004).

Golder (2004) documented similar habitat conditions consisting of pools and riffles dominated by boulder, cobble, and gravel substrate in the area of the Ells River where *baseline* reach ELR-F3 is located, which is consistent with observations by JOSMP. In the lower portion of the Ells River, where *test* reach ELR-F1 is located, Golder (2004) documented habitat consisting primarily of fine sediment, which is also consistent with observations in 2014 (Table 5.8-18).

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reach ELR-F1 and *baseline* reach ELR-F3 were within the range of regional *baseline* variability (Figure 5.8-15).

Classification of Results Differences in measurement endpoints for the fish assemblage at *test* reach ELR-F1 were classified as **Moderate** given that abundance and CPUE have decreased over time and all measurement endpoints were lower compared to *baseline* reach ELR-F3. It is noted; however, that there was a decrease in the ATI value, indicating a greater proportion of sensitive species in the assemblage, and all measurement endpoints were within regional *baseline* conditions.

Figure 5.8-3 The observed (test) hydrograph and estimated baseline hydrograph for the Ells River in the 2014 WY, compared to historical values.



Note: The observed 2014 WY hydrograph was based on Ells River at the Canadian Natural Bridge, Station S14A. The upstream drainage area is 2,420 km^2. Historical values were calculated for all months from 1975 to 1986 (WSC Station 07DA017) and from 2004 to 2013 (JOSMP Station S14A); open-water values also incorporated Station S14A data from 2001 to 2003.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.8-2 Estimated water balance at Ells River above Joslyn Creek (JOSMP Station S14A), 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**324.562**	**Observed discharge at Ells River at the Canadian Natural Bridge, JOSMP Station S14A**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.475	Estimated 3.55 km^2 of the Ells River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	+0.968	Estimated 36.2 km^2 of the Ells River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Ells River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Ells River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**324.070**	**Estimated *baseline* discharge at Ells River at the Canadian Natural Bridge, JOSMP Station S14A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	+0.493	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**+0.150**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on Ells River at the Canadian Natural Bridge, JOSMP Station S14A, 2014 WY provisional data.

Note: All values in this table presented to three decimal places.

Table 5.8-3 Calculated change in hydrologic measurement endpoints for the Ells River watershed, 2014 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	16.560	16.585	+0.15%
Mean winter discharge	3.655	3.660	+0.15%
Annual maximum daily discharge	83.804	83.931	+0.15%
Open-water season minimum daily discharge	2.076	2.080	+0.15%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from JOSMP Station S14A.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.8-4 Concentrations of water quality measurement endpoints, mouth of Ells River (*test* station ELR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	13	7.8	8.2	8.4
Total suspended solids	mg/L	-	4.2	13	<3.0	7.0	16
Conductivity	µS/cm	-	264	13	175	225	272
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	13	0.003	0.011	0.020
Total nitrogen	mg/L	-	0.54	13	0.30	0.62	1.32
Nitrate+nitrite	mg/L	3	<0.054	13	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	7.4	13	11	15	20
Ions							
Sodium	mg/L	-	15.4	13	8.0	10.7	18.0
Calcium	mg/L	-	29.8	13	21.6	24.6	30.4
Magnesium	mg/L	-	9.3	13	6.5	7.3	9.1
Chloride	mg/L	120	2.0	13	<0.5	1.8	4.0
Sulphate	mg/L	309	22.1	13	10.5	15.5	27.9
Total dissolved solids	mg/L	-	187	13	110	165	220
Total alkalinity	mg/L	-	108	13	76	97	117
Selected metals							
Total aluminum	mg/L	0.1	**0.126**	13	0.060	**0.324**	**0.673**
Dissolved aluminum	mg/L	0.05	0.005	13	0.006	0.014	**0.078**
Total arsenic	mg/L	0.005	0.0008	13	<0.0005	0.0009	0.0012
Total boron	mg/L	1.2	0.066	13	0.041	0.061	0.083
Total molybdenum	mg/L	0.073	0.00071	13	0.00064	0.00070	0.00084
Total mercury (ultra-trace)	ng/L	5, 13	1.3	11	<0.9	<1.2	2
Total strontium	mg/L	-	0.139	13	0.095	0.122	0.140
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.78	3	0.07	0.23	0.49
Oilsands Extractable	mg/L	-	2.20	3	0.43	0.64	1.25
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	1.730	3	3.770	4.430	15.20
Total dibenzothiophenes	ng/L	-	102.6	3	120.2	134.5	238.8
Total PAHs	ng/L	-	338.0	3	448.1	550.9	903.4
Total Parent PAHs	ng/L	-	18.79	3	24.92	25.21	36.30
Total Alkylated PAHs	ng/L	-	319.2	3	423.1	525.7	867.1
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.003**	13	0.002	**0.006**	**0.135**
Total iron	mg/L	0.3	**0.553**	13	**0.448**	**0.699**	**1.140**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.8-5 Concentrations of water quality measurement endpoints, Ells River upstream of development (*baseline* station ELR-3), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.1	8.0
Total suspended solids	mg/L	-	<3.0	<3.0
Conductivity	µS/cm	-	234	191
Nutrients				
Total dissolved phosphorus	mg/L	-	0.016	0.014
Total nitrogen	mg/L	-	0.574	0.571
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	16.5	13.7
Ions				
Sodium	mg/L	-	12.20	8.70
Calcium	mg/L	-	28.7	24.5
Magnesium	mg/L	-	7.91	7.16
Chloride	mg/L	120	0.690	0.520
Sulphate	mg/L	309	17.0	12.1
Total dissolved solids	mg/L	-	161	133
Total alkalinity	mg/L	-	99.2	84.9
Selected metals				
Total aluminum	mg/L	0.1	**0.105**	**0.134**
Dissolved aluminum	mg/L	0.05	0.0054	0.0076
Total arsenic	mg/L	0.005	0.00081	0.00082
Total boron	mg/L	1.2	0.060	0.049
Total molybdenum	mg/L	0.073	0.00064	0.00064
Total mercury (ultra-trace)	ng/L	5, 13	0.260	0.880
Total strontium	mg/L	-	0.122	0.102
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.46	0.23
Oilsands Extractable	mg/L	-	1.50	0.27
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	0.593	1.220
Total dibenzothiophenes	ng/L	-	6.442	6.672
Total PAHs	ng/L	-	78.90	102.5
Total Parent PAHs	ng/L	-	13.28	22.44
Total Alkylated PAHs	ng/L	-	65.62	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Sulphide	mg/L	0.002	**0.0036**	<0.002
Total iron	mg/L	0.3	**0.526**	**0.474**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.8-6 Concentrations of water quality measurement endpoints, Namur Lake (*baseline* station NAL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014
			Value
Physical variables			
pH	pH units	6.5-9.0	7.6
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	73
Nutrients			
Total dissolved phosphorus	mg/L	-	0.035
Total nitrogen	mg/L	-	0.324
Nitrate+nitrite	mg/L	3	<0.054
Dissolved organic carbon	mg/L	-	7.9
Ions			
Sodium	mg/L	-	3.2
Calcium	mg/L	-	7.5
Magnesium	mg/L	-	2.42
Chloride	mg/L	120	<0.50
Sulphate	mg/L	128	7.7
Total dissolved solids	mg/L	-	30
Total alkalinity	mg/L	-	26.2
Selected metals			
Total aluminum	mg/L	0.1	0.020
Dissolved aluminum	mg/L	0.05	0.0006
Total arsenic	mg/L	0.005	0.00038
Total boron	mg/L	1.2	0.026
Total molybdenum	mg/L	0.073	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	1.710
Total strontium	mg/L	-	0.042
Total hydrocarbons			
BTEX	mg/L	-	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25
Naphthenic Acids	mg/L	-	0.37
Oilsands Extractable	mg/L	-	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<7.210
Retene	ng/L	-	<0.407
Total dibenzothiophenes	ng/L	-	4.134
Total PAHs	ng/L	-	74.46
Total Parent PAHs	ng/L	-	13.26
Total Alkylated PAHs	ng/L	-	61.20

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.8-7 Concentrations of water quality measurement endpoints, Gardiner Lake (*baseline* station GAL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014
			Value
Physical variables			
pH	pH units	6.5-9.0	7.9
Total suspended solids	mg/L	-	<6.0
Conductivity	µS/cm	-	136
Nutrients			
Total dissolved phosphorus	mg/L	-	0.028
Total nitrogen	mg/L	-	1.314
Nitrate+nitrite	mg/L	3	<0.054
Dissolved organic carbon	mg/L	-	16.3
Ions			
Sodium	mg/L	-	3.40
Calcium	mg/L	-	18.3
Magnesium	mg/L	-	5.36
Chloride	mg/L	120	<0.500
Sulphate	mg/L	218	4.4
Total dissolved solids	mg/L	-	101
Total alkalinity	mg/L	-	63.1
Selected metals			
Total aluminum	mg/L	0.1	**0.257**
Dissolved aluminum	mg/L	0.05	0.0025
Total arsenic	mg/L	0.005	0.00123
Total boron	mg/L	1.2	0.026
Total molybdenum	mg/L	0.073	0.00067
Total mercury (ultra-trace)	ng/L	5, 13	0.230
Total strontium	mg/L	-	0.069
Total hydrocarbons			
BTEX	mg/L	-	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25
Naphthenic Acids	mg/L	-	0.94
Oilsands Extractable	mg/L	-	1.90
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<7.21
Retene	ng/L	-	2.070
Total dibenzothiophenes	ng/L	-	4.134
Total PAHs	ng/L	-	79.85
Total Parent PAHs	ng/L	-	13.27
Total Alkylated PAHs	ng/L	-	66.58
Other variables that exceeded CCME/AESRD guidelines in fall 2014			
Sulphide	mg/L	0.002	**0.0039**
Total iron	mg/L	0.3	**0.63**
Total phenols	mg/L	0.004	**0.0046**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Figure 5.8-4 Piper diagram of fall ion concentrations in the Ells River watershed.

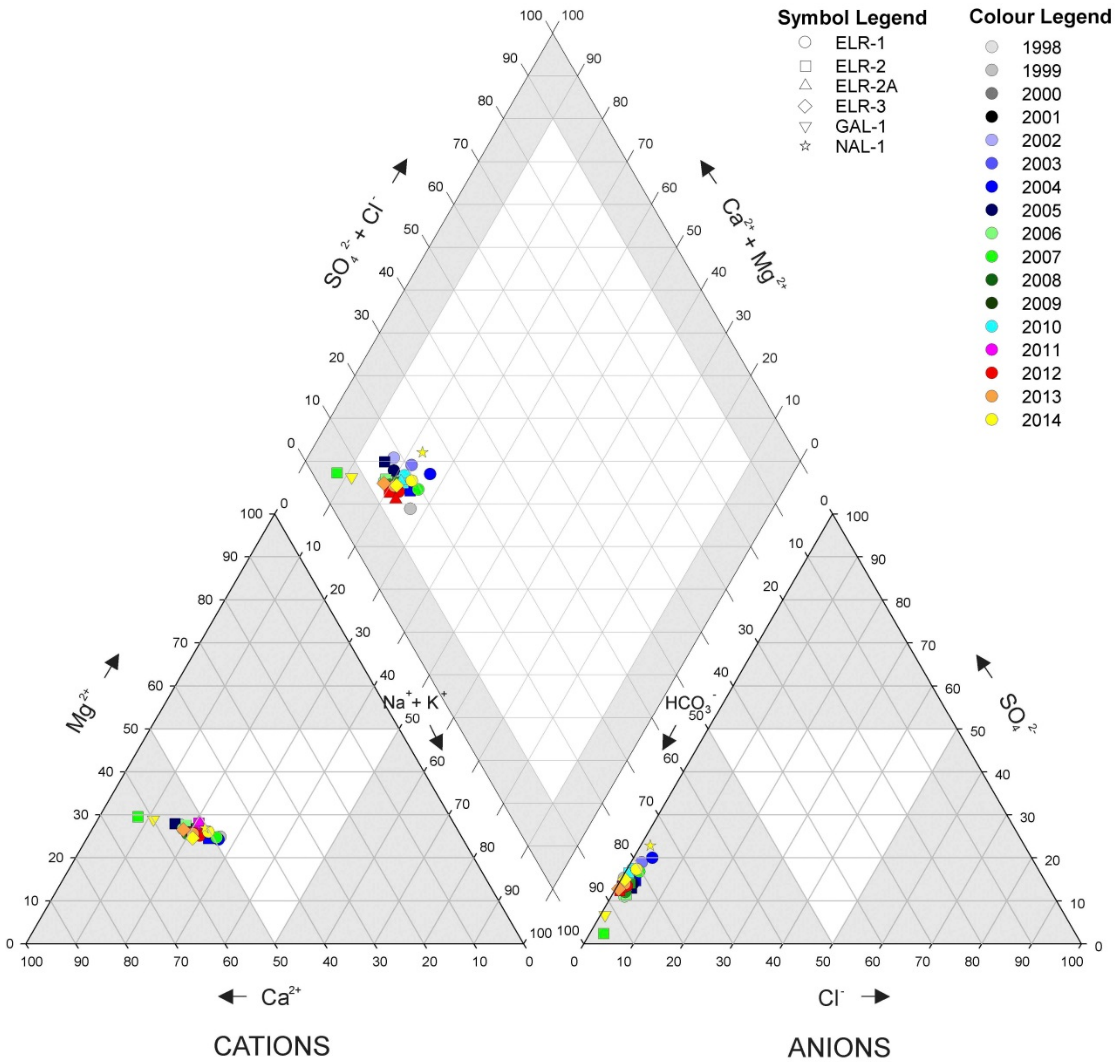


Table 5.8-8 Water quality guideline exceedances, Ells River watershed, 2014.

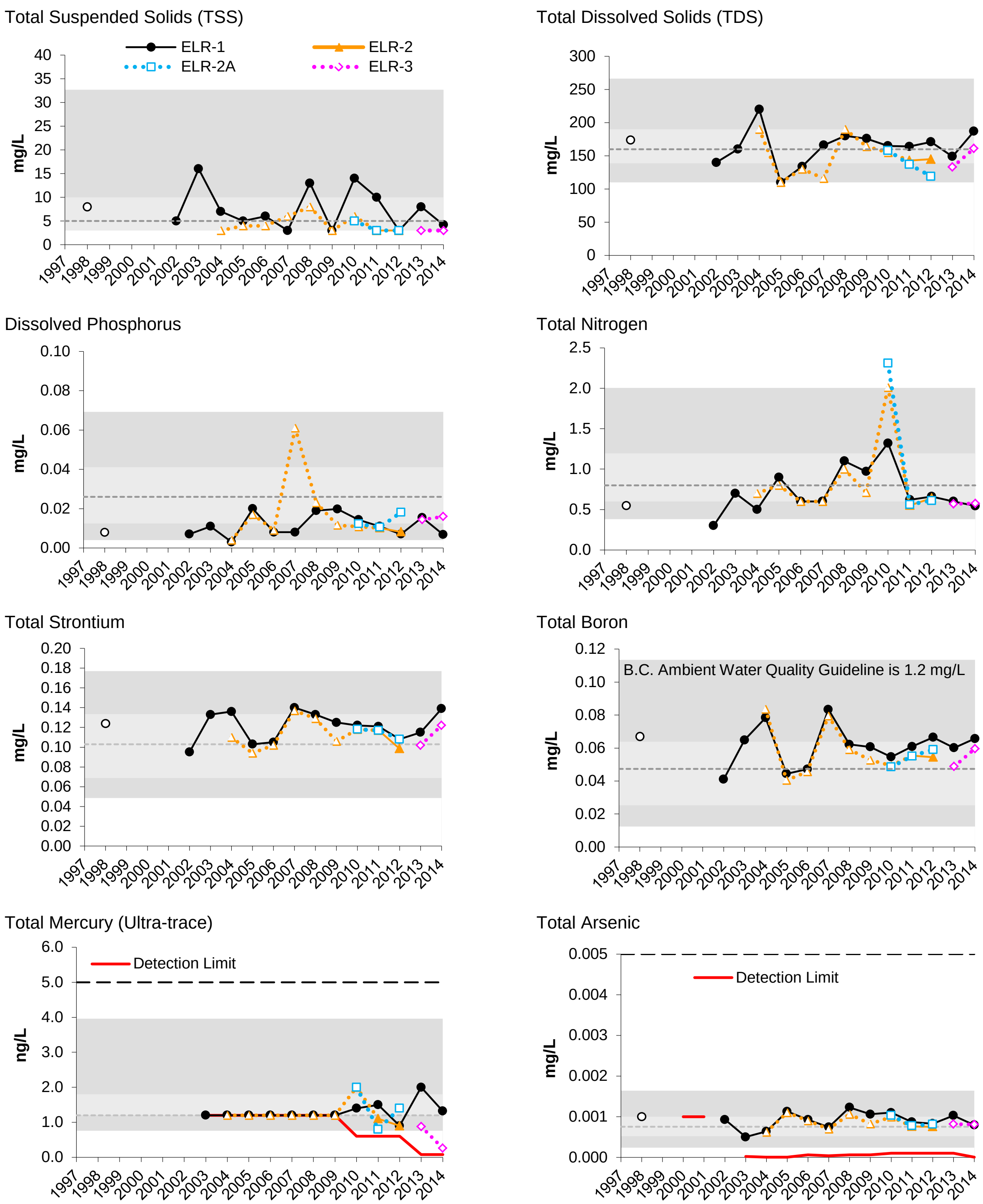
Variable	Units	Guideline[a]	ELR-1	ELR-3	GAL-1	NAL-1
Winter						
Total aluminum	mg/L	0.1	ns	0.305	ns	ns
Total iron	mg/L	0.3	ns	0.534	ns	ns
Total phenols	mg/L	0.004	ns	0.0056	ns	ns
Spring						
Dissolved aluminum	mg/L	0.1	ns	0.0638	-	-
Dissolved iron	mg/L	0.3	ns	0.448	-	-
Sulphide	mg/L	0.002	ns	0.0102	-	-
Total aluminum	mg/L	0.1	ns	7.57	-	-
Total chromium	mg/L	0.001	ns	0.00586	-	-
Total copper	mg/L	0.002[b]	ns	0.00408	-	-
Total iron	mg/L	0.3	ns	5.76	-	-
Total lead	mg/L	0.0017[b]	ns	0.00317	-	-
Total mercury (ultra-trace)	ng/L	5, 13	ns	13.4	-	-
Total phenols	mg/L	0.004	ns	0.0071	0.0041	-
Summer						
Sulphide	mg/L	0.002	ns	0.0084	0.0024	-
Total aluminum	mg/L	0.1	ns	2.73	-	-
Total chromium	mg/L	0.001	ns	0.00262	-	-
Total copper	mg/L	0.002[b]	ns	0.00213	-	-
Total iron	mg/L	0.3	ns	2.29	-	-
Total phenols	mg/L	0.004	ns	0.0059	0.0046	-
Fall						
Sulphide	mg/L	0.002	0.003	0.004	0.004	-
Total aluminum	mg/L	0.1	0.126	0.105	0.257	-
Total iron	mg/L	0.3	0.553	0.526	0.63	-
Total phenols	mg/L	0.004	-	-	0.005	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

ns = not sampled

Figure 5.8-5 Selected water quality measurement endpoints in the Ells River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



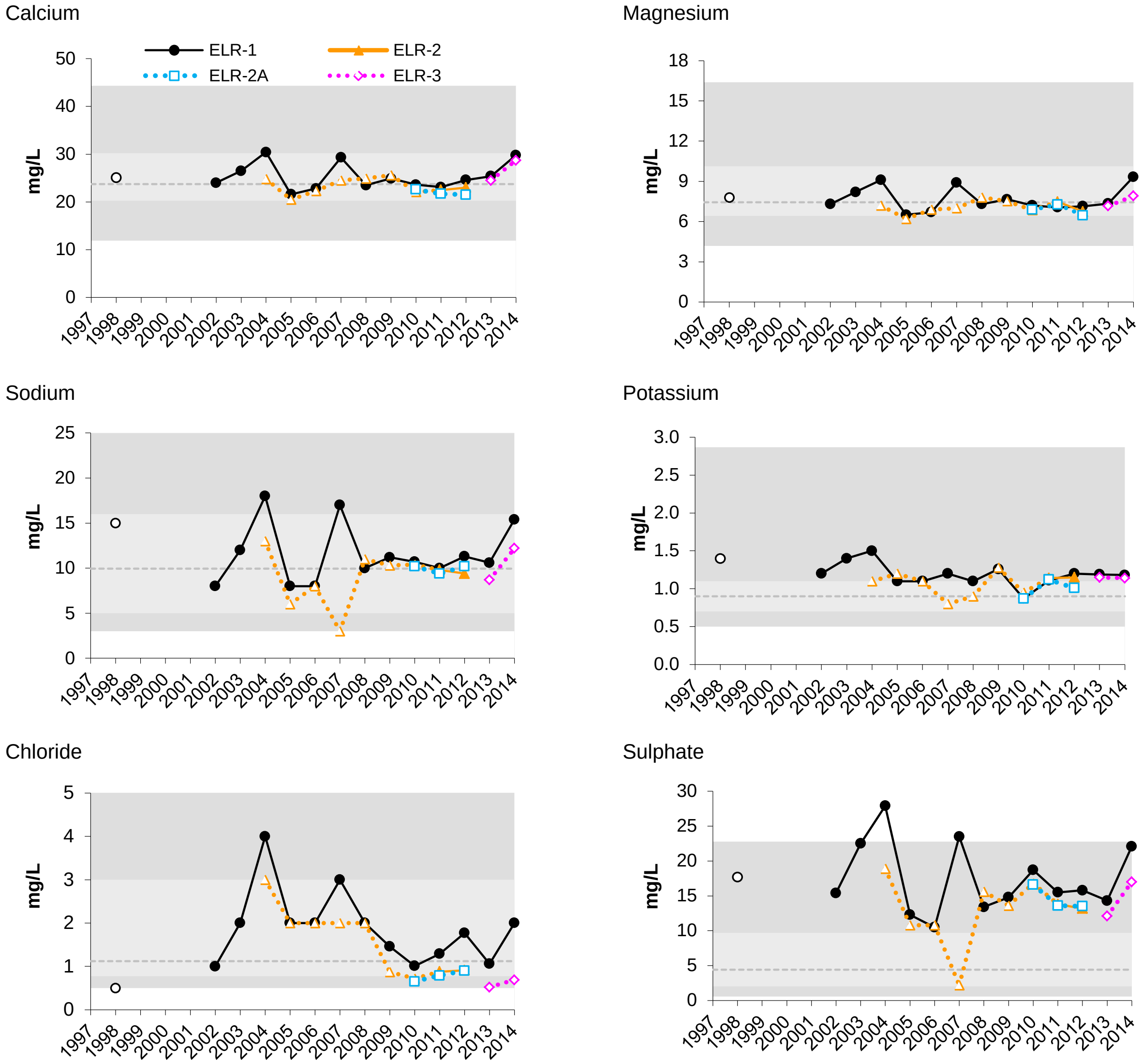
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.8-5 (Cont'd.)



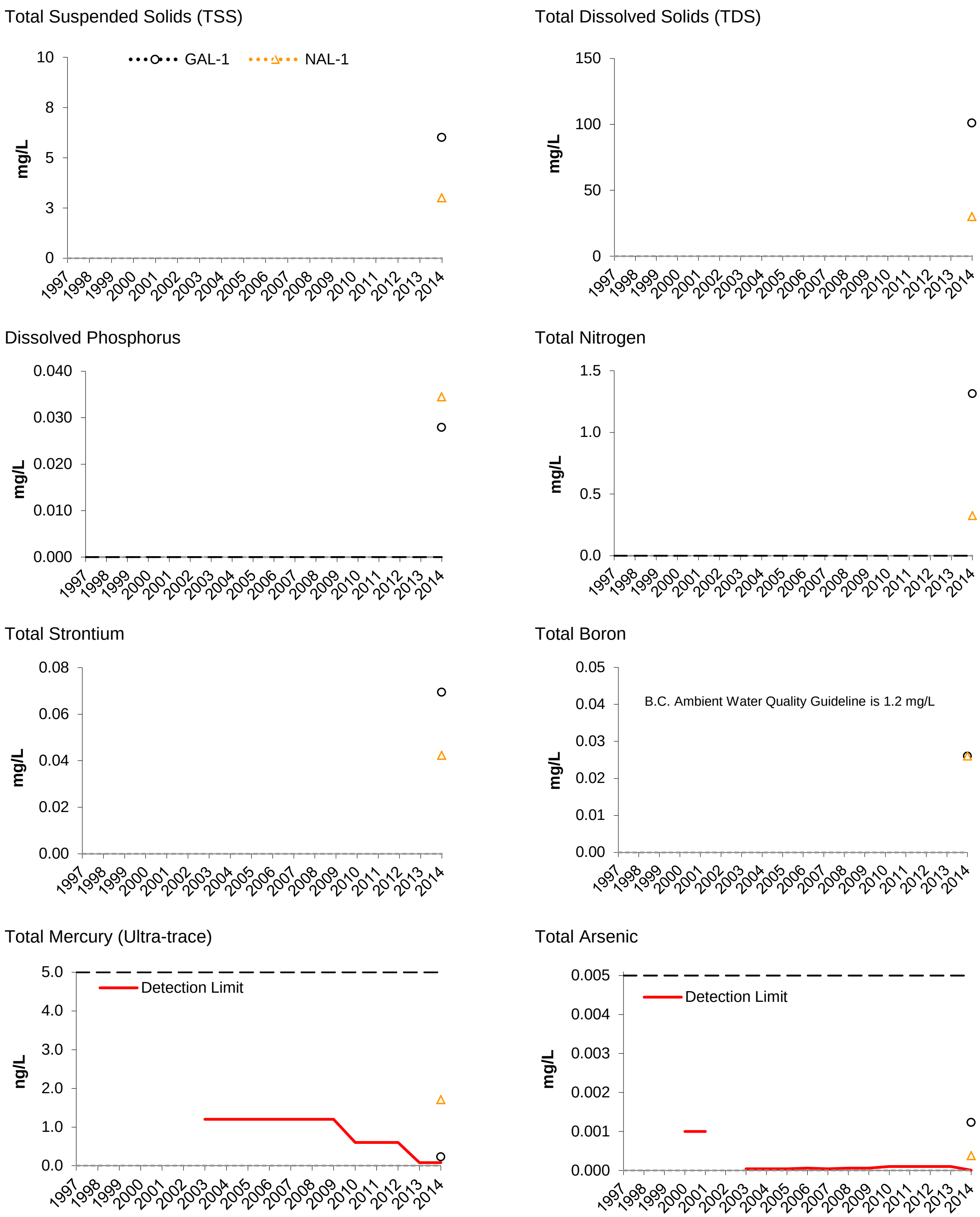
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

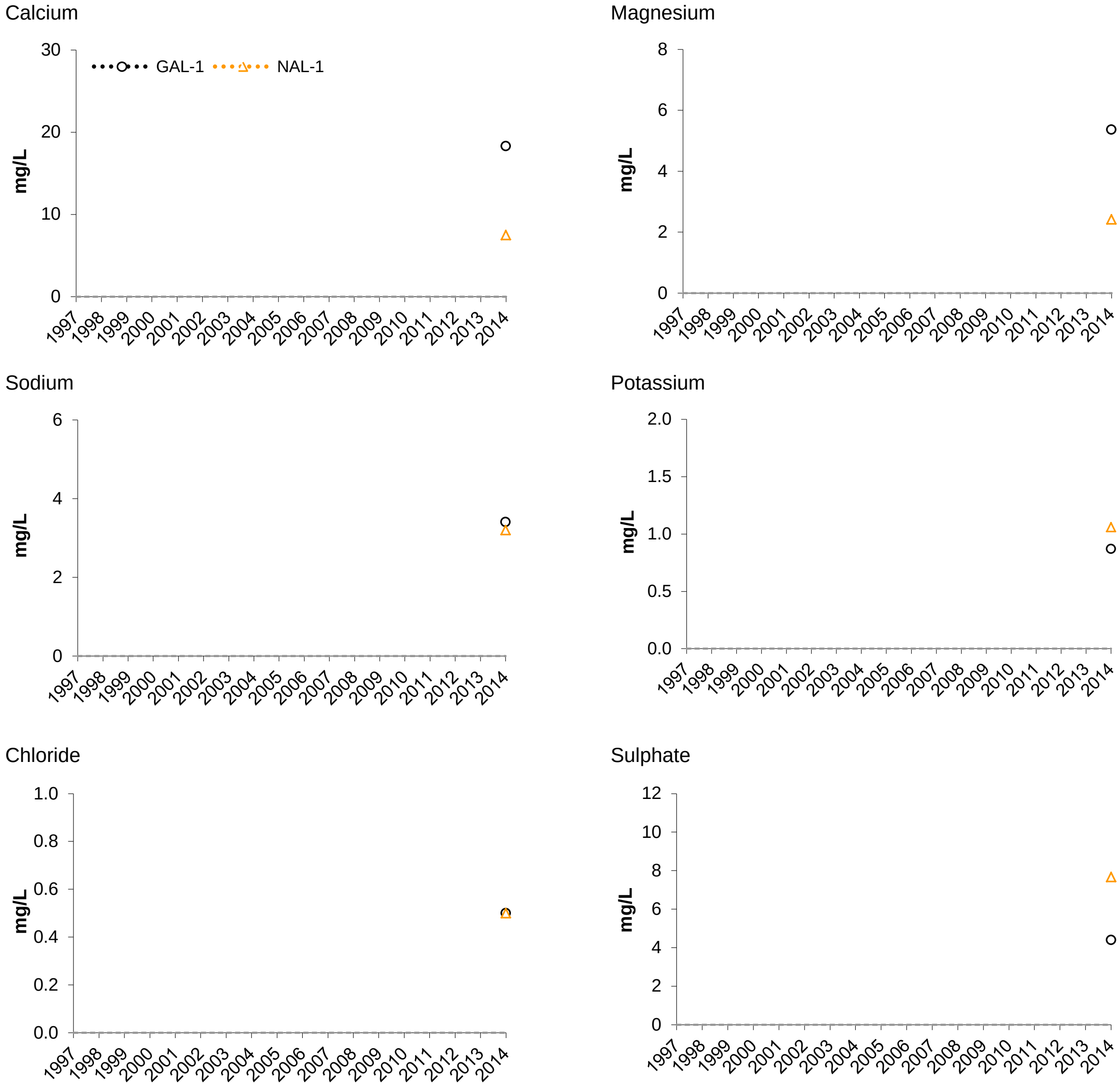
Figure 5.8-6 Selected water quality measurement endpoints for Namur and Gardiner lakes (fall data).



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Figure 5.8-6 (Cont'd.)



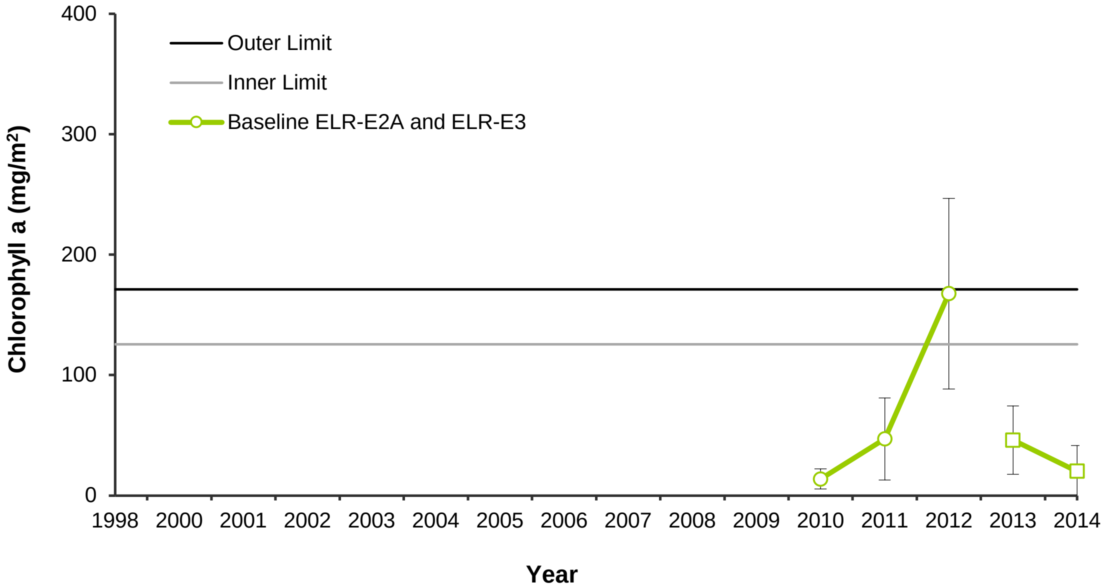
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Table 5.8-9 Average habitat characteristics of benthic invertebrate sampling locations in the Ells River, fall 2014.

Variable	Units	ELR-D1 Lower *Test* Reach	ELR-E3 Upper *Baseline* Reach
Sample date	-	Sept 6, 2014	Sept 8, 2014
Habitat	-	Depositional	Erosional
Water depth	m	0.3	0.3
Current velocity	m/s	0.43	0.67
Field Water Quality			
Dissolved oxygen	mg/L	9.7	10.5
Conductivity	µS/cm	232	226
pH	pH units	7.6	8.6
Water temperature	°C	11.5	7.3
Sediment Composition (mean ± 1SD)			
Sand	%	87±31	
Silt	%	2±1	
Clay	%	1±1	
Total Organic Carbon	%	0.7±0.3	
Sand/Silt/Clay	%		8±15
Small Gravel	%		22±30
Large Gravel	%		25±20
Small Cobble	%		25±25
Large Cobble	%		16±22
Boulder	%		2±2
Bedrock	%		

Figure 5.8-7 Periphyton chlorophyll *a* biomass in *baseline* reaches ELR-E2A (2010 to 2012) and ELR-E3 (2013 to 2014) of the Ells River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2013.

Note: *Baseline* reach ELR-E2A (2010 to 2012) was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Table 5.8-10 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the lower Ells River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach ELR-D1		
	2003	2004-2013	2014
Nematoda	<1	<1 to 3	-
Naididae	24	2 to 17	-
Tubificidae	52	18 to 62	14
Enchytraeidae	-	0 to <1	-
Hydracarina	<1	0 to 2	-
Gastropoda	<1	0 to 1	-
Bivalvia	<1	0 to 2	-
Ceratopogonidae	3	0 to 7	4
Chironomidae	19	17 to 76	72
Diptera (misc.)	-	0 to 2	<1
Coleoptera	-	0 to <1	-
Ephemeroptera	<1	<1 to 1	-
Odonata	<1	0 to <1	-
Trichoptera	<1	0 to <1	-
Heteroptera	<1	-	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	715	48 to 732	111
Richness	12	4 to 20	4
Equitability	0.38	0.27 to 0.57	0.44
% EPT	1	0 to 1	0

Table 5.8-11 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at the upper Ells River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach ELR-E2A	*Baseline* Reach ELR-E3	
	2010-2012	2013	2014
Nematoda	<1 to 2	3	3
Naididae	4 to 10	8	3
Tubificidae	<1 to 1	1	<1
Lumbriculidae	-	-	<1
Enchytraeidae	<1 to 1	1	2
Hydracarina	9 to 13	9	6
Gastropoda	<1 to 1	<1	<1
Bivalvia	0 to <1	<1	<1
Ceratopogonidae	<1 to 1	<1	<1
Chironomidae	42 to 60	58	38
Diptera (misc)	2 to 3	1	5
Coleoptera	0 to <1	<1	<1
Ephemeroptera	9 to 20	12	22
Odonata	0 to <1	1	4
Plecoptera	0 to 2	3	9
Trichoptera	6 to 15	3	7
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	1,133 to 1,915	2,238	1,130
Richness	38 to 42	43	38
Equitability	0.22 to 0.31	0.24	0.33
% EPT	17 to 37	20	39

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Table 5.8-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach ELR-D1.

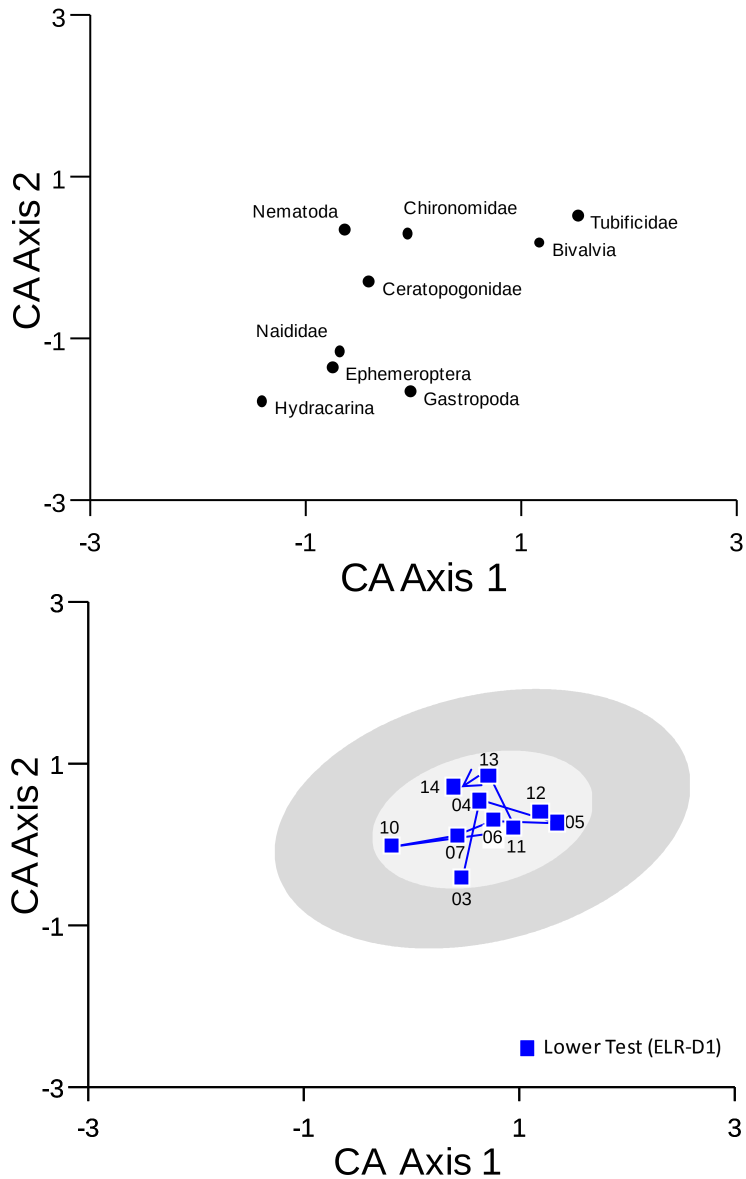
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**0.004**	**0.001**	25	34	Decreasing over time; lower in 2014 than mean of all previous years.
Log of Richness	**<0.001**	**<0.001**	23	37	Decreasing over time; lower in 2014 than mean of all previous years.
Equitability	0.539	0.539	2	2	No change.
Log of EPT	**0.009**	0.173	44	12	Decreasing over time.
CA Axis 1	0.791	0.332	0	5	No change.
CA Axis 2	**0.002**	**0.049**	32	12	Increasing over time; higher in 2014 than mean of all previous years.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

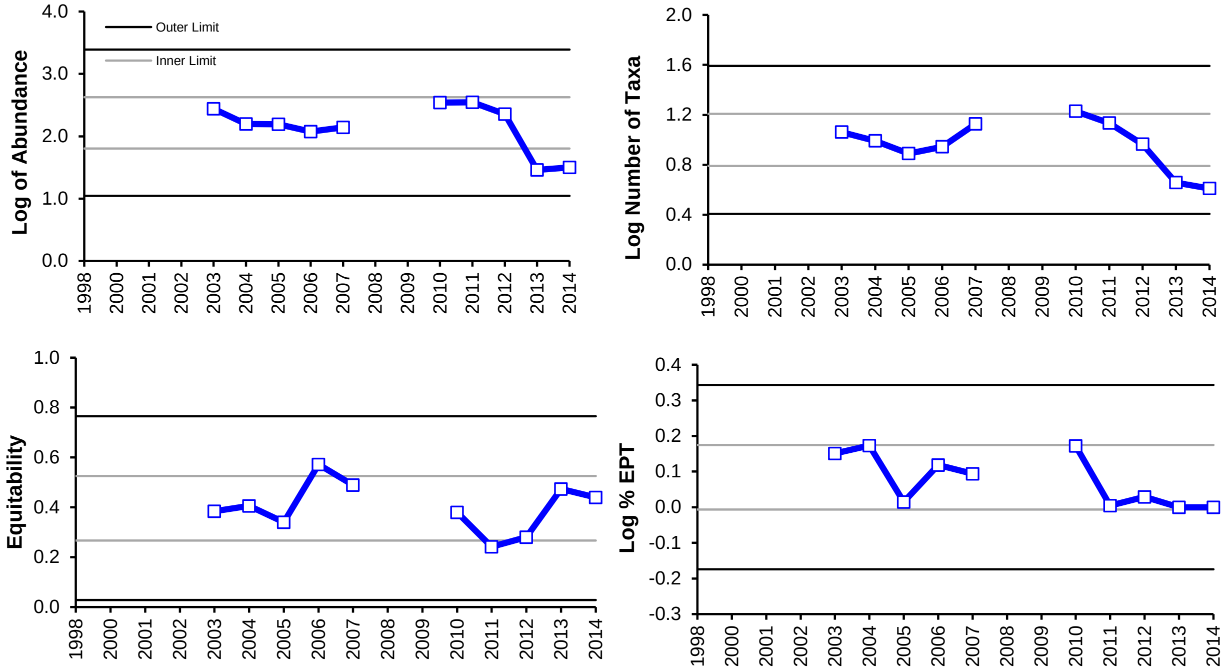
Note: Abundance, richness, and %EPT data were log_{10}(x+1) transformed.

Figure 5.8-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Ells River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years (2003 to 2013).

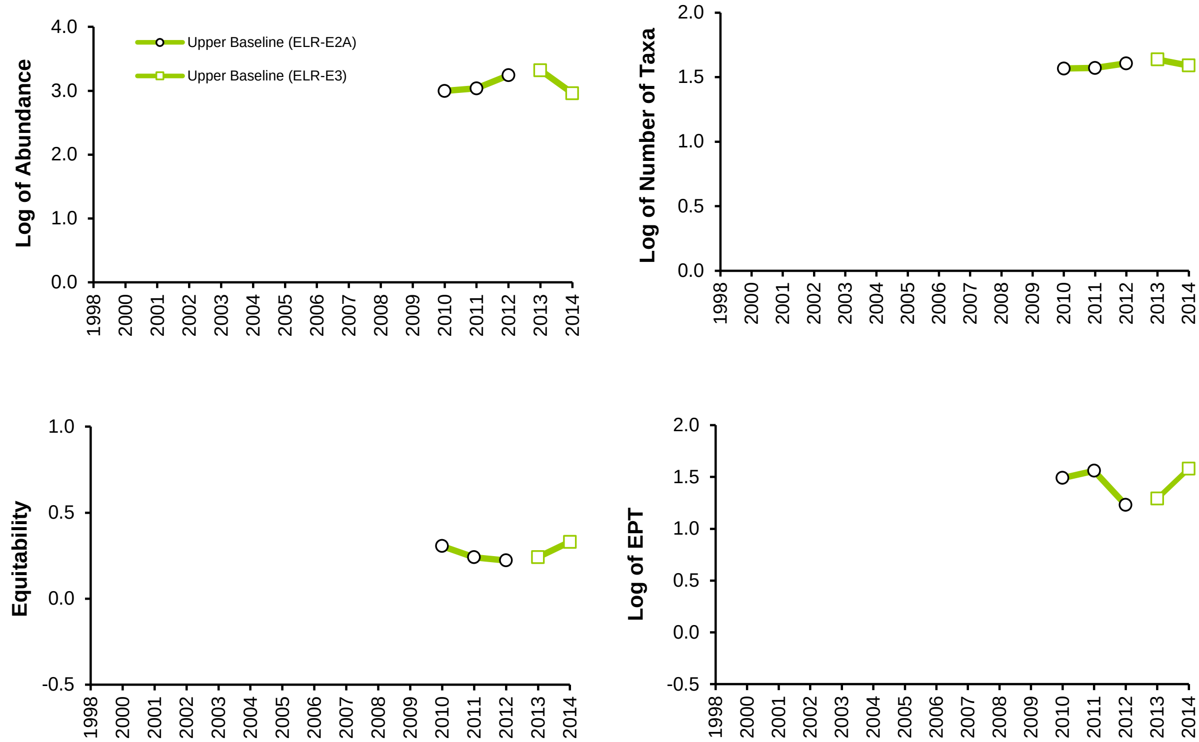
Figure 5.8-9 Variation in benthic invertebrate community measurement endpoints at *test* reach ELR-D1 of the Ells River relative to the historical range of variability.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach ELR-D1 (2003 to 2013).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

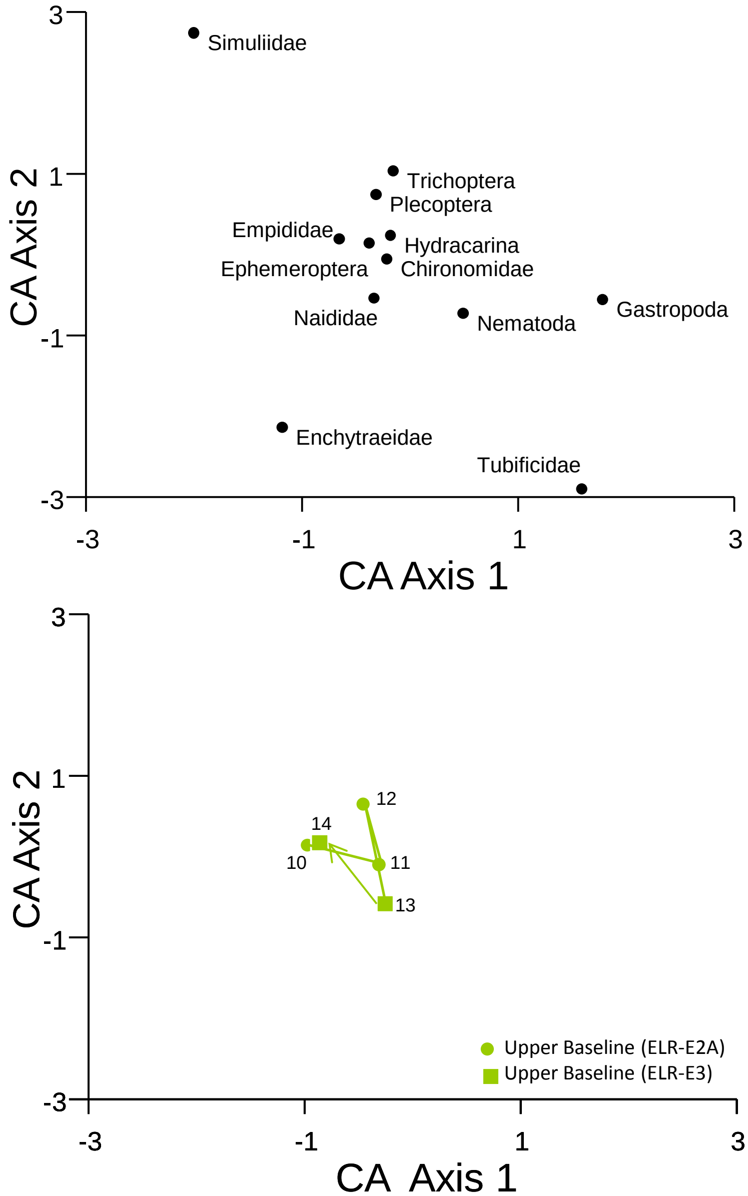
Figure 5.8-10 Variation in benthic invertebrate community measurement endpoints at *baseline* reaches ELR-E2A and ELR-E3 of the Ells River.



Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.8-11 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the upper *baseline* reaches of the Ells River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.8-13 Average habitat characteristics of benthic invertebrate sampling locations in Namur and Gardiner lakes, fall 2014.

Variable	Units	Namur Lake	Gardiner Lake
Sample date	-	Sept 6, 2014	Sept 8, 2014
Habitat	-	Depositional	Depositional
Water depth	m	1.1	0.63
Field Water Quality			
Dissolved oxygen	mg/L	9.6	10.3
Conductivity	µS/cm	69	176
pH	pH units	7.31	7.98
Water temperature	°C	11.8	7.2
Sediment Composition (mean ± 1SD)			
Sand	%	94±7	96±1
Silt	%	4±5	2±1
Clay	%	2±3	2±1
Total Organic Carbon	%	0.7±0.5	0.4±0.1

Table 5.8-14 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Namur and Gardiner Lakes.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Namur Lake	Gardiner Lake
	2014	
Nematoda	29	15
Oligochaeta	<1	<1
Naididae	6	1
Tubificidae	1	4
Enchytraeidae	2	10
Lumbriculidae	1	<1
Hirudinea	<1	<1
Hydracarina	22	<1
Amphipoda	3	3
Gastropoda	7	<1
Bivalvia	6	3
Ceratopogonidae	<1	<1
Chironomidae	17	61
Diptera (misc)	<1	<1
Ephemeroptera	3	<1
Odonata	<1	-
Trichoptera	1	<1
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance per sample	820	1,190
Richness	24	21
Equitability	0.2	0.15
% EPT	6	0.21

Table 5.8-15 Concentrations of selected sediment quality measurement endpoints, Ells River (*test* station ELR-D1), fall 2014.

Variables	Units	Guideline	September 2014	1998-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>1.4</u>	11	3.0	7.0	26
Silt	%	-	3.4	11	3.0	14	51
Sand	%	-	<u>95.2</u>	11	23	81	94
Total organic carbon	%	-	1.04	11	0.40	2.13	2.82
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<7.5	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<7.5	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	**175**	8	73	**192.5**	**320**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,440**	8	**890**	**1,595**	**3,000**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	870	8	510	845	1,600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	11	0.0009	0.0036	0.0094
Retene	mg/kg	-	0.12	10	0.067	0.193	0.713
Total dibenzothiophenes	mg/kg	-	6.974	11	1.278	5.427	9.885
Total PAHs	mg/kg	-	17.145	11	4.809	16.156	25.096
Total Parent PAHs	mg/kg	-	0.283	11	0.218	0.411	0.571
Total Alkylated PAHs	mg/kg	-	16.862	11	4.461	15.765	24.525
Predicted PAH toxicity[3]	H.I.	1.0	**2.03**	11	**1.18**	**1.95**	**3.5**
Metals that exceeded CCME guidelines in 2014							
none							
Other analytes that exceeded CCME guidelines in 2014							
Chrysene	mg/kg	0.0571	**0.138**	11	**0.072**	**0.134**	**0.226**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	4.0	8	3.8	6.9	8.8
Chironomus growth - 10d	mg/organism	-	2.3	8	0.72	2.04	3.74
Hyalella survival - 14d	# surviving	-	9.0	9	8.0	9.0	10
Hyalella growth - 14d	mg/organism	-	0.26	9	0.1	0.13	1.6

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

ns = not sampled

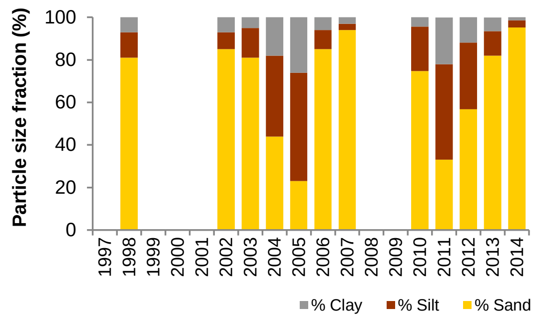
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

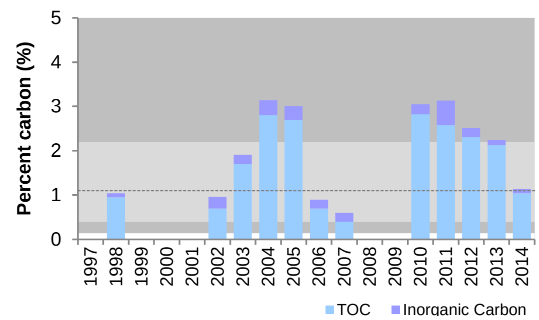
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-12 Variation in sediment quality measurement endpoints in the Ells River, *test* station ELR-D1.

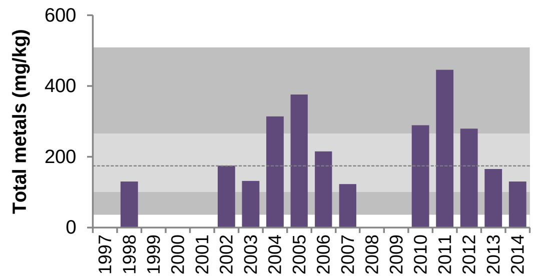
Particle size distribution



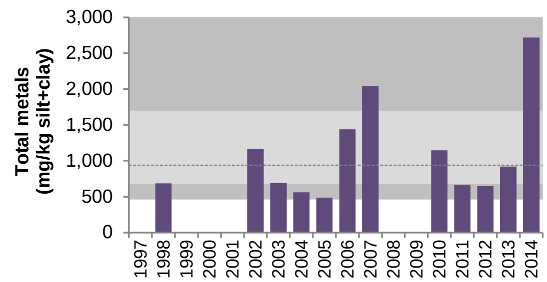
Carbon Content[1]



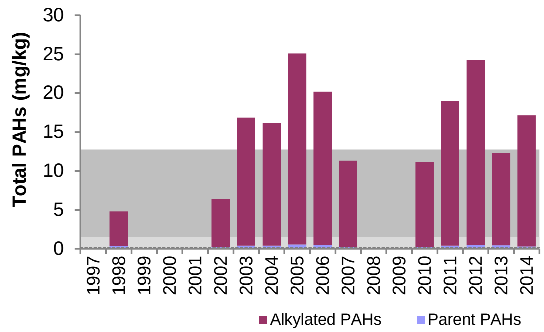
Total Metals[2]



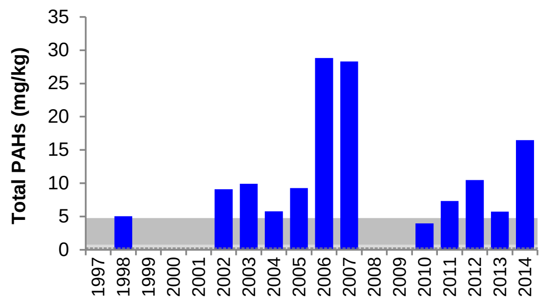
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



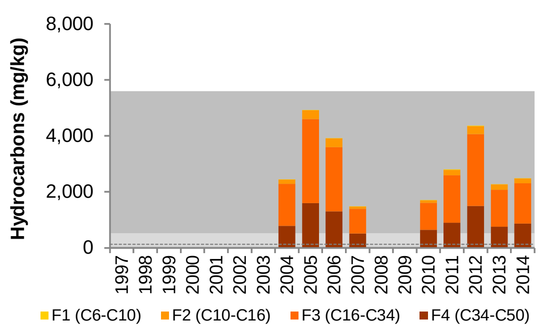
Total PAHs



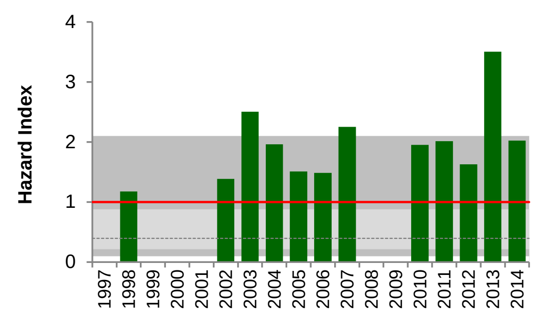
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-16 Concentrations of selected sediment quality measurement endpoints, Namur Lake (*test* station NAL-1), fall 2014.

Variables	Units	Guideline	September 2014
			Value
Physical variables			
Clay	%	-	0.74
Silt	%	-	1.0
Sand	%	-	98.2
Total organic carbon	%	-	0.43
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	38
Fraction 4 (C34-C50)	mg/kg	2,800[1]	27
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.00035
Retene	mg/kg	-	0.0036
Total dibenzothiophenes	mg/kg	-	0.0021
Total PAHs	mg/kg	-	0.0319
Total Parent PAHs	mg/kg	-	0.0038
Total Alkylated PAHs	mg/kg	-	0.0281
Predicted PAH toxicity[3]	H.I.	1.0	0.1038
Metals that exceeded CCME guidelines in 2014			
none			
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	8.3
Chironomus growth - 10d	mg/organism	-	3.38
Hyalella survival - 14d	# surviving	-	9.8
Hyalella growth - 14d	mg/organism	-	0.42

Values in **bold** indicate concentrations exceeding guidelines.

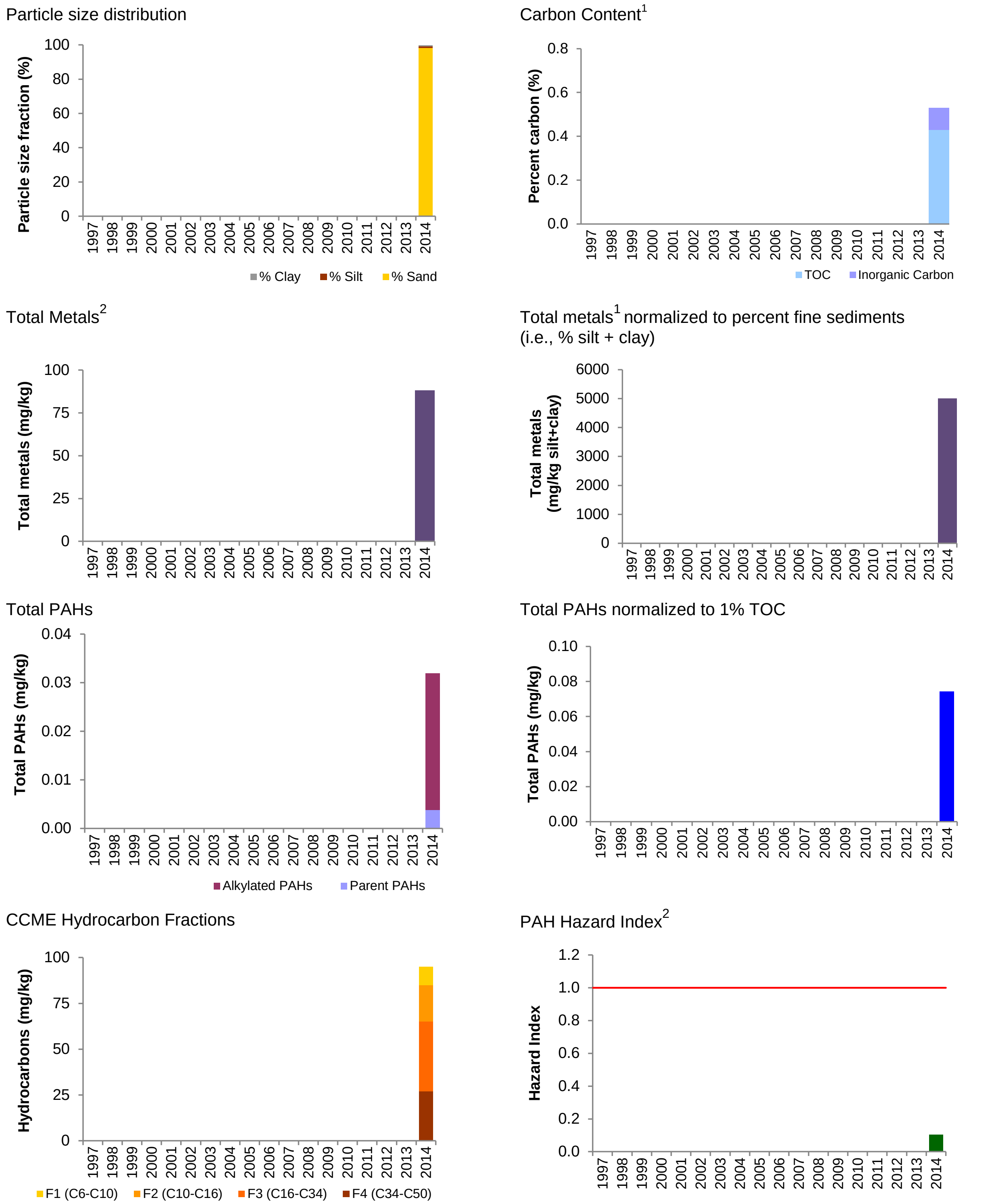
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-13 Variation in sediment quality measurement endpoints in Namur Lake, *test* station NAL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-17 Concentrations of selected sediment quality measurement endpoints, Gardiner Lake (*test* station GAL-1), fall 2014.

Variables	Units	Guideline	September 2014
			Value
Physical variables			
Clay	%	-	2.67
Silt	%	-	2.16
Sand	%	-	95.2
Total organic carbon	%	-	0.34
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.00029
Retene	mg/kg	-	0.0031
Total dibenzothiophenes	mg/kg	-	0.0021
Total PAHs	mg/kg	-	0.0270
Total Parent PAHs	mg/kg	-	0.0039
Total Alkylated PAHs	mg/kg	-	0.0231
Predicted PAH toxicity[3]	H.I.	1.0	0.1222
Metals that exceeded CCME guidelines in 2014			
none			
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	8.7
Chironomus growth - 10d	mg/organism	-	2.75
Hyalella survival - 14d	# surviving	-	9.2
Hyalella growth - 14d	mg/organism	-	0.43

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

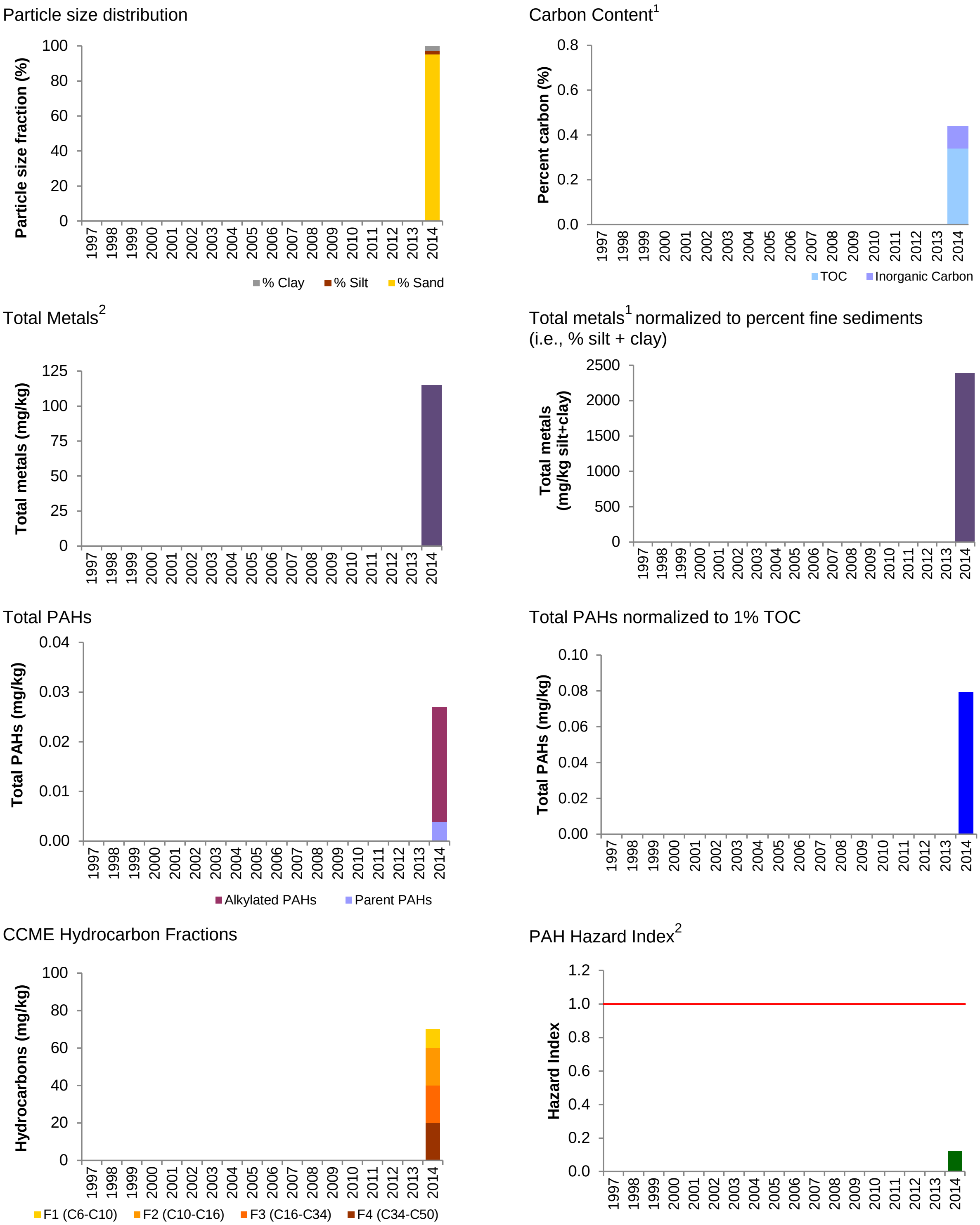
ns = not sampled

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-14 Variation in sediment quality measurement endpoints in Gardiner Lake, *test* station GAL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-18 Average habitat characteristics of fish assemblage monitoring locations of the Ells River, fall 2014.

Variable	Units	ELR-F1 Lower *Test* Reach	ELR-F3 Upper *Baseline* Reach
Sample date	-	Sept 3, 2014	Sept 7, 2014
Habitat type	-	run	run/riffle
Maximum depth	m	1.31	0.88
Mean depth	m	1.21	0.70
Bankfull channel width	m	37.0	39.8
Wetted channel width	m	18.0	32.8
Substrate			
Dominant	-	sand	sand
Subdominant	-	fines	cobble
Instream cover			
Dominant	-	large and small woody debris	boulders
Subdominant	-	macrophytes and filamentous algae	filamentous algae
Field water quality			
Dissolved oxygen	mg/L	9.0	10.0
Conductivity	µS/cm	221	196
pH	pH units	6.45	7.92
Water temperature	^{0}C	12.7	10.1
Water velocity			
Left bank velocity	m/s	1.34	0.24
Left bank water depth	m	0.59	0.50
Centre of channel velocity	m/s	1.75	0.27
Centre of channel water depth	m	0.64	0.67
Right bank velocity	m/s	1.10	0.21
Right bank water depth	m	0.67	0.46
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.8-19 Total number and percent composition of fish species captured at reaches of the Ells River, 2010 to 2014.

Common Name	Code	Total Species Catch											Percent of Total Catch										
		ELR-F1					ELR-F2	ELR-F2A			ELR-F3		ELR-F1					ELR-F2	ELR-F2A			ELR-F3	
		2010	2011	2012	2013	2014	2012	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2012	2010	2011	2012	2013	2014
burbot	BURB	-	-	-	5	1	-	-	-	-	1	-	0	0	0	29.4	6.7	0	0	0	0	0.5	0
fathead minnow	FTMN	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	34	-	-	-	-	-	160	-	-	1	-	30.6	0	0	0	0	0	52.5	0	0	0.5	0
lake chub	LKCH	-	4	5	4	2	40	-	1	99	-	23	0	26.7	11.6	23.5	13.3	34.8	0	1.4	43.6	0	31.9
lake whitefish	LKWH	-	-	9	-	-	-	-	-	-	-	-	0	0	20.9	0	0	0	0	0	0	0	0
longnose dace	LNDC	2	2	-	-	7	16	-	19	18	51	15	1.8	13.3	0	0	46.7	13.9	0	26.4	7.9	26.4	20.8
longnose sucker	LNSC	-	-	1	-	-	-	13	-	25	4	-	0	0	2.3	0	0	0	4.3	0	11.0	2.1	0
northern pike	NRPK	-	-	-	-	-	1	-	-	1	-	-	0	0	0	0	0	0.9	0	0	0.4	0	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	-	-	-	-	0	0	0	5.9	0	0	0	0	0	0	0
pearl dace	PRDC	46	-	7	-	-	-	82	43	-	97	-	41.4	0	16.3	0	0	0	26.9	59.7	0	50.3	0
slimy sculpin	SLSC	-	-	-	-	4	-	-	1	-	4	3	0	0	0	0	26.7	0	0	1.4	0	2.1	4.2
spoonhead sculpin	SPSC	-	-	-	3	-	-	-	-	-	1	-	0	0	0	17.6	0	0	0	0	0	0.5	0
spottail shiner	SPSH	-	1	-	-	-	-	-	-	-	-	-	0	6.7	0	0	0	0	0	0	0	0	0
trout-perch	TRPR	1	6	18	1	-	9	4	6	48	24	28	0.9	40	41.9	5.9	0	7.8	1.3	8.3	21.1	12.4	38.9
walleye	WALL	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	12	-	2	3	1	49	46	2	36	11	3	10.8	0	4.7	17.6	6.7	42.6	15.1	2.8	15.9	5.7	4.2
yellow perch	YLPR	15	2	1	-	-	-	-	-	-	-	-	13.5	13.3	2.3	0	0	0	0	0	0	0	0
sucker sp. *		1	-		-	-	-	-	-	-	-	-	0.9	0	0	0	0	0	0	0	0	0	0
Total Count		**111**	**15**	**43**	**17**	**15**	**115**	**305**	**72**	**227**	**193**	**72**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**5**	**7**	**6**	**5**	**5**	**5**	**6**	**6**	**9**	**5**	**6**	**5**	**7**	**6**	**5**	**8**	**5**	**6**	**6**	**9**	**5**
Electrofishing Effort (secs)		**5,258**	**1,307**	**1,979**	**-**	**2,373**	**2,170**	**3,959**	**1,614**	**1,956**	**2,522**	**2,557**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

* Not included in total species richness count.

Underline denotes a *baseline* reach.

Table 5.8-20 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of the Ells River, 2010 to 2014.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ELR-F1	2010	0.37	0.25	7	3.40	1.07	0.58	0.12	7.02	0.21	2.35	1.53
	2011	0.06	0.07	6	1.40	1.34	0.30	0.27	6.92	0.65	1.08	1.18
	2012	0.14	0.11	7	3.00	1.87	0.38	0.25	7.07	1.54	2.18	1.68
	2013	0.04	0.03	6	2.00	1.00	0.32	0.29	4.85	2.34	0.77	0.59
	2014	0.04	0.02	5	2.20	0.45	0.81	0.20	4.99	1.20	0.63	0.29
ELR-F2	2012	0.38	0.23	5	2.80	1.10	0.49	0.28	6.80	0.58	5.33	3.30
ELR-F2A	2010	0.61	0.26	5	3.90	0.74	0.55	0.11	6.89	0.23	7.75	3.40
	2011	0.29	0.13	6	3.20	0.84	0.54	0.28	6.62	0.28	4.54	2.22
	2012	0.91	0.24	6	5.00	0.71	0.70	0.06	6.44	0.30	11.63	3.27
ELR-F3	2013	0.35	0.13	8	5.60	1.52	0.64	0.03	6.68	0.19	7.69	2.81
	2014	0.12	0.06	9	3.80	0.84	0.64	0.10	6.72	0.55	2.81	1.47

* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

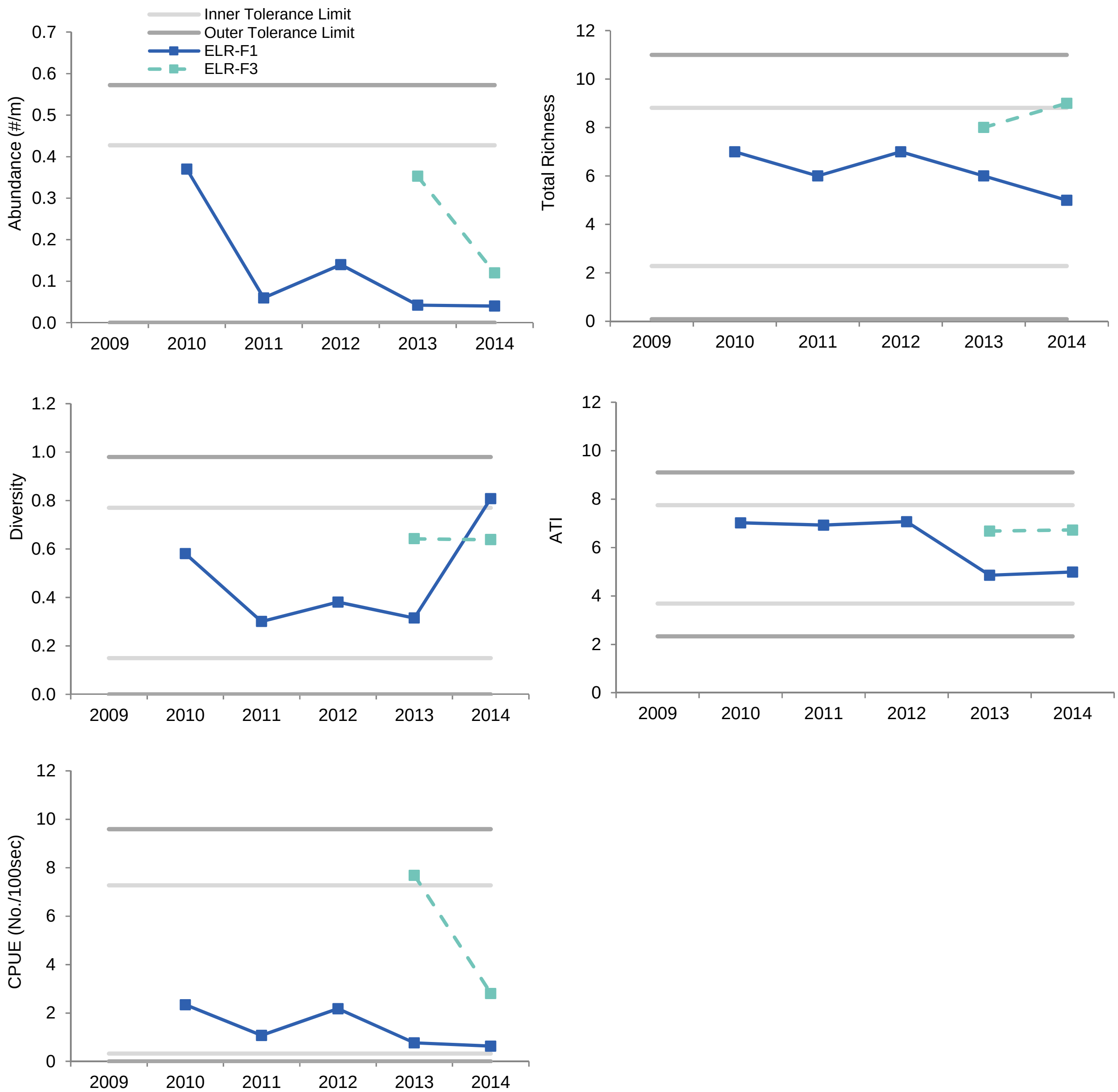
Table 5.8-21 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for *test* reach ELR-F1 of the Ells River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
	Time Trend	Time Trend	
Abundance	**<0.001**	41	Decreasing over time.
Richness	0.070	12	No change.
Diversity	0.520	2	No change.
ATI	**0.003**	27	Decreasing over time.
CPUE (No./100 sec)	**0.010**	21	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-15).

Figure 5.8-15 Variation in fish assemblage measurement endpoints for reaches of the Ells River from 2010 to 2014 relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

5.9 CLEARWATER RIVER WATERSHED

Table 5.9-1 Summary of results for the Clearwater River watershed.

Clearwater River Watershed	Summary of 2014 Conditions		
	Clearwater River		*High Hills River*
Climate and Hydrology			
Criteria	**07CD001** at Draper	**07CD005/S42** above the Christina River	**S51** near the Mouth
Mean open-water season discharge	not measured	not measured	not measured
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	not measured	not measured	not measured
Minimum open-water season discharge	not measured	not measured	not measured
Water Quality			
Criteria	**CLR-1** upstream of Fort McMurray	**CLR-2** upstream of Christina River	**HHR-1** at the mouth
Water Quality	○	○	○
Benthic Invertebrate Communities and Sediment Quality			
Criteria	**CLR-D1** upstream of Fort McMurray	**CLR-D2** upstream of Christina River	**HHR-E1** at the mouth
Benthic Invertebrate Communities	○	n/a	n/a
Sediment Quality Index	○	○	no station
Fish Populations			
Criteria	**Fish Inventory Reaches (CR1, CR2, CR3)**		**HHR-F1** at the mouth
Fish Assemblages	no criteria	no criteria	n/a

Legend and Notes

○ Negligible - Low

○ Moderate

○ High

baseline

test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

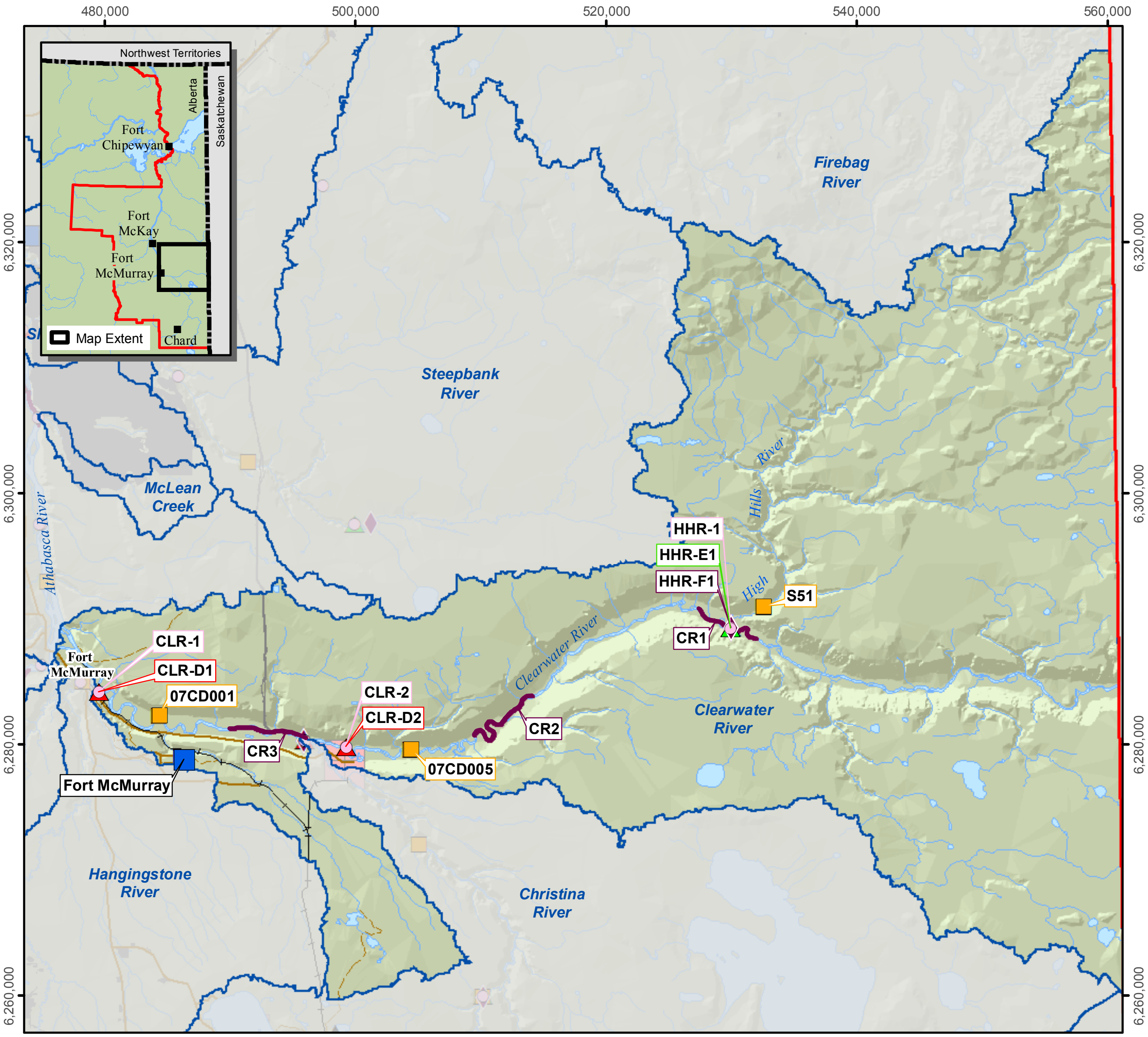
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baselines*; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.9-1 Clearwater River watershed.



Legend

Lake/Pond
River/Stream
Watershed Boundary
Major Road
Secondary Road
Railway
First Nations Reserve
Regional Municipality of Wood Buffalo Boundary
Land Change Area as of 2014[a]
Water Withdrawal Location[b]
Water Discharge Location[b]
Hydrometric Station
Climate Station
Water Quality Station
Benthic Invertebrate Communities Reach
Benthic Invertebrate Communities Reach and Sediment Quality Station
Fish Assemblage Reach
Fish Inventory Reach

0 2.5 5 10 km

N

Scale: 1:500,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.9-2 Representative monitoring stations of the Clearwater River watershed, fall 2014.

Benthic Invertebrate Reach HHR-E1 (High Hills River): facing downstream

Fish Assemblage Reach HHR-F1 (High Hills River): facing downstream

Benthic Invertebrate Reach CLR-D1 (Clearwater River): cross channel, facing upstream

Benthic Invertebrate Reach CLR-D2 (Clearwater River): cross-channel

5.9.1 Summary of 2014 Conditions

As of 2014, there has been no land change in the Clearwater River watershed from oil sands development; however, there has been some development in the watershed for the town of Fort McMurray. Given the influence of the Christina River on the Clearwater River and the increasing oil sands development in the Christina River watershed, the designations of specific areas of the Clearwater River watershed are as follows:

1. The Clearwater River downstream of the confluence with the Christina River is designated as *test*.
2. The Clearwater River upstream of the confluence with the Christina River is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Populations components in the Clearwater River watershed in 2014. Table 5.9-1 is a summary of the 2014 assessment of the Clearwater River watershed, while Figure 5.9-1 denotes the location of the monitoring stations for each component. Figure 5.9-2 contains fall 2014 photos of representative monitoring stations in the watersheds.

Hydrology Flows decreased from November 2013 to January 2014 and then remained relatively constant until early April. Flows then increased in mid-April in response to spring thaw, and reached the annual peak flow on June 12 (489 m^3/s) shortly after rainfall accumulations starting in late May. Flows then receded until the minimum open-water daily flow of 81.2 m^3/s on September 25. Flows from early July until the end of October were within the historical interquartile range. There was no effect in the Clearwater River watershed related to oil sands development in 2014. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

Water Quality In fall 2014, water quality at all stations of the Clearwater River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. Concentrations that exceeded previously-measured concentrations most frequently occurred at *baseline* station HHR-1 on the High Hills River, due to the limited historical data available for comparison. All stations showed similar ionic composition to previous years of sampling, with the ionic composition at *baseline* station HHR-1 continuing to be more dominated by calcium and bicarbonate ions than the stations of the Clearwater River mainstem. No trends in measurement endpoints were observed over time, with the exception of a decreasing trend in potassium at *test* station CLR-1. In 2014, there were few water quality guideline exceedances, with the exception of spring at *baseline* station HHR-1. Concentrations of many water quality variables fluctuated across months in 2014 at *baseline* station CLR-2. Despite these fluctuations, the ionic composition of the Clearwater River remained fairly consistent across the year, with only slight differences in May and June. Concentrations of many water quality variables (e.g., metals) in May, June, and July exceeded guidelines and frequently exceeded fall regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of benthic invertebrate communities at *test* reach CLR-D1 were classified as **Negligible-Low** because the observed differences in equitability and CA axis scores were not related to oil sands development given similar trends were observed at both the *test* and *baseline* reaches. Equitability was higher at the *test* reach generally across all years of sampling but the reach had a relatively diverse community, and contained a number of taxa considered sensitive to degrading habitat such as the chironomid *Lopesocladius* and the mayfly *Ametropus neavei* (Ephemeroptera).

Sediments at *test* station CLR-D1 and *baseline* station CLR-D2 were composed of sand, with concentrations of hydrocarbon fractions and PAHs below detection limits or in very low concentrations. Chronic toxicity tests yielded high survival and growth rates for the midge *Chironomus* and the amphipod *Hyalella* at both at *test* station CLR-D1 and *baseline* station CLR-D2, indicating low toxicity of sediments. The SQI value for both *test* CLR-D1 and *baseline* CLR-D2 in fall 2014 was 100, indicating **Negligible-Low** differences from regional *baseline* conditions.

The benthic invertebrate community at *baseline* reach HHR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and chironomids that reflected good water quality conditions. The relative abundance of naidid worms (50%) was much higher in 2013, but similar to 2011 and 2012. *Baseline* reach HHR-E1 was used as a regional *baseline* reach for comparisons to *test* reaches. Sediment quality monitoring was not conducted on the High Hills River given it is an erosional river.

Fish Populations (fish inventory) The objective of the fish inventory program on the Clearwater River was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years included:

- The total catch in spring and summer of 2014 decreased by 440 and 420 fish from 2013, respectively. Comparisons were unable to be carried out in fall because the *baseline* reaches were not sampled due to low water levels.

- The abundance of goldeye in spring 2014 was the highest recorded since 2009. This increase may be related to an increase in survival rates among the population given that the dominant age class in 2011 was five years which has shifted to an older age class of seven years in 2013 and 2014.

- The dominant age classes for northern pike have been two and three year-olds since 2012, which has been a shift towards a younger age class.

- The percentage of external abnormalities increased in 2014 from 2013, with the majority of abnormalities observed in white sucker (9.6%) and a higher percentage of overall abnormalities observed in summer (+9.2%). The increase in abnormalities was primarily driven by the increase in parasites on fish, which could be related to higher water temperatures in the river.

Fish Populations (fish assemblages) The fish assemblage at *baseline* reach HHR-F1 was consistent with other *baseline* reaches of similar habitat conditions (i.e., cluster 1 *baseline* group). Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

5.9.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Clearwater River watershed in the 2014 WY was conducted at the following locations:

- WSC Station 07CD001, Clearwater River at Draper;

- WSC Station 07CD005, Clearwater River above the Christina River; and

- JOSMP Station S51, High Hills River near the mouth.

The Christina River watershed flows into the Clearwater River; however, due to the size, number of stations, and complexity of this watershed, the results were presented, separately from the Clearwater River, in Section 5.10. Data from WSC Station 07CD001 were used to describe the 2014 WY hydrologic conditions of the Clearwater River, and are presented below. Data from JOSMP Station S51 can be found in Appendix C.

Continuous hydrometric data have been collected year-round at WSC Station 07CD001 since 1957. The historical flow record is summarized in Figure 5.9-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Clearwater River have a typical seasonal runoff pattern characteristic of a northern environment. Flows during winter are typically lower than the open-water season, and generally decrease from November until March. Spring thaw, and the resulting rapid increase in flows, typically occurs in mid-April. Monthly flows are highest in May, at the peak of freshet, and often remain elevated in June and July when total monthly rainfalls are highest (Figure 4.2-2). Flows generally recede after freshet until the end of the water year, in response to declining rainfall inputs and eventual river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.9-3). Flows decreased from November 2013 to January 2014 and then remained relatively constant until early April. Flows recorded during this period were between historical median and maxima flows. Flows then increased in mid-April in response to spring thaw, and reached the annual peak flow on June 12 (489 m^3/s) shortly after rainfall accumulations starting in late May. This peak was 25% higher than the historical mean annual maximum daily flow (392 m^3/s). Flows then receded until the minimum open-water daily flow of 81.2 m^3/s on September 25, which was 9% lower than the historical mean minimum daily flow of 89.2 m^3/s calculated for the open-water period. Flows from early July until the end of October were within the historical interquartile range.

The 2014 water year runoff volume recorded at WSC Station 07CD001 was 4,308 million m^3. This value was 14% higher than the historical mean water year runoff volume if 3,775 million m^3.

The only effects in the Clearwater River watershed related to oil sands development in 2014, were within the Christina River watershed (see Section 5.10). Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

5.9.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Clearwater River upstream of Fort McMurray, but downstream of the confluence of the Christina River (*test* station CLR-1), sampled since 2001;
- the Clearwater River upstream of the confluence with the Christina River (*baseline* station CLR-2), sampled since 2001; and
- the High Hills River near its mouth, a tributary to the Clearwater River (*baseline* station HHR-1), sampled since 2011.

Baseline station HHR-1 on the High Hills River was also sampled in winter, spring, and summer 2014 in an effort to obtain seasonal *baseline* data. Additionally, *baseline* station CLR-2 was sampled as part of the monthly sampling program in 2014. *Baseline* station CLR-2 has been sampled monthly since May 2013.

Temporal Trends The only significant trend (α=0.05) in fall concentrations of water quality measurement endpoints over time was a decreasing concentration of potassium at *test* station CLR-1. There were no significant trends at *baseline* station CLR-2. Trend analysis was not conducted on *baseline* station HHR-1 because only four years of data have been collected.

2014 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations (Table 5.9-2 to Table 5.9-4), with the following exceptions:

- Dissolved aluminum, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations, and naphthenic acids and oilsands exctractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station CLR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- Naphthenic acids and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations, and total nitrogen, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station CLR-2; and
- Conductivity, sodium, calcium, total boron, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations, and total dissolved phosphorus, total nitrogen, dissolved organic carbon, dissolved aluminum, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station HHR-1.

Ion Balance The ionic composition of water at all stations of the Clearwater River watershed in fall 2014 was similar to previous years (Figure 5.9-4). Stations on the Clearwater River (*test* station CLR-1 and *baseline* station CLR-2) were generally evenly dominated by calcium, potassium, and sodium cations, and bicarbonate anions. The proportion of chloride has historically been slightly lower at *test* station CLR-1 relative to *baseline* station CLR-2. *Baseline* station HHR-1 of the High Hills River was dominated by calcium and bicarbonate and has remained very consistent across sampling years.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum exceeded the water quality guideline at all stations in the Clearwater River watershed in fall 2014 (Table 5.9-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the Clearwater River watershed in fall 2014 (Table 5.9-5):

- Total iron at *test* station CLR-1 and *baseline* stations CLR-2 and HHR-1; and
- Total phenols at *test* station CLR-1.

In addition, the following water quality guideline exceedances occurred in winter, spring, and summer at *baseline* station HHR-1 (Table 5.9-5);

- Winter – total aluminum and total iron;
- Spring – total and dissolved iron, sulphide, total aluminum, total chromium, total copper, total lead, total mercury (ultra-trace), and total phenols; and
- Summer – total and dissolved iron, sulphide, total aluminum, and total chromium.

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, most of the water quality measurement endpoints were within regional *baseline* concentrations, with the exception of the following (Figure 5.9-5):

- Total nitrogen, with concentrations below the 5th percentile of regional *baseline* concentrations at *baseline* stations CLR-2 and HHR-1;
- Sodium, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CLR-1; and
- Chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CLR-1 and *baseline* station CLR-2.

Water Quality Index WQI values in fall 2014 at *test* station CLR-1 (97.5) and *baseline* stations CLR-2 (100) and HHR-1 (100) indicated **Negligible-Low** differences from regional *baseline* water quality conditions.

Monthly Water Quality Results Water quality samples were collected monthly on the Clearwater River in 2014. Monthly sampling was initiated in January 2013 at *test* station CLR-1, but was shifted to *baseline* station CLR-2 in May 2013 as requested through the JOSMP. All monthly testing in 2014 was conducted at *baseline* station CLR-2. Monthly results for *baseline* station CLR-2 are summarized in Table 5.9-6, with historical ranges from May to December 2013.

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances at *baseline* station CLR-2 in 2014 (Table 5.9-7) included:

- sulphide in February, May, June, July, and November;
- total phenols in May;
- total aluminum in all months, with the exception of January;
- dissolved aluminum in June;
- total iron in all months;
- dissolved iron in all months except August, September, and October;
- total chromium in May, June, and July; and
- total mercury (ultra-trace) in June.

2014 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2014, most monthly water quality data collected at *baseline* station CLR-2 were within the range of the regional *baseline* concentrations observed in fall (Figure 5.9-6), with the exception of:

- total suspended solids in May, June, and July, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations;
- total dissolved solids in May and June, with concentrations below the 5th percentile of fall regional *baseline* concentrations;
- total nitrogen, with concentrations below the 5th percentile of fall regional *baseline* concentrations in January, February, March, July, September, October, and December;

- total strontium in May, with a concentration below the 5th percentile of fall regional *baseline* concentrations;
- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations in May and June, but were below the 5th percentile of fall regional *baseline* concentrations in March, April, and December;
- calcium and hardness, with concentrations below the 5th percentile of fall regional *baseline* concentration in January, May, June, and July;
- magnesium, with concentrations below the 5th percentile of regional *baseline* concentrations in May, June, July, and October;
- sodium, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations in November;
- chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations in January, February, March, April, September, November, and December;
- pH, with values below the 5th percentile of fall regional *baseline* concentrations from January to July, and December; and
- total alkalinity, with concentrations below the 5th percentile of regional *baseline* concentrations from May to July.

Monthly Ion Balance The ionic composition of water at *baseline* station CLR-2 remained consistent across most months in 2014, with a cation composition primarily dominated by sodium, potassium, and calcium (Figure 5.9-7). The ionic composition in May and June had a notably lower proportion of chloride than the other months.

Classification of Fall Results In fall 2014, water quality at all stations of the Clearwater River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. Concentrations that exceeded previously-measured concentrations most frequently occurred at *baseline* station HHR-1, due to the limited historical data available for comparison (n=3). All stations showed similar ionic composition to previous years of sampling, with the ionic composition at *baseline* station HHR-1 continuing to be more dominated by calcium and bicarbonate ions than the stations of the Clearwater River mainstem. No trends in measurement endpoints were observed over time, with the exception of a decreasing trend in potassium at *test* station CLR-1. In 2014, there were few water quality guideline exceedances, with the exception of spring at *baseline* station HHR-1.

Summary of Monthly Results Concentrations of many water quality variables fluctuated across months in 2014 at *baseline* station CLR-2. Despite these fluctuations, the ionic composition of the Clearwater River remained fairly consistent across the year, with only slight differences in May and June. Concentrations of many water quality variables (e.g., metals) in May, June, and July exceeded guidelines and frequently exceeded the fall regional *baseline* conditions.

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- the Clearwater River downstream of the confluence with the Christina River (depositional *test* reach CLR-D1), designated and sampled as a *baseline* reach in 2001, designated and sampled as a *test* reach from 2002 to 2005, 2008, 2011, and 2014;
- the Clearwater River upstream of the confluence with the Christina River (depositional *test* reach CLR-D2), sampled from 2001 to 2005, 2008, 2011, and 2014; and
- the High Hills River near its mouth (erosional *baseline* reach HHR-E1), sampled since 2011.

Clearwater River

2014 Habitat Conditions Water at *test* reach CLR-D1 in fall 2014 had a mean depth of 0.68 m (where samples were collected), moderate velocity (1.3 m/s), moderate conductivity (269 µS/cm), high dissolved oxygen (9.1 mg/L), and a pH of 6.97 (Table 5.9-8). The substrate was primarily comprised of sand (89%), with low organic carbon content (<1%) (Table 5.9-8).

Water at *baseline* reach CLR-D2 in fall 2014 had a mean depth of 1.1 m, (where samples were collected), slow velocity (0.27 m/s), moderate conductivity (211 µS/cm), moderately high dissolved oxygen (9.3 mg/L), and a pH of 6.56 (Table 5.9-8). The substrate was mostly sand with some silt (11%) and small amounts of clay (4%), and low organic carbon content (<1%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of the lower depositional *test* reach (CLR-D1) was dominated by Chironomidae (68%) with subdominant taxa consisting of Nematoda (17%) (Table 5.9-9). Chironomids consisted primarily of moderately pollution-tolerant forms including *Polypedilum, Paralauterborniella*, *Cryptochironomus*, and *Paracladopelma*. EPT taxa were nearly absent from the lower *test* reach, with the exception of one individual each of *Ametropus neavei* and *Brachycerus* mayflies. A single bivalve (*Pisidium*) was collected in one replicate sample.

The benthic invertebrate community of the upper depositional *baseline* reach (CLR-D2) was dominated by chironomids (85%) with subdominant taxa consisting of Ephemeroptera (5%), and Tubificidae (5%) (Table 5.9-9). Chironomids at the upper *baseline* reach tended to be forms associated with better water quality conditions such as *Lopesocladius* and *Robackia* (Mandeville 2001); however, common forms were also abundant (*Polypedilum* and *Paracladopelma*). Ephemeroptera (*Siphloplectron*) and Trichoptera (*Hydropsyche* and *Brachycentrus*) were found in low relative abundances. Bivalves (*Pisidium/Sphaerium*) were present as well in low relative abundances.

Temporal Comparisons Below are the temporal and spatial comparisons of benthic communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of the Clearwater River. For the purpose of this report, a comparison was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach CLR-D1 included testing for:

- changes over time during the *test* period (i.e., since 2002, Hypothesis 4, Section 3.2.3.1);
- changes between 2014 values and the mean of all available *baseline* data for the Clearwater River;
- changes between 2014 values and the mean of all previous years of sampling (2001 to 2013); and
- changes from before (2001) and after (2002 to present) the lower *test* reach was designated as *test*.

Spatial comparisons of measurement endpoints for *test* reach CLR-D1 included testing for:

- differences from *baseline* reach CLR-D2 over time during the *test* period (2002 to 2014);
- differences from *baseline* reach CLR-D2 from before (2001) to after (2002 to present) the lower reach was designated as test (Hypothesis 1, Section 3.2.3.1);

Equitability was higher at *test* reach CLR-D1, with the difference between the *test* and *baseline* reaches accounting for 26% of the variation in annual means (Table 5.9-10).

CA Axis 1 scores were lower during the *test* period at the *test* reach, which accounted for 29% of the variance in annual means (Table 5.9-10). The higher CA Axis 1 scores during the *baseline* period (2001) reflected a larger relative abundances of bivalves in 2001 (the only *baseline* year, Figure 5.9-8).

CA Axis 2 scores were higher during the *test* period, which accounted for 33% of the variance in annual means (Table 5.9-10). The higher CA axis 2 scores during the *test* period reflected a higher relative abundance of chironomids in the *test* period (Figure 5.9-8).

Comparison to Published Literature The benthic invertebrate community at *test* reach CLR-D1 was typical for a shifting-sand environment. The community was dominated by chironomids, including many forms that are widely distributed and tolerant of various conditions (e.g., *Polypedilum*, *Micropsectra*/*Tanytarsus*), forms that are more common in sand or shifting sands (e.g., *Cryptochironomus*), and other forms that are indicative of low levels of organic nutrients (e.g., *Lopesocladius*) (Beck 1977). Naidid and tubificid worms were present in low relative abundances (i.e., 6% combined), which indicated low levels of organic input (Hynes 1960; Griffiths 1998; Mandeville 2001); however, nematodes were unusually abundant.

The benthic invertebrate community at *baseline* reach CLR-D2 was somewhat similar to that of the lower *test* reach. Chironomidae were dominant, with *Robackia* and *Lopesocladius* being the most dominant genera. The community contained representatives of EPT taxa, including mayflies (*Siphloplectron*) and Trichoptera (*Hydropsyche* and *Brachycentrus*), which indicated high water and substrate quality (Mandeville 2001).

2014 Results Relative to Regional *Baseline* Conditions Values of measurement endpoints for *test* reach CLR-D1 were within the inner tolerance limits for the normal range of regional *baseline* conditions (Figure 5.9-9).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach CLR-D1 were classified as **Negligible-Low** because the observed differences in equitability and CA axis scores were not related to oil sands development given similar trends were observed at both the test and baseline reaches. Equitability was higher at the *test* reach generally across all years of sampling but the reach had a relatively diverse community, and contained a number of taxa considered sensitive to degrading habitat such as the chironomid *Lopesocladius* and the mayfly *Ametropus neavei* (Ephemeroptera).

High Hills River

2014 Habitat Conditions Water at *baseline* reach HHR-E1 in fall 2014 was shallow (0.25 m), with a pH of 7.7, high velocity (1.9 m/s), high dissolved oxygen (10.1 mg/L), and moderate conductivity (217 µS/cm) (Table 5.9-11). The substrate consisted primarily of small cobble (34%) and gravel (53%) with some sand/silt/clay (10%) (Table 5.9-11). Periphyton chlorophyll *a* biomass averaged 40 mg/m^2 and was much higher than 2013, but still within the normal range of variation for *baseline* erosional reaches (Figure 5.9-10).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *baseline* reach HHR-E1 was dominated by Naididae worms (50%) with subdominant taxa consisting of chironomids (14%), Ephemeroptera (14%), and Trichoptera (8%) (Table 5.9-12). Chironomids consisted primarily of *Cricotopus/Orthocladius* and *Rheotanytarsus.* Mayflies were diverse and dominated by *Baetis, Rhithrogena,* and *Ephemerella*. Trichoptera were mainly *Lepidostoma, Brachycentrus,* and *Hydrosyche*. Plecoptera (Capniidae, Chloroperlidae, *Zapada, Claassenia sabulosa*) were also present. Permanent aquatic forms were represented by a single organism of the limpet *Ferrissia rivularis*.

Comparison to Published Guidelines The benthic invertebrate community of *baseline* reach HHR-E1 contained a benthic fauna that generally reflected good water quality; however, the percentage of the community as worms increased from 2013 and the percentage of EPT taxa decreased. Permanent aquatic organisms that were present in 2013 were nearly absent in 2014; however, larvae of flying insects (mayflies, stoneflies, and caddisflies) were diverse and relatively abundant indicating favourable water quality at *baseline* reach HHR-E1. The dominant forms of Chironomidae found are known to represent fair to good water quality (Mandeville 2002). For example, the chironomid *Rheotanytarsus*, which was present at *baseline* reach HHR-E1, tends to be present in rocky streams with good flows (Merritt and Cummins 1996).

2014 Results Relative to Historical Conditions Values of all measurement endpoints in fall 2014 showed improvement in the benthic invertebrate community compared to 2013, with the exception of a decrease in the percentage of EPT taxa (Figure 5.9-11). CA Axis scores were generally similar to observations in 2013 (Figure 5.9-12).

Summary of Results The benthic invertebrate community at *baseline* reach HHR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and chironomids that reflected good water quality conditions. The relative abundance of naidid worms (50%) was much higher in 2013, but similar to 2011 and 2012. *Baseline* reach HHR-E1 was used as a regional *baseline* reach for comparisons to *test* reaches.

5.9.4.2 Sediment Quality

In fall 2014, sediment quality samples were collected from:

- the lower Clearwater River (*test* station CLR-D1), sampled in 2001 to 2003, 2008, 2011, and 2014; and
- the Clearwater River above the Christina River confluence (*baseline* station CLR-D2), sampled in 2001 to 2003, 2008, 2011, and 2014.

Temporal Trends No trend analysis was possible for either *test* station CLR-D1 or *baseline* station CLR-D2 in fall 2014 due to the limited years of historical data that were available (n=6).

2014 Results Relative to Historical Concentrations Sediment collected at *test* station CLR-D1 and *baseline* station CLR-D2 was predominantly composed of sand, with very small amounts of silt, clay, and low organic carbon content (Table 5.9-13 and Table 5.9-14). The percentage of sand exceeded the previously-measured maximum percentage, while the percentage of total organic carbon was below the previously-measured minimum percentage and the detection limit in 2014 at *test* station CLR-D1. Concentrations of PAHs at both stations and chronic toxicity measurement endpoints at *test* station CLR-D1 have only been sampled twice historically so should not be compared directly to previous results. Sediment toxicity measurements at *test* station CLR-D1 and *baseline* station CLR-D2 had high survival for both the midge *Chironomus* (100% and 90%, respectively) and the amphipod *Hyalella* (94% and 86%, respectively). The ten-day growth rate of *Hyalella* at *baseline* station CLR-D2 exceeded the previously-measured maximum value in 2014. Generally the growth rates of both *Hyalella* and *Chironomus* were high in 2014 at both stations (Table 5.9-13 and Table 5.9-14).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment quality measurement endpoints exceeded applicable CCME guidelines at *test* station CLR-D1 or *baseline* station CLR-D2 (Table 5.9-13 and Table 5.9-14).

2014 Results Relative to Regional *Baseline* Concentrations All sediment quality measurement endpoints at *test* station CLR-D1 and *baseline* station CLR-D2 in fall 2014 were within regional *baseline* concentrations, with the exception of the PAH Hazard Index, which was below the 5^{th} percentile of regional *baseline* values at *baseline* station CLR-D2 (Figure 5.9-13 and Figure 5.9-14).

Sediment Quality Index The SQI values for *test* CLR-D1 and *baseline* CLR-D2 in fall 2014 was 100, indicating **Negligible-Low** differences from regional *baseline* conditions.

Classification of Results Sediments at *test* station CLR-D1 and *baseline* station CLR-D2 were composed of sand, with concentrations of hydrocarbon fractions and PAHs below detection limits or in very low concentrations. Chronic toxicity tests yielded high survival and growth rates for the midge *Chironomus* and the amphipod *Hyalella* at both at *test* station CLR-D1 and *baseline* station CLR-D2, indicating low toxicity of sediments. The SQI value for both *test* CLR-D1 and *baseline* CLR-D2 in fall 2014 was 100, indicating **Negligible-Low** differences from regional *baseline* conditions.

5.9.5 Fish Populations

Fish population monitoring in the Clearwater River watershed in 2014 consisted of a spring, summer, and fall fish inventory on the Clearwater River mainstem and fish assemblage monitoring at one *baseline* reach on the High Hills River. With the exception of fall 2011 and 2014, *baseline* reaches (CR1 and CR2) have been continually sampled in spring and fall since 2003. The *test* reach (CR3) has also been sampled since 2003 in spring and fall; all three reaches have been sampled in summer since 2009.

5.9.5.1 Clearwater River Fish Inventory

Temporal and Spatial Comparisons

Temporal and spatial comparisons were conducted to assess changes by season and area of the river for the following measurement endpoints: species composition, species richness, catch per unit effort (CPUE), age-frequency distribution, size-at-age (growth), and condition factor.

Total Catch and Species Composition A total of 436 fish were captured in three reaches of the Clearwater River during the 2014 spring, summer, and fall inventories (Table 5.9-15, Figure 5.9-15), of which:

- 108 fish representing 11 species were captured in spring;
- 247 fish representing ten species were captured in summer; and
- 71 fish representing six species were captured in fall (*test* reach only).

A total of 14 species were captured across all three seasons during the 2014 Clearwater River fish inventory. The dominant large-bodied fish species captured across seasons were goldeye (34.3% in spring), white sucker (33.6%) in summer, and longnose sucker (47.9%) in fall. Spottail shiner was the dominant small-bodied species in spring (5.6%) while flathead chub was dominant in summer (13.8%) and fall (15.5%).

The total catch in 2014 was substantially lower across all seasons compared to 2013. Total catch in spring and summer were the lowest recorded since sampling was initiated in 2003 (spring) and 2009 (summer); fall comparisons were not conducted because the *baseline* reaches were not sampled due to low water levels (Figure 5.9-16).

Species Richness Species richness was compared between *baseline* reaches CR1 and CR2 and *test* reach CR3 in 2014 in spring and summer. The number of species captured at *baseline* reaches CR1 and CR2 was greater than *test* reach CR3 (Table 5.9-15).

Species richness was lower at the *baseline* reaches in spring and summer of 2014 when compared to 2013. Richness at the *test* reaches was considerably lower in 2014. Total species richness across seasons and reaches in 2014 was lower than all previous sampling years (Figure 5.9-16).

Catch Per Unit Effort Seasonal catch per unit effort (CPUE) of large-bodied KIR fish species at *test* and *baseline* reaches is provided in Figure 5.9-17. White sucker had the highest CPUE at the *baseline* reaches while goldeye and longnose sucker had the highest CPUE at the *test* reaches in spring and summer.

Total CPUE in 2014 across all reaches for each season and species is provided in Figure 5.9-18. Goldeye had the highest CPUE in spring while white sucker and longnose sucker had the highest CPUE in summer and fall. The CPUE of white sucker decreased in 2014, primarily in spring and fall when CPUE decreased by approximately 85% from 2013 in both seasons. CPUE of goldeye was slightly higher in spring as well as CPUE of longnose sucker in both summer and fall in 2014 compared to 2013.

Age-Frequency Distributions and Size-at-Age With the exception of additional ageing data collected from 2004 to 2009 for northern pike and walleye, all species-specific results were assessed using data from 2011 to 2014. Statistical differences in size-at-age were tested using analysis of covariance (ANCOVA) followed by Tukey post-hoc tests to determine significant differences between annual data. Only large-bodied KIR fish species with adequate samples sizes ($n \geq 20$, Table 5.9-16) and regression lines with equal slopes ($p > 0.01$) were included and only significant differences were reported. The relative age-frequency distributions of large-bodied KIR fish species for years when ageing data were collected are presented in Figure 5.9-19 to Figure 5.9-23. Species-specific results were as follows:

- The dominant age class for goldeye in 2014 was six years with a subdominant age class of three years. These results were consistent with 2013. Although sample sizes have been relatively small across years, a shift towards a slightly older dominant age class has been observed since 2012 (Figure 5.9-19).
- Ageing data collected in 2014 for longnose sucker exhibited a relatively even distribution ranging from two to ten years of age. Similarly, the dominant age classes in 2013 were also spread out among these years while dominance in 2011 and 2012 were centered on younger age classes from two to four years (Figure 5.9-20).
- The dominant age class of northern pike in 2014 was two years; these results were consistent with 2012 and 2013 when the dominant age classes were two and three years, respectively (Figure 5.9-21).
- The walleye population was slightly older in 2014; dominant age classes ranged from two to eight years whereas dominance was more centered on three in five years in 2013 and 2012, respectively (Figure 5.9-22).
- There was a bi-modal age distribution for white sucker in 2014, with co-dominant age classes of three and five years. A similar trend was observed in 2013 with co-dominant age classes of two, five, and six years. The dominant age class in 2012 was within these bi-modal distributions at four years (Figure 5.9-23).

Condition Factor Mean condition factor of large-bodied KIR fish species were compared between reaches and seasons. Fish captured in spring were excluded from comparisons due to the influence of spawning on condition (i.e., an increase in reproductive tissue). Summer and fall mean condition (± 2SD) were compared between species captured in the *test* and *baseline* reaches in 2014 (Figure 5.9-24). Temporal trends in mean condition across all reaches from 2003 to 2014 are presented in Figure 5.9-25. Statistical comparisons were not performed due to insufficient sample sizes (Table 5.9-17). Species-specific trends were as follows:

- Mean condition of goldeye across all reaches was slightly lower in summer 2014 compared to 2013; there were no goldeye captured in fall 2014.
- Comparisons of mean condition of longnose sucker between *test* and *baseline* reaches were not completed given that longnose sucker were not captured in the *baseline* reaches in 2014. Mean condition of longnose sucker was slightly lower in summer and fall 2014 compared to 2013 while remaining within the historical range.
- Mean condition of northern pike has been relatively stable across years in summer. Fall comparisons were not possible as no northern pike were captured in 2014.
- Mean condition of walleye in 2014 was slightly lower in summer and similar in fall compared to 2013.
- Mean condition of white sucker at the *test* reaches was within the *baseline* range of variability in summer and fall 2014. With the exception of slightly lower condition in summer 2012, mean condition has been relatively stable across years in both seasons.

External Health Assessment

Abnormalities present in fish captured in 2014 were primarily associated with parasites, minor skin aberrations or wounds, and fin erosion. In 2014, 3.4%, 14.2%, and 2.3% of fish captured were found to have some sort of external abnormality in spring, summer, and fall, respectively. The percentage of external abnormalities in 2014 was higher in spring (+1.9%) and summer (+9.2%); and slightly lower in fall (-0.6%) compared to 2013.

The percentage of fish exhibiting some form of external pathology from 2003 to 2014 is summarized in Table 5.9-18 and Figure 5.9-26. Of the 436 fish captured in 2014, 87 (20%) had some form of external pathological abnormality such as growths/lesions, parasites, or body deformities. Overall, the incidences of growths/lesions in 2014 increased from 2013 (+16.8%), which was primarily driven by an increase in observed parasites (+7.7%), body deformities (+1.4%), and growths/lesions (+0.5%). Species with external abnormalities in 2014 included goldeye, longnose sucker, northern pike, walleye, and white sucker. Abnormalities from 2011 (1.5%), 2012 (1.5%), 2013 (2.3%), and 2014 (9.6%) were primarily observed in white sucker.

Summary

The objective of the fish inventory program on the Clearwater River was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individual fish within these populations. Key findings, with respect to changes observed in 2014 compared to previous years are summarized in this section.

Total Catch and Species Richness The total catch in spring and summer of 2014 decreased by 440 and 420 fish from 2013, respectively. Comparisons could not be made for fall because the *baseline* reaches were not sampled due to low water levels. Although historical data for water temperature was unavailable for the Clearwater River, it was likely that it was similar to the Athabasca River, which were higher in 2014 compared to 2013, possibly explaining the lower capture success.

Species Composition and Age-Frequency Distributions The abundance of goldeye in spring 2014 was the highest recorded since 2009. This increase may be related to an increase in survival rates among the population; the dominant age class in 2011 was five years, which shifted to seven years in 2013 and 2014. The dominant age classes for northern pike have been two and three years since 2012, which has been a shift towards a younger age class. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

External Health Assessment The percentage of external abnormalities increased considerably in 2014 from 2013, with the majority of abnormalities observed in white sucker (9.6%) and a higher percentage of overall abnormalities observed in summer (+9.2%). The increase in abnormalities was primarily driven by the increase in parasites on fish. This could be related to higher water temperatures in the river; the incidences of parasites was much lower in 2013.

5.9.5.2 High Hills River Fish Assemblage Monitoring

Fish assemblages were sampled in fall 2014 at *baseline* reach HHR-F1, which has been sampled since 2011. This reach was at the same location as the benthic invertebrate community *baseline* reach HHR-E1 and provided regional baseline data for the monitoring program.

2014 Habitat Conditions *Baseline* reach HHR-F1 was comprised of run and riffle habitat, with a wetted width of 17.5 m and a bankfull width of 25.5 m (Table 5.9-19). The substrate was comprised of cobble with small amounts of sand. Water at *baseline* reach HHR-F1 had a mean depth of 0.83 m, moderate velocity (mean=0.63 m/s), a pH of 8.56, moderate conductivity (219 µS/cm), high dissolved oxygen (10.9 mg/L), and a temperature of 5.3˚C. Instream cover consisted of small and large woody debris, overhanging vegetation, and boulders (Table 5.9-19).

Relative Abundance of Fish Species The total catch of fish species at *baseline* reach HHR-F1 was slightly lower in 2014 compared to previous years and dominated by slimy sculpin (40%) and longnose dace (27%) (Table 5.9-20). The dominance of slimy sculpin in the fish assemblage has been consistent across years (Table 5.9-20).

Temporal and Spatial Comparisons Sampling was initiated in High Hills River in fall 2011; therefore, temporal comparisons were conducted for 2011 to 2014. Statistical analyses were not performed given reach HHR-F1 was in *baseline* condition.

There were slight increases in abundance, richness, diversity, and CPUE in 2014 compared to 2013 (Table 5.9 21). There was a small decrease in the assemblage tolerance index (ATI), indicating a greater proportion of sensitive species in the assemblage (e.g., burbot and longnose dace) compared to previous years.

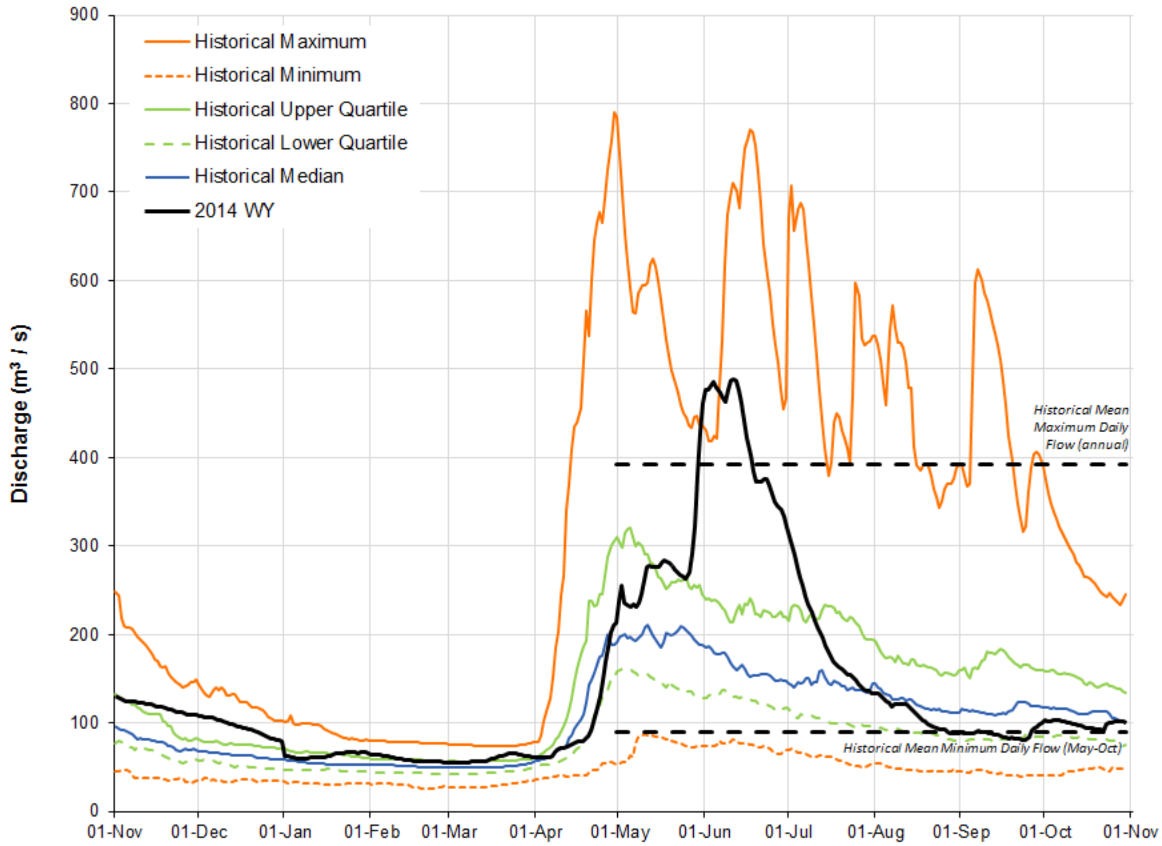
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the Athabasca oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of nine fish species were recorded in the High Hills River between 2011 and 2014; JOSMP has documented a total of nine fish species of which three have not been previously recorded in the High Hills River. Three sportfish species (Arctic grayling, mountain whitefish, and northern pike) have been previously documented, although further upstream on the High Hills River, and have not been documented by JOSMP.

Golder (2004) documented similar habitat conditions to what have been observed by JOSMP in 2014, with habitat consisting of pools and riffles, and substrate consisting of gravel, sand, and silt. These conditions provide excellent refugia and habitat for sportfish species coming from the Clearwater River.

2014 Results Relative to Regional *Baseline* Conditions Mean values for all measurement endpoints at *baseline* reach HHR-F1 were within the range of regional *baseline* conditions (Figure 5.9 27).

Classification of Results The fish assemblage at *baseline* reach HHR-F1 was consistent with other *baseline* reaches of similar habitat conditions (i.e., cluster 1 *baseline* group). Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

Figure 5.9-3 Hydrograph for the Clearwater River at Draper for the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on WSC Station 07CD001, Clearwater River at Draper, provisional data for November 1, 2013 to October 31, 2014. The upstream gross drainage area is 30,792 km^2. Historical values were calculated for the period from 1958 to 2013.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.9-2 Concentrations of water quality measurement endpoints, mouth of Clearwater River (*test* station CLR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	13	7.5	8.0	8.2
Total suspended solids	mg/L	-	14	13	<3	16	209
Conductivity	µS/cm	-	290	13	177	214	300
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	13	0.006	0.020	0.044
Total nitrogen	mg/L	-	0.41	13	0.30	0.60	1.72
Nitrate+nitrite	mg/L	3	<0.054	13	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	9.0	13	8.0	11.0	20.4
Ions							
Sodium	mg/L	-	29.7	13	13.1	19.0	31.0
Calcium	mg/L	-	18.9	13	14.7	17.1	20.1
Magnesium	mg/L	-	6.2	13	5.0	5.6	6.5
Chloride	mg/L	120	36.5	13	13.2	25.0	43.0
Sulphate	mg/L	218	5.92	13	1.40	6.00	7.70
Total dissolved solids	mg/L	-	168	13	60	150	200
Total alkalinity	mg/L	-	74	13	56	68	79
Selected metals							
Total aluminum	mg/L	0.1	**0.314**	13	**0.140**	**0.606**	**4.97**
Dissolved aluminum	mg/L	0.05	<u>0.004</u>	13	0.006	0.010	**0.125**
Total arsenic	mg/L	0.005	0.0006	13	0.0005	0.0008	0.0016
Total boron	mg/L	1.2	0.045	13	0.021	0.034	0.055
Total molybdenum	mg/L	0.073	0.00022	13	0.00012	0.00020	0.00036
Total mercury (ultra-trace)	ng/L	5, 13	1.2	11	<0.6	<1.2	**13.5**
Total strontium	mg/L	-	0.112	13	0.066	0.098	0.126
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.40</u>	3	0.05	0.05	0.15
Oilsands Extractable	mg/L	-	<u>1.30</u>	3	0.32	0.32	0.64
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<15.16	19.30
Retene	ng/L	-	<0.407	3	<2.07	3.70	15.40
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	6.565	40.49	64.23
Total PAHs	ng/L	-	<u>74.94</u>	3	172.6	259.4	465.3
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	25.19	25.66	36.86
Total Alkylated PAHs	ng/L	-	<u>61.68</u>	3	147.4	233.7	428.4
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.79**	13	**0.51**	**1.24**	**5.04**
Total phenols	mg/L	0.004	**0.005**	13	<0.001	**0.005**	**0.009**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.9-3 Concentrations of water quality measurement endpoints, upper Clearwater River (*baseline* station CLR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	13	7.2	7.9	8.1
Total suspended solids	mg/L	-	10	13	3	19	174
Conductivity	µS/cm	-	225	13	138	187	253
Nutrients							
Total dissolved phosphorus	mg/L	-	0.009	13	0.008	0.019	0.026
Total nitrogen	mg/L	-	<u>0.25</u>	13	0.30	0.50	1.20
Nitrate+nitrite	mg/L	3	<0.054	13	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	6.1	13	6.0	8.3	24.2
Ions							
Sodium	mg/L	-	24.9	13	11.0	18.0	29.0
Calcium	mg/L	-	12.9	13	10.0	11.9	21.6
Magnesium	mg/L	-	4.6	13	3.4	4.2	7.0
Chloride	mg/L	120	31.7	13	14.8	26.6	43.0
Sulphate	mg/L	218	5.4	13	<0.5	5.5	7.7
Total dissolved solids	mg/L	-	126	13	40	130	177
Total alkalinity	mg/L	-	50.9	13	39.0	48.0	57.6
Selected metals							
Total aluminum	mg/L	0.1	**0.315**	13	**0.102**	**0.328**	**5.00**
Dissolved aluminum	mg/L	0.05	0.003	13	0.003	0.009	**0.185**
Total arsenic	mg/L	0.005	0.0004	13	0.0004	0.0005	0.0014
Total boron	mg/L	1.2	0.027	13	0.014	0.024	0.051
Total molybdenum	mg/L	0.073	0.00013	13	0.00009	0.00012	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	1.5	11	0.8	<1.2	**13.7**
Total strontium	mg/L	-	0.093	13	0.061	0.080	0.103
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.3	<0.25	<0.3
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.3	<0.25	<0.3
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.3	<0.25	<0.3
Naphthenic Acids	mg/L	-	<u>0.39</u>	3	0.02	0.06	0.21
Oilsands Extractable	mg/L	-	<u>1.20</u>	3	0.19	0.34	0.72
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.932	3	<2.07	9.610	37.90
Total dibenzothiophenes	ng/L	-	<u>4.134</u>	3	5.844	6.672	36.18
Total PAHs	ng/L	-	<u>75.13</u>	3	114.0	151.2	318.2
Total Parent PAHs	ng/L	-	<u>14.28</u>	3	19.24	22.44	29.90
Total Alkylated PAHs	ng/L	-	<u>60.85</u>	3	91.57	131.9	288.3
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**0.710**	13	**0.545**	**1.170**	**5.360**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.9-4 Concentrations of water quality measurement endpoints, High Hills River (*baseline* station HHR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	3	8.0	8.2	8.4
Total suspended solids	mg/L	-	10	3	6.0	36	55
Conductivity	µS/cm	-	<u>266</u>	3	160	249	259
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.041</u>	3	0.050	0.056	0.069
Total nitrogen	mg/L	-	<u>0.344</u>	3	0.381	0.451	0.811
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	<u>9.1</u>	3	11.1	12.8	26.5
Ions							
Sodium	mg/L	-	<u>9.3</u>	3	5.8	9.0	9.2
Calcium	mg/L	-	<u>34.1</u>	3	20.9	30.8	33.4
Magnesium	mg/L	-	9.42	3	6.07	9.74	10.5
Chloride	mg/L	120	<0.50	3	<0.50	<0.50	0.62
Sulphate	mg/L	128	3.89	3	2.07	2.64	4.40
Total dissolved solids	mg/L	-	170	3	114	155	174
Total alkalinity	mg/L	-	135	3	81	129	135
Selected metals							
Total aluminum	mg/L	0.1	**0.46**	3	**0.28**	**1.23**	**3.57**
Dissolved aluminum	mg/L	0.05	<u>0.006</u>	3	0.009	0.017	**0.055**
Total arsenic	mg/L	0.005	0.00059	3	0.00052	0.00093	0.00094
Total boron	mg/L	1.2	<u>0.058</u>	3	0.041	0.054	0.057
Total molybdenum	mg/L	0.073	0.00026	3	0.00024	0.00025	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	1.60	3	0.70	3.20	4.80
Total strontium	mg/L	-	0.089	3	0.058	0.090	0.098
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.25</u>	3	0.03	0.12	0.24
Oilsands Extractable	mg/L	-	<u>0.50</u>	3	0.28	0.38	0.42
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	7.570	10.10	<15.16
Retene	ng/L	-	1.880	3	0.910	4.580	9.340
Total dibenzothiophenes	ng/L	-	<u>4.262</u>	3	5.844	6.672	35.32
Total PAHs	ng/L	-	<u>75.86</u>	3	110.6	151.1	236.5
Total Parent PAHs	ng/L	-	<u>13.26</u>	3	18.80	19.20	22.93
Total Alkylated PAHs	ng/L	-	<u>62.60</u>	3	87.65	131.9	217.7
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**1.01**	3	**0.62**	**1.98**	**2.28**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Figure 5.9-4 Piper diagram of fall ion concentrations in the Clearwater River watershed.

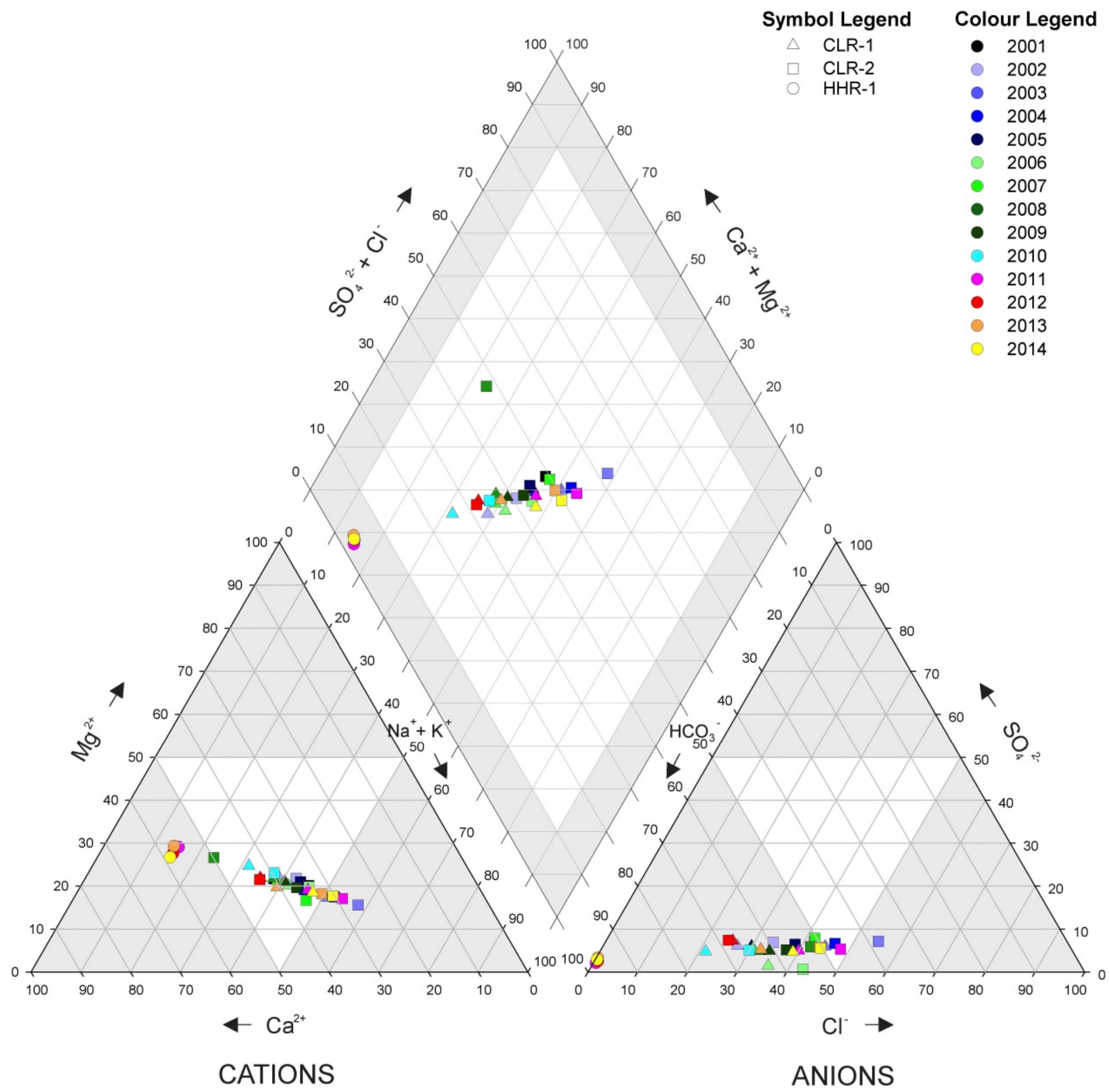


Table 5.9-5 Seasonal water quality guideline exceedances, Clearwater River watershed, 2014.

Variable	Units	Guideline[a]	CLR-1	CLR-2	HHR-1
Winter					
Dissolved iron	mg/L	0.3	ns	0.446	-
Total aluminum	mg/L	0.1	ns	0.168	0.706
Total iron	mg/L	0.3	ns	0.986	1.26
Spring					
Dissolved iron	mg/L	0.3	ns	0.57	0.568
Sulphide	mg/L	0.002	ns	0.0032	0.0035
Total aluminum	mg/L	0.1	ns	2.85	5.55
Total chromium	mg/L	0.001	ns	0.00236	0.004
Total copper	mg/L	0.002[b]	ns	-	0.003
Total iron	mg/L	0.3	ns	2.69	3.64
Total lead	mg/L	0.001[b]	ns	-	0.0021
Total mercury (ultra-trace)	ng/L	5, 13	ns	-	10.6
Total phenols	mg/L	0.004	ns	0.0043	0.01
Summer					
Dissolved iron	mg/L	0.3	ns	0.345	0.50
Sulphide	mg/L	0.002	ns	0.0033	0.0091
Total aluminum	mg/L	0.1	ns	1.36	2.08
Total chromium	mg/L	0.001	ns	0.00136	0.00174
Total iron	mg/L	0.3	ns	1.54	2.04
Fall					
Total aluminum	mg/L	0.1	0.314	0.315	0.455
Total iron	mg/L	0.3	0.792	0.71	1.01
Total phenols	mg/L	0.004	0.0047	-	-

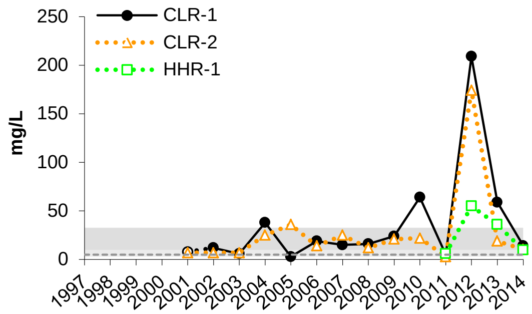
[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

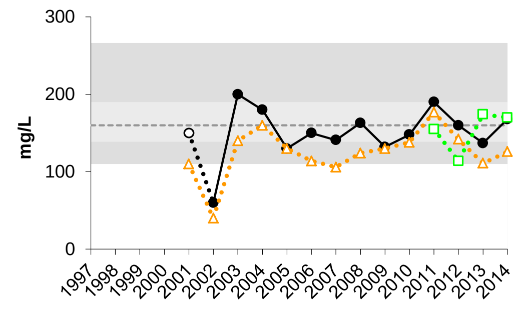
ns = not sampled.

Figure 5.9-5 Concentrations of selected water quality measurement endpoints in the Clearwater watershed (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

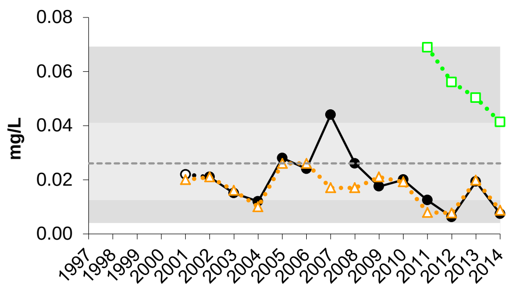
Total Suspended Solids (TSS)



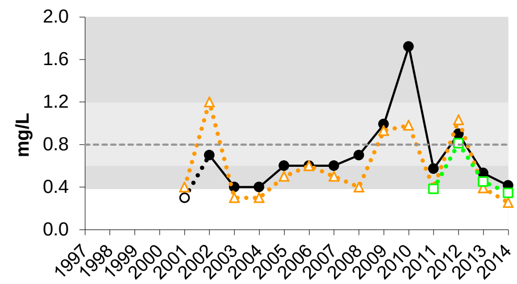
Total Dissolved Solids (TDS)



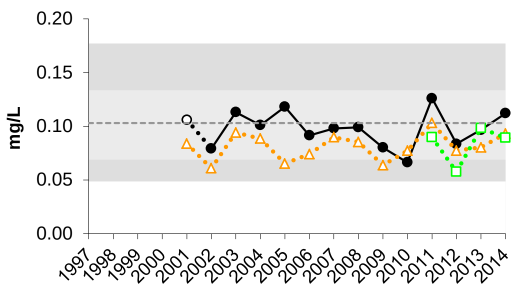
Dissolved Phosphorus



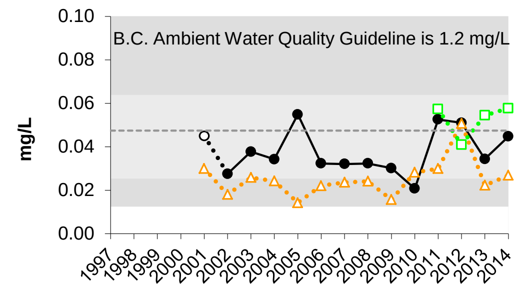
Total Nitrogen



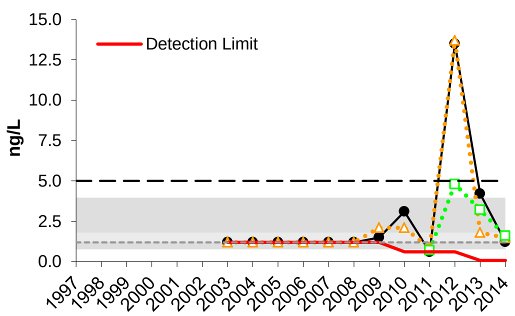
Total Strontium



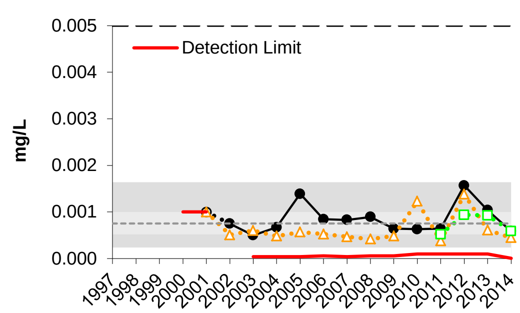
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



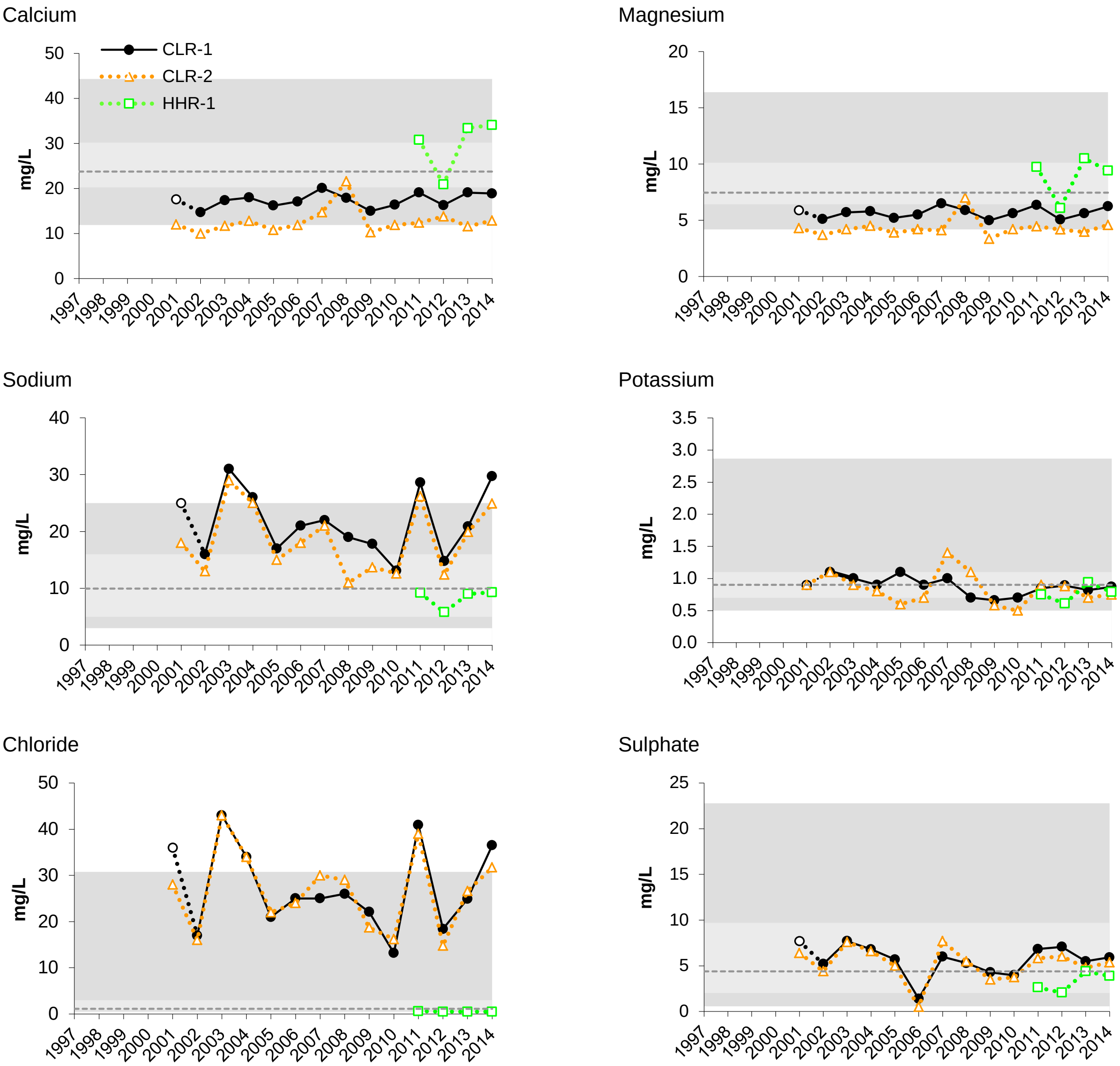
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.9-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.9-6 Monthly water quality measurement endpoints for the upper Clearwater River (*baseline* station CLR-2), January to December 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence						2013 Range (n=8)	
			n	Min		Median	Max		Min	Max
Physical variables										
pH	pH units	6.5-9.0	12	7.25	(May)	7.45	7.91	(October)	7.29	7.81
Total suspended solids	mg/L	-	12	4.7	(February)	7	13.8	(June)	<3	192
Conductivity	µS/cm	-	12	106	(May)	221	346	(November)	92	197
Nutrients										
Total dissolved phosphorus	mg/L	-	12	0.009	(September)	0.017	0.026	(August)	0.010	0.026
Total nitrogen	mg/L	-	12	0.254	(September)	0.335	0.544	(May)	0.271	0.881
Nitrate+nitrite	mg/L	3	12	<0.054	(May-Nov)	<0.054	0.139	(April)	<0.070	<0.071
Dissolved organic carbon	mg/L	-	12	5.0	(February)	7.0	12.8	(June)	6.3	15.1
Ions										
Sodium	mg/L	-	12	9.6	(May)	22.6	37.4	(November)	6.7	19.9
Calcium	mg/L	-	12	7.8	(May)	12.4	18.3	(November)	8.6	11.9
Magnesium	mg/L	-	12	2.8	(May)	4.3	6.1	(November)	2.5	4.0
Chloride	mg/L	120	12	10.6	(May)	31.3	55.8	(November)	6.6	29.0
Sulphate	mg/L	429	12	2.6	(May)	5.9	10.4	(November)	2.6	5.3
Total dissolved solids	mg/L	-	12	104	(May)	127	177	(November)	101	150
Total alkalinity	mg/L	-	12	31.4	(May)	50.9	72.6	(November)	32.5	46.8
Selected metals										
Total aluminum	mg/L	0.1	12	0.041	(January)	**0.310**	**7.280**	(June)	0.048	**8.190**
Dissolved aluminum	mg/L	0.05	12	0.003	(September)	0.007	**0.079**	(June)	0.010	**0.089**
Total arsenic	mg/L	0.005	12	0.0003	(January)	0.0004	0.0013	(June)	0.0003	0.0016
Total boron	mg/L	1.2	12	0.017	(May)	0.025	0.039	(November)	0.019	0.028
Total molybdenum	mg/L	0.073	12	<0.00010	(Jan-Apr)	0.00011	0.00016	(June)	<0.00010	0.00014
Total mercury (ultra-trace)	ng/L	5, 13	12	0.53	(December)	1.12	**8.37**	(June)	0.69	**9.70**
Total strontium	mg/L	-	12	0.048	(May)	0.083	0.126	(November)	0.056	0.080
Total hydrocarbons										
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	12	<0.02	(August)	0.12	0.39	(September)	0.04	0.31
Oilsands Extractable	mg/L	-	12	0.14	(April)	0.50	1.30	(October)	0.08	0.48
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	12	<7.21	-	<7.21	222	(April)	<15.16	<15.16
Retene	ng/L	-	12	0.64	(March)	1.18	4.10	(June)	1.33	16.70
Total dibenzothiophenes	ng/L	-	12	4.13	-	4.13	4.70	(April)	6.67	8.43
Total PAHs	ng/L	-	12	74.1	(December)	76.6	738.3	(April)	102.5	191.9
Total Parent PAHs	ng/L	-	12	13.3	(January)	13.9	239.4	(April)	22.4	29.1
Total Alkylated PAHs	ng/L	-	12	60.8	(December)	62.9	498.9	(April)	80.0	169.4
Other variables that exceeded CCME/AESRD guidelines in 2014[1]										
Total phenols	mg/L	0.004	1	<0.001	-	0.002	**0.004**	(May)	0.001	**0.010**
Sulphide	mg/L	0.002	5	<0.002	-	0.00005	**0.004**	(June)	<0.002	**0.010**
Total iron	mg/L	0.3	12	**0.6830**	(January)	**0.9110**	**3.710**	(June)	**0.74**	**6.52**
Dissolved iron	mg/L	0.3	9	0.191	(September)	**0.380**	**0.570**	(May)	**0.433**	**1.150**
Total chromium	mg/L	0.001	3	<0.00030	(Jan, Apr)	0.00042	**0.005**	(June)	<0.0003	**0.009**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

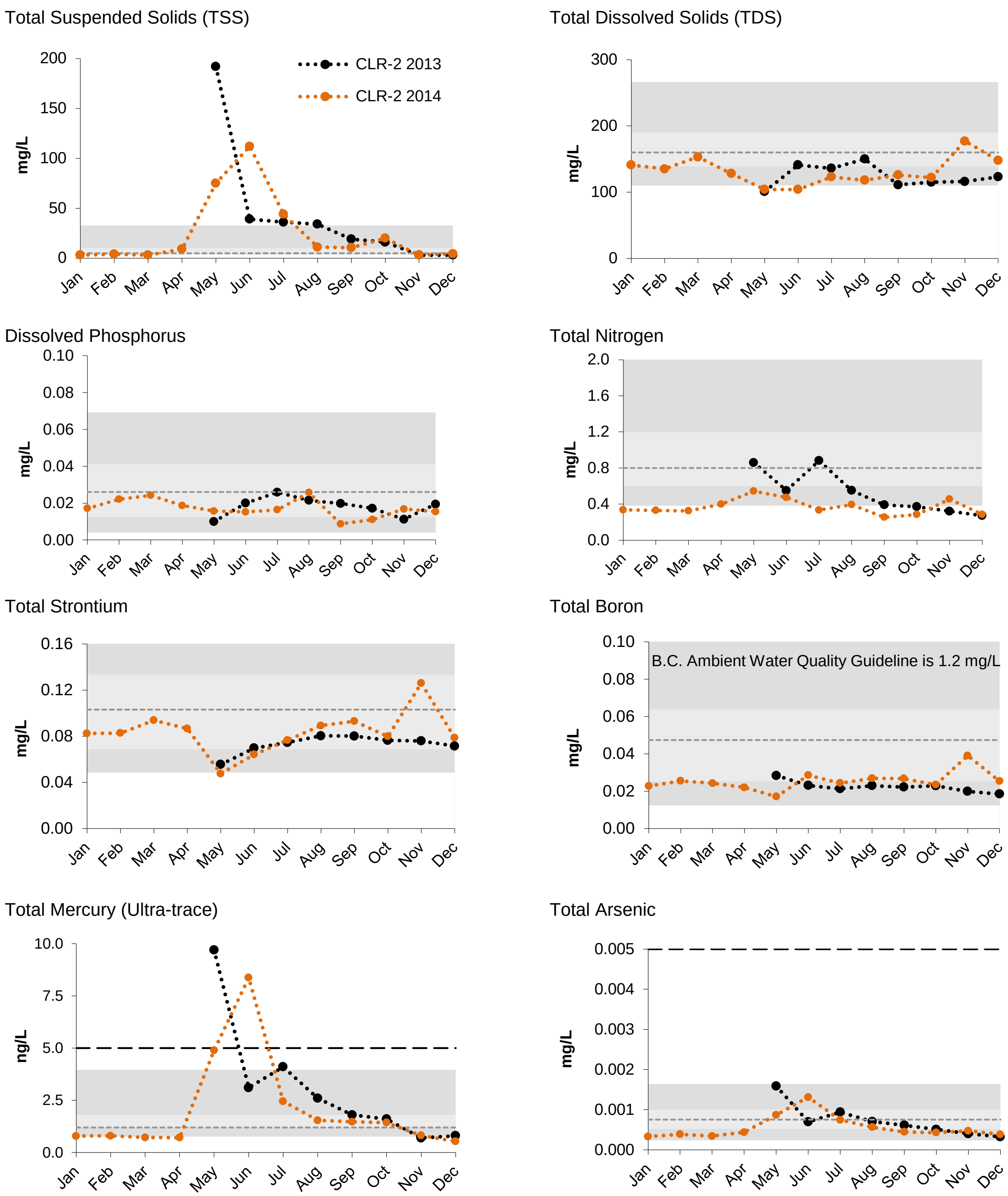
[1] n value refers to number of exceedances in 2014.

Table 5.9-7 Monthly water quality guideline exceedances for the upper Clearwater River (*baseline* station CLR-2), January to December 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	-	-	-	-	0.0043	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	-	0.0022	-	-	0.0032	0.0038	0.0033	-	-	-	0.0025	-
Total aluminum	mg/L	0.1	-	0.304	0.168	0.138	2.850	7.280	1.360	0.416	0.315	0.668	0.17	0.149
Dissolved aluminum	mg/L	0.05	-	-	-	-	-	0.0794	-	-	-	-	-	-
Total iron	mg/L	0.3	0.68	0.90	0.99	0.93	2.69	3.71	1.54	0.82	0.71	0.97	0.86	0.723
Dissolved iron	mg/L	0.3	0.401	0.406	0.446	0.435	0.570	0.343	0.345	-	-	-	0.401	0.359
Total chromium	mg/L	0.001	-	-	-	-	0.0024	0.00535	0.00136	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5, 13	-	-	-	-	-	8.37	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.9-6 Concentrations of selected water quality measurement endpoints in the Clearwater watershed (monthly data) relative to regional *baseline* fall concentrations.



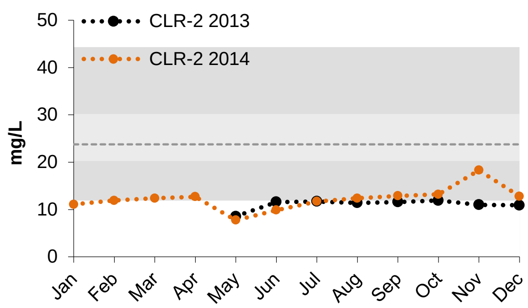
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

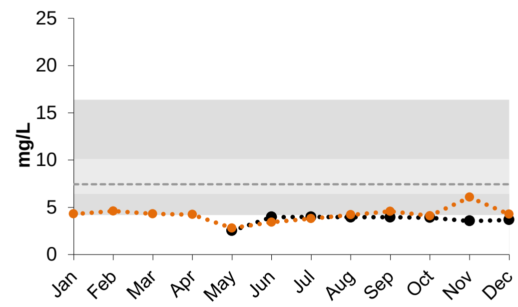
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.9-6 (Cont'd.)

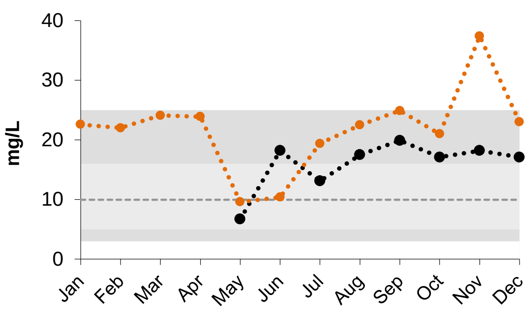
Calcium



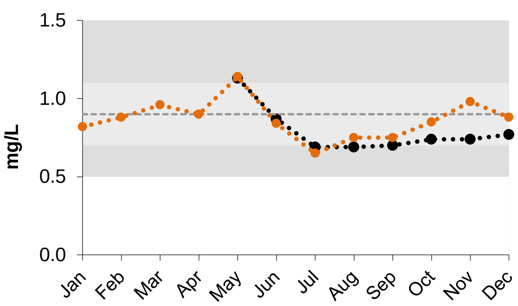
Magnesium



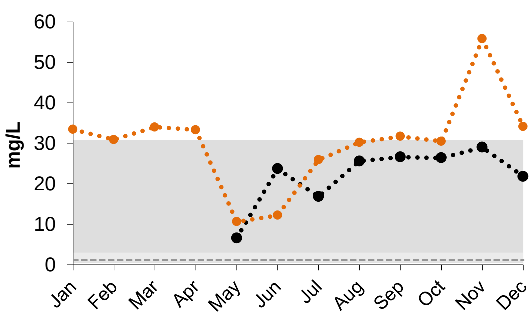
Sodium



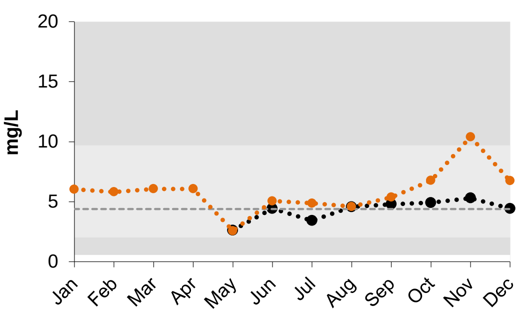
Potassium



Chloride



Sulphate



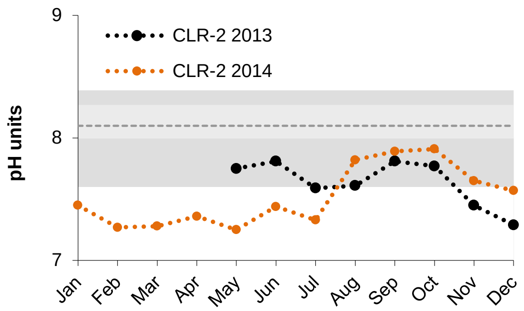
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

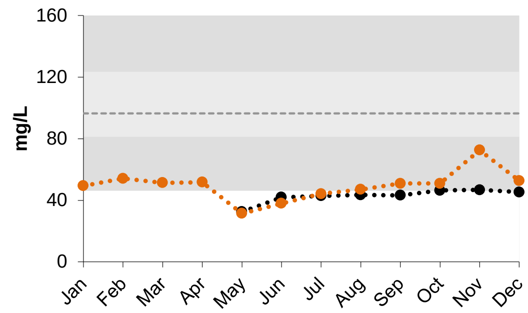
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.9-6 (Cont'd.)

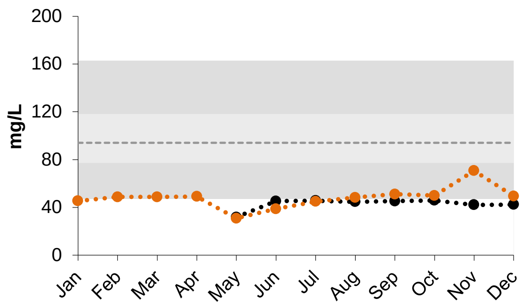
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.9-7 Piper diagram of monthly ion concentrations at *baseline* station CLR-2 of the Clearwater River.

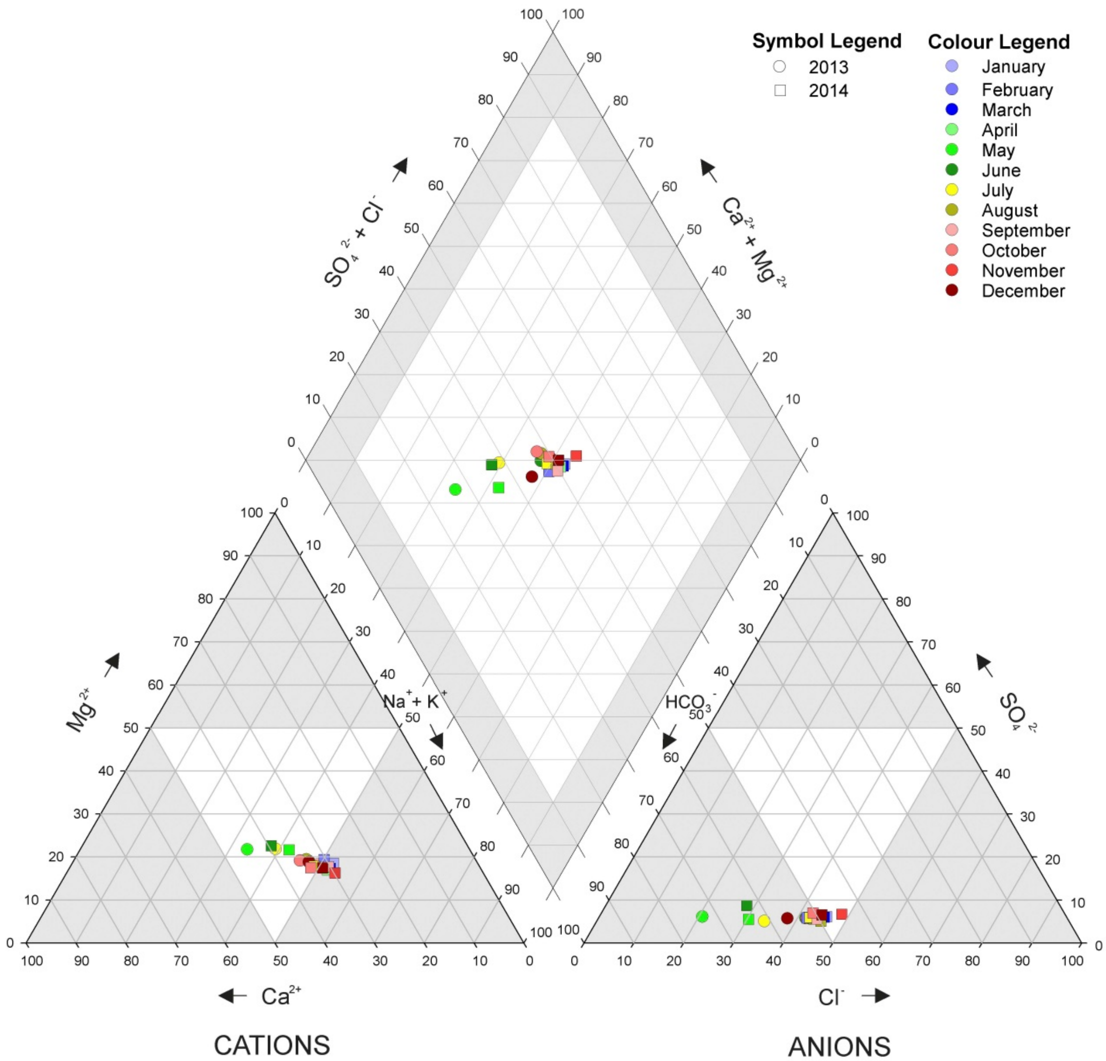


Table 5.9-8 Average habitat characteristics of the benthic invertebrate community sampling locations of the Clearwater River, fall 2014.

Variable	Units	CLR-D1 Lower *Test* Reach	CLR-D2 Upper *Baseline* Reach
Sample date	-	Sept 5, 2014	Sept 6, 2014
Habitat	-	Depositional	Depositional
Water depth	m	0.68	1.11
Current velocity	m/s	1.33	0.27
Field Water Quality			
Dissolved oxygen	mg/L	9.1	9.3
Conductivity	µS/cm	269	211
pH	pH units	6.97	6.56
Water temperature	°C	13.3	13.1
Sediment Composition (mean ± 1SD)			
Sand	%	89±12	86±18
Silt	%	8±9	11±14
Clay	%	3±3	4±4
Total Organic Carbon	%	0.4±0.4	0.5±0.6

Table 5.9-9 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community of the Clearwater River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach CLR-D1			*Baseline* Reach CLR-D2		
	2001	2002-2011	2014	2001	2002-2011	2014
Nematoda	<1	<1 to 4	17	1	<1 to 8	<1
Naididae	3	<1 to 5	1	21	<1 to 10	1
Tubificidae	27	6 to 31	5	26	<1 to 45	5
Enchytraeidae	-	0 to 2	<1	<1	0 to 1	<1
Lumbriculidae	-	0 to <1	-	-	0 to <1	-
Erpobdellidae	-	-	-	-	0 to <1	-
Glossiphoniidae	<1	-	-	<1	0 to <1	-
Hydracarina	<1	0 to <1	-	<1	0 to <1	-
Amphipoda	-	-	-	<1	0 to <1	-
Gastropoda	<1	0 to <1	-	1	0 to <1	-
Bivalvia	20	0 to 7	<1	11	<1 to 33	<1
Ceratopogonidae	1	<1 to 6	4	1	<1 to 4	2
Chironomidae	38	51 to 87	68	34	27 to 87	85
Dolichopodidae	-	-	-	-	0 to <1	-
Diptera (misc.)	<1	0 to 2	2	<1	0 to 2	1
Coleoptera	-	0 to <1	-	<1	0 to <1	-
Ephemeroptera	<1	<1 to 2	1	1	<1 to 1	5
Odonata	1	0 to 1	<1	<1	0 to 2	<1
Plecoptera	-	0 to 1	-	<1	0 to 1	-
Trichoptera	-	0 to 1	-	<1	0 to 2	<1
Megaloptera	-	-	-	<1	-	-
Heteroptera	<1	-	-	-	0 to <1	-
Lepidoptera	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	362	34 to 229	127	415	113 to 657	210
Richness	14	6 to 15	8	10	3 to 15	10
Equitability	0.38	0.44 to 0.81	0.54	0.31	0.31 to 0.60	0.40
% EPT	1	<1 to 8	1	0	<1 to 4	5

Table 5.9-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for the Clearwater River.

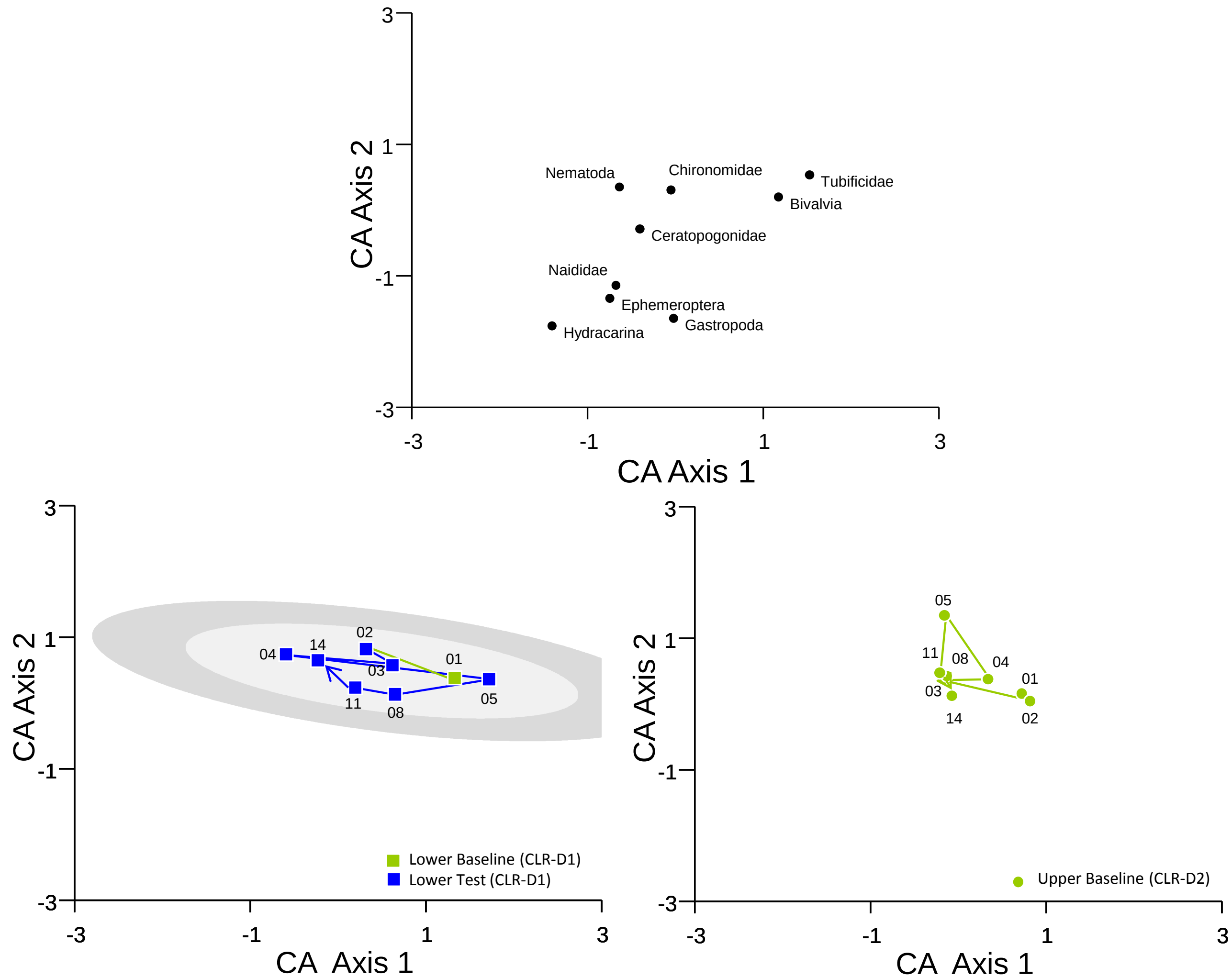
Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	Test Reach vs. *Baseline* Reach	*Test* Period vs. *Baseline* Period	Differences between *Test* and *Baseline* Reaches from Before to After Lower Reach was Designated as *Test*	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	*Test* Period vs. *Baseline* Period	Differences between *Test* and *Baseline* Reaches from Before to After Lower Reach was Designated as *Test*	Time Trend (*Test* Period)	Difference in Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**0.002**	**0.001**	0.926	0.079	0.897	**0.012**	0.198	15	18	0	5	0	10	3	Lower at *test* reach; lower during *test* period at *test* reach; lower in 2014 than mean of *baseline* years.
Log of Richness	**0.002**	**0.006**	0.485	0.480	0.015	0.248	0.823	11	9	1	1	7	1	0	Lower at *test* reach; lower during *test* period at *test* reach.
Equitability	**<0.001**	0.148	0.853	0.315	0.537	0.148	0.895	26	17	0	2	1	4	0	Higher at *test* reach.
Log of EPT	0.067	0.099	0.510	0.303	0.535	0.303	0.609	11	9	1	4	1	4	1	No change.
CA Axis 1	**0.053**	**<0.001**	**0.047**	0.118	**0.017**	0.981	0.364	4	29	4	2	6	0	1	Lower at *test* reach; lower during *test* period at *test* reach; decreasing at a greater rate at *baseline* reach.
CA Axis 2	**0.013**	**<0.001**	0.360	0.119	0.159	0.330	**0.030**	4	33	1	2	1	1	3	Lower at *baseline* reach; higher during *test* period at *test* reach; higher in 2014 score than mean of previous years.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

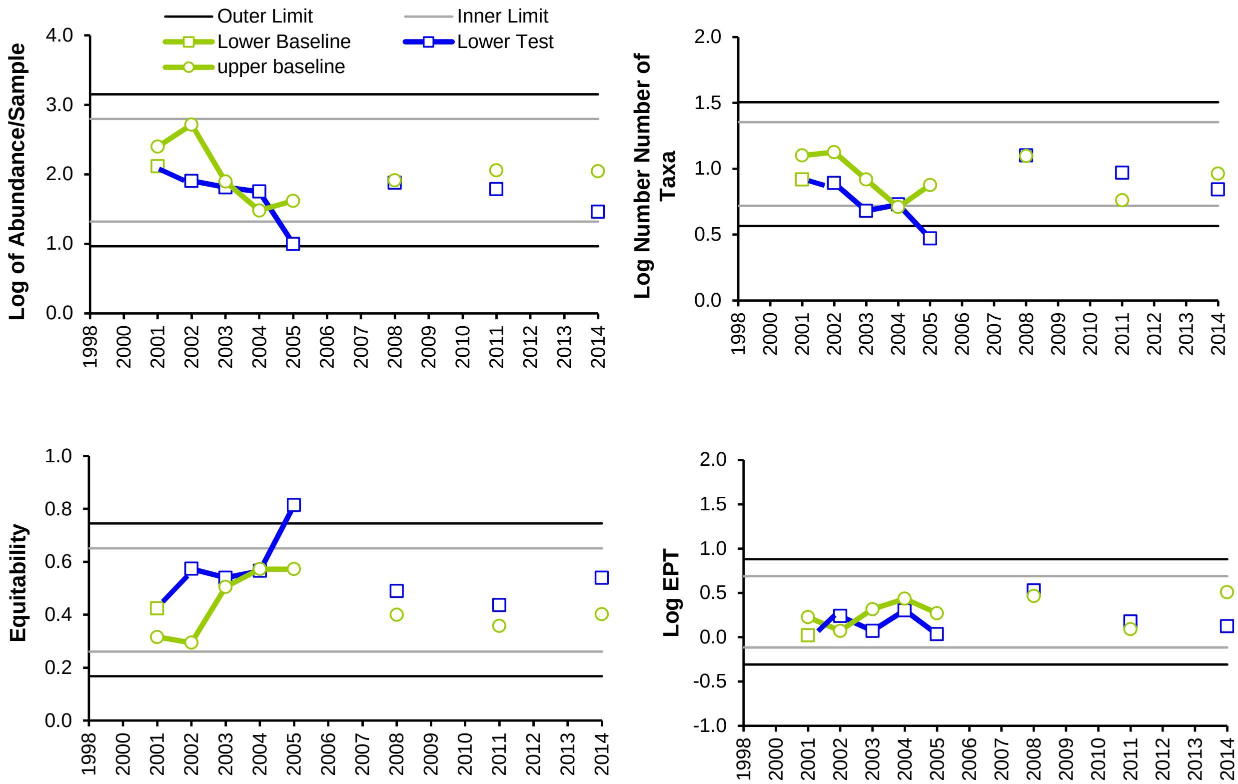
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.9-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel for *test* reach CLR-D1 are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.9-9 Variation in benthic invertebrate community measurement endpoints of the Clearwater River.

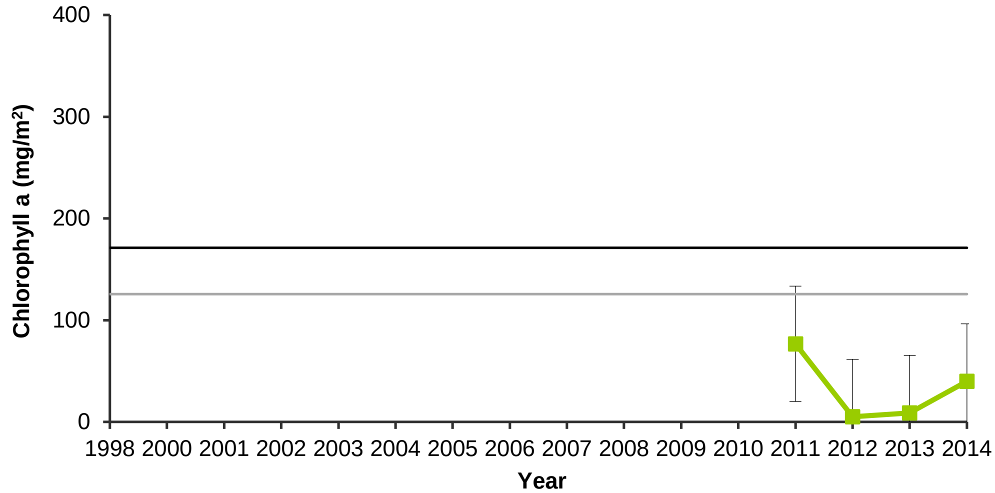


Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.9-11 Average habitat characteristics of the benthic invertebrate community sampling location of the High Hills River, fall 2014.

Variable	Units	HHR-E1
Sample date	-	Sept 4, 2014
Habitat	-	Erosional
Water depth	m	0.25
Current velocity	m/s	1.93
Field Water Quality		
Dissolved oxygen	mg/L	10.1
Conductivity	µS/cm	217
pH	pH units	7.7
Water temperature	°C	11
Sediment Composition (mean ± 1SD)		
Sand/Silt/Clay	%	10±4
Small Gravel	%	20±10
Large Gravel	%	34±7
Small Cobble	%	34±10
Large Cobble	%	3±7
Boulder	%	
Bedrock	%	

Figure 5.9-10 Periphyton chlorophyll *a* biomass in the High Hills River.

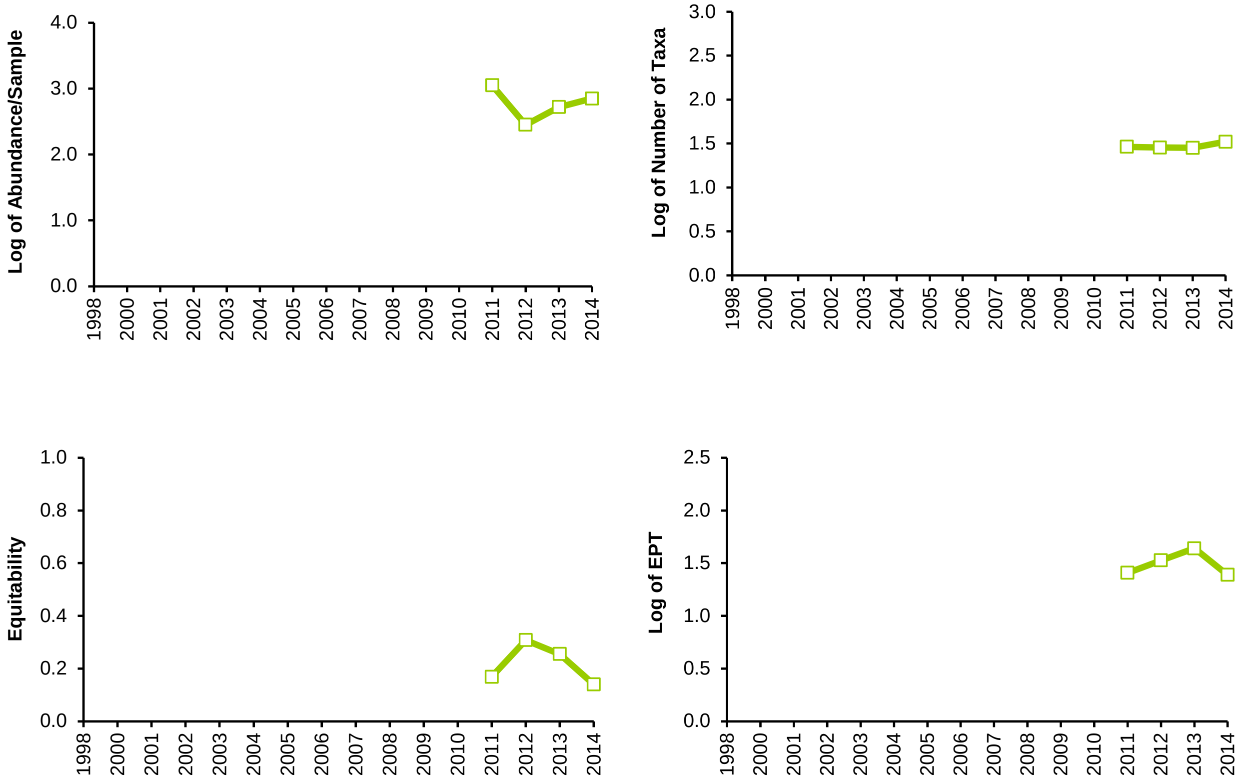


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2013.

Table 5.9-12 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community of the High Hills River.

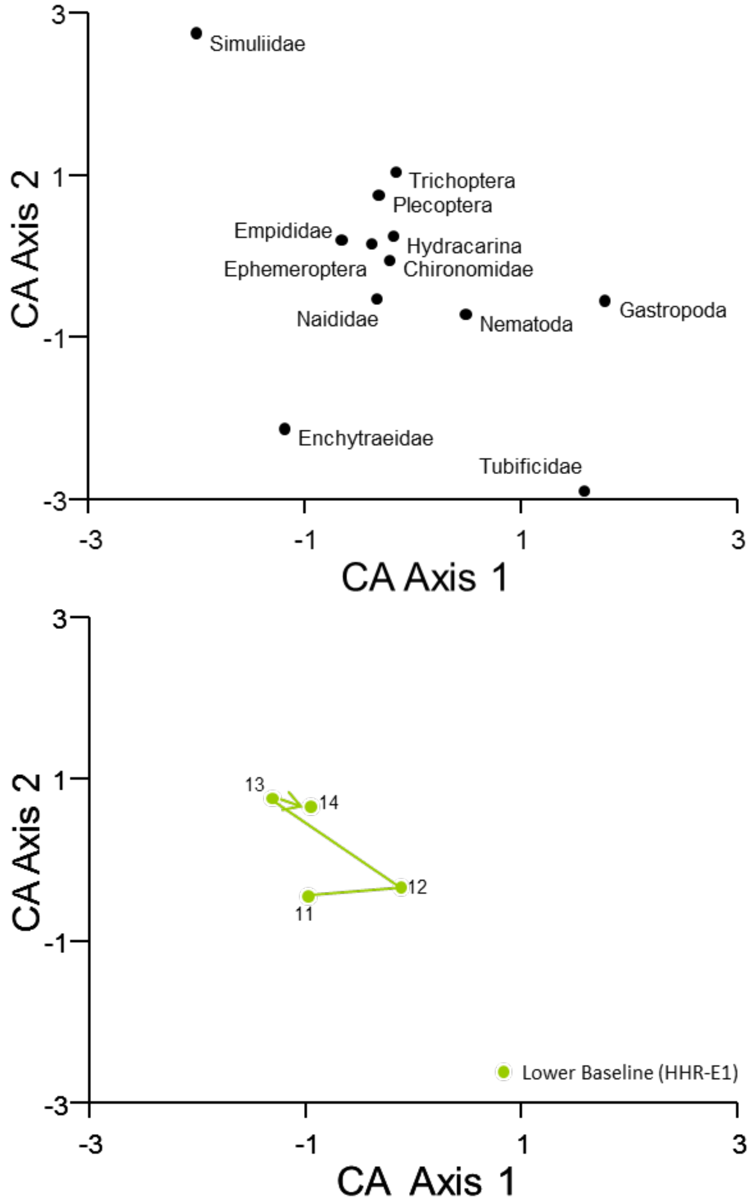
Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach HHR-E1		
	2011	2012-2013	2014
Nematoda	<1	<1 to 2	<1
Naididae	42	10 to 24	50
Tubificidae	-	0 to 2	<1
Enchytraeidae	7	1 to 5	-
Hydracarina	5	4 to 5	1
Gastropoda	<1	0 to 4	<1
Bivalvia	-	0 to <1	-
Ceratopogonidae	-	<1 to 3	-
Chironomidae	13	11 to 23	14
Dolichopodidae	-	0 to <1	-
Psychodidae	<1	-	-
Diptera (misc.)	3	3 to 8	7
Coleoptera	<1	0 to <1	<1
Ephemeroptera	19	26 to 36	14
Odonata	<1	<1	<1
Plecoptera	1	2 to 3	5
Trichoptera	6	7 to 9	8
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	1,219	362 to 610	899
Richness	30	28 to 30	33
Equitability	0.17	0.3	0.14
% EPT	27	37 to 46	28

Figure 5.9-11 Variation in benthic invertebrate community measurement endpoints in the High Hills River.



Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.9-12 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the High Hills River (*baseline* reach HHR-E1).



Note: The top panel is the scatterplot of taxa scores while the bottom panel is the scatterplot of sample scores.

Table 5.9-13 Concentrations of selected sediment quality measurement endpoints, Clearwater River (*test* station CLR-D1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	5	0.65	2.0	33
Silt	%	-	<1	5	0.73	12	29
Sand	%	-	100	5	38.0	84.0	98.6
Total organic carbon	%	-	<0.1	5	0.1	0.3	1.0
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<5	<7.5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<5	<7.5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<5	<12.5	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	26	2	<5	<12.5	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	22	2	<7	<13.5	<20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.00037	5	0.00016	0.00087	0.00250
Retene	mg/kg	-	<0.001	5	0.00088	0.0100	0.0473
Total dibenzothiophenes	mg/kg	-	0.0111	5	0.0097	0.1060	0.5204
Total PAHs	mg/kg	-	0.1339	5	0.0705	0.4336	1.8128
Total Parent PAHs	mg/kg	-	0.0111	5	0.0039	0.0299	0.0871
Total Alkylated PAHs	mg/kg	-	0.1228	5	0.0666	0.4037	1.7257
Predicted PAH toxicity[3]	H.I.	1.0	0.5409	5	0.1663	0.698	30.98
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	10	2	5.0	7.2	9.4
Chironomus growth - 10d	mg/organism	-	3.53	2	1.1	1.29	1.48
Hyalella survival - 14d	# surviving	-	9.4	2	7.0	8.0	9.0
Hyalella growth - 14d	mg/organism	-	0.39	2	0.1	0.22	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.9-14 Concentrations of selected sediment quality measurement endpoints, Clearwater River (*baseline* station CLR-D2), fall 2014.

Variables	Units	Guideline	September 2014	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	5	0.35	2	12
Silt	%	-	<1	5	0.16	2	35
Sand	%	-	99.2	5	52	96	99.5
Total organic carbon	%	-	0.18	5	<0.1	0.2	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<5	<7.5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<5	<7.5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	43	65
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	2	<20	380	740
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	2	<20	235	450
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.00024	5	<0.000055	0.0012	0.002
Retene	mg/kg	-	0.0005	5	0.0002	0.0025	0.0040
Total dibenzothiophenes	mg/kg	-	0.0017	5	0.0013	0.0017	0.0046
Total PAHs	mg/kg	-	0.0120	5	0.0119	0.0328	0.2007
Total Parent PAHs	mg/kg	-	0.0020	5	0.0011	0.0053	0.0244
Total Alkylated PAHs	mg/kg	-	0.0100	5	0.0086	0.0265	0.1763
Predicted PAH toxicity[3]	H.I.	1.0	0.0508	5	0.0027	0.1965	0.3947
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.0	3	8.0	9.2	9.6
Chironomus growth - 10d	mg/organism	-	2.6	3	1.1	1.53	2.6
Hyalella survival - 14d	# surviving	-	8.6	3	8	8.8	9.8
Hyalella growth - 14d	mg/organism	-	<u>0.45</u>	3	0.1	0.25	0.33

Values in **bold** indicate concentrations exceeding guidelines.

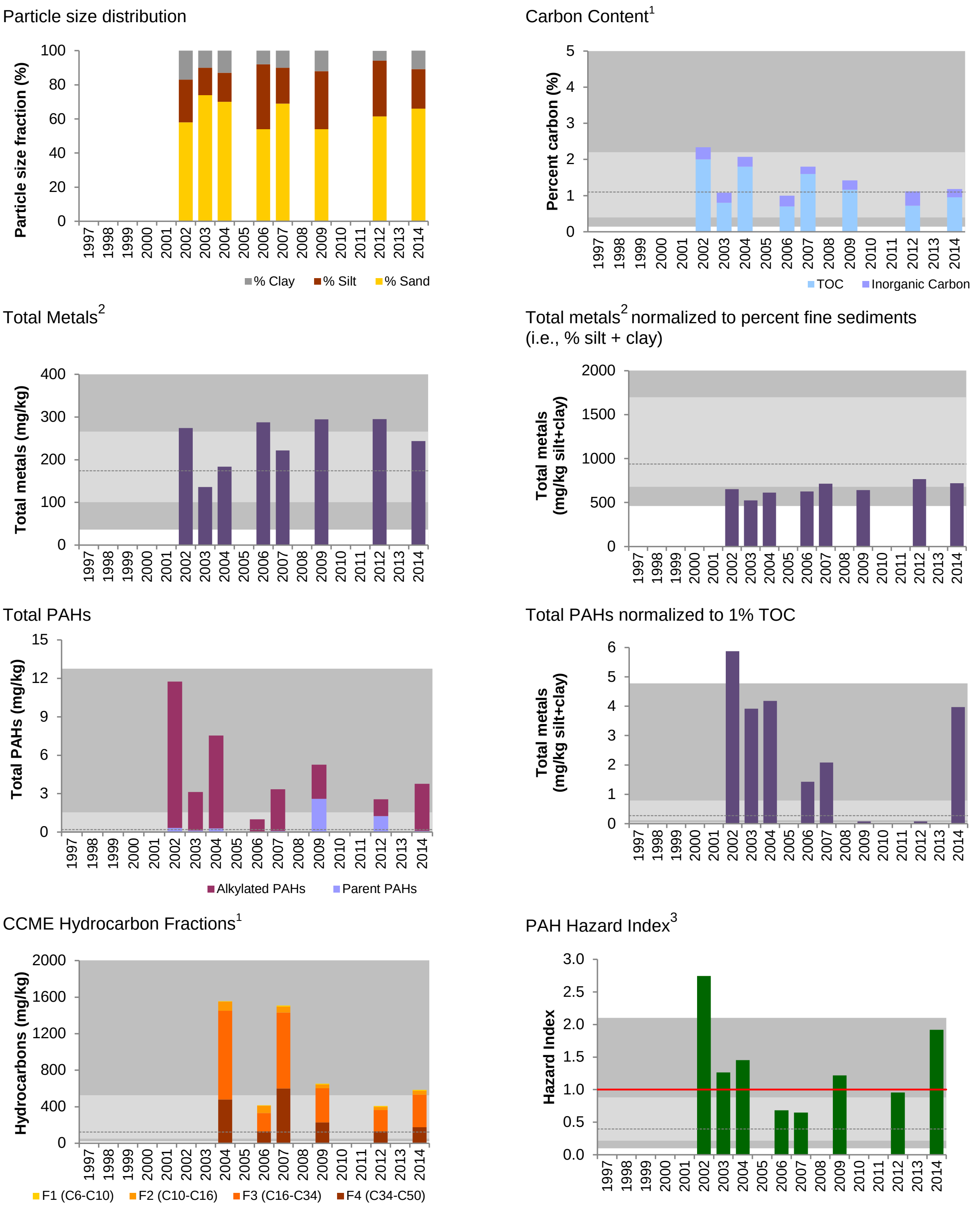
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.9-13 Variation in sediment quality measurement endpoints for the Clearwater River (*test* station CLR-D1).



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

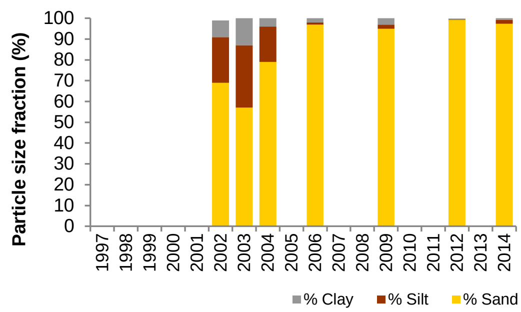
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

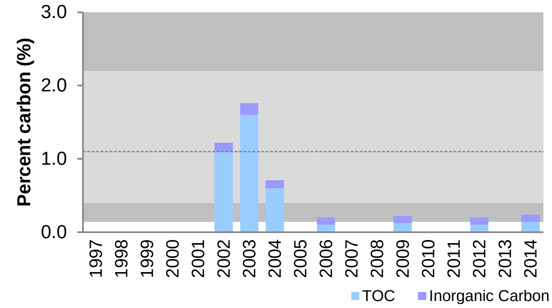
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.9-14 Variation in sediment quality measurement endpoints for the Clearwater River (*baseline* station CLR-D2).

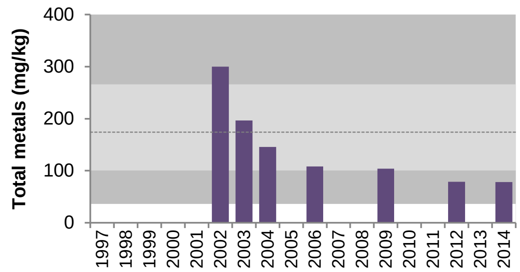
Particle size distribution



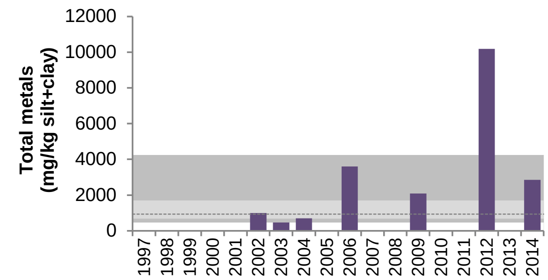
Carbon Content[1]



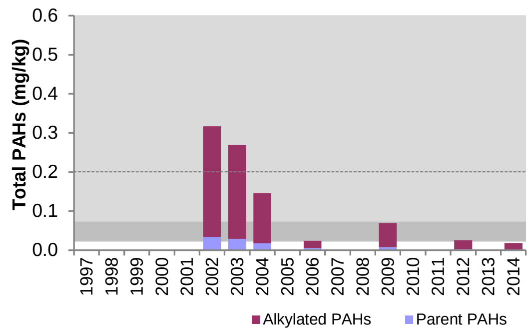
Total Metals[2]



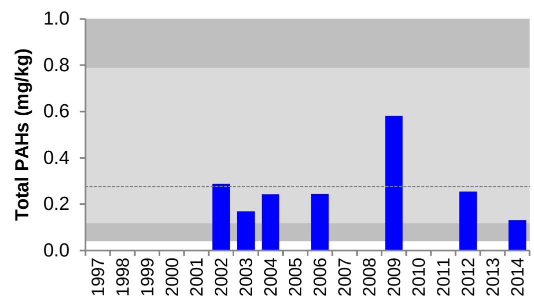
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



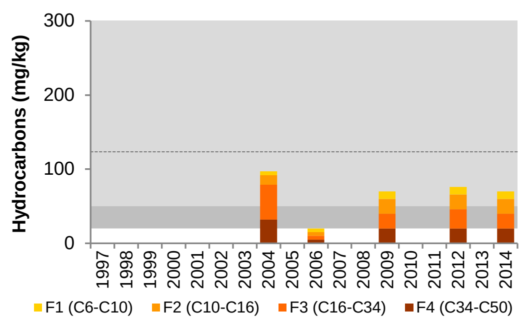
Total PAHs



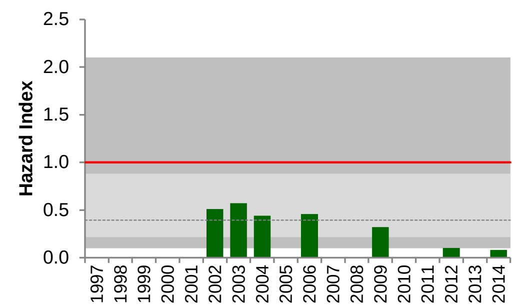
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.9-15 Fish species composition at *baseline* (CR1, CR2) and *test* (CR3) reaches of the Clearwater River during spring, summer, and fall 2014.

Species	Spring				Summer				Fall	
	Baseline	**%**	***Test***	**%**	***Baseline***	**%**	***Test***	**%**	***Test***	**%**
Arctic grayling	-	-	-	-	1	0.9	-	-	-	-
brook stickleback	-	-	-	-	-	-	-	-	-	-
burbot	-	-	-	-	-	-	-	-	-	-
emerald shiner	1	1.3	-	-	-	-	-	-	-	-
flathead chub	4	5.3	-	-	4	3.6	30	21.9	11	15.5
goldeye	16	21.3	21	48.8	15	13.6	2	1.5	-	-
lake chub	1	1.3	-	-	1	0.9	4	2.9	-	-
lake whitefish	-	-	1	2.3	1	0.9	-	-	1	1.4
longnose sucker	4	5.3	-	-	10	9.1	49	35.8	34	47.9
mountain whitefish	-	-	-	-	-	-	-	-	-	-
northern redbelly dace	-	-	-	-	-	-	-	-	-	-
northern pike	5	6.7	9	3.8	9	8.2	5	3.6	-	-
slimy sculpin	1	1.3	-	-	-	-	-	-	-	-
spoonhead sculpin	-	-	-	-	-	-	-	-	1	1.4
spottail shiner	6	8.0	-	-	4	3.6	6	4.4	-	-
trout-perch	-	-	-	-	2	1.8	1	0.7	-	-
walleye	4	5.3	8	18.6	1	0.9	19	13.9	9	12.7
white sucker	23	30.7	4	9.3	62	56.4	21	15.3	15	21.1
yellow perch	-	-	-	-	-	-	-	-	-	-
Total # Species	**10**		**5**		**11**		**9**		**6**	
Total # Fish	**75**		**43**		**110**		**137**		**71**	

Note: The *baseline* reaches were not sampled in fall due to low water levels, which prevented boat access to these reaches.

Figure 5.9-15 Total catch and number of species captured during the Clearwater River spring, summer, and fall fish inventories, 2003 to 2014.

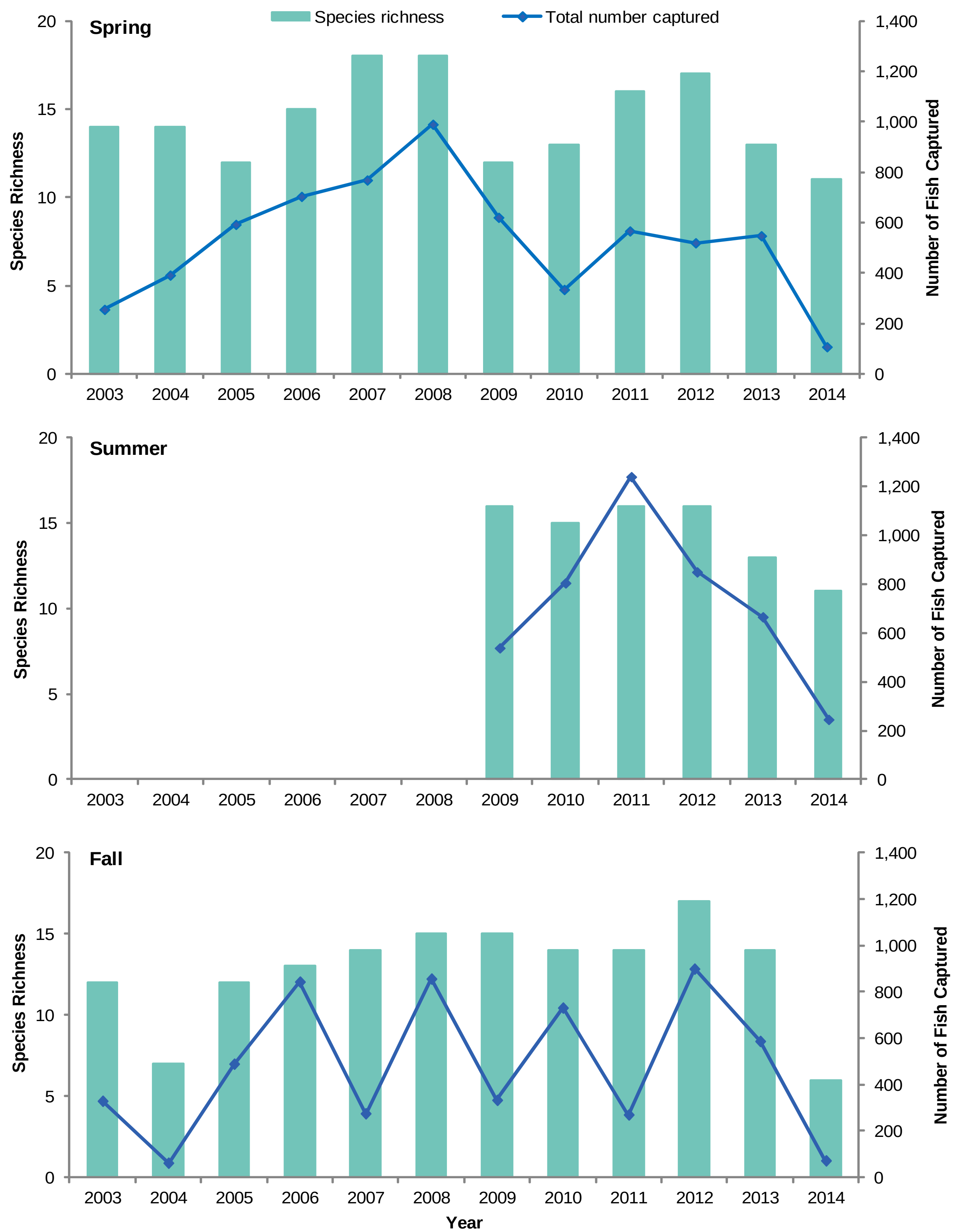
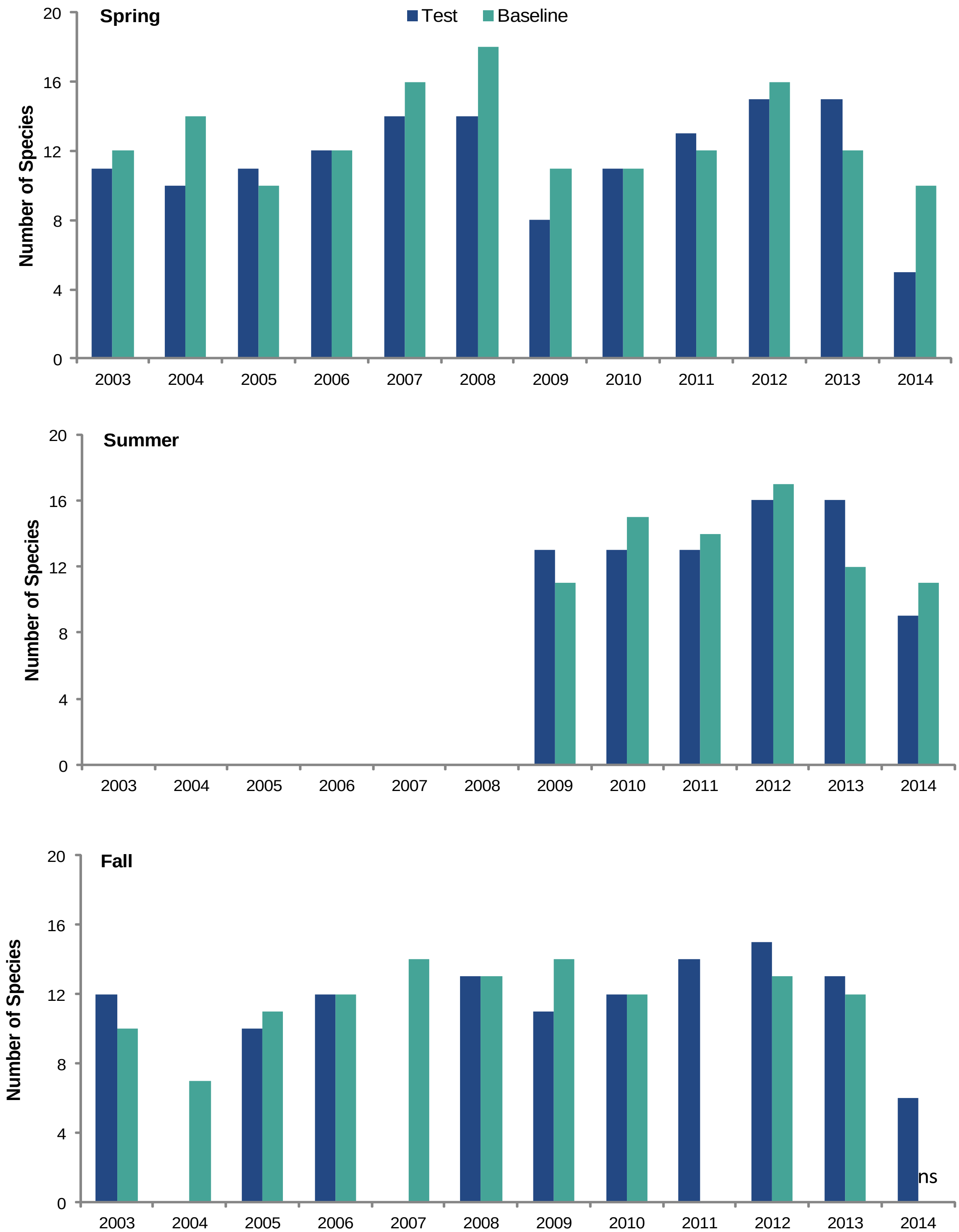


Figure 5.9-16 Number of species captured at *test* and *baseline* reaches during the Clearwater River spring, summer, and fall fish inventories, 2003 to 2014.



ns = not sampled

Figure 5.9-17 Seasonal catch-per-unit-effort (CPUE ± 1SD) of large-bodied KIR fish species at *test* and *baseline* reaches of the Clearwater River, 2014.

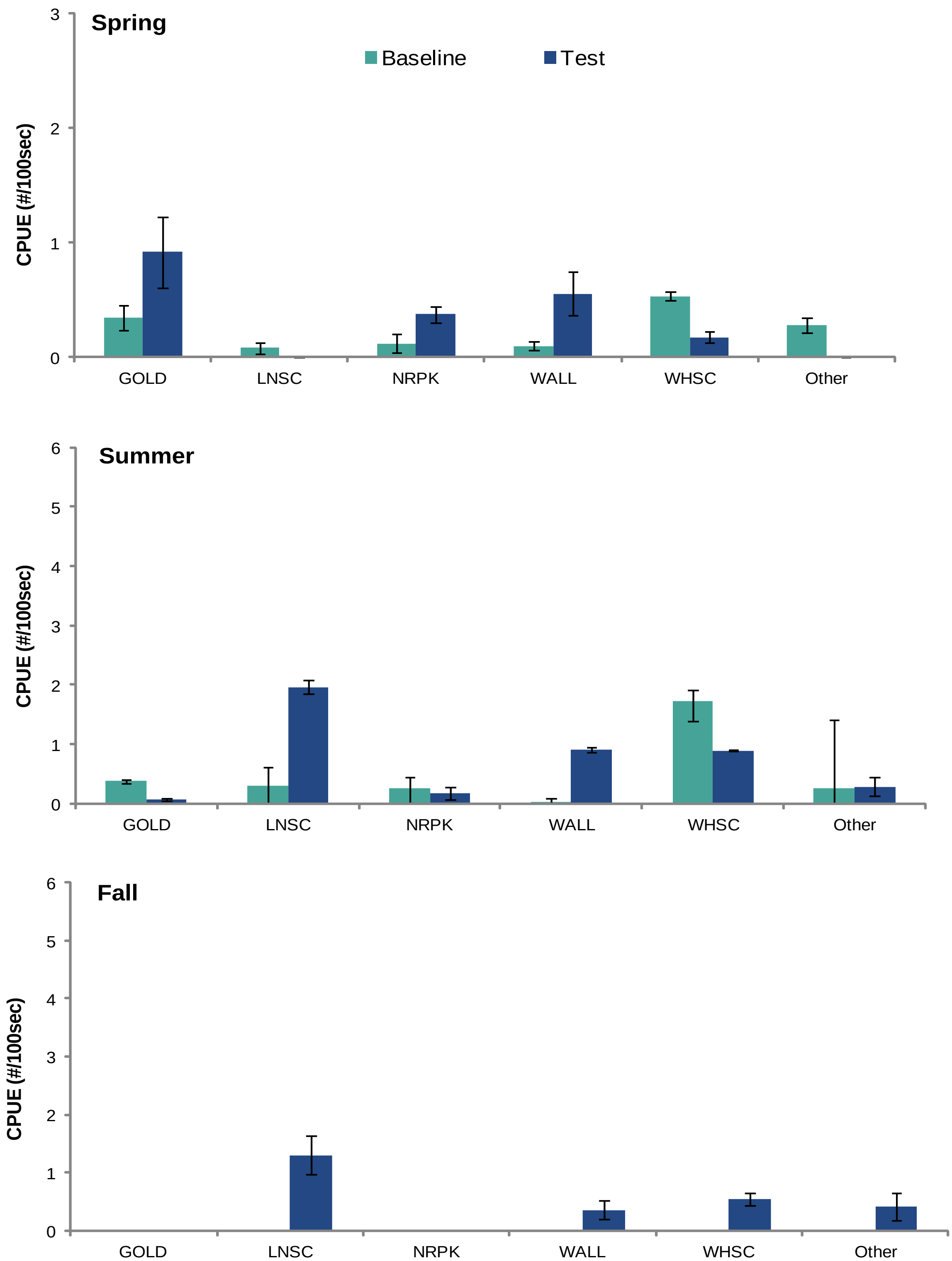


Figure 5.9-18 Seasonal catch per unit effort (CPUE ± 1SD) of large-bodied KIR fish species in the Clearwater River, 2003 to 2014.

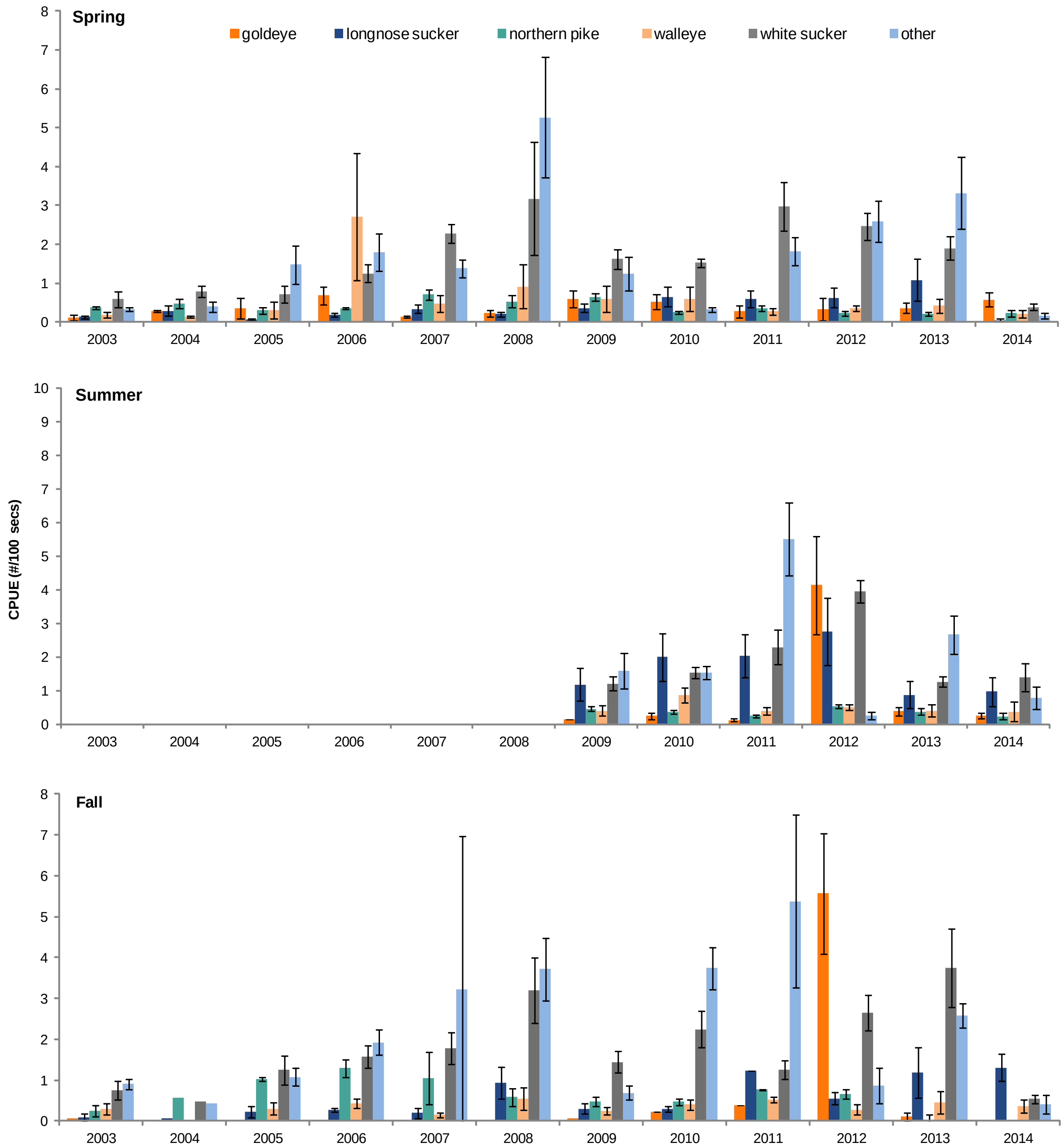
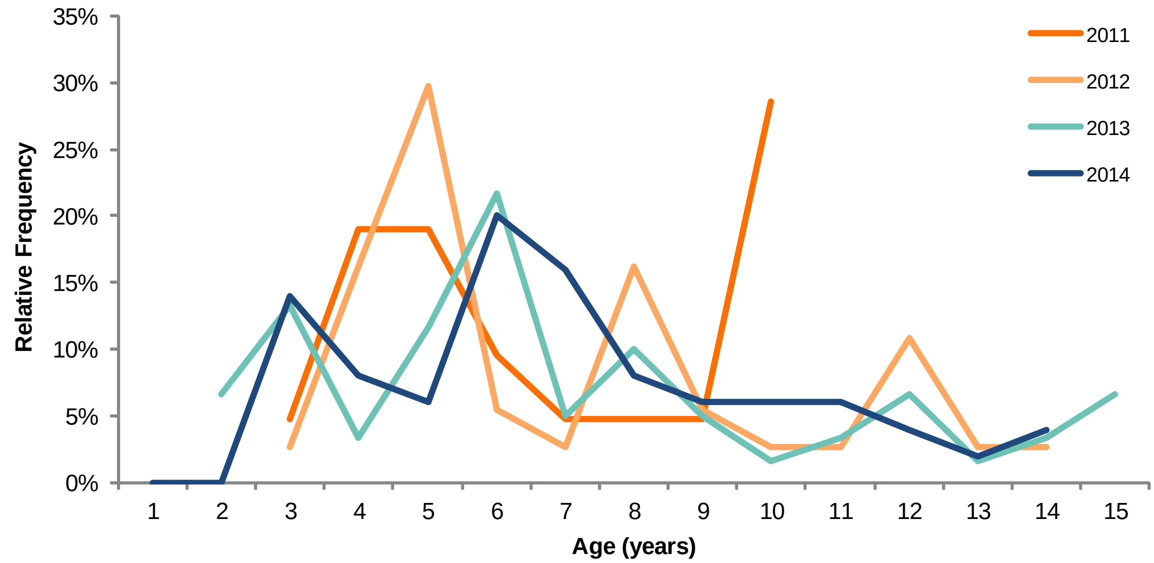


Table 5.9-16 Number of ageing structures for each fish species used in age-frequency distributions and size-at-age relationships for large-bodied KIR species in the Clearwater River.

Year	Sample Size (n)				
	Goldeye	Longnose Sucker	Northern Pike	Walleye	White Sucker
2004 to 2011	21	35	240	139	157
2012	37	50	111	59	161
2013	60	44	91	70	176
2014	50	42	25	31	70

Figure 5.9-19 Relative age-frequency distributions and size-at-age relationships for goldeye in spring, summer, and fall, 2011 to 2014.



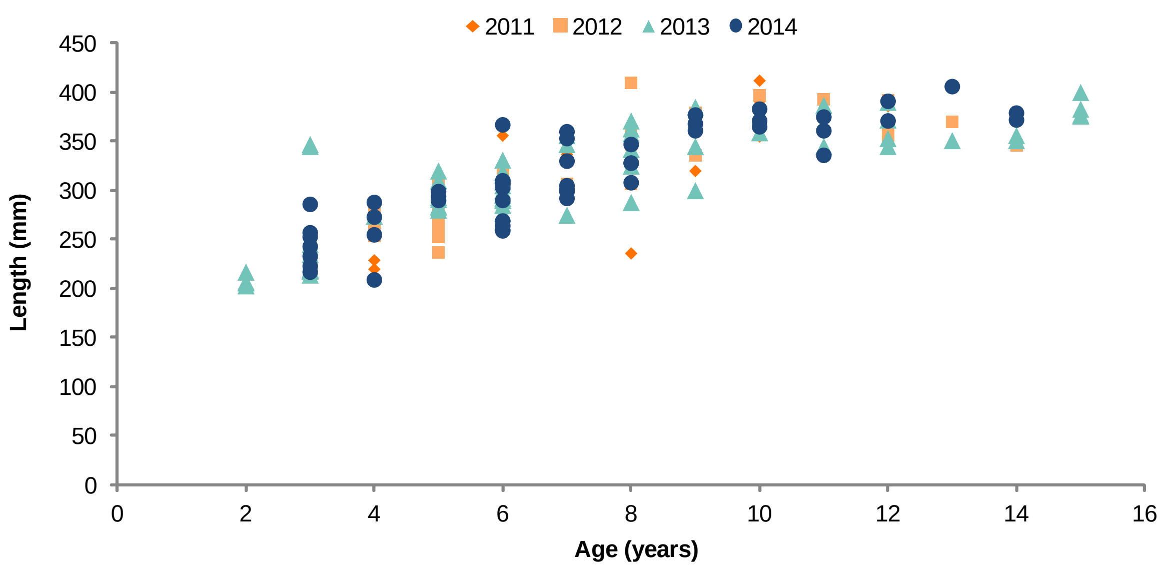


Figure 5.9-20 Relative age-frequency distributions and size-at-age relationships for longnose sucker in spring, summer, and fall, 2011 to 2014.

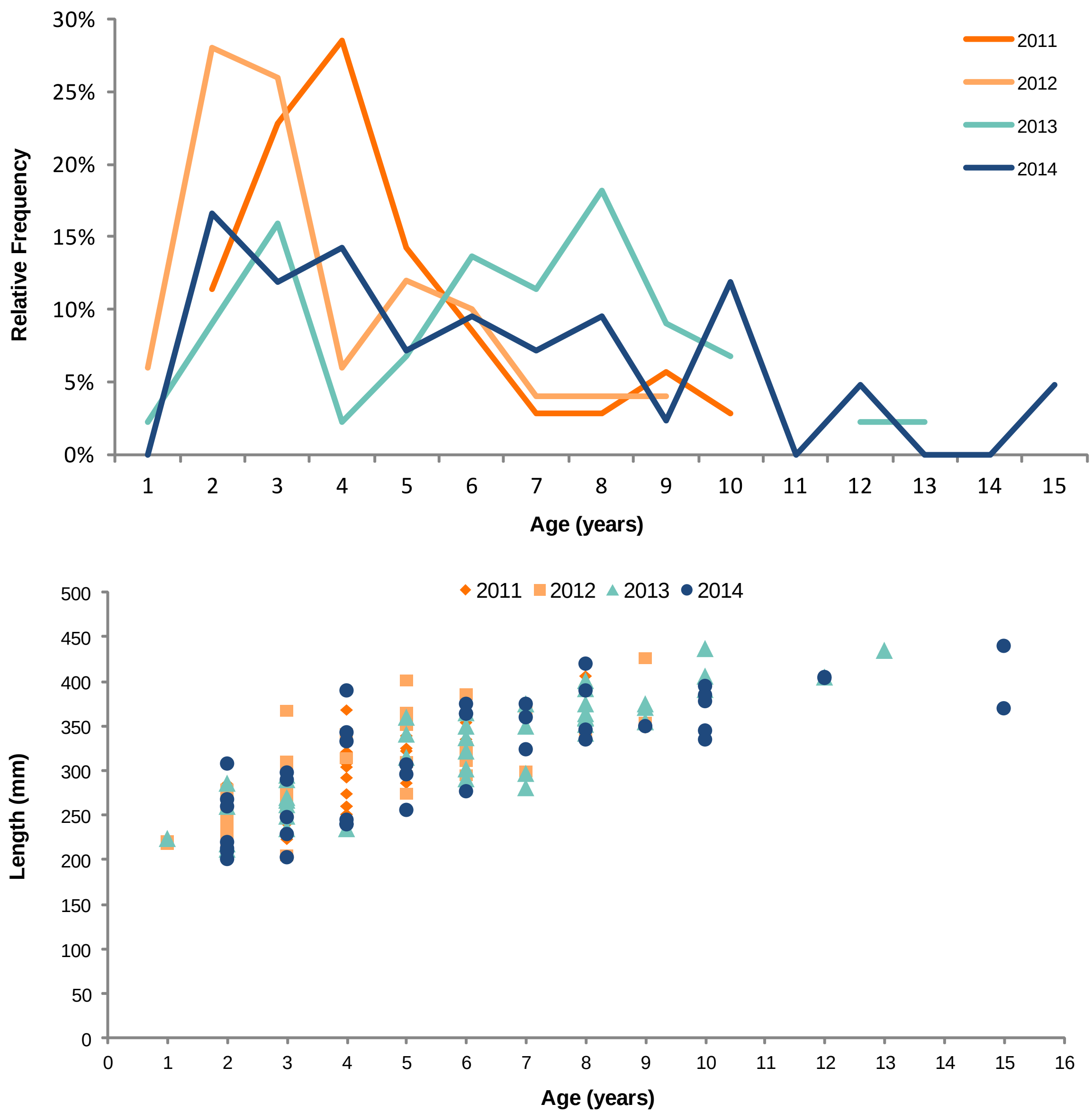


Figure 5.9-21 Relative age-frequency distribution and size-at-age relationship for northern pike in spring, summer, and fall, 2004 to 2014.

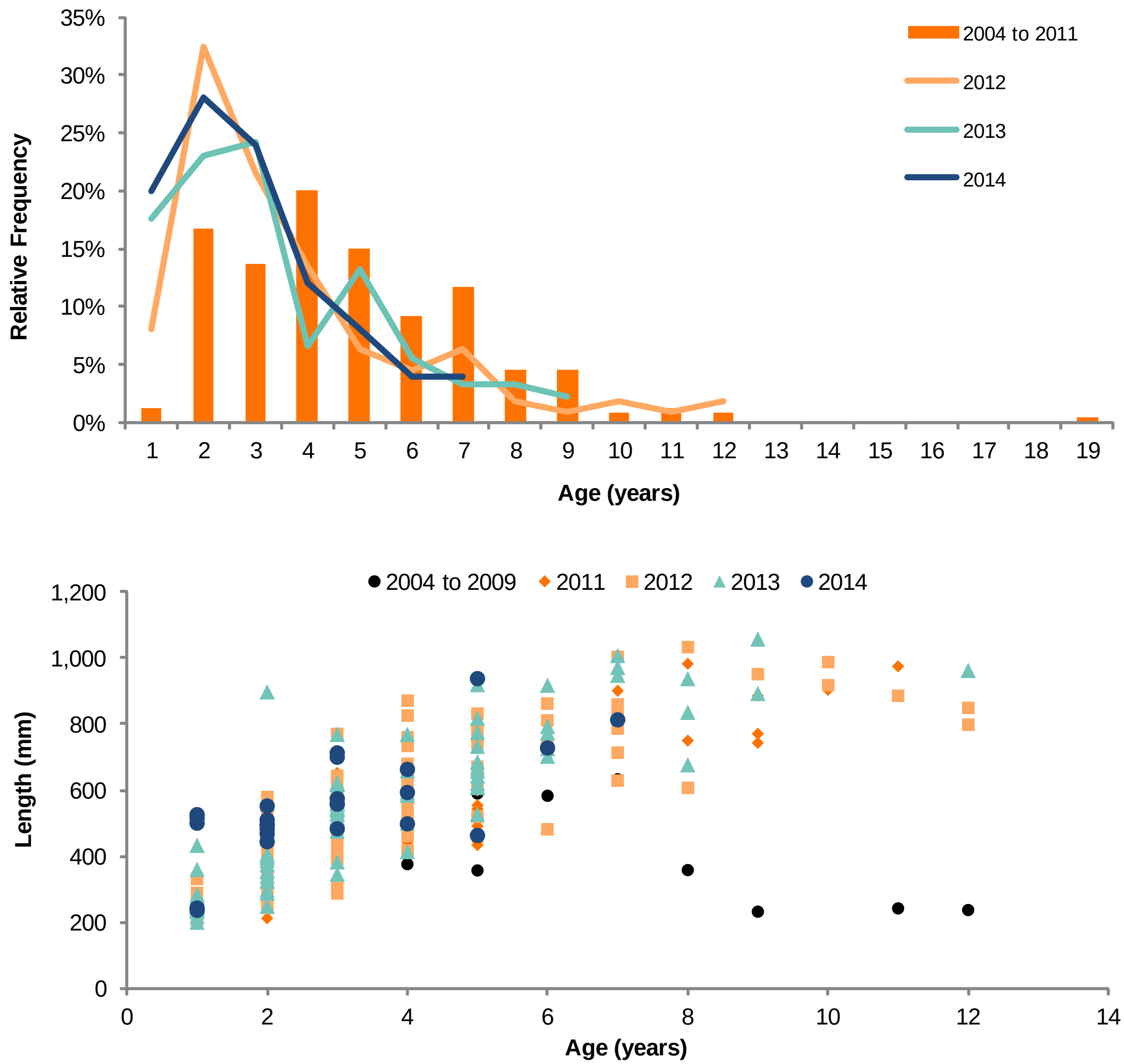


Figure 5.9-22 Relative age-frequency distributions and size-at-age relationships for walleye in spring, summer, and fall, 2004 to 2014.

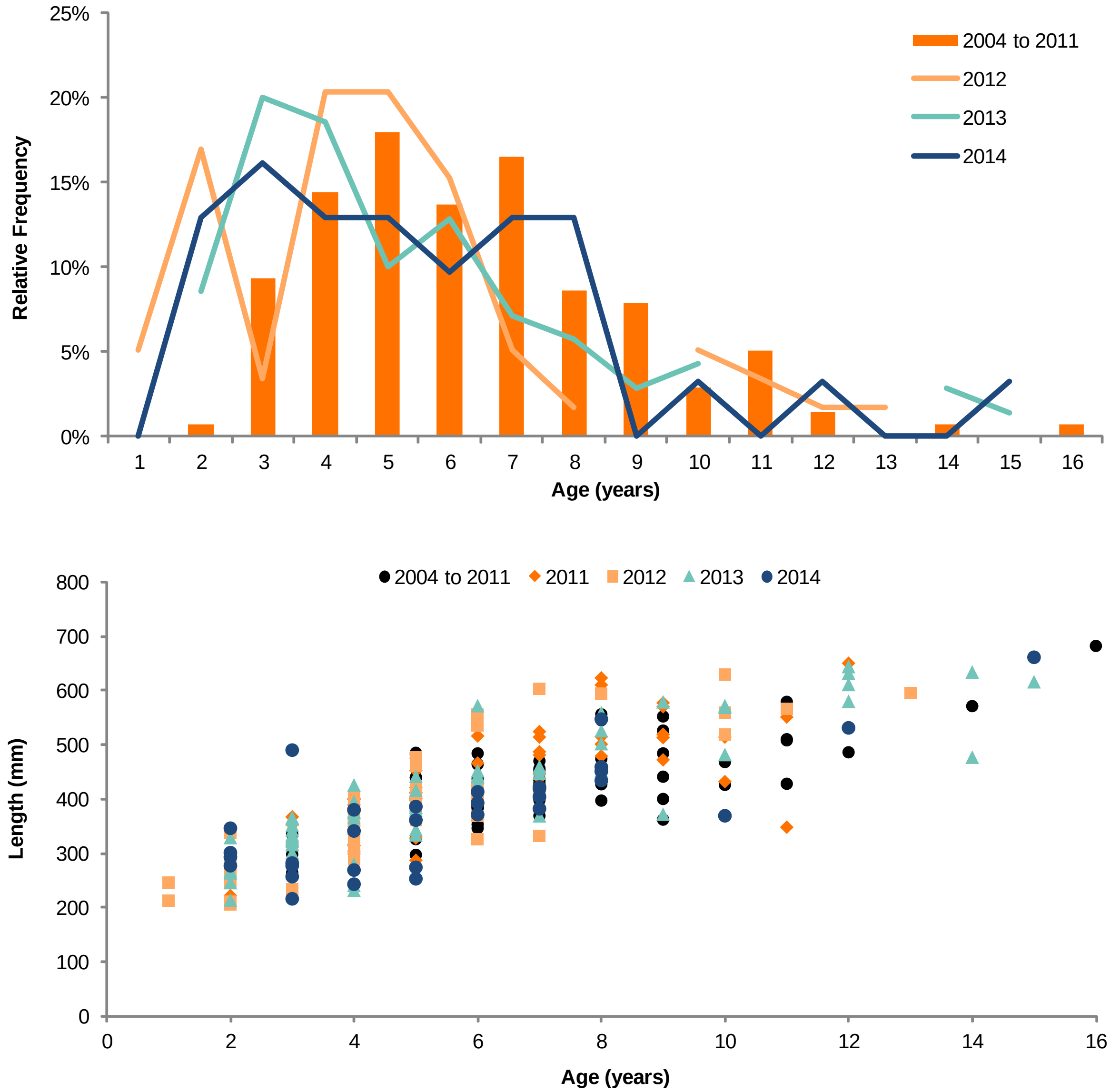


Figure 5.9-23 Relative age-frequency distributions and size-at-age relationships for white sucker in spring, summer, and fall, 2011 to 2014.

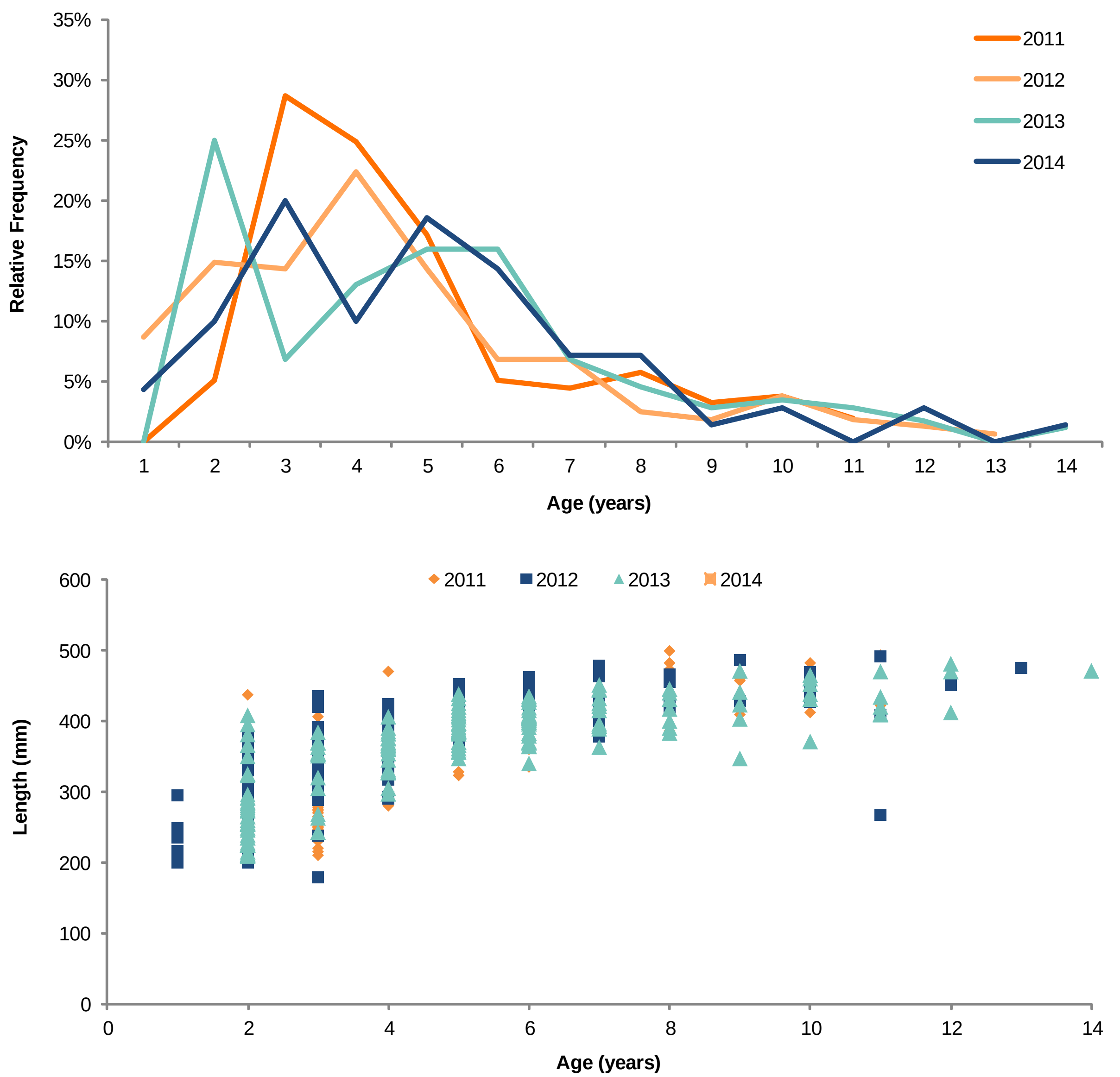
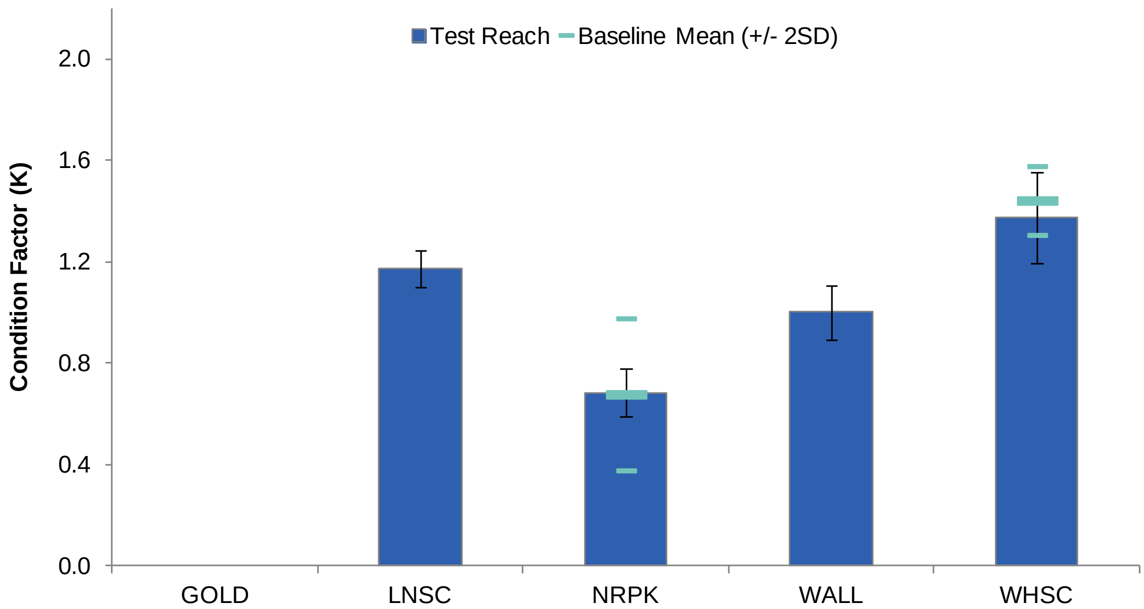


Figure 5.9-24 Condition factor (±2SD) of large-bodied KIR fish species captured in *test* areas of the Clearwater River during the summer and fall fish inventories, relative to the *baseline* range of variability in 2014.



Note: No goldeye were captured in the *test* areas and no longnose sucker or walleye were captured in the *baseline* reach in 2014.

Figure 5.9-25 Condition factor (±2SD) of large-bodied KIR fish species captured in the Clearwater River, summer and fall 2003 to 2014.

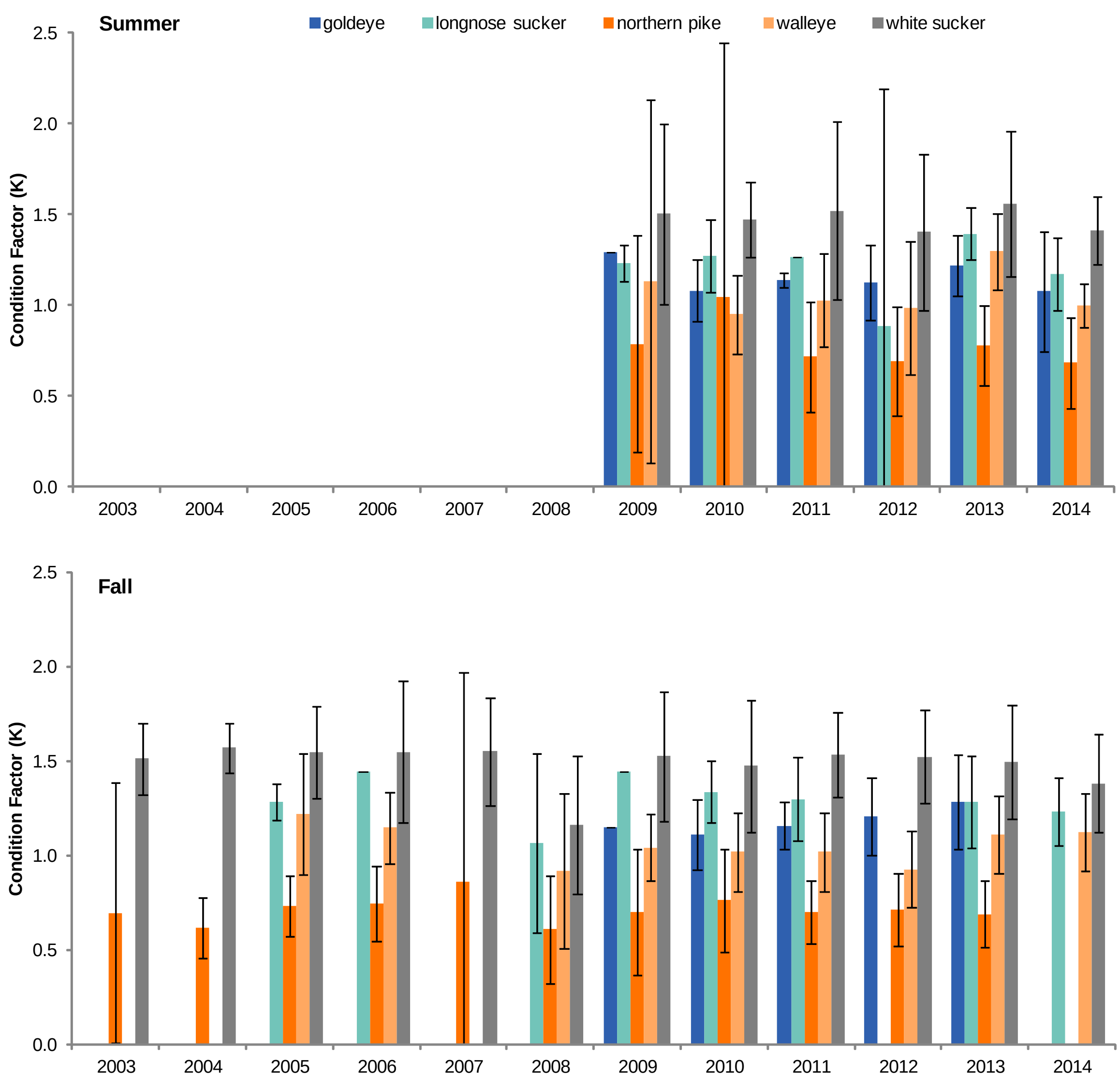


Table 5.9-17 Number of fish of the adult size class to assess condition of large-bodied KIR species over time in the Clearwater River.

Year	Sample Size (n)									
	Goldeye (>300 mm)		Longnose Sucker (>350 mm)		Northern Pike (>400 mm)		Walleye (>400 mm)		White Sucker (>350 mm)	
	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer
2003	2	-	1	-	53	-	6	-	29	-
2004	-	-	-	-	6	-	-	-	12	-
2005	-	-	5	-	64	-	24	-	98	-
2006	-	-	-	-	88	-	25	-	103	-
2007	-	-	-	-	27	-	-	-	7	-
2008	-	-	7	-	60	-	17	-	37	-
2009	1	1	1	7	46	33	6	11	80	34
2010	3	7	4	5	41	43	11	20	106	82
2011	5	3	7	2	9	28	6	19	15	107
2012	3	7	-	3	36	22	6	12	51	64
2013	4	15	12	9	21	30	9	9	140	48
2014	-	11	12	10	-	10	2	6	13	34

Table 5.9-18 Percent of total fish captured by species with external pathology (i.e., growth/lesion, deformity, and parasite), 2003 to 2014.

Year	% Growth/Lesion	% Deformity (body/fins)	% Parasites	Total # fish
1999	2.78	1.39	1.39	72
2003	0.17	0.51	0.17	584
2004	0.00	0.00	0.88	453
2005	0.19	0.00	0.00	1,081
2006	0.26	0.13	0.65	1,546
2007	0.38	0.19	0.48	1,043
2008	0.49	0.05	0.60	1,845
2009	0.27	0.13	1.67	1,493
2010	0.53	0.21	0.64	1,871
2011	0.19	0.14	0.24	2,077
2012	0.22	0.31	0.13	2,271
2013	0.44	0.22	0.06	1,801
2014	0.94	1.64	7.75	436

Figure 5.9-26 Percent of total fish captured in the Clearwater River with external pathology, 2003 to 2014.

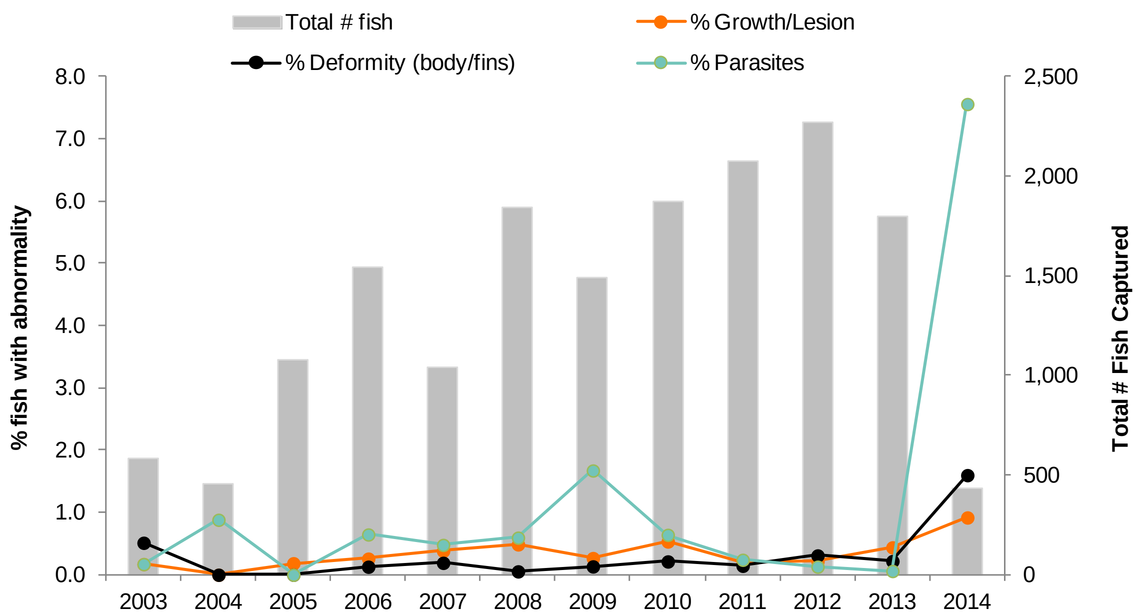


Table 5.9-19 Average habitat characteristics of fish assemblage monitoring locations of High Hills River, fall 2014.

Variable	Units	HHR-F1 Lower *Baseline* Reach
Sample date	-	Sept 15, 2014
Habitat type	-	run/riffle
Maximum depth	m	1.20
Mean depth	m	0.83
Bankfull channel width	m	25.5
Wetted channel width	m	17.5
Substrate		
Dominant	-	cobble
Subdominant	-	sand
Instream cover		
Dominant	-	large woody debris, small woody debris, overhanging vegetation, boulders
Subdominant	-	undercut banks
Field water quality		
Dissolved oxygen	mg/L	10.9
Conductivity	µS/cm	219
pH	pH units	8.56
Water temperature	^{0}C	5.3
Water velocity		
Left bank velocity	m/s	0.17
Left bank water depth	m	0.78
Centre of channel velocity	m/s	0.91
Centre of channel water depth	m	0.55
Right bank velocity	m/s	0.81
Right bank water depth	m	0.40
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	overhanging vegetation

Table 5.9-20 Total number and percent composition of fish species captured at the lower reach of the High Hills River, 2011 to 2014.

Common Name	Code	Total Species Catch				Percent of Total Catch			
		2011	2012	2013	2014	2011	2012	2013	2014
burbot	BURB	-	1	1	7	0	2	2.1	15.6
finescale dace	FNDC	-	2	-	-	0	4	0	0
lake chub	LKCH	-	-	4	5	0	0	8.3	11.1
lake whitefish	LKWH	-	-	-	-	0	0	0	0
longnose dace	LNDC	8	-	8	12	8	0	16.7	26.7
longnose sucker	LNSC	22	-	13	1	22	0	27.1	2.2
slimy sculpin	SLSC	47	48	18	18	47	94	37.5	40.0
spoonhead sculpin	SPSC	6	-	1	-	6	0	2.1	0
trout-perch	TRPR	-	-	1	-	0	0	2.1	0
walleye	WALL	-	-	-	-	0	0	0	0
white sucker	WHSC	17	-	1	2	17	0	2.1	4.4
yellow perch	YLPR	-	-	-	-	0	0	0	0
sucker sp. *		-	-	1	-	0	0	2.1	0
Total Count		**100**	**51**	**48**	**45**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**3**	**9**	**6**	**5**	**3**	**9**	**6**
Electrofishing effort (secs)		**1,355**	**1,520**	**2,027**	**2,533**	**-**	**-**	**-**	**-**

* Not included in total species richness count.

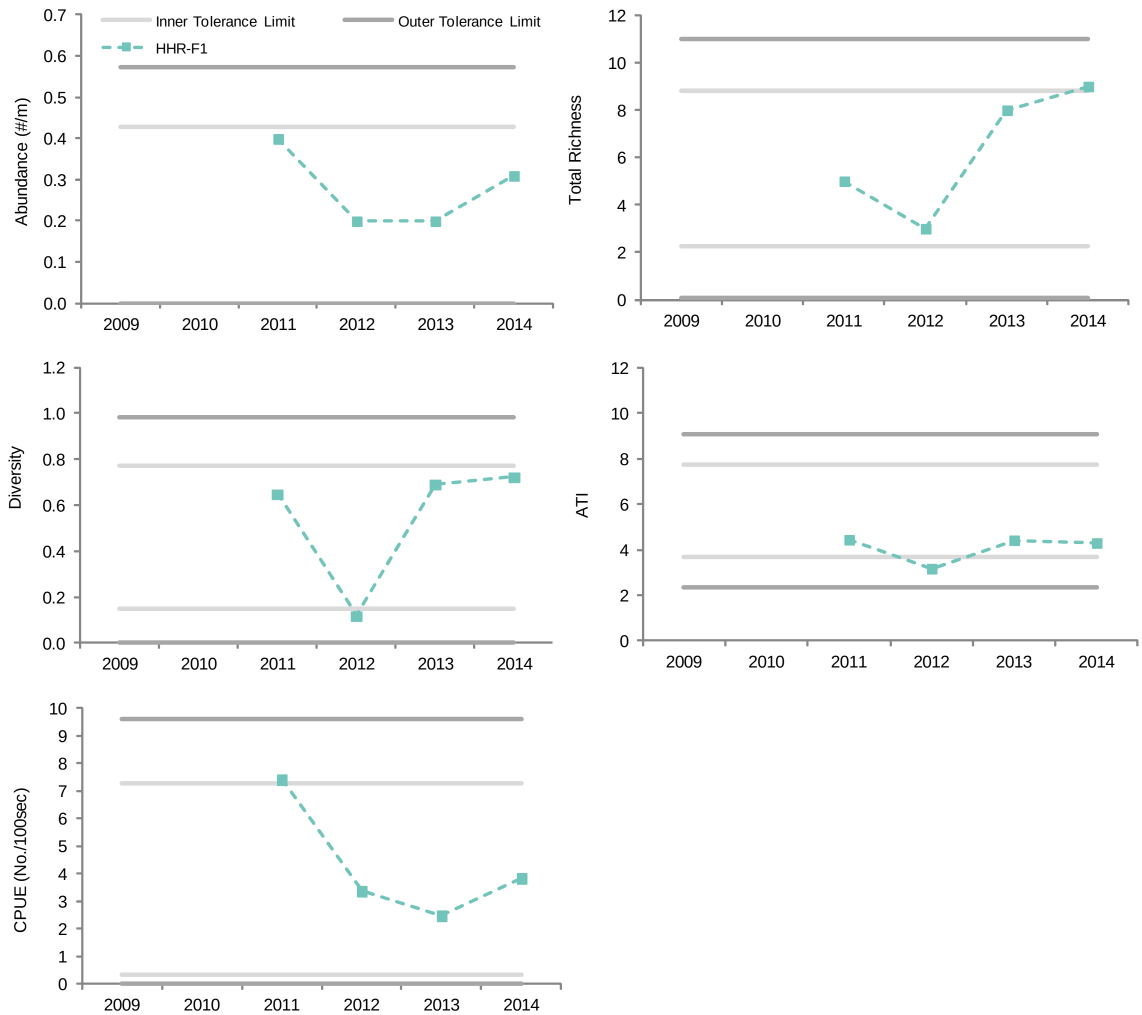
Table 5.9 21 Summary of fish assemblage measurement endpoints (± 1SD) for *baseline* reach HHR-F1 of the High Hills River, 2011 to 2014.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HHR-F1	2011	0.40	0.09	5	4.60	0.55	0.65	0.08	4.44	0.67	7.40	1.66
	2012	0.20	0.07	3	1.60	0.89	0.12	0.16	3.17	0.26	3.36	1.21
	2013	0.07	0.04	8	4.60	1.14	0.69	0.06	4.42	0.41	2.47	1.26
	2014	0.31	0.08	9	5.60	1.14	0.72	0.06	4.30	0.48	3.82	1.03

* unknown species not included in calculation.

SD = standard deviation across sub-reaches within a reach.

Figure 5.9 27 Variation in fish assemblage measurement endpoints for the High Hills River from 2011 to 2014, relative to regional *baseline* conditions (cluster 1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using all available *baseline* data from cluster 1 (see Table 3.2-14 and Table 3.2-15).

5.10 CHRISTINA RIVER WATERSHED

Table 5.10-1 Summary of results for the Christina River watershed.

Christina River Watershed	Summary of 2014 Conditions													
	Christina River				*Tributaries to Christina Lake*							*Other Tributaries*	*Lakes*	
Climate and Hydrology														
Criteria	**S47A** near the mouth	**07CE002/ S29** near Chard	no station	**S61** above Statoil Leismer	**S58** Sawbones Creek	**S63** Sunday Creek	**S63** Sunday Creek at Hwy 881	**S64** Unnamed Creek east of Christina Lake	**S60** Unnamed Creek south of Christina Lake	**S62** Birch Creek at Hwy 881	**JAR-1** Jackfish River at the mouth	**S55** Gregoire River near the mouth	**07CE906** Christina Lake	**07CE001** Gregoire Lake near Fort McMurray
Mean open-water season discharge	Negligible - Low	not measured		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Mean winter discharge	Negligible - Low	not measured		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Annual maximum daily discharge	Negligible - Low	not measured		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Minimum open-water season discharge	Negligible - Low	not measured		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Water Quality														
Criteria	**CHR-1** at the mouth	**CHR-2** upstream of Janvier	**CHR-3** upstream of Jackfish River	**CHR-4** above Statoil Leismer	**SAC-1** Sawbones Creek	**SUC-1** Sunday Creek at Christina Lake inlet	**SUC-2** Sunday Creek at Hwy 881	**UNC-2** Unnamed Creek east of Christina Lake	**UNC-3** Unnamed Creek south of Christina Lake	**BRC-1** Birch Creek at Hwy 881	**JAR-1** Jackfish River at the mouth	**GRR-1** Gregoire River near the mouth	**CHL-1** Christina Lake	**GRL-1** Gregoire Lake
Water Quality	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Moderate	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality														
Criteria	**CHR-D1** at the mouth	**CHR-D2** upstream of Janvier	**CHR-D3** upstream of Jackfish River	**CHR-D4** above Statoil Leismer	**SAC-D1** Sawbones Creek	**SUC-D1** Sunday Creek at Christina Lake inlet	**SUC-D2** Sunday Creek at Hwy 881	**UNC-D2** Unnamed Creek east of Christina Lake	**UNC-D3** Unnamed Creek south of Christina Lake	**BRC-D1** Birch Creek at Hwy 881	**JAR-E1** Jackfish River at the mouth	**GRR-E1** Gregoire River near the mouth	**CHL-1** Christina Lake	**GRL-1** Gregoire Lake
Benthic Invertebrate Communities	Negligible - Low	Negligible - Low	Negligible - Low	n/a	Negligible - Low	Moderate	n/a	Negligible - Low	Negligible - Low	n/a	Negligible - Low	Negligible - Low	Moderate	Negligible - Low
Sediment Quality Index	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	n/a	n/a	n/a	n/a
Fish Populations														
Criteria	**CHR-F1** at the mouth	**CHR-F2** upstream of Janvier	**CHR-F3** upstream of Jackfish River	**CHR-F4** above Statoil Leismer	**SAC-F1** Sawbones Creek	**SUC-F1** Sunday Creek at Christina Lake inlet	**SUC-F2** Sunday Creek at Hwy 881	**UNC-F2** Unnamed Creek east of Christina Lake	**UNC-F3** Unnamed Creek south of Christina Lake	**BRC-F1** Birch Creek at Hwy 881	**JAR-F1** Jackfish River at the mouth	**GRR-F1** Gregoire River near the mouth	no reach	no reach
Fish Assemblages	Negligible - Low	Negligible - Low	Negligible - Low	n/a	High	Negligible - Low	n/a	High	High	n/a	Negligible - Low	Negligible - Low		

Legend and Notes

Negligible - Low   Moderate   High   *baseline*   *test*

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches or no regional *baseline* conditions for lakes to classify results

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

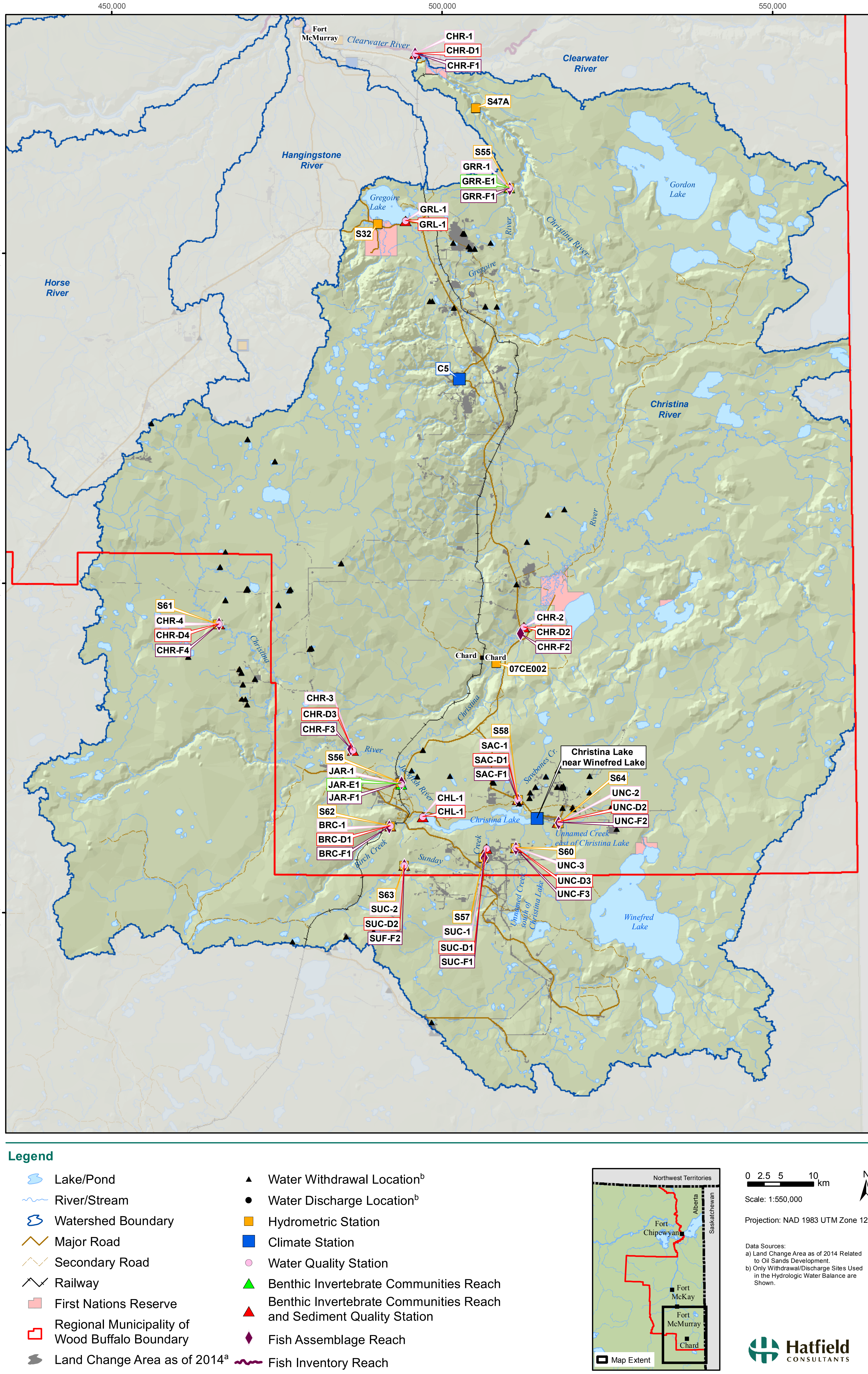
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline conditions*; see Section 3.3.1.10 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.3 for a description of the classification methodology.

Figure 5.10-1 Christina River watershed.



K:\Data\Project\JOSMP6784_MXD\TechRpt\JOSMP6784_K10_Christina_20150330_ss.mxd

Figure 5.10-2 Representative monitoring stations of the Christina River watershed, fall 2014.

Benthic and Sediment Quality Reach CHR-D3 (Christina River): facing downstream

Benthic and Sediment Quality Reach SAC-D1 (Sawbones Creek): facing upstream

Benthic and Sediment Quality Reach UNC-D2 (Unnamed Creek): facing downstream

Benthic and Sediment Quality Reach SUC-D1 (Sunday Creek): facing upstream

Hydrology Station S56 (Jackfish River): facing downstream

Hydrology Station S55 (Gregoire River): facing upstream

5.10.1 Summary of 2014 Conditions

As of 2014, approximately 1% (13,756 ha) of the Christina River watershed had undergone land change from oil sands development (Table 2.3-1). The Christina River watershed downstream of the Statoil project near the upper portion of the watershed, and the watershed where Cenovus, MEG Energy, and Devon projects are surrounding Christina Lake, is designated as *test*. The tributaries flowing in (e.g., Sawbones and Sunday creeks, downstream of development) and out (Jackfish River) of Christina Lake, as well as the lake itself, are designated as *test*. Gregoire Lake and Gregoire River downstream of the Nexen project are also designated as *test*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in the Christina River watershed in 2014. Table 5.10-1 is a summary of the 2014 assessment of the Christina River watershed, while Figure 5.10-1 denotes the location of the monitoring stations for each component, reported project water withdrawal and discharge locations, and the areas with land change as of 2014. Figure 5.10-2 contains photos of representative monitoring stations in the watersheds.

Hydrology For the 2014 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrographs for the Christina River were 0.1%, 0.0%, 0.1%, and 0.1%, respectively. These differences were classified as **Negligible-Low**.

In the 2014 WY, the water level of Christina Lake generally decreased slightly from November 2013 to early April 2014, and remained below historical median levels throughout this period. By early April, the lake level was close to the historical minima, but then increased in late April due to the spring thaw. The annual peak of 555.00 masl occurred on June 5, shortly after rainfall accumulations, and all values from June 2 to June 12 exceeded historical maxima recorded on these dates. The lake level decreased after this peak, dropping below historical median levels after mid-July and was close to historical minima from early August until late-September. The annual minimum lake level of 553.88 masl occurred on September 24, and the lake level then remained relatively constant until the end of the 2014 WY.

Continuous, year-round hydrometric data have been collected at JOSMP Station S56, Jackfish River below Christina Lake since May 2012. Before this, seasonal hydrometric data from March to October were collected at WSC station 07CE005 from 1982 to 1995. In the 2014 WY, Jackfish River flows declined gradually from November until mid-April, and then increased due to the spring thaw in late April. Flows increased again in late May, shortly after rainfall accumulations, and the annual peak flow of 44.1 m^3/s occurred on June 7. All flows from May 30 to June 12 exceeded historical maxima recorded on these dates. Flows then decreased rapidly until late July, and stabilized thereafter, remaining within the historical interquartile range until the end of the year. The minimum open-water daily flow of 1.27 m^3/s was recorded on September 25 and was 56% higher than the historical mean minimum daily flow of 0.82 m^3/s calculated for the open-water period.

Water Quality In fall 2014, water quality at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* stations BRC-1, CHR-4, and SUC-2 indicated **Negligible-Low** differences from regional *baseline* conditions. *Test* station GRR-1 indicated **Moderate** changes from regional *baseline* water quality conditions, given that concentrations of several water quality measurement endpoints (e.g., total metals) exceeded relevant guidelines and regional *baseline* conditions in 2014. Due to limited historical data at most sampling stations, it was only possible to compare *test* stations CHR-1 and CHR-2 to historical results. Generally these stations were similar to previous years, but many ions in fall 2014 had higher concentrations than previously-measured maximums. Despite higher ion concentrations, the ionic composition at *test* stations CHR-1 and CHR-2 remained similar across sampling years. The ionic composition at all other stations has also remained similar across sampling years, when comparisons were possible.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* stations CHR-1 and CHR-2, which were sampled on a monthly basis. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months at *test* stations CHR-1, while *test* station CHR-2 did not show any fluctuation in ionic composition throughout the year. The highest number of water quality guideline and regional fall *baseline* concentration exceedances occurred in May, June, July, and August, which were also the months where maximum annual concentrations of metals were most frequently reached at both stations.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D1 were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time and the significant difference in 2014 CA Axis 1 scores relative to the mean of previous years were not indicative of a negative change at the lower *test* reach. All measurement endpoints were within the inner tolerance limits of the normal range of variation for previous years of sampling. Although overall abundance was low, the relative abundance of worms was high, and the reach contained mayflies and stoneflies, suggesting reasonably good habitat quality.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D2 were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time reflected a shift in taxa composition at *test* reach CHR-D2 in 2014, with the absence of several relatively abundant taxa found in previous years, including Tubificidae, Bivalvia, Ephemeroptera, and Trichoptera. Other missing taxa in 2014 included Enchytraeidae, Hydracarina, Coleoptera, and Odonata. In 2014, chironomids were one of the only taxa found at *test* reach CHR-D2. All measurement endpoints were within the inner tolerance limits of the normal range of variation for means from previous years of sampling.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D3 were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches. *Test* reach CHR-D3 was sampled in erosional habitat with a Hess sampler in 2013 and in depositional habitat using an Ekman grab in 2014, confounding any assessment of changes in composition (or condition). The benthic fauna at *test* reach CHR-D3 in 2014, were representative of good habitat quality, with the presence of mayflies, stoneflies, and caddisflies, and only a small relative abundance of worms.

Differences in measurement endpoints at *test* reach SUC-D1 were classified as **Moderate.** *Test* reach SUC-D1 contained a benthic invertebrate community with lower abundance, richness, and percentage of EPT taxa, and higher CA Axis 2 scores than the upper *baseline* reach, indicating that the *test* reach was of lower quality than the upper *baseline* reach. However, taxa richness and the percentage of EPT taxa have increased over the past three years of sampling at *test* reach SUC-D1, indicating improving conditions. Additionally, all measurement endpoints for the lower *test* reach have consistently remained within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches, indicating generally acceptable conditions at this reach.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were classified as **Negligible-Low.** Although there were large variations in abundance, total numbers were well within the inner tolerance limits of regional *baseline* conditions for depositional reaches. None of the other measurement endpoints varied significantly, and all were within the range of regional *baseline* conditions for depositional reaches. The benthic invertebrate community of *test* reach SAC-D1 was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects.

Differences in measurement endpoints of benthic invertebrate communities at *test* reaches UNC-D2 and UNC-D3 (unnamed creeks east and south of Christina Lake) were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of regional *baseline* depositional reaches. Richness was higher than the *baseline* range of variability in 2014 at *test* reach UNC-D3 and equitability for *test* reach UNC-D2 was just below the lower outer limit of the *baseline* range, neither of which indicated a negative change. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach GRR-E1 were classified as **Negligible-Low.** Although naidid worms accounted for a large proportion of the benthic fauna (>40%), flying insects were present in relatively high numbers.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach JAR-E1 were classified as **Negligible-Low** because the community was highly diverse, and the statistically significant increases in richness and EPT in 2014 were considered to be positive changes. All measurement endpoints, with the exception of abundance, were within regional *baseline* ranges. Abundance was higher than the inner tolerance limit for the 95^{th} percentile of regional *baseline* reaches.

Differences in measurement endpoints of the benthic invertebrate community at *test* station CHL-1 in fall 2014 were classified as **Moderate** because several measurement endpoints (richness, abundance, EPT taxa) were lower than the previous two years, indicating a potential negative change. However, the lake still contained a diverse benthic fauna that included several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies, and caddisflies).

Differences in measurement endpoints of the benthic invertebrate community at *test* station GRL-1 (Gregoire Lake) in fall 2014 were classified as **Negligible-Low** given that amphipods, chironomids, and bivalves were abundant, the abundance of worms was relatively low, and there were no concerns regarding water quality of *test* station GRL-1 in 2014.

In fall 2014, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations at all stations, except total PAHs (absolute) and PAH hazard index values at *test* stations CHR-D2, CHR-D4, SUC-D1, and UNC-D3, which were below regional *baseline* ranges. Sediment quality at all stations in fall 2014 indicated **Negligible-Low** differences compared to regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) and Gregoire Lake (GRL-1) because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012 and 2013.

Fish Populations (fish assemblages) Differences in measurement endpoints for *test* reaches CHR-F1 and CHR-F3 were classified as **Negligible-Low** because all measurement endpoints were within the range of *baseline* variability. Differences in measurement endpoints for *test* reach CHR-F2 were also classified as **Negligible-Low** because only two measurement endpoints (abundance and CPUE) were below the range of *baseline* variability.

Differences in measurement endpoints for *test* reach GRR-F1 were classified as **Negligible-Low** because all measurement endpoints were within the *baseline* range of variability. Differences in measurement endpoints for *test* reach JAR-F1 were classified as **Negligible-Low** because although diversity and richness exceeded the *baseline* range of variability, this was indicative of a positive change in the fish assemblage. Only abundance was below the *baseline* range of variability, indicating a potential negative change in the fish assemblage.

Differences in measurement endpoints for fish assemblages for *test* reach SUC-F1 were classified as **Negligible-Low** because all measurement endpoints were within the range of *baseline* variability. Differences in measurement endpoints for fish assemblages at *test* reaches SAC-F1, UNC-F2, and UNC-F3 were classified as **High** because all measurement endpoints were near or below the lower tolerance limit of the *baseline* range of variability due to low or no catch of fish at these reaches.

5.10.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Christina River watershed in the 2014 WY was conducted at the following locations:

- JOSMP Station S47A, Christina River near the mouth;
- WSC Station 07CE002, Christina River near Chard (formerly JOSMP Station S29);
- JOSMP Station S32, Surmont Creek at Highway 881;
- JOSMP Station S55, Gregoire River near the mouth;
- JOSMP Station S56, Jackfish River below Christina Lake (formerly WSC Station 07CE005);
- JOSMP Station S57, Sunday Creek above Christina Lake;
- JOSMP Station S58, Sawbones Creek above Christina Lake;
- JOSMP Station S60, Unnamed Creek South of Christina Lake;
- JOSMP Station S61, Christina River above Statoil Leismer;
- JOSMP Station S62, Birch Creek at Hwy 881;
- JOSMP Station S63, Sunday Creek at Hwy 881;
- JOSMP Station S64, Unnamed Creek East of Christina Lake; and
- WSC Station 07CE906, Christina Lake near Winefred Lake.

The data from JOSMP Station S47A, Christina River near the mouth, were used for the water balance analysis and are presented below. Hydrographs for Christina Lake (Station 07CE906) and Jackfish River (Station S56/07CE005) are also provided in this section, given these stations captured the conditions of the Christina Lake area prior to entering the Christina River. The data from other JOSMP stations can be found in Appendix C.

The historical time series statistics for JOSMP Station S47A, Christina River near the mouth, are summarized in Figure 5.10-3, including the median, interquartile range, and range of flows recorded daily through the water year. From 1967 to 2011, there was no monitoring station at the Christina River near the mouth, and flows were estimated as the difference between the measured flow at the Clearwater River above the Christina River (WSC Station 07CD005) and the Clearwater River above Draper (WSC Station 07CD001). Hydrometric data were collected at these WSC stations, concurrently, in the open-water period (May to October) from 1967 to 1975, annually from 1976 to 1996, and seasonally (March to October) from 1997 to 2010. Annual data from JOSMP Station S47A (formerly S47) were used from 2011 to 2013.

Flows of the Christina River near the mouth have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter flows are typically much lower than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in late March and April. Monthly flows are highest during May, at the peak of freshet, or June and July when total monthly rainfall are highest. Flows then generally recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.10-3). Flows steadily decreased from November 2013 to early April 2014, and remained within the historical inter-quartile range during this period (Figure 5.10-3). Flows then increased rapidly until data collection ceased on April 28, due to an equipment malfunction. Monitoring resumed on May 21, and flows increased shortly after in response to rainfall accumulations. The 2014 WY peak flow of 308.3 m^3/s occurred on June 13 and was 77% higher than the historical annual mean maximum flow. Flows on most dates in June were higher than the historical maxima. Flows then decreased from July until the minimum open-water daily flow of 16.8 m^3/s was recorded on September 25. This was 1% lower than the historical mean minimum daily flow of 16.9 m^3/s calculated for the open-water period. Flows then increased in late September due to rainfall, and then decreased slowly through October. All flows from mid-July to October remained within the historical median range.

Overall, the annual runoff volume in the 2014 WY was 1,643 million m^3. This value was 41% higher than the mean historical annual runoff volume based on the available period of record. Both of these values were likely to be underestimated, when accounting for the missing period of data from April 29 to May 20, 2014.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Christina River near the mouth (JOSMP Station S47A) is summarized in Table 5.10-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2014 was estimated to be 14.0 km^2 (Table 2.3-1). The loss of flow to the Christina River that would have otherwise occurred from this land area was estimated at 1.764 million m^3.

2. As of 2014, the area of land change in the Christina River watershed that was not closed-circuited was estimated to be 123.6 km^2 (Table 2.3-1). The increase in flow to the Christina River that would not have otherwise occurred from this land area was estimated at 3.113 million m^3.

3. Nexen withdrew approximately 0.130 million m^3 (129,846 m^3) of water in the 2014 WY.

4. Statoil withdrew approximately 0.026 million m^3 (25,581 m^3) of water in the 2014 WY.

5. MEG withdrew approximately 0.134 million m^3 (133,616 m^3) of water in the 2014 WY.

6. Canadian Natural Kirby withdrew approximately 0.021 million m^3 (21,103 m^3) of water in the 2014 WY.

Total water withdrawals were approximately 0.307 million m^3 (306,166 m^3) in the 2014 WY. Water withdrawals were for a range of activities, including drilling, seismic surveys, construction, and dust control. The total withdrawal sum applied in the water balance analysis (0.298 million m^3) was slightly lower, to account for the period from April 29 to May 20 when there was no observed hydrograph and the water balance could not be completed. All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2014 WY was an increase in water volume of 1.051 million m^3 in the Christina River at JOSMP Station S47A. The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were +0.08%, -0.04%, +0.08% and +0.08%, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.10-3). These differences were classified as **Negligible-Low**. Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to further characterize the cumulative hydrological effects across the watershed.

Continuous lake level data for Christina Lake have been collected for WSC station 07CE906 from 2002 to 2014, with some data for 2001. In the 2014 WY, the lake level decreased slightly from November 2013 to early April 2014 (Figure 5.10-4), and remained below historical median levels throughout this period. By early April, the lake level was close to the historical minima, but then increased in late April due to the spring thaw. The annual peak lake level of 555.00 masl occurred on June 5, shortly after rainfall accumulations, and all values from June 2 to June 12 exceeded historical maxima recorded on these dates. The lake level decreased after this peak, dropping below historical median levels after mid-July and was close to historical minima from early August until late-September. The annual minimum lake level of 553.88 masl occurred on September 24, and the lake level remained relatively constant until the end of October.

Continuous, year-round hydrometric data have been collected at JOSMP Station S56, Jackfish River below Christina Lake since May 2012. Before this, seasonal hydrometric data from March to October were collected at WSC station 07CE005 from 1982 to 1995. In the 2014 WY, flows declined gradually from November until mid-April, and then increased due to the spring thaw in late April (Figure 5.10-5). Flows increased again in late May, shortly after rainfall accumulations to an annual peak flow of 44.1 m^3/s on June 7. Flows from May 30 to June 12 exceeded historical maxima recorded on these dates. Flows then decreased rapidly until late July, and stabilized thereafter, remaining within the historical interquartile range until the end of the year. The minimum open-water daily flow of 1.27 m³/s was recorded on September 25 and was 56% higher than the historical mean minimum daily flow of 0.82 m³/s calculated for the open-water period.

5.10.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Christina River near its mouth (*test* station CHR-1), sampled since 2002;
- the Christina River upstream of Janvier (*test* station CHR-2), sampled since 2002, designated as *test* in 2010;
- the Christina River upstream of Jackfish River (*test* station CHR-3), sampled since 2013;
- the Christina River upstream of development (*baseline* station CHR-4), sampled since 2013;
- Sawbones Creek (*test* station SAC-1), sampled since 2012;
- Sunday Creek at the inlet into Christina Lake (*test* station SUC-1), sampled since 2012;
- Sunday Creek upstream (*baseline* station SUC-2), sampled since 2013;
- Birch Creek (*baseline* station BRC-1), sampled since 2013;
- Unnamed Creek east of Christina Lake (*test* station UNC-2), sampled since 2013;
- Unnamed Creek south of Christina Lake (*test* station UNC-3), sampled since 2013;
- Jackfish River (*test* station JAR-1), sampled since 2012;
- Christina Lake (*test* station CHL-1), sampled since 2012;
- Gregoire River (*test* station GRR-1), initiated in 2014; and
- Gregoire Lake (*test* station GRL-1), initiated in 2014.

Test stations CHR-3, SAC-1, SUC-1, UNC-2, UNC-3, JAR-1, CHL-1, and *baseline* stations CHR-4, BRC-1, and SUC-2 were also sampled in winter, spring, and summer 2014 in an effort to gain three years of seasonal data. Seasonal sampling also was done at new *test* stations GRR-1 and GRL-1 in spring and summer 2014. *Test* stations CHR-1 and CHR-2 were sampled monthly; however, monthly sampling at *test* station CHR-2 was initiated in April 2014.

Temporal Trends The only significant trend (α=0.05) in fall water quality measurement endpoints was a decreasing concentration of chloride at *test* station CHR-2. There were no significant trends at *test* station CHR-1. Trend analysis was not conducted for *test* stations CHR-3, SAC-1, SUC-1, UNC-2, UNC-3, JAR-1, GRR-1, GRL-1, and CHL-1, and *baseline* stations CHR-4, BRC-1, and SUC-2 because of insufficient data available.

2014 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations (Table 5.10-4 to Table 5.10-17), with the exception of:

- conductivity, sodium, calcium, magnesium, chloride, sulphate, total dissolved solids, total alkalinity, total boron, total strontium, and naphthenic acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station CHR-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- dissolved phosphorus, total nitrogen, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station CHR-1;
- conductivity, sodium, calcium, magnesium, sulphate, total alkalinity, total boron, total molybdenum, total strontium, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station CHR-2; and
- dissolved phosphorus, total nitrogen, dissolved aluminum, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station CHR-2.

No historical comparisons were conducted for *test* stations CHR-3, UNC-2, UNC-3, SAC-1, SUC-1, JAR-1, GRR-1, GRL-1, and CHL-1 and *baseline* stations CHR-4, SUC-2, and BRC-1 due to limited (<3 years) or no historical data available (Table 5.10-6 to Table 5.10-17).

Ion Balance The ionic composition of water at all stations in the Christina River watershed in fall 2014 was dominated by calcium and bicarbonate ions (Figure 5.10-6 and Figure 5.10-7). Stations on the mainstem Christina River showed consistent ionic composition across sampling years; however, *test* station CHR-1 differed from the remaining mainstem stations because it consistently had a slightly greater dominance of chloride and slightly lower dominance of calcium (Figure 5.10-6). This was likely related to known saline seeps in the Christina River between stations CHR-1 and CHR-2. Tributary stations sampled in fall 2014 were all generally similar in ionic composition and dominated by calcium and bicarbonate (Figure 5.10-7). T*est* stations GRL-1 and GRR-1 were notably different from the other tributary stations, still being dominated by calcium and bicarbonate but with bicarbonate dominating to a lesser extent than the other tributary stations. Results in 2014 were similar to the ionic composition observed in previous years (where historical data were available), with the exception of *test* station SUC-1, which was dominated slightly less by bicarbonate ions in 2013 relative to 2012 and 2014 (Figure 5.10-7). Overall, the ionic composition of tributary stations was very similar to *test* stations CHR-2 and CHR-3, and *baseline* station CHR-4 on the Christina River mainstem (Figure 5.10-6 and Figure 5.10-7).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines In fall 2014, concentrations of water quality measurement endpoints at stations in the Christina River watershed were below water quality guidelines (Table 5.10-4 to Table 5.10-17), with the exception of total aluminum at *test* stations CHR-1, GRL-1, GRR-1, UNC-3, and SUC-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the Christina River watershed in fall 2014 (Table 5.10-18):

- Dissolved iron at *baseline* stations CHR-4 and SUC-2;
- Sulphide at *test* stations CHR-2 and GRR-1, and *baseline* station CHR-4;
- Total chromium at *test* stations CHR-1, GRR-1, and SUC-1;
- Total phenols at *test* stations CHR-2, CHR-3, SAC-1, SUC-1, UNC-2, CHL-1, and GRR-1; and
- Total iron at *test* stations CHR-1, CHR-2, CHR-3, SUC-1, GRR-1, UNC-2, and UNC-3, and *baseline* stations BRC-1, SUC-2, and CHR-4.

There were many water quality guideline exceedances in winter, spring, and summer at *test* stations CHR-3, CHL-1, SAC-1, JAR-1, UNC-2, UNC-3, and SUC-1 and *baseline* stations BRC-1, CHR-4, and SUC-2. New *test* station GRR-1 (Gregoire River) had many guideline exceedances in spring and summer 2014, but *test* station GRL-1 (Gregoire Lake) did not have any (Gregoire River flows from Gregoire Lake). Most exceedances observed in the monthly data were by the same variables that exceeded guidelines in fall 2014 (Table 5.10-18). Additionally, many total metals exceeded guidelines in spring and summer at *test* stations CHR-1, CHR-2, GRR-1 and *baseline* station BRC-1. These metals were likely associated with high particulate concentrations in the water, as total suspended solids at these stations were high and dissolved metals remained fairly consistent during these time periods.

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, most water quality measurement endpoints were within regional *baseline* concentrations (Figure 5.10-9 and Figure 5.10-10), with the exception of:

- total suspended solids, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station GRR-1;
- total dissolved solids, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CHR-1 and below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1;
- total nitrogen, with concentrations below the 5th percentile of regional *baseline* concentrations at *baseline* stations BRC-1 and SUC-2;
- total strontium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CHR-3 and below the 5th percentile or regional *baseline* concentrations at *test* station SAC-1;
- total boron, with a concentration below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1 and a concentration that exceeded the 95th percentile of regional *baseline* concentration at *test* station GRR-1;
- total mercury (ultra-trace), with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station SUC-1, CHR-3, and UNC-3, and *baseline* station BRC-1;

- total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station CHR-4;

- calcium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations SUC-1 and CHR-3 and *baseline* stations BRC-1 and CHR-4;

- sodium and chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CHR-1;

- Sodium, with a concentration below the 5th percentile of regional *baseline* data at *test* station SAC-1; and

- sulphate, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* stations SAC-1.

Lakes did not contribute to the regional *baseline* concentration calculations; therefore, Christina Lake and Gregoire Lake were not compared to regional *baseline* conditions (Figure 5.10-11). There were not adequate *baseline*-lake data from the region to develop a lake-specific regional *baseline* range of conditions

Water Quality Index The WQI values at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* stations CHR-4, BRC-1, and SUC-2 indicated **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2014 (Table 5.10-19). The WQI at *test* station GRR-1 (70.0) indicated a **Moderate** difference from regional *baseline* water quality conditions, given that concentrations of several water quality measurement endpoints (mostly total metals, perhaps related to high TSS) exceeded regional *baseline* concentrations (Table 5.10-19). A WQI was not generated for *test* stations CHL-1 (Christina Lake) and GRL-1 (Gregoire Lake) because lakes were not compared to regional *baseline* concentrations.

Monthly Water Quality Results Water quality samples were collected monthly during 2014 at *test* station CHR-1 (Table 5.10-20) and monthly starting in April at *test* station CHR-2 (Table 5.10-21). Generally the lowest concentration of ions occurred in May and June, and the highest concentrations occurred in March and April at both stations.

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances that were measured at *test* station CHR-1 in 2014 included (Table 5.10-22):

- total phenols in February, May, June, and August;
- total chromium from April to July, and September;
- total aluminum in all months except January, and dissolved aluminum in June;
- total mercury (ultra-trace) in May, June, and July;
- sulphide from May to August, October, and November; and
- total iron in all months and dissolved iron in January, May, July, August, November, and December.

Water quality guideline exceedances that were measured at *test* station CHR-2 in 2014 included (Table 5.10-23):

- total phenols from April to September;
- sulphide from May to September and November;
- total aluminum from May to August;
- total iron in all months measured (April to December);
- dissolved iron in May, July, August, October, November, and December; and
- total chromium and total mercury (ultra-trace) in May and June.

2014 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2014, most monthly data collected at *test* station CHR-1 and *test* station CHR-2 were within regional *baseline* conditions observed in fall (Figure 5.10-12), with the exception of:

- total suspended solids, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in April, May, June (annual maximum), and July at *test* station CHR-1 and May and June (annual maximum) at *test* station CHR-2;
- total dissolved solids, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, September, and December at *test* station CHR-1;
- total dissolved solids, with concentrations below the 5th percentile of regional *baseline* fall concentrations at *test* station CHR-2 in May and June;
- total strontium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, November, and December at *test* station CHR-1 and in April and December at *test* station CHR-2;
- total boron, with a concentration that exceeded the 95th percentile of regional *baseline* fall concentrations in March at *test* station CHR-1;
- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from April to July at *test* station CHR-1 and from May and June at *test* station CHR-2;
- total mercury (ultra-trace), with a concentration below the 5th percentile of regional *baseline* fall concentrations in December at *test* station CHR-2;
- total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from May to July at *test* station CHR-1 and in June at *test* station CHR-2;
- calcium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from February to April at *test* station CHR-1 and in April and December at *test* station CHR-2;
- magnesium, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station CHR-2 in May and June;

- sodium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, and September to December at *test* station CHR-1; and
- chloride, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, September, November, and December at *test* station CHR-1.

Monthly Ion Balance The ionic composition of water at *test* station CHR-1 was dominated by bicarbonate throughout 2014. Seasonal changes in ionic composition were apparent, where the ionic composition in winter was dominated more by chloride and less by calcium (January to April) and shifted to a greater dominance in calcium in summer (May to August). This was consistent with greater influence of saline groundwater seepage in winter when the influence of surface runoff is weakest. The ionic composition of *test* station CHR-2 remained consistent throughout the year and was dominated by calcium and bicarbonate (Figure 5.10-13).

Classification of Fall Results In fall 2014, water quality at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* stations BRC-1, CHR-4, and SUC-2 indicated **Negligible-Low** differences from regional *baseline* conditions (Table 5.10-1). *Test* station GRR-1 indicated **Moderate** changes from regional *baseline* water quality conditions, given that concentrations of several water quality measurement endpoints (e.g., total metals) exceeded relevant guidelines and regional *baseline* conditions in 2014 (Table 5.10-1). Due to limited historical data at most sampling stations, it was only possible to compare *test* stations CHR-1 and CHR-2 to historical results. Generally these stations were similar to previous years, but many ions in fall 2014 had higher concentrations than previously-measured maximums. Despite higher ion concentrations, the ionic composition at *test* stations CHR-1 and CHR-2 remained similar across sampling years. The ionic composition of water at all other stations has also remained similar across sampling years, where comparisons were possible.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* stations CHR-1 and CHR-2. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months at *test* stations CHR-1, while *test* station CHR-2 did not show any fluctuation in ionic composition throughout the year. The highest number of water quality guideline and regional fall *baseline* concentration exceedances occurred in May, June, July, and August, which were also the months where maximum annual concentrations of metals were most frequently reached at both stations.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *test* reach CHR-D1 (lower Christina River), sampled from 2002 to 2007, 2009, 2012, 2014;
- depositional *test* reach CHR-D2 (middle Christina River), sampled from 2002 to 2006 and 2009 as a *baseline* reach, sampled in 2012 and 2014 as a *test* reach;

- depositional *test* reach CHR-D3 (Christina River, upstream of Jackfish River), sampled in erosional habitat in 2013 and switched to depositional in 2014 to be consistent with the other reaches on the Christina River;
- depositional *baseline* reach CHR-D4 (upper Christina River), sampled since 2013;
- depositional *test* reach SUC-D1 (lower Sunday Creek), sampled since 2012;
- depositional *baseline* reach SUC-D2 (upper Sunday Creek), sampled since 2013;
- depositional *test* reach SAC-D1 (Sawbones Creek), sampled since 2012;
- depositional *test* reach UNC-D2 (unnamed creek, east of Christina Lake), sampled since 2013;
- depositional *test* reach UNC-D3 (unnamed creek, south of Christina Lake), sampled since 2013;
- depositional *baseline* reach BRC-D1 (Birch Creek), sampled since 2013;
- erosional *test* reach JAR-E1 (Jackfish River), sampled since 2012;
- erosional *test* reach GRR-E1 (Gregoire River), initiated as a new reach in fall 2014;
- Christina Lake (*test* station CHL-1), sampled since 2012; and
- Gregoire Lake (*test* station GRL-1), initiated as a new station in fall 2014.

Christina River Mainstem

2014 Habitat Conditions Water at *test* reach CHR-D1 in fall 2014 was shallow (0.35 m), slightly alkaline (pH=7.14), with high dissolved oxygen (9.8 mg/L), and moderate conductivity (372 µS/cm). The substrate was primarily comprised of sand (81%) with some silt (13%) and a small amount of clay (6%) with low total organic carbon content (<1%) (Table 5.10-24).

Water at *test* reach CHR-D2 in fall 2014, was shallow (0.3 m), alkaline (pH: 8.7), with high dissolved oxygen (12.3 mg/L), and moderate conductivity (325 µS/cm). The substrate was almost entirely comprised of sand (99%) with low total organic carbon content (<1%) (Table 5.10-24).

Water at *test* reach CHR-D3 in fall 2014, was shallow (0.5 m), slightly alkaline (pH: 7.8), with high dissolved oxygen (10.8 mg/L), and moderate conductivity (338 µS/cm). The substrate was almost entirely comprised of sand (98%) with low total organic carbon content (<1%) (Table 5.10-24).

Water at *baseline* reach CHR-D4 in fall 2014, was shallow (0.4 m), alkaline (pH: 8.1), with moderate velocity (0.3 m/s), high dissolved oxygen (9.0 mg/L), and moderate conductivity (280 µS/cm). The substrate was almost entirely comprised of sand (98%), with low total organic carbon content (<1%) (Table 5.10-24).

Relative Abundance of Benthic Community Taxa The benthic invertebrate community at *test* reach CHR-D1 was dominated by chironomids (62%) with subdominant taxa consisting of tubificid worms (16%), Nematoda (8%), Ceratopogonidae (4%), and miscellaneous Diptera (4%) (Table 5.10-25). Chironomids were primarily of the genera *Polypedilum, Paralauterborniella,* and *Stempellinella.* EPT taxa were sparse and represented only by mayflies (*Ametropus neavei* and *Brachycentrus)*. Dragonflies

(*Gomphus* and *Ophiogomphus)* were present in low relative abundances. Permanent aquatic forms were represented by a single bivalve (*Pisidium)* in one replicate sample (Table 5.10-25).

The benthic invertebrate community at *test* reach CHR-D2 was dominated by chironomids (93%) with various other taxa present in low relative abundances (~1%) (Table 5.10-25). Chironomids were primarily of the genera *Robackia* and *Polypedilum*. EPT taxa were sparse and represented only by a single mayfly *(Centroptilum)*. Permanent aquatic forms (gastropods: *Valvatidae*; bivalves: *Pisidium/Sphaerium*) were present in low relative abundances.

The benthic invertebrate community at *test* reach CHR-D3 was dominated by chironomids (96%) with subdominant taxa consisting of Plecoptera (2%) and low relative abundances of naidid and tubificid worms and miscellaneous Diptera (~1%, Table 5.10-26). Chironomids were primarily of the genera *Robackia, Chironomus, Polypedilum, Lopesocladius/Rheosmittia,* and *Paracladopelma.* Several flying insects (mayflies: *Ametropus neavei, Callibaetis, Tricorythodes,* and *Siphloplecton*; and stoneflies: *Isoperla*) were present in low relative abundances (Table 5.10-26).

The benthic invertebrate community at *baseline* reach CHR-D4 was dominated by chironomids (93%), which were diverse with 30 genera present. Chironomids were primarily of the genera *Polypedilum, Rheosmittia,* and *Saetheria*. Several flying insects (mayflies: *Caenis*, *Leptophlebia*; caddisflies: *Ceraclea*, *Limnephilus/Philarctus*; and stoneflies: too small to identify to family or better) were found at this reach in 2014, along with bivalves (*Pisidium*/*Sphaerium*) (Table 5.10-26).

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the lower and middle *test* reaches of the Christina River. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal and spatial comparisons were not conducted for *test* reach CHR-D3 and *baseline* reach CHR-D4 given that these reaches have only been sampled for two years (2013 and 2014).

Temporal comparisons of measurement endpoints for *test* reach CHR-D1 included testing for:

- changes over time during the *test* period (Hypothesis 1, Section 3.2.3.1); and
- changes between 2014 values and the mean of all previous years of sampling.

Temporal comparisons of measurement endpoints for *test* reach CHR-D2 included testing for:

- changes over time during the *test* period (Hypothesis 1, Section 3.2.3.1); and
- changes between 2014 values and the mean of all previous years of sampling.

CA Axis 1 scores decreased over time at *test* reach CHR-D1 and were lower in 2014 than the mean of all previous years. These effects accounted for 46% and 31% of the variance in annual means, respectively (Table 5.10-27). The decrease in CA Axis 1 scores was likely attributed to a decrease in bivalves and tubificid worms, and a slight increase in nematodes.

CA Axis 1 scores decreased over time at *test* reach CHR-D2, accounting for 45% of the variance in annual means (Table 5.10-28).

Comparison to Published Guidelines The lower *test* reach CHR-D1 contained a benthic invertebrate community typical of a sandy-bottomed river (i.e., which typically does not support a high diversity of benthic fauna; Barton and Smith 1984). The benthic invertebrate community had low overall abundance (a mean of 201 taxa), with high relative abundance of tolerant taxa (tubificids), and a low percentage of EPT taxa. Some sensitive taxa (Ephemeroptera, Plecoptera, and bivalves) were present in low relative abundances (>1%).

The middle *test* reach CHR-D2 contained a benthic invertebrate community with low abundance, diversity, richness, and percentage of EPT taxa compared to *test* reach CHR-D1; however, the percentage of EPT taxa, was higher in 2014 than in previous years. When compared to lower *test* reach CHR-D1, chironomids were slightly less diverse at the middle *test* station (CHR-D2) in 2014, but the overall abundance of worms was much lower.

In 2014, *test* reach CHR-D3 contained a benthic invertebrate community that was less diverse than 2013, which was likely attributed to the shift in sampling habitat from erosional to depositional. Chironomids were not diverse at *test* reach CHR-D3; however, the dominant taxon *Robackia demeijerei* is considered relatively sensitive (Mandeville 2002). EPT taxa were found in low relative abundance in 2014, and were lower relative to 2013 (EPT taxa are generally less abundant in depositional habitat compared to erosional habitat). Taxa richness at *test* reach CHR-D3 in 2014 was lower than 2013, and permanent aquatic forms were sparse.

Baseline reach CHR-D4 contained a benthic invertebrate community representative of a healthy, sand-bottomed river. The community was dominated by chironomids and the relative abundance of worms was low (~10%). EPT taxa were present in low relative abundances and several permanent aquatic forms (fingernail clams) were present, consistent with the sand-dominated substrate characteristics of the reach.

2014 Results Relative to Historical or Regional *Baseline* Conditions Values of all measurement endpoints at *test* reaches CHR-D1 and CHR-D2 were within the inner tolerance limits of the normal range of variation from previous years of sampling (Figure 5.10-14, Figure 5.10-15, Figure 5.10-16). Given there is only one year of depositional data for *test* reach CHR-D3, values of measurement endpoints were compared to the regional range of *baseline* variability. All measurement endpoints for *test* reach CHR-D3 were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches (Figure 5.10-16, Figure 5.10-17). *Baseline* reach CHR-D4 was sampled to provide *baseline* data for the regional *baseline* range of variability (Figure 5.10-18).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D1 were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time and the significant difference in 2014 CA Axis 1 scores relative to the mean of previous years were not indicative of a negative change at the lower *test* reach. All measurement endpoints were within the inner tolerance limits of the normal range of variation for means from previous years of sampling. Although overall abundance was low, the relative abundance of worms was high, and the reach contained mayflies and stoneflies, suggesting reasonably good habitat quality.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D2 were classified as **Negligible-Low**. The decreasing trend in CA Axis 1 scores over time reflected a shift in taxa composition at *test* reach CHR-D2 in 2014, with the absence of several relatively abundant taxa found in previous years, including Tubificidae, Bivalvia, Ephemeroptera, and Trichoptera. Other missing taxa in 2014 included Enchytraeidae, Hydracarina, Coleoptera, and Odonata. In 2014, chironomids were one of the only taxa found at *test* reach CHR-D2. All measurement endpoints were within the inner tolerance limits of the normal range of variation from previous years of sampling.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D3 were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches. *Test* reach CHR-D3 was sampled in erosional habitat with a Hess sampler in 2013 and in depositional habitat using an Ekman grab in 2014, confounding any assessment of changes in composition (or condition). The benthic fauna at *test* reach CHR-D3 in 2014, were representative of good habitat quality, with the presence of mayflies, stoneflies, and caddisflies, and only a small relative abundance of worms.

Sunday Creek

2014 Habitat Conditions Water at *test* reach SUC-D1 in fall 2014, was relatively deep (0.69 m), with a pH of 6.9, fast velocity (0.7 m/s), high dissolved oxygen (9.3 mg/L), and moderate conductivity (382 µS/cm). The substrate consisted almost entirely of sand (97%) with low total organic carbon content (<1%) (Table 5.10-29).

Water at *baseline* reach SUC-D2 in fall 2014 was shallow (0.37 m), with a pH of 6.3, slow velocity (0.2 m/s), high dissolved oxygen (9.0 mg/L), and moderate conductivity (231 µS/cm). The substrate consisted almost entirely of sand (92%) with low total organic carbon content (<1%) (Table 5.10-29).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach SUC-D1 was dominated by chironomids (79%) with subdominant taxa consisting of *Naididae* (5%) and miscellaneous Diptera (5%) (Table 5.10-30). Dominant chironomids included the genera *Saetheria, Polypedilum,* and *Paracladopelma*. Miscellaneous Diptera included members of the families *Tipulidae*, *Empididae*, and *Tabanidae*. Flying insects (Ephemeroptera, Trichoptera, and Plecoptera) were sparse at *test* reach SUC-D1 in 2014. Permanent aquatic forms such as *Pisidium*/*Sphaerium* clams were present in low relative abundances.

The benthic invertebrate community at *baseline* reach SUC-D2 was dominated by chironomids (70%) with subdominant taxa consisting of naidid worms (6%) (Table 5.10-30). Chironomids were diverse and included *Tanytarsus*, *Paralauterborniella*, *Ablabesmyia*, and *Polypedilum*. Several flying insects (mayflies: *Baetis, Baetisca, Ephemerella, Hexagenia limbata*, and *Siphloplecton*; and caddisflies: *Limnephilidae*) were present at *baseline* reach SUC-D2 in 2014, along with low numbers of gastropods (*Planorbidae*, *Ancylidae,* and *Gyraulus*) and bivalves (*Pisidium/Sphaerium*) (Table 5.10-30).

Temporal and Spatial Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of Sunday Creek. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Comparisons of measurement endpoints for *test* reach SUC-D1 included testing for:

- differences from *baseline* reach SUC-D2 over time (Hypothesis 2, Section 3.2.3.1);
- changes over time during the *test* period (i.e., since 2012, Hypothesis 1, Section 3.2.3.1);
- differences between 2014 values and the mean of all available *baseline* data; and
- changes in 2014 values and the mean of all previous years of sampling (2012 to 2013).

Abundance, richness, and the percentage of EPT taxa significantly increased over time at *test* reach SUC-D1 from 2012 to 2014, accounting for >20% of the variance in annual means (Table 5.10-31).

Abundance, richness, and the percentage of EPT taxa were lower at *test* reach SUC-D1 in 2014 than the mean of previous years at *baseline* reach SUC-D2, accounting for 39%, 55%, and 59% of the variance in annual means, respectively (Table 5.10-31).

The percentage of EPT taxa was higher in 2014 than the mean of all previous years at the lower *test* reach, accounting for 39% of the variance in annual means (Table 5.10-31).

CA Axis 2 scores were higher at the lower *test* reach and were higher in 2014 than the mean of previous years at upper *baseline* reach SUC-D2, accounting for 29% and 62% of the variance in annual means, respectively. CA Axis 2 scores decreased over time at the lower *test* reach and were lower in 2014 than the mean of all previous years, accounting for 34% and 41% of the variance in annual means, respectively (Table 5.10-31). Differences in CA Axis 2 scores reflected higher relative abundances of mayflies (Ephemeroptera) and lower relative abundances of chironomids in the upper *baseline* reach SUC-D2 (Table 5.10-30 and Figure 5.10-20).

Comparison to Published Literature *Test* reach SUC-D1 contained a benthic invertebrate community typical of a sand-bottomed creeks with dominant taxa consisting of chironomids, and with the presence of mayflies (*Caenis, Baetisca, Hexagenia limbata, Acerpenna*), and clams (*Pisidium/Sphaerium*). Worms only accounted for a moderate fraction (<10%) of the community, suggesting good water quality conditions (Hynes 1960; Griffiths 1998).

Baseline reach SUC-D2 contained a benthic invertebrate community typical of a creek with a soft, sand-based bottom. Chironomids were dominant, with common forms that were moderately tolerant of degraded water quality conditions (Mandeville 2002). The benthic invertebrate community at *baseline* reach SUC-D2 also included a variety of worms, in addition to mayflies, caddisflies, fingernail clams, and gastropods all in low relative abundances.

2014 Results Relative to Regional *Baseline* Conditions With only three years of data, *test* reach SUC-D1 was compared to the regional range of variability for *baseline* depositional reaches. All measurement endpoints of benthic invertebrate communities at *test* reach SUC-D1 were within the inner tolerance limits of the normal range of variation for means from the regional *baseline* depositional reaches (Figure 5.10-19, Figure 5.10-20).

Classification of Results Differences in measurement endpoints at *test* reach SUC-D1 were classified as **Moderate.** *Test* reach SUC-D1 contained a benthic invertebrate community with lower abundance, richness, and percentage of EPT taxa, and higher CA Axis 2 scores than the upper *baseline* reach, indicating that the lower *test* reach was of lower quality than the upper *baseline* reach. However, taxa richness and the percentage of EPT taxa have increased over the past three years of sampling at *test* reach SUC-D1, indicating improving conditions. Additionally, all measurement endpoints for the lower *test* reach have consistently remained within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches, indicating generally acceptable conditions at this reach.

Tributaries of Christina Lake

2014 Habitat Conditions Water at *test* reach SAC-D1 (Sawbones Creek) in fall 2014 was relatively deep (0.8 m), slightly alkaline (pH: 7.4), with slow velocity, high dissolved oxygen (14.2 mg/L), and low conductivity (58 µS/cm). The substrate consisted primarily of sand (75%), with small amounts of silt (11%) and clay (4%), and low total organic carbon content (1%) (Table 5.10-32).

Water at *test* reach UNC-D2 (Unnamed Creek east of Christina Lake) in fall 2014 had a depth of 0.5 m, a pH of 7.5, high dissolved oxygen (9.9 mg/L), and moderate conductivity (258 µS/cm). The substrate consisted primarily of sand (87%), with low total organic carbon content (1.4%) (Table 5.10-32).

Water at *test* reach UNC-D3 (Unnamed Creek south of Christina Lake) in fall 2014 was shallow (0.3 m), slightly alkaline (pH: 7.5), with high dissolved oxygen (9.9 mg/L), and moderate conductivity (364 µS/cm). The substrate consisted almost entirely of sand (98%), with low total organic carbon content (<1%) (Table 5.10-32).

Water at *baseline* reach BRC-D1 (Birch Creek) in fall 2014 had a depth of 0.4 m, a pH of 7.7, moderate velocity (0.45 m/s), high dissolved oxygen (11.0 mg/L), and moderate conductivity (338 µS/cm). The substrate consisted almost entirely of sand (96%), with small amounts of silt (3%) and clay (1%), and low total organic carbon (<1 %) (Table 5.10-32).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach SAC-D1 was dominated by chironomids (69%) with subdominant taxa consisting of Ceratopogonidae (7%), nematodes (5%), and tubificid worms (5%) (Table 5.10-33). Dominant chironomids included *Tanytarsus, Polypedilum,* and *Micropsectra/Tanytarsus*. Ephemeroptera (*Callibaetis, Hexagenia Limbata*, *Eurylophella, and Leptophlebia*) were present in low relative abundances, as were gastropods (*Gyraulus* and *Ferrissia rivularis*) and bivalves (*Pisidium/Sphaerium*).

The benthic invertebrate community at *test* reach UNC-D2 was dominated by chironomids (78%) with subdominant taxa consisting of Ceratopogonidae (6%) and Tubificidae (5%) (Table 5.10-33). Chironomids were diverse and included *Polypedilum, Cladotanytarsus, Paralauterborniella,* and *Tanytarsus*. Several flying insects (mayflies: *Callibaetis* and *Siphloplecton*; and caddisflies: *Oecetis* and *Oxyethira*) were found in low relative abundances in 2014. Amphipods (*Hyalella azteca* and *Gammarus lacustris*) and bivalves (*Pisidium/Sphaerium*) were present at *test* reach UNC-D2 in fall 2014 (Table 5.10-33).

The benthic invertebrate community at *test* reach UNC-D3 was dominated by chironomids (59%) with subdominant taxa consisting of miscellaneous Diptera (18%), naidid worms (7%), and Ephemeroptera (5%) (Table 5.10-33). Chironomids were dominated by *Stempellina* and *Saetheria*. Several flying insects (mayflies: *Baetisca* and *Siphloplecton*; and two unidentified caddisflies) were present in fall 2014. Amphipods (*Hyalella azteca*), gastropods (*Gyraulus*), and bivalves (*Pisidium/Sphaerium*) were also found at *test* reach UNC-D3 (Table 5.10-33).

The benthic invertebrate community at *baseline* reach BRC-D1 was dominated by chironomids (82%) with subdominant taxa consisting of miscellaneous Diptera (13%) (Table 5.10-33). Chironomids were primarily of the genera *Micropsectra, Paratendipes,* and *Tanytarsus*. Several flying insects (mayflies: *Centroptilum*, *Leptophlebiidae*, and *Heptageniidae*; stoneflies: *Zapada*; and caddisflies: *Brachycentrus, Ptilostomis*) were present but sparse in 2014 (Table 5.10-33).

Temporal and Spatial Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Sawbones Creek. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal and spatial comparisons were not conducted for *test* reaches UNC-D2, UNC-D3, GRR-E1, and *baseline* reach BRC-D1 given that reaches UNC-D2, UNC-D3, and BRC-D1 have only been sampled for two years (2013 and 2014), and 2014 was the first year of sampling at *test* reach GRR-E1.

Temporal comparisons of measurement endpoints for *test* reach SAC-D1 included testing for:

- changes over time during the *test* period (Hypothesis 1, Section 3.2.3.1); and
- changes between 2014 values and the mean of all previous years of sampling.

Total abundance significantly decreased over time at *test* reach SAC-D1 and was lower in 2014 than the mean of previous years (2012 and 2013). These effects accounted for 100% and 74% of the variance in annual means, respectively (Table 5.10-34).

Comparison to Published Literature The benthic invertebrate community at *test* reach SAC-D1 had a low relative abundance of worms (<10%) in all years of sampling (2012 to 2014), and relatively high diversity of benthic fauna for a sand-bottomed creek. Chironomids were abundant and diverse; and flying insects and permanent aquatic forms were also present, indicating good water quality (Hynes 1960; Griffiths 1998; Mandeville 2001).

The benthic invertebrate community of *test* reach UNC-D2 was representative of a depositional, sand-bottomed river, with a high diversity of chironomids and low relative abundance of worms (<10%). The presence of permanent aquatic forms (amphipods, bivalves, and gastropods) and flying insects (mayflies and caddisflies) suggested good long-term water quality.

Similar to *test* reach UNC-D2, the benthic invertebrate community of *test* reach UNC-D3 was representative of a depositional, sand-bottomed river, with high abundance of chironomids. The presence of permanent aquatic forms (amphipods, bivalves, and gastropods) and flying insects (mayflies) suggested good long-term water quality.

The benthic invertebrate community of *baseline* reach BRC-D1 was representative of a depositional, sand-bottomed river, with a high diversity of chironomids and low relative abundance of worms. Abundance was relatively high, but richness was relatively low compared to the other depositional reaches on tributaries to Christina Lake (i.e., UNC-D2, UNC-D3, SAC-D1) in 2014.

2014 Results Relative to Regional *Baseline* Conditions Values of all measurement endpoints of benthic invertebrate communities at all three depositional *test* reaches (SAC-D1, UNC-D1, UNC-D3) were within the inner tolerance limits of regional *baseline* conditions for depositional reaches, with two exceptions: richness at UNC-D3 was higher than the inner tolerance limit for the 95th percentile of regional *baseline* depositional reaches; and equitability at UNC-D2 was lower than the outer tolerance limit for regional *baseline* depositional reaches (Figure 5.10-21 to Figure 5.10-23).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were classified as **Negligible-Low.** Although there were large variations in abundance, total numbers were well within the inner tolerance limits of regional *baseline* conditions for depositional reaches. None of the other measurement endpoints varied significantly, and all were within the range of regional *baseline* conditions for depositional reaches. The benthic invertebrate community of *test* reach SAC-D1 was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects.

Differences in measurement endpoints of benthic invertebrate communities at *test* reaches UNC-D2 and UNC-D3 were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of regional *baseline* depositional reaches. Richness was higher than the *baseline* range of variability in 2014 at *test* reach UNC-D3 and equitability for *test* reach UNC-D2 was just below the lower outer limit of the *baseline* range, neither of which indicated a negative change. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects.

Gregoire River

2014 Habitat Conditions Water at *test* reach GRR-E1 in fall 2014, was shallow (0.2 m), alkaline (pH: 8.0), with high dissolved oxygen (11.0 mg/L), and moderate conductivity (282 µS/cm). The substrate was primarily boulder (50%) and cobble (47%) (Table 5.10-32). Periphyton chlorophyll *a* biomass averaged 120 mg/m^2, which was within the inner tolerance limits of regional erosional *baseline* reaches (Figure 5.10-24).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach GRR-E1 was dominated by naidid worms (44%) and chironomids (36%) with subdominant taxa consisting of Ephemeroptera (12%) and Trichoptera (5%). Chironomids were primarily of the genera *Rheotanytarsus*, *Cricotopus/Orthocladius*, and *Tvetenia.* Several flying insects (mayflies*: Baetis, Ephemerella,* and *Heptageniidae*; stoneflies: *Isoperla, Skwala*, and *Taeniopteryx;* and caddisflies: *Hydropsyche, Mayatrichia, Oecetis,* and *Neureclipsis)* were present at *test* reach GRR-E1 in 2014 (Table 5.10-33).

Comparison to Published Literature The benthic invertebrate community of *test* reach GRR-E1 was representative of a healthy erosional river. Flying insects were abundant in 2014 and the percentage of EPT taxa was high. The abundance of nematodes was also high; however, this was not a cause for concern at this time.

2014 Results Relative to Regional *Baseline* Conditions Values of all measurement endpoints of benthic invertebrate communities at erosional *test* reach GRR-E1 were within the inner tolerance limits of regional *baseline* conditions for erosional reaches (Figure 5.10-25).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach GRR-E1 were classified as **Negligible-Low.** Although naidid worms accounted for a large proportion of the benthic fauna (>40%), flying insects were present in relatively high numbers.

Jackfish River

2014 Habitat Conditions Water at *test* reach JAR-E1 in fall 2014 was shallow (0.25 m in sampled areas), with fast velocity (0.85 m/s), a pH of 7.2, high dissolved oxygen (8.3 mg/L), and moderate conductivity (149 µS/cm) (Table 5.10-35). The substrate consisted primarily of small (35%) and large (32%) cobble (Table 5.10-35). Periphyton chlorophyll *a* biomass averaged 16 mg/m^2, which was lower than results from the previous two years, but within the inner tolerance limits for the range of variation for regional *baseline* conditions (Figure 5.10-26).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach JAR-E1 was dominated by Ephemeroptera (39%), Trichoptera (22%), and Chironomidae (19%) (Table 5.10-36). Mayflies were diverse (14 genera) and dominated by *Baetis, Acerpenna pygmaea* and *Ephemerella*. Trichoptera consisted primarily of *Hydopsyche*, *Oecetis, Neureclipsis* and *Chimarra*. Plecoptera (*Acroneuria abnormis, Skwala, Pteronarcys*, and *Isoperla*) were present in low relative abundances. Chironomids were diverse and represented by *Polypedilum, Lopescladius, Thienemannimyia gr*., and *Tvetenia*. Bivalvia (*Pisidium/Sphaerium*) and Gastropoda (*Ferrissia rivularis and Gyraulus*) were present in low relative abundances.

Temporal and Spatial Comparisons A single temporal comparison was conducted for *test* reach JAR-E1 to assess the differences in mean values of measurement endpoints between 2014 and the two previous years (2012 and 2013).

Richness was significantly higher in 2014 compared to the mean of the two previous years, accounting for 62% of the variance in annual means (Table 5.10-37). The percentage of EPT taxa was significantly higher in 2014 compared to the mean of the two previous years, accounting for 88% of the variance in annual means (Table 5.10-37).

Comparison to Published Literature The benthic invertebrate community of *test* reach JAR-E1 contained a benthic fauna that reflected good water and sediment quality. The percentage of the community as worms was low (~5%) and the percentage of EPT taxa was generally high. The presence of permanent aquatic organisms such as bivalves and gastropods in the reach was indicative of good long-term water quality. The dominant forms of Chironomidae present are known to represent fair to good water quality (Mandeville 2002). For example, the chironomid *Rheotanytarsus* tends to occur in rocky streams with good flows (Merritt and Cummins 1996).

2014 Results Relative to Regional *Baseline* Conditions Abundance at *test* reach JAR-E1 has exceeded the inner tolerance limit for the upper 95th percentile for regional *baseline* erosional reaches for the past three years (Figure 5.10-27). In 2014, abundance approached, but did not exceed the outer tolerance limit for regional *baseline* conditions of erosional reaches. Taxa richness (43 taxa per sample, on average) and the percentage of EPT taxa were also high, relative to regional *baseline* conditions, but were within the inner tolerance limit for their normal ranges (Figure 5.10-27). CA Axis 1 and 2 scores were within the range of variation for *baseline* erosional reaches (Figure 5.10-28). The high richness and percent EPT taxa indicated that the habitat of Jackfish River was of good quality.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach JAR-E1 were classified as **Negligible-Low** because the community was highly diverse, and the statistically significant increases in richness and percentage of EPT taxa in 2014 were considered to be positive changes.

Christina Lake

2014 Habitat Conditions Water in Christina Lake in fall 2014 had a pH of 7.05 and moderate conductivity (173 µS/cm) (Table 5.10-38). Samples were collected at a depth of 1.1 m. The substrate of Christina Lake consisted primarily of sand (92%) with small amounts of silt and clay, and low organic carbon content (2.1%) (Table 5.10-38).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Christina Lake at *test* station CHL-1 in fall 2014 was dominated by chironomids (20%), Amphipoda (17%), and Nematoda (16%) with subdominant taxa consisting of tubificid worms (14%) and naidid worms (13%) (Table 5.10-39). Nineteen kinds of chironomids were present in Christina Lake in fall 2014, with *Pseudochironomus*, *Stictochironomus,* and *Procladius* as the most common. Amphipods included *Hyalella azteca* and *Gammarus lacustris*, both of which are commonly distributed in Canada (Väinölä et al. 2008). Bivalves (*Pisidium/Sphaerium*) were present and gastropods were relatively diverse and primarily composed of the following families: Hydrobiidae, Planorbidae, and Valvatidae. Ephemeroptera (*Caenis, Ephemera,* and *Leptophlebidae*) were present as were four types of caddisfly (*Molanna, Mystacides, Oecetis,* and Limnephillidae). A few individual dragonflies (Gomphidae) and damselflies (*Enallagma*) were also present at *test* station CHL-1.

Temporal Comparisons Two temporal comparisons were conducted for Christina Lake at *test* station CHL-1 in 2014 and included testing for:

- changes over time in values of measurement endpoints (Hypothesis 7, Section 3.2.3.1); and
- a difference between in values of measurement endpoints in 2014 and the two previous years of sampling.

Abundance, richness, equitability, and the percentage of EPT taxa decreased over time and were lower in 2014 than the mean of the two previous years of sampling. These changes explained greater than 20% of the variance in annual means (Table 5.10-40).

Comparison to Published Literature The benthic invertebrate community of Christina Lake was diverse, and contained several forms typical of sandy-nearshore lake environments, including two kinds of amphipods, two genera of fingernail clam, and several kinds of snails (gastropods) (Table 5.10-39). The presence of several large insects such as Ephemeroptera, Odonata (though in low relative abundances), and Trichoptera in Christina Lake indicated that the benthic habitat of Christina Lake was in good condition.

2014 Results Relative to Historical Conditions The benthic invertebrate community of Christina Lake in 2014 was somewhat different than the previous two years; chironomid abundance was lower in 2014 and naidid and tubificid worm abundance was higher. Permanent aquatic forms (bivalves, gastropods, amphipods) were present in all three years. Mayflies and caddisflies were present with a healthy diversity during all three years. Abundance, richness, equitability, and percent EPT taxa were lower in 2014 than the mean of previous years of sampling (Figure 5.10-29). CA axis 1 scores were similar between all three years, but CA axis 2 scores were lower in 2013 and 2014 relative to 2012 (Figure 5.10-30).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* station CHL-1 in fall 2014 were classified as **Moderate** (Table 5.10-1) because several measurement endpoints (richness, abundance, EPT taxa) were lower than the previous two years, indicating a potential negative change. However, the lake still contained a diverse benthic fauna that included several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies, and caddisflies).

Gregoire Lake

2014 Habitat Conditions Water in Gregoire Lake in the fall of 2014 was slightly alkaline (pH=7.89), with low conductivity (119 µS/cm) (Table 5.10-41). Samples were collected at a depth of 1.2 m. The substrate of Gregoire Lake consisted primarily of sand (94%), and low organic carbon content (<1%) (Table 5.10-41).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Gregoire Lake at *test* station GRL-1 in fall 2014 was dominated by chironomids (58%), amphipods (*Hyalella Azteca*; 13%), bivalves (11%), and nematodes (7%) (Table 5.10-42). Chironomids were composed of 13 taxa; however, *Stichtochironomus* was the most abundant, followed by *Polypedilum* and *Cryptochironomus*. Though gastropods were absent from Gregoire Lake, fingernail clams (*Pisidium/Sphaerium*) were plentiful. EPT taxa were sparse, but present in the lake (Ephemeroptera: *Ephemera* and *Leptophlebia*; Trichoptera: *Helicopsyche, Lepidostoma, Mystacides,* and *Molanna*).

Comparison to Published Literature The benthic invertebrate community of Gregoire Lake reflected generally good water quality and lentic (lake-like) conditions. The community contained high relative abundances of permanent aquatic forms such as Amphipoda (13%), fingernail clams (Bivalvia: *Sphaeriidae*), and gastropods and included the presence of EPT taxa, which are consistent with good long-term water quality (Niemi et al. 1990; Pennak 1989).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* station GRL-1 in fall 2014 were classified as **Negligible-Low** given that amphipods, chironomids, and bivalves were abundant, the abundance of worms was relatively low, and there were no concerns regarding the water quality of *test* station GRL-1 in 2014.

5.10.4.2 Sediment Quality

Sediment quality was sampled in depositional reaches of the Christina River watershed in the same locations as benthic invertebrate community sampling in fall 2014:

- *test* station CHR-D1 on the Christina River at the mouth of the river, sampled since 2002;
- *test* station CHR-D2 on the Christina River upstream of Janvier, sampled since 2002;
- *test* station CHR-D3 on the Christina River upstream of Jackfish River, sampling initiated in 2014;
- *baseline* station CHR-D4 on the Christina River upstream of development, sampled since 2013;

- *baseline* station BRC-D1 on Birch Creek, sampled since 2013;
- *test* station SAC-D1 on Sawbones Creek, sampled since 2012;
- *test* station SUC-D1 on Sunday Creek at the inlet into Christina Lake, sampled since 2012;
- *baseline* station SUC-D2 on Sunday Creek upstream, sampled since 2013;
- *test* station UNC-D2 on Unnamed Creek, east of Christina Lake, sampled since 2013;
- *test* station UNC-D3 on Unnamed Creek, south of Christina Lake, sampled since 2013;
- *test* station CHL-1 on Christina Lake, sampled since 2012; and
- *test* station GRL-1 on Gregoire Lake, sampling initiated in 2014.

Temporal Trends The following significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected in fall 2014:

- Decreasing concentrations of total PAHs at *test* stations CHR-D1 and CHR-D2;
- A decreasing concentration of total normalized PAHs at *test* stations CHR-D1;
- Decreasing values of the hazard index at *test* stations CHR-D1 and CHR-D2;
- Decreasing concentrations of total metals, total arsenic, and total parent PAHs at *test* stations CHR-D2; and
- Decreasing concentrations of total alkylated PAHs at *test* stations CHR-D1 and CHR-D2.

Due to insufficient data (n<5), no trend analyses were conducted on *baseline* stations BRC-D1, CHR-D4, SUC-D2, and *test* stations CHR-D3, CHL-1, GRL-1, SAC-D1, SUC-D1, UNC-D2, and UNC-D3.

2014 Results Relative to Historical Concentrations Sediment sampling at stations BRC-1, CHR-D3, CHR-D4, CHL-1, GRL-1, SUC-D2, UNC-D2, and UNC-D3 was initiated in either 2012 or 2013; therefore, no historical comparisons were possible for these stations.

In fall 2014, sediments at stations of the Christine River (*test* stations CHR-D1, CHR-D2, and CHR-D3, and *baseline* station CHR-D4) were predominantly composed of sand, with generally low concentrations of total organic carbon, PAHs, and hydrocarbons (Table 5.10-43 to Table 5.10-46). All sediment quality measurements endpoints at *test* station CHR-D1 were within the range of previously-measured concentrations, with the exception of naphthalene, which was below the previously-measured minimum concentration (Table 5.10-43). Concentrations of hydrocarbons at *test* station CHR-D2 were within previously-measured results, while some PAH concentrations, including naphthalene, total PAHs, total parent PAHs, total alkylated PAHs, and the predicted PAH toxicity were below previously-measured minimum concentrations (Table 5.10-44). Toxicity tests at all four stations showed high *Hyalella* survival rates (92%, 100%, 90%, and 98%, respectively) and slightly lower *Chironomus* survival (88%, 80%, 74%, and 83%, respectively) (Table 5.10-43 to Table 5.10-46). Toxicity results for *test* stations CHR-D1 and CHR-D2 were within the range of previously-measured values.

Sediments at Birch Creek (*baseline* station BRC-D1) were predominantly composed of sand (88.2%), while sediments at *test* station SAC-D1 (Sawbones Creek) were mainly composed of silt (50.3%) (Table 5.10-47 and Table 5.10-48). In general, sediments at both stations had low concentrations of total organic carbon, PAHs, and hydrocarbons. Toxicity tests at both stations showed higher *Hyalella* survival (94% at BRC-D1 and 90% at SAC-D1) than *Chironomus* survival (66% at BRC-D1 and 88% at SAC-D1), but higher *Chironomus* growth than *Hyalella* growth (Table 5.10-47 and Table 5.10-48).

Sediments at *test* station SUC-D1 and *baseline* station SUC-D2 of Sunday Creek were predominantly composed of sand (98% and 94.2%, respectively), similar to 2012 and 2013 (Table 5.10-49 and Table 5.10-50). Sediments at both stations generally had low concentrations of total organic carbon, PAHs, and hydrocarbons. *Hyalella* survival at stations SUC-D1 and SUC-D2 (98% and 94%, respectively) was higher than *Chironomus* survival (80% and 90%, respectively) (Table 5.10-49 and Table 5.10-50).

Sediments at *test* station UNC-D2 and *test* station UNC-D3 (Unnamed Creeks flowing in Christina Lake) in fall 2014 were predominantly composed of sand (93% and 98.1%, respectively), similar to 2013 (Table 5.10-51 and Table 5.10-52). Sediments at both stations generally had low concentrations of total organic carbon, PAHs, and hydrocarbons. Toxicity tests at both stations showed high *Hyalella* survival (96% at UNC-D2 and 98% at UNC-D3) and slightly lower *Chironomus* survival (88% at UNC-D2 and 84% at UNC-D3) (Table 5.10-51 and Table 5.10-52).

Sediments at Christina Lake (*test* station CHL-1) and Gregoire Lake (*test* station GRL-1) were predominantly composed of sand (77.6% and 88.8%, respectively), with generally low concentrations of PAHs (Table 5.10-53 and Table 5.10-54). Sediment at *test* station GRL-1 exhibited low concentrations of total hydrocarbons relative to other locations, while hydrocarbon concentrations at *test* station CHL-1 were higher than observations in 2012 and 2013. Toxicity tests showed high *Hyalella* (90%) and *Chironomus* (86%) survival at *test* station GRL-1, and lower survival of both *Hyalella* (68%) and *Chironomus* (80%) at *test* station CHL-1 (Table 5.10-53 and Table 5.10-54).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines The following concentrations exceeded the applicable CCME guidelines:

- Concentrations of F1 hydrocarbons exceeded the guideline of 30 mg/kg at *test* station SAC-D1;
- Concentrations of F3 hydrocarbons exceeded the threshold value of 300 mg/kg and PAH toxicity exceeded the threshold value of 1.0 at *test* station CHR-D1; and
- Concentrations of F1 and F3 hydrocarbons and total arsenic exceeded the relevant guidelines at *test* station CHL-1.

No sediment quality measurement endpoints in fall 2014 exceeded relevant CCME sediment quality guidelines at *test* stations CHR-D2, CHR-D3, GRL-1, SUC-D1, UNC-D2, UNC-D3, or at *baseline* stations BRC-D1, CHR-D4, and SUC-D2 (Table 5.10-43 to Table 5.10-54).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of all sediment quality measurement endpoints were with the range of regional *baseline* concentrations (Figure 5.10-31 to Figure 5.10-40), with the exception of:

- total PAHs (absolute) and PAH Hazard Index values at *test* station CHR-D2, *baseline* station CHR-D4, *test* station SUC-D1, and *test* station UNC-D3, which were below the 5th percentile of regional *baseline* concentrations;

- total metals normalized to percent fines at *test* station CHR-D4, which exceeded the 95th percentile of regional *baseline* concentrations; and

- total metals normalized to percent fines at *test* station SAC-D1, which was below the 5th percentile of regional *baseline* concentrations.

Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) and Gregoire Lake (GRL-1) because lakes were not included in the calculation of *baseline* concentrations, given the ecological differences between lakes and rivers (Figure 5.10-41 and Figure 5.10-42).

Sediment Quality Index SQI values for all stations in fall 2014 indicated **Negligible-Low** differences in sediment quality conditions from regional *baseline* conditions (Table 5.10-55). No SQI value was calculated for Christina Lake and Gregoire Lake because lakes were not compared to regional *baseline* conditions.

Classification of Results In fall 2014, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations, except total PAHs (absolute) and PAH hazard index values at *test* stations CHR-D2, CHR-D4, SUC-D1, and UNC-D3, which were below regional *baseline* ranges. Sediment quality at all stations in fall 2014 indicated **Negligible-Low** differences compared to regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) and Gregoire Lake (GRL-1) because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012 and 2013.

5.10.5 Fish Populations

In 2014, fish population monitoring in the Christina River watershed consisted of fish assemblage monitoring at reaches of the Christina River and tributaries to the Christina River and Christina Lake. Each of these reaches were co-located with benthic invertebrate reaches (Figure 5.10-2).

5.10.5.1 Fish Assemblage Monitoring

Christina River Mainstem

Fish assemblages were sampled in fall 2014 on the Christina River at:

- *test* reach CHR-F1 of the lower Christina River, sampled only in 2012;

- *test* reach CHR-F2 of the middle Christina River, sampled only in 2012;

- *test* reach CHR-F3 above Jackfish River, sampled since 2013; and

- *baseline* reach CHR-F4 of the upper Christina River, sampled since 2013.

2014 Habitat Conditions *Test* reach CHR-F1 was comprised of riffle and run habitat with a wetted width of 81.0 m and a bankfull width of 87.2 m. The substrate was comprised entirely of coarse gravel. Water at *test* reach CHR-F1 had a mean depth of 0.64 m with high velocity (mean=0.85 m/s), was slightly alkaline (pH: 8.71), with moderate conductivity (361 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 12.6˚C. Instream cover was dominated by boulders (Table 5.10-56).

Test reach CHR-F2 was comprised of run habitat with a wetted width of 36.5 m and a bankfull width of 57.5 m. The substrate was comprised entirely of sand. Water at *test* reach CHR-F2 had a mean depth of 0.71 m with moderate velocity (mean=0.41 m/s), was slightly alkaline (pH: 8.16), with moderate conductivity (256 µS/cm), high dissolved oxygen (10.0 mg/L), and a temperature of 8.6˚C. Instream cover was comprised of small woody debris (Table 5.10-56).

Test reach CHR-F3 was comprised of run habitat with a wetted width of 38.5 m and a bankfull width of 43.5 m. The substrate was comprised primarily of cobble with some small boulders. Water at *test* reach CHR-F3 had a mean depth of 0.61 m with moderate velocity (mean=0.35 m/s); was alkaline (pH: 7.78), with moderate conductivity (294 µS/cm), moderate dissolved oxygen (9.2 mg/L), and a temperature of 12.1˚C. Instream cover was dominated by boulders with small amounts of small woody debris and algae (Table 5.10-56).

Baseline reach CHR-F4 was comprised of run habitat, with a wetted width of 16.5 m and a bankfull width of 18.3 m. The substrate was comprised of fine material with some cobble. Water at *baseline* reach CHR-F4 had a mean depth of 0.72 m with slow velocity (mean=0.20 m/s), was alkaline (pH: 7.79), with moderate conductivity (275 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 10.8˚C. Instream cover was dominated by undercut banks and boulders with small amounts overhanging vegetation, and small woody debris (Table 5.10-56).

Relative Abundance of Fish Species The total catch of fish species at *test* reach CHR-F1 was higher in 2014 compared to 2012 and was dominated by lake chub (35%), burbot (28%), and longnose dace (26%) (Table 5.10-57). Only 11 fish were captured at *test* reach CHR-F2, which was lower than the total catch in 2012. The species composition was dominated by burbot (46%) and northern pike (36%). The total catch of fish species at *baseline* reach CHR-F3 was lower in 2014 compared to 2013 and dominated by slimy sculpin (40%). Similarly, the total catch also decreased at *baseline* reach CHR-F4 and the species composition was dominated by pearl dace (42%) and white sucker (36%) (Table 5.10-57).

Temporal and Spatial Comparisons Sampling was carried out for only two years at all reaches in the Christina River mainstem; therefore, temporal comparisons were only made between the two years of data for each reach. Spatial comparisons were conducted between *baseline* reach CHR-F4 and each of the *test* reaches. Given that only two years of data exists, statistical comparisons were not performed.

With the exception of diversity, all measurement endpoints exhibited a change in a positive direction (increase in abundance, CPUE, and richness, and a decrease in ATI) at *test* reach CHR-F1 compared to 2012 (Table 5.10-58, Figure 5.10-43). Total richness and ATI exhibited a decrease from 2012 to 2014 at *test* reach CHR-F2 (Figure 5.10-44). The lower ATI value was likely due the higher proportion of burbot in the catch in 2014. Abundance, CPUE, richness, and diversity decreased and ATI increased from 2013 to 2014 at *test* reach CHR-F3 (Figure 5.10-43). All measurement endpoints, with the exception of diversity, decreased from 2013 to 2014 at *baseline* reach CHR-F4, indicating similar patterns across reaches (Table 5.10-58, Figure 5.10-43, and Figure 5.10-44).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the Athabasca oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of 20 fish species were recorded in the Christina River; whereas JOSMP found only 15 species from 2012 to 2014. Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., JOSMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder (2004).

Golder (2004) documented riffle and run habitat with a moderate flow and substrate consisting of sand, gravel, cobble, and boulders in the Christina river, which was consistent with habitat conditions documented in 2014 the three *test* reaches (Table 5.10-56). The Christina River provides good habitat for refugia and spawning fish migrating from the Clearwater River and; therefore, has a high potential to support recreational fisheries (Golder 2004). The upper portion of the Christina River (location of *baseline* reach CHR-F4) has different habitat consisting of deeper depositional areas, unlike habitat observed further downstream.

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reaches CHR-F1 and CHR-F3 were within the inner tolerance limits of regional *baseline* conditions (Figure 5.10-43). Abundance and CPUE for *test* reach CHR-F2 were below the inner tolerance limit for the 5^{th} percentile or regional *baseline* conditions (Figure 5.10-44).

Classification of Results Differences in measurement endpoints for *test* reaches CHR-F1 and CHR-F3 were classified as **Negligible-Low** because all measurement endpoints were within the range of *baseline* variability (Table 5.10-1). Differences in measurement endpoints for *test* reach CHR-F2 were also classified as **Negligible-Low** because only two measurement endpoints (abundance and CPUE) were below the range of *baseline* variability (Table 5.10-1).

Christina River Tributaries

Fish assemblages were sampled in fall 2014 in tributaries that flow into the Christina River, including:

- *test* reach GRR-F1 on the Gregoire River, sampled for the first time in 2014; and
- *test* reach JAR-F1 on the Jackfish River, sampled since 2012 (Jackfish River is also the outlet from Christina Lake).

2014 Habitat Conditions *Test* reach GRR-F1 was comprised of riffle and run habitat with a wetted width of 16.1 m and a bankfull width of 32.4 m. The substrate was comprised primarily of cobble with some small boulders. Water at *test* reach GRR-F1 had a mean depth of 0.32 m, with moderate velocity (mean=0.34 m/s), was alkaline (pH: 8.54), with moderate conductivity (295 µS/cm), high dissolved oxygen (9.0 mg/L), and a temperature of 11.3˚C. Instream cover was comprised of boulders with small amounts of small woody debris (Table 5.10-59).

Test reach JAR-F1 was comprised of riffle and run habitat with a wetted width of 32.8 m and a bankfull width of 35.3 m. The substrate was dominated by cobble with small amounts of coarse gravel. Water at *test* reach JAR-F1 had a mean depth of 0.47 m with negligible velocity, was alkaline (pH: 8.36), with moderate conductivity (175 µS/cm), moderate dissolved oxygen (8.8 mg/L), and a temperature of 9.8˚C. Instream cover was comprised of boulders with small amounts of algae (Table 5.10-59).

Relative Abundance of Fish Species The total catch of fish species at *test* reach GRR-F1 was 86 fish and was dominated by longnose dace (64%) (Table 5.10-60). The total catch of fish species at *test* reach JAR-F1 was higher in 2014 compared to previous years and was dominated by burbot (46%). The species composition at this reach was consistent with 2012 and 2013.

Temporal and Spatial Comparisons Temporal and spatial comparisons were not conducted for *test* reach GRR-F1 given that 2014 was the first year of monitoring and there was no upstream *baseline* reach on the Gregoire River.

Temporal comparisons were conducted for *test* reach JAR-F1 from 2012 to 2014. There were no spatial comparisons conducted for *test* reach JAR-F1 given there was no upstream *baseline* reach on the Jackfish River. All measurement endpoints increased in 2014 compared to 2013 at *test* reach JAR-F1. The increase in ATI indicated a greater proportion of more tolerant fish species in the assemblage as reflected by the presence of white sucker, walleye, and northern pike in the catch in 2014 (Table 5.10-58).

Comparison to Published Literature *Baseline* information for the area was limited to data in the AESRD FWMIS (Fisheries and Wildlife Management Information System) database (AESRD 2012). Arctic grayling, burbot, longnose sucker, northern pike, slimy sculpin, walleye, and white sucker have been documented in Jackfish River. All of these species were captured by JOSMP from 2012 to 2014 as well as two additional species (longnose dace and trout-perch) not previously documented. Lake chub, northern pike, spottail shiner, and walleye have been documented in Gregoire River. Sampling in 2014 by JOSMP only documented one species (lake chub) that was consistent with historical surveys; however, JOSMP captured five additional species (burbot, longnose dace, longnose sucker, slimy sculpin, and white sucker), which have not been previously documented.

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurements in 2014 at *test* reach GRR-F1 were within the inner tolerance limits of the *baseline* range of variability (Figure 5.10-43). Mean values of richness and diversity exceeded the inner tolerance limit of the 95^{th} percentile and abundance was below the inner tolerance limit of the 5^{th} percentile of the *baseline* range of variability for *test* reach JAR-F1 (Figure 5.10-44).

Classification of Results Differences in measurement endpoints for *test* reach GRR-F1 were classified as **Negligible-Low** because all measurement endpoints were within the *baseline* range of variability. Differences in measurement endpoints for *test* reach JAR-F1 were classified as **Negligible-Low** because although diversity and richness exceeded the *baseline* range of variability, this was indicative of a positive change in the fish assemblage. Only abundance was below the *baseline* range of variability, indicating a potential negative change in the fish assemblage.

Christina Lake Tributaries

Fish assemblages were sampled in fall 2014 at:

- *test* reach SUC-F1 on Sunday Creek, sampled since 2012;
- *baseline* reach SUC-F2 on Sunday Creek, sampled since 2013;
- *test* reach UNC-F2 on an unnamed creek east of Christina Lake, sampled since 2013;
- *test* reach UNC-F3 on an unnamed creek south of Christina Lake, sampled since 2013;
- *test* reach SAC-F1 on Sawbones Creek, sampled since 2012; and
- *baseline* reach BRC-F1 on Birch Creek, sampled since 2013.

2014 Habitat Conditions *Test* reach SUC-F1 was comprised of run habitat with a wetted width of 9.0 m and a bankfull width of 11.9 m. The substrate was comprised of sand with small sections of cobble. Water at *test* reach SUC-F1 had a mean depth of 0.77 m, slow velocity (mean=0.23 m/s), a pH of 8.36, moderate conductivity (288 µS/cm), and a temperature of 13.2˚C. Instream cover consisted of boulders with small amounts of macrophytes (Table 5.10-61).

Baseline reach SUC-F2 was comprised of run habitat with a wetted width of 6.7 m and a bankfull width of 7.0 m. The substrate was comprised of sand and fine material with some cobble. Water at *baseline* reach SUC-F2 had a mean depth of 0.83 m with almost negligible velocity (mean=0.02 m/s), a pH of 7.65, moderate conductivity (239 µS/cm), moderate dissolved oxygen (8.8 mg/L), and a temperature of 11.3˚C. Instream cover consisted of overhanging vegetation with undercut banks with some small woody debris (Table 5.10-61).

Test reach UNC-F2 was comprised of run habitat with a wetted width of 5.8 m and a bankfull width of 7.0 m. The substrate was comprised of fine material with small proportions of sand. Water at *test* reach UNC-F2 had a mean depth of 0.82 m, slow velocity (mean=0.05 m/s), a pH of 8.59, moderate conductivity (247 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 9.4˚C. Instream cover consisted of macrophytes with some undercut banks and overhanging vegetation (Table 5.10-61).

Test reach UNC-F3 was comprised of run habitat with a wetted width of 3.8 m and a bankfull width of 5.5 m. The substrate was comprised of sand with some fine material. Water at *test* reach UNC-F3 had a mean depth of 0.73 m, with almost negligible velocity (mean=0.03 m/s), a pH of 8.22, moderate conductivity (286 µS/cm), moderate dissolved oxygen (8.1 mg/L), and a temperature of 12.9˚C. Instream cover consisted of small woody debris with some undercut banks, overhanging vegetation, and macrophytes (Table 5.10-61).

Test reach SAC-F1 was comprised of run habitat with a wetted and bankfull width of 5.3 m. The substrate was comprised of fine material with small amounts of coarse gravel. Water at *test* reach SAC-F1 had a mean depth of 1.75 m, with almost negligible velocity (mean=0.01 m/s), a pH of 7.34, low conductivity (110 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 7.5 ˚C. Instream cover consisted of macrophytes with small amounts of overhanging vegetation, undercut banks, and woody debris (Table 5.10-61).

Baseline reach BRC-F1 was comprised of run habitat with a wetted width of 10.0 m and a bankfull width of 13.0 m. The substrate was comprised entirely of fine material. Water at *baseline* reach BRC-F1 had a mean depth of 0.99 m, negligible velocity, a pH of 8.04, high conductivity (335 µS/cm), moderate dissolved oxygen (8.4 mg/L), and a temperature of 11.4˚C. Instream cover consisted of overhanging vegetation and undercut banks with some live trees/roots and large woody debris (Table 5.10-61).

Relative Abundance of Fish Species The total catch of fish species at *test* reach SUC-F1 was higher in 2014 compared to 2013 by 34 fish and was dominated by slimy sculpin (62%), which was consistent with previous years (Table 5.10-62). The total catch of fish species was lower at *baseline* reach SUC-F2, both compared to *test* reach SUC-F1 and compared to 2013, and was dominated by white sucker (92%). Only two and eight fish were captured at *test* reaches UNC-F2 and UNC-F3, respectively; and both reaches were dominated by northern pike (>63%). There were no fish captured at *test* reach SAC-F1 in 2013 and 2014, and only a single northern pike was captured in 2012. Similarly, only one fish (slimy sculpin) was captured at *baseline* reach BRC-F1 in fall 2014.

Temporal and Spatial Comparisons Temporal comparisons were conducted from 2012 to 2014 for *test* reaches SUC-F1 and SAC-F1; all other reaches were compared between 2013 and 2014. Spatial comparisons were conducted between *test* reach SUC-F1 and *baseline* reach SUC-F2; and *test* reaches SAC-F1, UNC-F2, and UNC-F3, and *baseline* reach BRC-F1.

Abundance and CPUE were higher at *test* reach SUC-F1 in 2014 compared to 2012 and 2013 (Table 5.10-58, Figure 5.10-45). In addition, abundance, richness, and diversity were higher and ATI was lower at *test* reach SUC-F1 compared to *baseline* reach SUC-F2 in 2014.

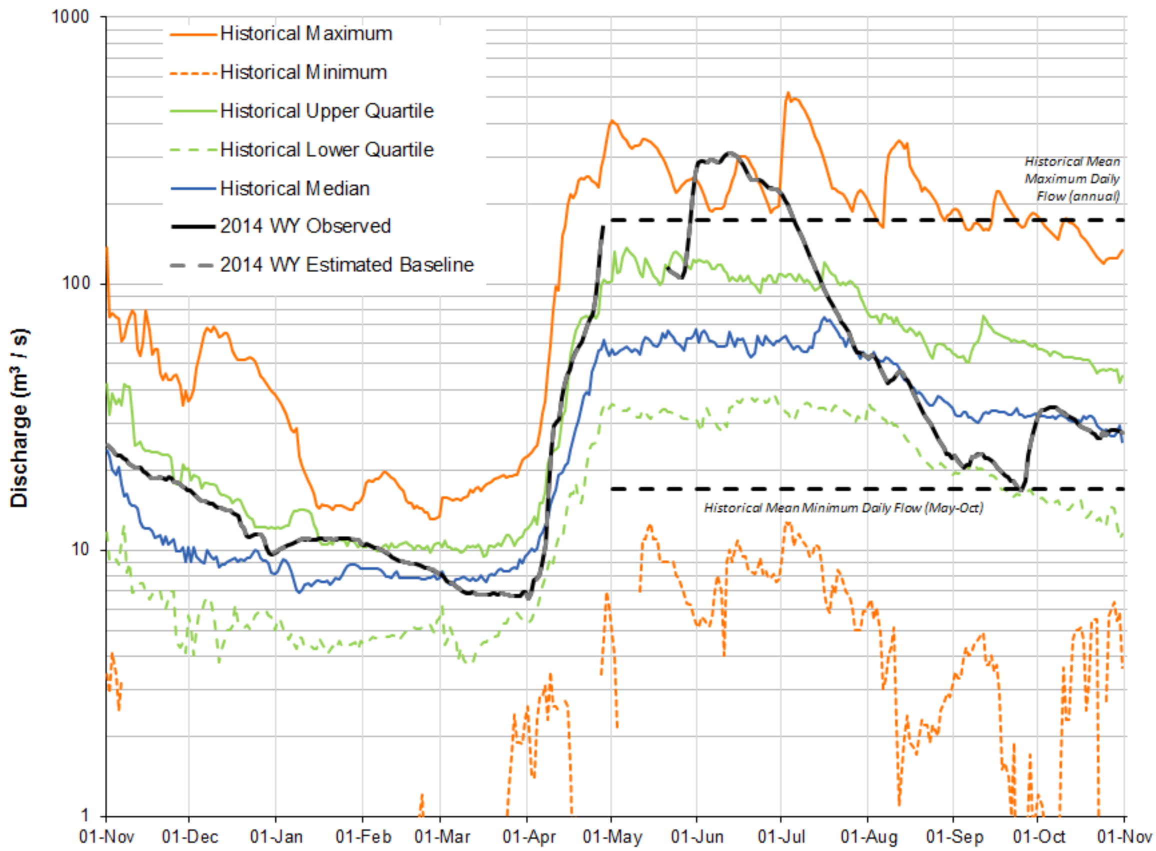
Given there were no fish captured at *test* reach SAC-F1 in 2013 and 2014, all measurement endpoints were consistently low and ATI could not be calculated (Table 5.10-58). There was also very low abundance, richness, diversity, and CPUE at *test* reaches UNC-F2, and UNC-F3 (Table 5.10-58). It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. An effort was made in 2014 to find better fish habitat in these creeks; however, it was apparent that these creeks exhibited similar habitat conditions along the entire length of the watercourse that was accessible by Argo and boat.

Comparison to Published Literature *Baseline* information for the area was limited to data in the AESRD FWMIS database (AESRD 2012). Previous studies at Sunday Creek have documented Arctic grayling, brook stickleback, Iowa darter, lake whitefish, northern pike, slimy sculpin, spottail shiner, walleye, spoonhead sculpin, and white sucker. Six of these ten species were captured at *test* reach SUC-F1 by JOSMP from 2012 to 2014 in addition to three species not previously documented including longnose sucker, lake chub, and pearl dace. There was no previous information for the unnamed creeks where *test* reaches UNC-F2 and UNC-F3 were located.

2014 Results Relative to Regional *Baseline* Conditions Mean values of measurement endpoints for *test* reach SUC-F1 were within the inner tolerance limits for the range of *baseline* variability (Figure 5.10-45). Mean values of all measurement endpoints, with the exception of abundance, were below (diversity, CPUE, richness) or above (ATI) the inner tolerance limits for the *baseline* range of variability at *test* reach UNC-F3 (Figure 5.10-45). Mean values of all measurement endpoints for *test* reach SAC-F1 and UNC-F2 were below the inner tolerance limit for the 5th percentile of *baseline* variability, with the exception of ATI. (Figure 5.10-46).

Classification of Results Differences in measurement endpoints for fish assemblages for *test* reach SUC-F1 were classified as **Negligible-Low** because all measurement endpoints within the range of *baseline* variability. Differences in measurement endpoints for fish assemblages at *test* reaches SAC-F1, UNC-F2, and UNC-F3 were classified as **High** because all measurement endpoints were near or below the *baseline* range of variability due to low or no catch of fish at these reaches.

Figure 5.10-3 The observed *test* hydrograph and estimated *baseline* hydrograph for the mouth of the Christina River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Christina River near the mouth, Station S47A. The upstream drainage area is 13,038 km². Historical data included estimated values from 1967 to 2011 and recorded data from 2012 to 2013. The estimated historical data from 1967 to 2011 were calculated from the difference between the measured flow at Clearwater River above Christina River, WSC Station 07CD005 and Clearwater River above Draper, WSC Station 07CD001.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.10-2 Estimated water balance for the mouth of the Christina River, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**1,643.426**	**Observed discharge at Christina River near the mouth (JOSMP Station S47A)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-1.764	Estimated 14.0 km^2 of the Christina River watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	3.113	Estimated 123.6 km^2 of the Christina River watershed with oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Christina River watershed, relative to the estimated *baseline* hydrograph	-0.298	Water withdrawn by Nexen, Statoil, MEG, and Canadian Natural, not including the period of April 29 to May 20
Water releases into the Christina River watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**1,642.375**	**Estimated *baseline* discharge at Christina River near the mouth, JOSMP Station S47A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	1.051	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**0.064**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table were presented to three decimal places.

Note: Observed volume of water discharged was calculated using available data for November 1 to October 31, 2014 for Christina River near the mouth, JOSMP Station S47A.

Table 5.10-3 Calculated change in hydrologic measurement endpoints for the mouth of the Christina River, 2014 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	96.538	96.466	0.075%
Mean winter discharge	12.069	12.074	-0.044%
Annual maximum daily discharge	308.332	308.091	0.075%
Open-water season minimum daily discharge	16.799	16.795	0.075%

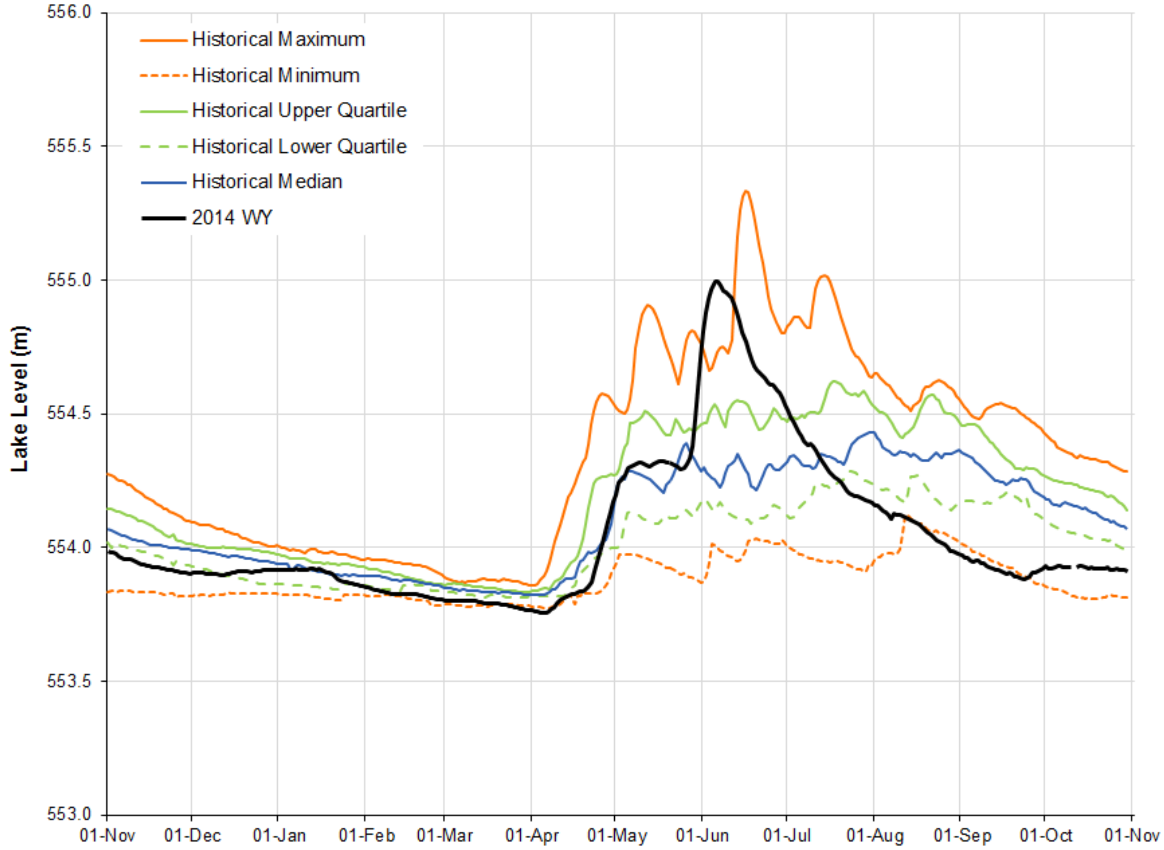
Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from JOSMP Station S47A.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

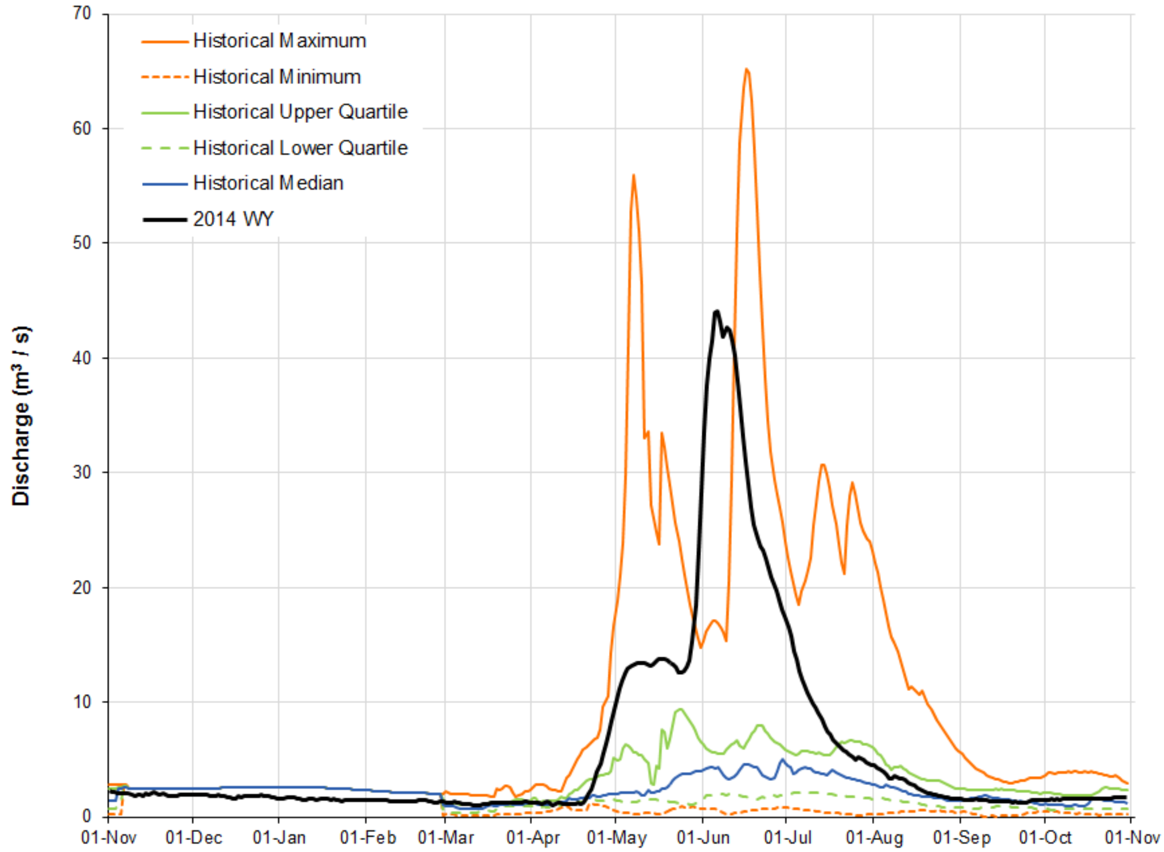
Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.10-4 Observed lake level of Christina Lake near Winfred Lake in the 2014 WY, compared to historical values.



Note: Based on provisional 2014 WY data recorded at Christina Lake near Winfred Lake WSC Station 07CE906. Historical values were calculated for the period from 2001 to 2013.

Figure 5.10-5 Hydrograph for Jackfish River below Christina Lake for the 2014 WY, compared to historical values.



Note: Based on provisional 2014 WY data recorded at Jackfish River below Christina Lake, JOSMP Station S56. Historical values were calculated for the period from 1982 to 1995 from WSC Station 07CE005 and JOSMP Station S56 for 2013.

Table 5.10-4 Concentrations of water quality measurement endpoints, mouth of Christina River (*test* station CHR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.12	12	8.10	8.30	8.40
Total suspended solids	mg/L	-	31	12	<3	26	123
Conductivity	µS/cm	-	431	12	210	293	375
Nutrients							
Total dissolved phosphorus	mg/L	-	0.005	12	0.017	0.024	0.054
Total nitrogen	mg/L	-	0.58	12	0.60	0.98	1.80
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	17.1	12	14.0	19.7	25.3
Ions							
Sodium	mg/L	-	43.4	12	12.8	24.0	34.0
Calcium	mg/L	-	35.0	12	22.0	26.9	30.9
Magnesium	mg/L	-	9.50	12	6.96	8.20	9.42
Chloride	mg/L	120	47.9	12	9.5	23.0	41.0
Sulphate	mg/L	309	9.80	12	2.20	6.71	8.49
Total dissolved solids	mg/L	-	271	12	140	193	250
Total alkalinity	mg/L	-	128	12	86	111	120
Selected metals							
Total aluminum	mg/L	0.1	**1.18**	12	**0.24**	**0.68**	**3.23**
Dissolved aluminum	mg/L	0.05	0.008	12	0.007	0.011	0.029
Total arsenic	mg/L	0.005	0.0010	12	0.0007	0.0011	0.0018
Total boron	mg/L	1.2	0.084	12	0.027	0.054	0.074
Total molybdenum	mg/L	0.073	0.00040	12	0.00016	0.00038	0.00044
Total mercury (ultra-trace)	ng/L	5, 13	2.10	11	1.20	1.30	6.00
Total strontium	mg/L	-	0.161	12	0.078	0.127	0.150
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.68	3	0.02	0.03	0.33
Oilsands Extractable	mg/L	-	0.80	3	0.37	0.48	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	1.66	3	2.01	<2.07	3.44
Total dibenzothiophenes	ng/L	-	19.77	3	6.01	16.30	52.14
Total PAHs	ng/L	-	138.5	3	148.1	154.6	316.3
Total Parent PAHs	ng/L	-	14.98	3	19.45	20.38	23.48
Total Alkylated PAHs	ng/L	-	123.5	3	124.7	135.2	295.9
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total chromium	mg/L	0.001	**0.0016**	12	0.0005	**0.0011**	**0.0037**
Total iron	mg/L	0.3	**1.59**	12	0.78	**1.55**	**3.81**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.10-5 Concentrations of water quality measurement endpoints, middle Christina River (*test* station CHR-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.49	12	7.90	8.20	8.35
Total suspended solids	mg/L	-	<3	12	<3	8	30
Conductivity	µS/cm	-	<u>325</u>	12	125	208	268
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.015</u>	12	0.016	0.035	0.065
Total nitrogen	mg/L	-	<u>0.414</u>	12	0.600	0.851	1.400
Nitrate+nitrite	mg/L	3	<0.054	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	15.3	12	13.0	18.0	29.2
Ions							
Sodium	mg/L	-	<u>11.5</u>	12	2.9	6.3	10.0
Calcium	mg/L	-	<u>43.0</u>	12	16.3	28.0	35.1
Magnesium	mg/L	-	<u>11.5</u>	12	4.6	8.1	10.6
Chloride	mg/L	120	0.57	12	<0.50	1.00	2.00
Sulphate	mg/L	309	<u>10.0</u>	12	<0.5	5.1	9.6
Total dissolved solids	mg/L	-	212	12	120	146	240
Total alkalinity	mg/L	-	<u>162</u>	12	59	104	138
Selected metals							
Total aluminum	mg/L	0.1	0.052	11	0.049	**0.186**	**0.511**
Dissolved aluminum	mg/L	0.05	<u>0.0017</u>	11	0.0033	0.0114	0.0193
Total arsenic	mg/L	0.005	0.0007	11	0.0007	0.0011	0.0016
Total boron	mg/L	1.2	<u>0.060</u>	11	0.022	0.032	0.051
Total molybdenum	mg/L	0.073	<u>0.00081</u>	11	0.00031	0.00042	0.00071
Total mercury (ultra-trace)	ng/L	5, 13	0.77	11	<0.60	<1.20	4.90
Total strontium	mg/L	-	<u>0.172</u>	11	0.055	0.099	0.156
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>0.62</u>	3	0.06	0.25	0.37
Oilsands Extractable	mg/L	-	<u>1.20</u>	3	0.40	0.61	0.82
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.407	3	<1.689	<2.071	<3.760
Total dibenzothiophenes	ng/L	-	<u>4.157</u>	3	5.844	6.672	35.40
Total PAHs	ng/L	-	<u>74.24</u>	3	102.98	153.69	210.64
Total Parent PAHs	ng/L	-	<u>13.38</u>	3	18.48	21.76	22.93
Total Alkylated PAHs	ng/L	-	<u>60.86</u>	3	80.05	131.94	192.16
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.0031**	12	<0.0020	**0.0054**	**0.0400**
Total iron	mg/L	0.3	**0.853**	11	**0.683**	**1.640**	**2.710**
Total phenols	mg/L	0.004	**0.017**	12	<0.001	**0.009**	**0.019**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.10-6 Concentrations of water quality measurement endpoints, Christina River upstream of Jackfish River (*test* station CHR-3), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.48	8.24
Total suspended solids	mg/L	-	<3	<3
Conductivity	µS/cm	-	342	233
Nutrients				
Total dissolved phosphorus	mg/L	-	0.019	0.090
Total nitrogen	mg/L	-	0.544	0.641
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	3.10	22.50
Ions				
Sodium	mg/L	-	10.5	7.5
Calcium	mg/L	-	47.8	33.5
Magnesium	mg/L	-	11.8	9.4
Chloride	mg/L	120	<0.50	<0.50
Sulphate	mg/L	309	7.90	5.96
Total dissolved solids	mg/L	-	155	187
Total alkalinity	mg/L	-	178	126
Selected metals				
Total aluminum	mg/L	0.1	0.039	0.057
Dissolved aluminum	mg/L	0.05	0.001	0.019
Total arsenic	mg/L	0.005	0.0011	0.0020
Total boron	mg/L	1.2	0.0572	0.0448
Total molybdenum	mg/L	0.073	0.0010	0.0009
Total mercury (ultra-trace)	ng/L	5, 13	0.69	1.50
Total strontium	mg/L	-	0.194	0.144
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.56	0.31
Oilsands Extractable	mg/L	-	0.80	0.49
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	<0.407	1.050
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	74.1	102.5
Total Parent PAHs	ng/L	-	13.26	22.44
Total Alkylated PAHs	ng/L	-	60.84	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Total iron	mg/L	0.3	**2.00**	**4.15**
Total phenols	mg/L	0.004	**0.0063**	**0.0097**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-7 Concentrations of water quality measurement endpoints, Christina River upstream of development (*baseline* station CHR-4), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.11	8.10
Total suspended solids	mg/L	-	18	18
Conductivity	µS/cm	-	328	221
Nutrients				
Total dissolved phosphorus	mg/L	-	0.006	0.118
Total nitrogen	mg/L	-	0.454	0.869
Nitrate+nitrite	mg/L	3	<0.054	0.079
Dissolved organic carbon	mg/L	-	13.9	26.1
Ions				
Sodium	mg/L	-	5.5	3.5
Calcium	mg/L	-	46.7	34.6
Magnesium	mg/L	-	11.0	8.21
Chloride	mg/L	120	<0.50	<0.50
Sulphate	mg/L	309	4.04	2.36
Total dissolved solids	mg/L	-	226	186
Total alkalinity	mg/L	-	169	114
Selected metals				
Total aluminum	mg/L	0.1	0.063	**0.227**
Dissolved aluminum	mg/L	0.05	0.003	0.027
Total arsenic	mg/L	0.005	0.0017	0.0025
Total boron	mg/L	1.2	0.0429	0.0256
Total molybdenum	mg/L	0.073	0.0007	0.0006
Total mercury (ultra-trace)	ng/L	5, 13	1.15	2.30
Total strontium	mg/L	-	0.163	0.124
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.46	0.38
Oilsands Extractable	mg/L	-	1.40	0.48
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	0.932	11.00
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	74.10	114.1
Total Parent PAHs	ng/L	-	13.26	22.44
Total Alkylated PAHs	ng/L	-	60.84	91.65
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Dissolved iron	mg/L	0.3	**0.311**	**6.44**
Sulphide	mg/L	0.002	**0.0025**	**0.0048**
Total iron	mg/L	0.3	**6.17**	**10.6**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-8 Concentrations of water quality measurement endpoints, Christina Lake (*test* station CHL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.05	2	8.11	8.14	8.17
Total suspended solids	mg/L	-	3.5	2	5.0	10.0	15.0
Conductivity	µS/cm	-	183	2	166	186	206
Nutrients							
Total dissolved phosphorus	mg/L	-	0.003	2	0.004	0.007	0.009
Total nitrogen	mg/L	-	0.534	2	0.631	0.676	0.721
Nitrate+nitrite	mg/L	3	<0.054	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	15.2	2	13.4	14.9	16.3
Ions							
Sodium	mg/L	-	5.2	2	4.5	5.3	6.1
Calcium	mg/L	-	24.4	2	22.3	23.0	23.6
Magnesium	mg/L	-	6.76	2	6.75	6.98	7.21
Chloride	mg/L	120	1.12	2	1.04	1.07	1.09
Sulphate	mg/L	309	0.850	2	0.870	0.940	1.01
Total dissolved solids	mg/L	-	159	2	140	141	141
Total alkalinity	mg/L	-	90.9	2	86.4	95.7	105
Selected metals							
Total aluminum	mg/L	0.1	0.043	2	0.014	**0.022**	**0.030**
Dissolved aluminum	mg/L	0.05	0.0013	2	<0.0010	0.0028	0.0046
Total arsenic	mg/L	0.005	0.0006	2	0.0005	0.0006	0.0007
Total boron	mg/L	1.2	0.025	2	0.021	0.024	0.026
Total molybdenum	mg/L	0.073	0.00024	2	0.00021	0.00022	0.00023
Total mercury (ultra-trace)	ng/L	5, 13	1.06	2	1.20	1.25	1.30
Total strontium	mg/L	-	0.061	2	0.061	0.068	0.074
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.18	2	0.11	0.20	0.29
Oilsands Extractable	mg/L	-	0.20	2	0.12	0.34	0.55
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	2	<8.76	<11.96	<15.16
Retene	ng/L	-	0.66	2	<0.51	<0.71	0.91
Total dibenzothiophenes	ng/L	-	13.15	2	6.67	20.99	35.30
Total PAHs	ng/L	-	106.0	2	103.3	164.2	225.2
Total Parent PAHs	ng/L	-	<u>13.86</u>	2	23.25	23.50	23.74
Total Alkylated PAHs	ng/L	-	92.18	2	80.05	140.74	201.43
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total phenols	mg/L	0.004	**0.0052**	2	**0.0048**	**0.0050**	**0.0052**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.10-9 Concentrations of water quality measurement endpoints, Sawbones Creek (*test* station SAC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.84	2	7.66	7.67	7.67
Total suspended solids	mg/L	-	<3	2	<3	<3	<3
Conductivity	µS/cm	-	113	2	95	119	143
Nutrients							
Total dissolved phosphorus	mg/L	-	0.012	2	0.024	0.028	0.032
Total nitrogen	mg/L	-	0.644	2	0.681	0.691	0.701
Nitrate+nitrite	mg/L	3	<0.054	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	20.3	2	19.8	23.1	26.4
Ions							
Sodium	mg/L	-	2.7	2	2.5	2.6	2.7
Calcium	mg/L	-	14.8	2	12.1	16.2	20.2
Magnesium	mg/L	-	4.77	2	3.72	4.87	6.01
Chloride	mg/L	120	<0.5	2	<0.5	<0.5	<0.5
Sulphate	mg/L	218	<0.5	2	<0.5	<0.5	<0.5
Total dissolved solids	mg/L	-	96	2	101	125	149
Total alkalinity	mg/L	-	57.4	2	47.8	59.5	71.2
Selected metals							
Total aluminum	mg/L	0.1	0.022	2	0.022	0.034	0.046
Dissolved aluminum	mg/L	0.05	0.0038	2	0.0057	0.0069	0.0082
Total arsenic	mg/L	0.005	0.0006	2	0.0007	0.0010	0.0012
Total boron	mg/L	1.2	0.011	2	0.011	0.015	0.019
Total molybdenum	mg/L	0.073	0.00004	2	<0.00010	<0.00010	<0.00010
Total mercury (ultra-trace)	ng/L	5, 13	0.95	2	1.00	1.05	1.10
Total strontium	mg/L	-	0.043	2	0.037	0.048	0.059
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.58	2	0.05	0.17	0.29
Oilsands Extractable	mg/L	-	1.10	2	0.30	0.56	0.81
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	2	<8.76	<11.96	<15.16
Retene	ng/L	-	<0.41	2	<0.51	<0.59	<0.67
Total dibenzothiophenes	ng/L	-	4.13	2	6.67	20.99	35.30
Total PAHs	ng/L	-	74.1	2	102.5	153.0	203.4
Total Parent PAHs	ng/L	-	13.26	2	16.42	19.46	22.50
Total Alkylated PAHs	ng/L	-	60.8	2	80.0	133.5	187.0
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total phenols	mg/L	0.004	**0.0070**	2	**0.0067**	**0.0077**	**0.0086**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.10-10 Concentrations of water quality measurement endpoints, Jackfish River (*test* station JAR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.97	2	8.03	8.05	8.07
Total suspended solids	mg/L	-	3	2	<3	<3	<3
Conductivity	µS/cm	-	183	2	175	191	207
Nutrients							
Total dissolved phosphorus	mg/L	-	0.006	2	0.010	0.012	0.015
Total nitrogen	mg/L	-	0.574	2	0.501	0.596	0.691
Nitrate+nitrite	mg/L	3	<0.054	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	15.5	2	15.9	16.0	16.1
Ions							
Sodium	mg/L	-	5.4	2	4.6	5.1	5.5
Calcium	mg/L	-	24.7	2	22.5	23.5	24.5
Magnesium	mg/L	-	6.91	2	6.67	6.98	7.29
Chloride	mg/L	120	1.02	2	1.05	1.06	1.06
Sulphate	mg/L	309	0.810	2	0.950	0.980	1.010
Total dissolved solids	mg/L	-	125	2	129	151	173
Total alkalinity	mg/L	-	91.7	2	89.3	98.2	107.0
Selected metals							
Total aluminum	mg/L	0.1	0.063	2	0.008	0.015	0.022
Dissolved aluminum	mg/L	0.05	0.0013	2	0.0012	0.0032	0.0053
Total arsenic	mg/L	0.005	0.0006	2	0.0005	0.0006	0.0007
Total boron	mg/L	1.2	0.026	2	0.022	0.026	0.030
Total molybdenum	mg/L	0.073	0.00022	2	0.00022	0.00022	0.00023
Total mercury (ultra-trace)	ng/L	5, 13	1.11	2	<0.60	0.80	1.00
Total strontium	mg/L	-	0.065	2	0.066	0.070	0.075
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.52	2	0.04	0.14	0.23
Oilsands Extractable	mg/L	-	1.60	2	0.36	0.45	0.54
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	2	<8.76	<11.96	<15.16
Retene	ng/L	-	3.85	2	<0.92	<1.03	1.14
Total dibenzothiophenes	ng/L	-	4.13	2	6.67	20.99	35.30
Total PAHs	ng/L	-	77.18	2	105.98	155.80	205.63
Total Parent PAHs	ng/L	-	13.73	2	16.59	19.78	22.96
Total Alkylated PAHs	ng/L	-	63.45	2	83.02	136.03	189.03

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.10-11 Concentrations of water quality measurement endpoints, lower Sunday Creek (*test* station SUC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.15	2	8.16	8.20	8.24
Total suspended solids	mg/L	-	17.0	2	<3.0	5.5	8.0
Conductivity	µS/cm	-	355	2	267	289	310
Nutrients							
Total dissolved phosphorus	mg/L	-	0.026	2	0.019	0.025	0.031
Total nitrogen	mg/L	-	0.734	2	0.503	0.537	0.571
Nitrate+nitrite	mg/L	3	<0.054	2	<0.071	0.072	0.073
Dissolved organic carbon	mg/L	-	21.4	2	14.4	16.2	18.0
Ions							
Sodium	mg/L	-	13.9	2	6.8	9.7	12.5
Calcium	mg/L	-	47.0	2	33.4	36.1	38.8
Magnesium	mg/L	-	14.0	2	10.4	10.8	11.2
Chloride	mg/L	120	3.07	2	3.86	5.08	6.29
Sulphate	mg/L	309	2.47	2	1.12	8.11	15.10
Total dissolved solids	mg/L	-	243	2	157	190	223
Total alkalinity	mg/L	-	183	2	135	139	142
Selected metals							
Total aluminum	mg/L	0.1	**0.962**	2	**0.142**	**0.191**	**0.239**
Dissolved aluminum	mg/L	0.05	0.0150	2	0.0044	0.0057	0.0069
Total arsenic	mg/L	0.005	0.0013	2	0.0009	0.0010	0.0010
Total boron	mg/L	1.2	0.037	2	0.027	0.031	0.034
Total molybdenum	mg/L	0.073	0.00036	2	0.00025	0.00042	0.00059
Total mercury (ultra-trace)	ng/L	5, 13	0.24	2	1.20	1.55	1.90
Total strontium	mg/L	-	0.126	2	0.085	0.101	0.116
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.42	2	0.20	0.24	0.28
Oilsands Extractable	mg/L	-	1.50	2	0.65	0.70	0.75
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	2	<8.76	<11.96	<15.16
Retene	ng/L	-	5.25	2	2.07	2.35	2.63
Total dibenzothiophenes	ng/L	-	12.12	2	6.67	20.99	35.30
Total PAHs	ng/L	-	133.0	2	103.2	154.5	205.8
Total Parent PAHs	ng/L	-	17.81	2	16.55	19.54	22.54
Total Alkylated PAHs	ng/L	-	115.16	2	80.62	134.94	189.26
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total chromium	mg/L	0.001	**0.00150**	2	<0.00030	0.00036	0.00042
Total iron	mg/L	0.300	**1.740**	2	**0.548**	**0.749**	**0.949**
Total phenols	mg/L	0.004	**0.0057**	2	0.0036	**0.0048**	**0.0060**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.10-12 Concentrations of water quality measurement endpoints, upper Sunday Creek (*baseline* station SUC-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.04	8.02
Total suspended solids	mg/L	-	<3	<3
Conductivity	µS/cm	-	287	227
Nutrients				
Total dissolved phosphorus	mg/L	-	0.027	0.018
Total nitrogen	mg/L	-	0.354	0.381
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	11.7	14.4
Ions				
Sodium	mg/L	-	3.7	3.0
Calcium	mg/L	-	39.9	34.3
Magnesium	mg/L	-	11.30	9.83
Chloride	mg/L	120	1.24	0.95
Sulphate	mg/L	309	0.92	0.54
Total dissolved solids	mg/L	-	170	144
Total alkalinity	mg/L	-	148	125
Selected metals				
Total aluminum	mg/L	0.1	0.083	0.068
Dissolved aluminum	mg/L	0.05	0.002	0.006
Total arsenic	mg/L	0.005	0.0011	0.0009
Total boron	mg/L	1.2	0.0225	0.0153
Total molybdenum	mg/L	0.073	0.0004	0.0003
Total mercury (ultra-trace)	ng/L	5, 13	0.82	0.94
Total strontium	mg/L	-	0.079	0.069
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.13	0.17
Oilsands Extractable	mg/L	-	1.00	0.43
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	0.872	1.470
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	74.8	103.0
Total Parent PAHs	ng/L	-	13.91	22.53
Total Alkylated PAHs	ng/L	-	60.84	80.49
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Dissolved iron	mg/L	0.3	**0.331**	0.224
Total iron	mg/L	0.3	**0.737**	**0.457**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-13 Concentrations of water quality measurement endpoints, Birch Creek (*baseline* station BRC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.25	8.48
Total suspended solids	mg/L	-	5.4	<3.0
Conductivity	µS/cm	-	402	341
Nutrients				
Total dissolved phosphorus	mg/L	-	0.015	0.032
Total nitrogen	mg/L	-	0.264	0.421
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	8.7	10.8
Ions				
Sodium	mg/L	-	16.2	13.6
Calcium	mg/L	-	48.4	45.9
Magnesium	mg/L	-	13.9	12.6
Chloride	mg/L	120	<0.5	<0.5
Sulphate	mg/L	309	5.66	4.95
Total dissolved solids	mg/L	-	232	197
Total alkalinity	mg/L	-	211	184
Selected metals				
Total aluminum	mg/L	0.1	0.038	0.079
Dissolved aluminum	mg/L	0.05	0.001	0.006
Total arsenic	mg/L	0.005	0.0015	0.0016
Total boron	mg/L	1.2	0.0601	0.0496
Total molybdenum	mg/L	0.073	0.0011	0.0010
Total mercury (ultra-trace)	ng/L	5, 13	0.75	0.80
Total strontium	mg/L	-	0.157	0.140
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.67	0.19
Oilsands Extractable	mg/L	-	1.20	0.45
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	0.465	<0.669
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	75.85	105.57
Total Parent PAHs	ng/L	-	14.46	25.53
Total Alkylated PAHs	ng/L	-	61.40	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Total iron	mg/L	0.3	**1.40**	**1.46**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-14 Concentrations of water quality measurement endpoints, Unnamed Creek, east of Christina Lake (*test* station UNC-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.29	7.91
Total suspended solids	mg/L	-	<3.0	5.0
Conductivity	µS/cm	-	269	136
Nutrients				
Total dissolved phosphorus	mg/L	-	0.026	0.022
Total nitrogen	mg/L	-	0.594	0.891
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	19.8	21.0
Ions				
Sodium	mg/L	-	11.7	2.6
Calcium	mg/L	-	32.2	18.8
Magnesium	mg/L	-	9.53	5.61
Chloride	mg/L	120	3.94	0.57
Sulphate	mg/L	309	1.42	<0.50
Total dissolved solids	mg/L	-	182	141
Total alkalinity	mg/L	-	133.0	68.4
Selected metals				
Total aluminum	mg/L	0.1	0.064	0.058
Dissolved aluminum	mg/L	0.05	0.003	0.006
Total arsenic	mg/L	0.005	0.0008	0.0008
Total boron	mg/L	1.2	0.0324	0.0147
Total molybdenum	mg/L	0.073	0.0004	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	1.06	1.10
Total strontium	mg/L	-	0.093	0.050
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.80	0.35
Oilsands Extractable	mg/L	-	0.80	0.76
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	<0.407	0.803
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	74.1	105.6
Total Parent PAHs	ng/L	-	13.26	25.53
Total Alkylated PAHs	ng/L	-	60.84	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Total iron	mg/L	0.3	**0.518**	**0.512**
Total phenols	mg/L	0.004	**0.006**	**0.008**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-15 Concentrations of water quality measurement endpoints, Unnamed Creek south of Christina Lake (*test* station UNC-3), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.08	8.11
Total suspended solids	mg/L	-	5.0	<3.0
Conductivity	µS/cm	-	339	227
Nutrients				
Total dissolved phosphorus	mg/L	-	0.027	0.040
Total nitrogen	mg/L	-	0.584	0.591
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	15.2	18.0
Ions				
Sodium	mg/L	-	13.6	6.60
Calcium	mg/L	-	42.3	31.1
Magnesium	mg/L	-	13.2	9.29
Chloride	mg/L	120	0.81	<0.50
Sulphate	mg/L	309	1.06	<0.50
Total dissolved solids	mg/L	-	212	179
Total alkalinity	mg/L	-	181	127
Selected metals				
Total aluminum	mg/L	0.1	**0.117**	0.092
Dissolved aluminum	mg/L	0.05	0.004	0.009
Total arsenic	mg/L	0.005	0.0013	0.0011
Total boron	mg/L	1.2	0.0445	0.0269
Total molybdenum	mg/L	0.073	0.0004	0.0002
Total mercury (ultra-trace)	ng/L	5, 13	0.45	0.95
Total strontium	mg/L	-	0.118	0.074
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.54	0.22
Oilsands Extractable	mg/L	-	1.60	0.94
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	0.514	<0.669
Total dibenzothiophenes	ng/L	-	4.134	6.672
Total PAHs	ng/L	-	74.17	105.6
Total Parent PAHs	ng/L	-	13.26	25.53
Total Alkylated PAHs	ng/L	-	60.91	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Total iron	mg/L	0.3	**0.913**	**0.577**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-16 Concentrations of water quality measurement endpoints, Gregoire River (*test* station GRR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014
			Value
Physical variables			
pH	pH units	6.5-9.0	8.22
Total suspended solids	mg/L	-	54.0
Conductivity	µS/cm	-	346
Nutrients			
Total dissolved phosphorus	mg/L	-	0.007
Total nitrogen	mg/L	-	0.474
Nitrate+nitrite	mg/L	3	<0.054
Dissolved organic carbon	mg/L	-	16.3
Ions			
Sodium	mg/L	-	22.3
Calcium	mg/L	-	39.7
Magnesium	mg/L	-	10.3
Chloride	mg/L	120	4.48
Sulphate	mg/L	309	15.6
Total dissolved solids	mg/L	-	245
Total alkalinity	mg/L	-	155
Selected metals			
Total aluminum	mg/L	0.1	**3.5**
Dissolved aluminum	mg/L	0.05	0.019
Total arsenic	mg/L	0.005	0.001
Total boron	mg/L	1.2	0.127
Total molybdenum	mg/L	0.073	0.00086
Total mercury (ultra-trace)	ng/L	5, 13	3.74
Total strontium	mg/L	-	0.165
Total hydrocarbons			
BTEX	mg/L	-	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25
Naphthenic Acids	mg/L	-	0.37
Oilsands Extractable	mg/L	-	1.30
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	7.57
Retene	ng/L	-	2.61
Total dibenzothiophenes	ng/L	-	4.134
Total PAHs	ng/L	-	96.95
Total Parent PAHs	ng/L	-	17.10
Total Alkylated PAHs	ng/L	-	79.84
Other variables that exceeded CCME/AESRD guidelines in fall 2014			
Sulphide	mg/L	0.002	**0.0032**
Total chromium	mg/L	0.001	**0.0041**
Total iron	mg/L	0.3	**2.78**
Total phenols	mg/L	0.004	**0.0047**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-17 Concentrations of water quality measurement endpoints, Gregoire Lake (*test* station GRL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014
			Value
Physical variables			
pH	pH units	6.5-9.0	7.80
Total suspended solids	mg/L	-	3.8
Conductivity	µS/cm	-	127
Nutrients			
Total dissolved phosphorus	mg/L	-	0.004
Total nitrogen	mg/L	-	0.564
Nitrate+nitrite	mg/L	3	<0.054
Dissolved organic carbon	mg/L	-	10.2
Ions			
Sodium	mg/L	-	3.20
Calcium	mg/L	-	15.4
Magnesium	mg/L	-	3.84
Chloride	mg/L	120	2.06
Sulphate	mg/L	218	10.5
Total dissolved solids	mg/L	-	92
Total alkalinity	mg/L	-	45
Selected metals			
Total aluminum	mg/L	0.1	**0.188**
Dissolved aluminum	mg/L	0.05	0.0031
Total arsenic	mg/L	0.005	0.0008
Total boron	mg/L	1.2	0.025
Total molybdenum	mg/L	0.073	0.00049
Total mercury (ultra-trace)	ng/L	5, 13	0.69
Total strontium	mg/L	-	0.058
Total hydrocarbons			
BTEX	mg/L	-	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25
Naphthenic Acids	mg/L	-	0.25
Oilsands Extractable	mg/L	-	0.50
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<7.210
Retene	ng/L	-	<0.407
Total dibenzothiophenes	ng/L	-	4.134
Total PAHs	ng/L	-	74.94
Total Parent PAHs	ng/L	-	13.26
Total Alkylated PAHs	ng/L	-	61.68

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Figure 5.10-6 Piper diagram of fall ion concentrations in the mainstem stations (*test* stations CHR-1, CHR-2, CHR-3, and *baseline* station CHR-4) of the Christina River.

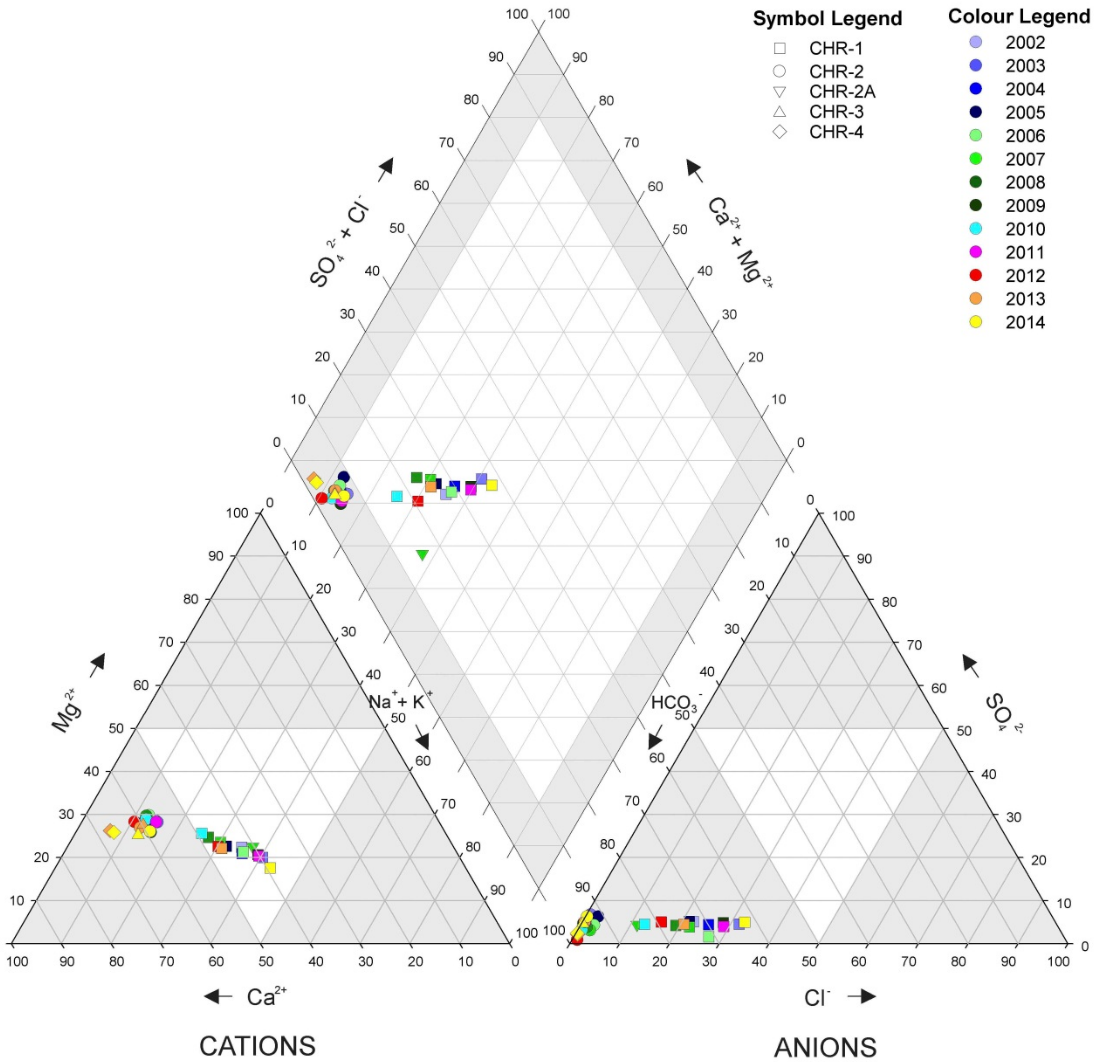


Figure 5.10-7 Piper diagram of fall ion concentrations in tributary stations (*test* stations CHL-1, GRL-1, GRR-1, and JAR-1) of the Christina River watershed.

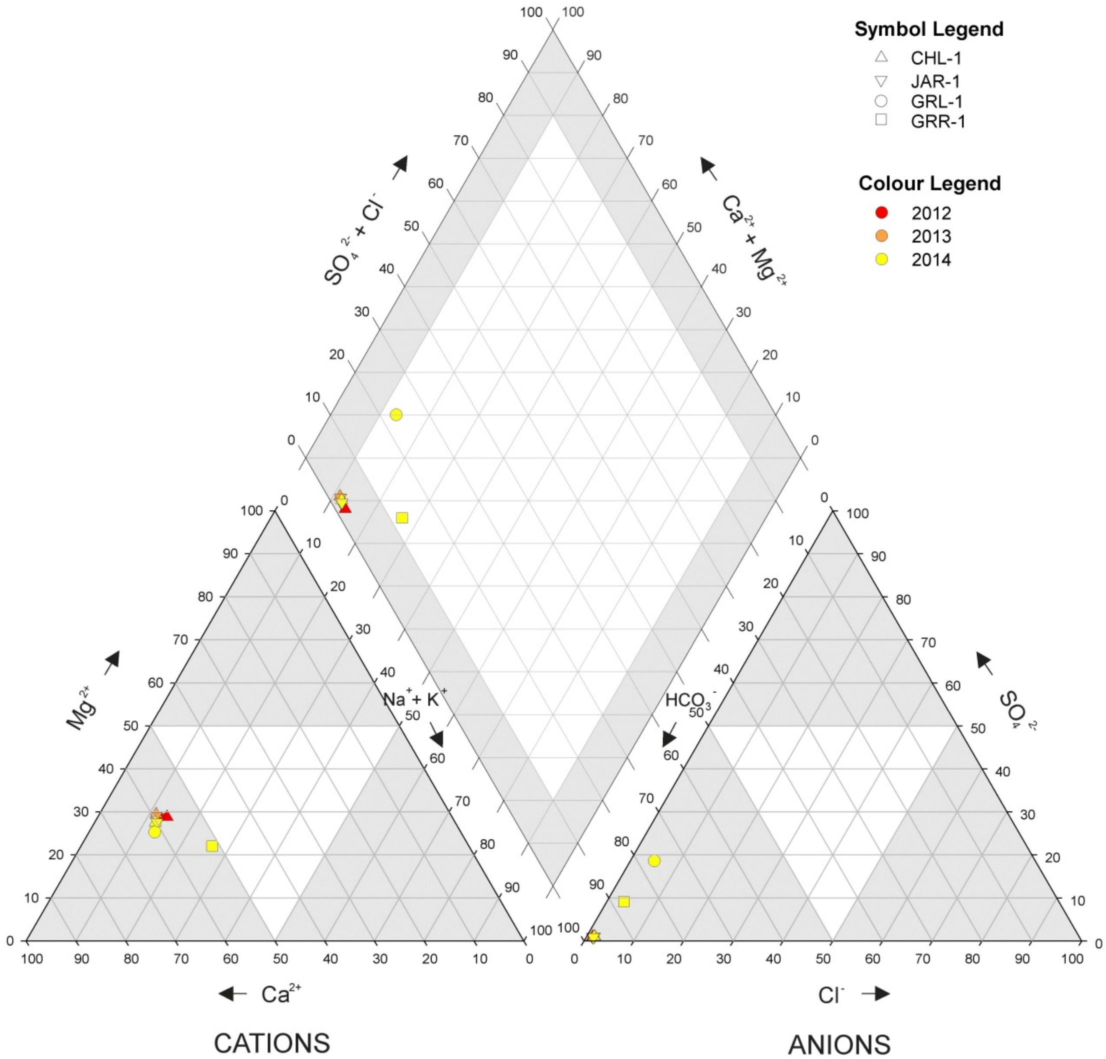


Figure 5.10-8 Piper diagram of fall ion concentrations in tributary stations (*test* stations CHL-1, SAC-1, SUC-1, UNC-2, UNC-3, and *baseline* stations BRC-1, SUC-2) of the Christina River watershed.

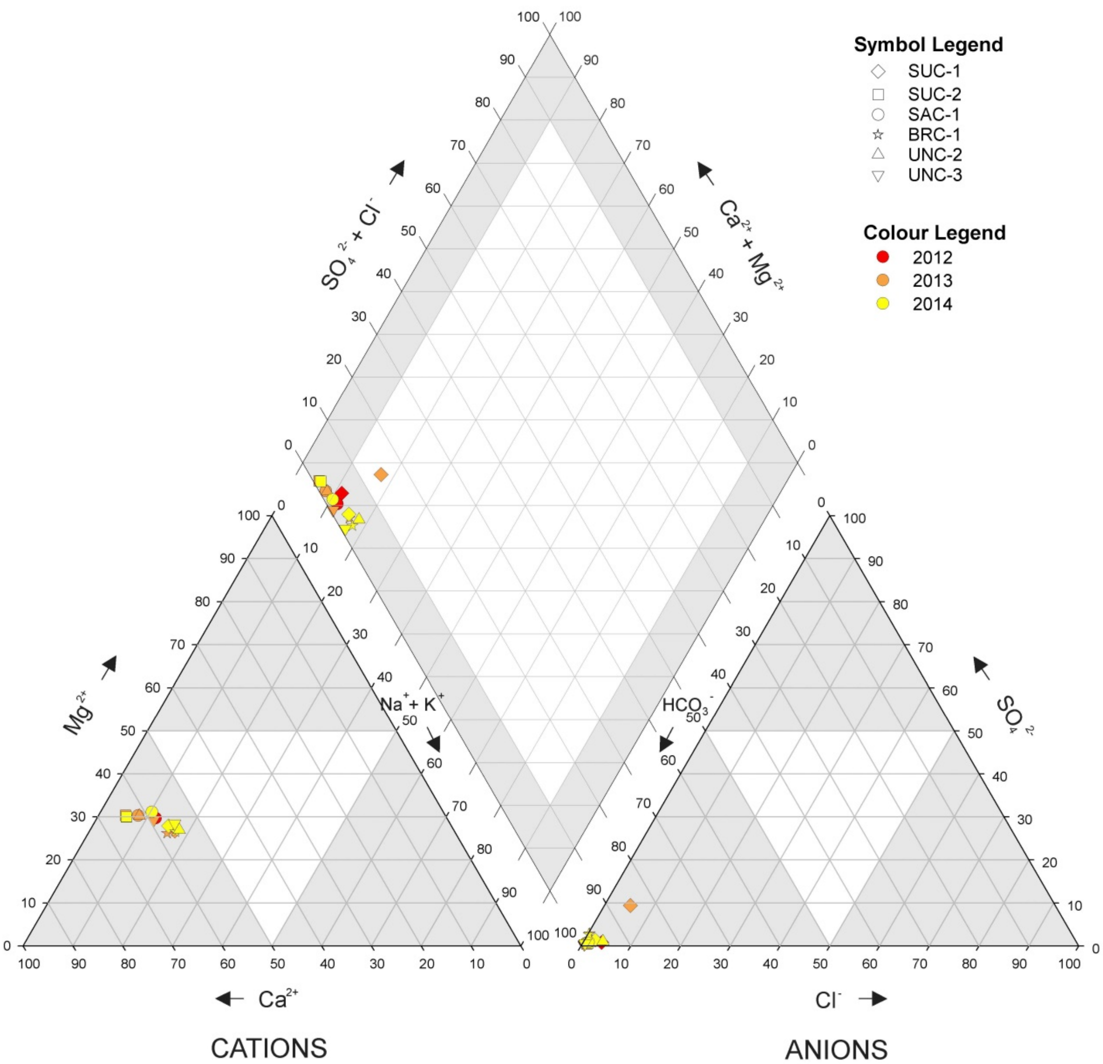


Table 5.10-18 Water quality guideline exceedances, Christina River watershed, 2014.

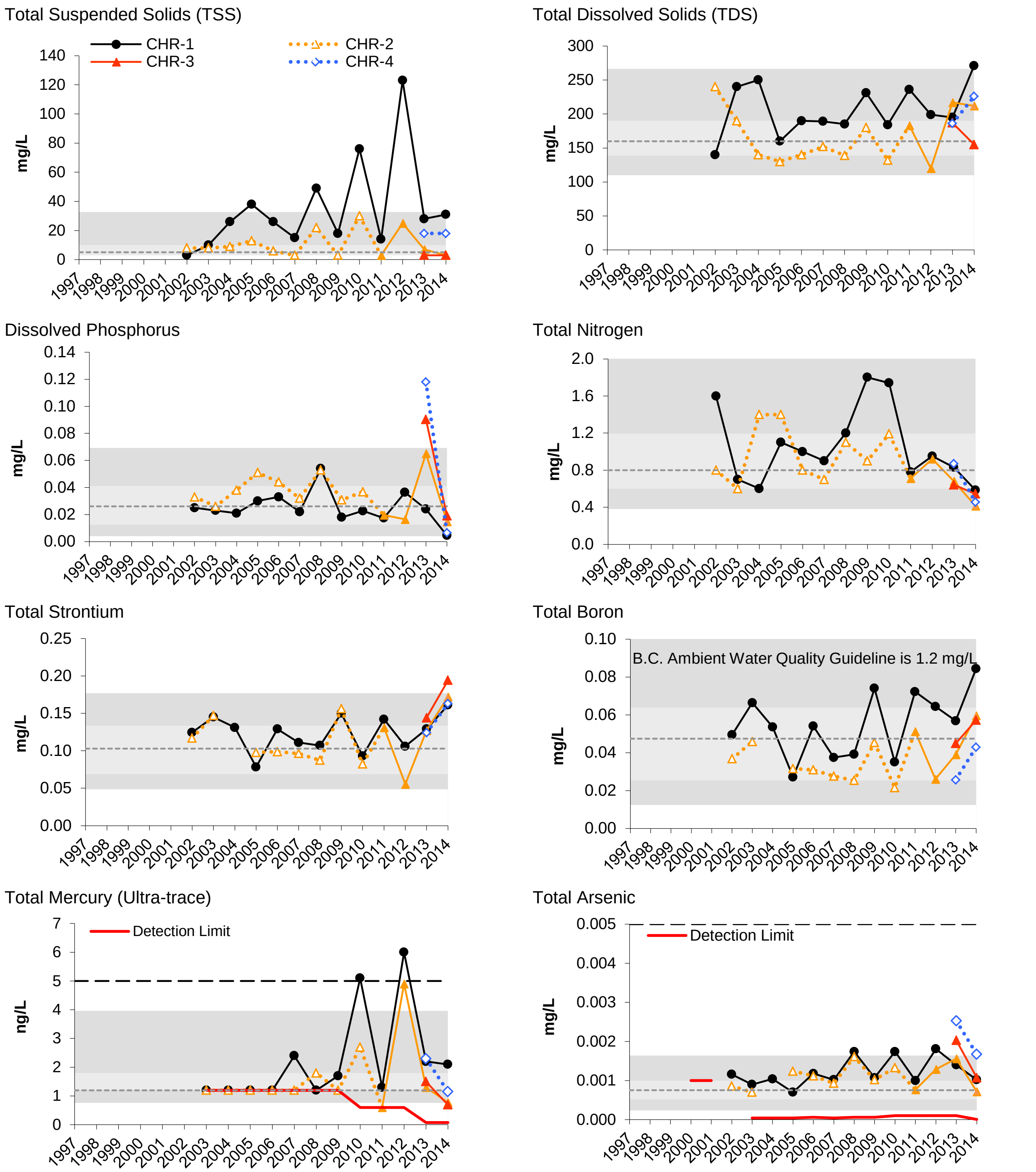
Variable	Units	Guideline[a]	BRC-1	CHR-1	CHR-2	CHR-3	CHR-4	CHL-1	GRL-1	GRR-1	JAR-1	SAC-1	SUC-1	SUC-2	UNC-2	UNC-3
Winter																
Dissolved iron	mg/L	0.3	-	-	ns	-	-	-	ns	ns	-	2.41	-	-	3.25	0.47
Sulphide	mg/L	0.002	-	-	ns	-	-	-	ns	ns	-	0.003	-	-	0.006	-
Total aluminum	mg/L	0.1	-	0.421	ns	-	-	-	ns	ns	-	-	0.261	0.288	-	0.530
Total iron	mg/L	0.3	0.98	1.17	ns	2.25	4.18	-	ns	ns	-	3.26	1.39	0.95	4.10	0.98
Total phenols	mg/L	0.004	-	-	ns	-	0.0053	0.0041	ns	ns	-	0.0088	-	-	0.0120	0.0055
Spring																
Dissolved iron	mg/L	0.3	0.363	0.601	0.448	0.700	0.862	-	-	0.443	-	-	-	-	-	-
Sulphide	mg/L	0.002	-	0.0022	0.0037	-	-	0.0024	-	0.0066	-	-	-	-	-	-
Total aluminum	mg/L	0.1	-	5.730	2.500	2.550	0.325	-	-	4.060	-	0.178	0.376	0.107	0.373	0.808
Total chromium	mg/L	0.001	-	0.00476	0.00210	0.00206	-	-	-	0.00351	-	-	-	-	-	-
Total copper	mg/L	0.002[b]	-	0.00378	-	-	-	-	-	0.00239	-	-	-	-	-	-
Total iron	mg/L	0.3	1.340	5.200	2.970	3.630	2.350	-	-	3.230	-	0.513	0.642	0.347	0.548	0.684
Total lead	mg/L	0.0018[b]	-	0.00282	-	-	-	-	-	-	-	-	-	-	-	-
Total phenols	mg/L	0.004	0.0048	0.0092	0.0075	0.0089	0.0109	-	-	0.0065	0.0041	0.0041	0.0045	0.0050	0.0049	0.0047
Summer																
Dissolved iron	mg/L	0.3	0.720	-	0.620	0.917	1.450	2.370	-	-	-	0.333	0.337	-	-	0.316
Sulphide	mg/L	0.002	0.0022	0.0033	0.0080	0.0047	0.0071	0.0083	-	0.0064	-	0.0033	0.0023	-	0.0033	0.0023
Total aluminum	mg/L	0.1	0.557	0.106	3.960	0.943	0.796	0.245	-	1.540	-	-	0.123	-	0.155	0.245
Total chromium	mg/L	0.001	-	-	0.00325	-	-	-	-	0.00129	-	-	-	-	-	-
Total copper	mg/L	0.002[b]	-	-	0.00211	-	-	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	1.74	-	3.37	2.42	3.21	5.12	-	1.32	-	0.65	0.64	0.31	0.65	0.68
Total mercury (ultra-trace)	ng/L	5, 13	-	5.5	-	-	-	-	-	-	-	-	-	-	-	-
Total phenols	mg/L	0.004	-	0.0041	-	0.0052	0.0069	0.0068	-	-	-	-	-	-	0.0050	-
Fall																
Dissolved iron	mg/L	0.3	-	-	-	-	0.31	-	-	-	-	-	-	0.33	-	-
Sulphide	mg/L	0.002	-	-	0.003	-	0.003	-	-	0.003	-	-	-	-	-	-
Total aluminum	mg/L	0.1	-	1.18	-	-	-	-	0.19	3.50	-	-	0.96	-	-	0.12
Total chromium	mg/L	0.001	-	0.0016	-	-	-	-	-	0.0041	-	-	0.0015	-	-	-
Total iron	mg/L	0.3	1.40	1.59	0.85	2.00	6.17	-	-	2.78	-	-	1.74	0.74	0.52	0.91
Total phenols	mg/L	0.004	-	-	0.017	0.006	-	0.005	-	0.005	-	0.007	0.006	-	0.006	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

ns = not sampled; underline denotes *baseline* stations.

Figure 5.10-9 Concentrations of selected water quality measurement endpoints in the mainstem stations (*test* stations CHR-1, CHR-2, CHR-3, and *baseline* station CHR-4) of the Christina River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



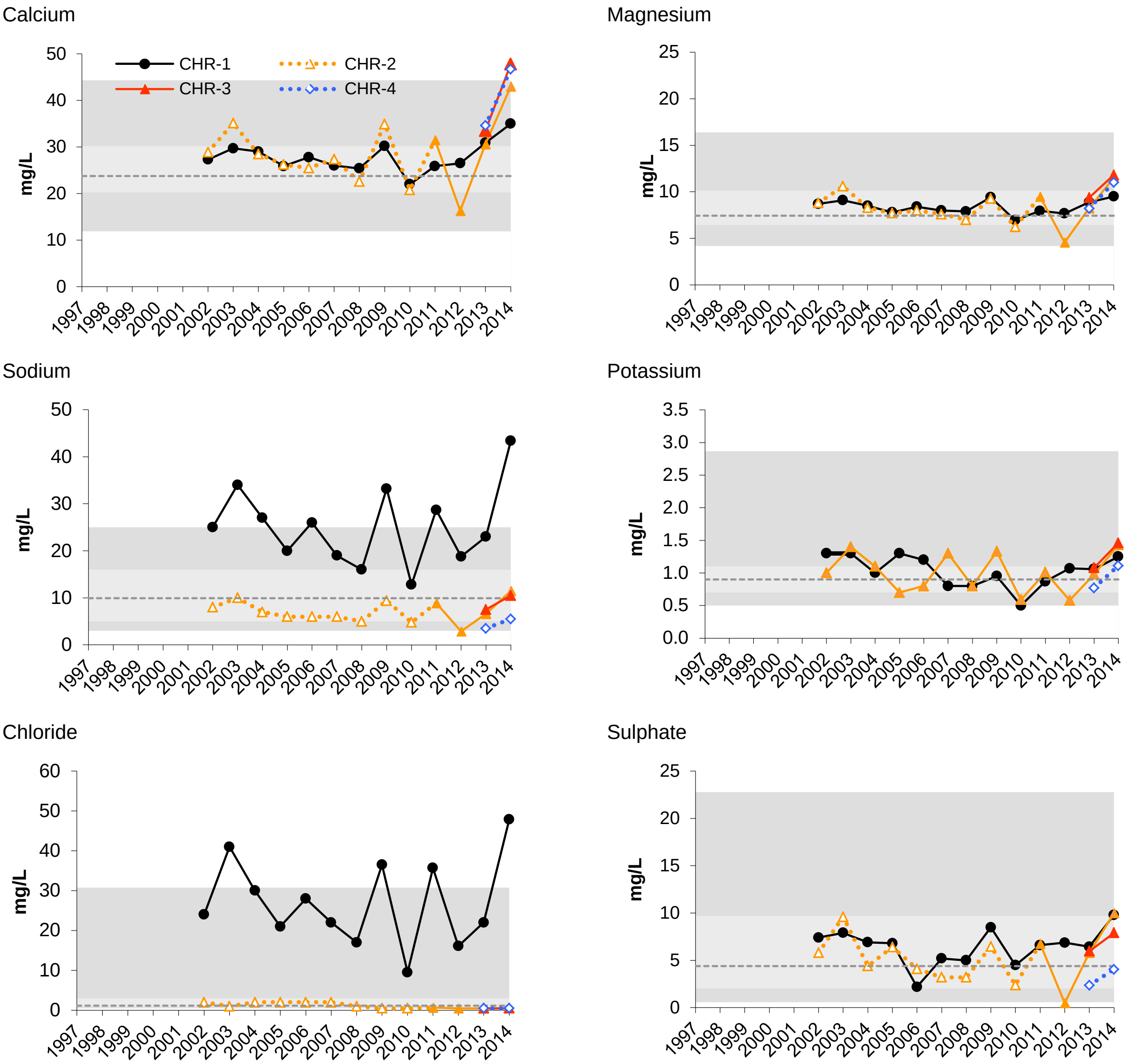
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-9 (Cont'd.)



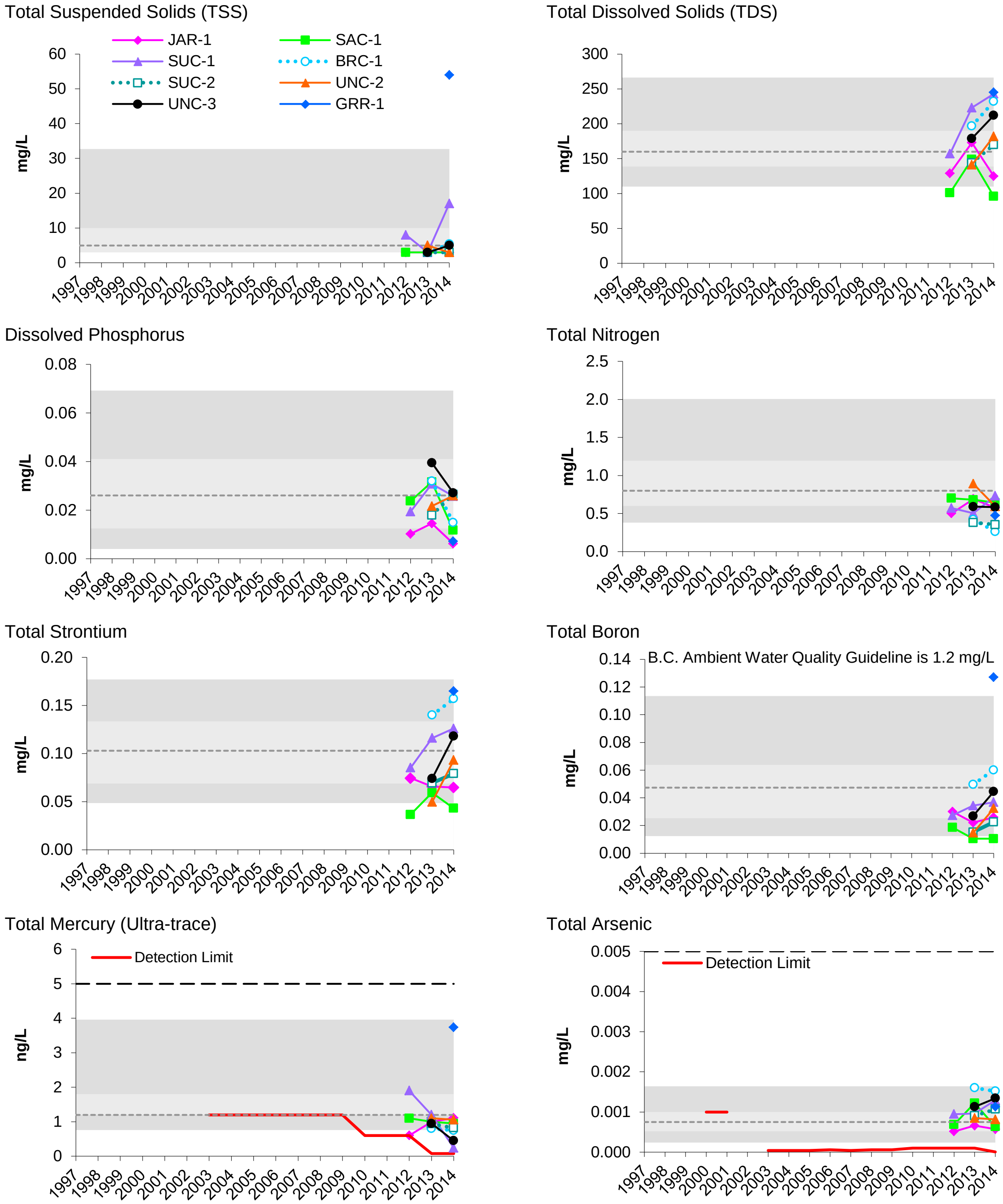
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-10 Concentrations of selected water quality measurement endpoints in the tributary stations (*test* stations GRR-1, JAR-1, SAC-1, SUC-1, UNC-2, UNC-3 and *baseline* stations BRC-1, SUC-2) of the Christina River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



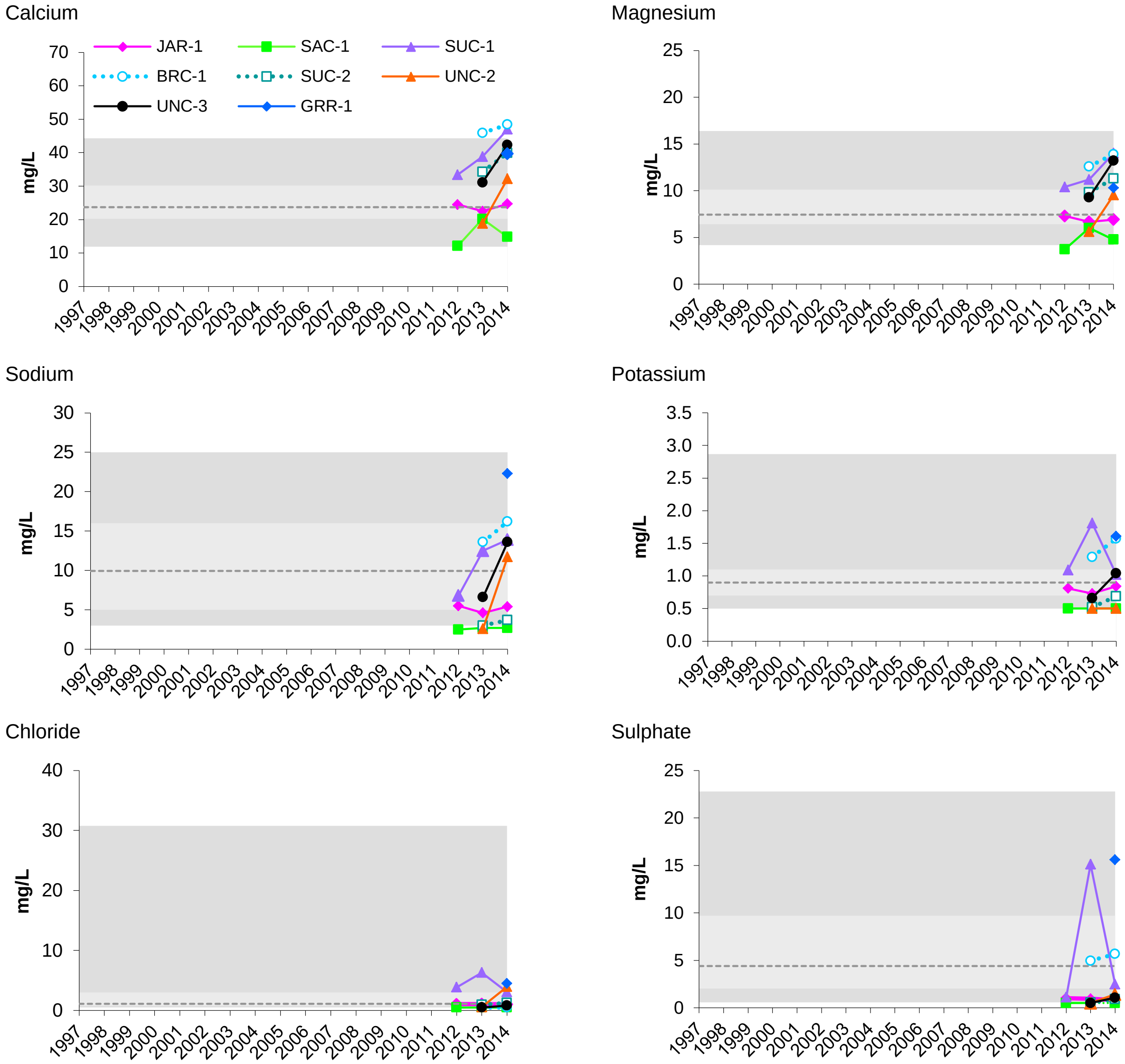
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-10 (Cont'd.)



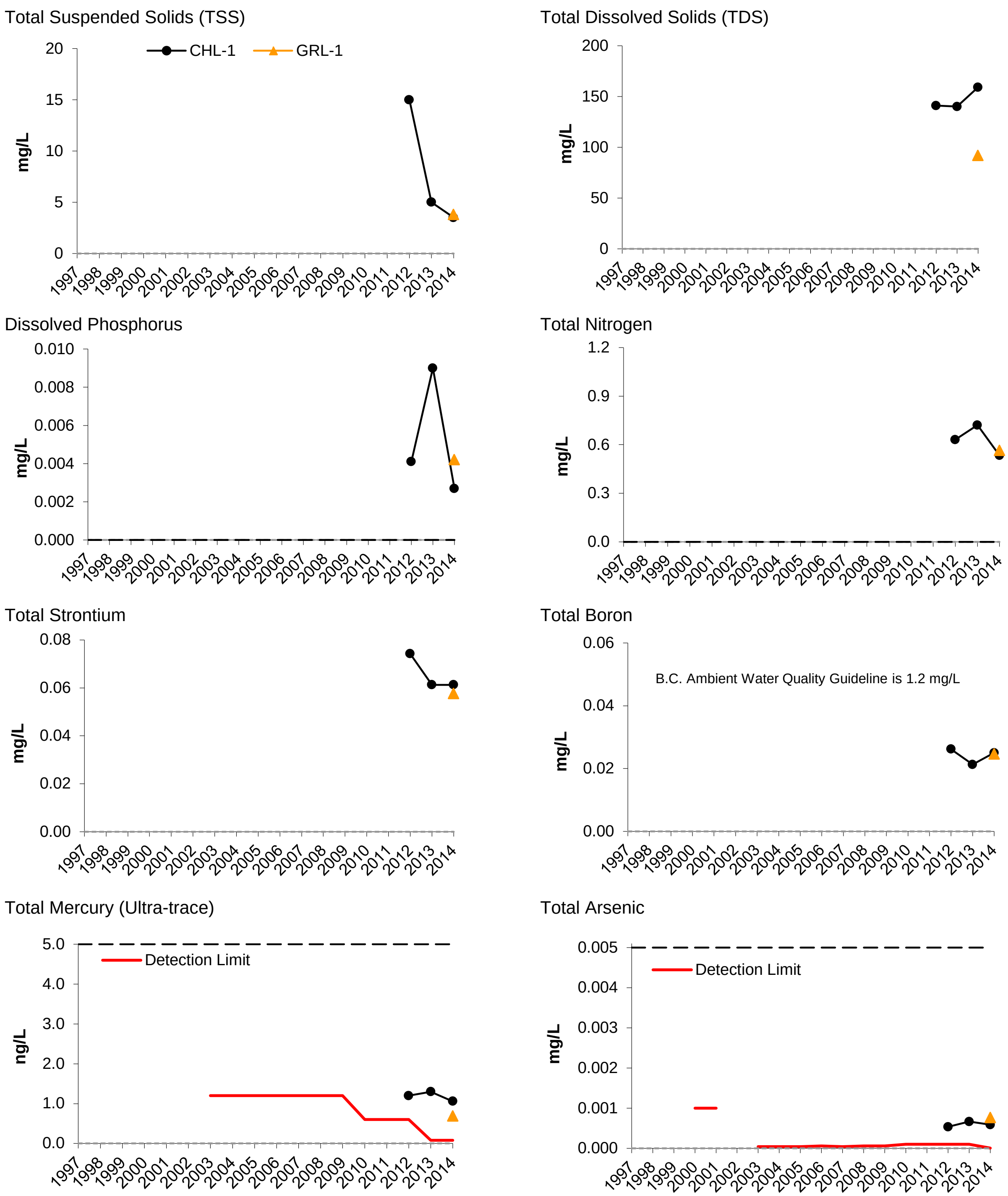
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

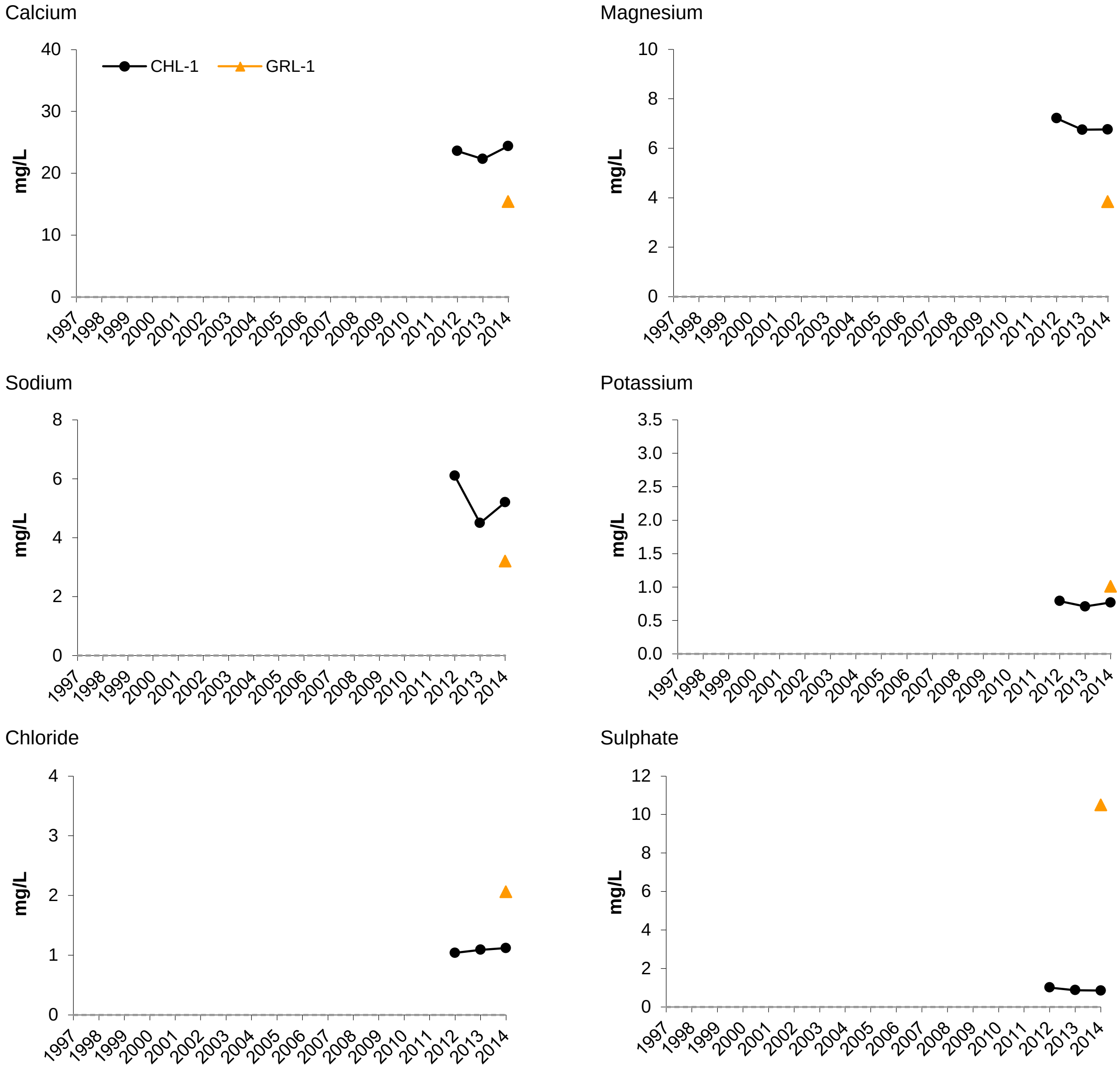
Figure 5.10-11 Concentrations of selected water quality measurement endpoints in Christina Lake and Gregoire Lake (fall data) relative to historical concentrations.



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Figure 5.10-11 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Table 5.10-19 Water quality index (fall 2014) for stations in the Christina River watershed.

Station Identifier	Location	2014 Designation	Water Quality Index	Classification
BRC-1	Birch Creek	*baseline*	83.6	Negligible-Low
CHR-1	near the mouth of the Christina River	*test*	88.4	Negligible-Low
CHR-2	upstream of Janvier	*test*	87.4	Negligible-Low
CHR-3	upstream of Jackfish River	*test*	83.6	Negligible-Low
CHR-4	upstream of development	*baseline*	87.6	Negligible-Low
GRR-1	Gregoire River	*test*	70.0	Moderate
JAR-1	Jackfish River	*test*	100.0	Negligible-Low
SAC-1	Sawbones Creek	*test*	100.0	Negligible-Low
SUC-1	Sunday Creek	*test*	86.1	Negligible-Low
SUC-2	Sunday Creek	*baseline*	100.0	Negligible-Low
UNC-2	Unnamed Creek east of Christina Lake	*test*	100.0	Negligible-Low
UNC-3	Unnamed Creek south of Christina Lake	*test*	95.0	Negligible-Low

Table 5.10-20 Monthly water quality measurement endpoints, Christina River near the mouth (*test* station CHR-1), January to December, 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence						2013 Range (n=12)	
			n	Min		Median	Max		Min	Max
Physical variables										
pH	pH units	6.5-9.0	12	7.61	(April)	7.82	8.25	(August)	7.73	8.33
Total suspended solids	mg/L	-	12	<3	(Aug, Dec)	17	524	(June)	3	1110
Conductivity	µS/cm	-	12	154	(June)	451	807	(March)	135	676
Nutrients										
Total dissolved phosphorus	mg/L	-	12	0.005	(September)	0.020	0.044	(July)	0.004	0.050
Total nitrogen	mg/L	-	12	0.584	(September)	0.903	**1.134**	(June)	0.711	2.421
Nitrate+nitrite	mg/L	3	12	<0.054	(May-Nov)	<0.054	0.391	(April)	0.070	0.349
Dissolved organic carbon	mg/L	-	12	15.4	(March)	18.1	23.3	(November)	7.6	24.4
Ions										
Sodium	mg/L	-	12	7.4	(June)	42.6	96.2	(March)	7.4	71.2
Calcium	mg/L	-	12	17.1	(June)	35.6	49.5	(April)	15.7	44.8
Magnesium	mg/L	-	12	5.1	(May)	9.9	15.5	(March)	4.1	14.1
Chloride	mg/L	120	12	4	(June)	48	120	(March)	3	107
Sulphate	mg/L	429	12	3.6	(July)	11.0	20.1	(April)	3.9	17.1
Total dissolved solids	mg/L	-	12	123	(May)	268	473	(March)	171	395
Total alkalinity	mg/L	-	12	65.6	(May)	143.0	219.0	(April)	56.1	177.0
Selected metals										
Total aluminum	mg/L	0.1	12	0.04	(January)	**0.80**	**10.40**	(June)	0.05	**23.40**
Dissolved aluminum	mg/L	0.05	12	0.003	(March)	0.007	**0.086**	(June)	0.006	**0.101**
Total arsenic	mg/L	0.005	12	0.0007	(January)	0.0010	0.0024	(June)	0.0008	0.0026
Total boron	mg/L	1.2	12	0.030	(May)	0.080	0.124	(March)	0.038	0.098
Total molybdenum	mg/L	0.073	12	0.0002	(June)	0.0004	0.0005	(April)	0.0001	0.0062
Total mercury (ultra-trace)	ng/L	5, 13	12	0.79	(March)	1.88	**18.80**	(June)	0.76	**10.00**
Total strontium	mg/L	-	12	0.072	(May)	0.185	0.318	(March)	0.079	0.240
Total hydrocarbons										
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-	0.1	0.1
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-	0.1	0.1
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	0.25	0.25
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	0.25	0.41
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-	0.25	0.25
Naphthenic Acids	mg/L	-	12	0.13	(March)	0.25	0.68	(September)	0.12	0.63
Oilsands Extractable	mg/L	-	12	0.28	(April)	0.90	1.50	(Oct, Nov)	0.17	1.69
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	12	<7.21	-	<7.21	1060	(April)	15.2	19.7
Retene	ng/L	-	12	0.5	(Mar, Dec)	1.2	35.5	(June)	0.7	106.0
Total dibenzothiophenes	ng/L	-	12	4.31	(March)	12.58	361.27	(June)	6.67	1347.56
Total PAHs	ng/L	-	12	79.6	(March)	122.6	3770.3	(April)	103.6	6026.3
Total Parent PAHs	ng/L	-	12	13.6	(December)	14.6	1103.0	(April)	22.6	232.3
Total Alkylated PAHs	ng/L	-	12	65.9	(March)	108.1	2667.3	(April)	80.8	5794.0
Other variables that exceeded CCME/AESRD guidelines in 2014[1]										
Total phenols	mg/L	0.004	4	<0.001	(December)	0.004	**0.009**	(May)	0.003	**0.010**
Sulphide	mg/L	0.002	6	<0.002	(Jan-Apr)	**0.002**	**0.008**	(July)	0.002	**0.020**
Total phosphorus	mg/L	0.05	12	**0.054**	(December)	**0.065**	**0.388**	(June)	**0.054**	**0.860**
Total iron	mg/L	0.3	12	**0.93**	(January)	**1.68**	**10.60**	(June)	**1.20**	**18.40**
Dissolved iron	mg/L	0.3	6	0.10	(April)	0.29	**0.71**	(November)	**0.43**	**1.07**
Total chromium	mg/L	0.001	5	<0.0003	(January)	0.0009	**0.0084**	(June)	0.0003	**0.0174**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

[1] n value refers to number of exceedances in 2014.

[2] Guideline is hardness dependent based on equation: $(e^{0.8545(\ln(hardness))-1.465})*0.2]/1000$ mg/L. Minimum guideline value = 0.002 mg/L.

Table 5.10-21 Monthly water quality measurement endpoints, Christina River upstream of Janvier (*test* station CHR-2), April to December, 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	9	7.43	(May)	8.04	8.49	(September)
Total suspended solids	mg/L	-	9	12.9	(December)	16.2	21.2	(August)
Conductivity	µS/cm	-	9	104	(May)	258	420	(April)
Nutrients								
Total dissolved phosphorus	mg/L	-	9	0.011	(April)	0.028	0.048	(August)
Total nitrogen	mg/L	-	9	0.414	(September)	0.584	0.934	(April)
Nitrate+nitrite	mg/L	3	9	<0.054	(May-Nov)	<0.054	0.444	(April)
Dissolved organic carbon	mg/L	-	9	13.9	(December)	16.5	20.6	(August)
Ions								
Sodium	mg/L	-	9	3.0	(May)	7.8	14.5	(April)
Calcium	mg/L	-	9	13.6	(June)	34.9	51.8	(April)
Magnesium	mg/L	-	9	4.0	(May)	8.7	14.9	(April)
Chloride	mg/L	120	9	<0.50	(June)	0.69	0.91	(November)
Sulphate	mg/L	429	9	2.7	(May)	7.1	12.9	(April)
Total dissolved solids	mg/L	-	9	88	(May)	167	262	(April)
Total alkalinity	mg/L	-	9	51.3	(May)	127.0	222.0	(April)
Selected metals								
Total aluminum	mg/L	0.1	9	0.05	(December)	**0.10**	**3.58**	(June)
Dissolved aluminum	mg/L	0.05	9	0.001	(April)	0.005	0.031	(June)
Total arsenic	mg/L	0.005	9	0.0007	(September)	0.0010	0.0017	(June)
Total boron	mg/L	1.2	9	0.019	(May)	0.042	0.069	(April)
Total molybdenum	mg/L	0.073	9	0.00029	(May)	0.00063	0.00084	(April)
Total mercury (ultra-trace)	ng/L	5, 13	9	0.71	(December)	1.04	**6.11**	(June)
Total strontium	mg/L	-	9	0.052	(May)	0.130	0.240	(April)
Total hydrocarbons								
BTEX	mg/L	-	9	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	9	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	9	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	9	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	9	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	9	<0.02	(July)	0.20	0.62	(September)
Oilsands Extractable	mg/L	-	9	0.30	(April)	1.20	2.40	(August)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	9	<7.21	-	<7.21	7.94	(December)
Retene	ng/L	-	9	<0.41	(Sept)	0.75	16.60	(July)
Total dibenzothiophenes	ng/L	-	9	4.13	-	4.16	8.87	(June)
Total PAHs	ng/L	-	9	74.2	(September)	94.6	120.2	(June)
Total Parent PAHs	ng/L	-	9	13.38	(September)	14.37	15.60	(June)
Total Alkylated PAHs	ng/L	-	9	60.8	(August)	80.8	104.6	(June)
Other variables that exceeded CCME/AESRD guidelines in 2014[1]								
Total phenols	mg/L	0.004	6	<0.001	(December)	**0.005**	**0.017**	(September)
Sulphide	mg/L	0.002	6	<0.002	(December)	**0.002**	**0.005**	(June)
Total iron	mg/L	0.3	9	**0.85**	(September)	**2.42**	**3.33**	(June)
Dissolved iron	mg/L	0.3	6	0.06	(April)	**0.45**	**1.28**	(August)
Total chromium	mg/L	0.001	2	<0.0003	(April)	0.0002	**0.0030**	(June)

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

[1] n value refers to number of exceedances in 2014.

[2] Guideline is hardness dependent based on equation: $(e^{0.8545(\ln(hardness))-1.465})*0.2]/1000$ mg/L. Minimum guideline value = 0.002 mg/L.

Table 5.10-22 Monthly water quality guideline exceedances, Christina River near the mouth (*test* station CHR-1), January to December 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	-	0.0045	-	-	0.0092	0.0046	-	0.0042	-	-	-	-
Sulphide	mg/L	0.002	-	-	-	-	0.0022	0.0079	0.0080	0.0026	-	0.0033	0.0041	-
Total aluminum	mg/L	0.1	-	0.82	0.42	3.09	5.73	10.40	3.96	0.77	1.18	0.77	0.38	0.21
Dissolved aluminum	mg/L	0.05	-	-	-	-	-	0.0861	-	-	-	-	-	-
Total iron	mg/L	0.3	0.93	1.35	1.17	2.07	5.20	10.60	3.37	1.76	1.59	1.37	1.93	1.33
Dissolved iron	mg/L	0.3	0.304	-	-	-	0.601	-	0.620	0.531	-	-	0.708	0.680
Total chromium	mg/L	0.001	-	-	-	0.0025	0.0048	0.0084	0.0033	-	0.0016	-	-	-
Total mercury (ultra-trace)	ng/L	5, 13	-	-	-	-	12.6	18.8	5.5	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

[1] Guideline is hardness dependent based on equation: $(e^{0.8545(\ln(hardness))-1.465})*0.2]/1000$ mg/L. Minimum guideline value = 0.002 mg/L.

Table 5.10-23 Monthly water quality guideline exceedances, Christina River upstream of Janvier (*baseline* station CHR-2), April to December 2014.

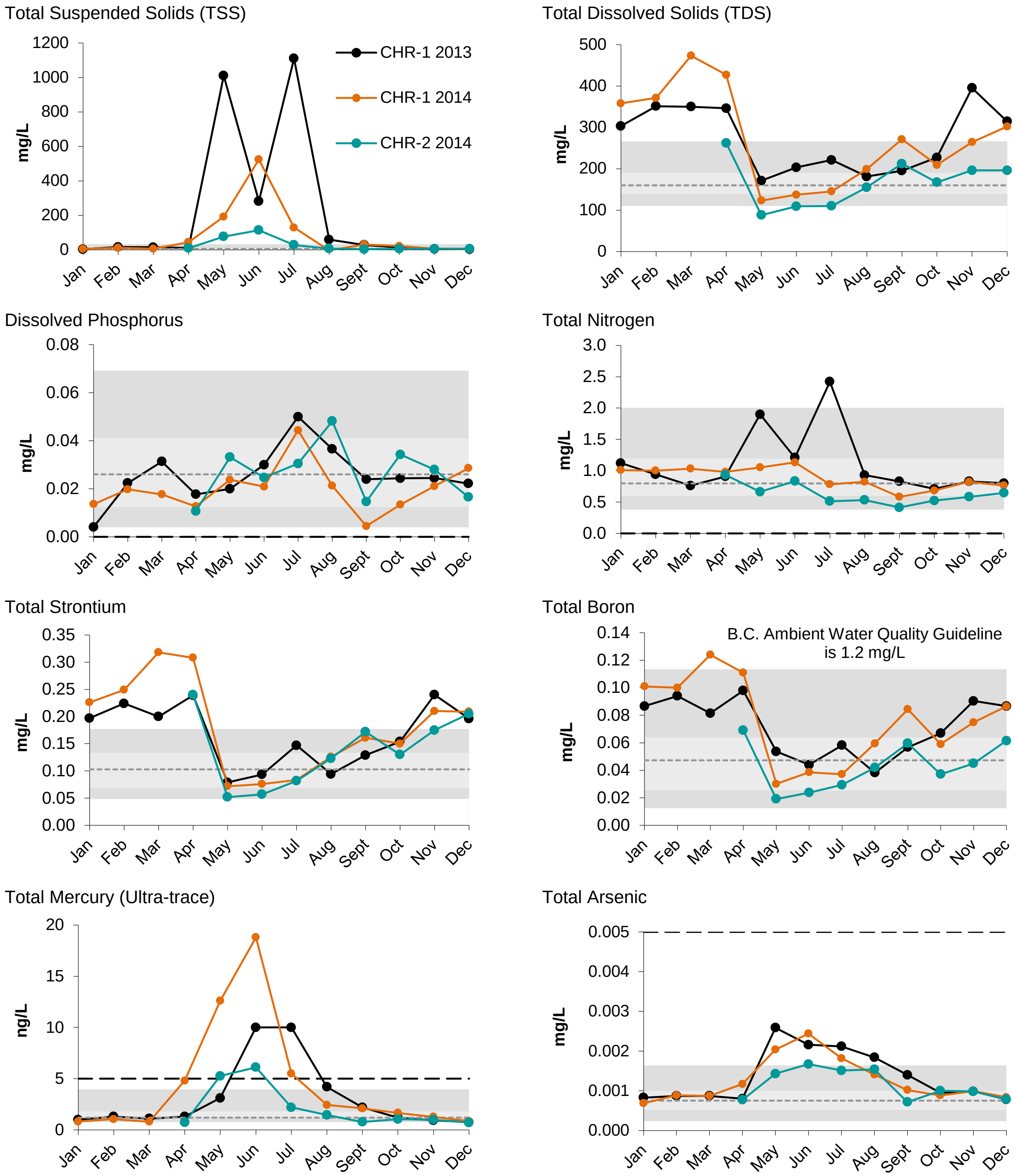
Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	ns	ns	ns	0.0046	0.0075	0.0058	0.0052	0.0048	0.0167	-	-	-
Sulphide	mg/L	0.002	ns	ns	ns	-	0.0037	0.0051	0.0047	0.0023	0.0031	-	0.0022	-
Total aluminum	mg/L	0.1	ns	ns	ns	-	2.50	3.58	0.94	0.24	-	-	-	-
Total iron	mg/L	0.3	ns	ns	ns	1.25	2.97	3.33	2.42	2.44	0.85	1.86	2.43	2.11
Dissolved iron	mg/L	0.30	ns	ns	ns	-	0.45	-	0.92	1.28	-	0.56	0.86	0.44
Total chromium	mg/L	0.001	ns	ns	ns	-	0.002	0.003	-	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5,13	ns	ns	ns	-	5.26	6.11	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

[1] Guideline is hardness dependent based on equation: ($e^{0.8545(\ln(hardness))-1.465}$)*0.2]/1000 mg/L. Minimum guideline value = 0.002 mg/L.

ns = not sampled

Figure 5.10-12 Concentrations of selected water quality measurement endpoints in the Christina River (*test* stations CHR-1, CHR-2) (monthly data) relative to regional *baseline* fall concentrations.



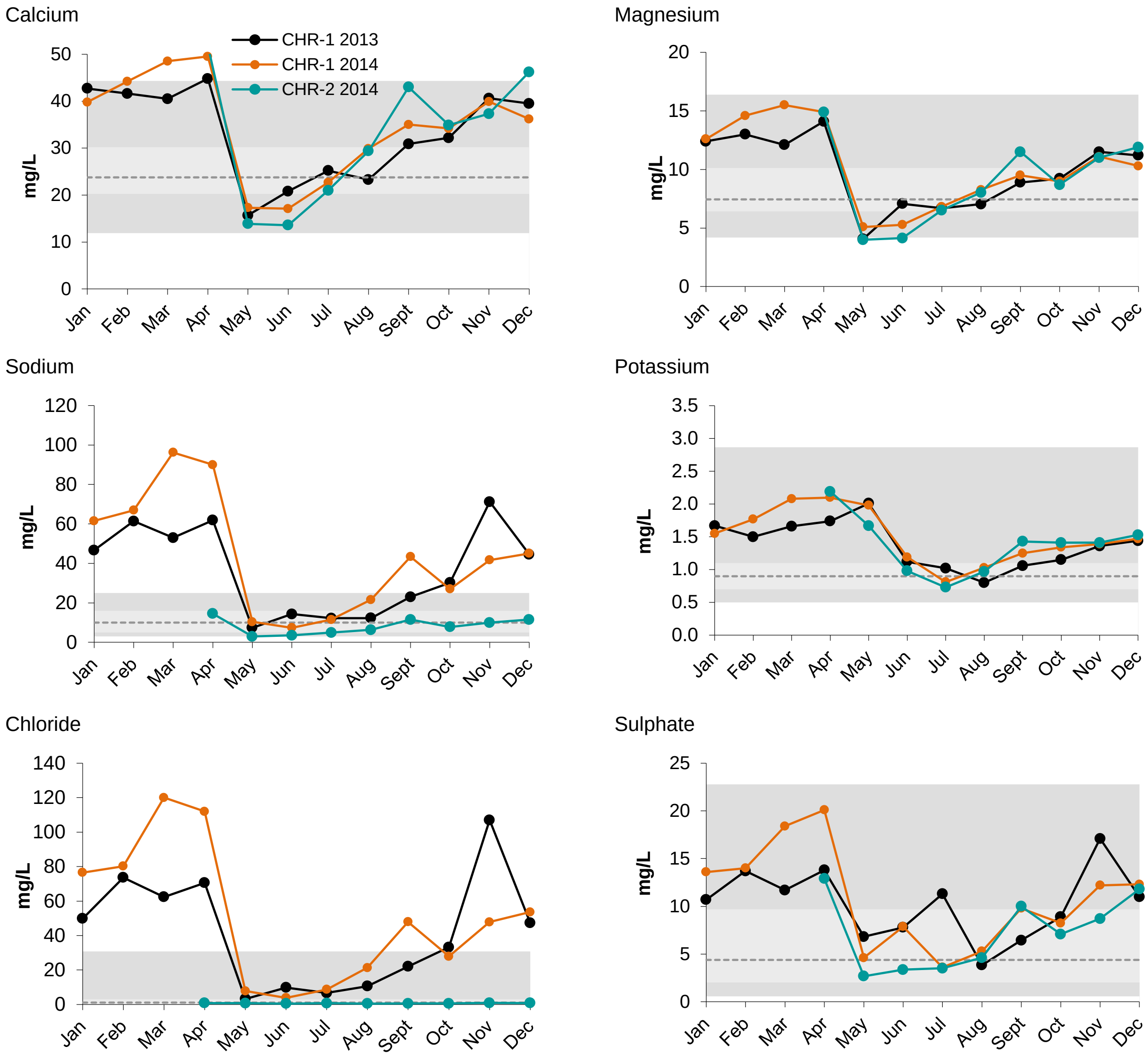
Non-detectable values are shown at the detection limit.

- - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-12 (Cont'd.)



Non-detectable values are shown at the detection limit.

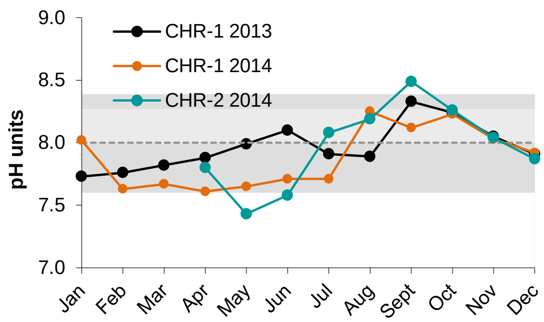
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

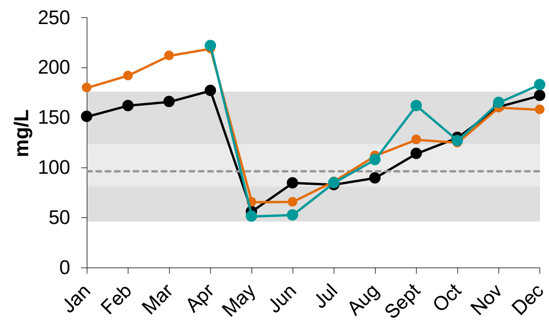
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-12 (Cont'd.)

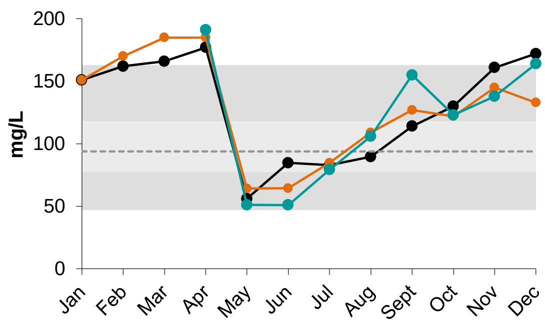
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling in fall. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-13 Piper diagram of monthly ion concentrations in the Christina River (*test* stations CHR-1, CHR-2).

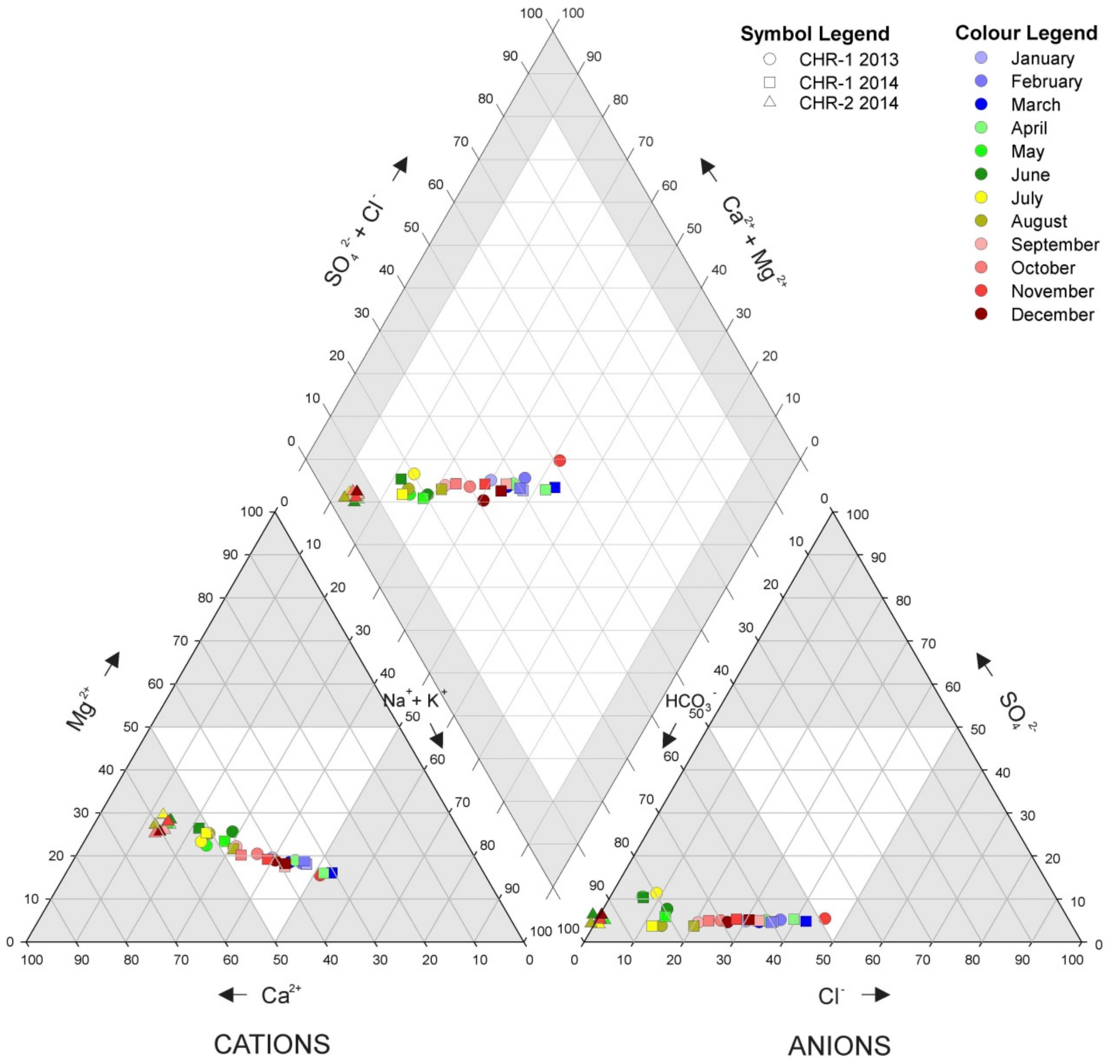


Table 5.10-24 Average habitat characteristics of benthic invertebrate community sampling locations in the Christina River, fall 2014.

Variable	Units	CHR-D1 Lower *Test* Reach	CHR-D2 Middle *Test* Reach	CHR-D3 Upper *Test* Reach	CHR-D4 Upper *Baseline* Reach
Sample date	-	Sept 7, 2014	Sept 13, 2014	Sept 3, 2014	Sept 4, 2014
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	0.35	0.31	0.50	0.40
Current velocity	m/s	0.44	0.30	0.29	0.30
Field Water Quality					
Dissolved oxygen	mg/L	9.8	12.3	10.8	9.0
Conductivity	µS/cm	372	325	338	280
pH	pH units	7.14	8.68	7.8	8.1
Water temperature	°C	11.9	9.8	9.8	9.5
Sediment Composition (mean ± 1SD)					
Sand	%	81±17	99±1	99±1	99±1
Silt	%	13±13	0.6±0.6	1±1	0.6±0.5
Clay	%	7±4	0.5±0.2	0.3±0.3	0.8±0.3
Total Organic Carbon	%	0.7±0.5	0.1±0.02	0.2±0.2	0.2±0.1

Table 5.10-25 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at the lower and middle *test* reaches of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach CHR-D1			*Test* Reach CHR-D2		
	2002	2003-2012	2014	2002	2003-2012	2014
Nematoda	1	1 to 6	8	1	0 to 11	<1
Naididae	<1	<1 to 5	2	-	0 to 9	<1
Tubificidae	44	5 to 71	16	23	<1 to 33	-
Enchytraeidae	-	0 to <1	<1	-	0 to 3	-
Lumbriculidae	-	o to <1	-	-	-	-
Erpobdellidae	-	0 to <1	-	-	-	-
Glossiphoniidae	<1	-	-	<1	-	-
Hydracarina	-	0 to <1	<1	-	0 to <1	-
Gastropoda	2	0 to 2	-	<1	-	-
Bivalvia	11	0 to 1	1	3	0 to 7	-
Ceratopogonidae	<1	1 to 8	4	2	0 to 2	<1
Chironomidae	39	15 to 70	62	44	28 to 99	96
Diptera (misc.)	<1	0 to 3	4	<1	0 to 4	1
Coleoptera	-	0 to <1	-	-	0 to <1	-
Ephemeroptera	-	<1 to 1	1	2	<1 to 6	-
Odonata	<1	<1 to 1	<1	<1	0 to <1	-
Plecoptera	<1	<1 to 1	<1	-	0 to <1	2
Trichoptera	<1	0 to <1	-	<1	0 to 5	-
Heteroptera	-	0 to <1	-	<1	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	516	39 to 1,024	201	1,110	26 to 719	64
Richness	11	7 to 20	15	20	5 to 12	7
Equitability	0.31	0.17 to 0.49	0.39	0.2	0.26 to 0.57	0.49
Percent EPT	0.5	1 to 6	1	2.6	1 to 11	3

Table 5.10-26 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at the upper *test* and *baseline* reaches of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year			
	Test Reach CHR-E3	*Test* Reach CHR-D3	*Baseline* Reach CHR-D4	
	2013	2014	2013	2014
Nematoda	7	<1	3	2
Oligochaeta	<1	<1	<1	-
Naididae	5	1	1	<1
Tubificidae	<1	<1	6	1
Enchytraeidae	1	<1	<1	<1
Lumbriculidae	-	-	-	<1
Hirudinea	-	-	<1	<1
Hydracarina	1	<1	5	<1
Gastropoda	-	<1	<1	-
Bivalvia	<1	<1	1	<1
Ceratopogonidae	1	1	3	2
Chironomidae	64	93	79	93
Diptera (misc)	<1	1	<1	<1
Coleoptera	1	<1	<1	-
Ephemeroptera	8	<1	<1	<1
Odonata	<1	<1	-	-
Plecoptera	5	-	-	<1
Trichoptera	6	<1	<1	<1
Benthic Invertebrate Community Measurement Endpoints				
Total Abundance per sample	440	114	124	451
Richness	31	10	15	15
Equitability	0.36	0.3	0.37	0.19
% EPT	21	<1	1	<1

Table 5.10-27 Results of ANOVA testing for differences in benthic invertebrate community endpoints in Christina River *test* reach (CHR-D1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	0.041	0.219	8	3	No change.
Log of Richness	**0.001**	**0.001**	19	18	Increasing over time; higher in 2014 than mean of previous years.
Equitability	0.865	0.822	0	0	No change.
Log of EPT	0.269	0.943	28	0	No change.
CA Axis 1	**<0.001**	**<0.001**	46	31	Decreasing over time; lower in 2014 than mean of previous years.
CA Axis 2	0.224	0.612	4	1	No change.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.10-28 Results of ANOVA testing for differences in benthic invertebrate community endpoints in Christina River *test* reach (CHR-D2).

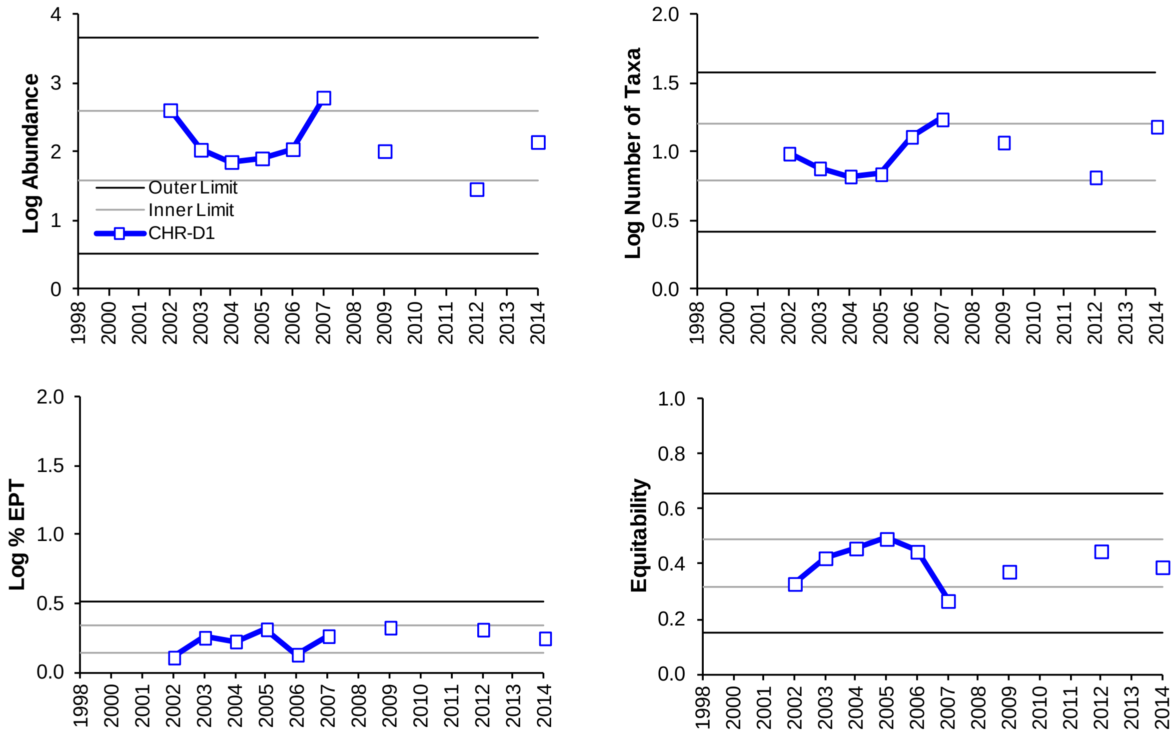
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**0.002**	0.169	11	2	Decreasing over time.
Log of Richness	0.153	0.698	3	0	No change.
Equitability	**0.045**	0.381	10	2	Increasing over time.
Log of EPT	0.387	0.604	5	2	No change.
CA Axis 1	**<0.001**	**0.045**	45	13	Decreasing over time; lower in 2014 than mean of previous years.
CA Axis 2	**0.007**	0.528	11	1	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

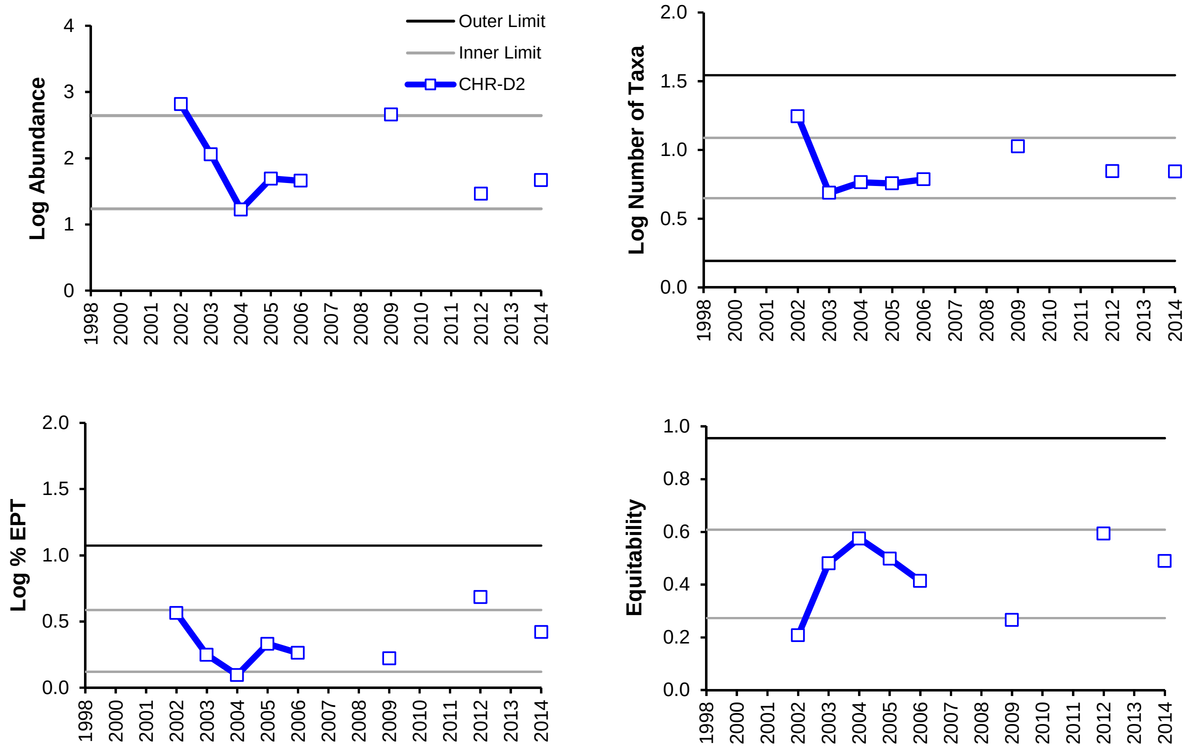
Figure 5.10-14 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-D1 of the Christina River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years of sampling at this reach up to and including 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

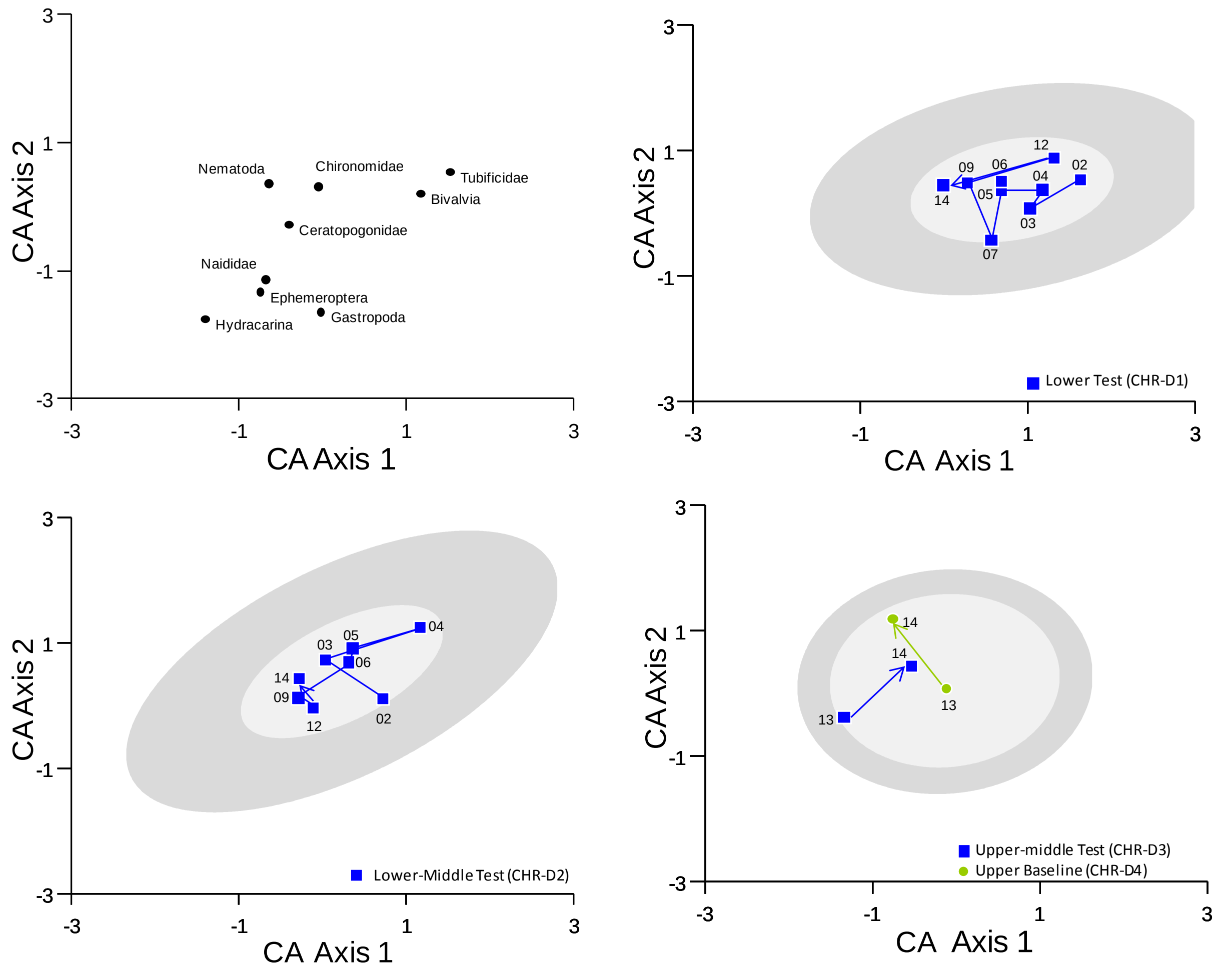
Figure 5.10-15 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-D2 of the Christina River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years of sampling at this reach up to and including 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

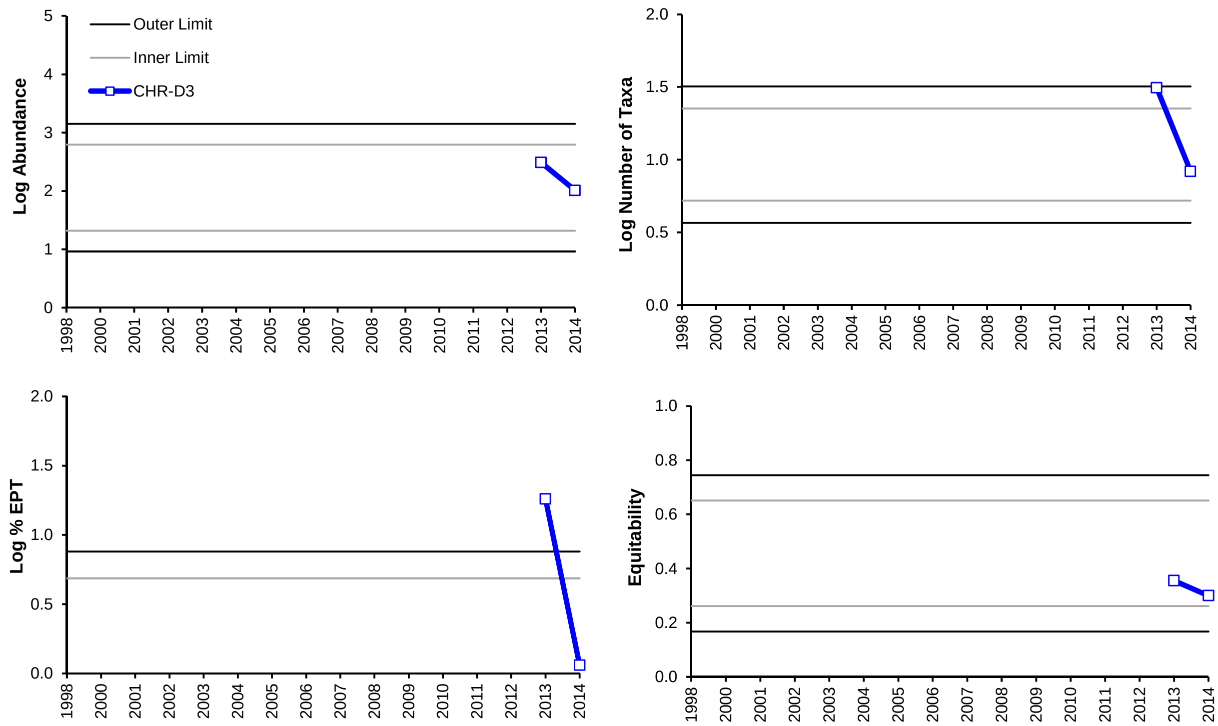
Figure 5.10-16 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reaches CHR-D1, CHR-D2, and CHR-D3, and upper *baseline* reach CHR-D4 of the Christina River.



Note: The upper left panel is the scatterplot of taxa scores while the other three panels are scatterplots of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches.

Note: Sampling at station CHR-D3 was conducted in erosional habitat in 2013 but was shifted to depositional habitat in 2014 to be consistent with other reaches of the Christina River.

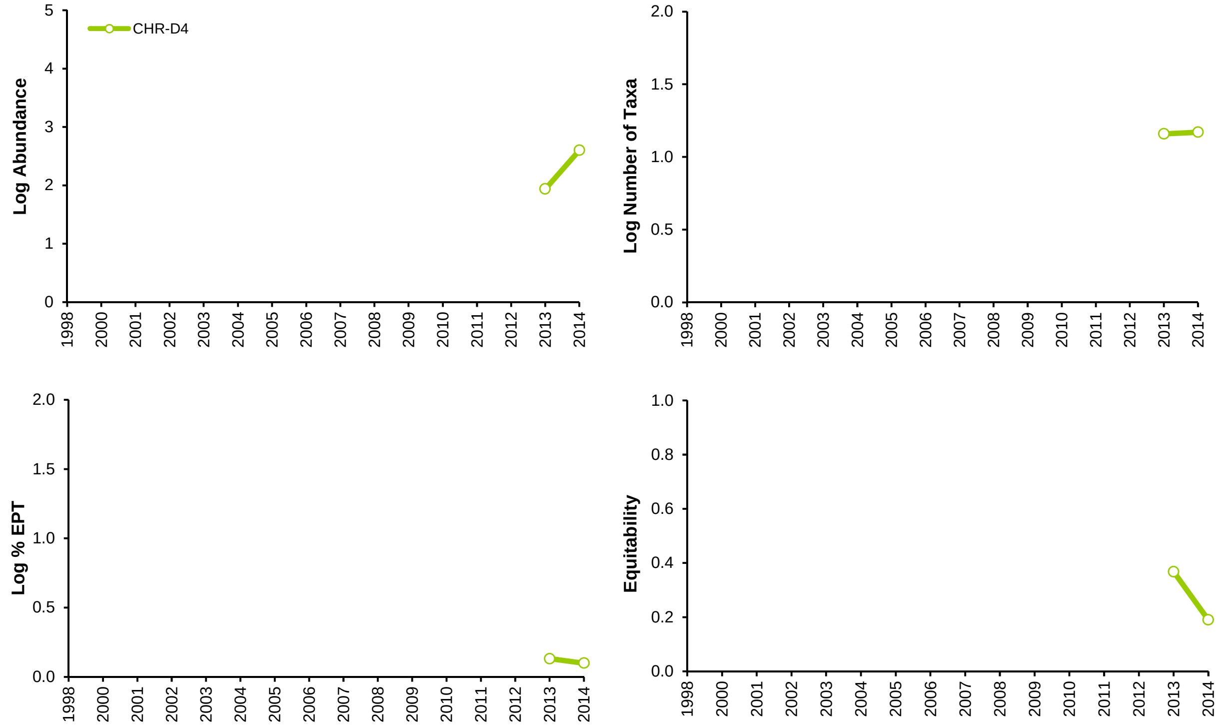
Figure 5.10-17 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-D3 of the Christina River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.10-18 Variation in benthic invertebrate community measurement endpoints at *baseline* reach CHR-D4 of the Christina River.



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.10-29 Average habitat characteristics of benthic invertebrate community sampling locations in Sunday Creek, fall 2014.

Variable	Units	SUC-D1 Lower *Test* Reach	SUC-D2 Upper *Baseline* Reach
Sample date	-	Sept 8, 2014	Sept 3, 2014
Habitat	-	Depositional	Depositional
Water depth	m	0.69	0.37
Current velocity	m/s	0.73	0.20
Field Water Quality			
Dissolved oxygen	mg/L	9.3	9.0
Conductivity	µS/cm	382	231
pH	pH units	6.9	6.3
Water temperature	°C	8.6	11.0
Sediment Composition (mean ± 1SD)			
Sand	%	97±3	92±5
Silt	%	2±2	4±3
Clay	%	2±1	4±2
Total Organic Carbon	%	0.2±0.1	0.6±0.9

Table 5.10-30 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Sunday Creek.

Taxon	Percent Major Taxa Enumerated in Each Year				
	Test Reach SUC-D1			*Baseline* Reach SUC-D2	
	2012	2013	2014	2013	2014
Nematoda	<1	3	3	3	4
Oligochaeta	<1	-	-	<1	-
Naididae	2	1	5	4	6
Tubificidae	2	<1	1	2	4
Enchytraeidae	-	<1	-	<1	-
Hirudinea	-	-	-	-	<1
Hydracarina	<1	<1	1	1	<1
Amphipoda	-	-	-	-	<1
Gastropoda	<1	<1	-	<1	1
Bivalvia	2	2	<1	1	3
Ceratopogonidae	2	4	3	7	4
Chironomidae	80	87	79	78	70
Diptera (misc)	7	3	5	1	3
Coleoptera	-	-	-	<1	<1
Ephemeroptera	<1	<1	2	2	4
Odonata	<1	<1	<1	<1	<1
Plecoptera	-	<1	<1	-	<1
Trichoptera	<1	<1	<1	1	<1
Heteroptera	-	<1	-	<1	-
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance per sample	168	258	304	1,429	454
Richness	14	16	22	26	24
Equitability	0.39	0.33	0.30	0.23	0.25
% EPT	<1	1	3	3	4

Table 5.10-31 Results of ANOVA testing for differences in benthic invertebrate community endpoints in Sunday Creek *test* reach (SUC-D1).

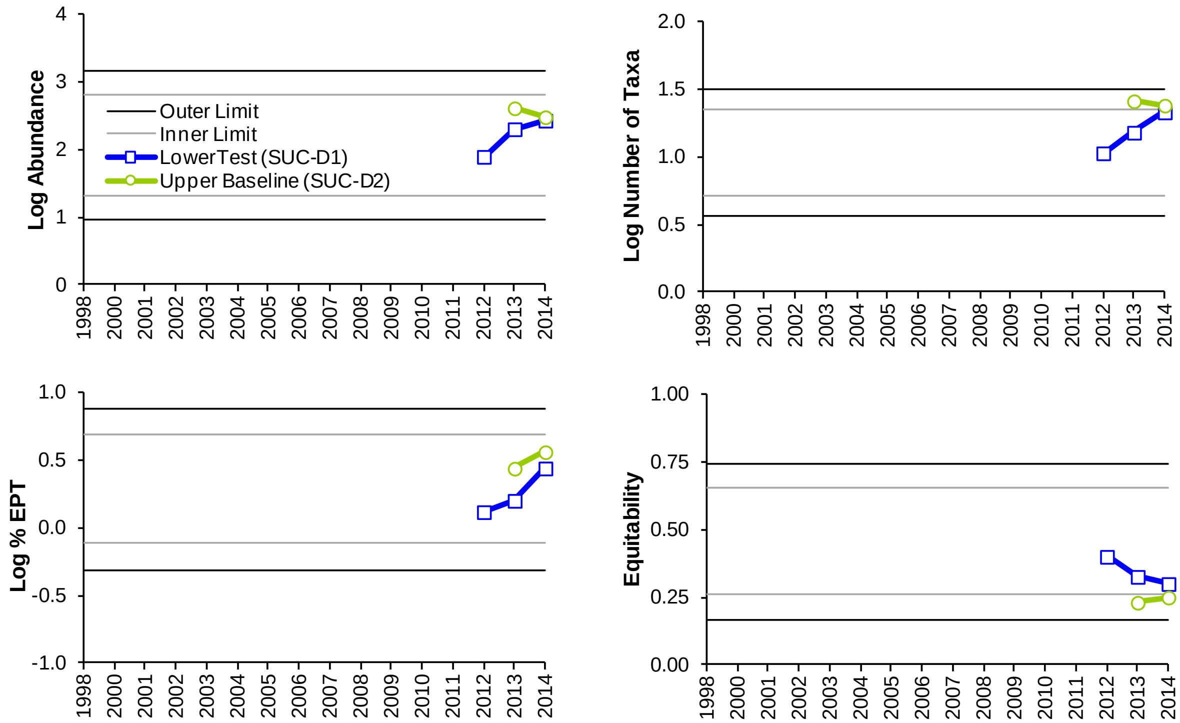
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	0.218	**0.014**	**0.024**	0.075	11	47	39	24	Increasing over time at *test* reach; lower in 2014 at *test* reach than mean of *baseline* reach.
Log of Richness	**0.028**	**0.001**	**<0.001**	**0.002**	18	47	55	36	Lower at *test* reach; increasing over time at *test* reach; lower in 2014 at *test* reach than mean of *baseline* reach; and higher in 2014 at *test* reach than mean of previous years.
Equitability	0.078	0.102	0.086	0.242	31	26	29	13	No change.
Log of EPT	0.086	**0.030**	**0.008**	**0.029**	23	38	59	39	Increasing over time at *test* reach; lower in 2014 at *test* reach than mean of *baseline* reach; and higher in 2014 at *test* reach than mean of previous years.
CA Axis 1	0.417	0.120	0.396	0.376	9	34	10	11	No change.
CA Axis 2	**0.016**	**0.010**	**0.001**	**0.005**	29	34	62	41	Higher at *test* reach; decreasing over time at *test* reach; higher in 2014 at *test* reach than mean of *baseline* reach; and lower in 2014 at *test* reach than mean of previous years.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

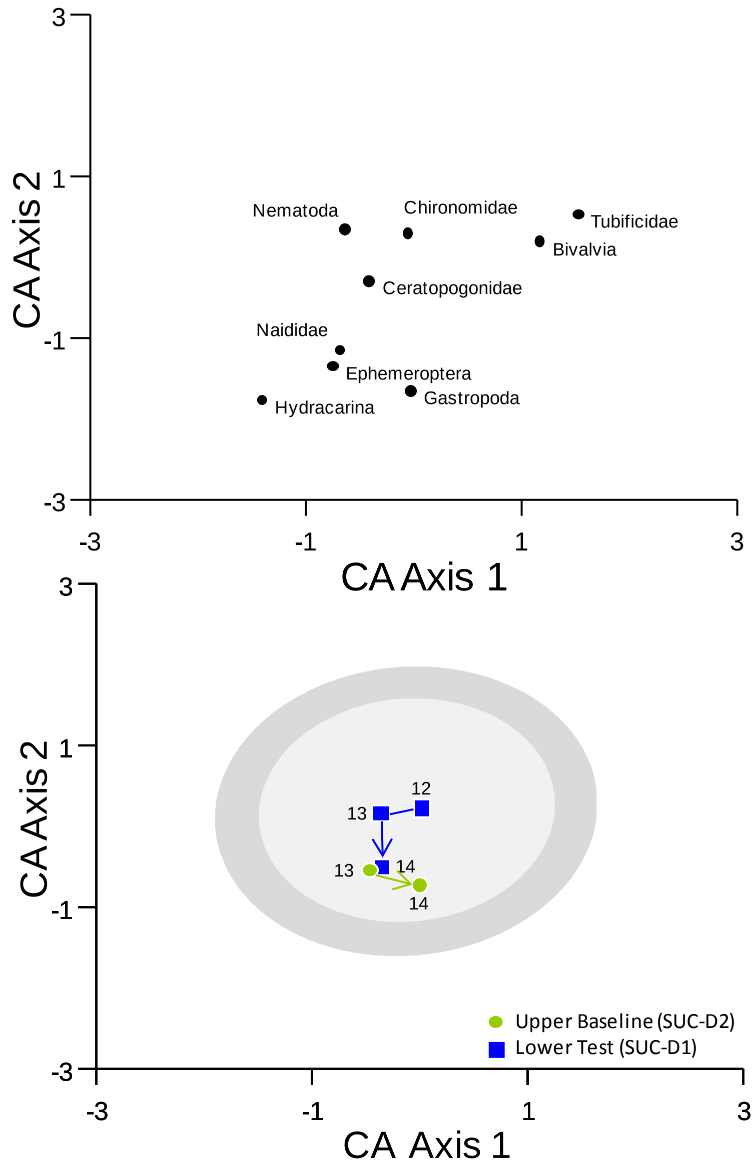
Figure 5.10-19 Variation in benthic invertebrate community measurement endpoints in Sunday Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2013.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.10-20 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reach SUC-D1 and *baseline* reach SUC-D2.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Table 5.10-32 Average habitat characteristics of benthic invertebrate community sampling locations at tributary *test* reaches SAC-D1, UNC-D2, UNC-D3, GRR-E1, and *baseline* reach BRC-D1 of the Christina River watershed, fall 2014.

Variable	Units	SAC-D1 Lower *Test* Reach of Sawbones Creek	UNC-D2 *Test* Reach of Unnamed Creek (east of CHL)	UNC-D3 *Test* Reach of Unnamed Creek (south of CHL)	BRC-D1 Lower *Baseline* Reach of Birch Creek	GRR-E1 Lower *Test* Reach of Gregoire River
Sample date	-	Sept 12, 2014	Sept 12, 2014	Sept 8, 2014	Sept 9, 2014	Sept 7, 2014
Habitat	-	Depositional	Depositional	Depositional	Depositional	Erosional
Water depth	m	0.77	0.53	0.33	0.4	0.2
Current velocity	m/s	Trace	0.21	0.18	0.45	0.6
Field Water Quality						
Dissolved oxygen	mg/L	14.2	8.9	9.9	11	11
Conductivity	µS/cm	57.5	258	364	338	282
pH	pH units	7.41	7.5	7.5	7.7	8.0
Water temperature	°C	8.25	8.1	9.6	6.0	9.8
Sediment Composition (mean ± 1SD)						
Sand	%	75±33	87±11	98±1	96±4	
Silt	%	11±17	7±10	1±1	3±3	
Clay	%	5±5	5±4	1±0.4	1±1	
Sand/Silt/Clay	%					3±4
Large Gravel	%					1±2
Small Cobble	%					13±9
Large Cobble	%					34±10
Boulder	%					50±12
Total Organic Carbon	%	1.1±1.6	1.4±2.4	0.2±0.1	0.4±0.3	

Table 5.10-33 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at *test* reaches SAC-D1, UNC-D2, UNC-D3, GRR-E1, and *baseline* reach BRC-D1 of the Christina River watershed, fall 2014.

Taxon	Percent Major Taxa Enumerated in Each Year									
	Reach SAC-D1			Reach UNC-D2 (East of CHL)		Reach UNC-D3 (South of CHL)		Reach BRC-D1		Reach GRR-E1
	2012	2013	2014	2013	2014	2013	2014	2013	2014	2014
Hydra	<1	<1	-	-	-	-	-	-	-	-
Nematoda	3	4	5	4	3	1	3	8	-	<1
Naididae	2	1	1	1	1	1	7	2	<1	44
Enchytraeidae	-	<1	<1	<1	<1	-	-	<1	-	-
Tubificidae	2	3	5	3	5	1	2	<1	<1	-
Lumbriculidae	<1	<1	<1	-	-	-	-	-	-	-
Erpobdellidae	1	-	<1	-	-	-	-	-	-	-
Hirudinea	-	-	-	-	<1	<1	<1	-	-	-
Hydracarina	1	1	2	2	3	<1	2	<1	<1	1
Amphipoda	<1	<1	<1	<1	1	<1	<1	-	-	-
Gastropoda	1	<1	<1	<1	-	<1	<1	-	-	-
Bivalvia	1	2	2	3	1	1	1	<1	-	-
Ceratopogonidae	5	7	7	9	6	8	2	9	<1	-
Chironomidae	68	77	69	77	78	75	59	67	82	36
Diptera (misc.)	<1	2	6	1	2	5	18	13	13	1
Coleoptera	<1	<1	<1	-	-	-	<1	-	-	-
Ephemeroptera	2	1	3	<1	<1	2	5	<1	2	12
Odonata	<1	-	-	-	-	<1	<1	<1	<1	<1
Plecoptera	-	-	-	<1	-	2	-	<1	<1	1
Trichoptera	<1	<1	<1	<1	1	3	<1	-	1	5
Benthic Invertebrate Community Measurement Endpoints										
Total Abundance per sample	780	346	200	513	569	595	150	209	739	2,275
Richness	31	22	21	21	19	26	25	9	9	29
Equitability	0.3	0.3	0.3	0.28	0.16	0.28	0.28	0.43	0.44	0.13
% EPT	2	2	3	1	1	8	5	1	4	18

Note: CHL = Christina Lake

Table 5.10-34 Results of ANOVA testing for differences in benthic invertebrate community endpoints in Sawbones Creek *test* reach (SAC-D1).

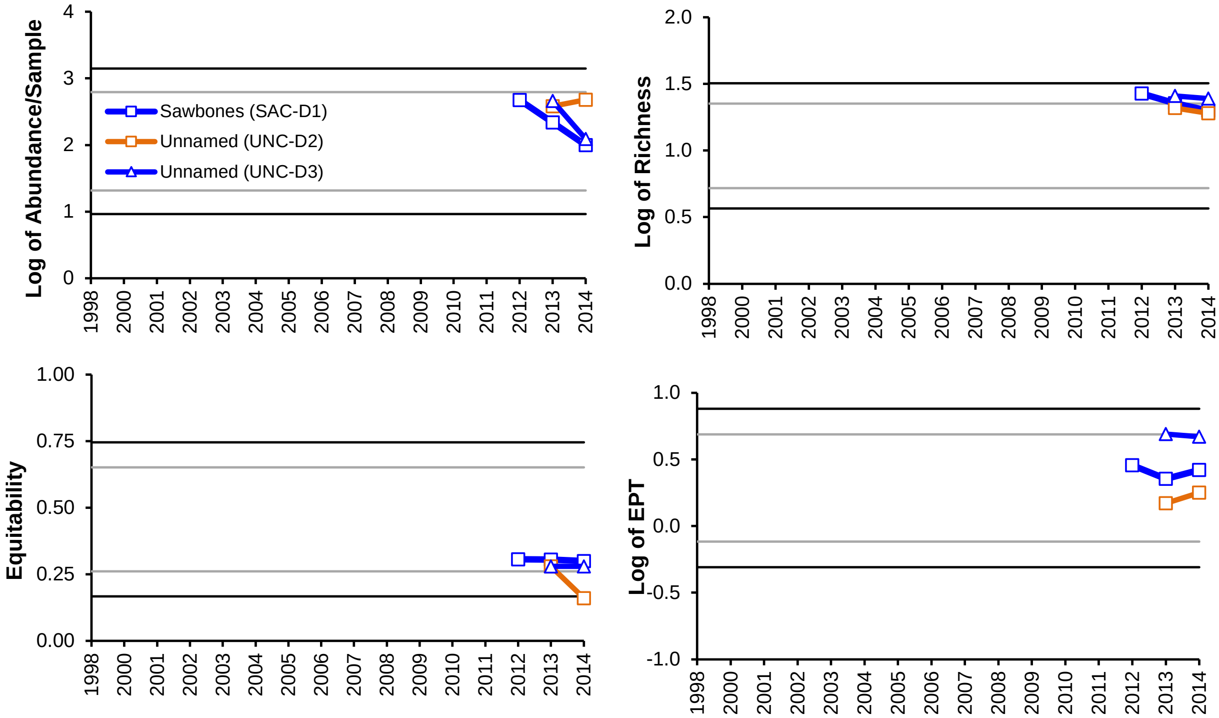
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Period)	2014 vs. Previous Years	Time Trend (Test Period)	2014 vs. Previous Years	
Log of Abundance	**0.005**	**0.014**	100	74	Decreasing over time; lower in 2014 than mean of previous years.
Log of Richness	0.101	0.175	99	67	No change.
Equitability	0.984	0.984	100	100	No change.
Log of EPT	0.805	0.921	13	2	No change.
CA Axis 1	0.642	0.501	42	89	No change.
CA Axis 2	0.102	0.733	36	2	No change.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

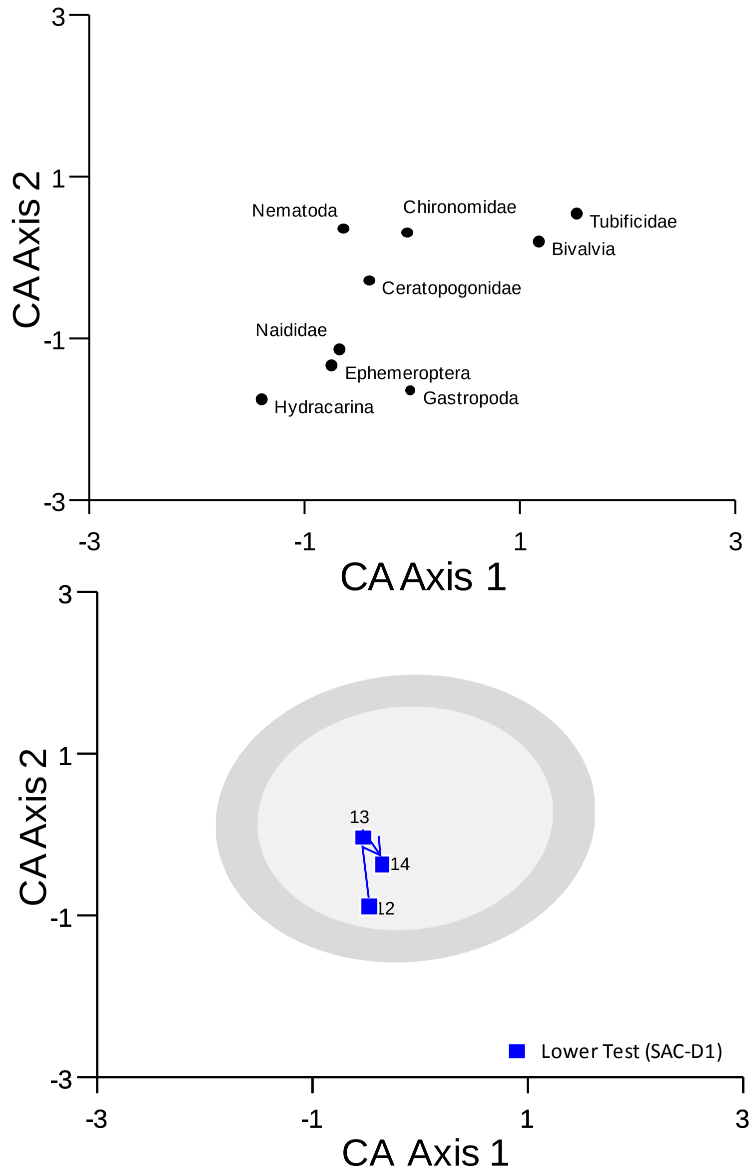
Figure 5.10-21 Variation in benthic invertebrate community measurement endpoints in Sawbones Creek, Unnamed Creeks 2 and 3 (east and south of Christina Lake).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches (1998 to 2013).

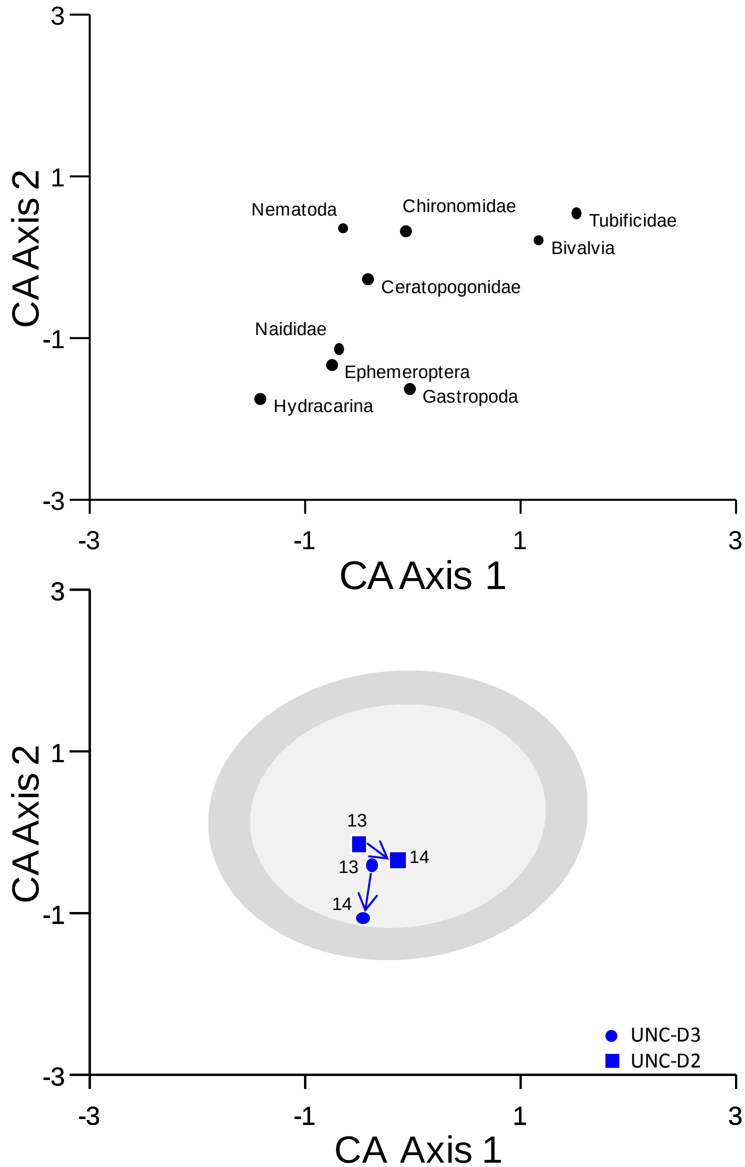
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.10-22 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reach SAC-D1.



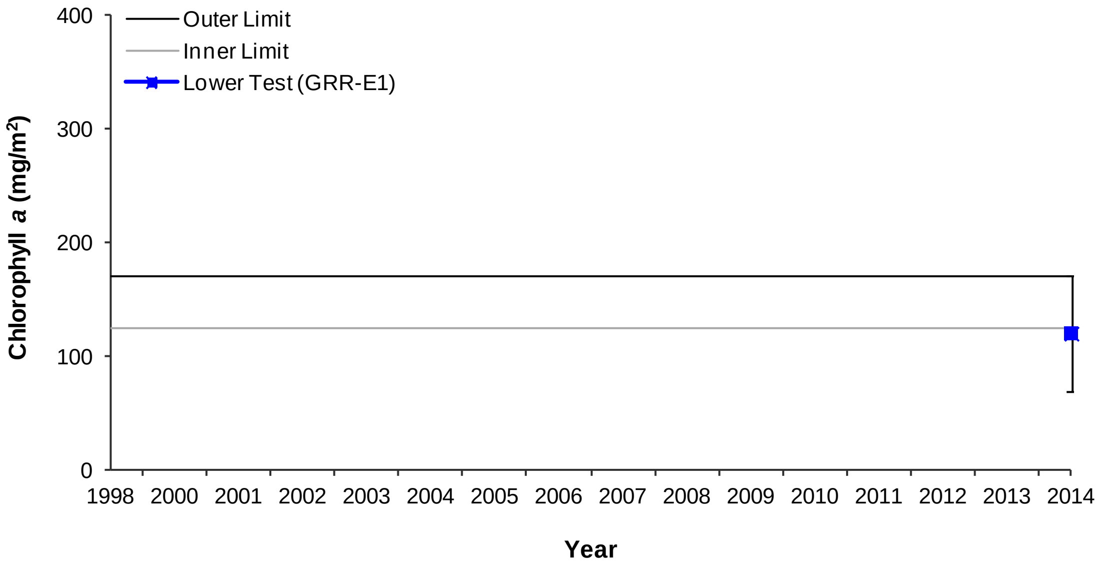
Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Figure 5.10-23 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reaches UNC-D2 and UNC-D3.



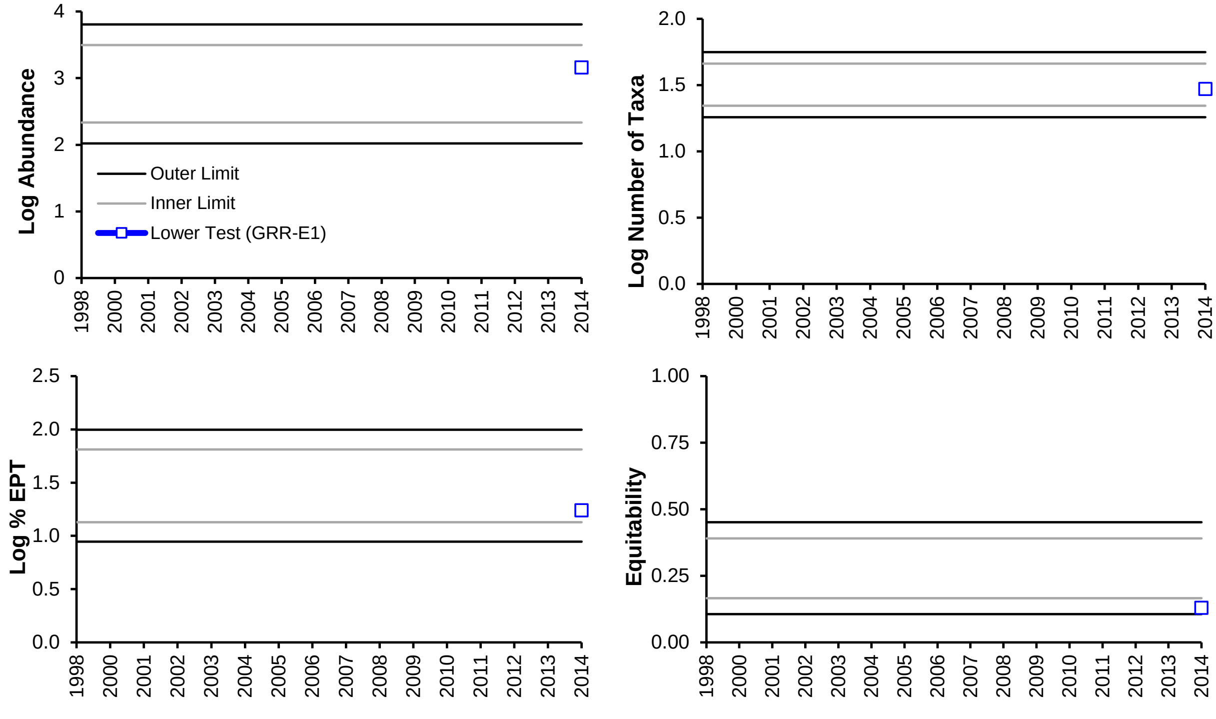
Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Figure 5.10-24 Periphyton chlorophyll *a* biomass at *test* reach GRR-E1 of the Christina River.



Note: Tolerance limits for the 5^{th} and 95^{th} percentiles were calculated using data from regional *baseline* erosional reaches.

Figure 5.10-25 Variation in benthic invertebrate community measurement endpoints in the Gregoire River.



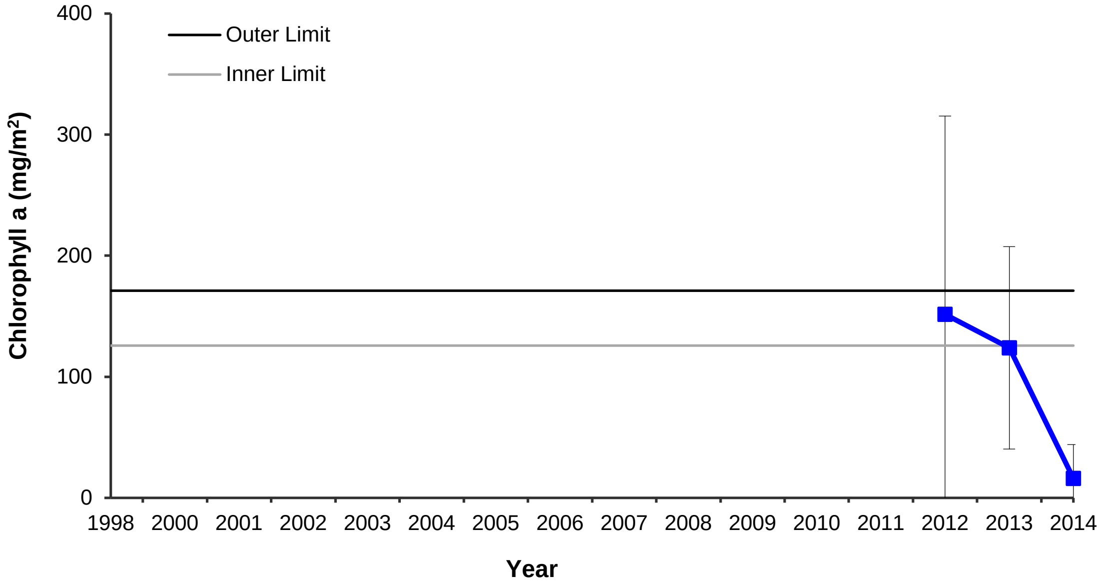
Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* erosional reaches (1998 to 2013).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.10-35 Average habitat characteristics of benthic invertebrate community sampling locations at *test* reach JAR-E1 of Jackfish River, fall 2014.

Variable	Units	JAR-E1 *Test* Reach
Sample date	-	Sept 7, 2014
Habitat	-	Erosional
Water depth	m	0.25
Current velocity	m/s	0.85
Field Water Quality		
Dissolved oxygen	mg/L	8.3
Conductivity	µS/cm	149
pH	pH units	7.2
Water temperature	°C	12.9
Sediment Composition (mean ± 1SD)		
Sand/Silt/Clay	%	3±2
Small Gravel	%	6±4
Large Gravel	%	10±6
Small Cobble	%	35±13
Large Cobble	%	32±12
Boulder	%	15±16
Bedrock	%	-

Figure 5.10-26 Periphyton chlorophyll *a* biomass at *test* reach JAR-E1 of Jackfish River.



Note: Tolerance limits for the lower 5th and upper 95th percentiles were computed using data from prior *baseline* years up to and including 2013.

Table 5.10-36 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community of Jackfish River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach JAR-E1		
	2012	2013	2014
Nematoda	1	5	2
Naididae	2	4	3
Tubificidae	<1	1	<1
Enchytraeidae	<1	1	1
Lumbriculidae	<1	-	-
Erpobdellidae	<1	-	-
Hydracarina	11	8	9
Amphipoda	<1	<1	<1
Gastropoda	1	1	<1
Bivalvia	<1	1	<1
Ceratopogonidae	<1	-	<1
Chironomidae	23	33	19
Diptera (misc.)	2	4	2
Coleoptera	<1	2	1
Ephemeroptera	29	29	39
Odonata	<1	<1	1
Plecoptera	<1	<1	1
Trichoptera	19	11	22
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	3,823	4,448	6,299
Richness	38	39	43
Equitability	0.28	0.28	0.27
% EPT	48	42	62

Table 5.10-37 Results of ANOVA testing for differences in benthic invertebrate community endpoints in the lower Jackfish River (JAR-E1).

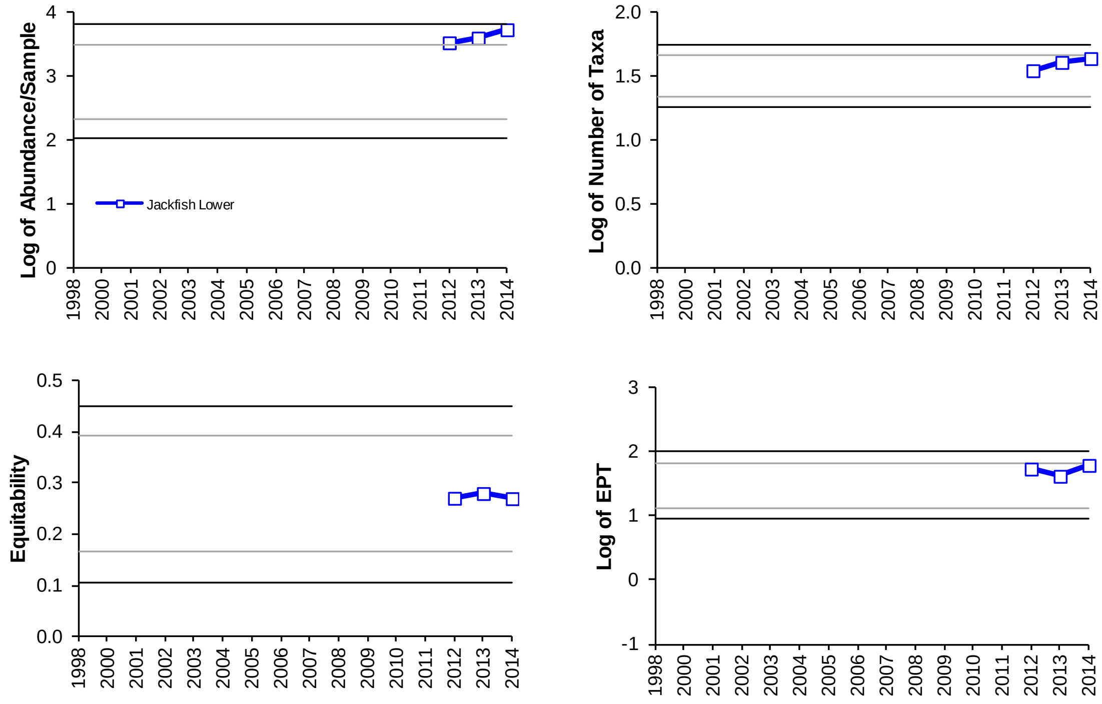
Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
	2014 vs. mean of previous years (2012 and 2013)		
Log of Abundance	0.061	87	No change.
Log of Richness	**0.016**	62	Higher in 2014 than mean of previous years.
Equitability	0.707	59	No change.
Log of EPT	**0.001**	62	Higher in 2014 than mean of previous years.
CA Axis 1	0.700	88	No change.
CA Axis 2	0.781	3	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

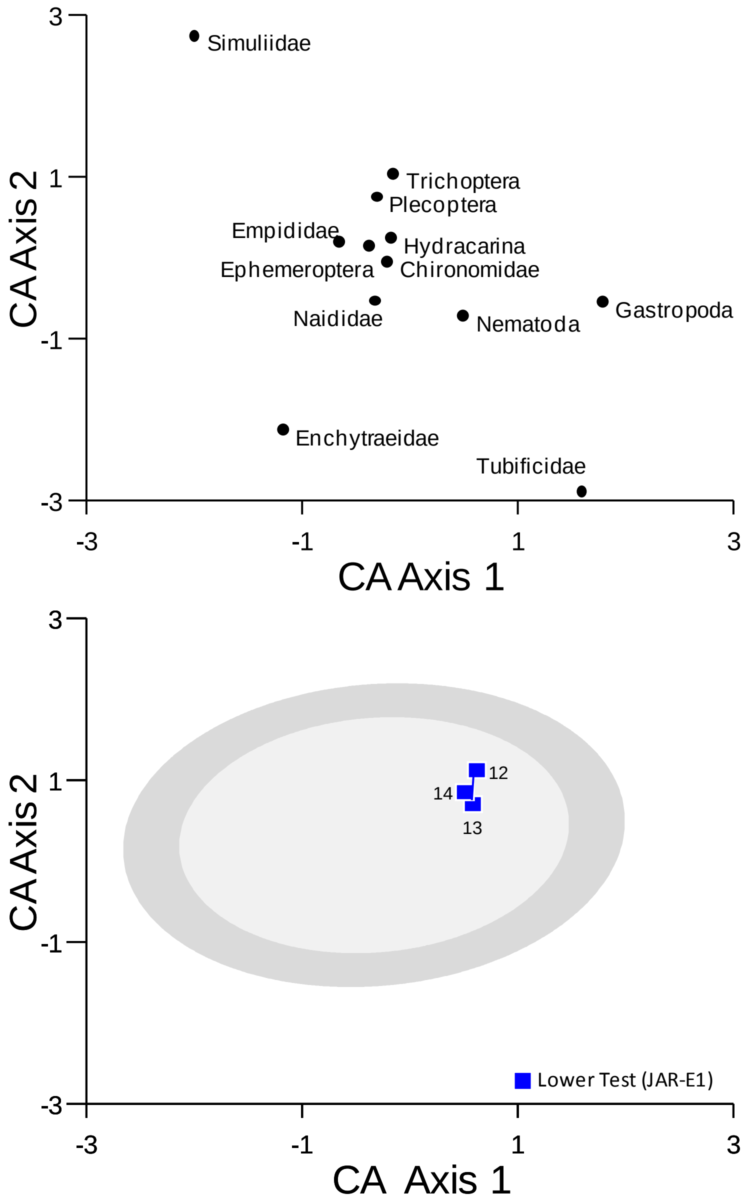
Figure 5.10-27 Variation in benthic invertebrate community measurement endpoints in Jackfish River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* erosional reaches.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.10-28 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing *test* reach JAR-E1.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* erosional reaches.

Table 5.10-38 Average habitat characteristics of benthic invertebrate sampling locations in Christina Lake, fall 2014.

Variable	Units	Christina Lake
Sample date	-	Sept 4, 2014
Habitat	-	Depositional
Water depth	m	1.1
Field Water Quality		
Dissolved oxygen	mg/L	8.0
Conductivity	µS/cm	173
pH	pH units	7.05
Water temperature	°C	16.8
Sediment Composition (mean ± 1SD)		
Sand	%	92±5
Silt	%	4±4
Clay	%	4±2
Total Organic Carbon	%	2.1±5.6

Table 5.10-39 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Christina Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Christina Lake		
	2012	2013	2014
Nematoda	11	12	16
Naididae	5	1	13
Tubificidae	<1	2	14
Enchytraeidae	2	1	5
Lumbriculidae	<1	-	<1
Hirudinea	<1	<1	<1
Hydracarina	2	1	<1
Amphipoda	11	11	17
Gastropoda	3	1	4
Bivalvia	4	1	4
Ceratopogonidae	1	3	1
Chironomidae	31	61	20
Diptera (misc)	<1	-	<1
Coleoptera	-	<1	<1
Ephemeroptera	2	6	2
Odonata	<1	<1	<1
Trichoptera	1	<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	638	593	255
Richness	33	27	20
Equitability	0.28	0.32	0.19
% EPT	3	8	2

Table 5.10-40 Results of ANOVA testing for differences in benthic invertebrate community endpoints in the Christina Lake (CHL-1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**<0.001**	**<0.001**	78	100	Decreasing over time; lower in 2014 than mean of all previous years.
Log of Richness	**<0.001**	**<0.001**	83	99	Decreasing over time; lower in 2014 than mean of all previous years.
Equitability	**0.044**	**0.010**	55	96	Decreasing over time; lower in 2014 than mean of all previous years.
Log of EPT	**0.029**	**0.003**	48	92	Decreasing over time; lower in 2014 than mean of all previous years.
CA Axis 1	0.278	0.534	95	53	No change.
CA Axis 2	0.237	0.616	56	10	No change.

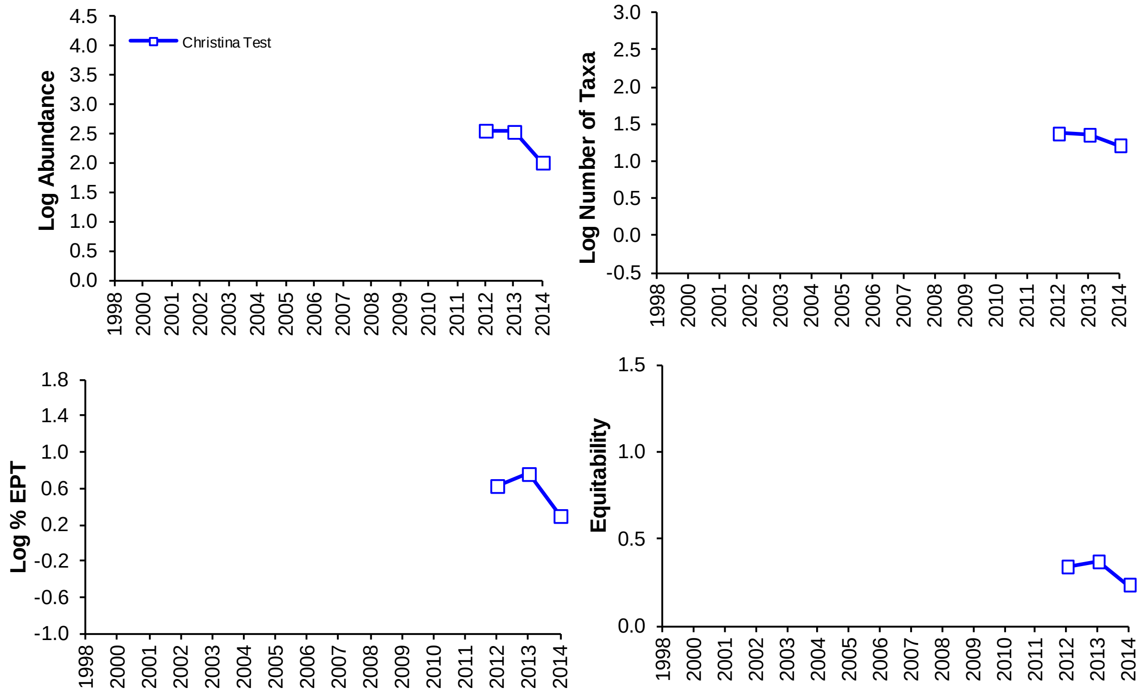
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common depth of 2 m.

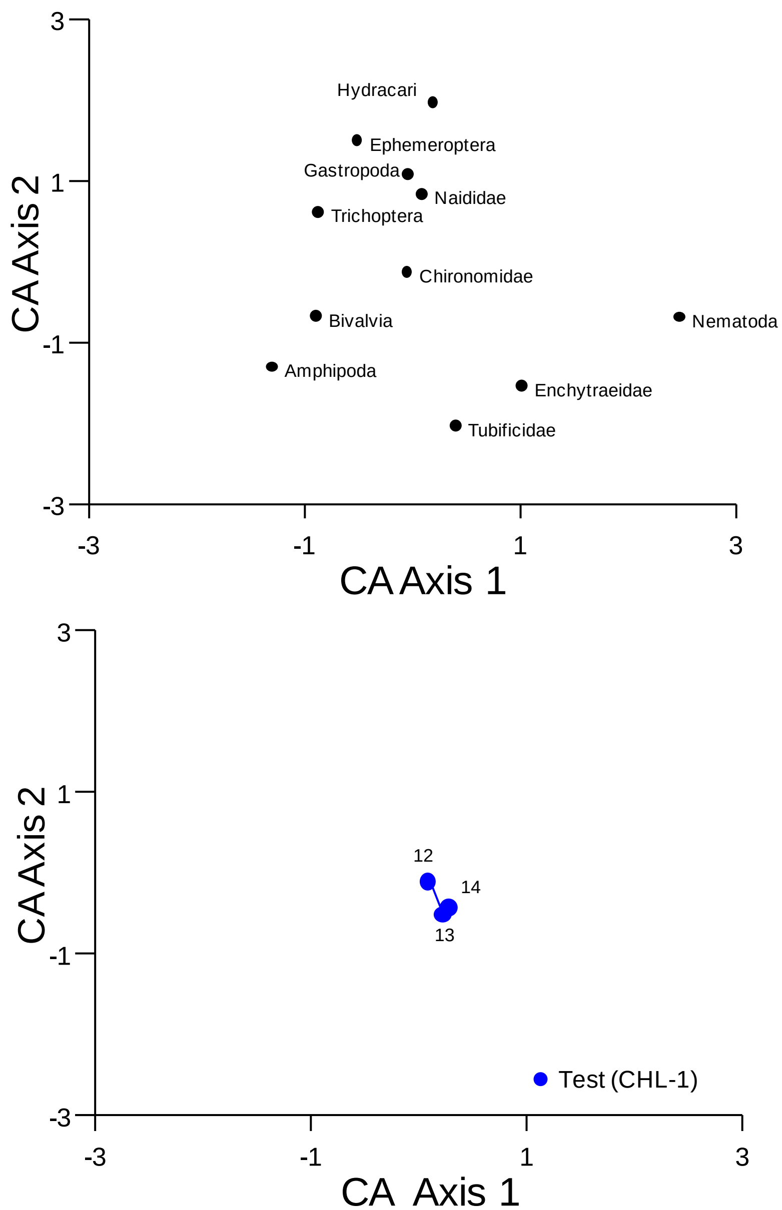
Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.10-29 Variation in benthic invertebrate community measurement endpoints in Christina Lake.



Note: Values have been adjusted to a common depth of 2 m.
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-30 Ordination (Correspondence Analysis) of benthic invertebrate communities in regional lakes, showing Christina Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.10-41 Average habitat characteristics of benthic invertebrate sampling locations in Gregoire Lake, fall 2014.

Variable	Units	Gregoire Lake
Sample date	-	Sept 4, 2014
Habitat	-	Depositional
Water depth	m	1.2
Field Water Quality		
Dissolved oxygen	mg/L	8.7
Conductivity	µS/cm	119
pH	pH units	7.89
Water temperature	°C	17.4
Sediment Composition (mean ± 1SD)		
Sand	%	94±5
Silt	%	4±5
Clay	%	2±1
Total Organic Carbon	%	0.4±0.2

Table 5.10-42 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Gregoire Lake.

Taxon	Percent Major Taxa Enumerated in Each Year
	Gregoire Lake
	2014
Hydra	<1
Nematoda	7
Oligochaeta	<1
Naididae	<1
Tubificidae	3
Enchytraeidae	<1
Lumbriculidae	<1
Hirudinea	<1
Hydracarina	<1
Amphipoda	13
Bivalvia	11
Ceratopogonidae	<1
Chironomidae	58
Diptera (misc)	<1
Coleoptera	<1
Ephemeroptera	2
Trichoptera	1
Benthic Invertebrate Community Measurement Endpoints	
Total Abundance per sample	243
Richness	16
Equitability	0.2
% EPT	3

Table 5.10-43 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D1), fall 2014.

Variables	Units	Guideline	September 2014	2002-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	10.8	7	5.8	10.0	17.0
Silt	%	-	23	7	16	25	38
Sand	%	-	66	7	54	62	74
Total organic carbon	%	-	0.95	7	0.70	1.16	2.00
Total hydrocarbons							
BTEX	mg/kg	-	<10	5	<5	<10	13
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	5	<5	<10	13
Fraction 2 (C10-C16)	mg/kg	150[1]	44	5	37	66	100
Fraction 3 (C16-C34)	mg/kg	300[1]	**355**	5	200	**374**	**970**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	176	5	130	228	600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0004</u>	7	0.0006	0.0017	0.0080
Retene	mg/kg	-	0.05	7	0.02	0.04	0.15
Total dibenzothiophenes	mg/kg	-	1.13	7	0.25	0.81	3.32
Total PAHs	mg/kg	-	3.78	7	1.00	3.13	11.75
Total Parent PAHs	mg/kg	-	0.10	7	0.04	0.09	0.32
Total Alkylated PAHs	mg/kg	-	3.68	7	0.95	3.01	11.43
Predicted PAH toxicity[3]	H.I.	1.0	**1.92**	7	0.65	**1.22**	**2.74**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	4	8.6	9.1	9.2
Chironomus growth - 10d	mg/organism	-	2.54	4	1.12	2.13	2.69
Hyalella survival - 14d	# surviving	-	9.2	4	6.0	8.7	9.4
Hyalella growth - 14d	mg/organism	-	0.28	4	0.10	0.23	0.30

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-44 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D2), fall 2014.

Variables	Units	Guideline	September 2014	2002-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.82	6	0.50	3.50	13.00
Silt	%	-	1.9	6	0.3	9.5	30.0
Sand	%	-	97.3	6	57.0	87.0	99.2
Total organic carbon	%	-	0.14	6	0.1	0.4	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<5	<7.5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<5	<7.5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	4	<5	<16.5	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	4	<5	23	47
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	4	<5	<20	32
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0003</u>	6	0.0004	0.0016	0.003
Retene	mg/kg	-	0.0007	6	0.0006	0.0081	0.092
Total dibenzothiophenes	mg/kg	-	0.0020	6	0.0013	0.0105	0.0205
Total PAHs	mg/kg	-	<u>0.0185</u>	6	0.0244	0.1078	0.3171
Total Parent PAHs	mg/kg	-	<u>0.0024</u>	6	0.0026	0.0127	0.0338
Total Alkylated PAHs	mg/kg	-	<u>0.0161</u>	6	0.0189	0.0951	0.2833
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.0830</u>	6	0.1025	0.4481	0.5705
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.0	5	5.0	7.2	9.2
Chironomus growth - 10d	mg/organism	-	3.7	5	1.4	1.8	4.3
Hyalella survival - 14d	# surviving	-	10.0	5	8.0	9.8	10.0
Hyalella growth - 14d	mg/organism	-	0.3	5	0.1	0.3	0.4

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-45 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D3), fall 2014.

Variables	Units	Guideline	September 2014
			Value
Physical variables			
Clay	%	-	0.84
Silt	%	-	3.95
Sand	%	-	95.2
Total organic carbon	%	-	0.6
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	36
Fraction 4 (C34-C50)	mg/kg	2,800[1]	21
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0003
Retene	mg/kg	-	0.0349
Total dibenzothiophenes	mg/kg	-	0.0079
Total PAHs	mg/kg	-	0.082
Total Parent PAHs	mg/kg	-	0.0043
Total Alkylated PAHs	mg/kg	-	0.078
Predicted PAH toxicity[3]	H.I.	1.0	0.32
Metals that exceeded CCME guidelines in 2014			
none			
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	7.4
Chironomus growth - 10d	mg/organism	-	2.32
Hyalella survival - 14d	# surviving	-	9.0
Hyalella growth - 14d	mg/organism	-	0.31

Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-46 Concentrations of selected sediment measurement endpoints, Christina River (*baseline* station CHR-D4), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	0.57	13
Silt	%	-	0.33	30
Sand	%	-	99.1	57
Total organic carbon	%	-	0.21	1.6
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0007	0.0010
Retene	mg/kg	-	0.0015	0.0001
Total dibenzothiophenes	mg/kg	-	0.0016	0.0019
Total PAHs	mg/kg	-	0.0162	0.0247
Total Parent PAHs	mg/kg	-	0.0030	0.0024
Total Alkylated PAHs	mg/kg	-	0.0131	0.0223
Predicted PAH toxicity[3]	H.I.	1.0	0.0714	0.1141
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	8.3	5.0
Chironomus growth - 10d	mg/organism	-	2.92	4.30
Hyalella survival - 14d	# surviving	-	9.8	10.0
Hyalella growth - 14d	mg/organism	-	0.43	0.11

Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-47 Concentrations of selected sediment measurement endpoints, Birch Creek (*baseline* station BRC-D1), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	2.9	10.0
Silt	%	-	9	20
Sand	%	-	88.2	70.0
Total organic carbon	%	-	0.61	1.50
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	56
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	23
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	<0.0013	0.0016
Retene	mg/kg	-	0.0027	0.0109
Total dibenzothiophenes	mg/kg	-	0.0035	0.0061
Total PAHs	mg/kg	-	0.0439	0.0913
Total Parent PAHs	mg/kg	-	0.0101	0.0185
Total Alkylated PAHs	mg/kg	-	0.0338	0.0728
Predicted PAH toxicity[3]	H.I.	1.0	0.1968	0.2525
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	66.0	6.2
Chironomus growth - 10d	mg/organism	-	2.82	3.15
Hyalella survival - 14d	# surviving	-	9.4	9.2
Hyalella growth - 14d	mg/organism	-	0.32	0.32

Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-48 Concentrations of selected sediment measurement endpoints, Sawbones Creek (*test* station SAC-D1), fall 2014.

Variables	Units	Guideline	September 2014	2012-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay[4]	%	-	8.34	2	5.41	5.69	5.96
Silt[4]	%	-	50.3	2	26.9	31.6	36.3
Sand[4]	%	-	41.4	2	57.8	62.8	67.7
Total organic carbon	%	-	5.02	2	4.08	5.02	5.95
Total hydrocarbons							
BTEX	mg/kg	-	<40	2	<20	<25	<30
Fraction 1 (C6-C10)	mg/kg	30[1]	**<40**	2	<20	<25	<30
Fraction 2 (C10-C16)	mg/kg	150[1]	<57	2	<29	31	33
Fraction 3 (C16-C34)	mg/kg	300[1]	233	2	101	175	249
Fraction 4 (C34-C50)	mg/kg	2,800[1]	131	2	51	98	145
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0019	2	0.0012	0.0012	0.0012
Retene	mg/kg	-	0.84	2	0.28	0.74	1.20
Total dibenzothiophenes	mg/kg	-	0.013	2	0.015	0.016	0.017
Total PAHs	mg/kg	-	1.045	2	0.498	0.941	1.384
Total Parent PAHs	mg/kg	-	0.017	2	0.025	0.025	0.026
Total Alkylated PAHs	mg/kg	-	1.027	2	0.473	0.916	1.359
Predicted PAH toxicity[3]	H.I.	1.0	0.799	2	0.361	1.398	2.435
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	2	5.6	7.3	9.0
Chironomus growth - 10d	mg/organism	-	1.7	2	2.3	2.4	2.6
Hyalella survival - 14d	# surviving	-	9.0	2	9.6	9.7	9.8
Hyalella growth - 14d	mg/organism	-	0.23	2	0.2	0.2	0.3

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-49 Concentrations of selected sediment measurement endpoints, Sunday Creek (*test* station SUC-D1), fall 2014.

Variables	Units	Guideline	September 2014	2012-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1.04	2	1.08	2.08	3.07
Silt	%	-	0.94	2	0.59	5.09	9.58
Sand	%	-	98.0	2	87.4	92.9	98.3
Total organic carbon	%	-	0.13	2	0.13	0.42	0.71
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	2	<20	24	28
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	2	<20	21	22
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<0.00065	2	0.00023	0.00037	0.00051
Retene	mg/kg	-	0.001	2	0.001	0.007	0.013
Total dibenzothiophenes	mg/kg	-	0.001	2	0.002	0.005	0.007
Total PAHs	mg/kg	-	0.017	2	0.028	0.054	0.081
Total Parent PAHs	mg/kg	-	0.003	2	0.002	0.005	0.008
Total Alkylated PAHs	mg/kg	-	0.014	2	0.025	0.049	0.073
Predicted PAH toxicity[3]	H.I.	1.0	0.076	2	0.126	0.228	0.33
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	2	5.4	6.2	7
Chironomus growth - 10d	mg/organism	-	1.47	2	0.9	2.4	3.9
Hyalella survival - 14d	# surviving	-	9.8	2	8.6	8.6	8.6
Hyalella growth - 14d	mg/organism	-	0.39	2	0.45	0.48	0.5

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-50 Concentrations of selected sediment measurement endpoints, Sunday Creek (*baseline* station SUC-D2), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	2.6	3.6
Silt	%	-	3.2	<1.0
Sand	%	-	94.2	95.6
Total organic carbon	%	-	0.24	0.12
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0003	0.0014
Retene	mg/kg	-	0.005	0.142
Total dibenzothiophenes	mg/kg	-	0.003	0.002
Total PAHs	mg/kg	-	0.029	0.173
Total Parent PAHs	mg/kg	-	0.004	0.003
Total Alkylated PAHs	mg/kg	-	0.026	0.170
Predicted PAH toxicity[3]	H.I.	1.0	0.139	0.928
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	9.0	7.6
Chironomus growth - 10d	mg/organism	-	2.3	5.5
Hyalella survival - 14d	# surviving	-	9.4	9.8
Hyalella growth - 14d	mg/organism	-	0.33	0.74

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-51 Concentrations of selected sediment measurement endpoints, Unnamed Creek (*test* station UNC-D2), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	3.87	5.23
Silt	%	-	3.1	32.6
Sand	%	-	93.0	62.2
Total organic carbon	%	-	0.47	6.40
Total hydrocarbons				
BTEX	mg/kg	-	<10	<60
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<60
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	39
Fraction 3 (C16-C34)	mg/kg	300[1]	42	374
Fraction 4 (C34-C50)	mg/kg	2,800[1]	33	188
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0005	0.0039
Retene	mg/kg	-	0.034	0.637
Total dibenzothiophenes	mg/kg	-	0.009	0.018
Total PAHs	mg/kg	-	0.113	0.963
Total Parent PAHs	mg/kg	-	0.007	0.046
Total Alkylated PAHs	mg/kg	-	0.106	0.918
Predicted PAH toxicity[3]	H.I.	1.0	0.35	0.50
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	8.8	6.2
Chironomus growth - 10d	mg/organism	-	1.64	1.85
Hyalella survival - 14d	# surviving	-	9.6	8.4
Hyalella growth - 14d	mg/organism	-	0.22	0.25

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-52 Concentrations of selected sediment measurement endpoints, Unnamed Creek (*test* station UNC-D3), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	1.13	1.04
Silt	%	-	0.74	1.97
Sand	%	-	98.1	97.0
Total organic carbon	%	-	0.20	0.29
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0003	0.0004
Retene	mg/kg	-	0.0016	0.0035
Total dibenzothiophenes	mg/kg	-	0.0020	0.0019
Total PAHs	mg/kg	-	0.0168	0.0203
Total Parent PAHs	mg/kg	-	0.0023	0.0021
Total Alkylated PAHs	mg/kg	-	0.0145	0.0182
Predicted PAH toxicity[3]	H.I.	1.0	0.0760	0.0943
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	8.4	6.2
Chironomus growth - 10d	mg/organism	-	2.14	3.58
Hyalella survival - 14d	# surviving	-	9.8	9
Hyalella growth - 14d	mg/organism	-	0.47	0.37

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-53 Concentrations of selected sediment measurement endpoints, Christina Lake (*test* station CHL-1), fall 2014.

Variables	Units	Guideline	September 2014	2012-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay[4]	%	-	8.2	2	0.92	0.96	1.00
Silt[4]	%	-	14.2	2	0.9	1.7	2.5
Sand[4]	%	-	77.6	2	97.0	97.6	98.2
Total organic carbon	%	-	17.90	2	0.22	0.22	0.22
Total hydrocarbons							
BTEX	mg/kg	-	<70	2	<10	<15	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	**<70**	2	<10	<15	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	40	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	**787**	2	<20	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	296	2	<20	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.004	2	0.0003	0.0005	0.0007
Retene	mg/kg	-	2.73	2	0.0033	0.0040	0.0047
Total dibenzothiophenes	mg/kg	-	0.0229	2	0.0016	0.0022	0.0027
Total PAHs	mg/kg	-	3.19	2	0.029	0.034	0.039
Total Parent PAHs	mg/kg	-	0.0710	2	0.0024	0.0042	0.0060
Total Alkylated PAHs	mg/kg	-	3.12	2	0.026	0.030	0.033
Predicted PAH toxicity[3]	H.I.	1.0	0.930	2	0.135	0.157	0.179
Metals that exceeded CCME guidelines in 2014							
Arsenic	mg/kg	5.9	**43.6**	2	0.28	0.47	0.65
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	2	7.4	7.9	8.4
Chironomus growth - 10d	mg/organism	-	2.11	2	2.8	4.2	5.6
Hyalella survival - 14d	# surviving	-	6.8	2	9.8	9.9	10.0
Hyalella growth - 14d	mg/organism	-	0.31	2	0.3	0.6	0.9

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations (n>3 years).

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-54 Concentrations of selected sediment measurement endpoints, Gregoire Lake (*test* station GRL-1), fall 2014.

Variables	Units	Guideline	September 2014
			Value
Physical variables			
Clay	%	-	3.4
Silt	%	-	7.8
Sand	%	-	88.8
Total organic carbon	%	-	0.14
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0003
Retene	mg/kg	-	0.0007
Total dibenzothiophenes	mg/kg	-	0.0041
Total PAHs	mg/kg	-	0.0233
Total Parent PAHs	mg/kg	-	0.0029
Total Alkylated PAHs	mg/kg	-	0.0204
Predicted PAH toxicity[3]	H.I.	1.0	0.1096
Metals that exceeded CCME guidelines in 2014			
none			
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	8.6
Chironomus growth - 10d	mg/organism	-	2.56
Hyalella survival - 14d	# surviving	-	9
Hyalella growth - 14d	mg/organism	-	0.32

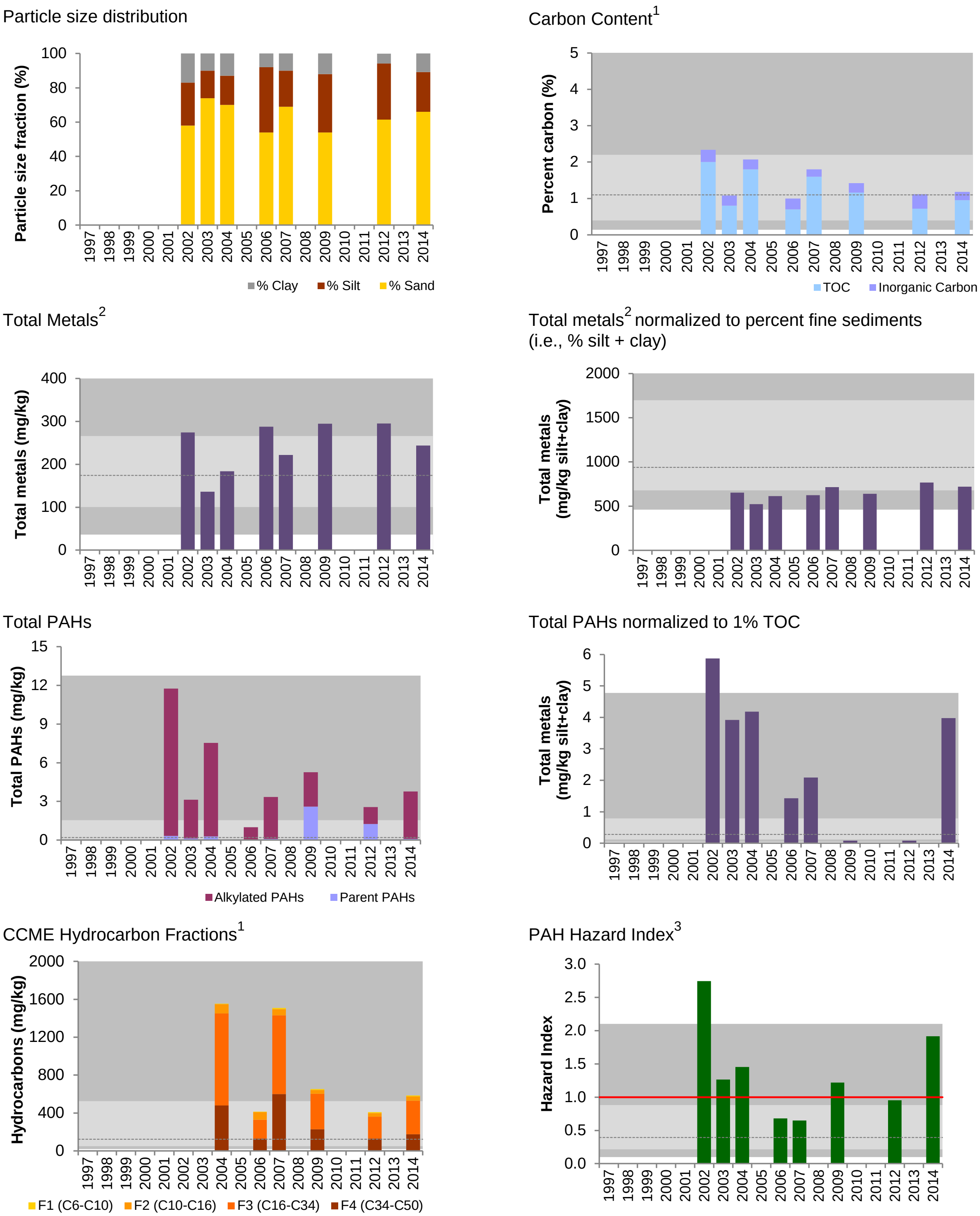
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-31 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D1.



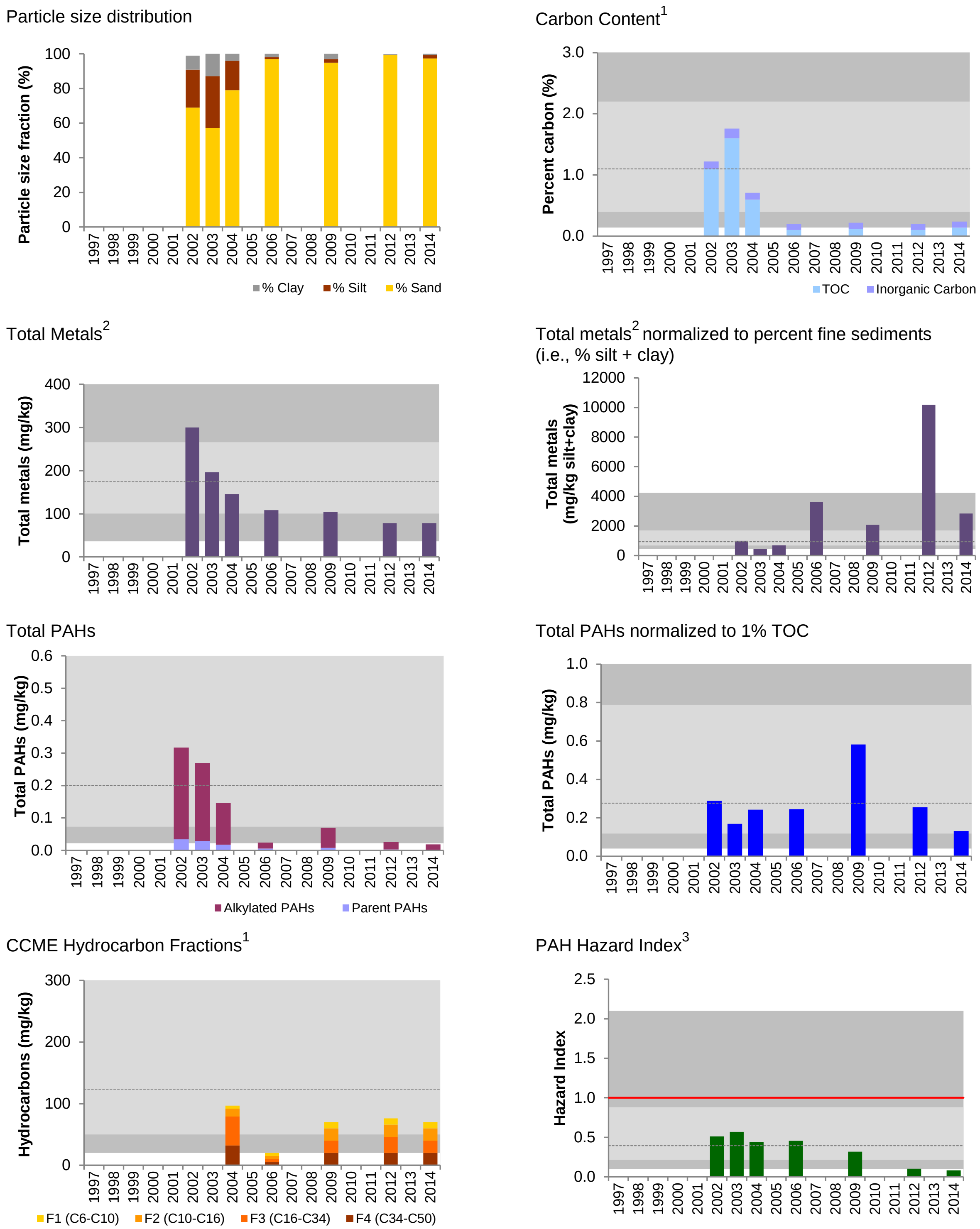
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-32 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D2.



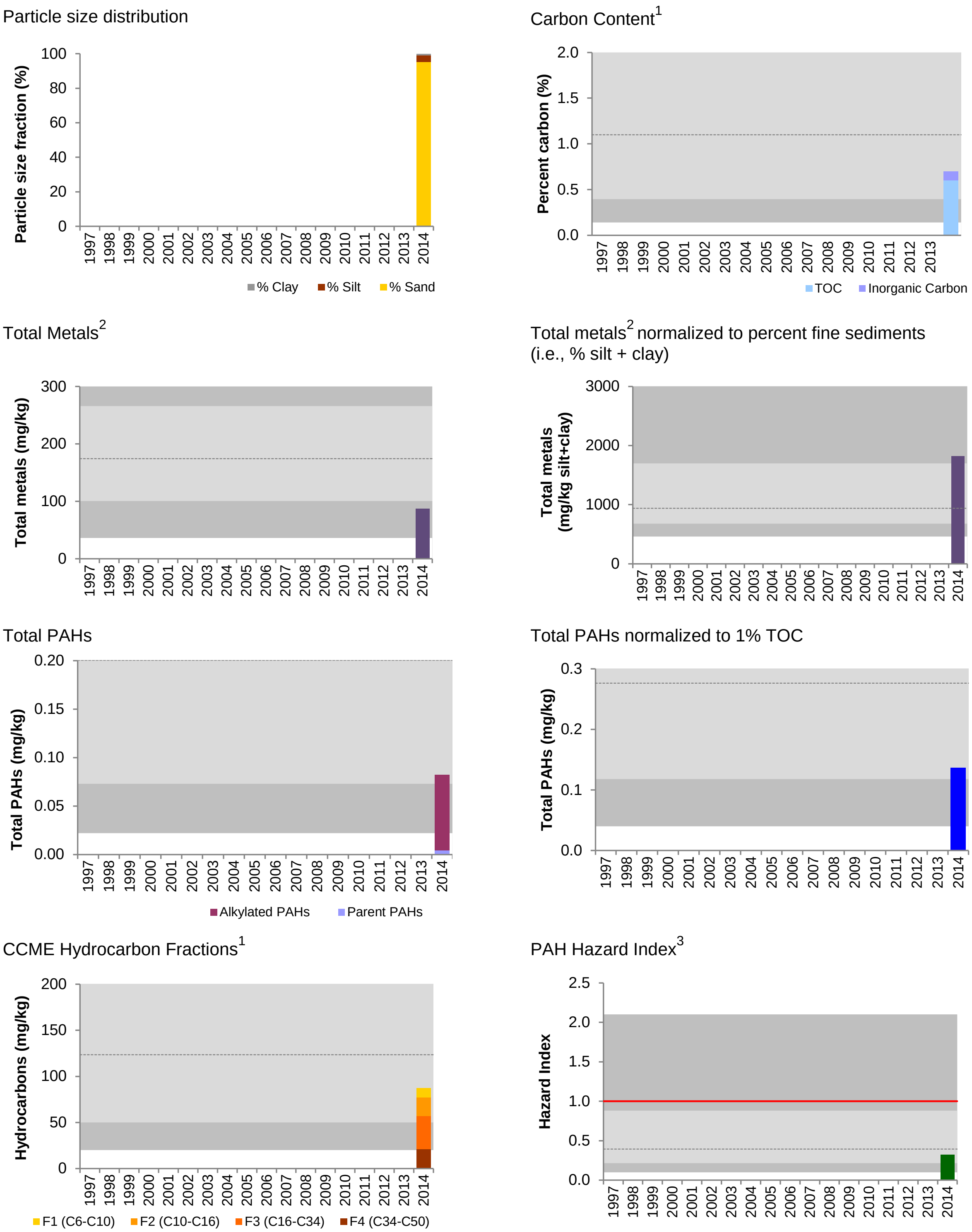
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-33 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D3.



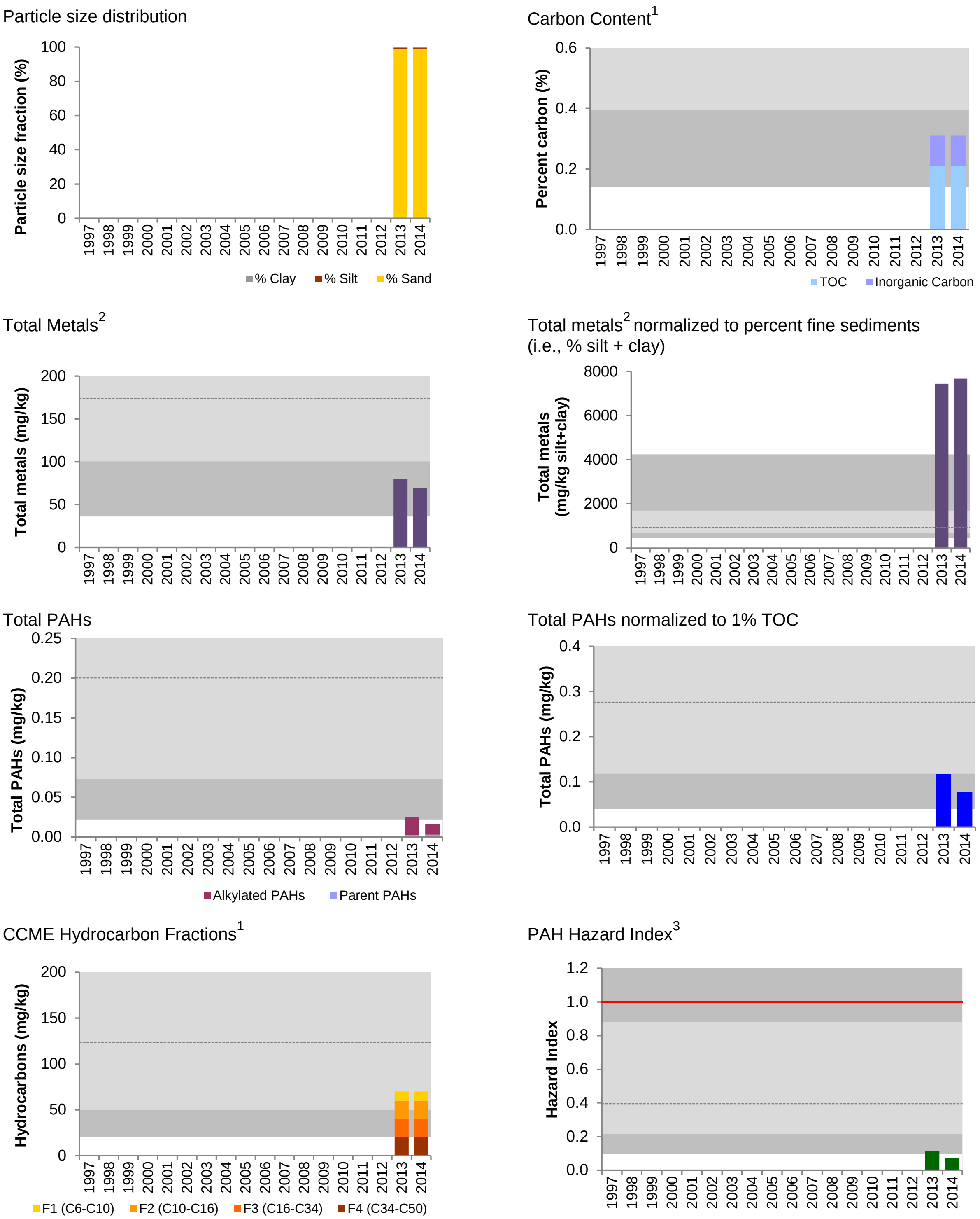
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-34 Variation in sediment quality measurement endpoints in the Christina River, *baseline* station CHR-D4.



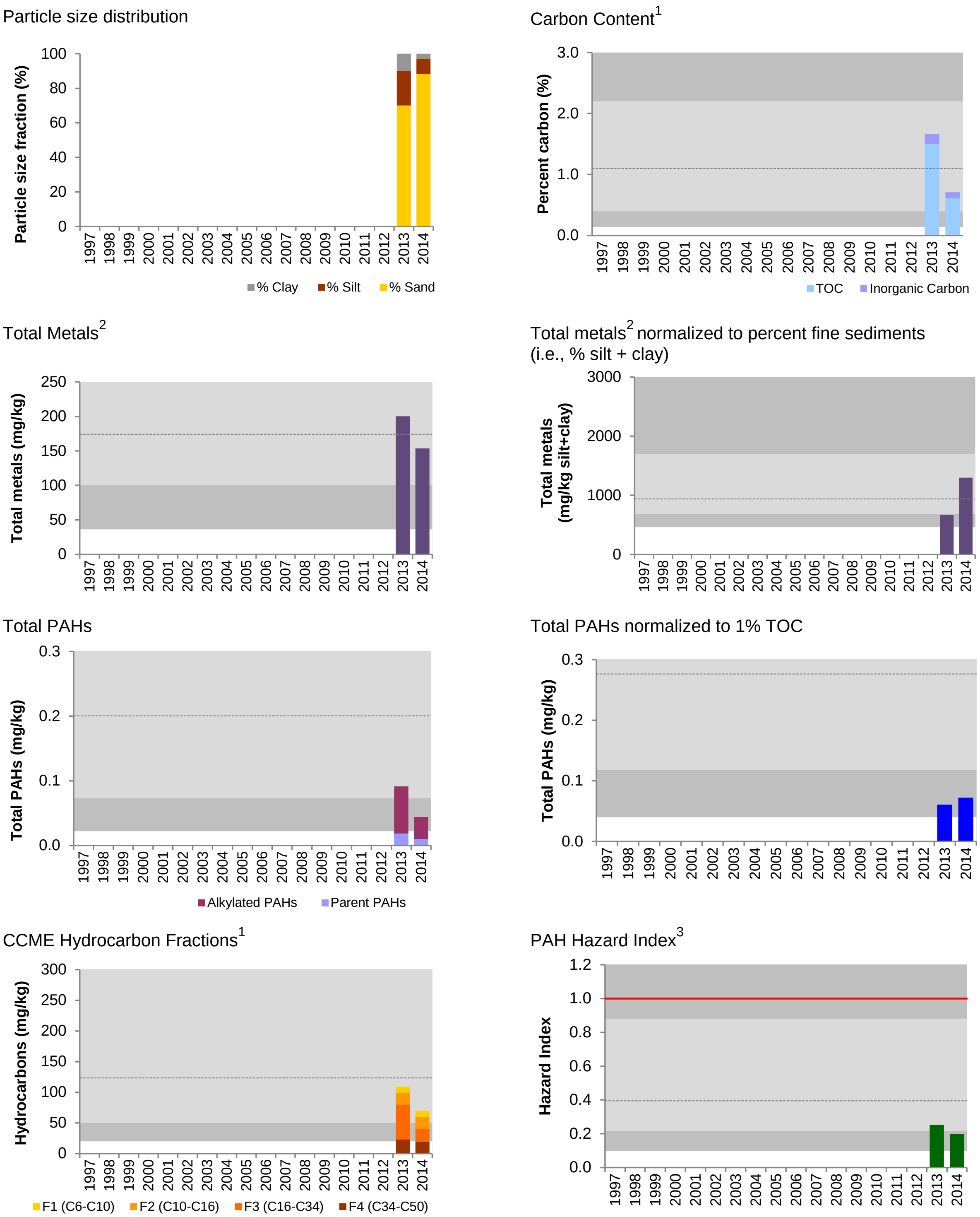
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-35 Variation in sediment quality measurement endpoints in the Birch Creek, *test* station BRC-D1.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

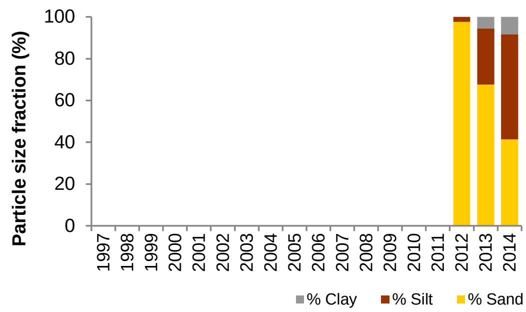
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

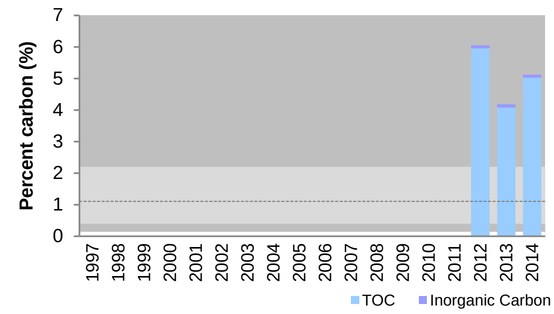
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-36 Variation in sediment quality measurement endpoints in the Sawbones Creek, *test* station SAC-D1.

Particle size distribution



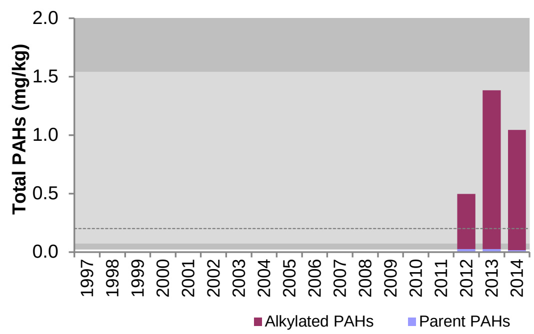
Carbon Content[1]



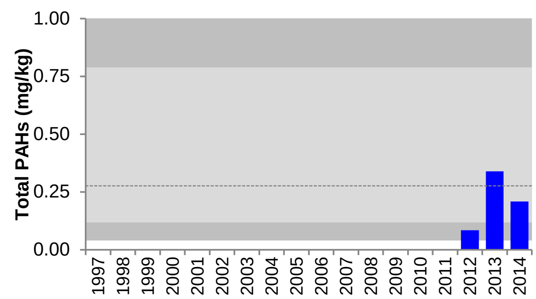
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)

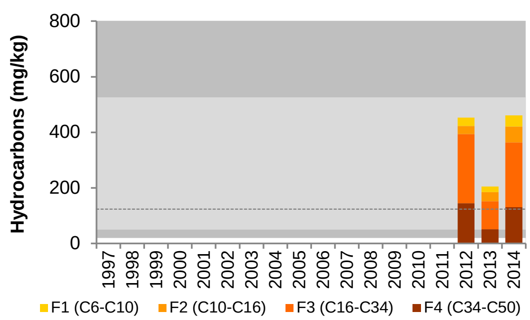
Total PAHs



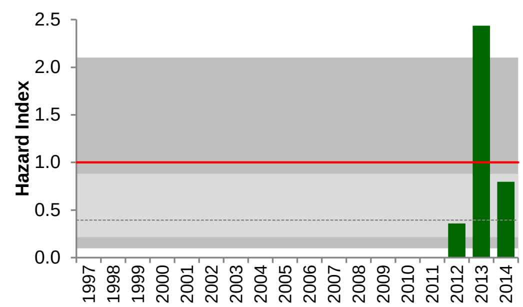
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



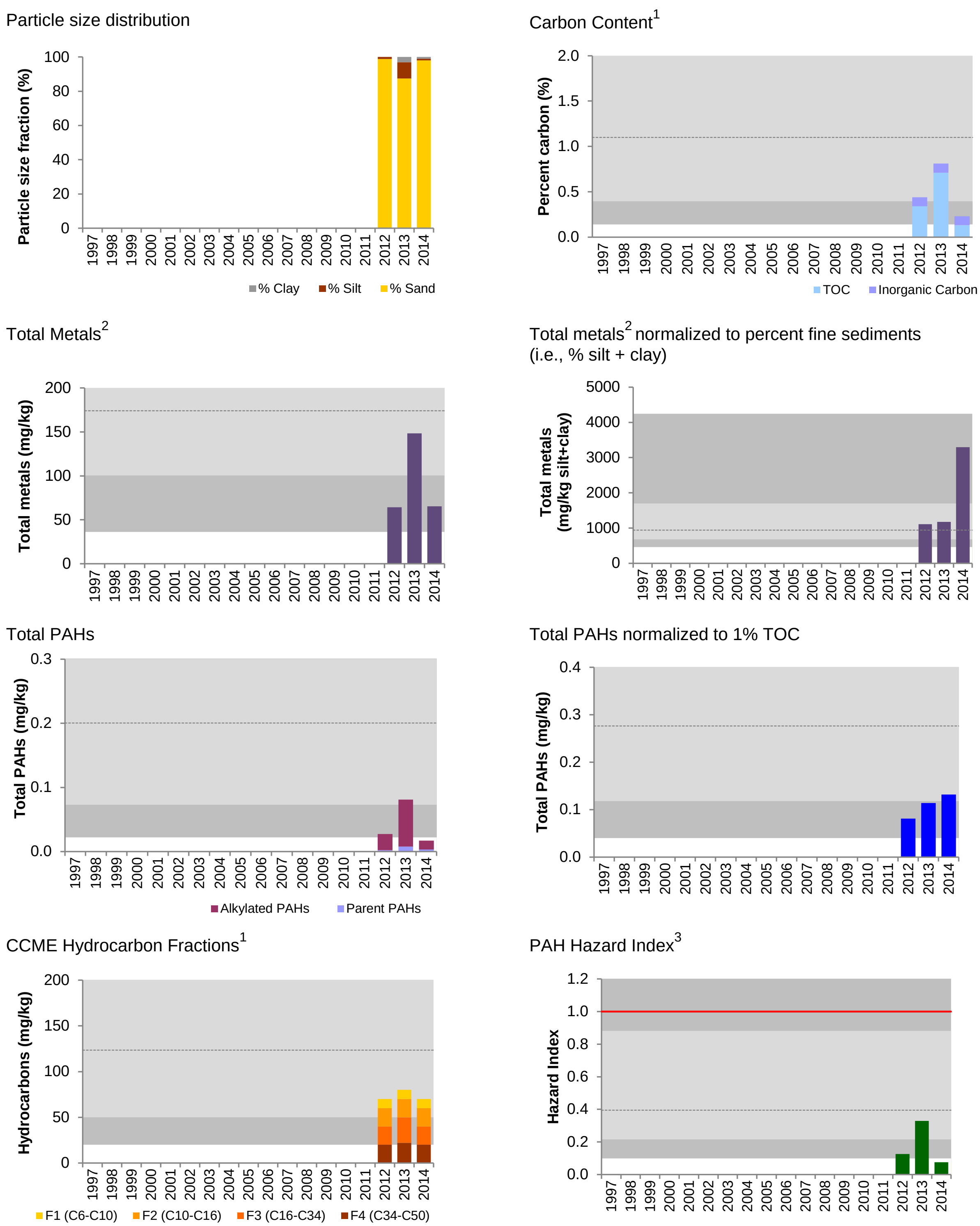
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-37 Variation in sediment quality measurement endpoints in the Sunday Creek, *test* station SUC-D1.



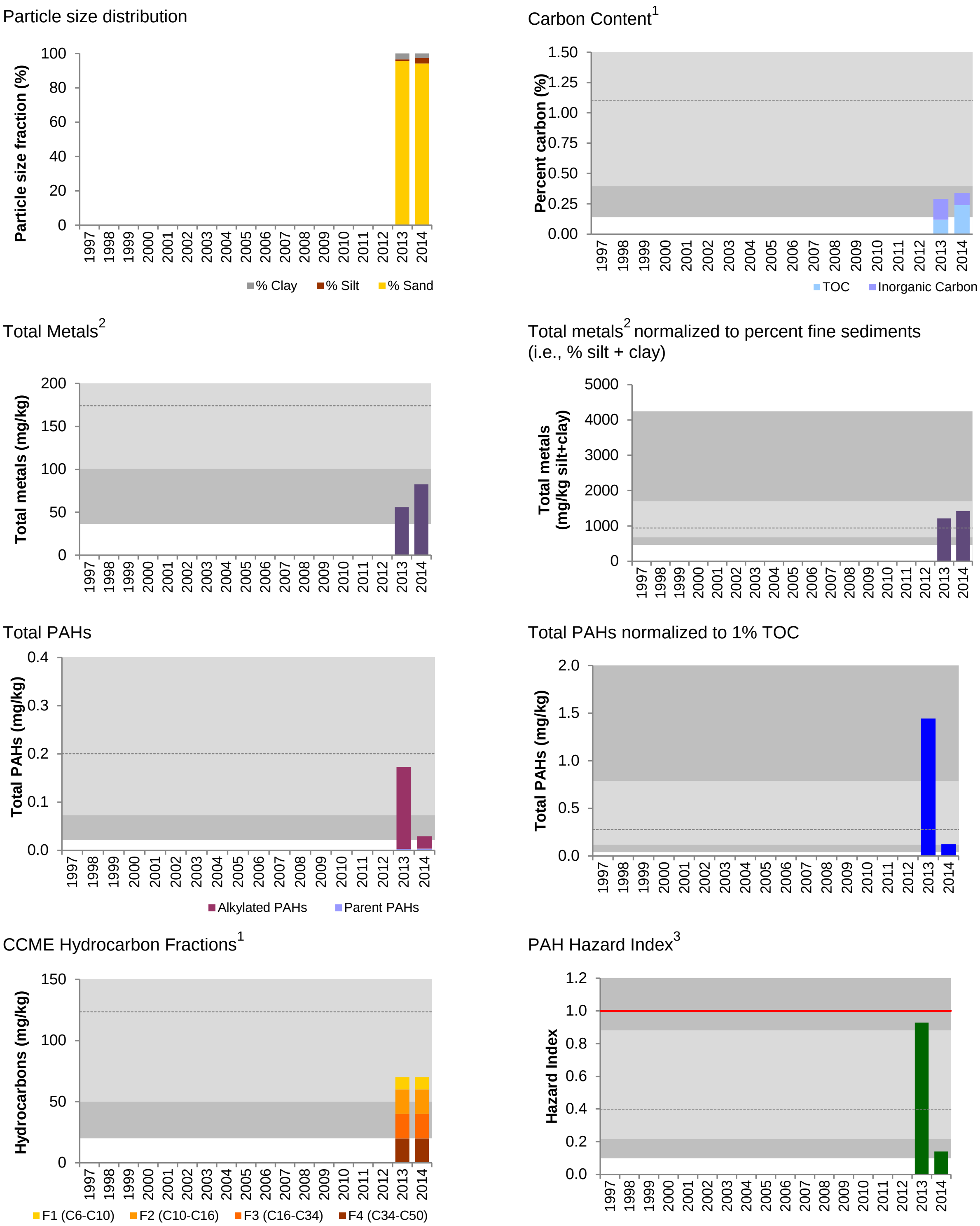
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-38 Variation in sediment quality measurement endpoints in the Sunday Creek, *baseline* station SUC-D2.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

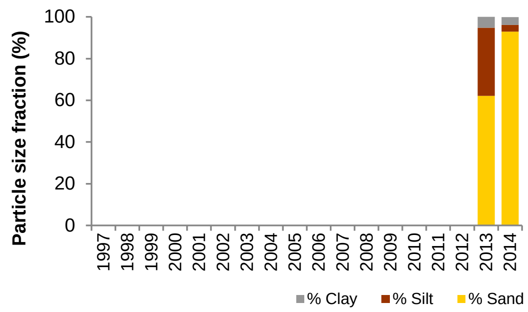
1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

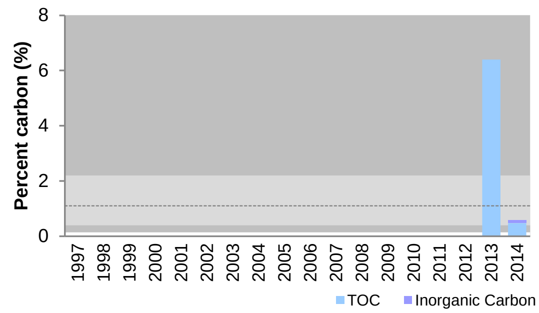
3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-39 Variation in sediment quality measurement endpoints in Unnamed Creek, *test* station UNC-D2.

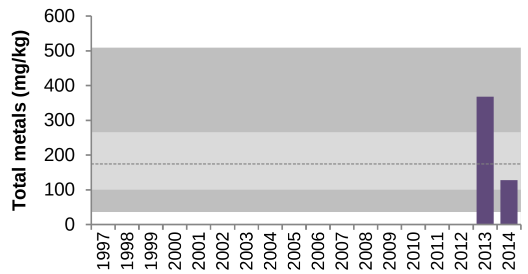
Particle size distribution



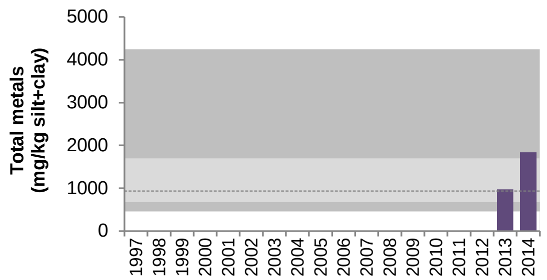
Carbon Content[1]



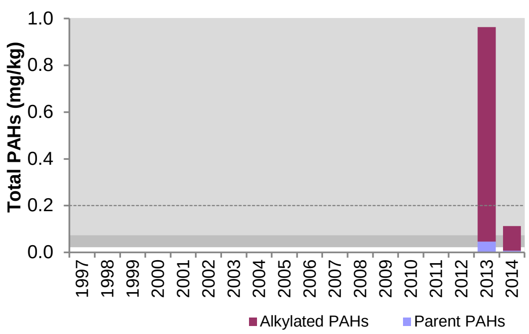
Total Metals[2]



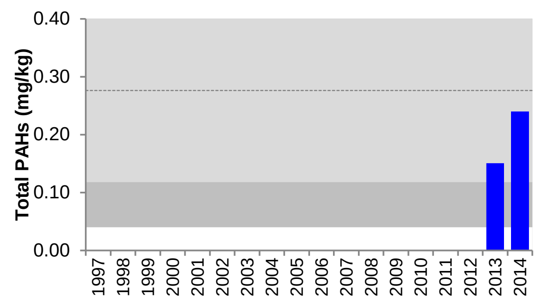
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



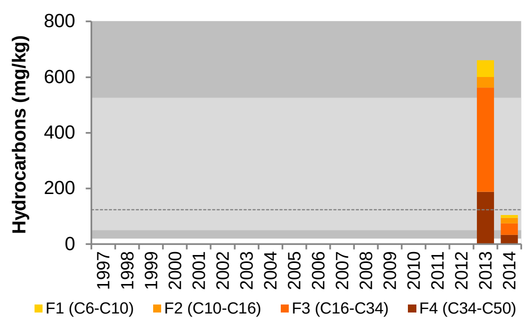
Total PAHs



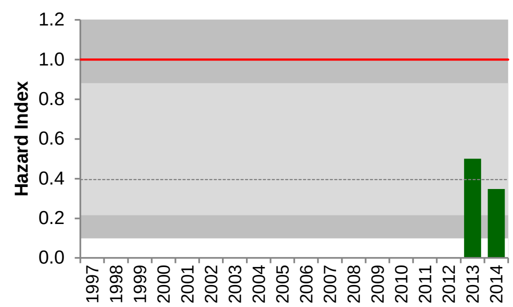
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



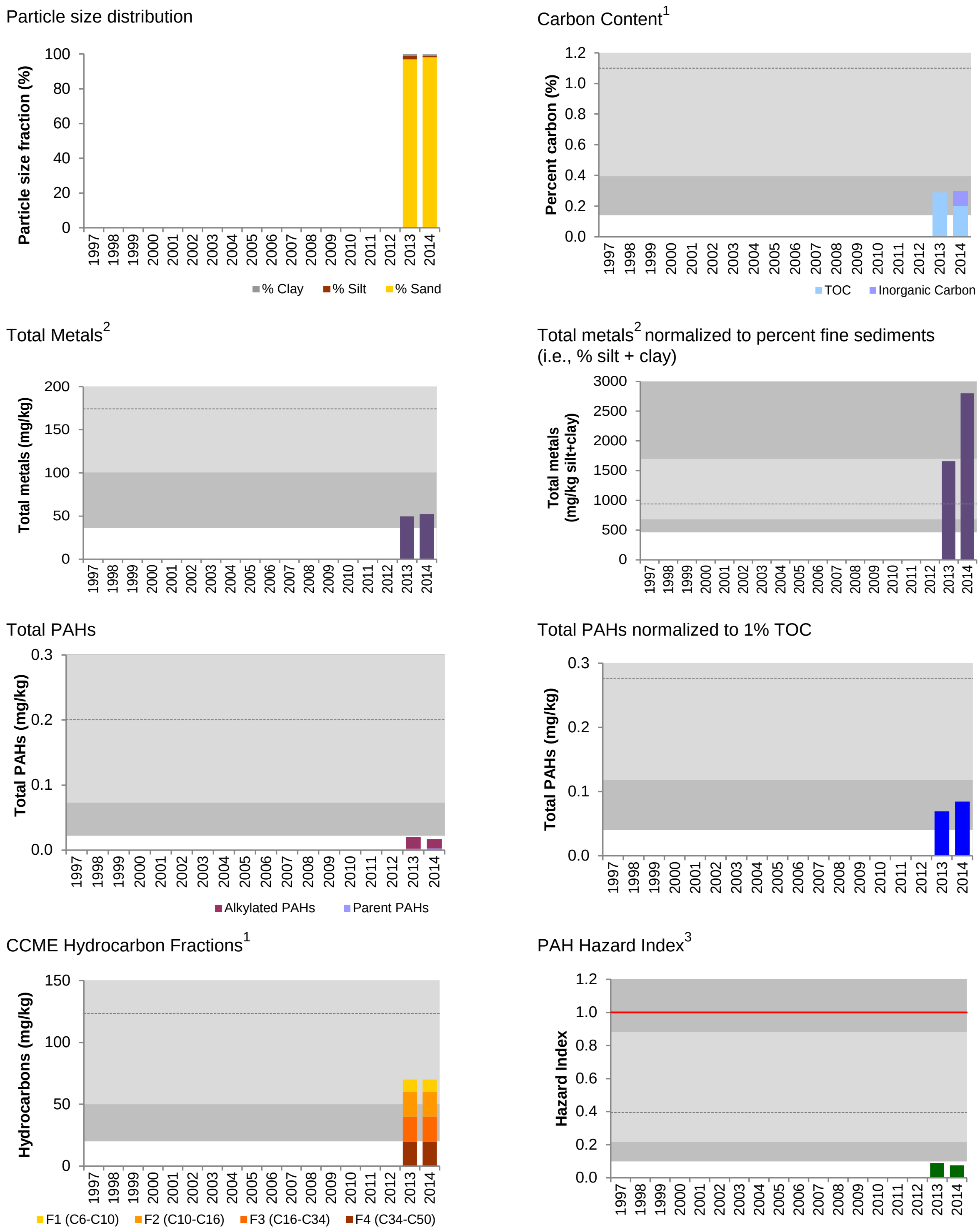
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-40 Variation in sediment quality measurement endpoints in Unnamed Creek, *test* station UNC-D3.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

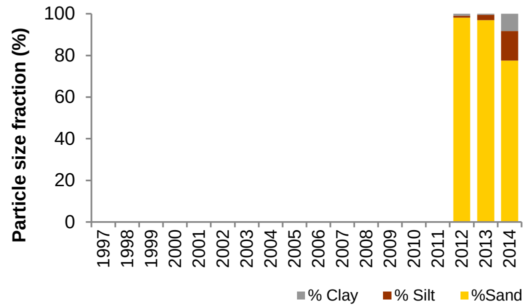
1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

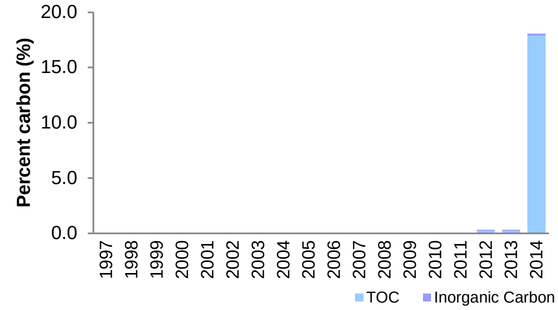
3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-41 Variation in sediment quality measurement endpoints in the Christina Lake, *test* station CHL-1.

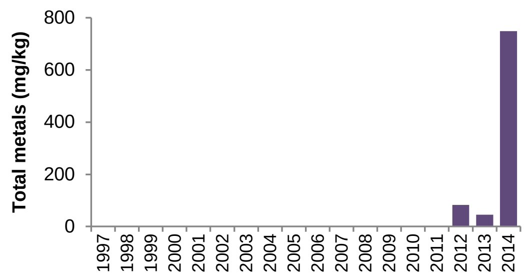
Particle size distribution



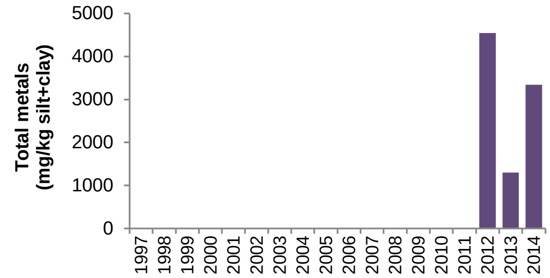
Carbon Content



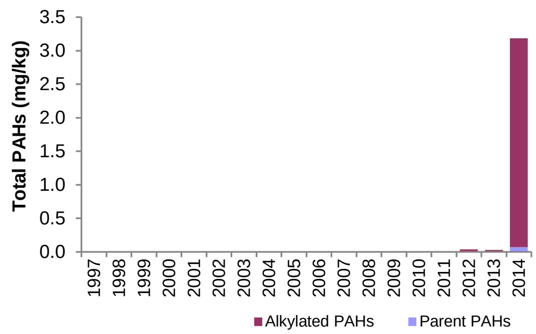
Total Metals[1]



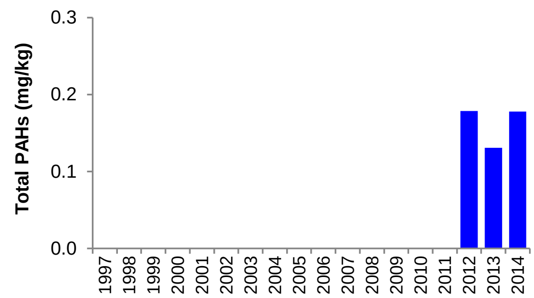
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



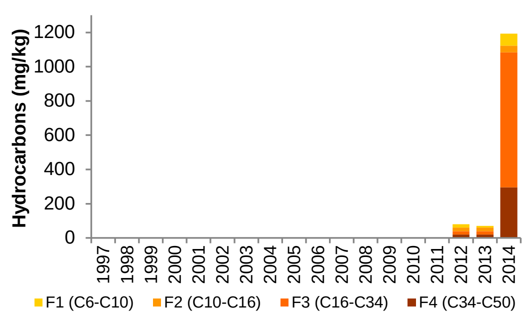
Total PAHs



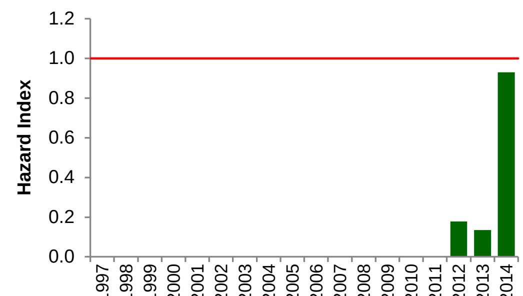
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions

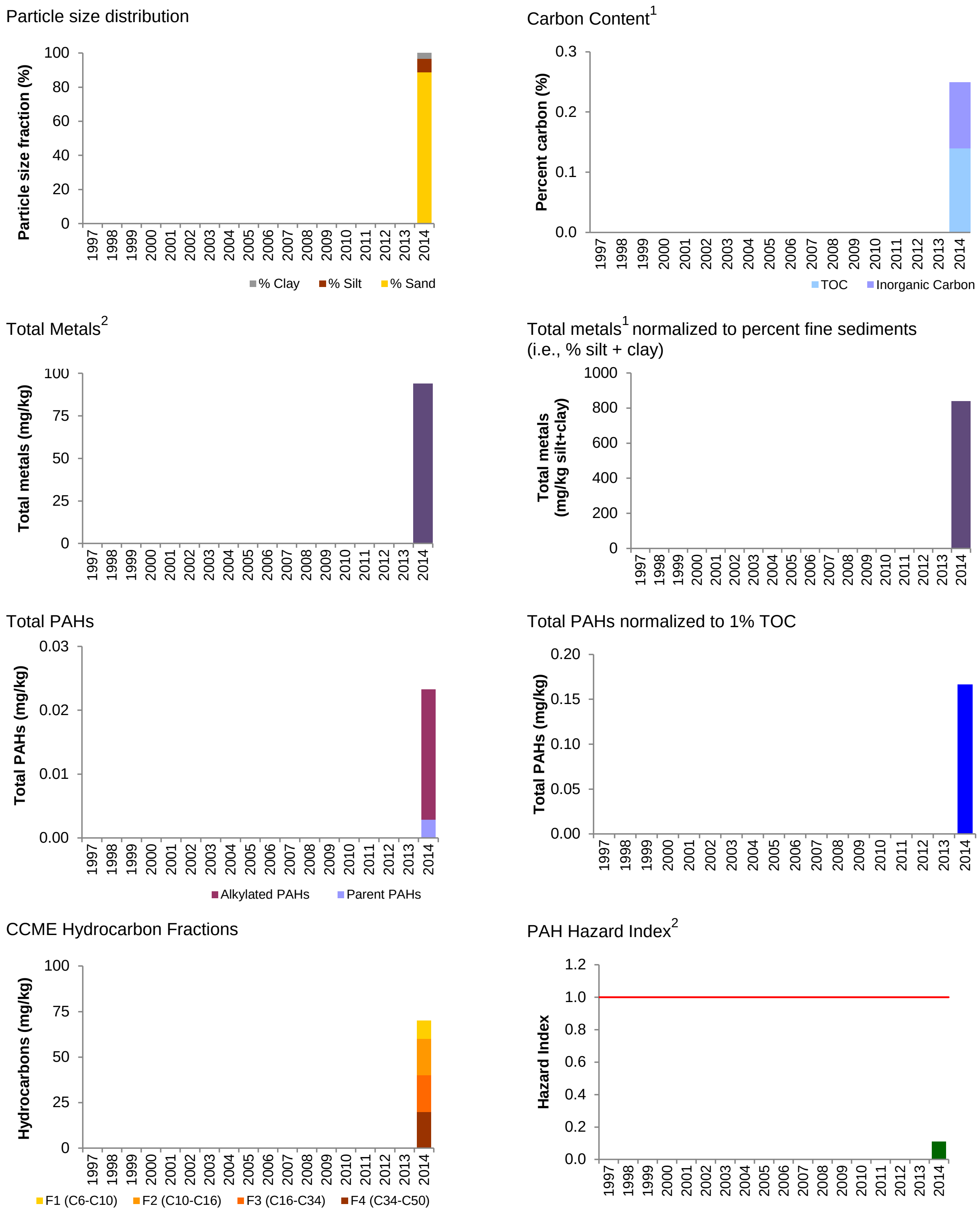


PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).
[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-42 Variation in sediment quality measurement endpoints in Gregoire Lake, *test* station GRL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-55 Sediment quality index (fall 2014) for stations in the Christina River watershed.

Station Identifier	Location	2014 Designation	Sediment Quality Index	Classification
BRC-D1	Birch Creek	*baseline*	95	Negligible-Low
CHR-D1	Lower Christina River	*test*	97.8	Negligible-Low
CHR-D2	Middle Christina River	*test*	100.0	Negligible-Low
CHR-D3	Upper Christina River	*test*	100.0	Negligible-Low
CHR-D4	Upper Christina River	*baseline*	100.0	Negligible-Low
SAC-D1	Sawbones Creek	*test*	95.5	Negligible-Low
SUC-D1	Lower Sunday Creek	*test*	100.0	Negligible-Low
SUC-D2	Upper Sunday Creek	*baseline*	100.0	Negligible-Low
UNC-D2	Unnamed Creek (east of Christina Lake)	*test*	94.0	Negligible-Low
UNC-D3	Unnamed Creek (south of Christina Lake)	*test*	100.0	Negligible-Low

Table 5.10-56 Average habitat characteristics of fish assemblage monitoring locations of the Christina River, fall 2014.

Variable	Units	CHR-F1 Lower *Test* Reach	CHR-F2 *Test* Reach below Jackfish River	CHR-F3 *Test* Reach above Jackfish River	CHR-F4 Upper *Baseline* Reach
Sample date	-	Sept 6, 2014	Sept 8, 2014	Sept 6, 2014	Sept 6, 2014
Habitat type	-	riffle/run	run	run	run
Maximum depth	m	0.88	71.0	0.66	0.75
Mean depth	m	0.64	71.0	0.61	0.72
Bankfull channel width	m	87.2	57.5	43.5	18.3
Wetted channel width	m	81.0	36.5	38.5	16.5
Substrate					
Dominant	-	coarse gravel	sand	cobble	fines
Subdominant	-	-	-	small boulder	cobble
Instream cover					
Dominant	-	boulders	small woody debris	boulders	undercut banks, boulders
Subdominant	-	-	-	overhanging vegetation, filamentous algae	overhanging vegetation, small woody debris
Field water quality					
Dissolved oxygen	mg/L	9.6	10.0	9.2	9.6
Conductivity	µS/cm	361	256	294	275
pH	pH units	8.71	8.16	7.78	7.79
Water temperature	^{0}C	12.6	8.6	12.1	10.8
Water velocity					
Left bank velocity	m/s	0.96	0.29	0.36	0.19
Left bank water depth	m	0.40	0.48	0.62	0.48
Centre of channel velocity	m/s	0.88	0.52	0.40	0.19
Centre of channel water depth	m	0.35	0.5	0.54	0.56
Right bank velocity	m/s	0.72	0.41	0.29	0.22
Right bank water depth	m	0.30	0.20	0.26	0.64
Riparian cover – understory (<5 m)					
Dominant	-	overhanging vegetation	woody shrubs and saplings	small woody debris	overhanging vegetation
Subdominant	-	woody shrubs and saplings	-	big and small trees	woody shrubs and saplings

Table 5.10-57 Total number and percent composition of fish species captured at reaches of the Christina River, 2014.

Common Name	Code	Total Species Catch								Percent of Total Catch							
		CHR-F1		CHR-F2		CHR-F3		<u>CHR-F4</u>		CHR-F1		CHR-F2		CHR-F3		<u>CHR-F4</u>	
		2012	2014	2012	2014	2013	2014	2013	2014	2012	2014	2012	2014	2013	2014	2013	2014
Arctic grayling	ARGR	-	-	2	-	-	-	-	-	0	0	3.7	0	0	0	0	0
brook stickleback	BRST	-	-	-	-	-	-	-	2	0	0	0	0	0	0	0	5.6
burbot	BURB	-	16	-	5	13	3	-	-	0	27.6	0	45.5	33.3	20.0	0	0
flathead chub	FLCH	1	-	-	-	-	-	-	-	3.8	0	0	0	0	0	0	0
goldeye	GOLD	7	-	-	-	-	-	-	-	26.9	0	0	0	0	0	0	0
lake chub	LKCH	5	20	3	-	-	-	1	-	19.2	34.5	5.6	0	0	0	1.9	0
longnose dace	LNDC	-	15	-	-	3	-	-	-	0	25.9	0	0	7.7	0	0	0
longnose sucker	LNSC	1	-	1	-	1	2	3	6	3.8	0	1.9	0	2.6	13.3	5.6	16.7
northern pike	NRPK	2	-	-	4	2	-	-	-	7.7	0	0	36.4	5.1	0	0	0
northern redbelly dace	NRDC	-	-	1	-	-	-	-	-	0	0	1.9	0	0	0	0	0
pearl dace	PRDC	-	-	1	1	1	1	35	15	0	0	1.9	9.1	2.6	6.7	64.8	41.7
slimy sculpin	SLSC	3	1	-	-	17	6	-	-	11.5	1.7	0	0	43.6	40.0	0	0
spoonhead sculpin	SPSC	-	1	-	-	-	-	-	-	0	1.7	0	0	0	0	0	0
trout-perch	TRPR	4	1	45	1	-	-	-	-	15.4	1.7	83.3	9.1	0	0	0	0
walleye	WALL	3	1	-	-	-	-	-	-	11.5	1.7	0	0	0	0	0	0
white sucker	WHSC	-	3	1	-	1	-	1	13	0	5.2	1.9	0	2.6	0	1.9	36.1
yellow perch	YLPR	-	-	-	-	-	3	-	-	0	0	0	0	0	20.0	0	0
sucker sp. *	-	-	-	-	-	1	-	14	-	0	0	0	0	2.6	0	25.9	0
Total		**26**	**58**	**54**	**11**	**39**	**15**	**54**	**36**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**8**	**8**	**7**	**4**	**7**	**5**	**4**	**4**	**8**	**8**	**7**	**4**	**7**	**5**	**4**	**4**
Electrofishing effort (secs)		**1,448**	**2,830**	**2,010**	**2,123**	**2,541**	**2,565**	**2,327**	**1,799**	-	-	-	-	-	-	-	-

* Unknown sucker species not included in species richness count.

Note: *Test* reaches CHR-F1 and CHR-F2 not sampled in 2013.

<u>Underline</u> denotes *baseline* reach.

Table 5.10-58 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of the Christina River watershed, 2012 to 2014.

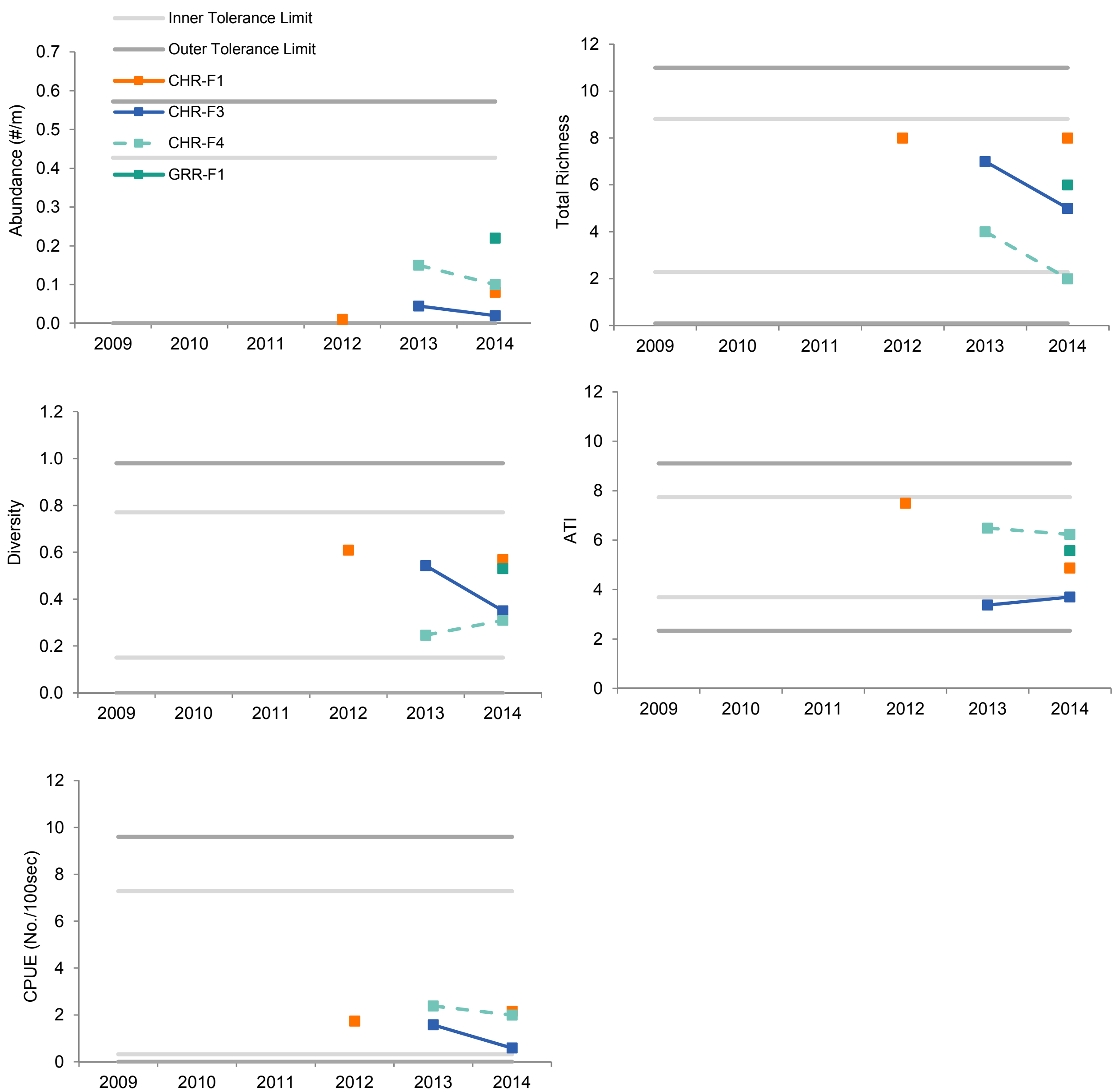
Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CHR-F1	2012	0.01	0.01	8	3.2	1.79	0.61	0.15	7.50	1.19	1.73	1.38
	2014	0.08	0.05	8	4.0	1.41	0.57	0.20	4.87	0.56	2.15	1.27
CHR-F2	2012	0.02	0.01	7	2.8	0.84	0.33	0.19	7.43	1.22	2.58	1.45
	2014	0.02	0.01	4	1.6	1.14	0.33	0.30	5.07	2.49	0.53	0.43
CHR-F3	2013	0.04	0.02	7	3.0	1.22	0.58	0.14	3.37	0.59	1.57	0.63
	2014	0.02	0.01	5	2.2	1.64	0.35	0.35	3.70	1.30	0.59	0.31
<u>CHR-F4</u>	2013	0.15	0.11	4	1.0	0.00	0.25	0.10	6.48	0.19	2.38	1.84
	2014	0.10	0.07	4	2.0	1.58	0.31	0.30	6.23	1.15	1.99	1.33
JAR-F1	2012	0.08	0.03	6	2.8	0.84	0.55	0.09	3.69	1.28	1.38	0.54
	2013	0.11	0.03	5	3.6	0.89	0.50	0.14	2.88	0.44	3.41	0.99
	2014	0.19	0.20	7	4.6	1.67	0.65	0.07	3.57	0.65	6.51	6.90
GRR-F1	2014	0.22	0.05	6	4.4	0.55	0.53	0.12	5.57	0.28	3.70	0.70
SAC-F1	2012	0.01	0.01	1	0.2	0.00	0.00	-	7.80	0.00	0.06	0.14
	2013	0.00	0.00	0	0.0	-	0.00	-	-	-	0.00	-
	2014	0.00	0.00	0	0.0	-	0.00	-	-	-	0.00	-
SUC-F1	2012	0.18	0.14	7	2.4	0.55	0.25	0.15	3.33	0.39	2.40	1.95
	2013	0.12	0.06	3	2.4	0.55	0.46	0.04	4.39	0.14	2.68	1.45
	2014	0.42	0.50	7	2.2	0.84	0.36	0.24	4.22	1.60	6.15	7.30
<u>SUC-F2</u>	2013	0.12	0.05	5	2.6	0.89	0.49	0.05	5.58	1.74	2.88	1.19
	2014	0.09	0.04	2	1.4	0.55	0.16	0.23	6.99	1.00	2.04	0.86
UNC-F2	2013	0.00	0.01	1	0.2	0.45	0.00	0.00	7.60	-	0.08	0.19
	2014	0.01	0.01	1	0.4	0.55	0.00	0.00	7.80	0.00	0.16	0.22
UNC-F3	2013	0.02	0.02	3	1.0	1.00	0.20	0.27	7.23	0.90	0.37	0.37
	2014	0.03	0.02	2	1.0	0.71	0.09	0.20	7.69	0.10	0.63	0.45
<u>BRC-F1</u>	2013	0.03	0.04	1	0.6	0.55	0.00	0.00	7.60	-	0.50	0.56
	2014	0.003	0.01	1	0.2	0.45	0.00	0.00	3.00	-	0.08	0.18

* Unknown species not included in analysis.

SD = standard deviation across sub-reaches within a reach.

<u>Underline</u> denotes *baseline* reaches.

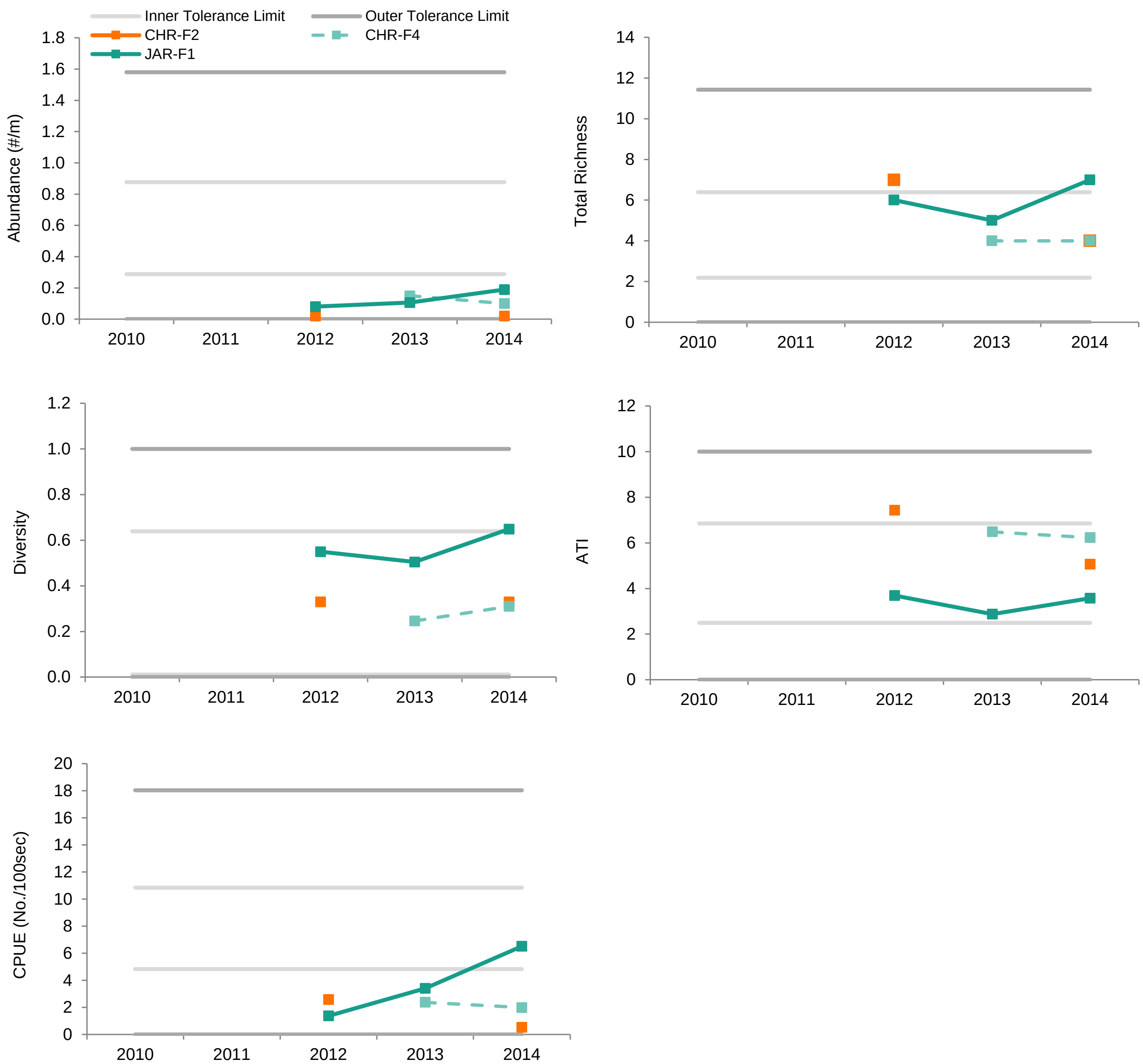
Figure 5.10-43 Variation in fish assemblage measurement endpoints for reaches of the Christina River and Gregoire River from 2012 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Figure 5.10-44 Variation in fish assemblage measurement endpoints for reaches of the Christina River and Jackfish River from 2012 to 2014, relative to regional *baseline* conditions (cluster 3).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 3 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: Although *baseline* reach CHR-F4 is not part of *baseline* cluster 3, the data were graphed to provide comparison to *test* reach CHR-F2.

Table 5.10-59 Average habitat characteristics of fish assemblage monitoring locations on tributaries of the Christina River, fall 2014.

Variable	Units	JAR-F1 *Test* Reach of Jackfish River	GRR-F1 *Test* Reach of Gregoire River
Sample date	-	Sept 13, 2014	Sept 6, 2014
Habitat type	-	riffle/run	riffle/run
Maximum depth	m	0.53	0.53
Mean depth	m	0.47	0.32
Bankfull channel width	m	35.3	32.4
Wetted channel width	m	32.8	16.1
Substrate			
Dominant	-	cobble	cobble
Subdominant	-	coarse gravel	small boulder
Instream cover			
Dominant	-	boulders	boulders
Subdominant	-	filamentous algae	small woody debris
Field water quality			
Dissolved oxygen	mg/L	8.8	9.0
Conductivity	µS/cm	175	295
pH	pH units	8.36	8.54
Water temperature	^{0}C	9.8	11.3
Water velocity			
Left bank velocity	m/s	0.10	0.26
Left bank water depth	m	0.38	0.27
Centre of channel velocity	m/s	0.26	0.29
Centre of channel water depth	m	0.53	0.30
Right bank velocity	m/s	0.16	0.47
Right bank water depth	m	0.37	0.39
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	-	-

Table 5.10-60 Total number and percent composition of fish species captured in tributaries of the Christina River, 2012 to 2014.

Common Name	Code	Total Species Catch				Percent of Total Catch			
		JAR-F1			GRR-F1	JAR-F1			GRR-F1
		2012	2013	2014	2014	2012	2013	2014	2014
Arctic grayling	ARGR	-	-	1	-	0	0	0.6	0
burbot	BURB	12	47	83	6	48.0	61.0	46.4	7.0
lake chub	LKCH	-	-	-	2	0	0	0	2.3
longnose dace	LNDC	2	8	21	55	8.0	10.4	11.7	64.0
longnose sucker	LNSC	1	4	8	1	4.0	5.2	4.5	1.2
northern pike	NRPK	1	-	4	-	4.0	0	2.2	0
slimy sculpin	SLSC	6	17	52	12	24.0	22.1	29.1	14.0
trout-perch	TRPR	-	1	-	-	0	1.3	0	0
walleye	WALL	-	-	4	-	0	0	2.2	0
white sucker	WHSC	3	-	6	10	12.0	0	3.4	11.6
Total		**25**	**77**	**179**	**86**	**100**	**100**	**179**	**100**
Total Species Richness		**6**	**5**	**8**	**6**	**6**	**5**	**8**	**21**
Electrofishing effort (secs)		**1,803**	**2,265**	**2,587**	**2,317**	-	-	-	-

Table 5.10-61 Average habitat characteristics of fish assemblage monitoring locations on tributaries to Christina Lake, fall 2014.

Variable	Units	SUC-F1 Lower *Test* Reach of Sunday Creek	SUC-F2 Upper *Baseline* Reach of Sunday Creek	BRC-F1 *Baseline* Reach of Birch Creek	SAC-F1 *Test* Reach of Sawbones Creek	UNC-F2 *Test* Reach of Unnamed Creek (east of CHL)	UNC-F3 *Test* Reach of Unnamed Creek (south of CHL)
Sample date	-	Sept 5, 2014	Sept 5, 2014	Sept 5, 2014	Sept 8, 2014	Sept 8, 2014	Sept 5, 2014
Habitat type	-	run	run	run	run	run	run
Maximum depth	m	1.20	1.14	1.20	2.20	0.98	0.92
Mean depth	m	0.77	0.83	0.99	1.75	0.82	0.73
Bankfull channel width	m	11.9	7.0	13.0	5.3	7.0	5.5
Wetted channel width	m	9.0	6.7	10.0	5.3	5.8	3.8
Substrate							
Dominant	-	sand	sand / fines	fines	fines	fines	sand
Subdominant	-	cobble	cobble	-	coarse gravel	sand	fines
Instream cover							
Dominant	-	boulders	overhanging vegetation	overhanging vegetation, undercut banks	macrophytes	macrophytes	small woody debris
Subdominant	-	macrophytes	undercut banks, small woody debris	live trees/roots, large woody debris	overhanging vegetation, undercut banks, large and small woody debris	undercut banks, overhangig vegetation	undercut banks, overhanging vegetation, macrophytes
Field water quality							
Dissolved oxygen	mg/L	8.9	8.8	8.4	9.6	9.2	8.1
Conductivity	µS/cm	288	239	335	110	247	286
pH	pH units	8.36	7.65	8.04	7.34	8.59	8.22
Water temperature	^{0}C	13.2	11.3	11.4	7.5	9.4	12.9
Water velocity							
Left bank velocity	m/s	0.19	0.00	0.00	0.00	0.13	0.02
Left bank water depth	m	0.20	0.22	0.44	1.50	0.82	0.33
Centre of channel velocity	m/s	0.16	0.04	0.00	0.02	0.01	0.04
Centre of channel water depth	m	0.33	0.41	0.64	1.69	0.41	0.45
Right bank velocity	m/s	0.33	0.01	0.00	0.02	0.01	0.03
Right bank water depth	m	0.27	0.30	0.77	1.70	0.38	0.67
Riparian cover- understory (<5 m)							
Dominant	-	woody shrubs and saplings	overhanging vegetation	woody shrubs and saplings	overhanging vegetation	overhanging vegetation	overhanging vegetation
Subdominant	-	overhanging vegetation	woody shrubs and saplings	overhanging vegetation	woody shrubs and saplings	-	-

CHL=Christina Lake

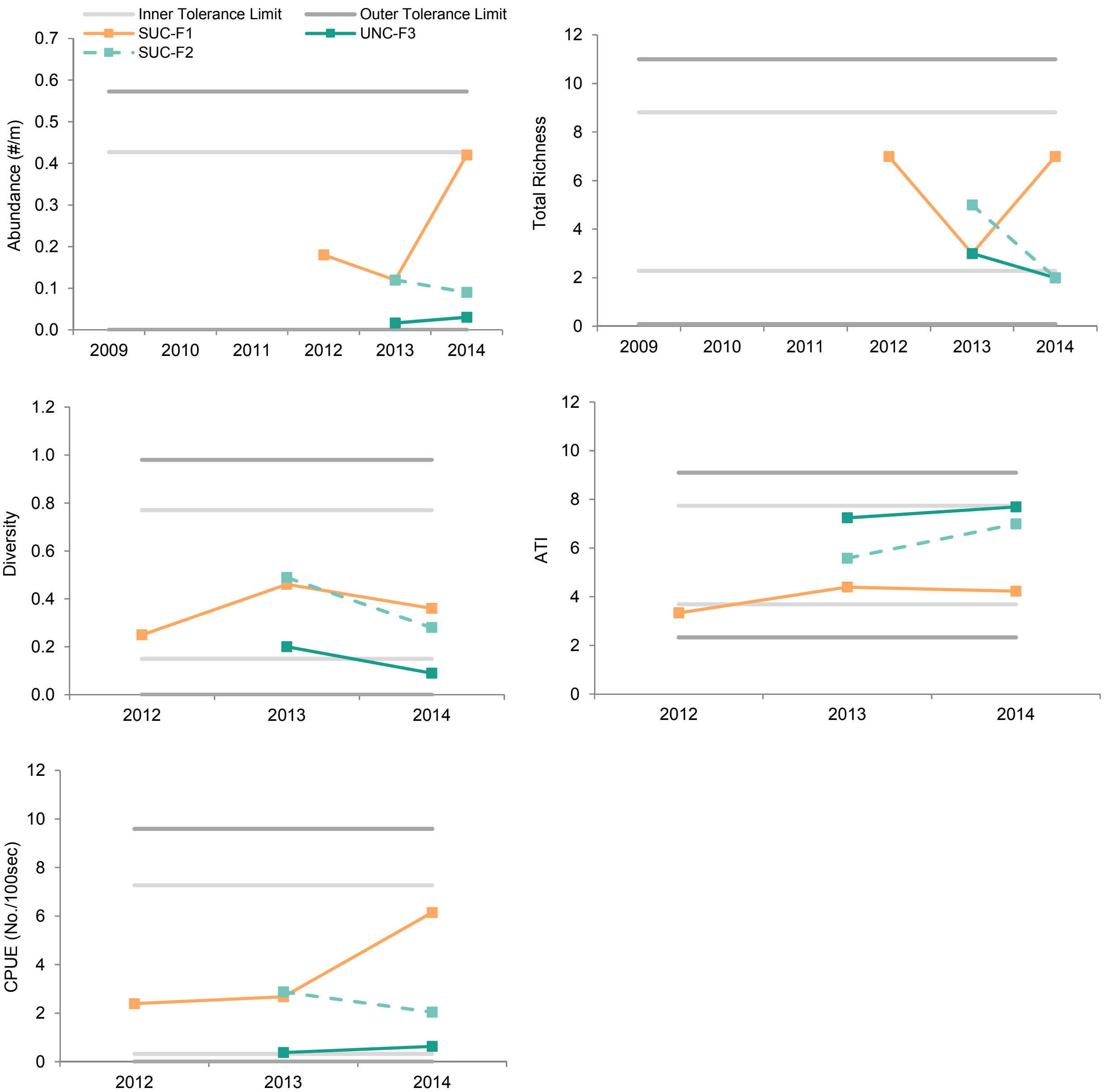
Table 5.10-62 Total number and percent composition of fish species captured in tributaries of Christina Lake, 2012 to 2014.

Common Name	Code	Total Species Catch														Percent of Total Catch													
		SUC-F1			SUC-F2		SAC-F1			UNC-F2		UNC-F3		BRC-F1		SUC-F1			SUC-F2		SAC-F1			UNC-F2		UNC-F3		BRC-F1	
		2012	2013	2014	2013	2014	2012	2013	2014	2013	2014	2013	2014	2013	2014	2012	2013	2014	2013	2014	2012	2013	2014	2013	2014	2013	2014	2013	2014
Arctic grayling	ARGR	1	-	2	-	-	-	-	-	-	-	-	-	-	-	2.3	0	2.1	0	0	0	0	0	0	0	0	0	0	0
brook stickleback	BRST	-	-	-	2	-	-	-	-	-	-	-	-	-	-	0	0	0	5.6	0	0	0	0	0	0	0	0	0	0
Iowa darter	IWDR	-	-	-	1	-	-	-	-	-	-	-	-	-	-	0	0	0	2.8	0	0	0	0	0	0	0	0	0.0	0
lake chub	LKCH	2	-	2	-	-	-	-	-	-	-	-	-	-	-	4.5	0	2.1	0	0	0	0	0	0	0	0	0	0	0
longnose sucker	LNSC	1	-	2	-	-	-	-	-	-	-	1	-	-	-	2.3	0	2.1	0	0	0	0	0	0	0	20.0	0	0	0
northern pike	NRPK	2	-	1	1	-	1	-	-	-	2	3	5	-	-	4.5	0	1.1	2.8	0	100	0	0	0	100	60.0	62.5	0	0
pearl dace	PRDC	1	12	-	-	-	-	-	-	-	-	-	-	-	-	2.3	20.0	0	0	0	0	0	0	0	0	0	0	0	0
slimy sculpin	SLSC	36	39	58	18	2	-	-	-	-	-	-	-	-	1	81.8	65.0	61.7	50.0	7.7	0	0	0	0	0	0	0	0	100
spottail shiner	SPSH	-	-	27	-	-	-	-	-	-	-	-	-	-	-	0	0	28.7	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	-	8	2	14	24	-	-	-	1	-	1	3	6	-	0	13.3	2.1	38.9	92.3	0	0	0	100.0	0	20.0	37.5	75.0	0
sucker sp. *		1	1	-	-	-	-	-	-	-	-	-	-	2	-	2.3	1.7	0	0	0	0	0	0	0	0	0	0	25.0	0
Total		**44**	**60**	**94**	**36**	**26**	**1**	**0**	**0**	**1**	**2**	**5**	**8**	**8**	**1**	**100**	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**3**	**7**	**5**	**2**	**1**	**0**	**0**	**1**	**1**	**3**	**2**	**1**	**1**	**6**	**3**	**7**	**5**	**2**	**1**	**0**	**0**	**1**	**1**	**3**	**2**	**8**	**1**
Electrofishing effort (secs)		**1,784**	**1,252**	**2,049**	**2,246**	**1,272**	**1,635**	**1,328**	**1,268**	**1,334**	**1,326**	**1,224**	**1,272**	**2,006**	**1,252**	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* not included in total species richness count.

Underline denotes *baseline* reaches.

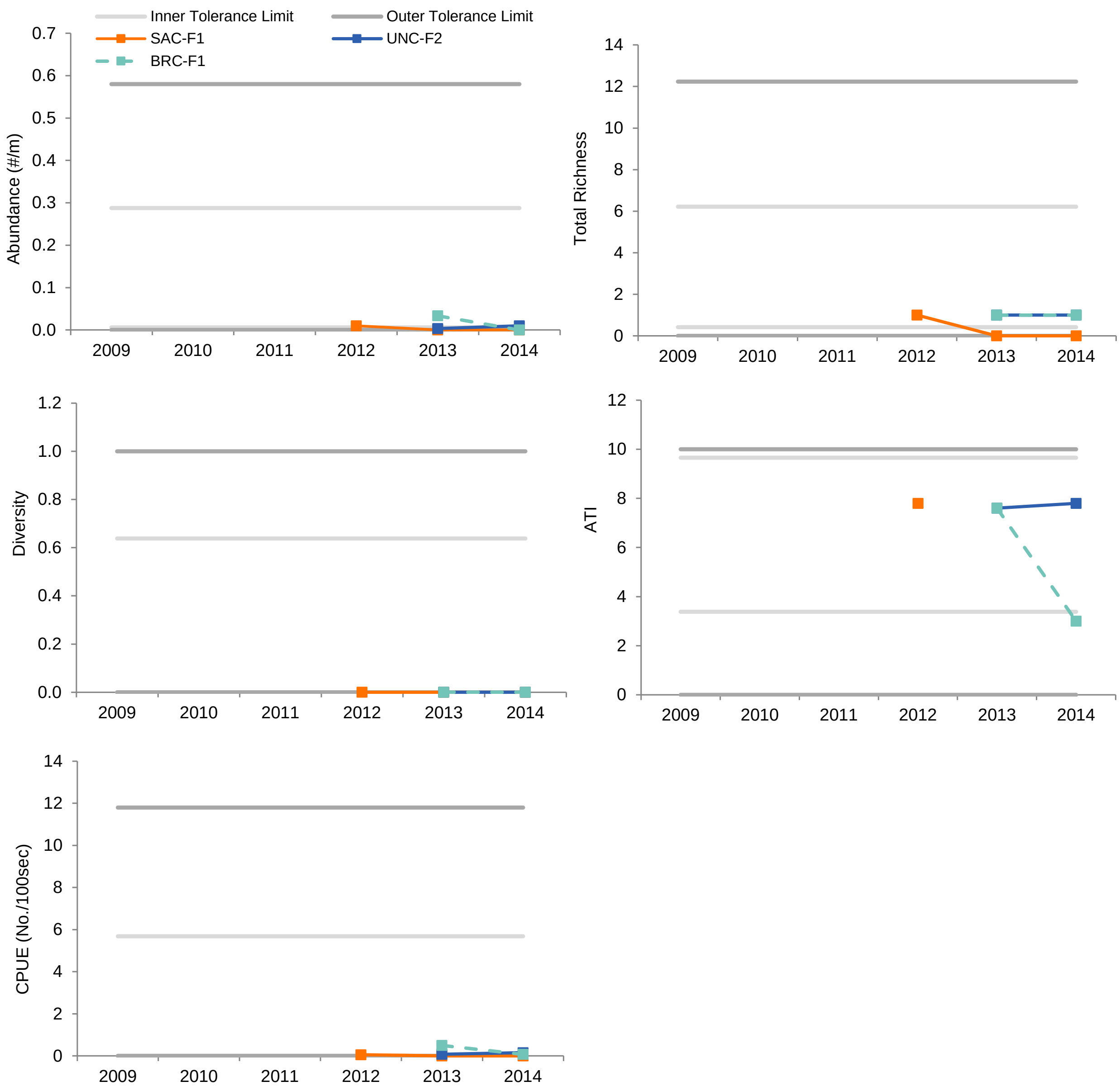
Figure 5.10-45 Variation in fish assemblage measurement endpoints for tributaries of Christina Lake (*test* reaches UNC-F3, SUC-F1, and *baseline* reach SUC-F2) from 2012 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Figure 5.10-46 Variation in fish assemblage measurement endpoints for tributaries of Christina Lake (*test* reaches SAC-F1, UNC-F2, and *baseline* reach BRC-F1) from 2012 to 2014, relative to regional *baseline* conditions (cluster 1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 1 (see Table 3.2-14 and Table 3.2-15).

Note: No fish were captured in 2013 and 2014 at SAC-F1; therefore, ATI could not be calculated.

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

5.11 HANGINGSTONE RIVER WATERSHED

Table 5.11-1 Summary of results for the Hangingstone River watershed.

Hangingstone River Watershed	Summary of 2014 Conditions	
Climate and Hydrology		
Criteria	**WSC 07CD004** Hangingstone River at Fort McMurray	no station
Mean open-water season discharge	[Negligible - Low]	
Mean winter discharge	[Negligible - Low]	
Annual maximum daily discharge	[Negligible - Low]	
Minimum open-water season discharge	[Negligible - Low]	
Water Quality		
Criteria	**HAR-1** upstream of Fort McMurray	**HAR-1A** at the mouth
Water Quality Index	[High]	[High]
Benthic Invertebrate Communities and Sediment Quality		
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2014		
Fish Populations		
No Fish Populations component activities conducted in 2014		

Legend and Notes

- Negligible - Low
- Moderate
- High

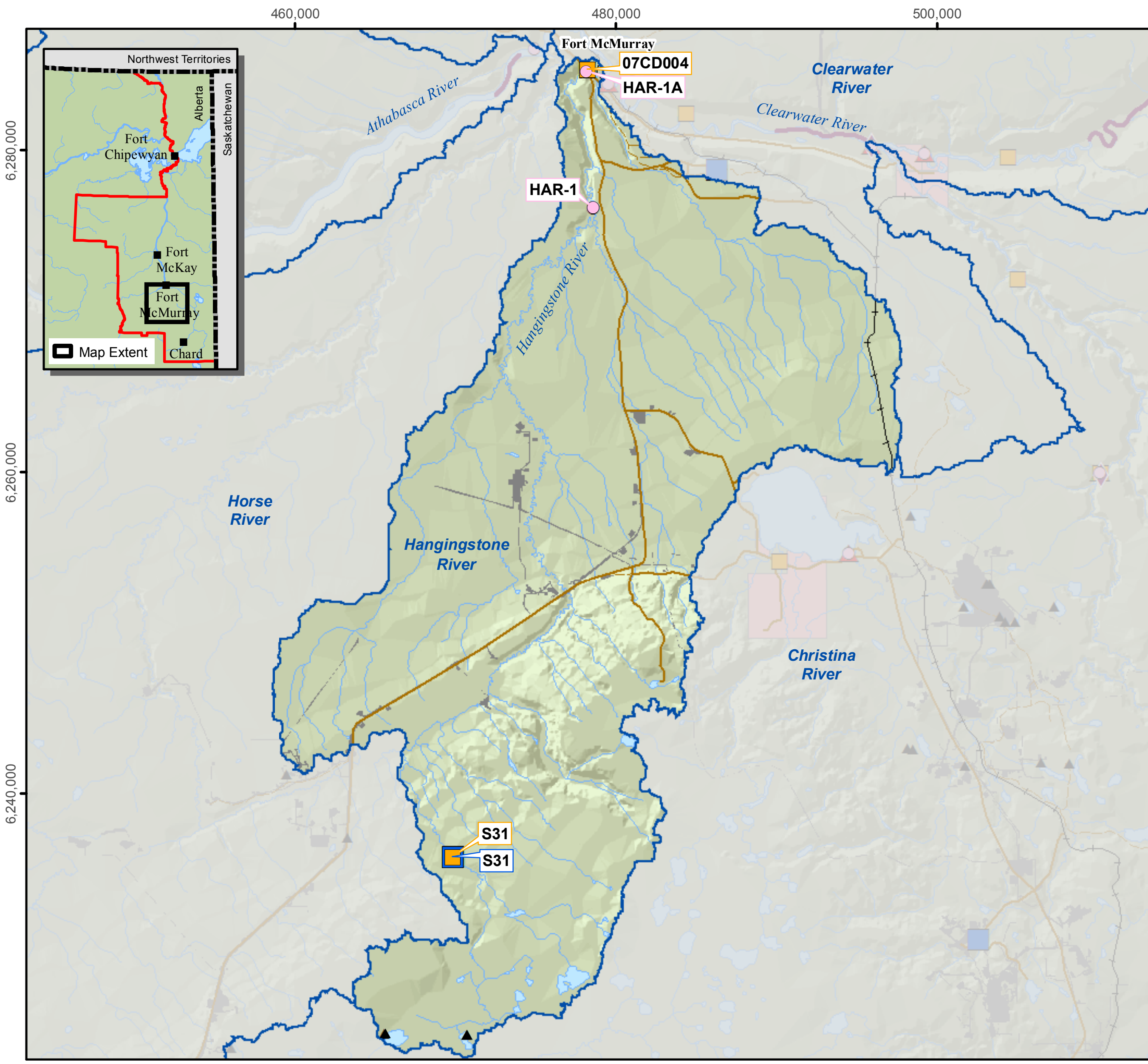
baseline

test

Hydrology: Measurement endpoints calculated on differences between observed hydrograph and estimated hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Figure 5.11-1 Hangingstone River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach

0 2.5 5 10 km
N

Scale: 1:400,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.11-2 Representative monitoring stations of the Hangingstone River watershed, fall 2014.

Water Quality Station HAR-1:
Left Downstream Bank, facing downstream

Water Quality Station HAR-1A:
Left Downstream Bank, facing downstream

5.11.1 Summary of 2014 Conditions

Approximately 1.2% (1,228 ha) of the Hangingstone River watershed had undergone land change as of 2014 from oil sands development, which was an increase from 2013 (Table 2.3-1). Land change has occurred in the upper portion of the watershed related to the JACOS Hangingstone project.

Monitoring activities were conducted for the Climate and Hydrology and Water Quality components in the Hangingstone River watershed in 2014. Table 5.11-1 is a summary of the 2014 assessment of the Hangingstone River watershed, while Figure 5.11-1 denotes the location of the monitoring stations for each component and the area of land change as of 2014 in the Hangingstone River watershed. Figure 5.11-2 contains fall 2014 photos of the water quality monitoring stations in the watershed.

Hydrology For the 2014 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were 0.2%, -0.1%, 0.2%, and 0.2%, respectively. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2014 between *test* stations HAR-1 and HAR-1A and regional *baseline* fall conditions were classified as **Moderate**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative to regional *baseline* concentrations. In addition, concentrations of a few metals and ions exceeded their historical range (2004 to 2008 and 2013) for *test* station HAR-1. Despite having higher concentrations of dissolved ions in 2014, the ionic composition at *test* station HAR-1 was similar to previous years and similar to *test* station HAR-1A.

5.11.2 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Hangingstone River watershed in the 2014 WY was conducted at the following locations:

- WSC Station 07CD004, Hangingstone River at Fort McMurray; and
- JOSMP Station S31, Hangingstone Creek at North Star Road.

Data from the WSC station were used for the water balance analysis and presented below; data from Station S31 can be found in Appendix C.

Seasonal data from March to October have been collected every year since 1970 at WSC Station 07CD004, with partial data collected from 1965 to 1969. Winter data (November to February) were also collected from 1970 to 1986.

The historical flow record for WSC Station 07CD004 is summarized in Figure 5.11-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Hangingstone River have a seasonal runoff pattern characteristic of a northern environment, with flows typically much lower in winter than during the open-water season, and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically begins in late March and continues through April. Monthly flows are highest during May, at the peak of freshet, and remain elevated in June and July when total monthly rainfall are highest (Figure 4.2-2). Flows then generally recede from August until the end of October in response to declining rainfall inputs and, eventually, river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.11-3). While flows from November to mid-December were below the previously-recorded minima during this period, the historical record during winter months was limited. The increase in flows due to spring thaw occurred in late April, which was slightly later than normal. The freshet annual peak of 48.1 m^3/s was recorded on May 31 and was 10% higher than the historical mean annual maximum daily flow (43.8 m^3/s). Flows then generally decreased through summer and early fall, and were mostly below historical median values for this period. The minimum open-water daily flow of 0.64 m^3/s was recorded on September 23, and was 32% lower than the historical mean minimum daily flow of 0.94 m^3/s, calculated for the open-water period.

The 2014 water year runoff volume recorded at WSC Station 07CD004 was 96.1 million m^3. This value was 20% lower than the historical mean water year runoff volume.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at WSC Station 07CD004 is summarized in Table 5.11-2. Key changes in flows included:

1. The closed-circuited land area as of 2014 in the Hangingstone River watershed was estimated to be 0.32 km^2 (Table 2.3-1). The loss of flow to the Hangingstone River that would have otherwise occurred from this land area was estimated at 0.032 million m^3.

2. As of 2014, the area of land change in the Hangingstone watershed that was not closed-circuited was estimated to be 12.0 km^2 (Table 2.3-1). The increase in flow to the Hangingstone River that would not have otherwise occurred was estimated at 0.239 million m^3.

3. In the 2014 WY, Nexen withdrew approximately 8,663 m^3 of water from two locations in the Hangingstone River watershed to support drilling and construction activities.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development was an increase in flow of 0.197 million m^3 to the Hangingstone River. For the 2014 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were 0.2%, -0.1%, 0.2%, and 0.2%, respectively. These differences were classified as **Negligible-Low** (Table 5.11-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the cumulative hydrological effects across the watershed.

5.11.3 Water Quality

In fall 2014, water quality samples were taken from:

- the Hangingstone River upstream of Fort McMurray (test station HAR-1), sampled in 2004 to 2008, 2013, and 2014; and
- the Hangingstone River near the mouth (*test* station HAR-1A), sampled since 2013.

Temporal Trends A significant (α=0.05) increasing trend in fall concentrations of sodium was observed at *test* station HAR-1. Trends over time could not be assessed at *test* station HAR-1A because there were not enough available historical data.

2014 Results Relative to Historical Concentrations Fall 2014 concentrations of water quality measurement endpoints were generally within previously-measured concentrations at *test* station HAR-1, with a few exceptions (Table 5.11-4). These exceptions included dissolved phosphorus, total nitrogen, dissolved organic carbon, and total and dissolved aluminum, with concentrations below previously-measured minimum concentrations. Historical comparisons were not possible for *test* station HAR-1A, given that sampling was initiated in 2013 (Table 5.11-5).

Ion Balance The ionic composition of water was similar at *test* stations HAR-1 and HAR-1A and dominated by calcium and bicarbonate (Figure 5.11-4). The ionic composition at *test* station HAR-1 in fall 2014 was similar to all previous years and similar to fall 2013 at *test* station HAR-1A.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of most water quality measurement endpoints measured at *test* stations HAR-1 and HAR-1A were below water quality guidelines in fall 2014, with the exception of total aluminum at both stations (Table 5.11-4, Table 5.11-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Hangingstone River (Table 5.11-6):

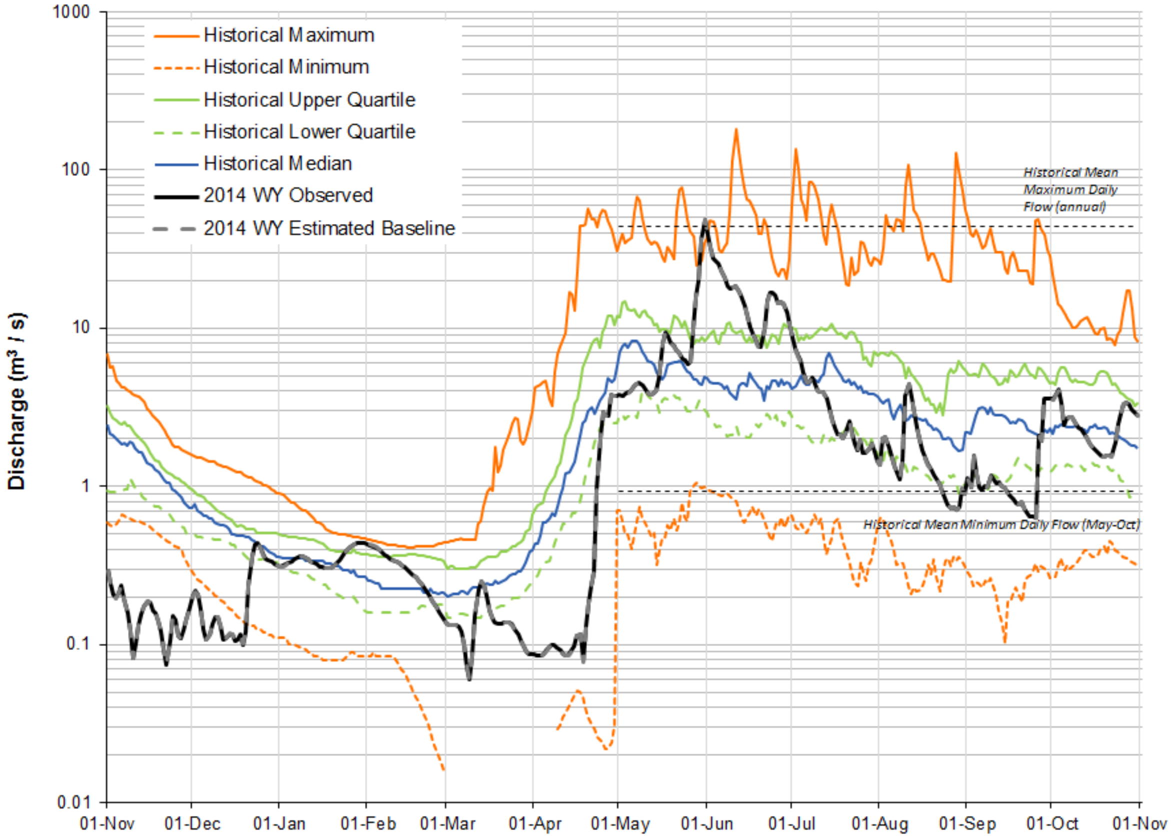
- total and dissolved iron and sulphide at *test* station HAR-1; and
- sulphide, total chromium, total iron, and total phenols at *test* station HAR-1A.

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of water quality measurement endpoints at *test* stations HAR-1 and HAR-1A were within regional *baseline* concentrations, with the exception of total strontium, total boron, sodium, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at both stations (Figure 5.11-5). Concentrations of total dissolved solids and calcium also exceeded the regional *baseline* concentrations at *test* station HAR-1A (Figure 5.11-5).

Water Quality Index The WQI values for *test* stations HAR-1 (76.7) and HAR-1A (66.5) indicated **Moderate** differences from regional *baseline* water quality conditions. These differences were primarily attributed to higher concentrations of dissolved ions and metals.

Classification of Results Differences in water quality in fall 2014 between *test* stations HAR-1 and HAR-1A and regional *baseline* fall conditions were classified as **Moderate**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative the regional *baseline* concentrations. In addition, concentrations of a few metals and ions exceeded their historical range (2004 to 2008 and 2013) for *test* station HAR-1. Despite having higher concentrations of dissolved ions in 2014, the ionic composition at *test* station HAR-1 was similar to previous years and similar to *test* station HAR-1A.

Figure 5.11-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Hangingstone River in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Hangingstone River at Fort McMurray, WSC Station 07CD004, provisional data. The upstream drainage area of WSC Station 07CD004 is 962 km^2, which is 10% smaller than the size of the entire Hangingstone River watershed (1,066 km^2). Historical values from March 1 to October 31 were calculated for the period from 1965 to 2013, and historical values for other months were calculated for the period from 1970 to 1987.

Note: Historical minimum daily flows were zero from March 1 to April 8, and were not plotted due to the logarithmic axis used in the graph.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.11-2 Estimated water balance at WSC Station 07CD004, Hangingstone River at Fort McMurray, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**96.133**	**Observed discharge, obtained from Hangingstone River at Fort McMurray, WSC Station 07CD004**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.032	Estimated 0.32 km^2 of Hangingstone River watershed closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.239	Estimated 12.0 km^2 of Hangingstone River watershed with land change as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Hangingstone River watershed, relative to the estimated *baseline* hydrograph	-0.009	8,663 m^3 withdrawn from sources in the Hangingstone River watershed for drilling and construction activities
Water releases into the Hangingstone River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between observed and estimated hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**95.935**	**Estimated discharge at Hangingstone River at Fort McMurray, WSC Station 07CD004**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	0.198	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**0.215%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on the Hangingstone River at Fort McMurray (WSC Station 07CD004), 2014 WY provisional data.

Note All values in this table presented to three decimal places.

Table 5.11-3 Estimated change in hydrologic measurement endpoints for the Hangingstone River watershed, 2014 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water period discharge	5.709	5.721	0.22%
Mean winter discharge	0.229	0.229	-0.07%
Annual maximum daily discharge	47.997	48.100	0.22%
Open-water period minimum daily discharge	0.636	0.637	0.22%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge was calculated from Hangingstone River at Fort McMurray (WSC Station 07CD004), 2014 WY provisional data.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.11-4 Concentrations of water quality measurement endpoints, Hangingstone River, above Fort McMurray (*test* station HAR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2004-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.20	6	8.00	8.20	8.48
Total suspended solids	mg/L	-	6.0	6	<3.0	7.0	12.0
Conductivity	µS/cm	-	396	6	231	233	487
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.016</u>	6	0.034	0.044	0.049
Total nitrogen	mg/L	-	<u>0.554</u>	6	0.601	0.850	1.00
Nitrate+nitrite	mg/L	3	<0.054	6	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	<u>16.1</u>	6	17.0	24.5	34.0
Ions							
Sodium	mg/L	-	29.5	6	17.0	19.5	41.7
Calcium	mg/L	-	41.1	6	22.3	25.8	50.2
Magnesium	mg/L	-	9.99	6	7.20	7.45	14.2
Chloride	mg/L	120	15.8	6	9.0	13.0	18.6
Sulphate	mg/L	309	28.5	6	9.60	11.1	42.0
Total dissolved solids	mg/L	-	259	6	167	200	315
Total alkalinity	mg/L	-	144	6	88.0	96.5	190
Selected metals							
Total aluminum	mg/L	0.1	**<u>0.137</u>**	6	**0.142**	**0.301**	**0.499**
Dissolved aluminum	mg/L	0.05	<u>0.008</u>	6	0.009	0.016	0.037
Total arsenic	mg/L	0.005	0.0015	6	0.0012	0.0015	0.0017
Total boron	mg/L	1.2	0.139	6	0.054	0.063	0.183
Total molybdenum	mg/L	0.073	0.0021	6	0.0007	0.0010	0.0029
Total mercury (ultra-trace)	ng/L	5, 13	1.74	6	<1.20	<1.21	2.30
Total strontium	mg/L	-	0.201	6	0.121	0.126	0.291
Total hydrocarbons							
BTEX	mg/L	-	<0.1	1	-	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	<0.1	1	-	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	<0.25	1	-	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	<0.25	1	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	<0.25	1	-	<0.25	-
Naphthenic Acids	mg/L	-	0.14	1	-	0.33	-
Oilsands Extractable	mg/L	-	1.10	1	-	0.42	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	1	-	<15.2	-
Retene	ng/L	-	0.617	1	-	0.678	-
Total dibenzothiophenes	ng/L	-	6.814	1	-	8.425	-
Total PAHs	ng/L	-	86.07	1	-	113.5	-
Total Parent PAHs	ng/L	-	14.48	1	-	22.96	-
Total Alkylated PAHs	ng/L	-	71.59	1	-	90.56	-
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.333**	6	0.268	**0.756**	**0.824**
Sulphide	mg/L	0.002	**0.004**	6	**0.003**	**0.006**	**0.018**
Total iron	mg/L	0.3	**<u>1.05</u>**	6	**1.13**	**1.38**	**1.57**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.11-5 Concentrations of water quality measurement endpoints, Hangingstone River near the mouth (*test* station HAR-1A), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	September 2013
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.44	8.52
Total suspended solids	mg/L	-	16	<3
Conductivity	µS/cm	-	494	553
Nutrients				
Total dissolved phosphorus	mg/L	-	0.014	0.025
Total nitrogen	mg/L	-	0.654	0.601
Nitrate+nitrite	mg/L	3	<0.054	<0.071
Dissolved organic carbon	mg/L	-	3.1	22.1
Ions				
Sodium	mg/L	-	37.1	49.4
Calcium	mg/L	-	46.6	54.3
Magnesium	mg/L	-	13.9	16.7
Chloride	mg/L	120	26.5	27.6
Sulphate	mg/L	309	35.2	49.5
Total dissolved solids	mg/L	-	314	357
Total alkalinity	mg/L	-	176	202
Selected metals				
Total aluminum	mg/L	0.1	**0.846**	**0.317**
Dissolved aluminum	mg/L	0.05	0.008	0.007
Total arsenic	mg/L	0.005	0.0015	0.0016
Total boron	mg/L	1.2	0.127	0.197
Total molybdenum	mg/L	0.073	0.0022	0.0026
Total mercury (ultra-trace)	ng/L	5, 13	3.21	1.70
Total strontium	mg/L	-	0.263	0.32
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.75	0.50
Oilsands Extractable	mg/L	-	0.90	0.56
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<7.21	<15.16
Retene	ng/L	-	7.240	1.640
Total dibenzothiophenes	ng/L	-	171.2	71.68
Total PAHs	ng/L	-	645.2	328.6
Total Parent PAHs	ng/L	-	54.83	33.71
Total Alkylated PAHs	ng/L	-	590.3	294.9
Other variables that exceeded CCME/AESRD guidelines in fall 2014				
Sulphide	mg/L	0.002	**0.0029**	0.0020
Total chromium	mg/L	0.001	**0.0013**	0.0004
Total iron	mg/L	0.3	**2.09**	**1.01**
Total phenols	mg/L	0.004	**0.0066**	**0.0070**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline.

Figure 5.11-4 Piper diagram of fall ion concentrations in Hangingstone River watershed.

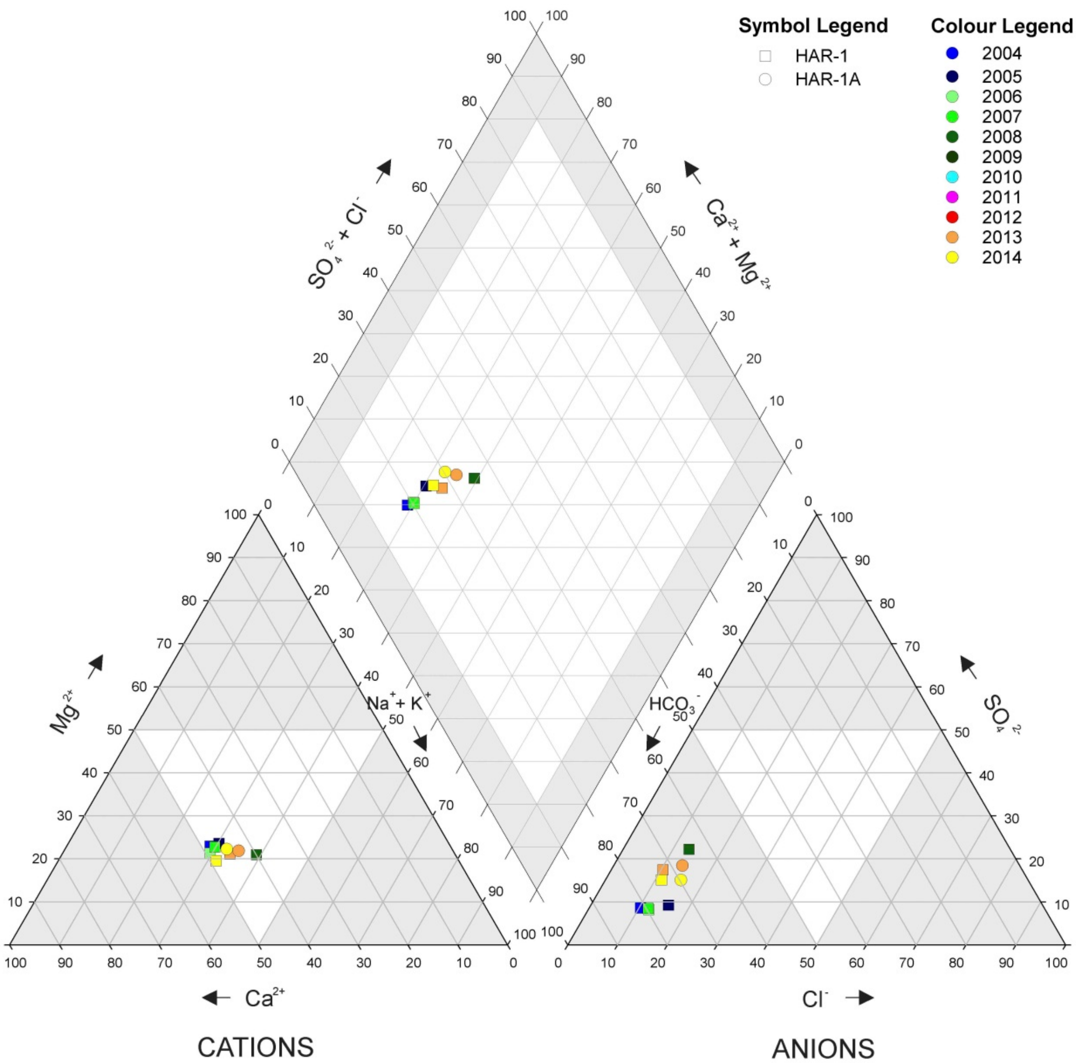
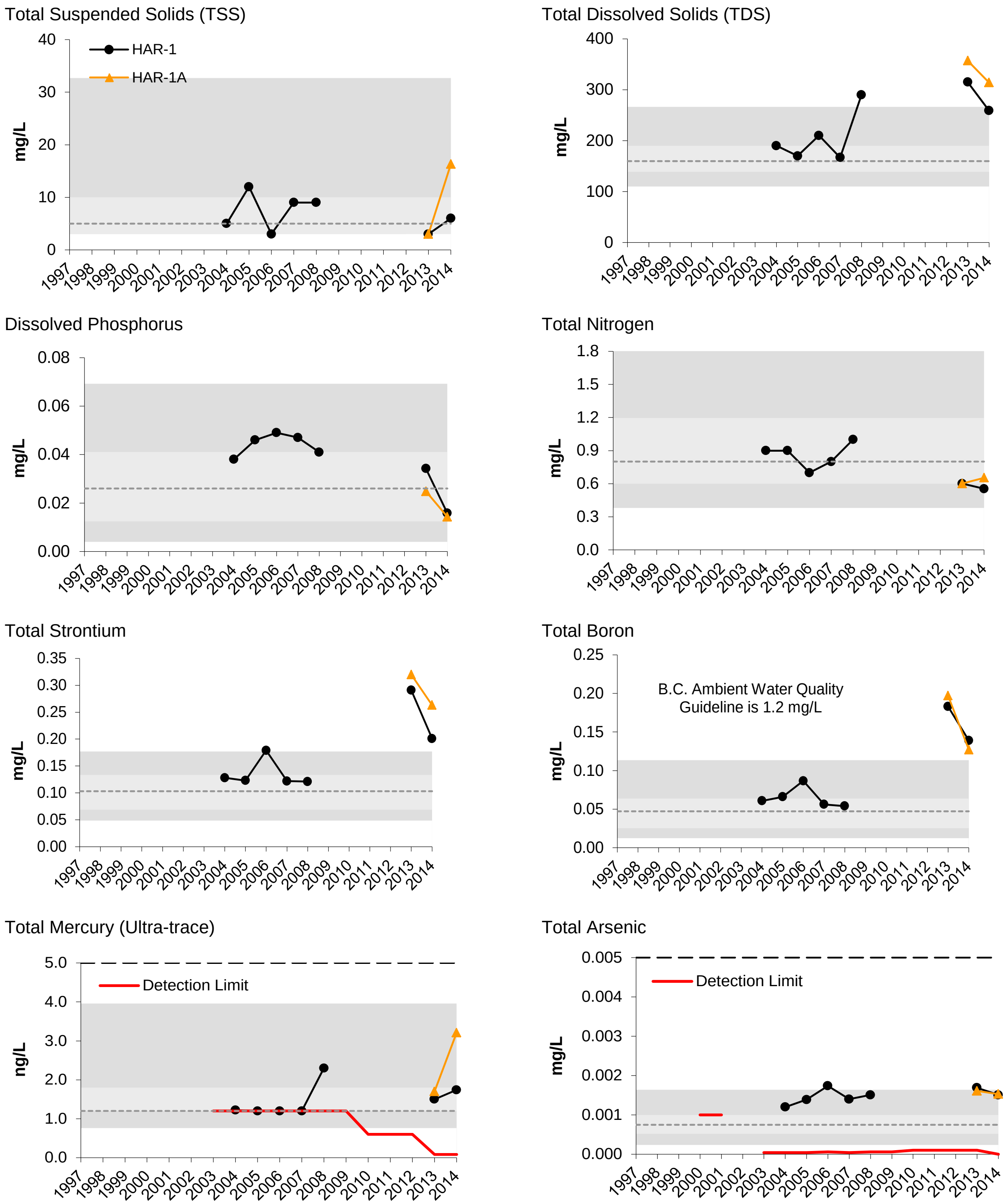


Table 5.11-6 Water quality guideline exceedances for the Hangingstone River watershed, fall 2014.

Variable	Units	Guideline[a]	HAR-1	HAR-1A
Dissolved iron	mg/L	0.3	0.333	-
Sulphide	mg/L	0.002	0.0042	0.0029
Total aluminum	mg/L	0.1	0.137	0.846
Total chromium	mg/L	0.001	-	0.0013
Total iron	mg/L	0.3	1.05	2.09
Total phenols	mg/L	0.004	-	0.0066

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.11-5 Concentrations of selected water quality measurement endpoints in the Hangingstone River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



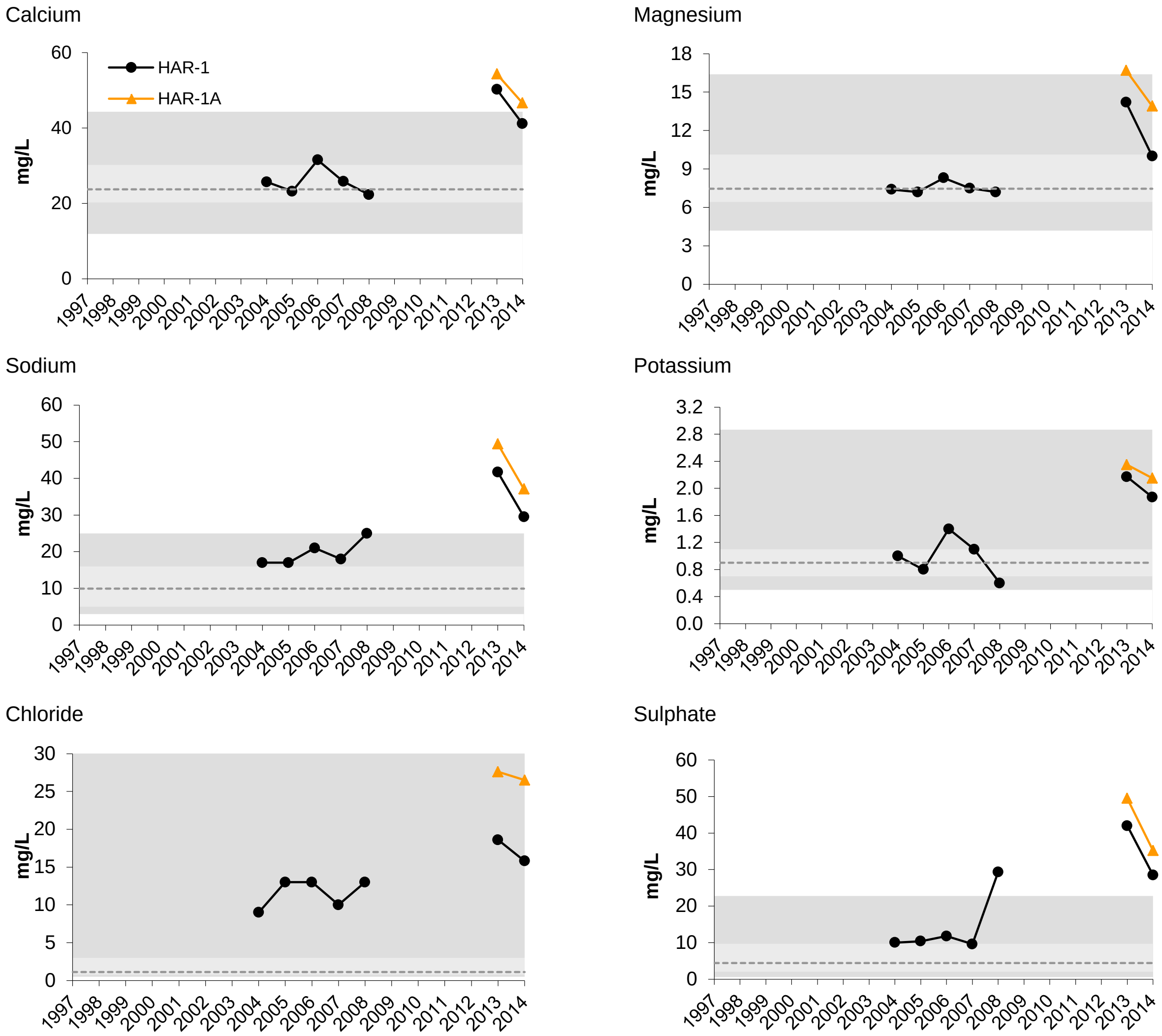
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.11-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●━━━● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

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5.12 PIERRE RIVER AREA

Table 5.12-1 Summary of results for watersheds in the Pierre River area.

Pierre River Area	Summary of 2014 Conditions			
Climate and Hydrology				
Criteria	**S48** Big Creek near the mouth	**S44** Pierre River near Fort McKay	**S50A** Red Clay Creek	**S49** Eymundson Creek near the mouth
Mean open-water season discharge	not measured			
Mean winter discharge	not measured			
Annual maximum daily discharge	not measured			
Minimum open-water season discharge	not measured			
Water Quality				
Criteria	**BIC-1** Big Creek at the mouth	**PIR-1** Pierre River at the mouth	**RCC-1** Red Clay Creek at the mouth	**EYC-1** Eymundson Creek at the mouth
Water Quality Index	🟡	🟡	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality				
Criteria	**BIC-D1** Big Creek at the mouth	**PIR-D1** Pierre River at the mouth	**RCC-E1** Red Clay Creek at the mouth	**EYC-D1** Eymundson Creek at the mouth
Benthic Invertebrate Communities	n/a	n/a	n/a	n/a
Sediment Quality	🟡	🟡	🟡	🟡
Fish Populations				
Criteria	**BIC-F1** Big Creek at the mouth	**PIR-F1** Pierre River at the mouth	**RCC-F1** Red Clay Creek at the mouth	**EYC-F1** Eymundson Creek at the mouth
Fish Assemblages	n/a	n/a	n/a	n/a

Legend and Notes

🟡 Negligible-Low
🟠 Moderate
🟤 High
baseline
test

n/a - not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

Hydrology: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

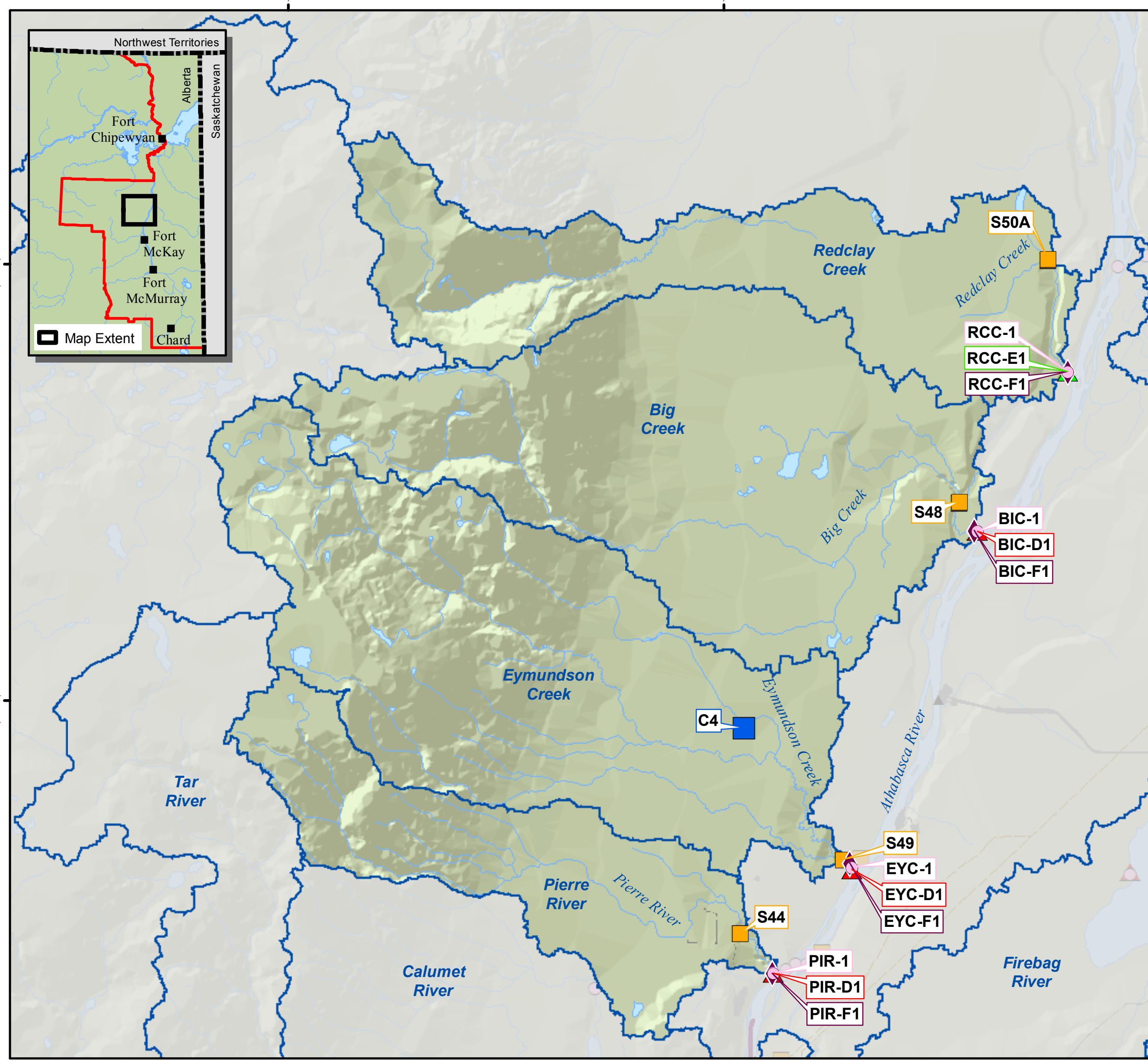
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.12-1 Pierre River area watersheds.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach

0 2 4 8 km N

Scale: 1:300,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.12-2 Representative monitoring stations of the watersheds in the Pierre River area, fall 2014.

Hydrology Station S49: Eymundson Creek

Hydrology Station S50A: Red Clay Creek

Benthic and Sediment Quality Reach EYC-D1 (Eymundson Creek): facing downstream

Benthic Invertebrate Reach RCC-E1 (Red Clay Creek): facing downstream

Benthic and Sediment Quality Reach BIC-D1 (Big Creek): facing downstream

Benthic and Sediment Quality Reach PIR-D1 (Pierre River): facing upstream

5.12.1 Summary of 2014 Conditions

As of 2014, 0.13% (18 ha) of the Pierre River watershed had undergone land change from oil sands developments (Table 2.3-1). This section includes 2014 results for the Pierre River, as well as three other adjacent tributaries to the Athabasca River, including Red Clay Creek, Big Creek, and Eymundson Creek, which are all designated as *baseline* watercourses.

Monitoring was conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in watersheds in this area in 2014. Monitoring in these watersheds was in advance of development activities for the Shell Pierre River Mine project and the Teck Frontier project. Hydrometric data have been collected to develop hydrographs for each watershed; however, water balances were not completed given that there was no development. Details for each hydrology station can be found in Appendix C.

Table 5.12-1 is a summary of the 2014 assessment of the watersheds in the Pierre River area, while Figure 5.12-1 denotes the location of the monitoring stations for each component. Figure 5.12-2 contains 2014 photos of various monitoring stations located in watersheds in the Pierre River area.

Water Quality Differences in water quality in fall 2014 between *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low** (Table 5.12-1). *Baseline* station EYC-1 differed from the other stations (BIC-1, PIR-1, and RCC-1) in this area in its ionic composition, with a higher concentration of sulphate and lower concentration of bicarbonate, which may suggest greater groundwater influence at this station. *Baseline* station EYC-1 also had a higher concentration of total suspended solids than the other stations.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1, and PIR-D1 were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; but also an increasing proportion of EPT taxa and more sensitive fauna. With the decrease in the abundance of worms and an increase in EPT taxa, *baseline* reach PIR-D1, in particular, showed improving conditions from 2013. The benthic invertebrate communities of *baseline* reach RCC-E1 had a greater proportion of tolerant worms in 2014 than 2013 but continued to maintain a good proportion of EPT taxa, indicating good habitat quality. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the Athabasca oil sands region.

All sediment stations of the Pierre River area had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions. Concentrations of sediment quality measurement endpoints did not exceed any sediment or soil quality guidelines at *baseline* station BIC-D1, while total arsenic exceeded the guideline at *baseline* stations EYC-D1 and PIR-D1, and F3 hydrocarbons and predicted PAH toxicity exceeded guidelines at *baseline* station PIR-D1. Survival of the midge *Chironomus* was fairly low at *baseline* stations BIC-D1 and PIR-D1 in 2014 (52% and to 58%, respectively). In general, all sediment quality measurement endpoints at all locations in fall 2014 were similar to results from fall 2013.

Fish Populations (fish assemblages) The fish assemblages at *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 were similar to other *baseline* reaches in the region, and with each other. Species composition was generally the same across each reach and there was a decrease in the catch of burbot in 2014 compared to 2013 at all reaches.

5.12.2 Water Quality

In fall 2014, water quality samples were collected in fall from:

- Big Creek (*baseline* station BIC-1), sampled since 2011;
- Eymundson Creek (*baseline* station EYC-1), sampled since 2011;
- Pierre River (*baseline* station PIR-1), sampled since 2011; and
- Red Clay Creek (*baseline* station RCC-1), sampled since 2011.

Water quality samples were also collected in winter at *baseline* stations BIC-1 and RCC-1.

Temporal Trends Trends in concentrations of water quality measurement endpoints were not assessed at these stations because only four years of data have been collected.

2014 Results Relative to Historical Concentrations Historical comparisons were conducted for the first time in 2014 at these stations, but it should be noted that only three years of historical data (2011 to 2013) were available for comparison. The following water quality measurement endpoints exceeded the range of previously-measured concentrations (Table 5.12-2 to Table 5.12-5):

- Total suspended solids, dissolved phosphorus, total nitrogen, dissolved organic carbon, sodium, total dissolved solids, total alkalinity, dissolved aluminum, total arsenic, total boron, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station BIC-1;
- Calcium and naphthenic acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station BIC-1;
- Dissolved phosphorus, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station EYC-1;
- Total nitrogen, retene, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station EYC-1;
- Total nitrogen, chloride, total arsenic, total boron, total molybdenum, total mercury, retene, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station PIR-1;
- Sulphate, naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station PIR-1;
- Dissolved phosphorus, total nitrogen, dissolved organic carbon, chloride, total dissolved solids, total alkalinity, total aluminum, dissolved aluminum, total arsenic, total boron, total molybdenum, total mercury (ultra-trace), total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station RCC-1; and
- Naphthenic acids, with a concentration that exceeded the previously-measured maximum concentration at *baseline* station RCC-1.

Ion Balance The ionic composition of water at *baseline* stations BIC-1, PIR-1, and RCC-1 in fall 2014 was generally similar and dominated by calcium and bicarbonate. Water at *baseline* station EYC-1 was less dominated by bicarbonate and showed a greater influence of sulphate. The ionic composition has remained consistent between sampling years at all stations (Figure 5.12-3).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of most water quality measurement endpoints measured at *baseline* stations BIC-1, PIR-1, RCC-1, and EYC-1 were below water quality guidelines in fall 2014, with the exception of (Table 5.12-2 to Table 5.12-5):

- Total aluminum at *baseline* stations BIC-1, EYC-1, and PIR-1; and
- Total mercury (ultra-trace) at *baseline* station EYC-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured at these *baseline* stations (Table 5.12-6):

- Sulphide, total iron, and phenols at *baseline* station BIC-1;
- Total and dissolved iron, sulphide, total chromium, and total phenols at *baseline* station EYC-1; and
- Total and dissolved iron, sulphide, total chromium, and total phenols at *baseline* station PIR-1.

Water quality was also sampled at *baseline* stations BIC-1 and RCC-1 in winter 2014. Sulphide, total aluminum, total iron, and total phenols exceeded water quality guidelines at *baseline* station BIC-1 and total iron exceeded water quality guidelines at *baseline* station RCC-1 during winter 2014 (Table 5.12-6).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of water quality measurement endpoints at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 were within regional *baseline* concentrations, with the exception of (Figure 5.12-4):

- Total arsenic, sulphate, total suspended solids, and total mercury (ultra-trace), with concentrations that exceeded the 95^{th} percentile of regional *baseline* concentrations at *baseline* station EYC-1; and
- Total arsenic, dissolved phosphorus, and total mercury (ultra-trace), with concentrations below the 5^{th} percentile of regional *baseline* concentrations at *baseline* station RCC-1.

Water Quality Index The WQI values for *baseline* stations BIC-1 (100), EYC-1 (82), PIR-1 (100), and RCC-1 (100) indicated **Negligible-Low** differences from regional *baseline* water quality conditions (Table 5.12-7).

Classification of Results Differences in water quality in fall 2014 between *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low** (Table 5.12-1). *Baseline* station EYC-1 differed from the other stations in this area (BIC-1, PIR-1, and RCC-1) in its ionic composition, with a higher concentration of sulphate and lower concentration of bicarbonate, which may suggest greater groundwater influence at this station. *Baseline* station EYC-1 also had a higher concentration of total suspended solids than the other stations.

5.12.3 Benthic Invertebrate Communities and Sediment Quality

5.12.3.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *baseline* reach BIC-D1 of Big Creek;
- depositional *baseline* reach EYC-D1 of Eymundson Creek;
- depositional *baseline* reach PIR-D1 of the Pierre River; and
- erosional *baseline* reach RCC-E1 of Red Clay Creek.

All four reaches were sampled for the first time in fall 2013.

2014 Habitat Conditions Water at *baseline* reach EYC-D1 in fall 2014 had a depth of approximately 0.5 m, a pH of 7.2, moderate velocity (0.46 m/s), moderate dissolved oxygen (6.7 mg/L), and high conductivity (450 µS/cm) (Table 5.12-8). The substrate consisted primarily of sand (80%) with small amounts of silt (13%) and clay (7%) (Table 5.12-8). The organic content of sediments at *baseline* reach EYC-D1 was low (<1%).

Water at *baseline* reach RCC-E1 in fall 2014 was shallow (0.2 m), a pH of 7.7, moderate velocity (0.58 m/s), high dissolved oxygen (10.2 mg/L), and high conductivity (482 µS/cm) (Table 5.12-8). The substrate consisted primarily of cobble and gravel. Periphyton chlorophyll *a* biomass averaged 223.7 mg/m^2 in fall 2014, which was higher than the normal range of variation of regional *baseline* reaches (Figure 5.12-5).

Water at *baseline* reach BIC-D1 in fall 2014 had a depth of approximately 0.5 m, a pH of 8.1, moderate velocity (0.4 m/s), high dissolved oxygen (12.2 mg/L), and high conductivity (426 µS/cm) (Table 5.12-8). The substrate consisted almost entirely of sand (95%) with low organic carbon content (<0.1%).

Water at *baseline* reach PIR-D1 in fall 2014 had a depth of approximately 0.4 m, a pH of 7.2, fast velocity (0.55 m/s), high dissolved oxygen (10.8 mg/L), and high conductivity (435 µS/cm) (Table 5.12-8). The substrate consisted primarily of sand (84%) with small amounts of silt (10%) and clay (6%) and low organic carbon content (1.7%) (Table 5.12-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *baseline* reach EYC-D1 was dominated by chironomids (63%) with subdominant taxa consisting of tubificid worms (11%) and Hydracarina (7%) (Table 5.12-9). Dominant chironomids included *Rheosmittia, Paracladopelma,* and *Procladius*. EPT taxa were sparse with only six mayflies of the family Leptophlebiidae found in one replicate sample.

The benthic invertebrate community at *baseline* reach RCC-E1 was diverse and dominated by Trichoptera (36%) and chironomids (28%) (Table 5.12-10). Caddisflies primarily included *Brachycentrus*, *Glossosoma*, *Cheumatopsyche*, and *Hydropsyche*. Dominant chironomids were *Polypedilum, Tvetenia, Tanytarsus,* and *Thienemannimyia.* Other flying insects present included Ephemeroptera (*Baetis, Leptophlebia*, and *Heptagenia*) and Plecoptera (*Zapada, Isoperla,* and *Skwala*). Permanent aquatic forms such as amphipods (*Hyalella Azteca* and *Gammarus lacustris*), bivalve clams (*Pisidium/Sphaerium*), and gastropods (*Gyraulus* and small Lymnaeidae) were found in low relative abundances (<1%) (Table 5.12-10).

The benthic invertebrate community at *baseline* reach BIC-D1 was dominated by chironomids (78%) with subdominant taxa consisting of miscellaneous Diptera (7%) (Table 5.12-11). Larvae of large flying insects were present in low relative abundance and included a few individual Ephemeroptera (*Centroptilum*, *Leptophlebia*, and *Siphloplecton*) stoneflies, and *Brychius* beetles. Dominant chironomids included *Tanytarsus, Rheosmittia*, and *Doncricotopus.*

The benthic invertebrate community at *baseline* reach PIR-D1 was dominated by chironomids (48%) with subdominant taxa consisting of Ephemeroptera (8%) and enchytraeid worms (8%) (Table 5.12-12). Ephemeroptera were primarily *Caenis* and were more abundant in one replicate sample (4) than any other sample from the reach. Other larvae of large flying insects included Trichoptera (*Hydroptila* and *Agrypnia*). Permanent aquatic forms were present in low relative abundances and included Bivalvia (*Pisidium/Sphaerium*) and a single *Lymnaea* Gastropod. Dominant chironomids included *Saetheria, Tanytarsus, Paratanytarsus,* and *Stempellinella* (Table 5.12-12).

Comparison to Published Guidelines The benthic invertebrate community of *baseline* reach EYC-D1 was typical of a sandy-bottomed river environment. Chironomids were dominant as well as worms. The dominant forms of Chironomidae that were present (i.e., *Paracladopelma*, *Procladius*) are known to be moderately tolerant of poor water quality conditions (Mandeville 2002). Flying insects (Ephemeroptera) were present at low relative abundances and richness was low, which are both common for sandy-bottomed rivers.

The benthic invertebrate community of *baseline* reach RCC-E1 was representative of good overall water quality. Chironomids were numerically dominant and the most common taxa were known to be moderately tolerant of poor water quality (Mandeville 2002). Although the abundance of worms was higher than 2013 (11%), flying insects were also common with Trichoptera almost as numerically abundant as chironomids. Several other forms of larval large flying insects (stoneflies and mayflies) were also present at *baseline* reach RCC-E1.

The benthic invertebrate community of *baseline* reach BIC-D1, which was also primarily sand substrate, had a fauna typical of the shifting habitat of a sandy-bottomed river. Chironomids were in relatively high abundance at this reach. The abundance of worms, specifically tubificids, decreased from 2013 potentially indicating a positive change in habitat conditions (Pennak 1989). The dominant chironomids present (e.g., *Tanytarsus*, *Rheotanytarsus*, *Doncricotopus*) are only moderately tolerant of poor water quality (Mandeville 2002).

The benthic invertebrate community of *baseline* reach PIR-D1 has slightly improved from 2013. Chironomids were still numerically dominant; however, the abundance of worms and nematodes decreased from 2013. Mayflies were relatively abundant and caddisflies (not present in 2013) were present in 2014. Permanent aquatic forms (amphipods and gastropods) were also newly present at *baseline* reach PIR-D1 in fall 2014. Overall, conditions at this reach in 2014 have shown improvement from the previous year.

2014 Results Relative to Regional *Baseline* Conditions Given that all benthic invertebrate communities reaches in the Pierre River area were *baseline*, the data collected contributed to the regional *baseline* conditions for comparisons to *test* reaches in the Athabasca oil sands region. Therefore, comparisons between these reaches and regional *baseline* conditions were not conducted.

Classification of Results The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1, and PIR-D1 were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; but also an increasing proportion of EPT taxa and more sensitive fauna. With the decrease in the abundance of worms and an increase in EPT taxa, *baseline* reach PIR-D1, in particular, showed improving conditions from 2013. The benthic invertebrate communities of *baseline* reach RCC-E1 had a greater proportion of tolerant worms in 2014 than 2013 but continued to maintain a good proportion of EPT taxa, indicating good habitat quality. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the Athabasca oil sands region.

5.12.3.2 Sediment Quality

In fall 2014, sediment quality samples were collected from:

- Big Creek (*baseline* station BIC-D1), sampled since 2013;
- Eymundson Creek (*baseline* station EYC-D1), sampled since 2013; and
- Pierre River (*baseline* station PIR-D1), sampled since 2013.

Temporal Trends No trend analysis on sediment quality measurement endpoints was possible for any of the stations, given 2014 was only the second year of sampling.

2014 Results Sediments at *baseline* stations PIR-D1, BIC-D1, and EYC-D1 were all dominated by sand. Concentrations of hydrocarbons and PAHs at all stations were generally similar between 2014 and 2013 (Table 5.12-13 to Table 5.12-15, Figure 5.12-6 to Figure 5.12-8).

Sediment toxicity tests showed high rates of *Hyalella* survival at all stations (94% at BIC-D1. and 98% at EYC-D1 and PIR-D1), but relatively low *Chironomus* survival (52% at BIC-D1, 88% at EYC-D1, and 58% at PIR-D1) (Table 5.12-13 to Table 5.12-15). Toxicity results in 2014 were similar to 2013, with the exception of *Chironomous* survival at *baseline* station EYC-D1, which was higher in 2014 (Table 5.12-13 and Table 5.12-15).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment quality measurement endpoints exceeded applicable CCME guidelines in fall 2014 at *baseline* station BIC-D1. The concentration of total arsenic at *baseline* station EYC-D1 exceeded the CCME guideline in fall 2014. Similar to 2013, concentrations of F3 hydrocarbons, predicted PAH toxicity, and total arsenic exceeded relevant guidelines at *baseline* station PIR-D1 in 2014 (Table 5.12-13 to Table 5.12-15).

2014 Results Relative Regional *Baseline* Concentrations In fall 2014, concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *baseline* station BIC-D1 (Figure 5.12-7). At *baseline* station PIR-D1, concentrations of total metals exceeded regional *baseline* concentrations in absolute terms, and when normalized to percent fines at *baseline* station EYC-D1 (Figure 5.12-6 and Figure 5.12-8).

Sediment Quality Index The SQI values calculated for *baseline* stations BIC-D1 (100), EYC-D1 (97.7), and PIR-D1 (91.3) indicated **Negligible-Low** differences from regional *baseline* conditions.

Classification of Results All stations of the Pierre River area had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions (Table 5.12-1). Concentrations of sediment quality measurement endpoints did not exceed any sediment or soil quality guidelines at *baseline* station BIC-D1, while total arsenic exceeded the guideline at *baseline* stations EYC-D1 and PIR-D1, and F3 hydrocarbons and predicted PAH toxicity exceeded guidelines at *baseline* station PIR-D1. Survival of the midge *Chironomus* was fairly low at *baseline* stations BIC-D1 and PIR-D1 in 2014 (52% and to 58%, respectively). In general, all sediment quality measurement endpoints at all locations in fall 2014 were similar to results from fall 2013.

5.12.4 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- depositional *baseline* reach BIC-F1, near the mouth of Big Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach BIC-D1), sampled since 2013;
- depositional *baseline* reach EYC-F1, near the mouth of Eymundson Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach EYC-D1), sampled since 2013;
- depositional *baseline* reach PIR-F1, near the mouth of the Pierre River (this reach is at the same location as the benthic invertebrate community *baseline* reach PIR-D1), sampled since 2013; and
- erosional *baseline* reach RCC-F1, near the mouth of Red Clay Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach RCC-E1), sampled since 2013.

2014 Habitat Conditions *Baseline* reach BIC-F1 was comprised of run habitat with a wetted width of 10.6 m and a bankfull width of 25.5 m. The substrate was comprised entirely of sand. Water at *baseline* reach BIC-F1 had a mean depth of 0.50 m, slow velocity (mean=0.25 m/s), a pH of 8.34, moderate conductivity (340 µS/cm), high dissolved oxygen (10.2 mg/L), and a temperature of 8.9ºC. Instream cover consisted primarily of small woody debris and algae (Table 5.12-16).

Baseline reach EYC-F1 was comprised of run habitat with a wetted width of 7.6 m and a bankfull width of 14.5 m. The substrate was comprised entirely of sand. Water at *baseline* reach EYC-F1 had a mean depth of 0.82 m, slow velocity (mean=0.27 m/s), a pH of 8.13, high conductivity (427 µS/cm), high dissolved oxygen (10.8 mg/L), and a temperature of 4.2ºC. Instream cover consisted of small and large woody debris (Table 5.12-16).

Baseline reach PIR-F1 was comprised of riffle and run habitat with a wetted width of 5.5 m and bankfull width of 12.2 m. The substrate consisted of coarse gravel with smaller proportions of fine materials. Water at *baseline* reach PIR-F1 had a mean depth of 0.67 m, slow velocity (mean=0.26 m/s), a pH of 8.03, high conductivity (401 µS/cm), and a temperature of 5.6˚C. Instream cover consisted primarily of small and large woody debris with small amounts of macrophytes and undercut banks (Table 5.12-16).

Baseline reach RCC-F1 was comprised of run and riffle habitat with a wetted width of 5.5 m and bankfull width of 11.2 m. The substrate was dominated by fine materials with some cobble. Water at *baseline* reach RCC-F1 had a mean depth of 0.40 m, with slow velocity (mean=0.22 m/s), a pH of 8.20, high conductivity (466 µS/cm), high dissolved oxygen (10.4 mg/L), and a temperature of 5.9ºC. Instream cover was comprised of small woody debris and algae with smaller amounts of macrophytes and large woody debris (Table 5.12-16).

Relative Abundance of Fish Species The total catch of fish species at *baseline* reaches BIC-F1, EYC-F1, and RCC-F1 increased in 2014 compared to 2013 and was dominated by lake chub (44%) and slimy sculpin (33%); flathead chub (59%) and lake chub (33%); and slimy sculpin (90%), respectively (Table 5.12-17). The total catch of fish species at *baseline* reach PIR-F1 was lower in 2014 and was dominated by lake chub (52%).

Temporal and Spatial Comparisons Sampling at *baseline* reaches in the Pierre River area was added to the monitoring program in 2013, in advance of oil sands development in that area. Therefore, only two years of data exist for these reaches to conduct spatial and temporal comparisons. All measurement endpoints were higher in 2014 compared to 2013 at *baseline* reaches BIC-F1 and EYC-F1 (Table 5.12-18). The increase in the assemblage tolerance index (ATI) value was due to the decrease in the proportion of burbot (sensitive species) and an increase in the proportion of flathead chub (reach EYC-F1 only; high-tolerant species) captured in 2014 compared to 2013 (Table 5.12-18).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the Athabasca oil sands region, which can be used as a *baseline* to compare results of subsequent investigations as many of the studies cited in Golder (2004) occurred prior to major expansion in the oil sands. Golder (2004) referenced Big Creek as Unnamed Tributary 47. Information on Big Creek in Golder (2004) was limited to one previous study in 1979 that found lake chub and sucker fry (species not specified) in the creek; however, additional data were collected as part of the baseline program for the Shell Pierre River Mine Application (Shell 2007). A total of ten species have been recorded in Big Creek, including one sportfish (burbot), two sucker species, and seven small-bodied fish species (Shell 2007). One additional small-bodied fish species (brook stickleback) was found in tributaries to Big Creek. Five species were documented during the JOSMP surveys in 2013 and 2014, all of which have previously been reported in Big Creek (Table 5.12-17).

Prior to the Shell EIA activities, information on Eymundson Creek was limited to one previous study in 1973 that documented flathead chub (Golder 2004). Eleven species were documented by Shell (2007), including two sportfish species, two sucker species, and seven small-bodied fish species. Eight species were documented by JOSMP in 2013 and 2014, including walleye, which has not previously been reported in Eymundson Creek (Table 5.12-17).

Shell (2007) documented 17 species in the Pierre River, mostly within 3 km of the mouth and included five sportfish species, two large-bodied species, and ten small-bodied fish species. Nine species were documented by JOSMP in 2013 and 2014, including finescale dace, which has not previously been reported (Table 5.12-17).

Information on Red Clay Creek was limited to one previous study in 1973 that found Arctic grayling Golder (2004); 14 species were documented by Shell (2007), including four sportfish, two sucker species, and eight small-bodied fish species. Ten species were documented by JOSMP in 2013 and 2014, including spoonhead sculpin, which has not previously been reported (Table 5.12-17). Sampling by Shell (2007) was multi-season using a variety of techniques targeting a broad range of life stages. Conversely, the JOSMP fish assemblage monitoring program collected fish by means of a standardized protocol using backpack electrofishing, which targeted small-bodied fish species and juvenile large-bodied fish species. These differences in fishing techniques may explain some of the observed variation in species richness reported by JOSMP versus historical studies.

Shell (2007) has documented similar habitat conditions where *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 are located, consisting of shallow run and riffle habitat, with some flat habitat of beaver ponds (Big and Eymundson creeks); low gradient, run habitat with silt and sand substrate (Pierre River); and run habitat with sandy substrate and areas of cobble and gravel that would be suitable for spawning (Red Clay Creek). Shell (2007) reported that these rivers have potential for small-bodied fish habitat and seasonal use by sportfish species (including potential spawning habitat), but limited overwintering conditions.

2014 Results Relative to Regional *Baseline* Conditions With the exception of ATI and diversity at *baseline* reach RCC-F1, mean values for all measurement endpoints were within the inner tolerance limits of regional *baseline* variability (Figure 5.12-9). Diversity and the ATI value for *baseline* reach RCC-F1 were below the inner tolerance limit for the 5^{th} percentile indicating a greater proportion of sensitive species (Whittier et al. 2007) but dominance of only a few species (slimy sculpin).

Classification of Results The fish assemblages at *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 were similar to other *baseline* reaches in the region, and with each other. Species composition was generally the same across each reach and there was a decrease in the catch of burbot in 2014 compared to 2013 at all reaches.

Table 5.12-2 Concentrations of water quality measurement endpoints, Big Creek (*baseline* station BIC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	3	8.1	8.2	8.4
Total suspended solids	mg/L	-	8.0	3	9.0	15.0	59.0
Conductivity	µS/cm	-	397	3	387	391	446
Nutrients							
Total dissolved phosphorus	mg/L	-	0.015	3	0.023	0.025	0.082
Total nitrogen	mg/L	-	0.654	3	0.891	0.891	0.911
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	17.1	3	21.0	22.1	27.3
Ions							
Sodium	mg/L	-	9.9	3	10.4	11.1	13.6
Calcium	mg/L	-	57.4	3	52.5	53.6	55.2
Magnesium	mg/L	-	14.1	3	12.4	13.6	15.1
Chloride	mg/L	120	<0.50	3	<0.50	0.63	0.73
Sulphate	mg/L	429	15.9	3	8.3	11.0	21.5
Total dissolved solids	mg/L	-	259	3	265	275	307
Total alkalinity	mg/L	-	195	3	199	203	223
Selected metals							
Total aluminum	mg/L	0.1	**0.246**	3	**0.179**	**0.417**	**1.740**
Dissolved aluminum	mg/L	0.05	0.002	3	0.003	0.004	0.009
Total arsenic	mg/L	0.005	0.0008	3	0.0010	0.0010	0.0017
Total boron	mg/L	1.2	0.055	3	0.058	0.060	0.069
Total molybdenum	mg/L	0.073	0.00033	3	0.00031	0.00037	0.00042
Total mercury (ultra-trace)	ng/L	5, 13	1.19	3	0.60	2.00	**6.10**
Total strontium	mg/L	-	0.159	3	0.147	0.168	0.204
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.10	3	0.05	0.43	0.60
Oilsands Extractable	mg/L	-	1.50	3	0.31	0.72	1.81
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	0.57	3	1.06	3.45	4.16
Total dibenzothiophenes	ng/L	-	4.13	3	8.98	10.46	35.30
Total PAHs	ng/L	-	75.4	3	125.4	168.6	206.5
Total Parent PAHs	ng/L	-	13.48	3	16.41	20.11	23.65
Total Alkylated PAHs	ng/L	-	61.9	3	101.7	148.5	190.0
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**1.39**	3	**1.25**	**1.46**	**4.76**
Total phenols	mg/L	0.004	**0.0046**	3	**0.0043**	**0.0065**	**0.0073**
Sulphide	mg/L	0.002	**0.006**	3	<0.002	**0.006**	**0.008**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.12-3 Concentrations of water quality measurement endpoints, Eymundson Creek (*baseline* station EYC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.01	3	7.95	8.27	8.33
Total suspended solids	mg/L	-	112	3	54	144	180
Conductivity	µS/cm	-	445	3	318	531	596
Nutrients							
Total dissolved phosphorus	mg/L	-	0.028	3	0.009	0.019	0.025
Total nitrogen	mg/L	-	0.79	3	0.97	0.98	1.10
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	23.3	3	23.0	26.1	31.2
Ions							
Sodium	mg/L	-	17.9	3	11.6	22.5	26.5
Calcium	mg/L	-	52.7	3	35.5	57.2	76.5
Magnesium	mg/L	-	14.8	3	9.9	17.3	22.3
Chloride	mg/L	120	2.06	3	1.52	3.61	3.62
Sulphate	mg/L	429	106	3	59	119	137
Total dissolved solids	mg/L	-	332	3	258	400	425
Total alkalinity	mg/L	-	5.0	3	98.7	151	177
Selected metals							
Total aluminum	mg/L	0.1	**3.35**	3	**1.78**	**4.24**	**5.13**
Dissolved aluminum	mg/L	0.05	0.037	3	0.013	0.022	**0.082**
Total arsenic	mg/L	0.005	0.0024	3	0.0023	0.0036	0.0038
Total boron	mg/L	1.2	0.092	3	0.074	0.106	0.113
Total molybdenum	mg/L	0.073	0.0013	3	0.0013	0.0020	0.0025
Total mercury (ultra-trace)	ng/L	5, 13	**12.7**	3	**9.2**	**13.0**	**21.0**
Total strontium	mg/L	-	0.170	3	0.114	0.225	0.226
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.20	3	0.10	0.51	0.54
Oilsands Extractable	mg/L	-	1.50	3	0.51	1.36	1.39
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	4.02	3	4.70	9.05	13.6
Total dibenzothiophenes	ng/L	-	63.83	3	37.08	79.88	226.49
Total PAHs	ng/L	-	250.1	3	278.4	419.1	729.8
Total Parent PAHs	ng/L	-	17.84	3	23.73	24.54	36.53
Total Alkylated PAHs	ng/L	-	232.3	3	253.8	395.4	693.2
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.821**	3	**0.187**	**0.865**	**1.850**
Total chromium	mg/L	0.001	**0.0051**	3	**0.0031**	**0.0049**	**0.0062**
Total iron	mg/L	0.3	**5.51**	3	**4.09**	**7.46**	**8.27**
Total phenols	mg/L	0.004	**0.0052**	3	**0.0070**	**0.0087**	**0.0098**
Sulphide	mg/L	0.002	**0.016**	3	**0.002**	**0.015**	**0.028**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.12-4 Concentrations of water quality measurement endpoints, Pierre River (*baseline* station PIR-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.20	3	8.08	8.28	8.40
Total suspended solids	mg/L	-	24.3	3	21.0	41.0	74.0
Conductivity	µS/cm	-	423	3	387	478	554
Nutrients							
Total dissolved phosphorus	mg/L	-	0.039	3	0.029	0.060	0.064
Total nitrogen	mg/L	-	0.81	3	0.93	1.08	1.42
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	28.6	3	28.3	31.7	41.3
Ions							
Sodium	mg/L	-	20.3	3	20.2	24.7	28.6
Calcium	mg/L	-	51.8	3	41.8	51.0	70.5
Magnesium	mg/L	-	14.5	3	12.1	15.2	20.1
Chloride	mg/L	120	4.05	3	5.46	7.48	8.70
Sulphate	mg/L	429	36.4	3	23.0	28.5	34.9
Total dissolved solids	mg/L	-	310	3	303	380	396
Total alkalinity	mg/L	-	180	3	173	206	265
Selected metals							
Total aluminum	mg/L	0.1	**0.56**	3	**0.48**	**1.38**	**1.50**
Dissolved aluminum	mg/L	0.05	0.013	3	0.008	0.008	0.022
Total arsenic	mg/L	0.005	0.0019	3	0.0024	0.0025	0.0026
Total boron	mg/L	1.2	0.095	3	0.100	0.113	0.122
Total molybdenum	mg/L	0.073	0.00094	3	0.00099	0.00118	0.00145
Total mercury (ultra-trace)	ng/L	5, 13	3.16	3	3.80	4.60	4.90
Total strontium	mg/L	-	0.205	3	0.164	0.223	0.258
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.50	3	0.06	0.51	1.01
Oilsands Extractable	mg/L	-	2.90	3	0.46	1.08	1.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	1.71	3	2.35	4.50	5.91
Total dibenzothiophenes	ng/L	-	67.15	3	43.35	51.32	238.24
Total PAHs	ng/L	-	242.1	3	260.2	309.5	764.2
Total Parent PAHs	ng/L	-	16.06	3	18.27	24.11	32.76
Total Alkylated PAHs	ng/L	-	226.0	3	242.0	285.4	731.4
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.67**	3	0.28	**0.79**	**1.74**
Sulphide	mg/L	0.002	**0.019**	3	**0.006**	**0.017**	**0.018**
Total chromium	mg/L	0.001	**0.0011**	3	**0.0011**	**0.0018**	**0.0019**
Total iron	mg/L	0.3	**2.18**	3	**2.78**	**2.89**	**2.90**
Total phenols	mg/L	0.004	**0.0054**	3	**0.0062**	**0.0068**	**0.0099**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.12-5 Concentrations of water quality measurement endpoints, Red Clay Creek (*baseline* station RCC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2011-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.36	3	8.07	8.30	8.38
Total suspended solids	mg/L	-	<3.0	3	<3.0	3.0	7.0
Conductivity	µS/cm	-	498	3	480	519	522
Nutrients							
Total dissolved phosphorus	mg/L	-	0.008	3	0.010	0.015	0.018
Total nitrogen	mg/L	-	0.404	3	0.501	0.521	0.551
Nitrate+nitrite	mg/L	3	<0.054	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	9.8	3	12.9	13.8	15.7
Ions							
Sodium	mg/L	-	11.2	3	10.6	13.5	15.7
Calcium	mg/L	-	71.8	3	63.4	68.6	72.0
Magnesium	mg/L	-	19.0	3	16.5	19.3	21.3
Chloride	mg/L	120	1.26	3	1.46	1.62	1.64
Sulphate	mg/L	429	44.7	3	35.9	45.2	54.6
Total dissolved solids	mg/L	-	306	3	317	337	337
Total alkalinity	mg/L	-	220	3	225	235	269
Selected metals							
Total aluminum	mg/L	0.1	0.011	3	0.033	0.058	**0.303**
Dissolved aluminum	mg/L	0.05	0.0005	3	0.0012	0.0015	0.0030
Total arsenic	mg/L	0.005	0.00014	3	0.00016	0.00019	0.00026
Total boron	mg/L	1.2	0.073	3	0.083	0.085	0.115
Total molybdenum	mg/L	0.073	0.00009	3	0.00010	0.00012	0.00014
Total mercury (ultra-trace)	ng/L	5, 13	0.49	3	0.61	1.00	1.20
Total strontium	mg/L	-	0.220	3	0.192	0.254	0.268
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.95	3	0.09	0.20	0.49
Oilsands Extractable	mg/L	-	1.50	3	0.48	0.93	1.91
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.407	3	0.514	<0.669	<2.071
Total dibenzothiophenes	ng/L	-	4.13	3	6.22	6.67	35.30
Total PAHs	ng/L	-	74.1	3	103.3	151.5	220.8
Total Parent PAHs	ng/L	-	13.26	3	16.44	19.23	22.86
Total Alkylated PAHs	ng/L	-	60.8	3	80.4	132.3	204.4

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.12-3 Piper diagram of ion balance in Big Creek, Eymundson Creek, Pierre River, and Red Clay Creek.

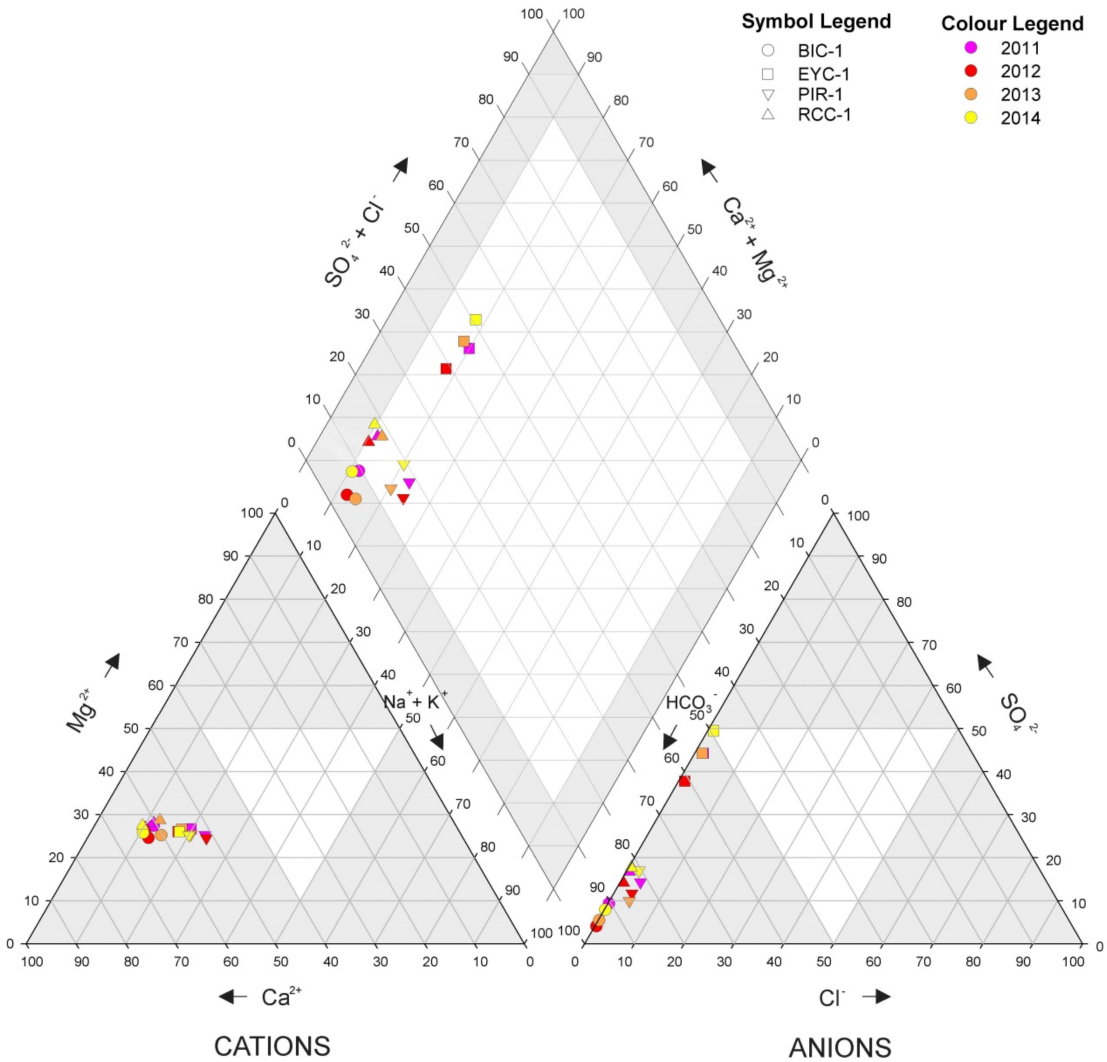


Table 5.12-6 Water quality guideline exceedances at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1, 2014.

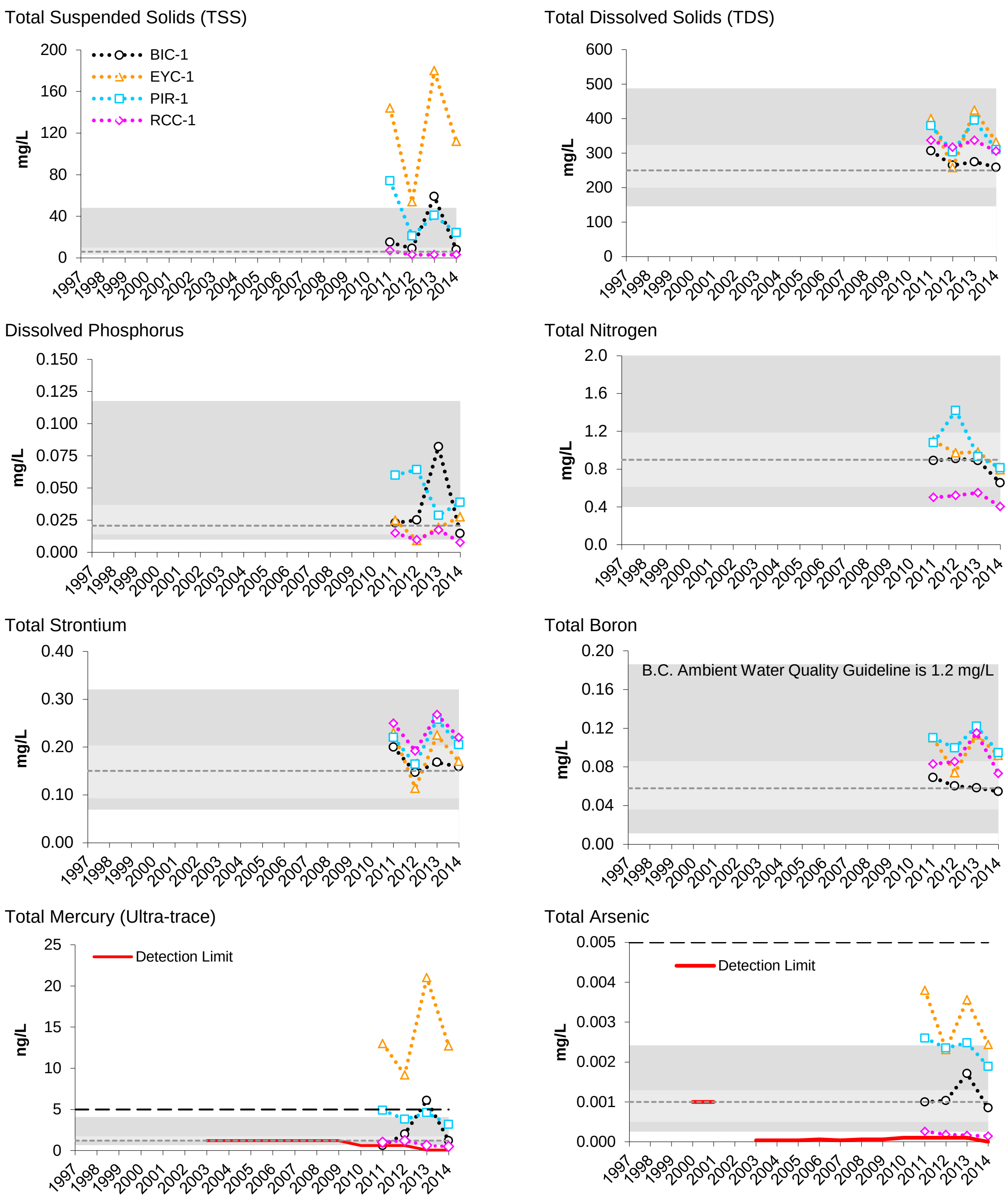
Variable	Units	Guideline[a]	BIC-1[b]	EYC-1	PIR-1	RCC-1[b]
Winter						
Sulphide	mg/L	0.002	0.008	ns	ns	-
Total aluminum	mg/L	0.1	0.49	ns	ns	-
Total iron	mg/L	0.3	1.22	ns	ns	0.96
Total phenols	mg/L	0.004	0.006	ns	ns	-
Fall						
Dissolved iron	mg/L	0.3	-	0.82	0.67	-
Sulphide	mg/L	0.002	0.0061	0.0155	0.0193	-
Total aluminum	mg/L	0.1	0.25	3.35	0.56	-
Total chromium	mg/L	0.001	-	0.0051	0.0011	-
Total iron	mg/L	0.3	1.39	5.51	2.18	-
Total mercury (ultra-trace)	ng/L	5, 13	-	12.7	-	-
Total phenols	mg/L	0.004	0.0046	0.0052	0.0054	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Only sampled in winter and fall 2014; seasonal sampling was discontinued in April 2014.

ns = not sampled

Figure 5.12-4 Concentrations of selected water quality measurement endpoints in *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 (fall data) relative to regional *baseline* fall concentrations.



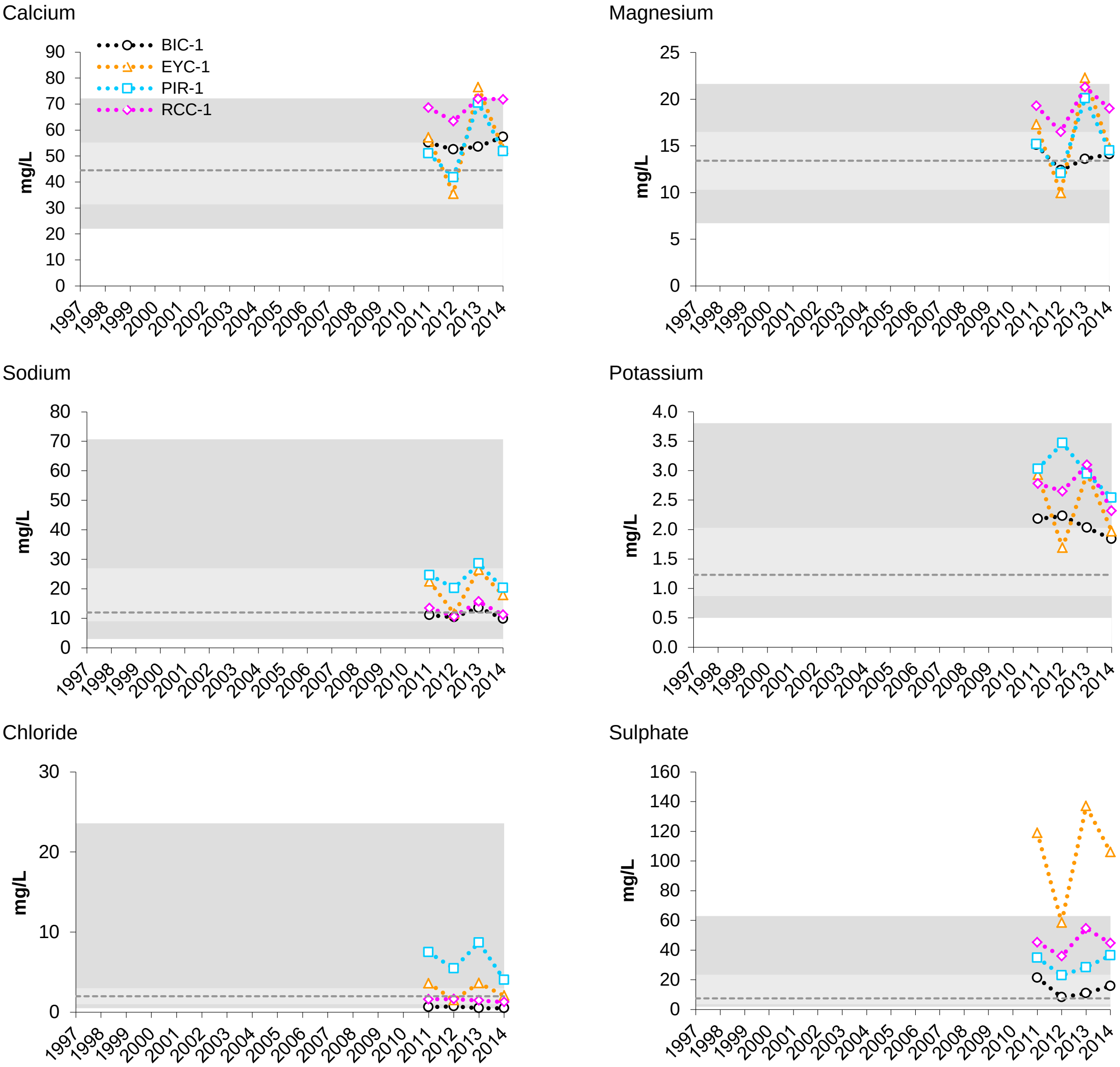
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.12-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.12-7 Water quality index (fall 2014) for the watersheds in the Pierre River area.

Station Identifier	Location	2014 Designation	Water Quality Index	Classification
BIC-1	near the mouth of Big Creek	*baseline*	100	Negligible-Low
EYC-1	near the mouth of Eymundson Creek	*baseline*	82	Negligible-Low
PIR-1	near the mouth of Pierre River	*baseline*	100	Negligible-Low
RCC-1	near the mouth of Red Clay Creek	*baseline*	100	Negligible-Low

Table 5.12-8 Average habitat characteristics of benthic invertebrate community sampling locations in the Pierre River area, fall 2014.

Variable	Units	EYC-D1 *Baseline* Reach of Eymundson Creek	RCC-E1 *Baseline* Reach of Red Clay Creek	BIC-D1 *Baseline* Reach of Big Creek	PIR-D1 *Baseline* Reach of Pierre River
Sample date	-	Sept 9, 2014	Sept 10, 2014	Sept 10, 2014	Sept 9, 2014
Habitat	-	Depositional	Erosional	Depositional	Depositional
Water depth	m	0.38	0.20	0.42	0.40
Current velocity	m/s	0.46	0.58	0.46	0.55
Field Water Quality					
Dissolved oxygen	mg/L	6.7	10.2	12.2	10.8
Conductivity	µS/cm	450	482	426	435
pH	pH units	7.2	7.7	8.1	7.2
Water temperature	°C	6.8	5.9	6.6	7.3
Sediment Composition (mean ± 1SD)					
Sand/Silt/Clay	%		7±5		
Small gravel	%		12±10		
Large gravel	%		28±13		
Small cobble	%		31±14		
Large cobble	%		21±20		
Boulder	%		2±3		
Sand	%	80±19		95±4	84±16
Silt	%	13±14		3±2	10±12
Clay	%	7±6		2±2	6±5
Total Organic Carbon	%	0.8±0.5		0.5±0.4	1.7±1.1

Figure 5.12-5 Periphyton chlorophyll *a* biomass at *baseline* reach RCC-E1 of Red Clay Creek.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* reaches for years up to and including 2013.

Table 5.12-9 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Eymundson Creek.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Reach EYC-D1	
	2013	2014
Nematoda	2	6
Naididae	6	<1
Tubificidae	14	11
Enchytraeidae	<1	3
Hydracarina	-	7
Ceratopogonidae	1	5
Chironomidae	65	63
Diptera (misc)	12	3
Ephemeroptera	<1	1
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance per sample	15	12
Richness	4	5
Equitability	0.72	0.79
% EPT	<1	1

Table 5.12-10 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Red Clay Creek.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Reach RCC-E1	
	2013	2014
Hydra	<1	-
Nematoda	1	1
Oligochaeta	<1	-
Naididae	3	11
Tubificidae	3	<1
Enchytraeidae	<1	<1
Hydracarina	3	4
Amphipoda	<1	<1
Gastropoda	<1	<1
Bivalvia	<1	<1
Ceratopogonidae	<1	-
Chironomidae	73	28
Diptera (misc)	5	11
Coleoptera	<1	<1
Ephemeroptera	2	3
Odonata	<1	<1
Neuroptera	<1	-
Plecoptera	<1	5
Trichoptera	8	36
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance per sample	3,514	3,381
Richness	31	36
Equitability	0.27	0.21
% EPT	11	45

Table 5.12-11 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Big Creek.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Reach BIC-D1	
	2013	2014
Nematoda	5	1
Naididae	2	-
Tubificidae	11	<1
Enchytraeidae	2	<1
Lumbriculidae	<1	-
Hydracarina	-	<1
Gastropoda	10	-
Bivalvia	1	-
Ceratopogonidae	<1	<1
Chironomidae	68	78
Diptera (misc)	2	7
Coleoptera	-	<1
Ephemeroptera	<1	<1
Plecoptera	-	<1
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance per sample	14	173
Richness	4	7
Equitability	0.75	0.57
% EPT	<1	<1

Table 5.12-12 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of the Pierre River.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Reach PIR-D1	
	2013	2014
Nematoda	17	2
Naididae	<1	2
Tubificidae	22	4
Enchytraeidae	<1	8
Hirudinea	<1	-
Hydracarina	<1	<1
Amphipoda	-	<1
Gastropoda	-	<1
Bivalvia	<1	2
Ceratopogonidae	1	2
Chironomidae	57	48
Diptera (misc)	<1	3
Ephemeroptera	2	8
Trichoptera	-	<1
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance per sample	326	205
Richness	11	13
Equitability	0.46	0.23
% EPT	2	8

Table 5.12-13 Concentrations of selected sediment quality measurement endpoints in Pierre River (*baseline* station PIR-D1), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	16.1	7.7
Silt	%	-	38.5	12.3
Sand	%	-	45.4	80.0
Total organic carbon	%	-	3.88	5.04
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	72	95
Fraction 3 (C16-C34)	mg/kg	300[1]	**868**	**1,130**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	735	972
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.002	0.003
Retene	mg/kg	-	0.294	0.099
Total dibenzothiophenes	mg/kg	-	1.98	4.08
Total PAHs	mg/kg	-	5.83	11.95
Total Parent PAHs	mg/kg	-	0.159	0.245
Total Alkylated PAHs	mg/kg	-	5.67	11.71
Predicted PAH toxicity[3]	H.I.	1.0	**1.01**	**1.56**
Metals that exceeded CCME guidelines in 2014				
Total arsenic	mg/kg	5.9	**7.49**	**5.93**
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	5.8	5.6
Chironomus growth - 10d	mg/organism	-	1.42	2.99
Hyalella survival - 14d	# surviving	-	9.8	8.4
Hyalella growth - 14d	mg/organism	-	0.25	0.24

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.12-14 Concentrations of selected sediment quality measurement endpoints in Big Creek (*baseline* station BIC-D1), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	2.71	2.02
Silt	%	-	2.55	6.63
Sand	%	-	94.7	91.4
Total organic carbon	%	-	0.75	0.40
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	62	63
Fraction 4 (C34-C50)	mg/kg	2,800[1]	78	86
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0006	0.0005
Retene	mg/kg	-	0.0042	0.0068
Total dibenzothiophenes	mg/kg	-	0.0282	0.0277
Total PAHs	mg/kg	-	0.1642	0.1787
Total Parent PAHs	mg/kg	-	0.0103	0.0108
Total Alkylated PAHs	mg/kg	-	0.1539	0.1680
Predicted PAH toxicity[3]	H.I.	1.0	0.2793	0.2894
Metals that exceeded CCME guidelines in 2014				
none				
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	5.2	6.4
Chironomus growth - 10d	mg/organism	-	1.5	2.6
Hyalella survival - 14d	# surviving	-	9.4	9.2
Hyalella growth - 14d	mg/organism	-	0.3	0.3

Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.12-15 Concentrations of selected sediment quality measurement endpoints in Eymundson Creek (*baseline* station EYC-D1), fall 2014.

Variables	Units	Guideline	September 2014	September 2013
			Value	Value
Physical variables				
Clay	%	-	2.2	19.3
Silt	%	-	2.3	31.4
Sand	%	-	95.5	49.3
Total organic carbon	%	-	0.49	1.67
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	31	25
Fraction 3 (C16-C34)	mg/kg	300[1]	221	161
Fraction 4 (C34-C50)	mg/kg	2,800[1]	179	97
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0006	0.0014
Retene	mg/kg	-	0.0109	0.0570
Total dibenzothiophenes	mg/kg	-	0.4586	0.8889
Total PAHs	mg/kg	-	1.35	2.98
Total Parent PAHs	mg/kg	-	0.0356	0.1024
Total Alkylated PAHs	mg/kg	-	1.31	2.88
Predicted PAH toxicity[3]	H.I.	1.0	0.91	**3.04**
Metals that exceeded CCME guidelines in 2014				
Arsenic (As)	mg/kg	5.9	**17.4**	**14.6**
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	8.8	4.6
Chironomus growth - 10d	mg/organism	-	2.89	3.91
Hyalella survival - 14d	# surviving	-	9.8	8.2
Hyalella growth - 14d	mg/organism	-	0.28	0.23

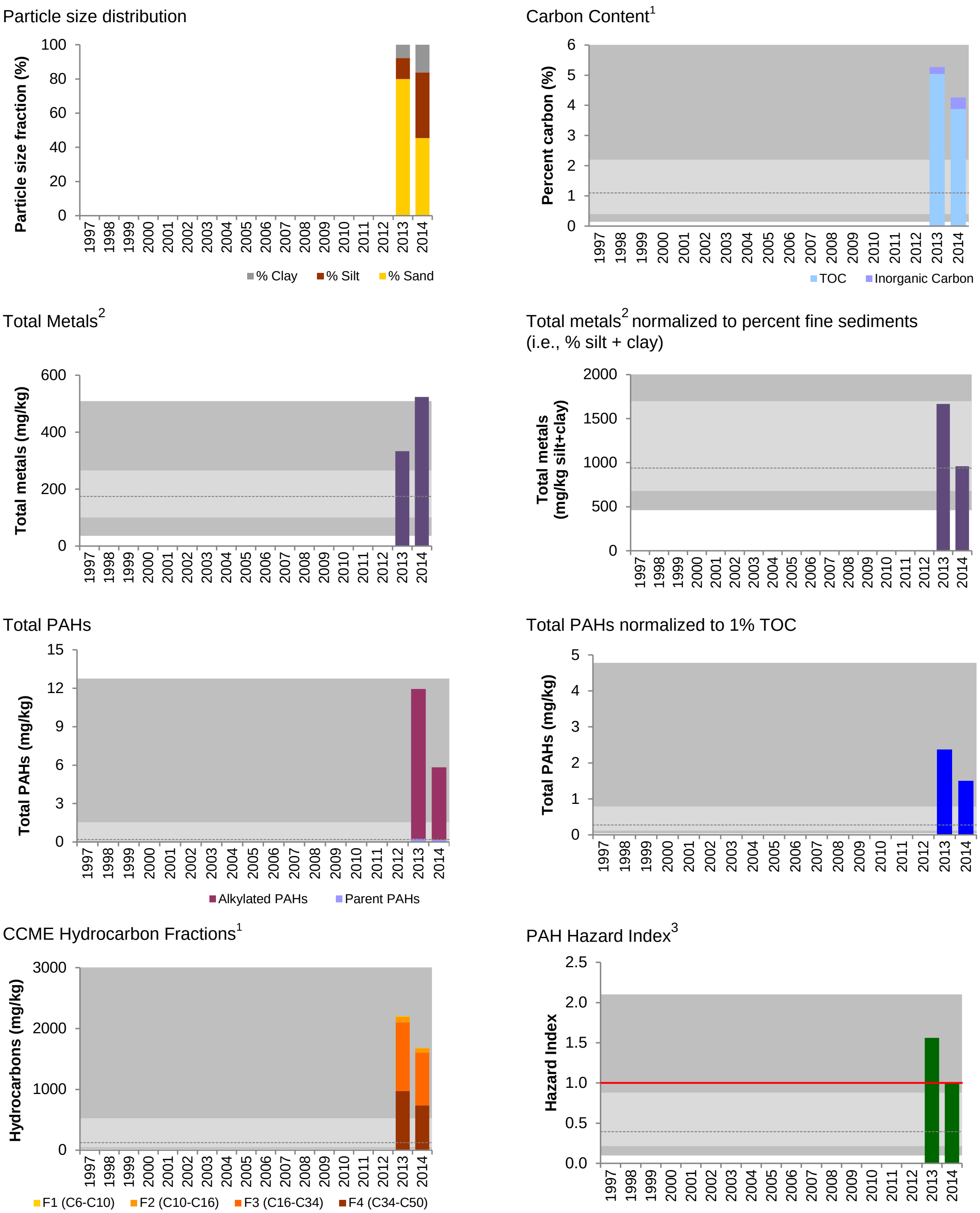
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.12-6 Variation in sediment quality measurement endpoints in Pierre River, *baseline* station PIR-D1.



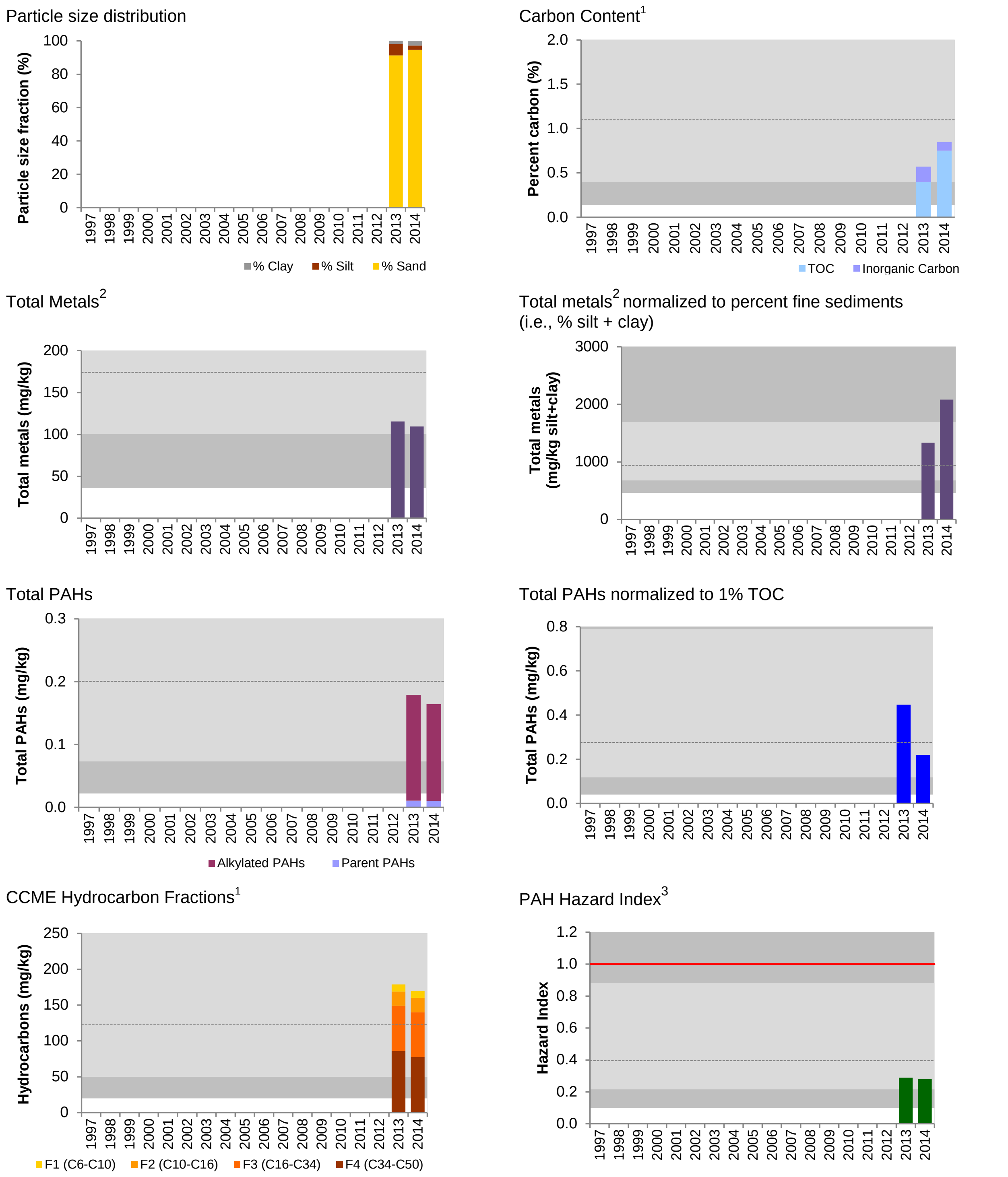
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.12-7 Variation in sediment quality measurement endpoints in Big Creek, *baseline* station BIC-D1.



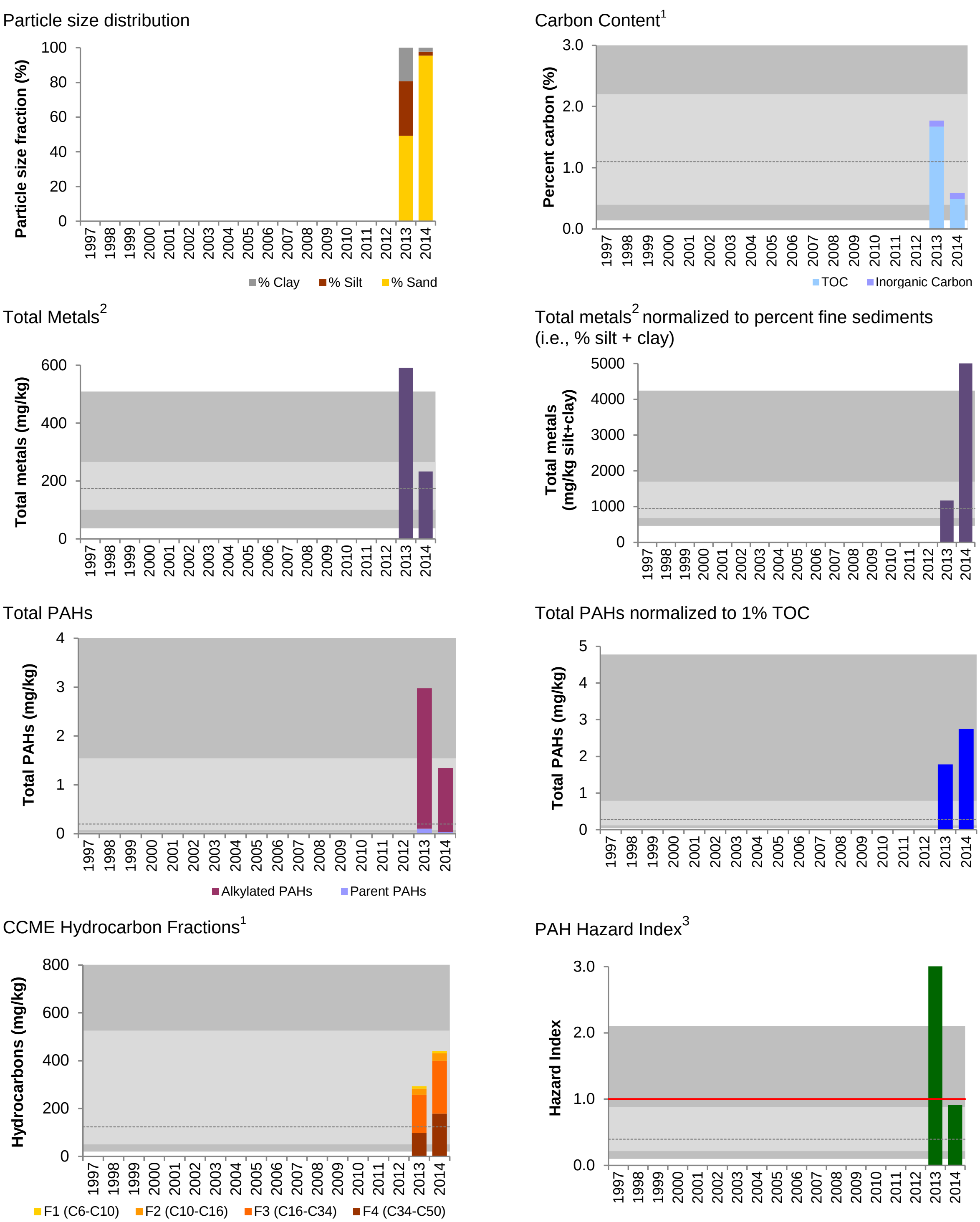
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.12-8 Variation in sediment quality measurement endpoints in Eymundson Creek, *baseline* station EYC-D1.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.12-16 Average habitat characteristics of fish assemblage monitoring locations in the Pierre River area, fall 2014.

Variable	Units	BIC-F1 *Baseline* Reach of Big Creek	EYC-F1 *Baseline* Reach of Eymundson Creek	PIR-F1 *Baseline* Reach of Pierre River	RCC-F1 *Baseline* Reach of Red Clay Creek
Sample date	-	Sept 7, 2014	Sept 11, 2014	Sept 3, 2014	Sept 12, 2014
Habitat type	-	run	run	riffle/run	run/riffle
Maximum depth	m	0.55	1.02	1.02	0.42
Mean depth	m	0.50	0.82	0.67	0.40
Bankfull channel width	m	10.6	14.5	12.2	11.2
Wetted channel width	m	25.5	7.6	5.5	5.5
Substrate					
Dominant	-	sand	sand	coarse gravel	fines
Subdominant	-	-	-	fines	cobble
Instream cover					
Dominant	-	small woody debris, filamentous algae	small woody debris	large and small woody debris	small woody debris, filamentous algae
Subdominant	-	large woody debris	large woody debris	undercut banks, macrophytes	macrophytes, large woody debris
Field water quality					
Dissolved oxygen	mg/L	10.2	10.8	10.4	10.4
Conductivity	µS/cm	340	427	401	466
pH	pH units	8.34	8.13	8.03	8.20
Water temperature	^{o}C	8.9	4.2	5.6	5.9
Water velocity					
Left bank velocity	m/s	0.16	0.23	0.00	0.15
Left bank water depth	m	0.35	0.18	0.38	0.20
Centre of channel velocity	m/s	0.41	0.29	0.49	0.22
Centre of channel water depth	m	0.36	0.36	0.24	0.24
Right bank velocity	m/s	0.18	0.30	0.30	0.28
Right bank water depth	m	0.19	0.33	0.26	0.28
Riparian cover – understory (<5 m)					
Dominant	-	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation	overhanging vegetation	-

Table 5.12-17 Total number and percent composition of fish species captured in tributaries of the Pierre River area, 2014.

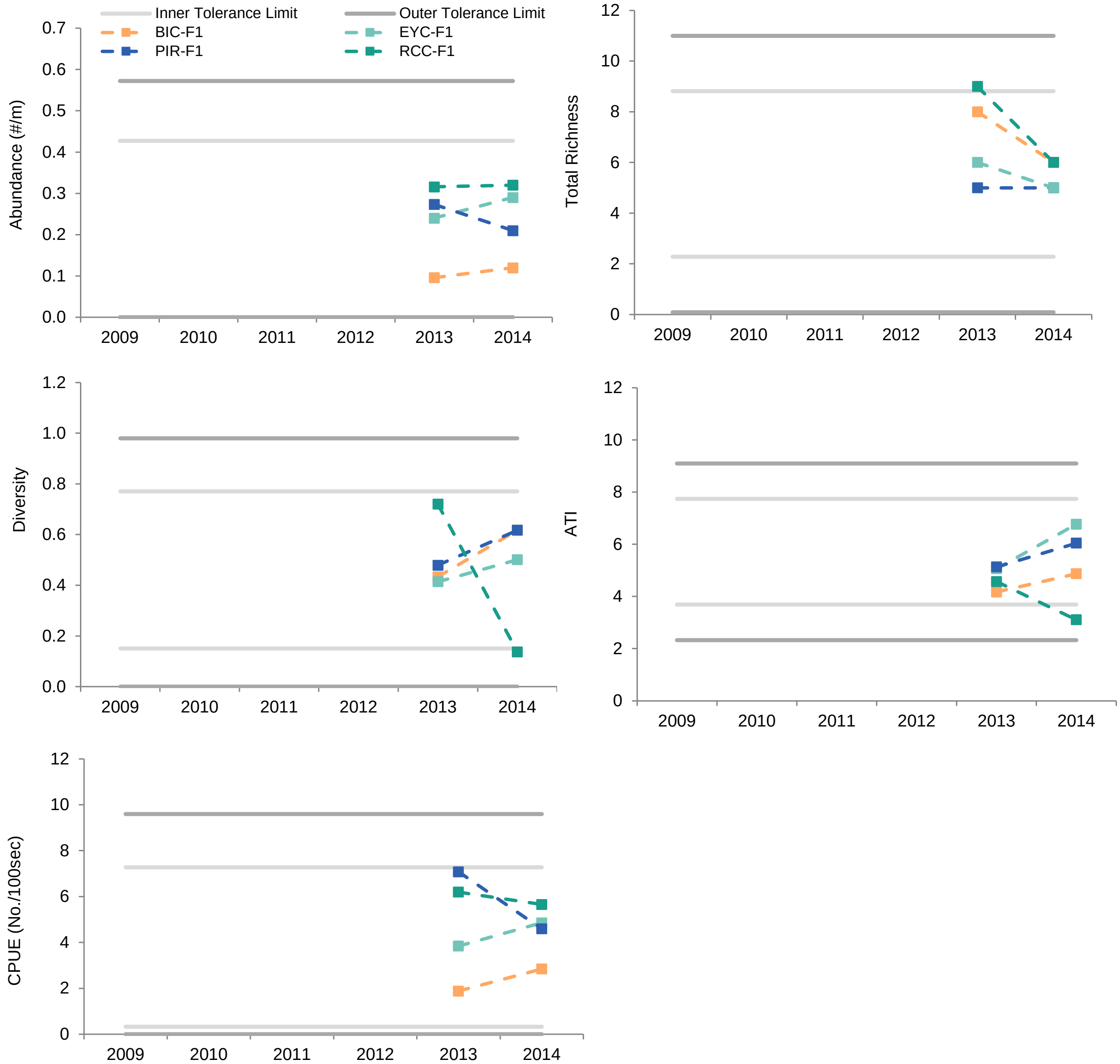
Common Name	Code	Total Species Catch								Percent of Total Catch							
		BIC-F1		EYC-F1		PIR-F1		RCC-F1		BIC-F1		EYC-F1		PIR-F1		RCC-F1	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
brook stickleback	BRST	-	-	-	-	-	-	9	-	0	0	0	0	0	0	12.2	0
burbot	BURB	9	1	9	2	10	5	28	4	37.5	2.8	15	2.3	12.2	7.9	37.8	4.2
finescale dace	FNDC	-	-	-	-	2	-	-	-	0	0	0	0	2.4	0	0	0
flathead chub	FLCH	-	-	2	51	-	-	-	-	0	0	3.3	58.6	0	0	0	0
lake chub	LKCH	2	16	44	29	44	33	2	-	8.3	44.4	73.3	33.3	53.7	52.4	2.7	0
lake whitefish	LKWH	-	-	-	-	-	1	-	-	0	0	0	0	0	1.6	0	0
longnose dace	LNDC	-	-	-	3	-	-	-	-	0	0	0	3.4	0	0	0	0
longnose sucker	LNSC	-	-	3	-	10	-	14	1	0	0	5	0	12.2	0	18.9	1.0
northern pike	NRPK	-	-	-	-	1	5	-	2	0	0	0	0	1.2	7.9	0	2.1
slimy sculpin	SLSC	1	12	-	-	2	-	11	87	4.2	33.3	0	0	2.4	0	14.9	90.6
spoonhead sculpin	SPSC	2	1	-	2	-	-	2	1	8.3	2.8	0	2.3	0	0	2.7	1.0
walleye	WALL	-	-	1	-	-	5	1	1	0	0	1.7	0	0	7.9	1.4	1.0
white sucker	WHSC	10	6	1	-	11	14	11	-	41.7	16.7	1.7	0	13.4	22.2	14.9	0
yellow perch	YLPR	-	-	-	-	2	-	1	-	0	0	0	0	2.4	0	1.4	0
Total Count		**24**	**36**	**60**	**87**	**82**	**63**	**74**	**96**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**5**	**6**	**5**	**8**	**6**	**9**	**6**	**5**	**5**	**6**	**5**	**8**	**6**	**9**	**6**
Electrofishing effort (secs)		**1,278**	**1,272**	**1,557**	**1,731**	**1,154**	**1,481**	**1,277**	**1,561**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 5.12-18 Summary of fish assemblage measurement endpoints (± 1SD) for tributaries of the Pierre River area, fall 2014.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BIC-F1	2013	0.10	0.06	5	2.60	1.14	0.43	0.28	4.17	1.56	1.88	1.09
	2014	0.12	0.06	5	3.20	1.10	0.62	0.10	4.87	0.71	2.84	1.29
EYC-F1	2013	0.24	0.09	6	3.20	0.84	0.41	0.07	5.06	0.34	3.84	1.42
	2014	0.29	0.19	5	2.80	0.45	0.50	0.05	6.77	0.36	4.86	2.54
PIR-F1	2013	0.27	0.18	8	4.20	2.17	0.48	0.31	5.13	0.95	7.08	4.79
	2014	0.21	0.07	6	4.60	0.55	0.62	0.09	6.05	0.45	4.59	1.63
RCC-F1	2013	0.32	0.09	9	5.40	1.82	0.72	0.10	4.57	1.27	6.19	1.79
	2014	0.32	0.16	6	2.20	1.30	0.14	0.16	3.11	0.15	5.66	2.38

SD = standard deviation across sub-reaches within a reach

Figure 5.12-9 Variation in fish assemblage measurement endpoints for *baseline* reaches of the Pierre River area from 2013 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach.

5.13 MISCELLANEOUS AQUATIC SYSTEMS

Table 5.13-1 Summary of results for the miscellaneous aquatic systems.

Miscellaneous Aquatic Systems	Summary of 2014 Conditions								
	Lakes		*Rivers/Creeks*						
Climate and Hydrology									
Criteria	**L3** Isadore's Lake	no station	**S6** Mills Creek at Highway 63	**S11** Poplar Creek at Highway 63	**S12** Fort Creek at Highway 63	no station	no station	no station	**S25** Susan Lake Outlet
Mean open-water season discharge	not measured		● (brown)	● (brown)	● (brown)				not measured
Mean winter discharge	not measured		● (brown)	○ (yellow)	not measured				not measured
Annual maximum daily discharge	not measured		● (brown)	○ (yellow)	● (brown)				not measured
Minimum open-water season discharge	not measured		● (brown)	○ (yellow)	● (brown)				not measured
Water Quality									
Criteria	**ISL-1** Isadore's Lake	**SHL-1** Shipyard Lake	**MIC-1** Mills Creek	**POC-1** Poplar Creek at the mouth	**FOC-1** Fort Creek at the mouth	**BER-1** Beaver River at the mouth	**BER-2** upper Beaver River	**MCC-1** McLean Creek at the mouth	no station
Water Quality Index	n/a	n/a	● (light orange)	● (light orange)	○ (yellow)	● (orange)	○ (yellow)	● (light orange)	
Benthic Invertebrate Communities and Sediment Quality									
Criteria	**ISL-1** Isadore's Lake	**SHL-1** Shipyard Lake	no reach	**POC-D1** Poplar Creek lower reach	**FOC-D1** Fort Creek at the mouth	no reach	**BER-D2** Beaver River upper reach	no reach	no reach
Benthic Invertebrate Communities	○ (yellow)	○ (yellow)		○ (yellow)	● (light orange)		n/a		
Sediment Quality Index	n/a	n/a		○ (yellow)	○ (yellow)		○ (yellow)		
Fish Populations									
Criteria	no reach	no reach	no reach	**POC-F1** Poplar Creek lower reach	**FOC-F1** Fort Creek at the mouth	no reach	**BER-F2** Beaver River upper reach	no reach	no reach
Fish Assemblages				○ (yellow)	● (orange)		n/a		

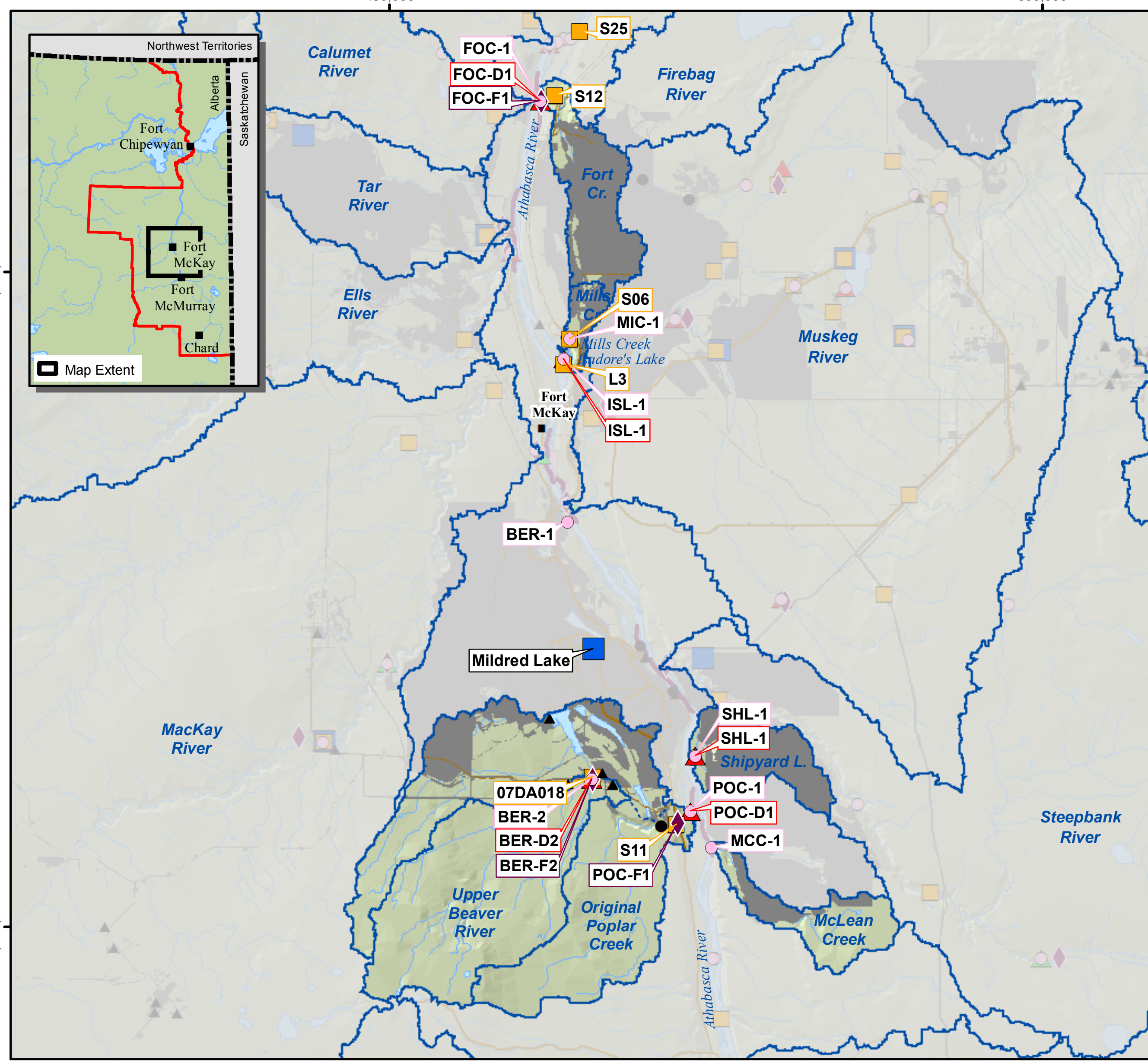
Legend and Notes

- ○ (yellow) Negligible - Low
- ● (orange) Moderate
- ● (brown) High

baseline (green shading)
test (blue shading)

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; >15% - High.
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; less than 60: High difference from regional *baseline* conditions.
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baselines*; see Section 3.3.1.10 for a detailed description of the classification methodology.
Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.
Fish Populations: Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.3 for a description of the classification methodology.

Figure 5.13-1 Miscellaneous aquatic systems.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2014[a]
- Water Withdrawal Location[b]
- Water Discharge Location[b]
- Hydrometric Station
- Climate Station
- Water Quality Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Assemblage Reach
- Fish Inventory Reach

0 2.5 5 10 km

N

Scale: 1:500,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2014 Related to Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.13-2 Representative monitoring stations of miscellaneous aquatic systems, fall 2014.

Benthic Invertebrate Reach BER-D2 (Beaver River): Right Downstream Bank, facing downstream

Water Quality Station FOC-1 (Fort Creek): Left Downstream Bank, facing downstream

Water Quality Station MCC-1 (McLean Creek) Near the Mouth, facing upstream

Fish Assemblage Reach POC-F1 (Poplar Creek): Centre of Channel, facing upstream

Water Quality Station ISL-1 (Isadore's Lake)

Water Quality Station SHL-1 (Shipyard Lake)

5.13.1 Summary of 2014 Conditions

This section includes 2014 results for the following aquatic systems, each with a specific status:

- Mills Creek, Poplar Creek (original water course), McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake are designated as *test*. Land change as of 2014 comprised 18.9% (5,388 ha) of the original Poplar Creek watershed, 83.6% (5,549 ha) of the Fort Creek watershed, 30.5% (1,418 ha) of the McLean Creek watershed, 63.8% (908 ha) of the Mills Creek watershed, 90.1% (4,644 ha) of the original watershed draining into Shipyard Lake, and 0.6% (121 ha) of the Upper Beaver River watershed (Table 2.3-1).

Table 5.13-1 is a summary of the 2014 assessment of the miscellaneous aquatic systems in the Athabasca oil sands region, while Figure 5.13-1 denotes the location of the monitoring stations for each component, reported water withdrawal and discharge locations, and the area of land change as of 2014. Figure 5.13-2 contains 2014 photos of various monitoring stations located in the miscellaneous aquatic systems of the Athabasca oil sands region.

Isadore's Lake and Mills Creek The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all 68.4% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**. These **High** magnitude of changes were due to land disturbance located immediately upstream of JOSMP Station S6. Given the limited size of the Mills Creek watershed downstream of JOSMP Station S6, the magnitude of impact would remain high along the entire length of Mills Creek; therefore, a longitudinal classification of Mills Creek was not conducted.

In the 2014 WY, the lake level slowly decreased by about 0.1 m from November to early April, and was within the historical interquartile range for this period. During spring thaw, the lake level initially rose by approximately 0.15 m, and then decreased sharply in mid-May. A second rise occurred in late May following rainfall accumulations, and lasted until the first week in June. The lake level then gradually increased until early September, until the peak annual lake level occurred before gradually decreasing until the end of October.

Differences in water quality in fall 2014 between Mills Creek and regional *baseline* fall conditions were classified as **Moderate**, due to relatively high concentrations of many ions that exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water at *test* stations ISL-1 and MIC-1 showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

Differences in measurement endpoints of the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because although there were significant time trends in %EPT and CA Axis 1, both were indicative of improving habitat quality. The percentage of EPT taxa has been higher than usual since 2013. Several of the measurement endpoints exceeded the tolerance limits of the normal range of variation; however, none of the exceedances were considered an indication of degrading conditions. Isadore's Lake, historically, has had low diversity and high abundances of nematodes making it unique in comparison to the other lakes in the program. In 2014, the relative abundance of nematodes was lower but the abundance of naidid worms was higher than previously observed in Isadore's Lake.

The percentage of EPT taxa and taxa richness have increased in recent years, suggesting that water and sediment quality of Isadore's Lake was potentially improving over time.

Sediment quality measurement endpoints at *test* station ISL-1 were generally within the range of previously-measured concentrations, with the exception of F2 hydrocarbons, retene, and total arsenic that exceeded previously-measured maximum concentrations and naphthalene, which was below the previously-measured minimum concentration. Concentrations of total arsenic, and F1, F2, and F3 hydrocarbons exceeded sediment quality guidelines in fall 2014, with the concentration of F3 hydrocarbons significantly higher than the guideline value. An SQI was not calculated for *test* station ISL-1 because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2014 at *test* station SHL-1 were within previously-measured concentrations. The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with oil sands development in the upper portion of the watershed (91% of the Shipyard Lake watershed has been disturbed). The WQI was not calculated for lakes in 2014 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the lack of *baseline* data for lakes in the region.

Differences in measurement endpoints of benthic invertebrate communities for Shipyard Lake in 2014 were classified as **Negligible-Low**. The increasing trend in taxa richness and lower equitability in 2014 were indicative of improving habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams and snails, indicating generally good water and sediment quality.

In fall 2014, some sediment quality measurement endpoints exceeded previously-measured maximum concentrations at *test* station SHL-1, including percent sand, total organic carbon, and all hydrocarbons (BTEX and all F1 to F4 fractions), while percent clay and silt were below previously-measured minimum values (Table 5.13-16). Concentrations of total arsenic, F1, F2, and F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene) exceeded sediment or soil quality guidelines in 2014. *Test* station SHL-1 was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

Poplar Creek and Beaver River The 2014 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -1.8%, +3.7% and -1.8%, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The 2014 WY mean open-water discharge was 22.7% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph and this difference was classified as **High**. Assessed changes to the hydrology of Poplar Creek, were classified as **High** from the mouth of the creek until the confluence with the Poplar Creek spillway (approximately 2 km upstream of JOSMP Station S11), and **Negligible-Low** upstream of the confluence. The results from the longitudinal assessment suggested that the extent of **High** hydrologic change was only limited to the lowest 4 km of Poplar Creek.

Concentrations of several water quality measurement endpoints, primarily ions, exceeded regional *baseline* concentrations at *test* stations BER-1 and POC-1, resulting in **Moderate** differences from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at *baseline* station BER-2, differences in water quality in fall 2014 between *baseline* station BER-2 and regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of most water quality measurement endpoints exhibited some variability throughout the year at *test* station POC-1, which was apparent in the ionic composition of water, which showed seasonal variability. Generally the highest concentrations of ions and metals occurred in September. Guideline exceedances occurred most frequently in January, June, August, and November; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

Differences in measurement endpoints of benthic invertebrate communities at *test* station POC-Dl were classified as **Negligible-Low** because although there were significant and large differences in equitability and the percentage of EPT taxa at the *test* reach (POC-D1) compared to the *baseline* reach (BER-D2), these changes were not indicative of degradation. In addition, the percentage of EPT taxa was higher in 2014 than 2013 and diversity has been steadily increasing over the last three years at *test* reach POC-D1. The benthic invertebrate community of the lower Poplar Creek (*test* reach POC-D1) was in generally good health and was comprised of what would be expected for a sandy-bottomed river dominated by worms and chironomids. The relative abundance of fingernail clams was higher in 2014 compared to 2013.

Differences in sediment quality observed in fall 2014 at *test* station POC-D1 and *baseline* station BER-D2 compared to regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of total hydrocarbons and PAHs at *test* station POC-D1 and *baseline* station BER-D2 were within historical ranges, with the exception of F2 hydrocarbon at *test* station POC-D1, which exceeded the previously-measured maximum, and total parent PAHs and the predicted PAH toxicity at *baseline* station BER-D2, which were below previously-measured minimum concentrations. No sediment quality measurement endpoints exceeded the CCME guidelines, with the exception of F2 and F3 hydrocarbons at *test* station POC-D1.

Differences in measurement endpoints of the fish assemblage at *test* reach POC-F1 were classified as **Negligible-Low** because the significant increases in richness, diversity, and CPUE and the significant decrease in ATI were not indicative of a negative change in the fish assemblage. In addition, all measurement endpoints for *test* reach POC-F1 were within the inner tolerance limits of the *baseline* range of variability.

McLean Creek Concentrations of water quality measurement endpoints at *test* station MCC-1 were generally within the range of previously-measured concentrations in fall 2014. The WQI value indicated **Moderate** differences between *test* station MCC-1 and regional *baseline* concentrations, mostly attributed to high levels of dissolved ions and total metals. Despite having no significant temporal trends, total dissolved solids and several ions have shown consistent annual increases since 2009.

Fort Creek The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 20.24% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**. This **High** magnitude of change was due to land disturbances throughout most of the watershed, upstream of JOSMP Station S12 (i.e., 84% of the watershed has been developed). Given the small size of the Fort Creek watershed, downstream of JOSMP Station S12, the magnitude of impacts would remain high along the entire length of Fort Creek; therefore, a longitudinal classification was not conducted for this watershed.

Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and regional *baseline* concentrations in fall 2014. Differences in water quality between *test* station FOC-1 and regional *baseline* conditions were classified as **Negligible-Low**. Many significant temporal trends in water quality measurement endpoints continued to be observed, including decreasing concentrations of dissolved phosphorus, total arsenic, and total nitrogen, and increasing concentrations of calcium, magnesium, potassium, total boron, total dissolved solids, total strontium, and sulphate. The ionic composition of water has showed a continued shift in anions over time, having a greater influence of sulphate in fall 2014 compared to earlier sampling years.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach FOC-DI were classified as **Moderate.** There were statistically significant and large variations in abundance, richness, and equitability, indicating potential degradation of habitat conditions. In addition, the percentage of EPT taxa was below the inner tolerance limits of the normal range of variability for this reach, but was still higher than values from *baseline* years (2001 to 2003). Lower richness and higher equitability during the *test* years were potentially suggestive of moderate degradation, but the presence of clams, snails, and particularly stoneflies suggested that habitat quality was not significantly degraded. The benthic invertebrate community of Fort Creek has typically had low diversity including during the *baseline* period, and the community in 2014 was consistent with previous years.

Sediment quality at *test* station FOC-D1 in fall 2014 showed **Negligible-Low** differences from regional *baseline* conditions. All sediment quality measurement endpoints were within the range of previously-measured concentrations, with concentrations of F3 hydrocarbon, dibenz(a,h)anthracene, and chrysene exceeding sediment quality guidelines in 2014.

Differences in measurement endpoints for the fish assemblage at *test* reach FOC-F1 were classified as **Moderate** because there were significant decreases in abundance, richness, and CPUE, implying a negative change to the fish assemblage.

Susan Lake Outlet Peak flow from Susan Lake in the 2014 open-water period occurred on May 30 (0.484 m^3/s) and was 28% lower than the open-water maximum daily mean flow (0.672 m^3/s). Flows decreased after this peak, and fluctuated until the end of the open-water period. Flows remained above historical median values on most dates, and often above historical maxima, especially during the month of June, but the historical record was limited.

5.13.2 Mills Creek and Isadore's Lake

Monitoring was conducted in 2014 in the Mills Creek watershed for the Climate and Hydrology and Water Quality components and at Isadore's Lake for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.2.1 Hydrologic Conditions: 2014 Water Year

Mills Creek

Hydrometric monitoring in the Mills Creek watershed was conducted at Mills Creek at Highway 63 (JOSMP Station S6), and data from this station were used for the water balance analysis.

Continuous hydrometric data during the open-water season (May to October) have been collected at JOSMP Station S6 from 1997 to 2014. More recently, annual data have been collected from 2006 to 2014.

The historical flow record for JOSMP Station S6 is summarized in Figure 5.13-3 and includes the median, interquartile, and range of flows recorded daily through the water year. At Mills Creek, flows in winter are typically much lower than during the open-water season, and generally decrease from November until March. Spring thaw, and the resulting rapid increase in flows, typically occurs in late March and April. Monthly flows during open-water conditions are generally highest during May, at the peak of freshet, but generally remain similar throughout other open-water months.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.13-3). Flows decreased from November to late February, and remained low until early May. Flows were typically below historical median values after mid-January, and below historical minima values from early April to mid-May. The minimum open-water daily flow of 0.005 m^3/s was recorded on several days in early May, and was 68% lower than the historical mean minimum daily flow of 0.016 m^3/s calculated for the open-water period. The increase in flow during spring thaw was very rapid, and the peak annual flow was recorded on May 30 (0.239 m^3/s). This was 101% higher than the historical mean annual maximum daily flow (0.119 m^3/s). Flows then fluctuated through the summer, but remained higher than historical median values until the end of the water year (Figure 5.13-3).

Overall, the annual runoff volume in the 2014 WY was 1.81 million m^3. This value was 121% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Mills Creek watershed, at JOSMP Station S6, is summarized in Table 5.13-2. Key changes in flows included:

1. The closed-circuited land change area as of 2014 was estimated to be 6.6 km^2 (Table 2.3-1). The loss of flow to the Mills River that would have otherwise occurred from this land area was estimated at 4.227 million m^3.
2. As of 2014, the area of land change in the Mills River watershed that was not closed-circuited was estimated to be 2.4 km^2 (Table 2.3-1). The increase in flow to Mills Creek that would not have otherwise occurred from this land area was estimated at 0.311 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was a decrease in water volume of 3.916 million m^3 in Mills Creek at JOSMP Station S6. The 2014 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all 68.4% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-3). These differences were classified as **High** (Table 5.13-1). These **High** magnitude of changes were due to land disturbance located immediately upstream of JOSMP Station S6. Given the limited size of the Mills Creek watershed downstream of JOSMP Station S6, the magnitude of impact would remain high along the length of Mills Creek; therefore, a longitudinal classification of Mills Creek was not conducted.

Isadore's Lake

Continuous lake level data for Isadore's Lake have been collected at Station L3 since February 2000. In the 2014 WY, the lake level slowly decreased by about 0.1 m from November to early April, and was within the historical interquartile range for this period (Figure 5.13-4). During spring thaw, the lake level initially rose by approximately 0.15 m, and then decreased sharply in mid-May. A second rise occurred in late May following rainfall accumulations, and lasted until the first week in June. The lake level then gradually increased until early September, until the peak annual lake level occurred on September 2 (234.023 masl). The lake level then gradually decreased until the end of October. All daily values from June to October were similar to historical maxima values recorded during these months.

5.13.2.2 Water Quality

In fall 2014, water quality samples were taken from:

- Isadore's Lake (*test* station ISL-1), sampled in 2000, 2001, and annually since 2004; and
- Mills Creek (*test* station MIC-1), sampled since 2010.

Water quality monitoring was initiated in Mills Creek in fall 2010 to assess the potential influence of water quality entering Isadore's Lake. Monitoring of Mills Creek was initiated to investigate changes that had been observed in the ionic characteristics of water in Isadore's Lake.

Temporal Trends Significant increasing trends (α=0.05) in fall concentrations of water quality measurement endpoints were detected, particularly for ions, at *test* station ISL-1, including chloride, sodium, sulphate, total boron, total dissolved solids, and total strontium. A significant decreasing trend in total arsenic was detected at *test* station ISL-1. Trend analysis was not performed for *test* station MIC-1 because only five years of data were available.

2014 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of historical concentrations in fall 2014 at *test* stations ISL-1 and MIC-1, with the exception of (Table 5.13-4 and Table 5.13-5):

- Total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station ISL-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- Conductivity, calcium, magnesium, chloride, sulphate, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station ISL;
- Total nitrogen, total alkalinity, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station MIC-1; and
- Sodium, dissolved organic carbon, magnesium, naphthenic acids, and oilsands extractable, with concentrations that exceeded previously-measured maximum concentrations at *test* station MIC-1.

Ion Balance In the first two years of sampling (2000 and 2001), the ionic composition of water at *test* station ISL-1 was dominated by calcium and bicarbonate. Since 2004, the anion composition has shifted to a greater proportion of sulphate, while calcium and magnesium continued to dominate the cation composition. The ionic composition in fall 2014 was similar to fall 2013, but prior to this was more dominated by bicarbonate. Between 2012 and 2013, the ionic composition of anions changed to being more dominated by sulphate and, to a lesser extent, by chloride than observed in previous years (Figure 5.13-5). The ionic composition of water at *test* station MIC-1 was consistent with that of *test* station ISL-1, but with a slightly lower relative concentration of magnesium. The consistent ionic composition between Mills Creek and Isadore's Lake supported the hypothesis that flows from Mills Creek have been responsible for influencing the ion composition of Isadore's Lake in recent years (Figure 5.13-5).

Comparison of Water Quality Measurement Endpoints to Published Guidelines No water quality measurement endpoints exceeded guidelines at *test* station ISL-1 in fall 2014 (Table 5.13-6). The concentration of sulphate exceeded the BC hardness-adjusted guideline at *test* station MIC-1 in fall 2014 (Table 5.13-5).

Other Water Quality Guideline Exceedances No other water quality measurement endpoints exceeded guidelines in fall 2014, except sulphide at *test* station ISL-1 (Table 5.13-6).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of water quality measurement endpoints at *test* station MIC-1 were within the range of regional *baseline* concentrations (Figure 5.13-6), with the exception of:

- total dissolved solids, total strontium, calcium, magnesium, potassium, chloride and sulphate, with concentrations that exceeded the 95^{th} percentile of regional *baseline* concentrations; and
- dissolved phosphorus, total nitrogen, and total mercury (ultra-trace), with concentrations below the 5^{th} percentile of regional *baseline* concentrations.

Concentrations of water quality measurement endpoints in Isadore's Lake were not compared to regional *baseline* concentrations because lakes were not included in the calculation of regional *baseline* conditions; however, water quality in the lake was generally similar to *test* station MIC-1, and most exceedances of regional *baseline* concentrations would similarly apply to Isadore's Lake (Figure 5.13-7).

Water Quality Index The WQI value for Mills Creek in fall 2014 was 79.7, indicating a **Moderate** difference in water quality compared to regional *baseline* conditions (Table 5.13-7). The low WQI was related to the concentration of a number of ions and dissolved measurement endpoints that exceeded the 95^{th} percentile of regional *baseline* concentrations at *test* station MIC-1. Because lakes were not compared to regional *baseline* concentrations, there was no WQI for *test* station ISL-1; however, due to similar water quality between Isadore's Lake and Mills Creek, it would be expected that similar exceedances of regional *baseline* concentrations would likely be observed.

Classification of Results Differences in water quality in fall 2014 between Mills Creek and regional *baseline* fall conditions were classified as **Moderate**, due to relatively high concentrations of many ions that exceeded the 95^{th} percentile of regional *baseline* concentrations. The ionic composition of water at *test* stations ISL-1 and MIC-1 showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

5.13.2.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 in Isadore's lake (*test* station ISL-1, depositional, sampled since 2006).

2014 Habitat Conditions Water in Isadore's Lake in fall 2014 was slightly alkaline (pH=7.26), with high conductivity (765 µS/cm). The substrate was dominated by silt (51%) with relatively high total organic carbon content (7.6%) (Table 5.13-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Isadore's Lake in fall 2014 was dominated by chironomids (53%) and nematodes (37%) (Table 5.13-9). Chironomids were principally of the genera *Einfeldia, Tanytarsus, Paratanytarsus*, and *Dicrotendipes* all of which are commonly distributed in north-temperate lakes (Wiederholm 1983). Larvae of flying insects were sparse but were represented by Ephemeroptera (*Caenis*) in most replicate samples, and by the dragonfly *Leucorrhinia intacta*. Gastropods were primarily *Gyraulus* and a few *Valvata sincera* (two replicate samples).

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Isadore's Lake. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

The temporal comparisons of measurement endpoints included testing for:

- a trend over time; and
- a difference between 2014 and all previous years.

Richness was higher in 2014 than the mean of all previous years of sampling (2009 to 2013), which accounted for 33% of the variance in annual means (Table 5.13-10).

Equitability was lower in 2014 than the mean of previous years, which accounted for 42% of the variance in annual means (Table 5.13-10).

The percentage of EPT taxa increased over time and was higher in 2014 than the mean of all previous years, with the effect accounting for 49% and 30% of the variance in annual means, respectively (Table 5.13-10).

CA Axis 1 scores decreased over time and were lower in 2014 than the mean of all previous years of sampling. These effects accounted for 21% and 37% of the variance in annual means, respectively (Table 5.13-10). The decrease in CA Axis 1 scores reflected an increase in the relative abundance of gastropods over time (Figure 5.13-8).

CA Axis 2 scores were higher in 2014 than the mean of previous years, accounting for 45% of the variance in annual means (Table 5.13-10). The increase in CA Axis 2 scores was likely due to the increase in the relative abundance of naidid worms over time in the lake (Figure 5.13-8).

Comparison to Published Literature The benthic invertebrate community of Isadore's Lake was slightly different compared to 2013. The abundance of tolerant nematodes decreased while the abundance of Naididae worms was higher, possibly indicating a change in water quality (Pennak 1989). Gastropods were less diverse but chironomids were still abundant in 2014. Larvae of flying insects were found at Isadore's Lake including *Caenis* mayflies and dragonflies suggesting that conditions were at least moderately favourable.

2014 Results Relative to Historical Conditions Richness, equitability, and the percentage of EPT taxa exceeded the inner tolerance limit of the normal range from all previous years of sampling at Isadore's Lake (Figure 5.13-9). Richness and percentage of EPT taxa were higher than the inner tolerance limits, while equitability was lower. None of these results were indicative of degraded conditions at *test* station ISL-1.

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because although there were significant time trends in %EPT and CA Axis 1, both were indicative of improving habitat quality. The percentage of EPT taxa has been higher than usual since 2013. Several of the measurement endpoints exceeded the tolerance limits of the normal range of variation; however, none of the exceedances were considered an indication of degrading conditions. Isadore's Lake, historically, has had low diversity and high abundances of nematodes making it unique in comparison to the other lakes in the program. In 2014, the relative abundance of nematodes was lower but the abundance of naidid worms was higher than previously observed in Isadore's Lake. The percentage of EPT taxa and richness have increased in recent years, suggesting that water and sediment quality of Isadore's Lake was potentially improving over time.

Sediment Quality

Sediment quality in fall 2014 was sampled in Isadore's Lake (*test* station ISL-1, sampled in 2001 and continuously from 2006 to 2014) at the same location as benthic invertebrate sampling.

Temporal Trends A significant (α=0.05) decreasing trend in the concentration of total metals and an increasing trend in the concentration of F3 hydrocarbons were observed at *test* station ISL-1.

2014 Results Relative to Historical Concentrations Sediment composition at *test* station ISL-1 sampled in 2014 was primarily comprised of silt (55%) (Table 5.13-11, Figure 5.13-10). The organic carbon content was within previously-measured concentrations in 2014. Concentrations of all hydrocarbon fractions were within previously-measured ranges, with the exception of F2 hydrocarbons, which exceeded the previously-measured maximum. Concentrations of PAHs were generally within previously-measured concentrations, with the exception of naphthalene (below previously-measured minimum concentrations) and retene (above previously-measured maximum concentrations). The concentration of total arsenic also exceeded the previously-measured maximum concentration (Table 5.13-11, Figure 5.13-10).

Survival and growth of *Chironomus* and *Hyalella* at *test* station ISL-1 were within previously-measured ranges, with the exception of the growth of *Hyalella*, which slightly exceeded the previously-measured maximum value (Table 5.13-11).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints at *test* station ISL-1 that exceeded the sediment or soil quality guidelines in fall 2014 included F1, F2, and F3 hydrocarbons, and total arsenic (Table 5.13-11).

2014 Results Relative Regional *Baseline* Concentrations No comparisons were made in fall 2014 between *test* station ISL-1 and regional *baseline* concentrations given that lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers (Figure 5.13-10).

Sediment Quality Index A *baseline*-referenced SQI was not calculated for *test* station ISL-1 because lakes were not included in the regional *baseline* conditions given potential ecological differences between lakes and rivers and the lack of *baseline* data for lakes in the region.

Classification of Results Sediment quality measurement endpoints at *test* station ISL-1 were generally within the range of previously-measured concentrations, with the exception of F2 hydrocarbons, retene, and total arsenic that exceeded previously-measured maximum concentrations and naphthalene, which was below the previously-measured minimum concentration. Concentrations of total arsenic, and CCME F1, F2, and F3 hydrocarbons exceeded sediment quality guidelines in fall 2014, with the concentration of F3 hydrocarbons significantly higher than the guideline value. An SQI was not calculated for *test* station ISL-1 because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

5.13.3 Shipyard Lake

Monitoring was conducted in Shipyard Lake in fall 2014 for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.3.1 Water Quality

Water quality samples were taken from Shipyard Lake in fall 2014 at *test* station SHL-1 (sampled annually from 1998 to 2014).

Temporal Trends Increasing significant trends ($\alpha=0.05$) in fall concentrations of water quality measurement endpoints at *test* station SHL-1 included chloride, potassium, sodium, and total boron.

2014 Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints at *test* station SHL-1 in fall 2014 were within previously-measured concentrations (Table 5.13-12 and Figure 5.13-7), with the exception of:

- calcium, total alkalinity, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only); and

- total arsenic, pH, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations.

Ion Balance The ionic composition of water at *test* station SHL-1 in fall 2014 continued a recent trend towards increasing relative concentrations of sodium, potassium, and chloride (Figure 5.13-5). The shift in the ionic composition of water in Shipyard Lake from calcium-bicarbonate to sodium-chloride may be a result of reduced surface-water inflow and increases in groundwater influence in the lake's catchment area (previously discussed further in RAMP 2010; 2011).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentration of all measurement endpoints at *test* station SHL-1 in fall 2014 were below published guidelines (Table 5.13-12).

Other Water Quality Guideline Exceedances The concentration of sulphide exceeded the water quality guideline in fall 2014 at *test* station SHL-1 (Table 5.13-6).

Classification of Results Concentrations of most water quality measurement endpoints in fall 2014 at *test* station SHL-1 were within previously-measured concentrations. The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with oil sands development in the upper portion of the watershed (91% of the Shipyard Lake watershed has been disturbed; see Table 2.3-1). The WQI was not calculated for lakes in 2014 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the lack of *baseline* data for lakes in the region.

5.13.3.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 in Shipyard Lake (*test* station SHL-1, sampled since 2000).

2014 Habitat Conditions Water in Shipyard Lake had a pH of 9.3 and moderate conductivity (362 µS/cm) (Table 5.13-13).The substrate of Shipyard Lake in fall 2014 was primarily composed of sand (50%), with moderate amounts of silt (29%) and clay (21%) and relatively high organic carbon content (~15%) (Table 5.13-13).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Shipyard Lake at *test* station SHL-1 in fall 2014 was dominated by Chironomidae (36%), Naididae (23%), and Amphipoda (18%) (Table 5.13-14). Several groups of flying insects (larvae) were present at *test* station SHL-1 including Ephemeroptera (*Caenis*), dragonflies from the family Libellulidae, *Enallagma* damselflies, and caddisflies (*Agraylea* and *Triaenodes*). Bivalves (*Pisidium/Sphaerium*) and gastropods, primarily from the family Valvatidae, were present in low relative abundances. Other permanent aquatic forms (Amphipoda: *Hyalella azteca*) were also present. Dominant chironomids included *Einfeldia*, *Cladotanytarsus, Procladius*, and *Tanytarsus* all of which are commonly distributed in north temperate regions (Wiederholm 1983).

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Shipyard Lake. A result was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

The temporal comparisons of measurement endpoints included testing for:

- a trend over time; and
- a difference between 2014 and all previous years.

Richness increased over time accounting for 21% of the variance in annual means (Table 5.13-15). Equitability decreased over time and was lower in 2014 than the mean of all previous years of sampling. These changes accounted for 30% and 37% of the variance in annual means, respectively (Table 5.13-15).

Comparison to Published Literature The benthic invertebrate community of Shipyard Lake contained fauna in 2014 that would be expected for a lake benthic community in the oil sands region (Parsons et al. 2010). The community contained several permanent aquatic forms such as fingernail clams (*Pisidium/Sphaerium*), snails (Gastropoda), and amphipods (*Hyalella azteca*). Larvae of larger flying insects (Ephemeroptera, Odonata, and Trichoptera) were present in Shipyard Lake in 2014 though in low relative abundances.

2014 Results Relative to Historical Conditions Equitability was below the inner tolerance limit for the normal range of variation for previous years of sampling at Shipyard Lake (Figure 5.13-11, Figure 5.13-12). Equitability in 2014 was much lower than any previous year; however, this decrease was not considered a negative change (i.e., lower equitability indicates greater diversity).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities for Shipyard Lake in 2014 were classified as **Negligible-Low**. The increasing trend in taxa richness and lower equitability in 2014 were indicative of improving habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams and snails, indicating generally good water and sediment quality.

Sediment Quality

Sediment quality of Shipyard Lake was sampled at *test* station SHL-1, which has been sampled from 2001 to 2004 and 2006 to 2014, in the same location where sampling for benthic invertebrate communities was conducted.

Temporal Trends Significant increasing trends (α=0.05) in concentrations of sediment quality measurement endpoints from 2001 to 2014 were detected at *test* station SHL-1 for total PAHs, total alkylated PAHs, and F2, F3, and F4 hydrocarbons.

2014 Results Relative to Historical Concentrations Sediments at *test* station SHL-1 in fall 2014 was dominated by sand (74%), with the percentage of sand exceeding the previously-measured maximum value and the percentages of silt and clay below the previous minima values (Table 5.13-16). Concentrations of total organic carbon, BTEX, and all hydrocarbon fractions at *test* station SHL-1 in 2014 exceeded previously-measured maximum concentrations, while PAHs concentrations were within previously-measured ranges. Toxicity tests showed relatively low survival of both the amphipod *Hyalella* (64%) and the midge *Chironomus* (60%) relative to other stations, although these values were within previously-measured ranges for this lake (Table 5.13-16).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints that exceeded sediment or soil quality guidelines at *test* station SHL-1 in fall 2014 included total arsenic; F1, F2, and F3 hydrocarbons; and some PAHs including benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene (Table 5.13-16).

2014 Results Relative Regional *Baseline* Concentrations No comparison was made in fall 2014 between Shipyard Lake and regional *baseline* concentrations, given that lakes are not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers (Figure 5.13-13).

Sediment Quality Index An SQI value was not calculated for *test* station SHL-1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers. In addition, there were limited lake *baseline* data for the oil sands region.

Classification of Results In fall 2014, some sediment quality measurement endpoints exceeded previously-measured maximum concentrations at *test* station SHL-1, including percent sand, total organic carbon, and all hydrocarbons (BTEX and all F1-F4 fractions), while percent clay and silt were below predicted-measured minimum values (Table 5.13-16). Concentrations of total arsenic, F1, F2, and F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene) exceeded sediment or soil quality guidelines in 2014. *Test* station SHL-1 was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

5.13.4 Poplar Creek and Beaver River

Monitoring was conducted in the Poplar Creek and Beaver River watersheds in 2014 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.4.1 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Poplar Creek watershed in the 2014 WY was conducted at the following locations:

- Poplar Creek at Highway 63 (JOSMP Station S11; WSC Station 07DA007); and
- Beaver River above Syncrude, WSC Station 07DA018 (formerly JOSMP Station S39).

Data from JOSMP Station S11 were used for the water balance analysis and are presented below; the data from each JOSMP station can be found in Appendix C.

At JOSMP Station S11 (WSC Station 07DA007), open-water data were available from 1973 to 1986 and from 1996 to 2014. Winter data were also collected from 1973 to 1986 and from 2013 to 2014; therefore, the data record in these years was annual.

The historical flow record for JOSMP Station S11 is summarized in Figure 5.13-14 and includes the median, interquartile, and range of flows recorded daily through the water year. Poplar Creek has typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are much lower than during the open-water season. Discharge generally decreases from November until March, and flow often ceases completely in late winter. Spring thaw, and the resulting rapid increase in flows typically occurs in late March and April. Monthly flows are highest during May, at the peak of freshet, and often remain elevated in June and July when total monthly rainfall accumulations are highest (Figure 5.13-14). Flows then generally recede from late July until the end of October, in response to declining rainfall inputs and eventually to river freeze-up.

In the 2014 WY, flows remained similar to the historical seasonal pattern described above (Figure 5.13-14). Flows decreased from November until mid-April, and then rapidly increased during the spring thaw. The peak annual flow of 36.4 m^3/s was reached on May 31, which was 240% higher than the mean annual maximum daily flow for the water year (10.7 m^3/s). Flows from May 28 to June 7 were above historical maxima recorded on these dates. Flows then decreased rapidly, until the minimum open-water flow of 0.001 m^3/s occurred over several days in late August, and was similar to historical minima during this period. This flow was much lower than the mean annual minimum daily flow (0.064 m^3/s). Flows then rose and fluctuated in September and October.

Overall, the annual runoff volume in the 2014 WY was 42.2 million m^3. This value was 25% higher than the mean historical annual runoff volume based on the available period of record. Flow data were missing from May 14 to May 16, and July 13 to July 17 when the pressure transducer was out of water due to low water levels.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Poplar Creek at Highway 63 (JOSMP Station S11) is summarized in Table 5.13-17. Key changes in flows included:

1. The closed-circuited land change area as of 2014 was estimated to be 3.1 km^2 (Table 2.3-1). The loss of flow to Poplar Creek that would have otherwise occurred from this land area was estimated at 0.895 million m^3.

2. As of 2014, the area of land change in the Poplar Creek watershed that was not closed-circuited was estimated to be 1.9 km^2 (Table 2.3-1). The increase in flow to Poplar Creek that would not have otherwise occurred from this land area was estimated at 0.110 million m^3.

3. In the 2014 WY, Syncrude reported a total discharge of 8.4 million m^3 of water to Poplar Creek via the Poplar Creek spillway. The final value applied within the water balance analysis (7.9 million m^3) was slightly reduced to account for the missing days of observed data, when the water balance could not be run.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was an increase in flow of 7.3 million m^3 at JOSMP Station S11 (WSC 07DA007). The observed *test* and estimated *baseline* hydrographs for Station S11 (WSC 07DA007), Poplar Creek at Highway 63, are presented in Figure 5.13-14. The 2014 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were -1.8%, +3.7% and -1.8%, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Figure 5.13-3). These differences were classified as **Negligible-Low** (Table 5.13-1).The 2014 WY mean open-water discharge was 22.7% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-3), and this difference was classified as **High** (Table 5.13-1).

The **High** classification of results required an additional longitudinal classification of changes that was completed for the length of Poplar Creek, using the methods outlined in Section 3.2.1.5. The results of this analysis are presented in Figure 5.13-15, which shows a map of classified hydrologic changes along the length of Poplar Creek. Assessed changes to the hydrology of Poplar Creek, were classified as **High** from the mouth of the creek until the confluence with the Poplar Creek spillway (approximately 2 km upstream of JOSMP Station S11), and **Negligible-Low** upstream of the confluence. The results from this longitudinal assessment suggested that the extent of **High** hydrologic change was only limited to the lowest 4 km of Poplar Creek.

5.13.4.2 Water Quality

In fall 2014, water quality samples were taken from:

- the Beaver River near its mouth (*test* station BER-1), sampled from 2003 to 2014;
- Poplar Creek near its mouth (*test* station POC-1), sampled from 2000 to 2014; and
- the upper Beaver River upstream of oil sands developments (*baseline* station BER-2), sampled from 2008 to 2014.

Monthly water quality sampling also was conducted at *test* station POC-1 in 2014 during all months except April. Water was frozen to depth in April 2014, so a sample could not be collected.

The upper Beaver River flows via the Poplar Creek Reservoir to Poplar Creek (i.e., it is hydrologically connected to *test* station POC-1) rather than to the lower Beaver River, where *test* station BER-1 is located. The lower Beaver River was isolated from the upper Beaver River watershed in the early 1970s through the development of Syncrude's Mildred Lake project. The lower Beaver River is downstream of a seepage-collection pond located downstream of the dam of the Mildred Lake tailings facility (seepage collected in this pond is pumped back into the tailings facility).

Temporal Trends There were no statistically significant (α=0.05) trends in fall concentrations of water quality measurement endpoints at *test* stations BER-1 and POC-1. Water quality at both stations has been highly variable over time. A significant increasing trend in potassium over time was observed at *baseline* station BER-2.

2014 Results Relative to Historical Concentrations Several water quality measurement endpoints were outside the range of previously-measured concentrations in fall 2014 at *test* stations BER-1, POC-1, and *baseline* station BER-2, including (Table 5.13-19 to Table 5.13-21):

- calcium, pH, and total alkalinity, with concentrations that exceeded previously-measured maximum concentrations at *test* station BER-1;

- total nitrogen, dissolved aluminum, retene, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *test* station BER-1 (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only);
- conductivity, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, total arsenic, total boron, total molybdenum, total strontium, CCME hydrocarbon fraction 3 (C16-C34), naphthenic acids, and oilsands extractable acids, with concentrations that exceeded previously-measured maximum concentrations at *test* station POC-1;
- dissolved phosphorus, pH, and total parent PAHs, with concentrations below previously-measured minimum concentrations at *test* station POC-1;
- conductivity, sodium, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, total molybdenum, and oilsands extractable acids, with concentrations the exceeded previously-measured maximum concentrations at *baseline* station BER-2; and
- total suspended solids, total nitrogen, dissolved aluminum, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations below previously-measured minimum concentrations at *baseline* station BER-2.

Ion Balance The ionic composition of water at *test* stations POC-1 and BER-1 have been highly variable across sampling years. *Test* station POC-1 showed a higher ionic influence of chloride and sodium in fall 2014 than all other sampling years, except 2001. Maximum concentrations of these ions were reached in 2001; however, 2014 results were comparably high and driving the ionic composition similarity between the two years. *Baseline* station BER-2 had less variability then *test* stations POC-1 and BER-1, particularly with anion contributions, as it has consistently been heavily dominated by bicarbonate ions (Figure 5.13-16).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of the following water quality measurement endpoints exceeded water quality guidelines in fall 2014 (Table 5.13-19 to Table 5.13-21):

- Chloride and total aluminum at *test* station BER-1;
- Chloride and total aluminum at *test* station POC-1; and
- Total aluminum at *baseline* station BER-2.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in fall 2014 (Table 5.13-6):

- Total iron and total phenols at *test* station BER-1;
- Total iron, and sulphide at *test* station POC-1; and
- Total and dissolved iron, and sulphide at *baseline* station BER-2.

2014 Results Relative to Regional *Baseline* Concentrations Concentrations of several water quality measurement endpoints in fall 2014 at *test* stations BER-1 and POC-1 and *baseline* station BER-2 exceeded regional *baseline* concentrations (Figure 5.13-17), including:

- Total dissolved solids, total strontium, calcium, magnesium, and chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations POC-1 and BER-1;
- Sulphate, with a concentration that exceeded the 95th percentile or regional *baseline* concentrations at *test* station BER-1;
- Total arsenic, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station POC-1;
- Sodium, with concentrations that exceeded the 95th percentile of regional *baseline* data at *test* station BER-1 and POC-1, and *baseline* station BER-2;
- Dissolved phosphorus, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* stations BER-1 and POC-1; and
- Total boron, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station POC-1 and *baseline* station BER-2.

Water Quality Index The WQI value for fall 2014 at *baseline* station BER-2 (95.8) indicated **Negligible-Low** differences from regional *baseline* concentrations (Table 5.13-7). The WQI value for *test* stations POC-1 (74.6) and BER-1 (77.0) indicated **Moderate** differences from regional *baseline* concentrations. Differences from regional *baseline* concentrations for these two stations were attributed to high concentrations of ions.

Monthly Water Quality Results Water quality sampling was also conducted monthly in 2013 and 2014 at *test* station POC-1. Generally the highest ion concentrations were observed in September and the highest concentrations of PAHs were found in June (Table 5.13-22).

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances that were measured in 2014 at *test* station POC-1 included (Table 5.13-23):

- total chromium and total mercury (ultra-trace) in June;
- total and dissolved zinc in November;
- total aluminum from May to December;
- chloride in January, August, September, and December;
- total selenium in January and August;
- sulphide and total iron for all months (except April, which was not sampled);
- dissolved iron in January, May, August and from October to December; and
- total phenols from January to July, excluding April (which was not sampled).

2014 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2014, monthly data for key measurement endpoints at *test* station POC-1 were within regional *baseline* fall concentrations with the following exceptions (Figure 5.13-18):

- Total suspended solids, which exceeded the 95th percentile of regional *baseline* fall concentrations in June (annual maximum);
- Total dissolved solids, total strontium, which exceeded the 95th percentile of regional *baseline* fall concentrations in January, August, September, and December;
- Total arsenic and calcium, which exceeded the 95th percentile of regional fall *baseline* concentrations in September;
- Sodium, which exceeded the 95th percentile of regional *baseline* fall concentrations in January, August, September, November, and December;
- Dissolved phosphorus, with a concentration below the 5th percentile of regional *baseline* fall concentrations in January and September (annual minimum);
- Total alkalinity and hardness, which exceeded the 95th percentile of regional *baseline* fall concentrations in January and September (annual maximum);
- Total boron and magnesium, which exceeded the 95th percentile of regional *baseline* fall concentrations in January, August, and September (annual maximum);
- Total mercury (ultra-trace), which exceeded the 95th percentile of regional *baseline* fall concentrations in June; and
- Chloride, which exceeded the 95th percentile of regional *baseline* concentrations in January (annual maximum), and from August to December.

Monthly Ion Balance The ionic composition of water at *test* station POC-1 showed a high level of variability across months in 2014, and to a greater extent than observed in 2013 (Figure 5.13-19). Variability was most notable in the anion composition, where chloride became more dominant in January, August, September, and December 2014. These months had the highest overall concentration of ions, but the concentrations of chloride and sodium increased to a greater extent than the other ions measured, causing the shift in ionic composition.

Classification of Fall Results Concentrations of several water quality measurement endpoints, primarily ions, exceeded regional *baseline* concentrations at *test* stations BER-1 and POC-1, resulting in **Moderate** differences from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at *baseline* station BER-2, differences in water quality in fall 2014 between *baseline* station BER-2 and regional *baseline* conditions were classified as **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited some variability throughout the year at *test* station POC-1, which was apparent in the ionic composition of water, which showed seasonal variability. Generally the highest concentrations of ions and metals occurred in September. Guideline exceedances occurred most frequently in January, June, August, and November; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

5.13.4.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at:

- depositional *test* reach POC-D1 of Poplar Creek, sampled since 2008; and
- depositional *baseline* reach BER-D2 of the Beaver River, sampled since 2008. This reach was used as *baseline* for comparison to *test* reach POC-D1.

2014 Habitat Conditions Water at *test* reach POC-D1 in fall 2014 was moderately deep (0.5 m), had a pH of 7.0, and very high conductivity (1,444 µS/cm). The substrate was primarily comprised of sand (66%), with some silt (20%) and clay (14%), with moderate organic carbon content (3.1%) (Table 5.13-24).

Water at *baseline* reach BER-D2 in fall 2014 was moderately deep (0.4 m), weakly alkaline (pH=7.7), with high conductivity (499 µS/cm). The substrate was primarily composed of silt (90%) with equal parts of sand and clay (5% each) (Table 5.13-24). The total organic content in sediments was low (1.0%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach POC-D1 was dominated by chironomids (44%) and tubificid worms (24%) with subdominant taxa consisting of Ceratopogonidae (11%) and Bivalvia (5%) (Table 5.13-25). Dominant chironomid genera consisted primarily of *Tanytarsus*, *Procladius*, *Polypedilum*, and *Cryptochironomus*, all of which are common in north-temperate waters (Wiederholm 1983). Ephemeroptera were represented by the genera *Caenis*, *Callibaetis*, *Hexagenia limbata*, *Siphloplectron*, and *Tricorythodes*. Other larvae of flying insects present included a single Hydropsyche caddisfly and several *Oecetis* caddisflies. Bivalves (*Pisidium*/*Sphaerium*) were abundant and gastropods (*Physa* and Planorbidae) were sparsely present.

The benthic invertebrate community at *baseline* reach BER-D2 was dominated by chironomids (52%) with subdominant taxa consisting of tubificid worms (13%) and Ephemeroptera (12%) (Table 5.13-25). Dominant chironomid genera consisted of *Rheotanytarsus*, *Paralauterborniella*, and *Tanytarsus*, all of which are common in north-temperate waters (Wiederholm 1983). Flying insect larvae were present in low relative abundances and were represented by Ephemeroptera (*Caenis* and *Hexagenia limbata*, and Leptophlebiidae), Plecoptera (*Taeniopteryx*), and Trichoptera (*Cheumatopsyche* and *Hydropsyche*). Permanent aquatic forms were also present at *baseline* reach BER-D2 in 2014 and included fingernail clams (Pisidium) and gastropods (Gyraulus).

Temporal and Spatial Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Poplar Creek. For the purpose of this report, a comparison was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the total variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach POC-D1 included testing for:

- changes over time during the *test* period (i.e., since 2008, Hypothesis 1, Section 3.2.3.1); and
- changes in 2014 values and the mean of all previous years of sampling (2008 to 2013).

Spatial comparisons of measurement endpoints for *test* reach POC-D1 included testing for:

- differences from *baseline* reach BER-D2 over time (Hypothesis 2, Section 3.2.3.1);
- differences between 2014 values and the mean of all available *baseline* data; and
- differences from *baseline* reach BER-D2 in 2014 values.

Abundance has been higher at *test* reach POC-D1 than *baseline* reach BER-D2 (Table 5.13-26). Equitability and the percentage of the fauna as EPT taxa have been lower at *test* reach POC-D1 than *baseline* reach BER-D2 (Table 5.13-26). The percentage of the EPT taxa was also lower in 2014 at the *test* reach (Poplar Creek) than the mean of all previous years for the *baseline* reach (Beaver Creek) and lower than the mean of previous years for the *test* reach. Equitability was higher for the *test* reach in 2014 than the mean of previous years. The variations in all of these comparisons explained a large amount of the variation (>20%) in annual reach means (Table 5.13-26).

There were significant decreasing and increasing trends over time in equitability and the percentage of EPT taxa, respectively, accounting for greater than 20% of the variance in annual means (Table 5.13-26).

The CA Axis 1 and 2 scores were higher at the *test* reach than the *baseline* reach, accounting for greater than 20% of the variance in annual means (Table 5.13-26), which was likely due to a greater proportion of gastropods and clams observed at the *test* reach compared to previous years (Figure 5.13-20).

Comparison to Published Literature The benthic invertebrate community at *test* reach POC-D1 in fall 2014 was what would be expected for a sandy-bottom stream. The percentage of the fauna as worms was high (~25%) and but so were chironomids (44%); which are typical of a sandy-bottomed river (Hynes 1960; Griffiths 1998). The benthic invertebrate community at Poplar Creek also included permanent aquatic forms such as fingernail clams and flying insects (mayflies and caddisflies) in equal or relative higher abundances to what has been found in previous years.

2014 Results Relative to Regional *Baseline* Conditions Values of measurement endpoints for benthic invertebrate communities at *test* reach POC-Dl and *baseline* reach BER-D2 were within the inner tolerance limits of the normal range of variation regional baseline *depositional* reaches, with the exception of equitability and the percentage of EPT taxa at *test* reach POC-D1 and EPT taxa at *baseline* reach BER-D2 (Figure 5.13-21). Equitability at *test* reach POC-D1 was lower than the inner tolerance limits in 2014 and the percentage of EPT taxa at both reaches was higher than the inner tolerance limits (Figure 5.13-21). None of these results were considered indicative of a negative change.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* station POC-Dl were classified as **Negligible-Low** because although there were significant and large differences in equitability and the percentage of EPT taxa at the *test* reach (POC-D1) compared to the *baseline* reach (BER-D2), these changes were not indicative of degradation. In addition, the percentage of EPT taxa was higher in 2014 than 2013 and diversity has been steadily increasing over the last three years at *test* reach POC-D1. The benthic invertebrate community of the lower Poplar Creek (*test* reach POC-D1) was in generally good health and was comprised of what would be expected for a sandy-bottomed river dominated by worms and chironomids. The relative abundance of fingernail clams was higher in 2014 compared to 2013.

Sediment Quality

Sediment quality was sampled in fall 2014, in the same locations as benthic invertebrate communities, at:

- *test* station POC-D1 (sampled in 1997, 2002, 2004, and 2008 to 2014); and
- *baseline* station BER-D2 (sampled from 2008 to 2014).

Temporal Trends No significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected for *test* station POC-D1 in fall 2014. A significant (α=0.05) decreasing trend in the PAH hazard index was observed at *baseline* station BER-D2.

2014 Results Relative to Historical Concentrations Sediment collected from *test* station POC-D1 was mostly comprised of sand (53.4%) and silt (30.8%). The organic carbon content in 2014 was lower than 2013, but still within the previously-measured concentrations (Table 5.13-27). Similar to 2013, sediments at *baseline* station BER-D2 in 2014 were dominated by sand (96.1%) (Table 5.13-28). Concentrations of all total hydrocarbon fractions were within previously-measured concentrations at *baseline* station BER-D2 and *test* station POC-D1, except F2 hydrocarbons at POC-D1, which exceeded the previously-measured maximum concentration (Table 5.13-27 and Table 5.13-28). Concentrations of most PAHs at *test* station POC-D1 were within the range of previously-measured concentrations, while total parent PAHs and predicted PAH toxicity at *baseline* station BER-D2 were below previously-measured minima in fall 2014.

Direct tests of sediment toxicity at *test* station POC-D1 and *baseline* station BER-D2 in 2014 showed survival and growth rates of *Hyalella* and *Chironomus* within the range of previously-measured values, except *Chironomus* growth at *test* station POC-D1, which was lower than the previously-measured minimum value (Table 5.13-27 and Table 5.13-28).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints at *test* station POC-D1 and *baseline* station BER-D2 in fall 2014 were below sediment quality guidelines, with the exception of F2 and F3 hydrocarbons at *test* station POC-D1 (Table 5.13-27 and Table 5.13-28).

2014 Results Relative Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints were within regional *baseline* concentrations except total metals normalized to percent fines, which exceeded the 95th percentile of regional *baseline* concentrations, and total PAHs and PAH Hazard Index, which were below the 5th percentile of the regional *baseline* concentrations at *baseline* station BER-D2 (Figure 5.13-22 and Figure 5.13-23).

Sediment Quality Index The SQI values for *test* station POC-D1 and b*aseline* station BER-D2 were 84.8 and 100 respectively (Table 5.13-7), indicating **Negligible-Low** differences in sediment quality conditions compared to regional *baseline* conditions.

Classification of Results Differences in sediment quality observed in fall 2014 at *test* station POC-D1 and *baseline* station BER-D2 compared to regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of total hydrocarbons and PAHs at *test* station POC-D1 and *baseline* station BER-D2 were within historical ranges, with the exception of F2 hydrocarbons at *test* station POC-D1, which exceeded the previously-measured maximum, and total parent PAHs and the predicted PAH toxicity at *baseline* station BER-D2 which were below previously-measured minimum concentrations. No sediment quality measurement endpoint exceeded the CCME guideline, with the exception of F2 and F3 hydrocarbons at *test* station POC-D1.

5.13.4.4 Fish Populations

Fish assemblages were sampled in fall 2014 at:

- *test* reach POC-F1, sampled in 2009 and from 2011 to 2014 (this reach is in the same location as the benthic invertebrate community *test* reach POC-D1); and
- *baseline* reach BER-F2, sampled in 2009 and from 2011 to 2014 (this reach is in the same location as the benthic invertebrate community *baseline* reach BER-D2).

2014 Habitat Conditions *Test* reach POC-F1 was comprised of riffle and run habitat with a wetted width of 6.9 m and a bankfull width of 15.0 m. The substrate was comprised of cobble with small proportions of fine material. Water at *test* reach POC-F1 had a mean depth of 0.32 m, slow velocity (mean=0.12 m/s), a pH of 8.23, high conductivity (460 µS/cm), high dissolved oxygen (9.3 mg/L), and a temperature of 9.3˚C. Instream cover consisted of boulders with some overhanging vegetation (Table 5.13-30).

Baseline reach BER-F2 was comprised of run habitat with a wetted width of 7.0 m and a bankfull width of 8.3 m. The substrate consisted almost entirely of sand and fines material. Water at *baseline* reach BER-F2 had a mean depth of 0.93 m, slow velocity (mean=0.19 m/s), a pH of 7.58, moderate conductivity (477 µS/cm), high dissolved oxygen (9.8 mg/L), and a temperature of 16.5˚C. Instream cover consisted of small woody debris with small amounts of macrophytes and overhanging vegetation (Table 5.13-30).

Relative Abundance of Fish Species The total catch of fish species at *test* reach POC-F1 was higher in 2014 compared to previous years of sampling (2009 to 2013), and was dominated by lake chub (41%) and longnose sucker (26%) (Table 5.13-31). The increase in total catch in 2013 and 2014 was primarily due to the shift in reach location to an area of the river that had suitable fish habitat and was easily wadeable. In previous years, fish sampling was conducted in deeper waters where the capture efficiency was lower. The total catch of fish species also increased at *baseline* reach BER-F2 in 2014, and was dominated by lake chub (76%) (Table 5.13-31).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach POC-F1 included testing for changes over time in measurement endpoints (2009 to 2014, Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach POC-F1 included testing for differences from *baseline* reach BER-F2 over time (Hypothesis 2, Section 3.2.4.4).

There were significant increases in richness ($p<0.001$), diversity ($p=0.006$), and CPUE ($p=0.045$) over time at *test* reach POC-F1, explaining greater than 20% of the variance in annual means (Table 5.13-33). There was a significant decrease in the assemblage tolerance index (ATI) over time ($p<0.001$) due to the greater proportion of burbot in the catch, which is considered a sensitive species (Whittier et al. 2007).

There were no significant differences in any measurement endpoints between *test* reach POC-F1 and *baseline* reach BER-F2 (Table 5.13-33).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the Athabasca oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of seventeen and fourteen fish species were recorded in Poplar Creek and the Beaver River, respectively. After four sampling events across five years, 13 fish species have been documented by JOSMP in Poplar Creek, including two small-bodied species and one sportfish species (walleye) not previously recorded in Golder (2004). A total of nine species have been found at *baseline* reach BER-F2 over the same period, including three small-bodied species not previously recorded. The higher species richness in studies cited in Golder (2004) were from multi-season sampling events using a variety of fishing techniques that were able to capture fish in all lifestages compared to the backpack electrofishing method used by JOSMP that targets smaller fish. A comparison of the JOSMP results to one of the intensive studies (Golder 2004) found that the species composition documented by JOSMP was similar to that found in previous studies using similar methodology.

Golder (2004) documented similar habitat conditions to what was observed by JOSMP at *test* reach POC-F1, consisting of riffle to run habitat with substrate dominated by boulders, sand, and silt. The habitat in Poplar Creek, where *test* reach POC-F1 was located, was documented as limited for feeding and overwintering activities (Golder 2004).

Similar habitat conditions were historically documented to what was observed by JOSMP at *baseline* reach BER-F2, which consisted of run habitat with silt and sand substrate (Golder 2004). Habitat of the upper Beaver River where *baseline* reach BER-F2 is located was characterized as having low habitat diversity and poor fish habitat (Golder 2004).

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints were within the inner tolerance limits of the regional range of *baseline* variability (Figure 5.13-24).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach POC-F1 were classified as **Negligible-Low** because the significant increases in richness, diversity, and CPUE, and the significant decrease in ATI were not indicative of a negative change in the fish assemblage. In addition, all measurement endpoints for *test* reach POC-F1 were within the inner tolerance limits of the *baseline* range of variability.

5.13.5 McLean Creek

Monitoring was conducted in the McLean Creek watershed in 2014 for the Water Quality component.

5.13.5.1 Water Quality

Water quality samples were collected in fall 2014 near the mouth of McLean Creek at *test* station MCC-1 (sampled from 1999 to 2014).

Temporal Trends There were no significant trends (α=0.05) observed at *test* station MCC-1 from 1997 to 2014. However, since 2009, concentrations of total dissolved solids and several ions and dissolved metals (e.g., strontium, boron, and sulphate) have shown consistent year-to-year increases.

2014 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints at *test* station MCC-1 in fall 2014 were within previously-measured concentrations, with the exception of sulphate and total molybdenum, with concentrations that exceeded previously-measured maximum concentrations (Table 5.13-34). Concentrations of total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were all below previously-measured minimum concentrations (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only).

Ion Balance The ionic composition of water at *test* station MCC-1 in fall 2014 was in similar proportions to values measured in previous years and dominated by calcium bicarbonate (Figure 5.13-25).

Comparison of Water Quality Measurement Endpoints to Published Guidelines All measurement endpoints were within water quality guidelines at *test* station MCC-1 in fall 2014, with the exception of total aluminum (Table 5.13-34).

Other Water Quality Guideline Exceedances Concentrations of total iron, sulphide, and total phenols exceeded relevant water quality guidelines at *test* station MCC-1 in fall 2014 (Table 5.13-6).

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints that exceeded the 95th percentile of regional *baseline* concentrations at *test* station MCC-1 in fall 2014 included total dissolved solids, total strontium, total boron, calcium, sodium, chloride, and sulphate (Figure 5.13-26).

Water Quality Index The WQI value of 66.0 for *test* station MCC-1 in fall 2014 indicated **Moderate** differences from regional *baseline* conditions (Table 5.13-7). This difference can primarily be attributed to high levels of dissolved ions and metals.

Classification of Results Concentrations of water quality measurement endpoints at *test* station MCC-1 were generally within the range of previously-measured concentrations in fall 2014. The WQI value indicated **Moderate** differences between *test* station MCC-1 and regional *baseline* concentrations, mostly attributed to high levels of dissolved ions and total metals. Despite having no significant temporal trends, total dissolved solids and several ions have shown consistent annual increases since 2009.

5.13.6 Fort Creek

Monitoring was conducted in the Fort Creek watershed in 2014 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.6.1 Hydrologic Conditions: 2014 Water Year

Hydrometric monitoring for the Fort Creek watershed in the 2014 WY was conducted at JOSMP Station S12, Fort Creek at Highway 63, during the open-water period (May to October). These data were used for the water balance analysis and presented below. Hydrometric data have been collected at this station, during the open-water period, from 2000 to 2001 and 2006 to 2014.

The historical flow record for JOSMP Station S12 is summarized in Figure 5.13-27 and includes the median, interquartile, and range of flows recorded daily through the open-water period. Hydrometric monitoring has historically begun in mid-April. In some cases, this was after the annual peak flow. Monthly flows are typically highest during May, or in June and July when total monthly rainfall totals are highest (Figure 5.13-27). Flows typically decrease slightly for the remaining months, but tend to fluctuate throughout the open-water period.

In the open-water period of the 2014 WY, flows remained similar to the historical seasonal pattern described above. The recorded peak flow was reached on May 30 (0.412 m^3/s), which was 10% lower than the mean annual maximum daily flow for the open-water period (0.456 m^3/s). Flows then decreased and the minimum open-water flow of 0.041 m^3/s on August 18. This was 81% higher than the mean annual minimum daily flow (0.023 m^3/s). Flows then increased slightly for the remainder of the water year. Throughout the open-water period, flows generally remained above historical median values, but below historical maxima.

Overall, the annual runoff volume in the open-water portion of the 2014 WY was 2.35 million m^3. This value was 49% higher than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for Fort Creek at Highway 63 is summarized in Table 5.13-35. Key changes in flow included:

1. The closed-circuited land change area as of 2014 was estimated to be 20 km^2 (Table 2.3-1). The loss of flow to Fort Creek that would have otherwise occurred from this land area was estimated at 0.924 million m^3.

2. As of 2014, the area of land change in the Fort Creek watershed that was not closed-circuited was estimated to be 35.5 km^2 (Table 2.3-1). The increase in flow to Fort Creek that would not have otherwise occurred from this land area was estimated at 0.328 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2014 WY was a loss of flow of 0.596 million m^3 in Fort Creek at JOSMP Station S12. The 2014 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 20.24% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-36). These differences were classified as **High** (Table 5.13-35). This **High** magnitude of change was due to land disturbances throughout most of the watershed, upstream of JOSMP Station S12 (i.e., 84% of the watershed has been developed, Table 2.3-2). Given the small size of the Fort Creek watershed, downstream of JOSMP Station S12, the magnitude of impacts would remain **High** along the entire length of Fort Creek (Figure 5.13-28).

5.13.6.2 Water Quality

In fall 2014, water quality samples were taken from the mouth of Fort Creek at *test* station FOC-1 (sampled intermittently from 2000 to 2014, designated as *baseline* until 2003).

Temporal Trends The following significant temporal trends (α=0.05) in concentrations of water quality measurement endpoints were detected at *test* station FOC-1 from 2000 to 2014:

- Decreasing concentrations of dissolved phosphorus, total arsenic, and total nitrogen; and
- Increasing concentrations of calcium, magnesium, potassium, total boron, total dissolved solids, total strontium, and sulphate.

2014 Results Relative to Historical Concentrations In fall 2014, concentrations of water quality measurement endpoints were within previously-measured concentrations, with the following exceptions (Table 5.13-37):

- Conductivity, sulphate, total dissolved solids, total molybdenum, and naphthenic acids, with concentrations that exceeded previously-measured maximum concentrations (it should be noted that waterborne PAHs and naphthenic acids/oilsands extractable acids have only been measured at the current, ultra-trace detection limits since 2011, and that comparisons of 2014 data for these analytes were made to 2011 to 2013 data only); and
- Total alkalinity, with a concentration below the previously-measured minimum concentration.

Ion Balance The ionic composition of water at *test* station FOC-1 in fall 2014 showed a continued shift over time towards a greater influence of sulphate, with no changes in cation composition (Figure 5.13-25).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints measured at *test* station FOC-1 were below water quality guidelines in fall 2014, with the exception of total aluminum (Table 5.13-37).

Other Water Quality Guideline Exceedances The concentration of total iron and sulphide exceeded the water quality guidelines at *test* station FOC-1 in fall 2014 (Table 5.13-6).

2014 Results Relative to Regional *Baseline* Concentrations In fall 2014, concentrations of water quality measurement endpoints at *test* station FOC-1 were within regional *baseline* concentrations, with the exception of (Figure 5.13-6):

- total dissolved solids, calcium, magnesium, and sulphate, with concentrations that exceeded the 95^{th} percentile of regional *baseline* concentrations; and
- dissolved phosphorus and total arsenic, with concentrations below the 5^{th} percentile of regional *baseline* concentrations.

Water Quality Index The WQI value for *test* station FOC-1 (88.5) indicated **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2014 (Table 5.13-7).

Classification of Results Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and regional *baseline* concentrations in fall 2014. Differences in water quality between *test* station FOC-1 and regional *baseline* conditions were classified as **Negligible-Low**. Many significant temporal trends in water quality measurement endpoints continued to be observed, including decreasing concentrations of dissolved phosphorus, total arsenic, and total nitrogen, and increasing concentrations of calcium, magnesium, potassium, total boron, total dissolved solids, total strontium, and sulphate. The ionic composition of water has showed a continued shift in anions over time, having a greater influence of sulphate in fall 2014 compared to earlier sampling years.

5.13.6.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2014 at depositional *test* reach FOC-D1 (designated as *baseline* from 2001 to 2003 and *test* from 2004 to 2014).

2014 Habitat Conditions Water at *test* reach FOC-D1 fall 2014 was shallow (0.4 m in sampled areas) with relatively slow velocity (0.36 m/s), a pH of 8.0, high dissolved oxygen (10.3 mg/L), and moderate conductivity (176 µS/cm) (Table 5.13-38). The substrate was primarily comprised of sand (87%) with relatively low organic carbon content (2.2%) (Table 5.13-38).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach FOC-Dl was dominated by chironomids (48%) with subdominant taxa consisting of Oligochaeta (34%; value includes unidentified oligochaetes, plus naidids, tubificids, and enchytraeids) and Gastropoda (9%) (Table 5.13-39). Larvae of large flying insects consisted only of a single Capniidae stonefly. Ephemeroptera and Trichoptera, which were present in 2013, were absent at *test* reach FOC-D1 in 2014. Chironomids were mainly *Lopesocladius/Rheosmittia* (Table 5.13-39). Permanent aquatic forms (Gastropoda: Lymnaeidae and Bivalvia: *Pisidium/Sphaerium*) were present and relatively abundant in Fort Creek in 2014.

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for Fort Creek. For the purpose of this report, a comparison was considered significant if the associated p-value was less than 0.05 and the variance explained by the comparison was greater than 20% of the variation in annual means.

Temporal comparisons of measurement endpoints for *test* reach FOC-D1 included testing for:

- changes from before (2001 to 2003) to after (2005 to present) the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- changes over time during the *test* period (i.e., since 2002, Hypothesis 2, Section 3.2.3.1);
- changes between 2014 values and the mean of all *baseline* years (2001 to 2003); and
- changes between 2014 values and the mean of all previous years of sampling.

Abundance was lower during the *test* period and lower in 2014 than the mean of *baseline* years at *test* reach FOC-D1 with variance explaining >20% in annual means in both cases (Table 5.13-40).

Richness was also lower during the *test* period, explaining 31% of the variance in annual means (Table 5.13-40).

Equitability was higher during the *test* period, explaining 25% of the variance in annual means (Table 5.13-40).

Comparison to Published Literature The benthic invertebrate community of *test* reach FOC-D1 was typical of a sandy-bottomed lotic system. The community had low diversity and a high relative abundance of chironomids and worms (48% and ~40%, respectively). Larvae of large flying insects were sparse, which is typical of sandy-bottomed rivers. Permanent aquatic forms were slightly more abundant in 2014 than 2013 with representatives from both Gastropoda and Bivalvia.

2014 Results Relative to Historical and Regional *Baseline* Conditions Values of measurement endpoints, with the exception of percent EPT taxa, for *test* reach FOC-D1 were within the inner tolerance limits of the normal range of variation of previous years of sampling in Fort Creek (Figure 5.13-29, Figure 5.13-30). When compared to regional *baseline* conditions, abundance and equitability were outside of the inner tolerance limits suggesting abundance was low and equitability was somewhat high indicating low diversity relative to *baseline* depositional reaches. The percentage of EPT taxa was lower than the inner tolerance limit of the normal range of variation of previous years of sampling in Fort Creek (Figure 5.13-30) but was within the inner tolerance limits for regional *baseline* depositional reaches.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach FOC-Dl were classified as **Moderate.** There were statistically significant and large variations in abundance, richness, and equitability, indicating potential degradation of habitat conditions. In addition, the percentage of EPT taxa was below the inner tolerance limits of the normal range of variability for this reach, but was still higher than values from *baseline* years (2001 to 2003). Lower richness and higher equitability during the *test* years were potentially suggestive of moderate degradation, but the presence of clams, snails, and particularly stoneflies suggested that habitat quality was not significantly degraded. The benthic invertebrate community of Fort Creek has typically had low diversity including during the *baseline* period, and the community in 2014 was consistent with previous years.

Sediment Quality

Sediment quality was sampled in fall 2014 at *test* station FOC-D1 in the same location as benthic invertebrate communities were sampled. *Test* reach FOC-D1 was designated as *baseline* in 2000 and 2002 and as *test* from 2006 to 2008 and 2010 to 2014.

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station FOC-D1 in fall 2014, with the exception of an increasing trend in the concentration of F4 hydrocarbons.

2014 Results Relative to Historical Concentrations Sediments at *test* station FOC-D1 were dominated by sand (64%), with all particle-size fractions within the range of previously-measured fractions. All sediment quality measurement endpoints at *test* station FOC-D1 in fall 2014 were within the range of previously-measured concentrations (Table 5.13-41).

Direct tests of sediment toxicity to invertebrates at *test* station FOC-D1 in 2014 showed high survival rates for both *Chironomus* (88%) and *Hyalella* (88%). All tests results were within previously-measured values (Table 5.13-41).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints at *test* station FOC-D1 that exceeded relevant sediment quality guidelines in 2014 included concentrations of F3 hydrocarbons, chrysene, and dibenz(a,h)anthracene (Table 5.13-41).

2014 Results Relative Regional *Baseline* Concentrations All sediment quality measurement endpoints at *test* station FOC-D1 in fall 2014 were within the range of regional *baseline* concentrations (Figure 5.13-31).

Sediment Quality Index An SQI value for *test* station FOC-D1 in fall 2014 of 91.4 indicated **Negligible-Low** differences from regional *baseline* conditions (Table 5.13-29). SQI values for *test* station FOC-D1 have been variable since sediment quality monitoring began in 2000, ranging from 59.8 to 100 (n=10).

Classification of Results Sediment quality at *test* station FOC-D1 in fall 2014 showed **Negligible-Low** differences from regional *baseline* conditions. All sediment quality measurement endpoints were within the range of previously-measured concentrations, with concentrations of F3 hydrocarbons, dibenz(a,h)anthracene, and chrysene exceeding sediment quality guidelines in 2014.

5.13.6.4 Fish Populations

Fish assemblages were sampled in fall 2014 at *test* reach FOC-F1, which has been sampled since 2011 and is at the same location as benthic invertebrate community *test* reach FOC-D1.

2014 Habitat Conditions *Test* reach FOC-F1 was comprised of run and riffle habitat, with a wetted width of 2.75 m and a bankfull width of 6.8 m. The substrate was comprised of sand and fine material. Water at *test* reach FOC-F1 had a mean depth of 0.64 m, slow velocity (mean=0.40 m/s), a pH of 7.86, high conductivity (617 µs/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 12.3˚C. Instream cover consisted of small woody debris with some undercut banks (Table 5.13-42).

Relative Abundance of Fish Species The total catch of fish species at *test* reach FOC-F1 has decreased since 2011, with only 13 fish captured in 2014. The dominant species captured in 2014 was lake chub as (46%) (Table 5.13-43).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach FOC-F1 included testing for changes over time in measurement endpoints (2011 to 2014, Hypothesis 1, Section 3.2.4.4). There was no upstream *baseline* reach to provide spatial comparisons to *test* reach FOC-F1.

There were significant decreases over time in abundance ($p<0.001$), richness ($p=0.030$), and CPUE ($p=0.001$) at *test* reach FOC-F1 (Table 5.13-44, Table 5.13-45). Although not significantly different, the assemblage tolerance index was higher compared to 2013 due to the lower number of burbot captured in 2014 (Table 5.13-43).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the Athabasca oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by JOSMP for the FAM program. Based on past studies, a total of eight fish species were documented in Fort Creek. Between 2011 and 2014, JOSMP found a total of 13 species and has captured all but one species (spoonhead sculpin) that have been found in previous studies (Golder 2004). The increase in the number of fish species documented by JOSMP was likely the result of increased fishing effort by JOSMP at *test* reach FOC-F1. The methods reported in Golder (2004) for Fort Creek were similar to those for JOSMP with respect to sampling method (backpack electrofishing) and fishing effort (1,212 seconds in one study); however, JOSMP has sampled across multiple years whereas previous surveys were typically for only one year.

Golder (2004) documented similar habitat conditions to what has been observed by JOSMP, with Fort Creek consisting of shallow glides and pools with some riffle sections dominated by silt substrate. Woody debris was also documented as the primary instream cover.

2014 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for *test* reach FOC-F1 were within the inner tolerance limits of regional *baseline* conditions (Figure 5.13-32).

Classification of Results Differences in measurement endpoints for the fish assemblage at *test* reach FOC-F1 were classified as **Moderate** because there were significant decreases in abundance, richness, and CPUE, implying a negative change to the fish assemblage.

5.13.7 Susan Lake Outlet

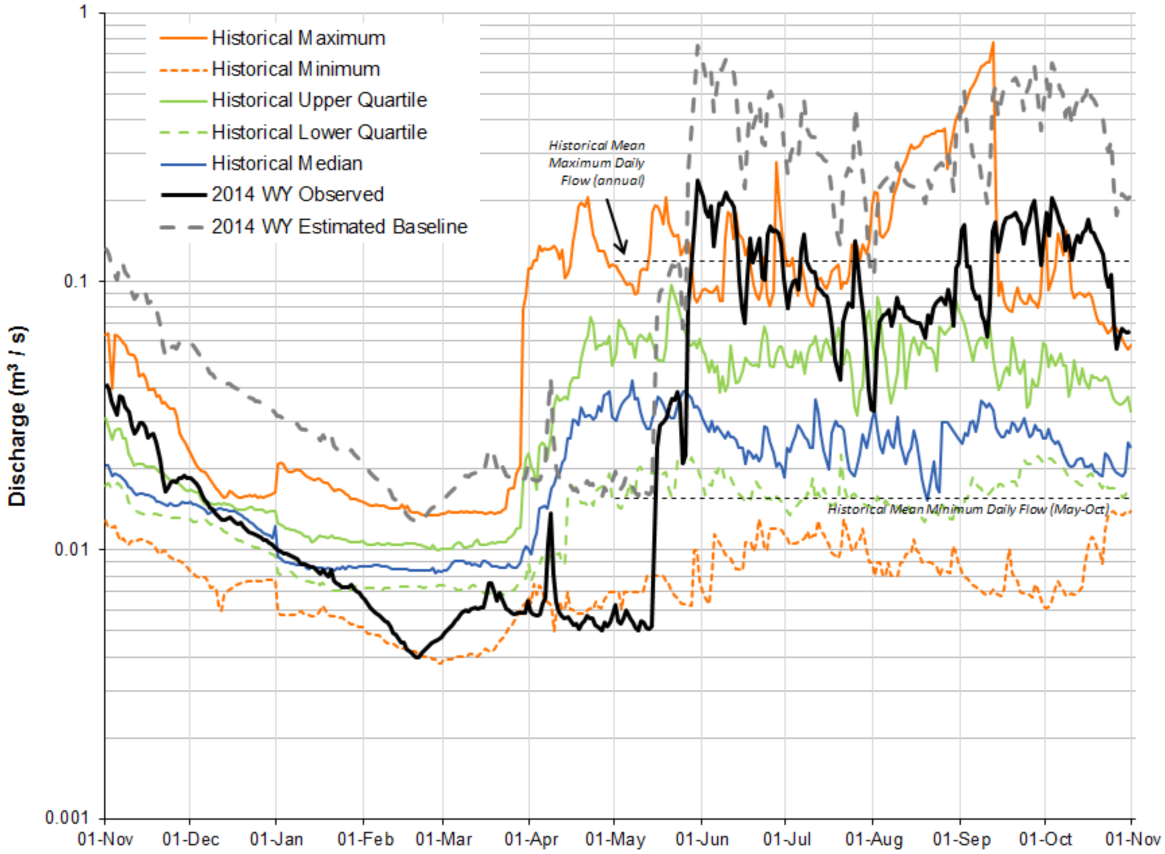
Hydrometric monitoring for the Susan Lake Outlet (JOSMP Station S25) watershed was conducted during the 2014 open-water period (May to October). While historical open-water period flow data have been collected since 2006, the record was limited to a few months (typically July to October) in some years; therefore, historical statistics for this station should be interpreted with caution.

The historical flow record for JOSMP Station S25 is summarized in Figure 5.13-33 and includes the median, interquartile, and range of flows recorded daily through the water year. Monthly flows are historically highest during May, and typically decline rapidly into June. Flows then generally remain low from June to the end of the water year, with occasional increases in flow due to rainfall events.

In the 2014 WY, monitoring commenced on April 29. Shortly after this, the minimum open-water flow of 0.027 m^3/s was reached on May 9. Peak flow in the 2014 open-water period occurred on May 30 (0.484 m^3/s) and was 28% lower than the open-water maximum daily mean flow (0.672 m^3/s). Flows decreased after this peak, and fluctuated until the end of the open-water period. Flows remained above historical median values on most dates, and often above historical maxima, especially during the month of June, but the historical record was limited.

Overall, the annual runoff volume in the open-water portion of the 2014 WY was 1.189 million m^3. This value was 43% higher than the mean historical annual runoff volume based on the available period of record.

Figure 5.13-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Mills Creek in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Mills Creek at Highway 63, S6. The upstream drainage area is 9 km². Historical values from May to October were calculated from data collected from 1997 to 2013 and from 2006 to 2013 for other months.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.13-2 Estimated water balance at Station S6, Mills Creek at Highway 63, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**1.813**	**Observed discharge, obtained from JOSMP Station S6**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-4.227	Estimated 6.6 km^2 of the Mills Ck. watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.331	Estimated 2.4 km^2 of the Mills Creek watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Mills Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Mills Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**5.729**	**Estimated *baseline* discharge at JOSMP Station S6**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-3.916	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**-68.356**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Table 5.13-3 Calculated change in hydrologic measurement endpoints for the Mills Creek watershed, 2014 WY.

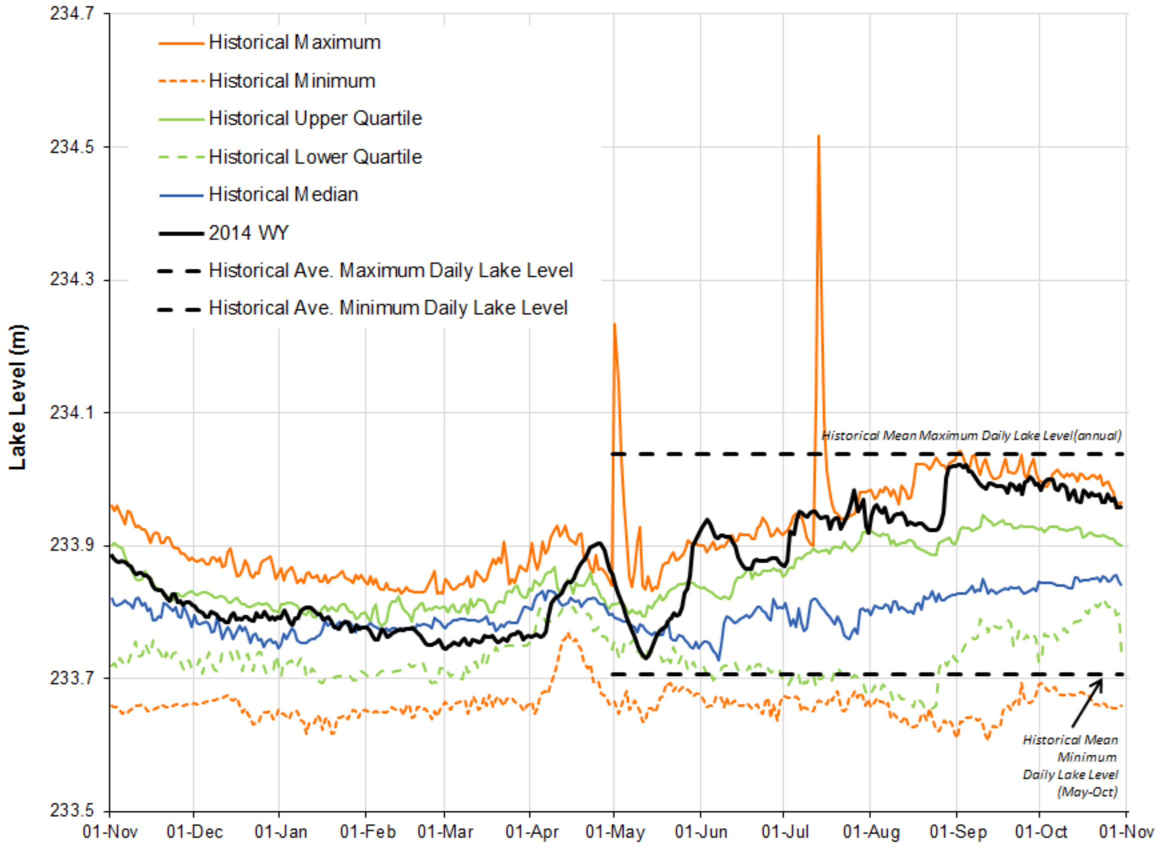
Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.103	0.326	-68.356%
Mean winter discharge	0.012	0.038	-68.356%
Annual maximum daily discharge	0.239	0.755	-68.356%
Open-water season minimum daily discharge	0.005	0.016	-68.356%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.13-4 Observed water level for Isadore's Lake for the 2014 WY, compared to historical values.



Note: Based on provisional 2014 WY data recorded at Isadore's Lake, JOSMP Station L3. Historical values were calculated for the period of 2000 to 2013.

Note: The historical mean minimum daily lake level was calculated for open-water months only (May to October). The historical mean maximum daily lake level was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.13-4 Concentrations of water quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	12	7.7	8.2	8.3
Total suspended solids	mg/L	-	<3.0	12	<3.0	6.0	10
Conductivity	µS/cm	-	891	12	353	568.5	769
Nutrients							
Total dissolved phosphorus	mg/L	-	0.004	12	0.003	0.008	0.067
Total nitrogen	mg/L	-	0.594	12	0.300	1.00	1.25
Nitrate+nitrite	mg/L	3	<0.054	12	<0.050	<0.086	0.300
Dissolved organic carbon	mg/L	-	10.2	12	8.00	10.6	12.9
Ions							
Sodium	mg/L	-	16.2	12	6.00	11.2	16.4
Calcium	mg/L	-	107	12	37.0	63.5	90.4
Magnesium	mg/L	-	37.0	12	25.0	29.9	36.0
Chloride	mg/L	120	38.8	12	4.0	16.8	35.2
Sulphate	mg/L	429	277	12	63.9	109	243
Total dissolved solids	mg/L	-	591	12	250	376	591
Total alkalinity	mg/L	-	126	12	116	153	227
Selected metals							
Total aluminum	mg/L	0.1	0.030	12	0.006	0.018	**0.182**
Dissolved aluminum	mg/L	0.05	0.0004	12	<0.001	<0.001	0.020
Total arsenic	mg/L	0.005	0.00054	12	0.00046	0.00072	0.00116
Total boron	mg/L	1.2	0.054	12	0.035	0.043	0.061
Total molybdenum	mg/L	0.073	0.00001	12	<0.00001	0.00010	0.00013
Total mercury (ultra-trace)	ng/L	5, 13	0.56	10	0.53	<1.2	1.6
Total strontium	mg/L	-	0.292	12	0.162	0.235	0.319
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.31	3	0.07	0.13	0.45
Oilsands Extractable	mg/L	-	1.70	3	0.38	0.67	1.29
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<14.13	<15.16
Retene	ng/L	-	0.429	3	<0.509	<0.717	<2.071
Total dibenzothiophenes	ng/L	-	7.249	3	6.020	8.089	35.45
Total PAHs	ng/L	-	81.47	3	107.2	176.7	308.2
Total Parent PAHs	ng/L	-	13.40	3	18.04	21.75	23.37
Total Alkylated PAHs	ng/L	-	68.06	3	83.88	155.0	290.1
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.004	**0.0225**	12	<0.002	**0.0080**	**0.0878**

[a] Sources for all guidelines are outlined in Table 3.2-5

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.13-5 Concentrations of water quality measurement endpoints, Mills Creek (*test* station MIC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	2010-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.14	4	8.06	8.14	8.19
Total suspended solids	mg/L	-	<3.0	4	<3.0	<3.0	5.0
Conductivity	µS/cm	-	1,290	4	859	904	1,290
Nutrients							
Total dissolved phosphorus	mg/L	-	<0.001	4	<0.001	0.002	0.005
Total nitrogen	mg/L	-	0.254	4	0.281	0.301	0.451
Nitrate+nitrite	mg/L	3	<0.054	4	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	24.40	4	6.40	7.20	8.40
Ions							
Sodium	mg/L	-	15.4	4	9.30	9.95	14.8
Calcium	mg/L	-	209	4	135	139	235
Magnesium	mg/L	-	53.7	4	33.4	36.0	52.1
Chloride	mg/L	120	38.2	4	19.4	21.2	50.2
Sulphate	mg/L	429	**438**	4	169	202	**443**
Total dissolved solids	mg/L	-	965	4	598	612	1,020
Total alkalinity	mg/L	-	225	4	246	266	313
Selected metals							
Total aluminum	mg/L	0.1	0.0040	4	<0.0030	0.0040	0.0107
Dissolved aluminum	mg/L	0.05	0.0002	4	<0.0010	0.0011	0.0024
Total arsenic	mg/L	0.005	0.00031	4	0.00029	0.00030	0.00037
Total boron	mg/L	1.2	0.0461	4	0.0360	0.0454	0.0532
Total molybdenum	mg/L	0.073	<0.0001	4	<0.0001	<0.0001	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	0.32	4	0.36	<0.60	0.60
Total strontium	mg/L	-	0.417	4	0.299	0.355	0.483
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	2.20	3	0.06	0.07	0.51
Oilsands Extractable	mg/L	-	2.60	3	0.32	0.82	0.94
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.76	<14.13	<15.16
Retene	ng/L	-	<0.407	3	<0.509	<0.669	<2.07
Total dibenzothiophenes	ng/L	-	5.206	3	6.672	6.814	35.30
Total PAHs	ng/L	-	75.68	3	102.5	177.8	205.7
Total Parent PAHs	ng/L	-	13.26	3	16.41	22.44	24.18
Total Alkylated PAHs	ng/L	-	62.42	3	80.05	153.6	189.3

[a] Sources for all guidelines are outlined in Table 3.2-5

Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.13-5 Piper diagram of fall ion balance in Isadore's Lake, Mills Creek, and Shipyard Lake.

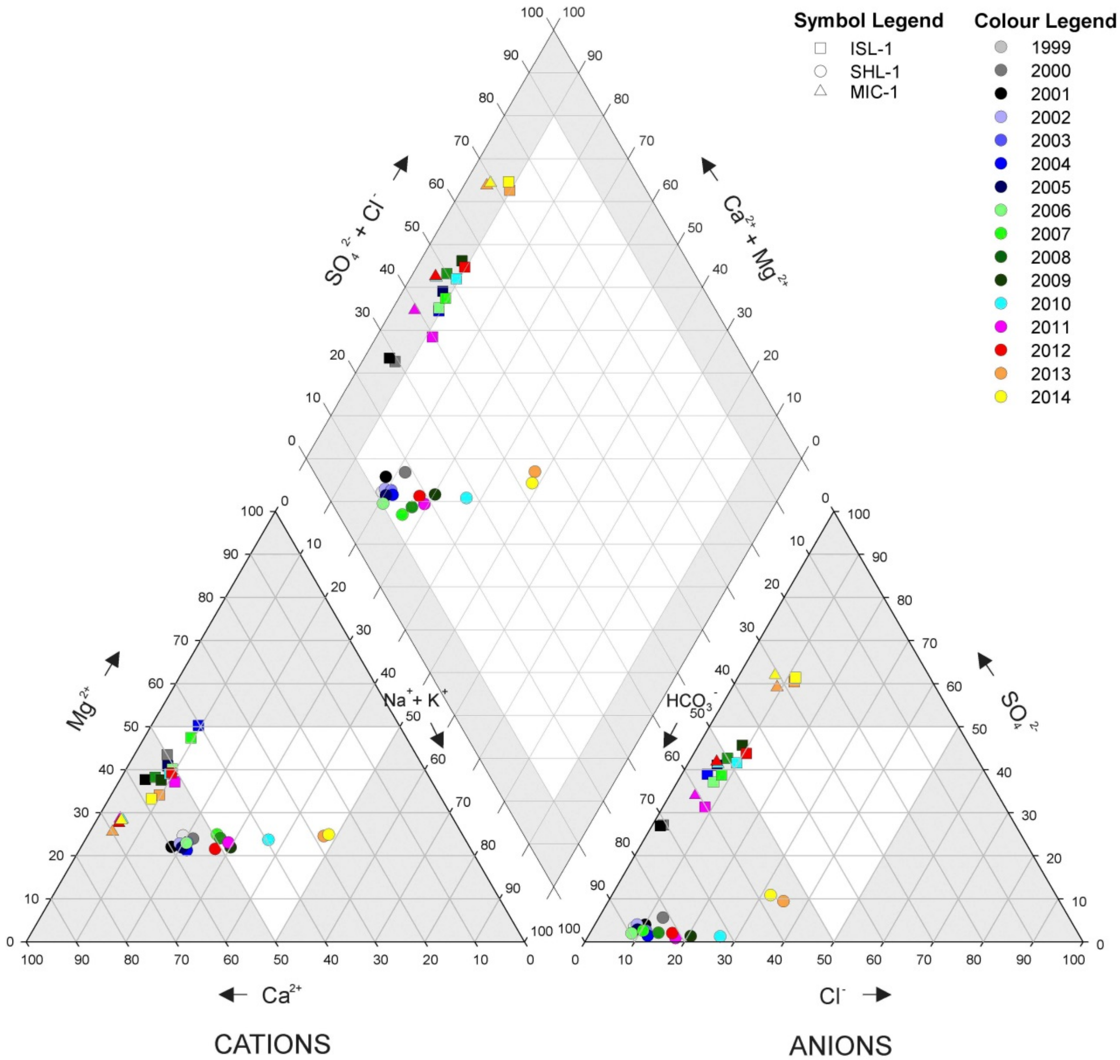


Table 5.13-6 Water quality guideline exceedances at *test* station BER-1, *baseline* station BER-2, *test* station POC-1, *test* station MCC-1, *test* station ISL-1, *test* station SHL-1, *test* station MIC-1, and *test* station FOC-1, fall 2014.

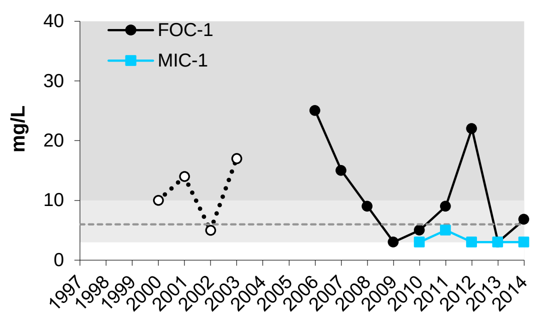
Variable	Units	Guideline[a]	POC-1	BER-1	BER-2	MCC-1	ISL-1	SHL-1	MIC-1	FOC-1
Fall										
Chloride	mg/L	120	308	-	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	-	-	0.39	-	-	-	-	-
pH	pH units	6.5-9.0	-	-	-	-	-	9.16	-	-
Sulphate	mg/L	410	-	-	-	-	-	-	438	-
Sulphide	mg/L	0.002	0.0034	-	0.0054	0.0042	0.023	0.0031	-	0.0022
Total aluminum	mg/L	0.1	0.29	0.11	0.49	0.20	-	-	-	0.138
Total iron	mg/L	0.3	5.30	5.56	1.95	0.59	-	-	-	0.65
Total phenols	mg/L	0.004	-	0.0063	-	0.0050	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

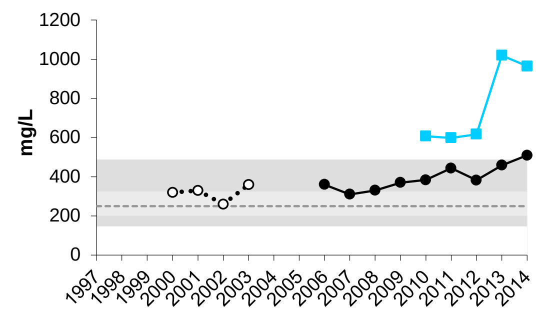
Underline denotes *baseline* station.

Figure 5.13-6 Concentrations of selected fall water quality measurement endpoints, Mills Creek (*test* station MIC-1) and Fort Creek (*test* station FOC-1) (fall data), relative to historical concentrations and regional *baseline* fall concentrations.

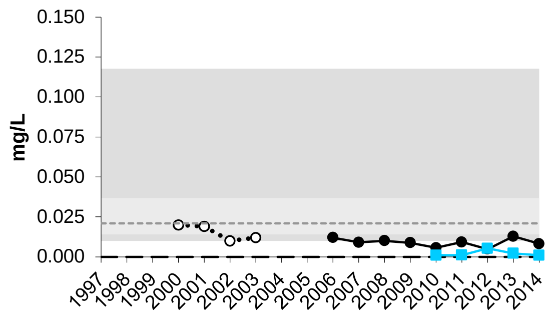
Total Suspended Solids (TSS)



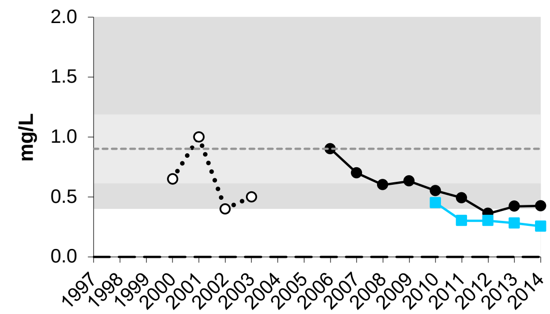
Total Dissolved Solids (TDS)



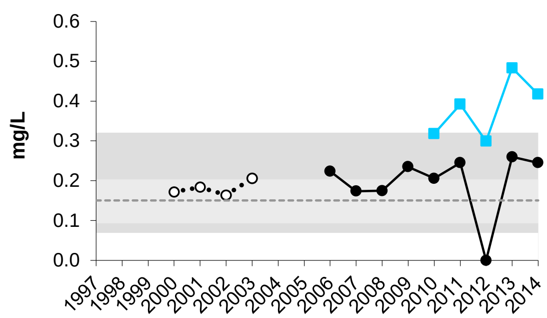
Dissolved Phosphorus



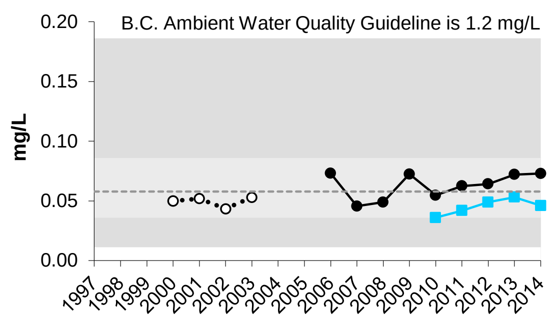
Total Nitrogen



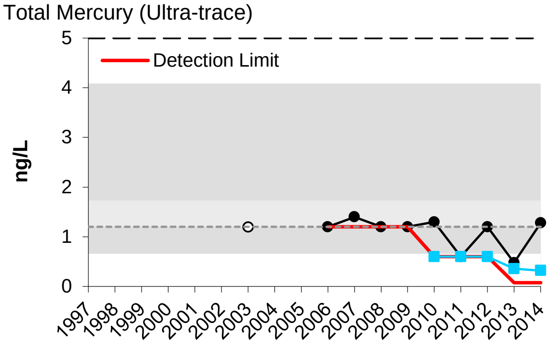
Total Strontium



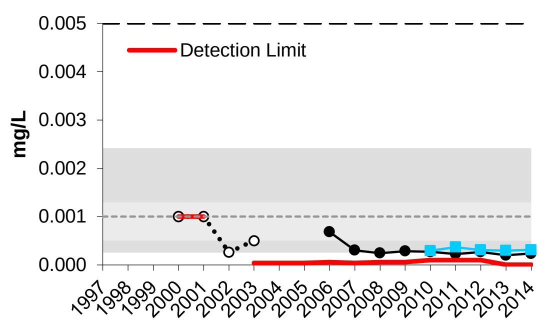
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



Non-detectable values are shown at the detection limit.

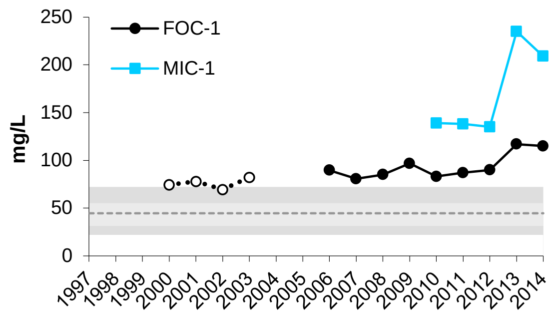
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

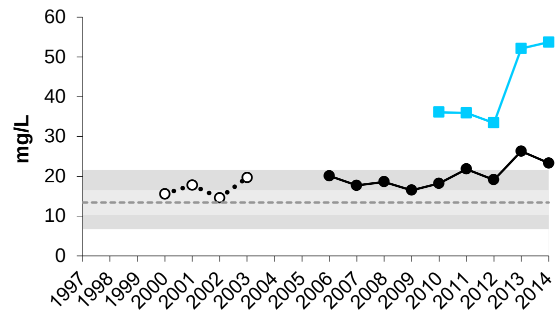
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-6 (Cont'd.)

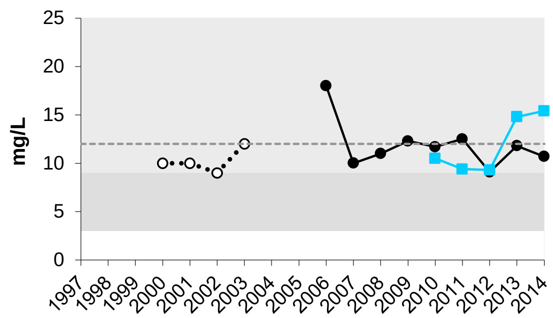
Calcium



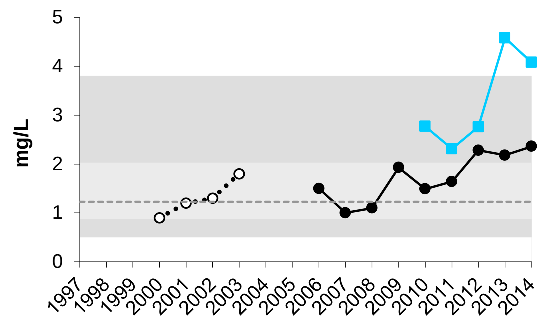
Magnesium



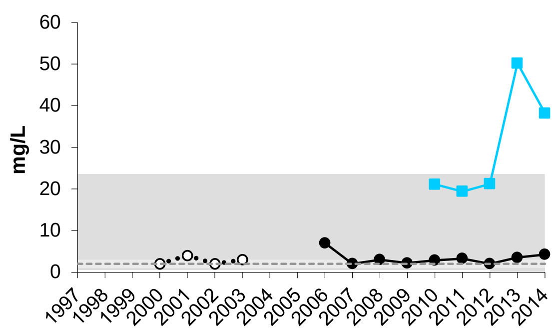
Sodium



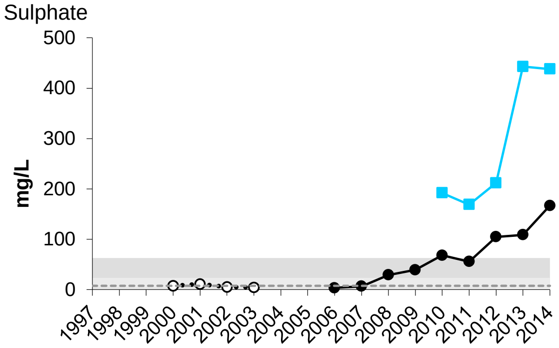
Potassium



Chloride



Sulphate



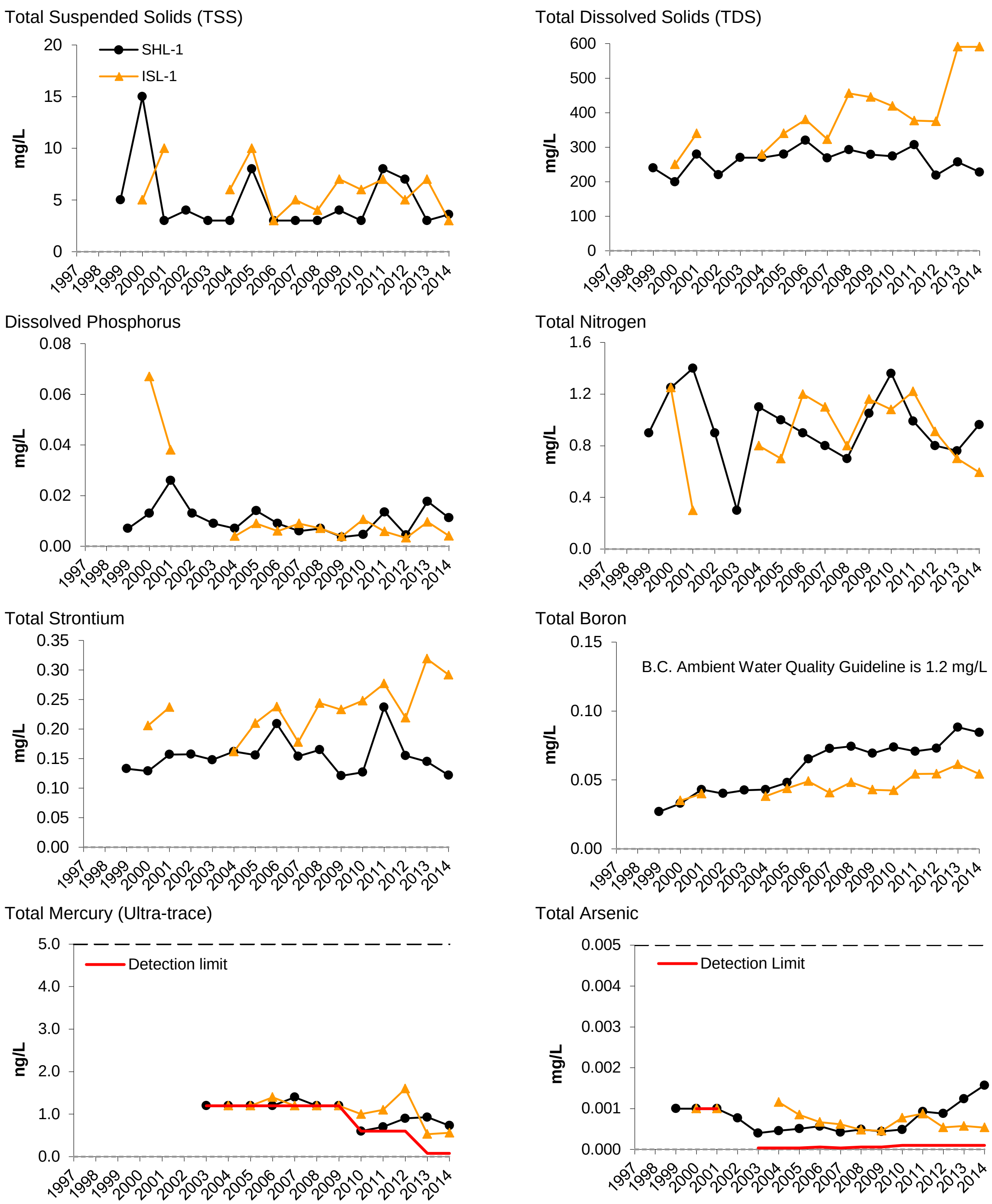
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○••••••○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-7 Concentrations of selected fall water quality measurement endpoints, Isadore's Lake (*test* station ISL-1) and Shipyard Lake (*test* station SHL-1) (fall data), relative to historical concentrations.

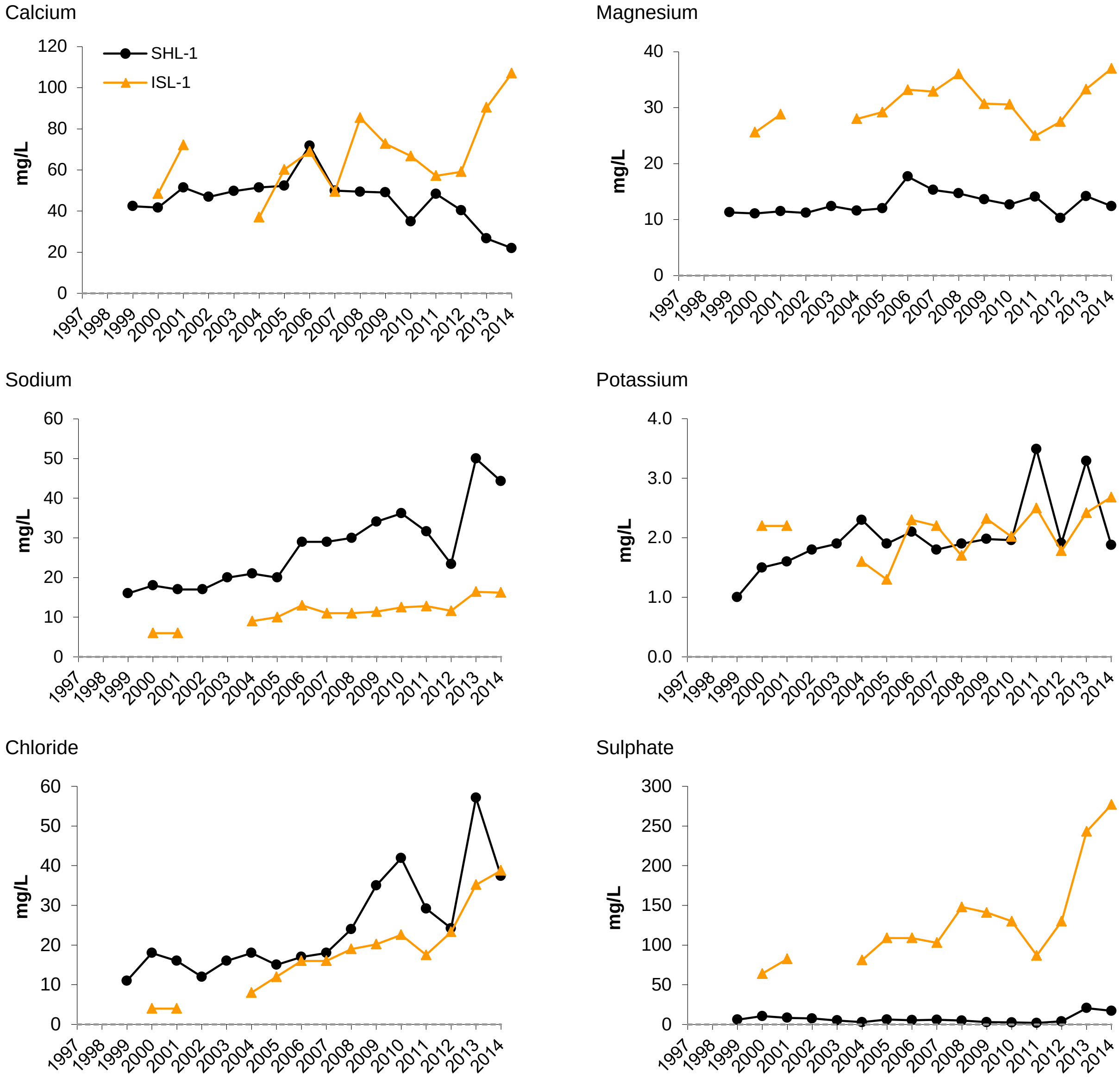


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.13-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Table 5.13-7 Water quality index (fall 2014) for miscellaneous watershed stations.

Station Identifier	Location	2014 Designation	Water Quality Index	Classification
BER-1	near the mouth of Beaver River	*test*	77.0	Moderate
BER-2	upper Beaver River	*baseline*	95.8	Negligible-Low
FOC-1	near the mouth of Fort Creek	*test*	88.5	Negligible-Low
MCC-1	near the mouth of McLean Creek	*test*	66.0	Moderate
MIC-1	Mills Creek	*test*	79.7	Moderate
POC-1	near the mouth of Poplar Creek	*test*	74.6	Moderate

Table 5.13-8 Average habitat characteristics of benthic invertebrate sampling locations in Isadore's Lake, fall 2014.

Variable	Units	Isadore's Lake
Sample date	-	Sept 3, 2014
Habitat	-	Depositional
Water depth	m	1.9
Field Water Quality		
Dissolved oxygen	mg/L	6.8
Conductivity	µS/cm	765
pH	pH units	7.26
Water temperature	°C	17
Sediment Composition (mean ± 1SD)		
Sand	%	20±7
Silt	%	51±5
Clay	%	29±4
Total Organic Carbon	%	7.6±2.1

Table 5.13-9 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Isadore's Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	2006	2007-2013	2014
Nematoda	72	12 to 69	3
Naididae	4	0 to 8	37
Tubificidae	-	0 to 2	<1
Hirudinea	-	0 to <1	<1
Hydracarina	-	0 to 8	<1
Gastropoda	-	0 to 4	2
Ceratopogonidae	<1	0 to 4	<1
Chironomidae	2	7 to 60	53
Diptera (misc)	<1	0 to 2	<1
Ephemeroptera	-	0 to 3	2
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	282	211 to 288	288
Richness	10	5 to 10	13
Equitability	0.23	0.36 to 0.57	0.27
% EPT	0	0 to 3	2

Table 5.13-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Isadore's Lake (ISL-1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	0.252	**0.017**	3	15	Higher in 2014 than mean of previous years.
Log of Richness	**0.011**	**<0.001**	14	33	Increasing over time; higher in 2014 than mean of previous years.
Equitability	0.104	**<0.001**	8	42	Lower in 2014 than mean of previous years.
Log of EPT	**<0.001**	**0.007**	49	30	Increasing over time; higher in 2014 than mean of previous years.
CA Axis 1	**0.002**	**<0.001**	21	37	Decreasing over time; lower in 2014 than mean of previous years.
CA Axis 2	**0.013**	**<0.001**	12	45	Increasing over time; higher in 2014 than mean of previous years.

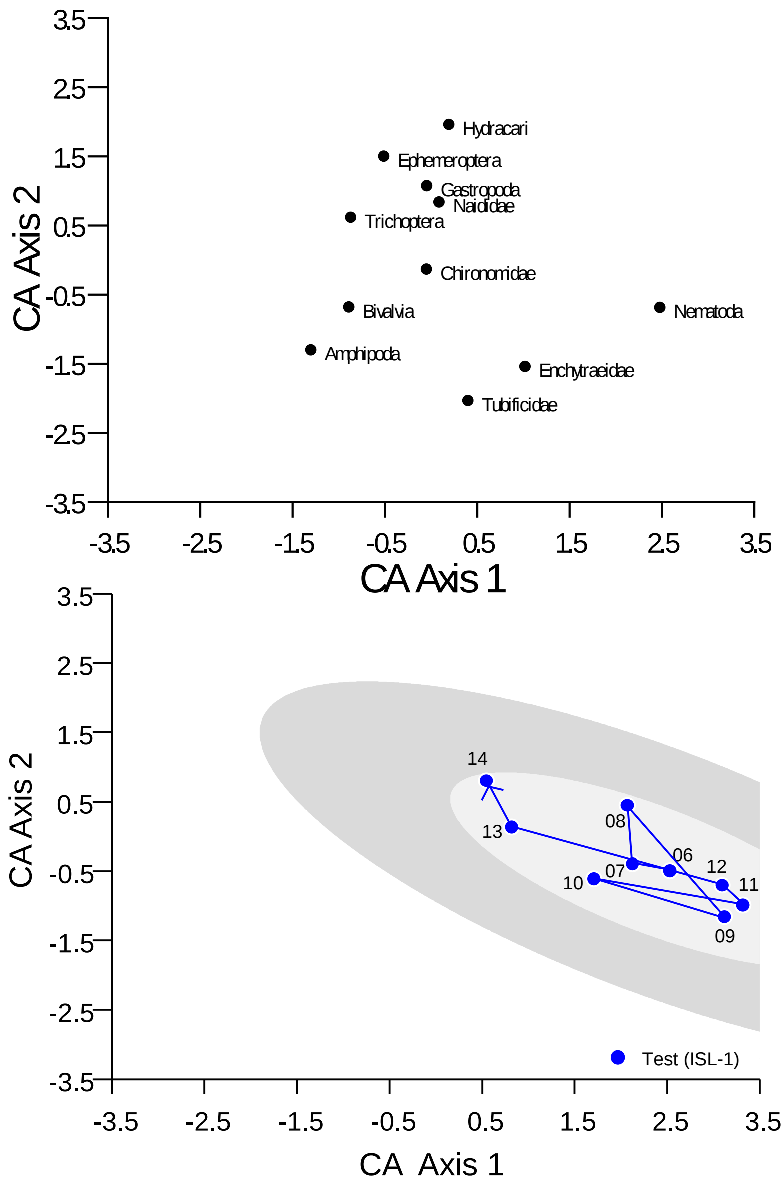
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

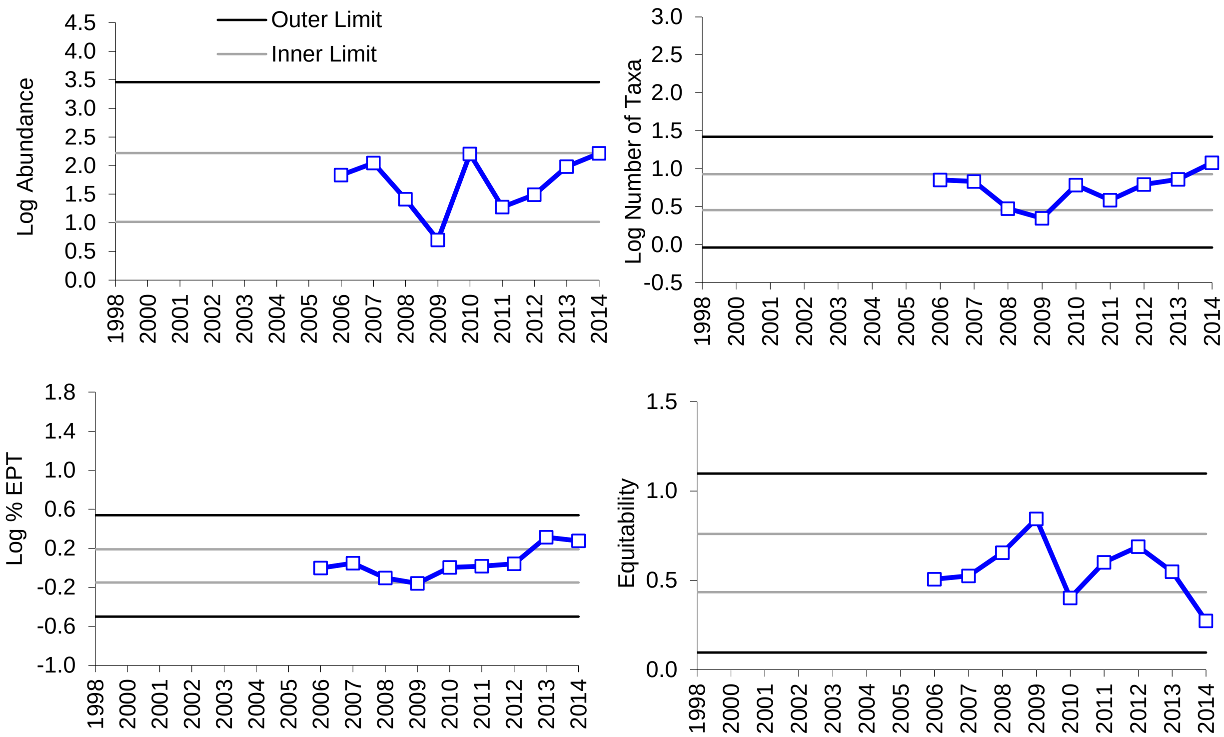
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-8 Ordination (Correspondence Analysis) of benthic invertebrate communities in regional lakes, showing Isadore's Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.13-9 Variation in benthic invertebrate community measurement endpoints in Isadore's Lake (*test* station ISL-1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2006 to 2013.

Note: Values shown have been adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.13-11 Concentrations of sediment quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	29.6	9	11.3	26	57
Silt	%	-	55	9	0.74	60.8	85.5
Sand	%	-	15.4	9	1.58	12	77.8
Total organic carbon	%	-	7.27	9	1.3	4.65	18.8
Total hydrocarbons							
BTEX	mg/kg	-	<100	8	<5	<15	<130
Fraction 1 (C6-C10)	mg/kg	30[1]	**<100**	8	<5	<15	**<130**
Fraction 2 (C10-C16)	mg/kg	150[1]	**1,670**	8	<5	<49	<126
Fraction 3 (C16-C34)	mg/kg	300[1]	**649**	8	150	**431**	**4,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	349	8	89	285.5	**3,500**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0049	9	0.0051	0.0067	0.0119
Retene	mg/kg	-	0.625	9	0.0367	0.0556	0.32
Total dibenzothiophenes	mg/kg	-	0.367	9	0.115	0.174	0.689
Total PAHs	mg/kg	-	2.519	9	0.779	1.539	3.534
Total Parent PAHs	mg/kg	-	0.15	9	0.068	0.143	0.256
Total Alkylated PAHs	mg/kg	-	2.37	9	0.711	1.415	3.278
Predicted PAH toxicity[3]	H.I.	1.0	0.2755	9	0.0723	0.5954	**1.2875**
Metals that exceeded CCME guidelines in 2014							
Total Arsenic	mg/kg	5.9	**7.47**	9	3.6	6.3	7.4
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.1	6	6.4	7.2	9
Chironomus growth - 10d	mg/organism	-	2.27	6	1.1	2.5	3
Hyalella survival - 14d	# surviving	-	7.5	6	6.4	8.6	9.8
Hyalella growth - 14d	mg/organism	-	0.46	6	0.2	0.3	0.4

Values in **bold** indicate concentrations exceeding guidelines.

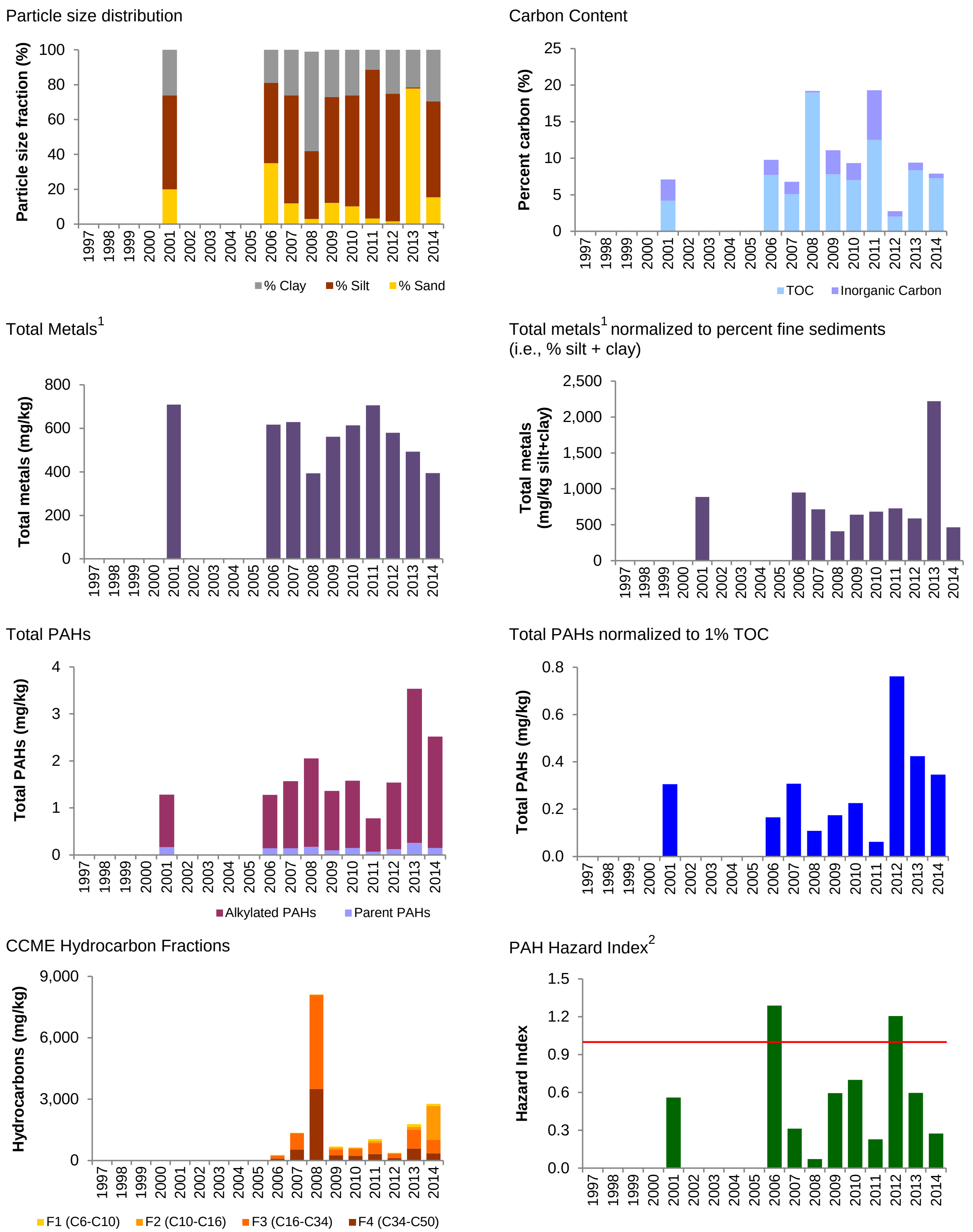
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-10 Variation in sediment quality measurement endpoints in Isadore's Lake, *test* station ISL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-12 Concentrations of water quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	12	7.7	8.2	8.3
Total suspended solids	mg/L	-	<3.0	12	<3.0	6.0	10
Conductivity	µS/cm	-	891	12	353	568.5	769
Nutrients							
Total dissolved phosphorus	mg/L	-	0.004	12	0.003	0.008	0.067
Total nitrogen	mg/L	-	0.594	12	0.300	1.00	1.25
Nitrate+nitrite	mg/L	3	<0.054	12	<0.050	<0.086	0.300
Dissolved organic carbon	mg/L	-	10.2	12	8.00	10.6	12.9
Ions							
Sodium	mg/L	-	16.2	12	6.00	11.2	16.4
Calcium	mg/L	-	107	12	37.0	63.5	90.4
Magnesium	mg/L	-	37.0	12	25.0	29.9	36.0
Chloride	mg/L	120	38.8	12	4.0	16.8	35.2
Sulphate	mg/L	429	277	12	63.9	109	243
Total dissolved solids	mg/L	-	591	12	250	376	591
Total alkalinity	mg/L	-	126	12	116	153	227
Selected metals							
Total aluminum	mg/L	0.1	0.030	12	0.006	0.018	**0.182**
Dissolved aluminum	mg/L	0.05	0.0004	12	<0.001	<0.001	0.020
Total arsenic	mg/L	0.005	0.00054	12	0.00046	0.00072	0.00116
Total boron	mg/L	1.2	0.054	12	0.035	0.043	0.061
Total molybdenum	mg/L	0.073	0.00001	12	<0.00001	0.00010	0.00013
Total mercury (ultra-trace)	ng/L	5, 13	0.56	10	0.53	<1.2	1.6
Total strontium	mg/L	-	0.292	12	0.162	0.235	0.319
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.31	3	0.07	0.13	0.45
Oilsands Extractable	mg/L	-	1.70	3	0.38	0.67	1.29
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<14.13	<15.16
Retene	ng/L	-	0.429	3	<0.509	<0.717	<2.071
Total dibenzothiophenes	ng/L	-	7.249	3	6.020	8.089	35.45
Total PAHs	ng/L	-	81.47	3	107.2	176.7	308.2
Total Parent PAHs	ng/L	-	13.40	3	18.04	21.75	23.37
Total Alkylated PAHs	ng/L	-	68.06	3	83.88	155.0	290.1
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.004	**0.0225**	12	<0.002	**0.0080**	**0.0878**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.13-13 Average habitat characteristics of benthic invertebrate sampling locations in Shipyard Lake, fall 2014.

Variable	Units	Shipyard Lake
Sample date	-	Sept 3, 2014
Habitat	-	Depositional
Water depth	m	1
Field Water Quality		
Dissolved oxygen	mg/L	12.5
Conductivity	µS/cm	362
pH	pH units	9.3
Water temperature	°C	18.5
Sediment Composition (mean ± 1SD)		
Sand	%	50±19
Silt	%	29±12
Clay	%	21±7
Total Organic Carbon	%	15.4±5.0

Table 5.13-14 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community of Shipyard Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	2000	2001-2013	2014
Hydra	-	0 to <1	-
Nematoda	-	0 to 21	7
Naididae	8	0 to 33	23
Tubificidae	1	0 to 7	3
Enchytraeidae	-	0 to 7	<1
Lumbriculidae	-	0 to <1	-
Hirudinea	-	0 to 1	<1
Hydracarina	-	0 to 4	5
Amphipoda	7	0 to 3	18
Gastropoda	18	<1 to 28	2
Bivalvia	7	<1 to 8	1
Ceratopogonidae	-	0 to 6	<1
Chironomidae	25	3 to 48	36
Diptera (misc)	3	0 to 53	<1
Ephemeroptera	16	0 to 6	<1
Odonata	3	0 to 1	<1
Trichoptera	2	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	95	28 to 1,254	574
Richness	13	4 to 27	16
Equitability	0.56	0.16 to 0.75	0.08
% EPT	19	<1 to 5	2

Table 5.13-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Shipyard Lake (SHL-1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2014 vs. Previous Years	Time Trend	2014 vs. Previous Years	
Log of Abundance	**<0.001**	**0.016**	17	4	Increasing over time; higher in 2014 than mean of previous years.
Log of Richness	**<0.001**	**0.037**	21	4	Increasing over time; higher in 2014 than mean of previous years.
Equitability	**<0.001**	**<0.001**	30	37	Decreasing over time; lower in 2014 than mean of previous years.
Log of EPT	**0.001**	**0.016**	7	1	Decreasing over time.
CA Axis 1	**0.001**	**0.037**	17	1	Increasing over time.
CA Axis 2	**0.033**	0.674	9	0	Increasing over time.

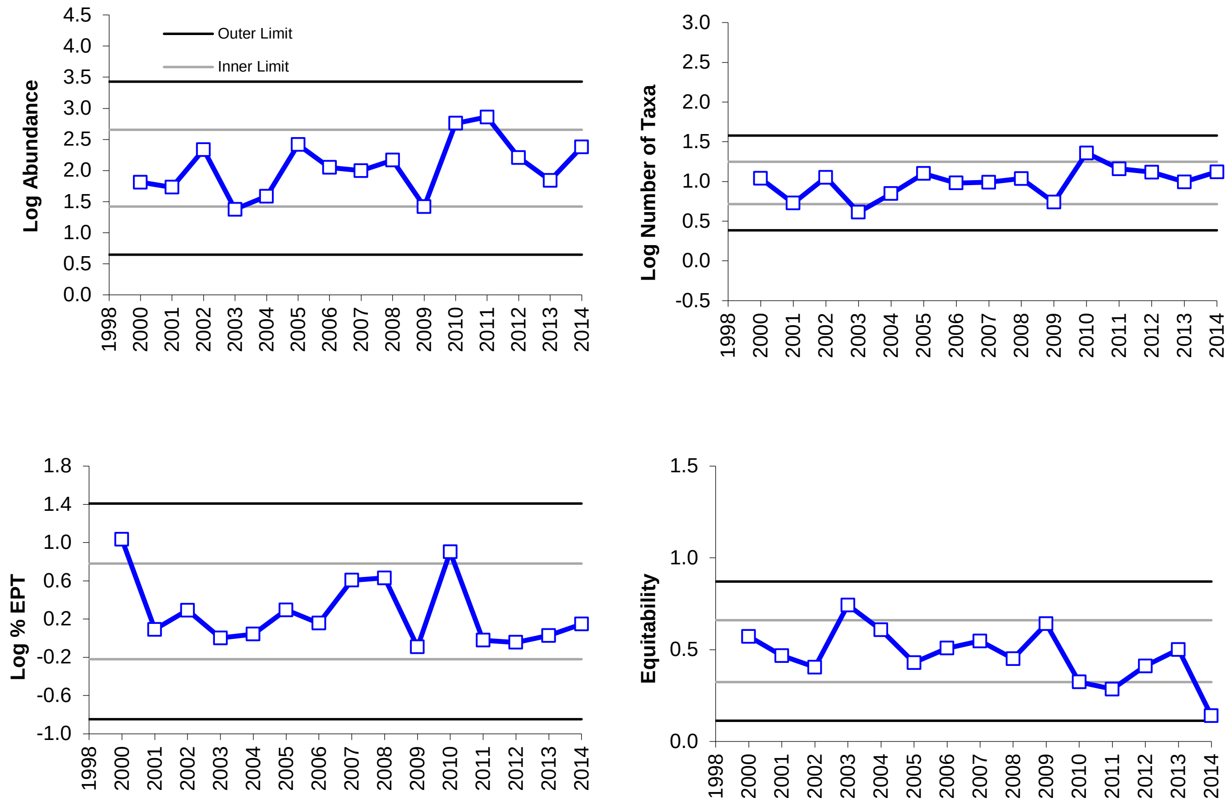
Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-11 Variation in benthic invertebrate community measurement endpoints in Shipyard Lake (*test* station SHL-1).

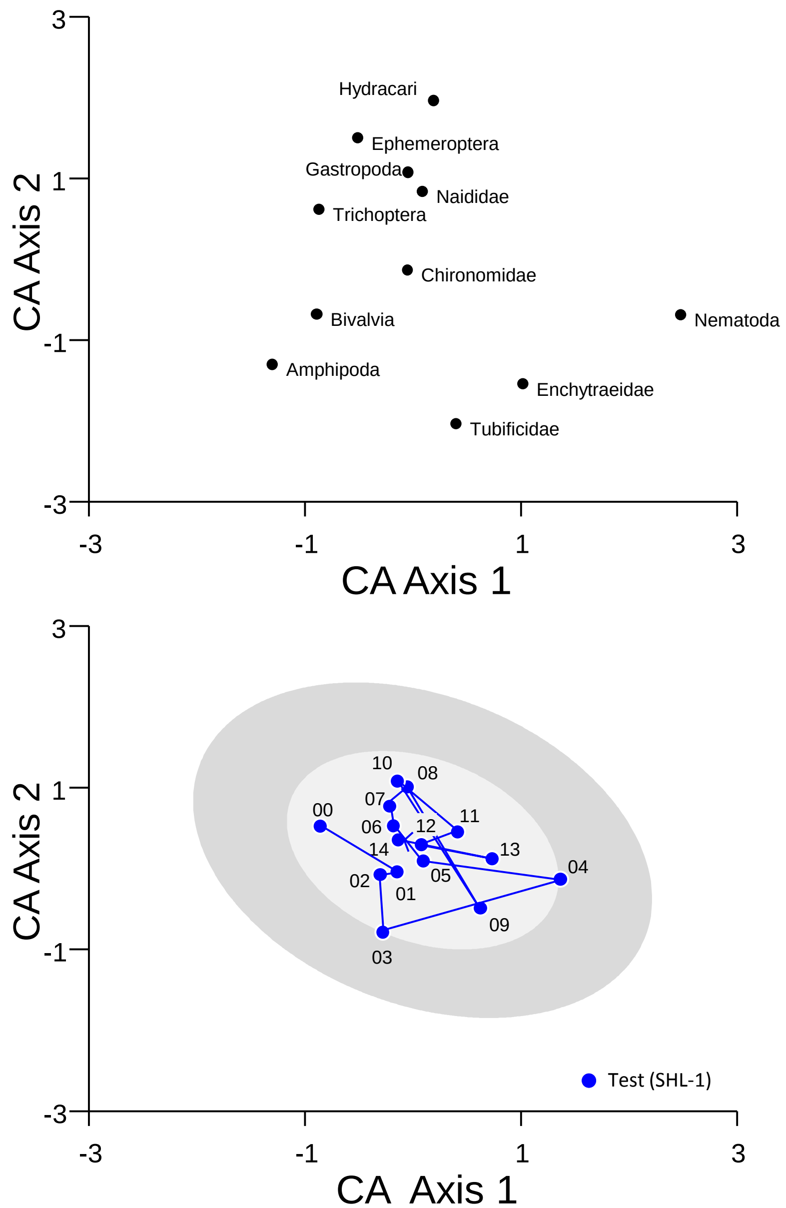


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2000 to 2013.

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.13-12 Ordination (Correspondence Analysis) of benthic invertebrate communities in regional lakes, showing Shipyard Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.13-16 Concentrations of sediment quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	9.6	11	12.8	36	60
Silt	%	-	16.4	11	36	42	86.2
Sand	%	-	74	11	1	5	40.8
Total organic carbon	%	-	25.9	12	5.5	12.5	19.6
Total hydrocarbons							
BTEX	mg/kg	-	<300	9	<5	<60	<240
Fraction 1 (C6-C10)	mg/kg	30[1]	**<300**	9	<5	<60	<240
Fraction 2 (C10-C16)	mg/kg	150[1]	**6,750**	9	<5	<102	**<313**
Fraction 3 (C16-C34)	mg/kg	300[1]	**3,030**	9	290	**939**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	1,400	9	<5	450	1,180
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0149	10	0.0108	0.0193	0.0306
Retene	mg/kg	-	0.12	12	0.046	0.0811	0.199
Total dibenzothiophenes	mg/kg	-	2.387	12	0.2645	0.8367	2.6221
Total PAHs	mg/kg	-	9.126	12	2.2756	5.874	10.7175
Total Parent PAHs	mg/kg	-	0.555	12	0.2305	0.3087	0.6725
Total Alkylated PAHs	mg/kg	-	8.571	12	2.02	5.5116	10.106
Predicted PAH toxicity[3]	H.I.	1.0	0.2337	12	0.0969	0.7904	**3.7862**
Metals that exceeded CCME guidelines in 2014							
Total Arsenic	mg/kg	5.9	**6.34**	12	5.5	**6.82**	**7.97**
Other analytes that exceeded CCME guidelines in 2014							
Benz[a]anthracene	mg/kg	0.0317	**0.052**	12	0.01	0.022	**0.064**
Benzo[a]pyrene	mg/kg	0.0319	**0.063**	12	0.013	0.027	**0.079**
Chrysene	mg/kg	0.0571	**0.139**	12	0.0334	0.0589	**0.1630**
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.0179**	12	0.0041	**0.0106**	**0.0273**
Phenanthrene	mg/kg	0.0419	**0.0605**	12	0.0258	0.0408	**0.0678**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6	8	5.6	7.6	8.8
Chironomus growth - 10d	mg/organism	-	2.68	8	1.25	2.09	4.04
Hyalella survival - 14d	# surviving	-	6.4	8	4	8	8.4
Hyalella growth - 14d	mg/organism	-	0.44	8	0.10	0.27	0.45

Values in **bold** indicate concentrations exceeding guidelines.

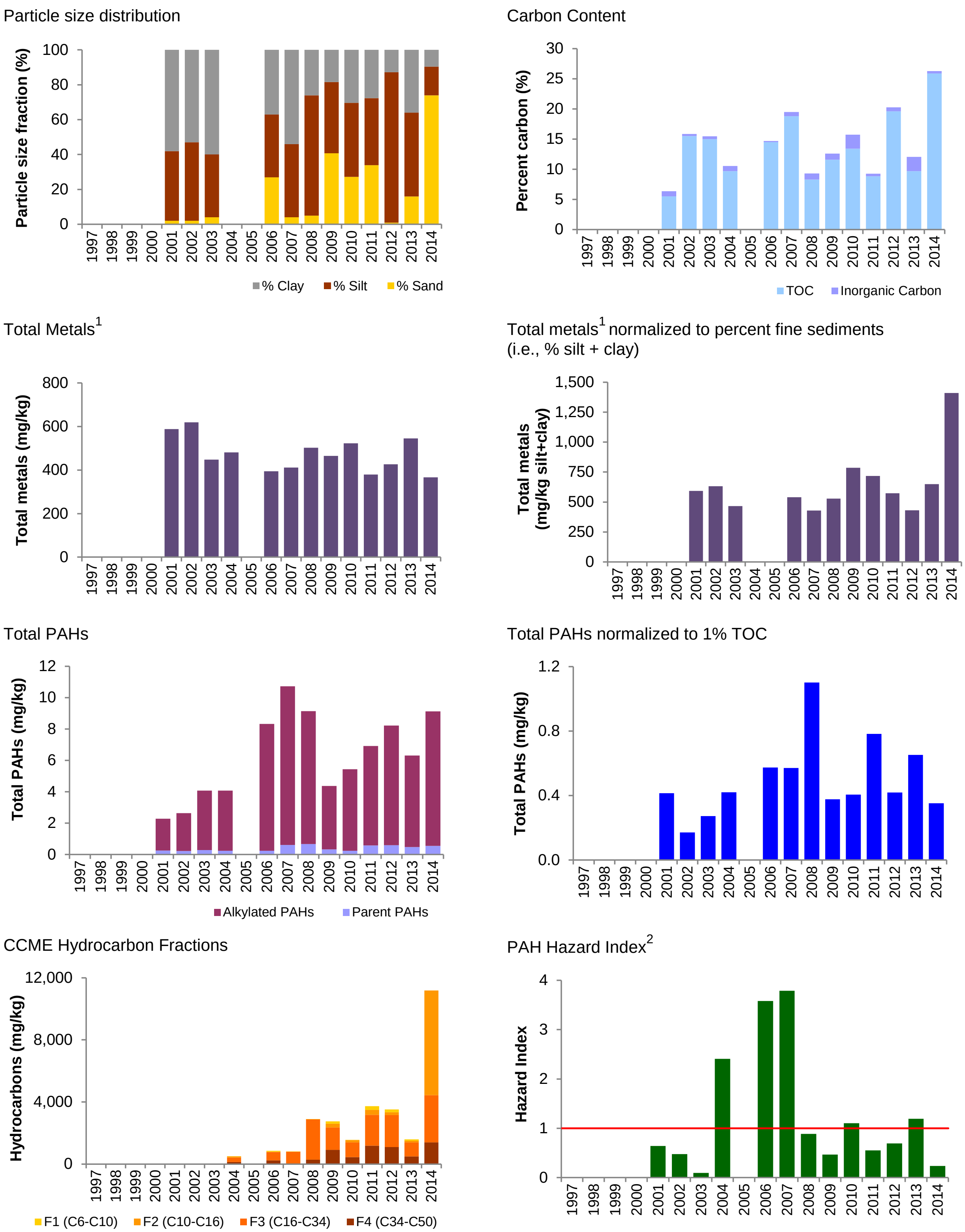
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

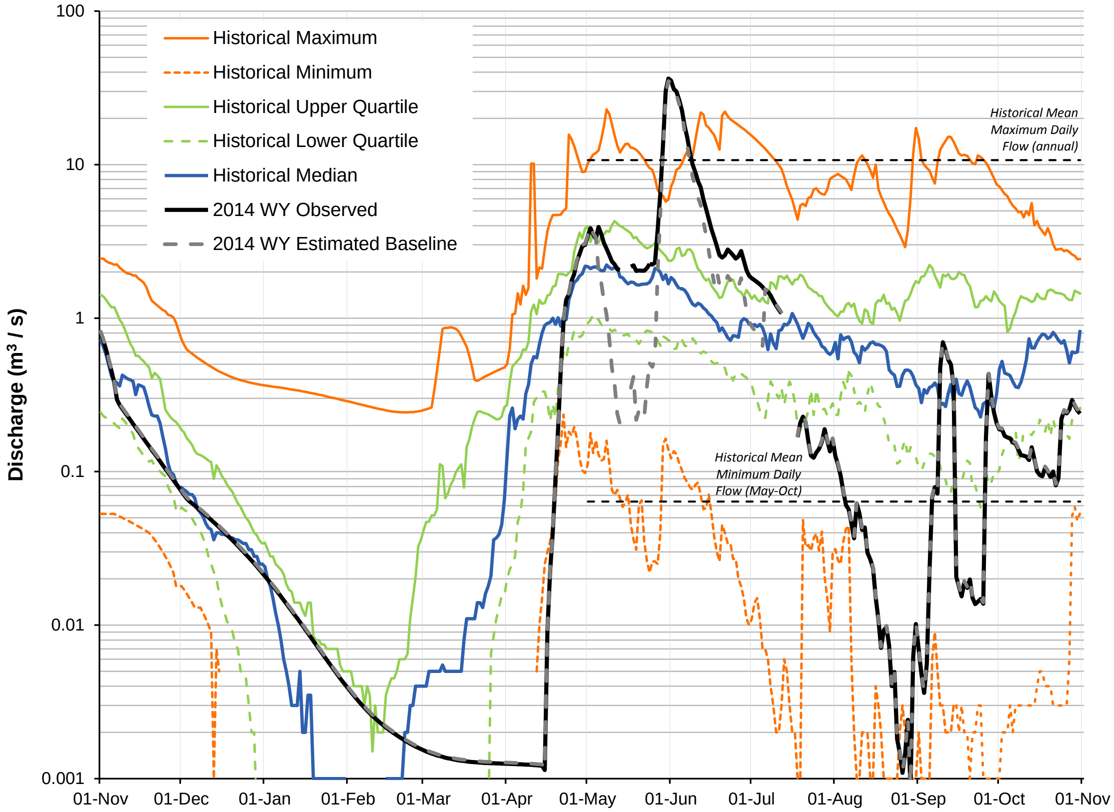
Figure 5.13-13 Variation in sediment quality measurement endpoints in Shipyard Lake, *test* station SHL-1.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.13-14 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Poplar Creek in 2014, compared to historical values.



Note: Observed 2014 WY hydrograph based on Poplar Creek at Highway 63, JOSMP Station S11 (WSC 07DA007). The upstream drainage area is 151 km^2. Historical values from May 1 to October 31 calculated from data collected from 1973 to 1986 and 1996 to 2013, and from 1973 to 1986 for other months.

Note: The historical mean minimum daily flow was calculated for open-water months only (May to October). The historical mean maximum daily flow was calculated annually, but only shown for open-water months (May to October) for clarity.

Table 5.13-17 Estimated water balance at WSC Station 07DA007 (JOSMP Station S11), Poplar Creek at Highway 63, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**42.231**	**Observed daily discharges, obtained from Poplar Creek at Highway 63, WSC Station 07DA007 (JOSMP Station S11).**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.726	Estimated 3.1 km^2 of the Poplar Creek watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	+0.089	Estimated 1.9 km^2 of the Poplar Creek watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Poplar Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Poplar Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	+7.943	Diversion from original upper Beaver River catchment area into Poplar Creek via the spillway (daily values provided by Syncrude).
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**34.925**	**Estimated *baseline* discharge at Poplar Creek at Highway 63, WSC Station 07DA007 (JOSMP Station S11).**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	+7.305	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**20.900**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table were presented to three decimal places.

Table 5.13-18 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed, 2014 WY.

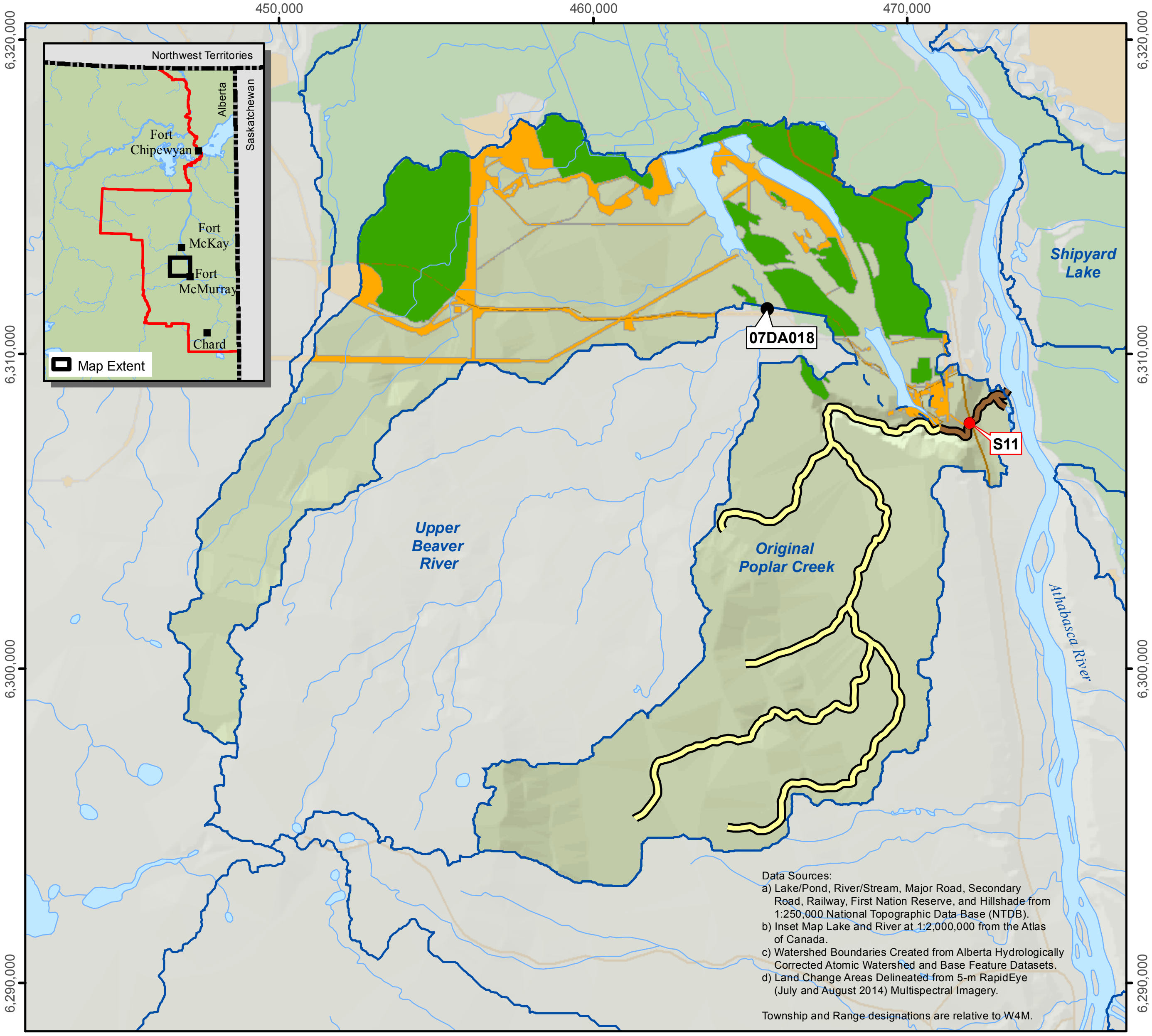
Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	2.616	2.133	+22.7%
Mean winter discharge	0.061	0.062	-1.8%
Annual maximum daily discharge	36.402	35.093	+3.7%
Open-water season minimum daily discharge	0.001	0.001	-1.8%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.13-15 Hydrologic change classification of the Original Poplar Creek, 2014 WY.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Sub-Watershed Boundary
- Major Road
- Secondary Road

Land Change Area as of 2014[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Hydrometric Station

- JOSMP Year-Round
- Water Survey of Canada

Hydrologic Change Classification

- Negligible-Low
- High

0 1 2 4 km

Scale: 1:200,000

Projection: NAD 1983 UTM Zone 12N

N

Hatfield CONSULTANTS

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Table 5.13-19 Concentrations of water quality measurement endpoints, lower Beaver River (*test* station BER-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.6</u>	11	8.0	8.1	8.4
Total suspended solids	mg/L	-	5.1	11	<3	13	150
Conductivity	µS/cm	-	1,500	11	566	1070	1,930
Nutrients							
Total dissolved phosphorus	mg/L	-	0.006	11	0.004	0.008	0.022
Total nitrogen	mg/L	-	<u>0.644</u>	11	0.700	**0.91**	**1.68**
Nitrate+nitrite	mg/L	3	<0.054	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	21.2	11	3.10	26.0	52.0
Ions							
Sodium	mg/L	-	173	11	53.0	118	267
Calcium	mg/L	-	<u>120</u>	11	49.1	72.9	116
Magnesium	mg/L	-	30.2	11	15.5	21.7	34.1
Chloride	mg/L	120	**205**	11	55.0	105	**364**
Sulphate	mg/L	309	94.3	11	50.7	72.3	128
Total dissolved solids	mg/L	-	888	11	450	654	1110
Total alkalinity	mg/L	-	<u>371</u>	11	158	266	363
Selected metals							
Total aluminum	mg/L	0.1	**0.108**	11	0.031	**0.318**	**5.320**
Dissolved aluminum	mg/L	0.05	<u>0.001</u>	11	0.002	0.005	0.045
Total arsenic	mg/L	0.005	0.0010	11	0.0007	0.0011	0.0021
Total boron	mg/L	1.2	0.18	11	0.09	0.15	0.24
Total molybdenum	mg/L	0.073	0.00034	11	0.00019	0.00031	0.00066
Total mercury (ultra-trace)	ng/L	5, 13	0.80	11	<1.2	1.9	**8.1**
Total strontium	mg/L	-	0.49	11	0.23	0.32	0.63
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	5.90	3	1.26	3.79	7.26
Oilsands Extractable	mg/L	-	6.00	3	0.960	3.47	9.34
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<15.16	15.70
Retene	ng/L	-	<u>0.482</u>	3	5.030	8.260	57.10
Total dibenzothiophenes	ng/L	-	<u>9.479</u>	3	39.94	42.03	49.63
Total PAHs	ng/L	-	<u>88.19</u>	3	334.7	363.4	372.3
Total Parent PAHs	ng/L	-	<u>13.86</u>	3	25.11	30.31	33.47
Total Alkylated PAHs	ng/L	-	<u>74.32</u>	3	301.2	338.3	342.0
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Total iron	mg/L	0.3	**5.56**	11	**1.79**	**3.49**	**6.97**
Total phenols	mg/L	0.004	**0.0063**	10	0.0020	**0.0080**	**0.0147**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.13-20 Concentrations of water quality measurement endpoints, Poplar Creek (*test* station POC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	14	8.2	8.3	8.4
Total suspended solids	mg/L	-	11	14	4.0	10	61
Conductivity	µS/cm	-	1,710	14	308	471	1,590
Nutrients							
Total dissolved phosphorus	mg/L	-	0.005	14	0.007	0.013	0.027
Total nitrogen	mg/L	-	1.15	14	0.300	1.08	2.11
Nitrate+nitrite	mg/L	3	<0.054	14	<0.050	0.100	0.100
Dissolved organic carbon	mg/L	-	27.1	14	4.70	25.0	32.0
Ions							
Sodium	mg/L	-	212	14	10.0	47.9	238
Calcium	mg/L	-	93.3	14	28.2	40.2	74.4
Magnesium	mg/L	-	30.4	14	9.70	14.4	29.3
Chloride	mg/L	120	**308**	14	2.00	29.0	**321**
Sulphate	mg/L	429	46.7	14	7.80	14.7	44.2
Total dissolved solids	mg/L	-	981	14	200	313	890
Total alkalinity	mg/L	-	356	14	135	195	304
Selected metals							
Total aluminum	mg/L	0.1	**0.289**	14	0.050	**0.291**	**1.44**
Dissolved aluminum	mg/L	0.05	0.0016	14	0.0019	0.0071	<0.090
Total arsenic	mg/L	0.005	0.0031	14	0.0008	0.0011	0.0023
Total boron	mg/L	1.2	0.215	14	0.039	0.136	0.179
Total molybdenum	mg/L	0.073	0.00096	14	0.00010	0.00027	0.00072
Total mercury (ultra-trace)	ng/L	5, 13	1.73	11	0.800	1.20	2.00
Total strontium	mg/L	-	0.547	14	0.149	0.239	0.513
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	0.46	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.60	3	0.19	0.59	0.81
Oilsands Extractable	mg/L	-	5.30	3	0.51	1.81	1.98
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.756	<14.13	<15.16
Retene	ng/L	-	1.10	3	1.30	1.99	2.17
Total dibenzothiophenes	ng/L	-	47.15	3	16.96	20.22	51.68
Total PAHs	ng/L	-	203.8	3	149.4	184.6	281.8
Total Parent PAHs	ng/L	-	16.13	3	18.16	20.41	24.45
Total Alkylated PAHs	ng/L	-	187.7	3	124.9	164.2	263.7
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.0034**	14	<0.003	**0.0066**	**0.0102**
Total iron	mg/L	0.3	**5.30**	14	**0.70**	**1.23**	**3.63**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.13-21 Concentrations of water quality measurement endpoints, upper Beaver River (*baseline* station BER-2), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	7.8	8.2	8.4
Total suspended solids	mg/L	-	5.4	6	6.0	9.0	93
Conductivity	µS/cm	-	558	6	255	429	511
Nutrients							
Total dissolved phosphorus	mg/L	-	0.052	6	0.037	0.065	0.105
Total nitrogen	mg/L	-	0.734	6	0.891	1.16	2.44
Nitrate+nitrite	mg/L	3	<0.054	6	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	17.6	6	17.6	25.45	34.0
Ions							
Sodium	mg/L	-	75.3	6	20.9	49.1	67.7
Calcium	mg/L	-	36.3	6	22.5	31.9	35.8
Magnesium	mg/L	-	12.5	6	7.52	10.9	12.2
Chloride	mg/L	120	1.59	6	0.680	1.51	2.00
Sulphate	mg/L	309	17.7	6	12.5	14.7	15.3
Total dissolved solids	mg/L	-	382	6	210	328	348
Total alkalinity	mg/L	-	285	6	118	220	266
Selected metals							
Total aluminum	mg/L	0.1	**0.486**	6	**0.266**	**0.466**	**2.17**
Dissolved aluminum	mg/L	0.05	0.011	6	0.012	0.025	0.034
Total arsenic	mg/L	0.005	0.0014	6	0.0014	0.0017	0.0019
Total boron	mg/L	1.2	0.420	6	0.089	0.242	0.424
Total molybdenum	mg/L	0.073	0.00075	6	0.00020	0.00048	0.00063
Total mercury (ultra-trace)	ng/L	5, 13	2.40	6	0.90	2.35	**10.6**
Total strontium	mg/L	-	0.212	6	0.146	0.194	0.267
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.37	3	0.32	0.37	0.44
Oilsands Extractable	mg/L	-	0.90	3	0.27	0.87	0.88
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	9.58	<14.13	<15.16
Retene	ng/L	-	1.310	3	1.260	1.850	2.860
Total dibenzothiophenes	ng/L	-	4.134	3	5.844	6.695	35.31
Total PAHs	ng/L	-	74.20	3	103.9	151.1	205.1
Total Parent PAHs	ng/L	-	13.26	3	17.69	19.20	22.44
Total Alkylated PAHs	ng/L	-	60.94	3	81.44	131.9	187.4
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Dissolved iron	mg/L	0.3	**0.387**	6	**0.737**	**0.924**	**1.70**
Sulphide	mg/L	0.002	**0.005**	6	**0.006**	**0.011**	**0.017**
Total iron	mg/L	0.3	**1.95**	6	**1.79**	**2.00**	**3.23**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.13-16 Piper diagram of fall ion balance at *test* station BER-1, *baseline* station BER-2, and *test* station POC-1, 1999 to 2014.

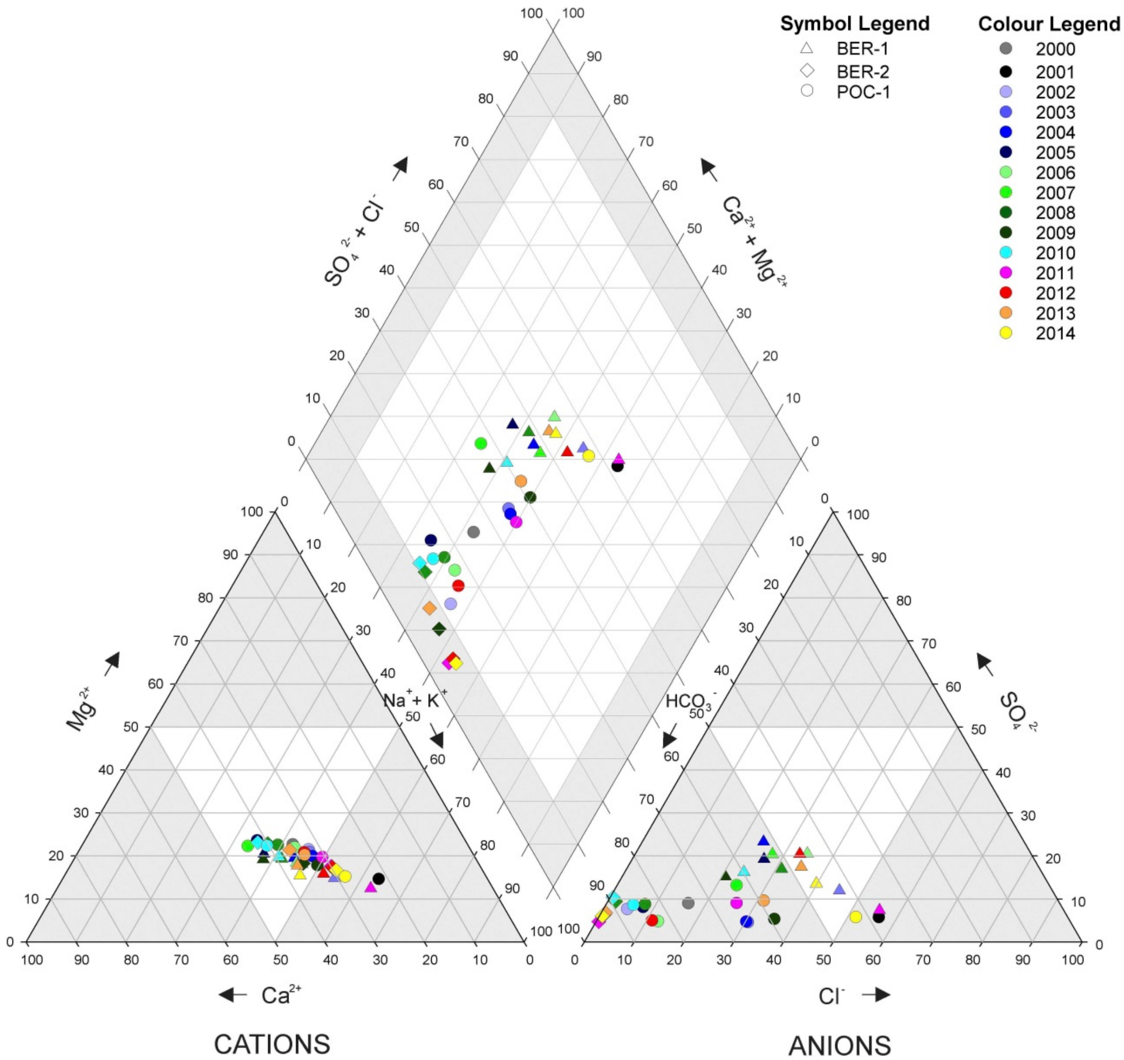
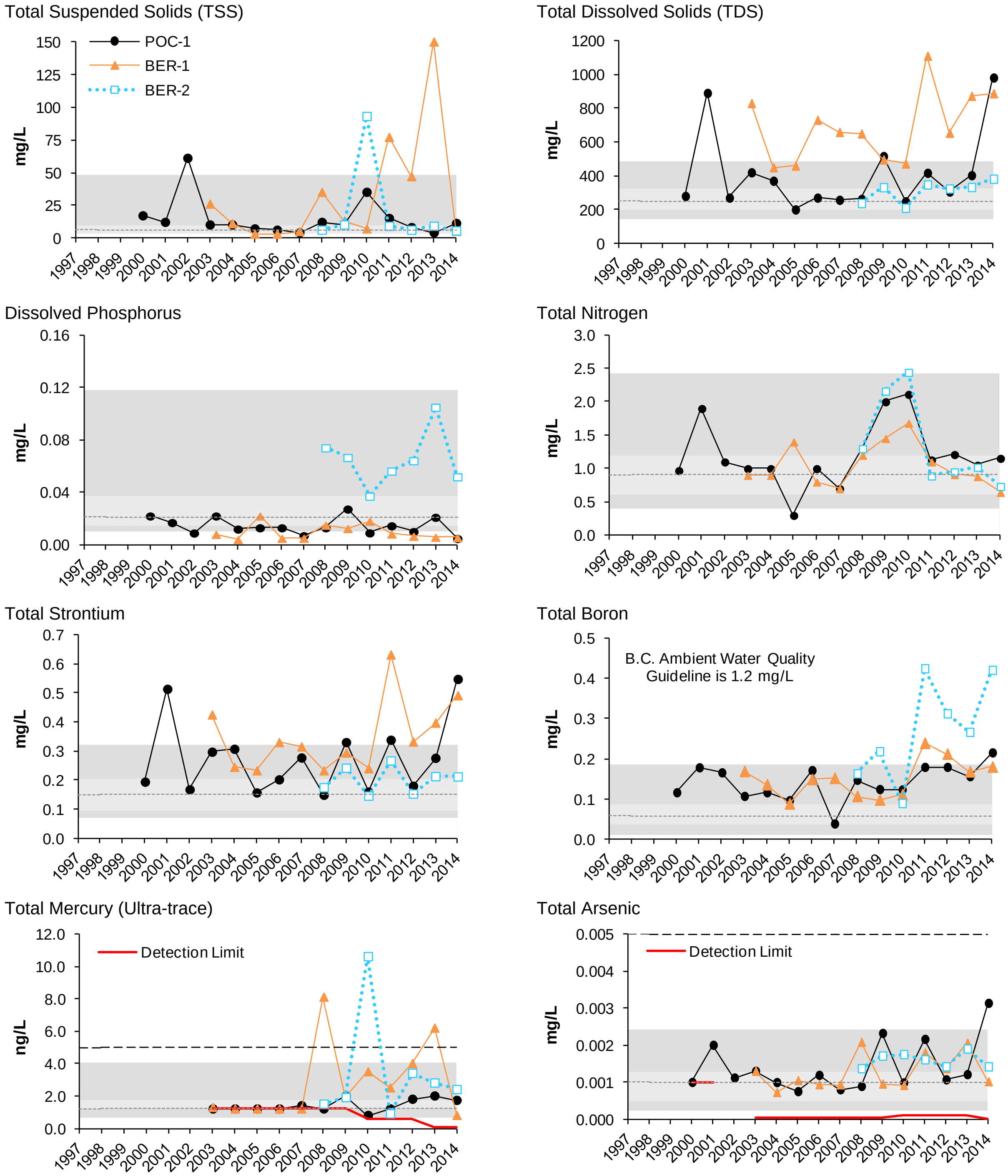


Figure 5.13-17 Concentrations of selected water quality measurement endpoints in *test* station BER-1, *test* station POC-1, and *baseline* station BER-2 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



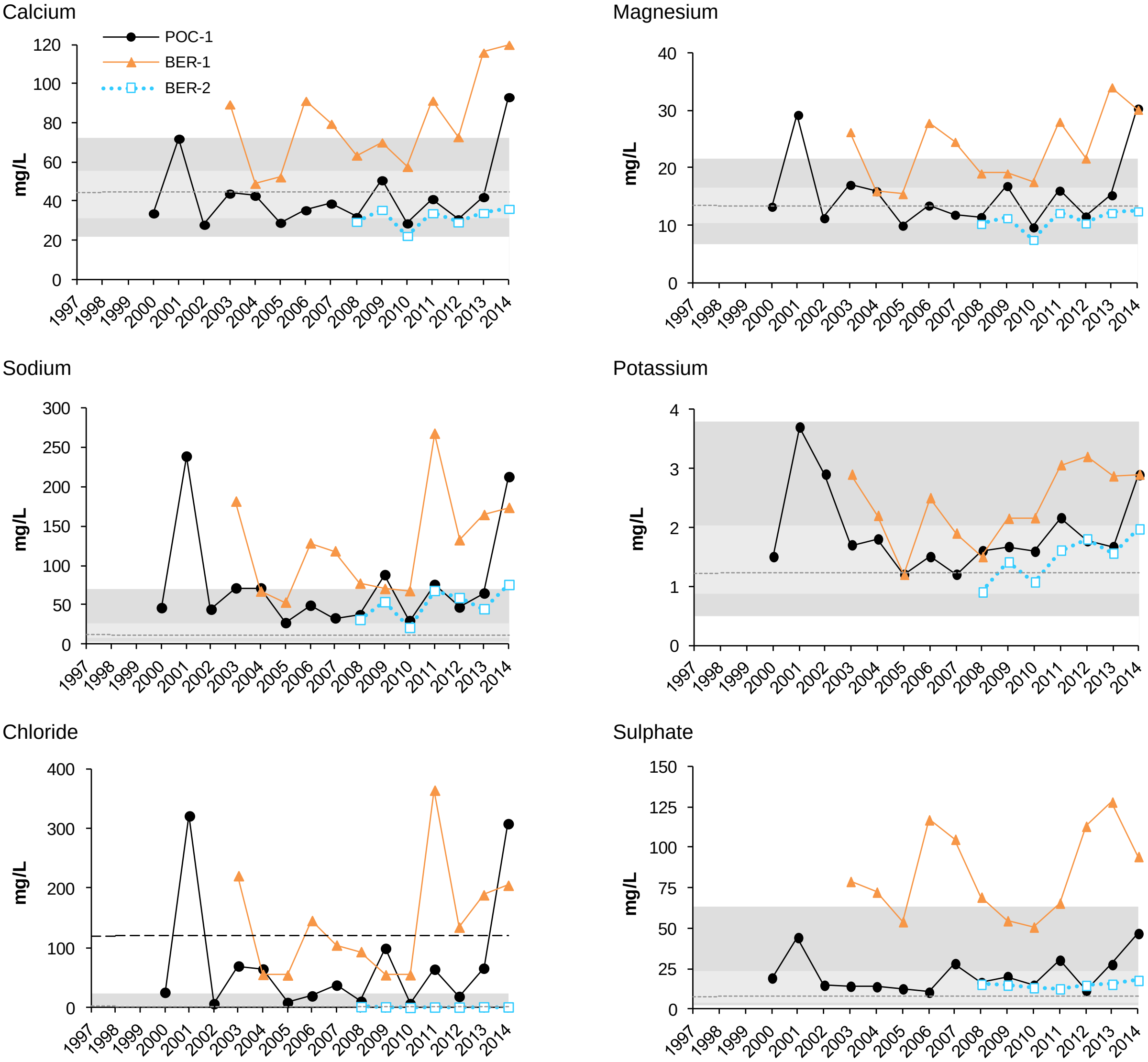
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O⋯⋯O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of fall sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-17 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of fall sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.13-22 Monthly water quality measurement endpoints, Poplar Creek (*test* station POC-1), January to December, 2014.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence						2013 Range (n=12)	
			n	Min		Median	Max		Min	Max
Physical variables										
pH	pH units	6.5-9.0	11	7.76	(May)	7.98	8.35	(October)	7.85	8.37
Total suspended solids	mg/L	-	11	19.4	(May)	27	32.7	(August)	<3	147
Conductivity	µS/cm	-	11	285	(June)	543	1820	(January)	247	899
Nutrients										
Total dissolved phosphorus	mg/L	-	11	0.005	(September)	0.014	0.039	(July)	0.004	0.028
Total nitrogen	mg/L	-	11	0.794	(October)	0.914	1.189	(March)	0.801	1.401
Nitrate+nitrite	mg/L	3	11	<0.054	(May-Nov)	<0.054	0.229	(March)	<0.070	0.208
Dissolved organic carbon	mg/L	-	11	20.3	(May)	28.5	32.9	(August)	21.1	33.8
Ions										
Sodium	mg/L	-	11	24.5	(July)	56.2	262.0	(January)	20.1	111.0
Calcium	mg/L	-	11	23.5	(June)	38.4	93.3	(September)	23.8	49.8
Magnesium	mg/L	-	11	8.5	(June)	13.9	30.4	(September)	8.2	20.1
Chloride	mg/L	120	11	4.9	(June)	51.0	**366.0**	(January)	5.0	**127.0**
Sulphate	mg/L	429	11	16.5	(May)	24.7	46.7	(September)	17.2	30.4
Total dissolved solids	mg/L	-	11	192	(May)	323	1070	(January)	217	546
Total alkalinity	mg/L	-	11	123	(June)	180	356	(September)	99	246
Selected metals										
Total aluminum	mg/L	0.1	11	0.053	(March)	**0.282**	**4.99**	(June)	0.043	**3.99**
Dissolved aluminum	mg/L	0.05	11	0.002	(September)	0.007	0.034	(June)	0.003	**0.057**
Total arsenic	mg/L	0.005	11	0.0006	(October)	0.0009	0.0031	(September)	0.0007	0.0012
Total boron	mg/L	1.2	11	0.101	(October)	0.147	0.215	(September)	0.088	0.189
Total molybdenum	mg/L	0.073	11	0.00017	(October)	0.00028	0.00096	(September)	0.00019	0.00321
Total mercury (ultra-trace)	ng/L	5, 13	11	0.765	(March)	1.73	**9.51**	(June)	<0.60	5.00
Total strontium	mg/L	-	11	0.120	(June)	0.258	0.627	(January)	0.127	0.368
Total hydrocarbons										
BTEX	mg/L	-	11	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	11	<0.1	-	<0.1	<0.1	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	11	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	11	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	11	<0.25	-	<0.25	<0.25	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	11	0.04	(July)	0.69	1.60	(August)	0.09	0.62
Oilsands Extractable	mg/L	-	11	0.48	(May)	2.60	9.00	(August)	0.28	1.98
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	11	<7.21	-	<7.21	654	(January)	<15.16	23.90
Retene	ng/L	-	11	0.43	(December)	0.95	55.4	(June)	<0.67	29.20
Total dibenzothiophenes	ng/L	-	11	11.04	(December)	29.14	2954.73	(June)	11.40	1115.00
Total PAHs	ng/L	-	11	95.4	(December)	195.8	8250.3	(June)	133.7	3614.8
Total Parent PAHs	ng/L	-	11	14.50	(March)	17.04	704.28	(January)	22.50	125.28
Total Alkylated PAHs	ng/L	-	11	80.2	(December)	178.9	8106.3	(June)	108.5	3489.5
Other variables that exceeded CCME/AESRD guidelines in 2014[1]										
Total phenols	mg/L	0.004	6	<0.001	(Nov, Dec)	**0.005**	**0.007**	(March)	0.003	**0.010**
Sulphide	mg/L	0.002	11	**0.0034**	(September)	**0.007**	**0.015**	(June)	0.0027	**0.020**
Total iron	mg/L	0.3	11	**0.356**	(March)	**1.960**	**5.300**	(September)	**0.477**	**2.620**
Dissolved iron	mg/L	0.3	6	0.0965	(September)	0.319	**1.870**	(December)	0.255	**1.520**
Total zinc	mg/L	0.03	1	0.000266	(February)	0.002	**0.047**	(November)	0.000446	0.006
Dissolved zinc	mg/L	0.03	1	<0.0002	(February)	0.00109	**0.0407**	(November)	0.000345	0.002
Total chromium	mg/L	0.001	1	<0.0003	(February)	0.00052	**0.00414**	(June)	<0.00030	**0.00381**
Total selenium	mg/L	0.001	2	<0.0003	(March)	0.00024	**0.00122**	(January)	<0.0003	0.00071

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

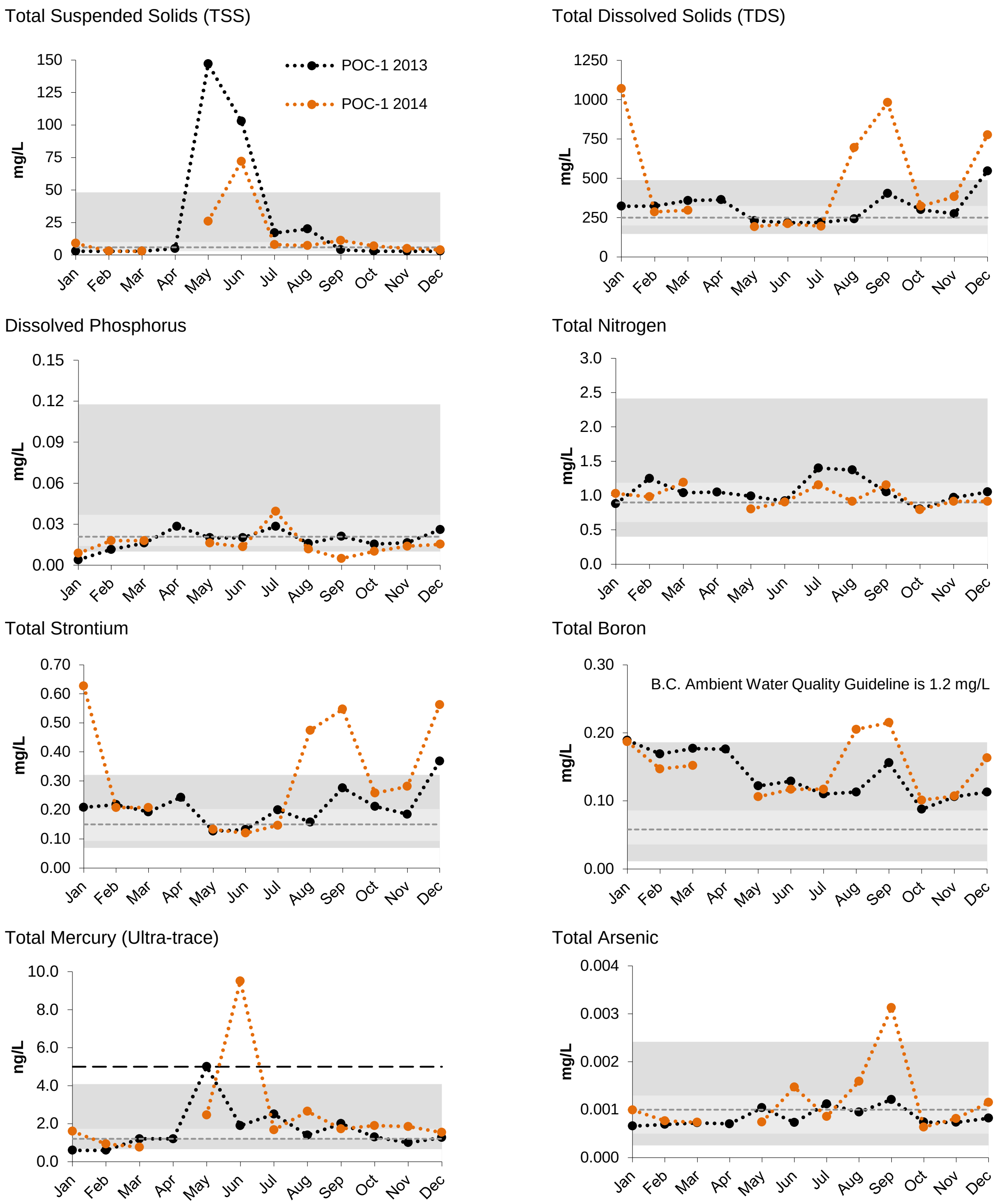
[1] n value refers to number of exceedances in 2014.

Table 5.13-23 Monthly water quality guideline exceedances, Poplar Creek (*test* station POC-1), January to December, 2014.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0049	0.0062	0.0073	ns	0.0062	0.0063	0.0065	-	-	-	-	-
Sulphide	mg/L	0.002	0.0037	0.0065	0.0098	ns	0.0043	0.0154	0.0134	0.0053	0.0034	0.0070	0.0115	0.0045
Total aluminum	mg/L	0.1	-	-	-	ns	0.9390	4.9900	0.2820	0.2720	0.2890	0.3550	0.4100	0.2790
Total iron	mg/L	0.3	2.910	0.424	0.356	ns	1.150	3.500	0.607	2.05	5.3	1.13	1.96	3.45
Dissolved iron	mg/L	0.3	0.545	-	-	ns	0.319	-	-	0.915	-	0.559	1.120	1.870
Total chromium	mg/L	0.001	-	-	-	ns	-	0.0041	-	-	-	-	-	-
Total zinc	mg/L	0.03	-	-	-	ns	-	-	-	-	-	-	0.0474	-
Dissolved zinc	mg/L	0.03	-	-	-	ns	-	-	-	-	-	-	0.0407	-
Chloride	mg/L	120	366	-	-	ns	-	-	-	179	308	-	-	243
Total selenium	mg/L	0.001	0.00122	-	-	ns	-	-	-	0.00113	-	-	-	-
Total mercury (ultra-trace)	ng/L	5,13	-	-	-	ns	-	9.51	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.13-18 Concentrations of selected water quality measurement endpoints in Poplar Creek (monthly data) relative to regional *baseline* fall concentrations.



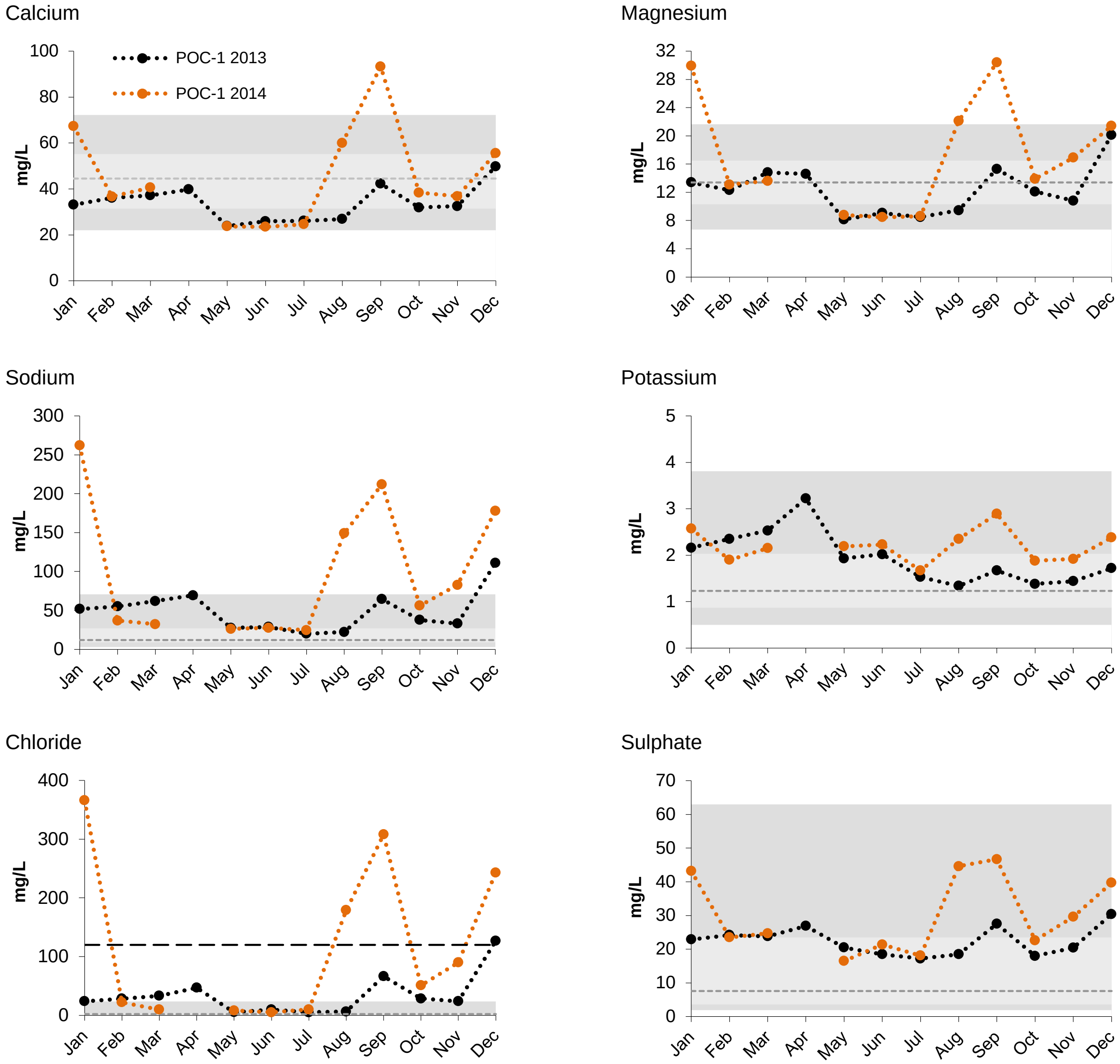
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of fall sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-18 (Cont'd.)



Non-detectable values are shown at the detection limit.

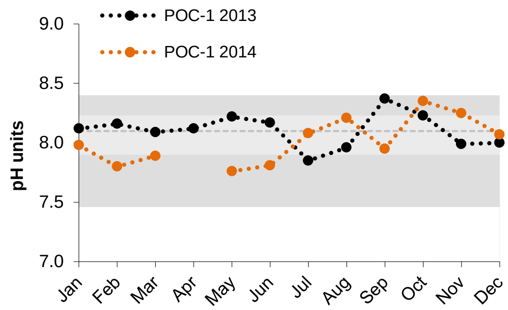
- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

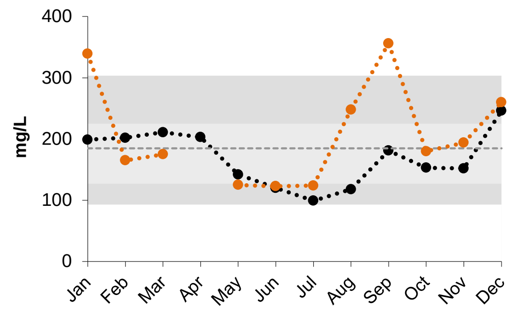
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of fall sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-18 (Cont'd.)

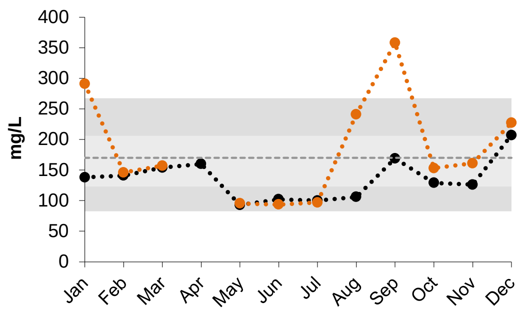
pH



Total Alkalinity



Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●———● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of fall sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-19 Piper diagram of monthly ion concentrations in Poplar Creek (*test* station POC-1).

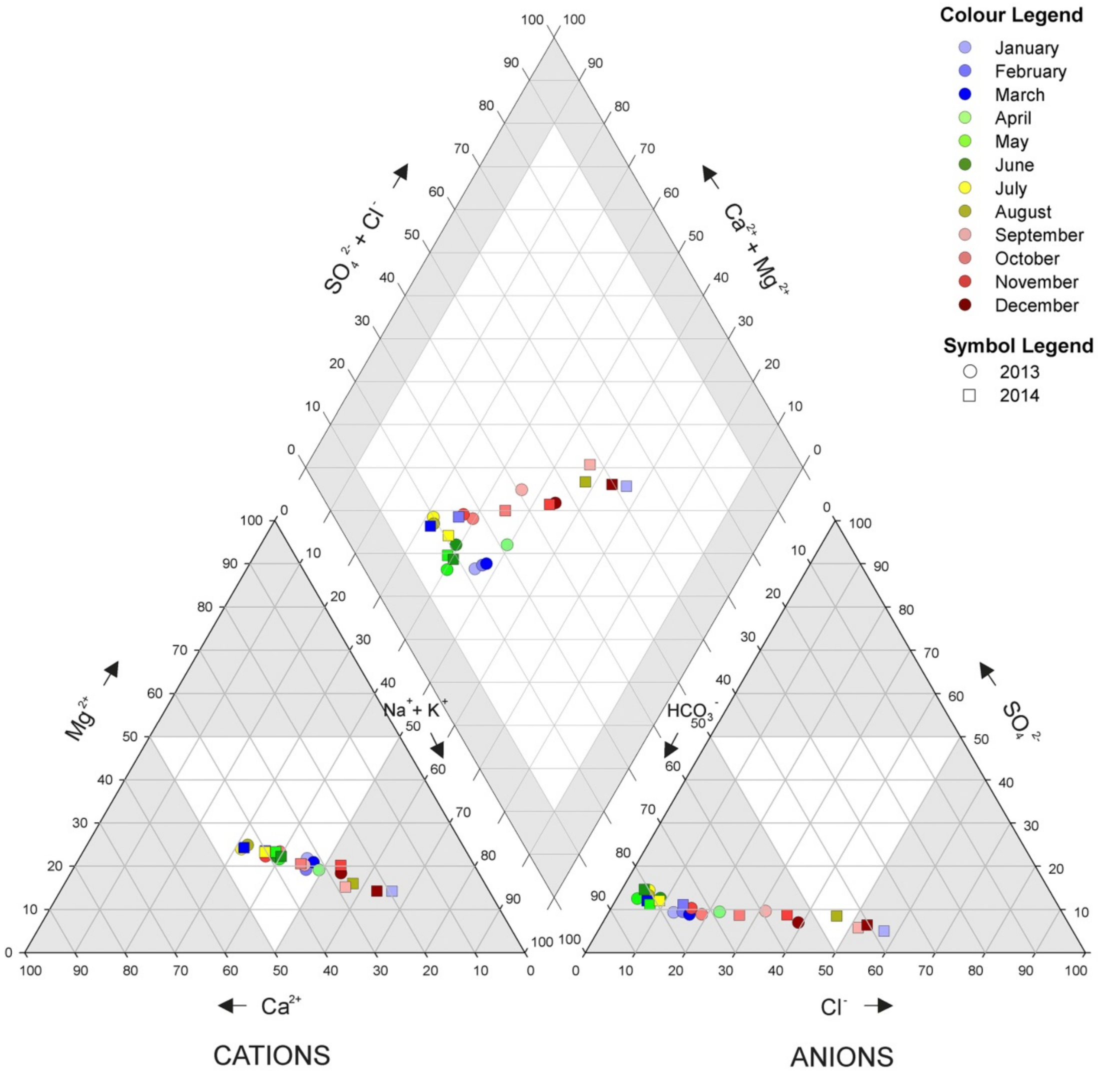


Table 5.13-24 Average habitat characteristics of benthic invertebrate sampling locations in the Beaver River and Poplar Creek, fall 2014.

Variable	Units	BER-D-2 Upper *Baseline* Reach of the Beaver River	POC-D-1 Lower *Test* Reach of Poplar Creek
Sample date	-	Sept 2, 2014	Sept 3, 2014
Habitat	-	Depositional	Depositional
Water depth	m	0.4	0.5
Current velocity	m/s	0.26	0.08
Field Water Quality			
Dissolved oxygen	mg/L	9.4	7.3
Conductivity	µS/cm	499	1444
pH	pH units	7.7	7.0
Water temperature	°C	14.3	13.2
Sediment Composition (mean ± 1SD)			
Sand	%	5±6	66±11
Silt	%	90±9	20±8
Clay	%	4±3	14±5
Total Organic Carbon	%	1.0±1.0	3.1±1.5

Table 5.13-25 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate communities at the upper Beaver River and lower Poplar Creek.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Upper Beaver River (*Baseline* Reach BER-D2)			Lower Poplar Creek (*Test* Reach POC-D1)		
	2008	2009-2013	2014	2008	2009-2013	2014
Hydra	-	0 to <1	<1	-	0 to <1	1
Nematoda	1	<1 to 4	3	2	1 to 5	3
Lumbriculidae	-	-	<1	-	-	-
Naididae	<1	4 to 8	3	<1	<1 to 2	1
Tubificidae	1	2 to 36	13	72	13 to 22	24
Enchytraeidae	<1	0 to 3	<1	-	0 to 17	-
Erpobdellidae	-	<1	-	-	-	-
Hirudinea	<1	0 to <1	-	-	0 to <1	<1
Hydracarina	1	<1 to 8	3	-	0 to <1	<1
Amphipoda	-	<1	<1	-	0 to <1	<1
Gastropoda	<1	<1 to 3	1	-	<1	<1
Bivalvia	1	<1	<1	1	4 to 13	5
Ceratopogonidae	6	3 to 11	5	2	0 to 5	11
Chironomidae	84	32 to 71	52	21	20 to 64	44
Dixidae	-	<1	-	-	-	-
Dolichopodidae	-	<1	-	-	-	-
Diptera (misc.)	1	0 to 3	4	<1	0 to <1	2
Coleoptera	-	2 to 10	3	<1	<1 to 2	1
Ephemeroptera	4	2 to 6	12	<1	<1	5
Odonata	-	<1	-	-	0 to <1	<1
Plecoptera	-	0 to <1	<1	-	-	-
Neuroptera	-	<1	-	-	-	-
Trichoptera	<1	0 to <1	<1	<1	<1	<1
Lepidoptera	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance per sample	174	101 to 672	382	185	364 to 1,054	263
Richness	13	8 to 26	16	8	18 to 25	17
Equitability	0.38	0.26 to 0.63	0.36	0.4	0.26 to 0.77	0.05
% EPT	3	<1 to 4	13	<1	<1	6

Table 5.13-26 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in *test* reach POC-D1 and *baseline* reach BER-D2.

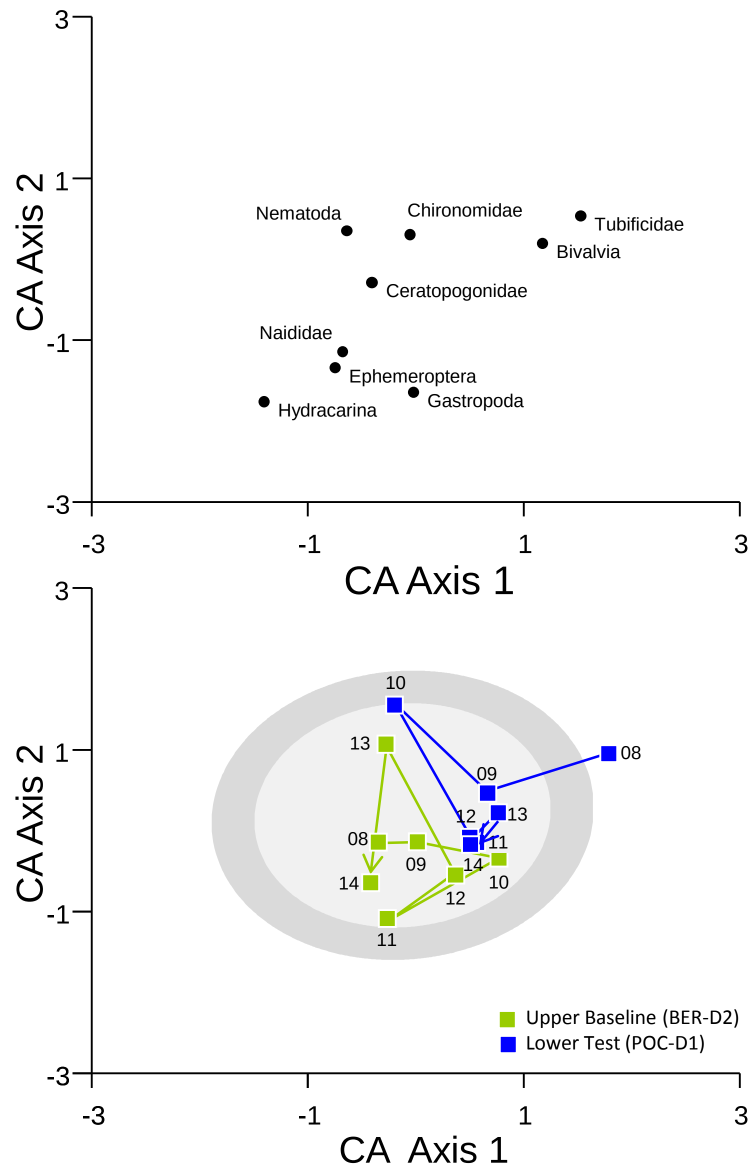
Measurement Endpoint	P-value					Variance Explained (%)					Nature of Change(s)
	Test Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	Difference between *Test* and *Baseline* Reaches (Time Trend)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Period)	Difference between *Test* and *Baseline* Reaches (Time Trend)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**<0.001**	0.477	0.910	**0.243**	0.142	28	1	0	2	3	Higher at *test* reach.
Log of Richness	0.175	**0.002**	0.495	0.110	0.295	3	17	1	4	2	Increasing over time at *test* reach.
Equitability	**<0.001**	**<0.001**	0.099	**<0.001**	**<0.001**	30	22	4	52	26	Lower at *test* reach; decreasing over time at *test* reach; lower in 2014 at *test* reach than means of the *baseline* reach and mean of previous years at *test* reach.
Log of EPT	**<0.001**	**<0.001**	0.475	0.071	**<0.001**	32	25	1	6	37	Lower at *test* reach; increased over time at *test* reach; higher in 2014 at *test* reach than mean of previous years.
CA Axis 1	**<0.001**	0.055	0.416	0.074	0.567	37	7	1	6	1	Higher at *test* reach.
CA Axis 2	**<0.001**	**0.016**	**0.002**	0.734	**0.017**	23	6	10	0	6	Higher at *test* reach; decreasing over time at *test* reach while increasing over time at *baseline* reach; higher in 2014 at *test* reach than mean of *baseline* reach.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

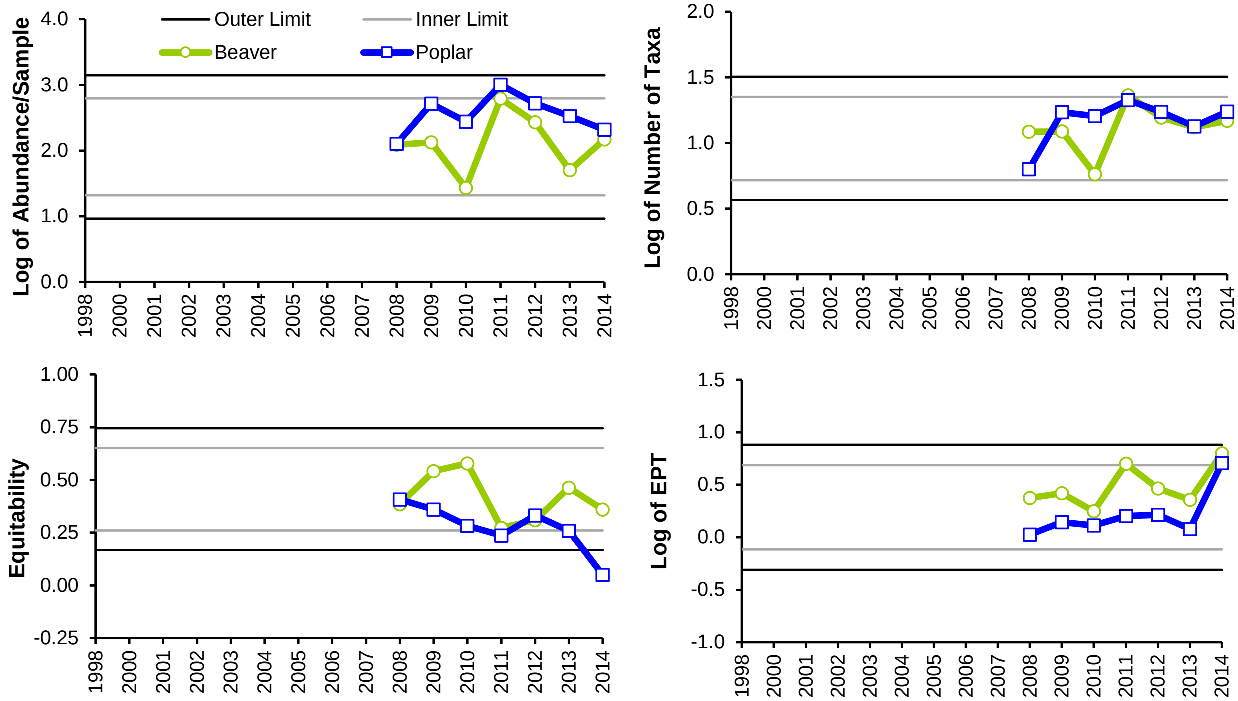
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-20 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing reaches of Poplar Creek and the Beaver River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches in the Athabasca oil sands region.

Figure 5.13-21 Variation in benthic invertebrate community measurement endpoints in Beaver River (*baseline* BER-D2) and Poplar Creek (*test* POC-D1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.13-27 Concentrations of sediment quality measurement endpoints, lower Poplar Creek (*test* station POC-D1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	15.8	9	8.26	19.7	35
Silt	%	-	30.8	9	13.3	27.2	68.3
Sand	%	-	53.4	9	0.89	62	73
Total organic carbon	%	-	1.79	9	1.07	2.2	2.53
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<u>**3,640**</u>	7	<5	39	143
Fraction 3 (C16-C34)	mg/kg	300[1]	**987**	7	170	**908**	**2,830**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	858	7	54	838	**2,820**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0034	9	0.0017	0.0076	0.0205
Retene	mg/kg	-	0.081	8	0.048	0.111	0.167
Total dibenzothiophenes	mg/kg	-	1.684	9	0.249	0.944	3.984
Total PAHs	mg/kg	-	5.114	9	1.753	3.4	13.261
Total Parent PAHs	mg/kg	-	0.17	9	0.122	0.2	0.44
Total Alkylated PAHs	mg/kg	-	4.944	9	1.605	3.191	12.821
Predicted PAH toxicity[3]	H.I.	1.0	0.266	9	0.159	**1.261**	**4.154**
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.4	7	4.2	7.4	9.2
Chironomus growth - 10d	mg/organism	-	<u>1.55</u>	7	1.61	1.74	3.85
Hyalella survival - 14d	# surviving	-	9.3	8	8	8.8	9.6
Hyalella growth - 14d	mg/organism	-	0.23	8	0.1	0.2	0.66

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.13-28 Concentrations of sediment quality measurement endpoints, upper Beaver River (*baseline* station BER-D2), fall 2014.

Variables	Units	Guideline	September 2014	2008-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2.15	6	2.4	5.4	9
Silt	%	-	1.7	6	1	4.46	21
Sand	%	-	96.1	6	70	90.7	95.6
Total organic carbon	%	-	0.28	6	0.1	0.37	1.97
Total hydrocarbons							
BTEX	mg/kg	-	<10	5	<10	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	5	<10	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	5	<20	<20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	5	<20	<20	119
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	5	<20	<20	94
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.00035	6	0.0003	0.001	0.003
Retene	mg/kg	-	0.0047	6	0.0015	0.0083	0.52
Total dibenzothiophenes	mg/kg	-	0.002	6	0.0015	0.0031	0.0145
Total PAHs	mg/kg	-	0.0193	6	0.0178	0.0546	0.7036
Total Parent PAHs	mg/kg	-	0.003	6	0.0037	0.0056	0.0173
Total Alkylated PAHs	mg/kg	-	0.0165	6	0.0141	0.049	0.6864
Predicted PAH toxicity[3]	H.I.	1.0	0.0897	5	0.1248	0.3578	0.8812
Metals that exceeded CCME guidelines in 2014							
none							
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.4	6	6.8	7.8	8.8
Chironomus growth - 10d	mg/organism	-	2.22	6	1.6	2.1	3.9
Hyalella survival - 14d	# surviving	-	9.6	6	6.6	8.8	9.6
Hyalella growth - 14d	mg/organism	-	0.26	6	0.2	0.4	0.5

Values in **bold** indicate concentrations exceeding guidelines.

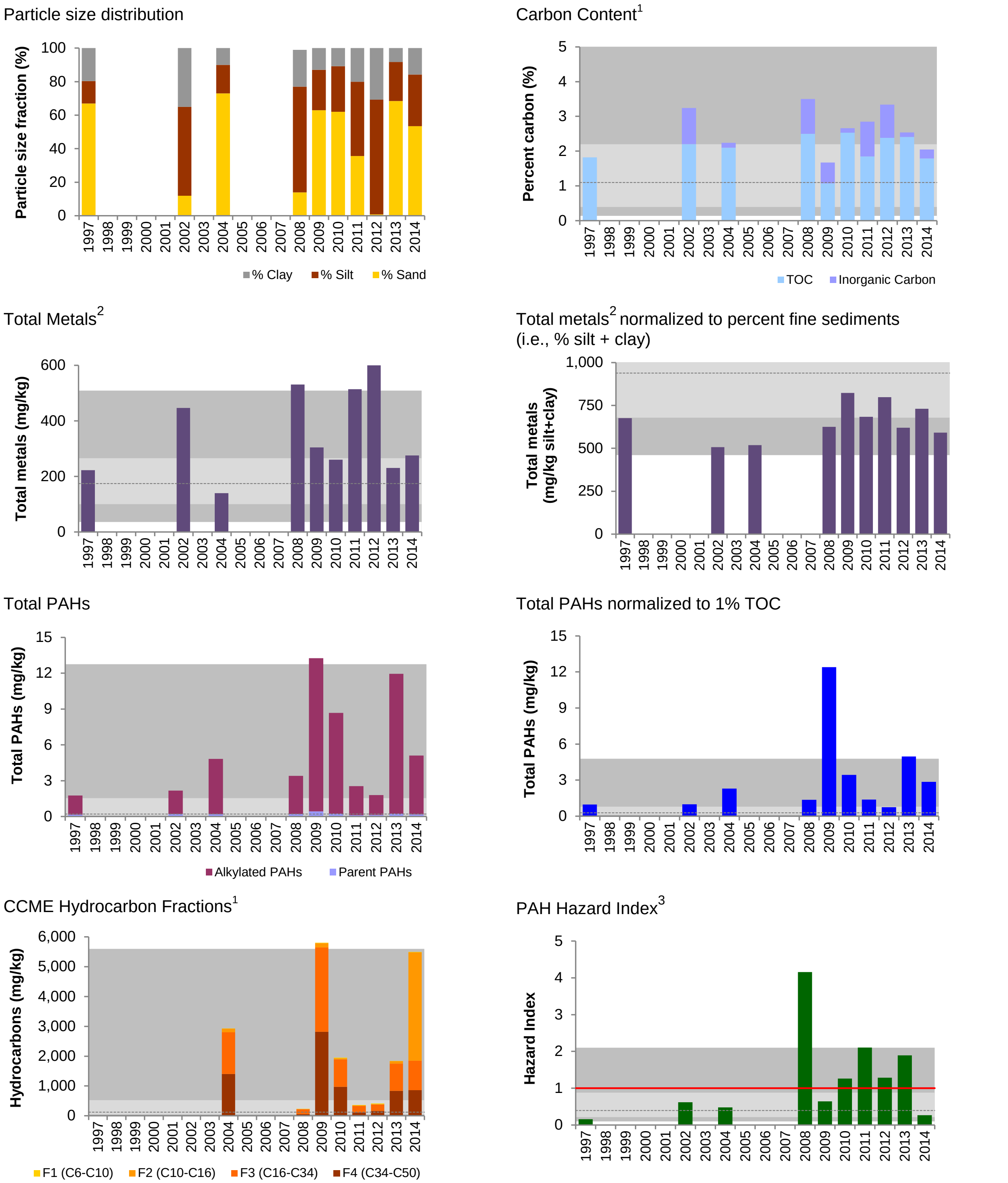
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-22 Variation in sediment quality measurement endpoints at *test* station POC-D1.



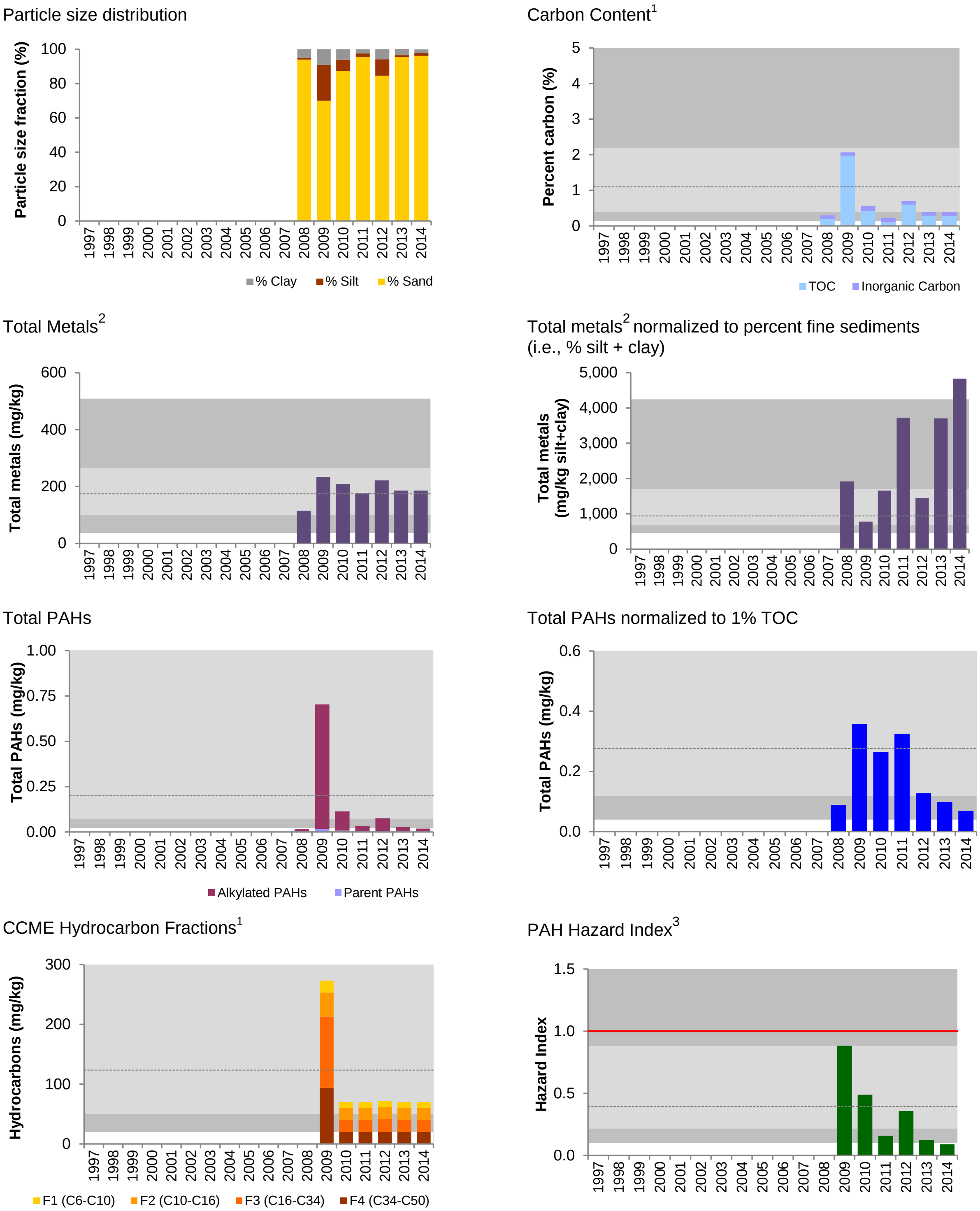
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.13-23 Variation in sediment quality measurement endpoints at *test* station BER-D2.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-29 Sediment quality index (fall 2014) for miscellaneous watershed stations.

Station Identifier	Location	2014 Designation	Sediment Quality Index	Classification
POC-D1	mouth of Poplar Creek	*test*	84.8	Negligible-Low
FOC-D1	mouth of Fort Creek	*test*	91.4	Negligible-Low
BER-D2	upper Beaver River	*baseline*	100.0	Negligible-Low

Table 5.13-30 Average habitat characteristics of fish assemblage monitoring locations of Poplar Creek and upper Beaver River, fall 2014.

Variable	Units	POC-F1 Lower *Test* Reach of Poplar Creek	BER-F2 Upper *Baseline* Reach of the Beaver River
Sample date	-	Sept 16, 2014	Sept 3, 2014
Habitat type	-	riffle/run	run
Maximum depth	m	0.46	1.18
Mean depth	m	0.32	0.93
Bankfull channel width	m	15.0	8.3
Wetted channel width	m	6.9	7.0
Substrate			
Dominant	-	cobble	sand
Subdominant	-	sand	cobble
Instream cover			
Dominant	-	boulders	small woody debris
Subdominant	-	overhanging vegetation	macrophytes, overhanging vegetation
Field water quality			
Dissolved oxygen	mg/L	9.3	9.8
Conductivity	µS/cm	460	477
pH	pH units	8.23	7.58
Water temperature	^{0}C	9.3	16.5
Water velocity			
Left bank velocity	m/s	0.15	0.12
Left bank water depth	m	0.16	0.46
Centre of channel velocity	m/s	0.07	0.33
Centre of channel water depth	m	0.16	0.70
Right bank velocity	m/s	0.15	0.12
Right bank water depth	m	0.15	0.38
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	overhanging vegetation
Subdominant	-	overhanging vegetation	-

Table 5.13-31 Total number and percent composition of fish species captured at reaches of Poplar Creek (*test* reach POC-F1) and the upper Beaver River (*baseline* reach BER-F2), 2009 to 2014.

Common Name	Code	Total Species Catch										Percent of Total Catch									
		BER-F2					POC-F1					BER-F2					POC-F1				
		2009	2011	2012	2013	2014	2009	2011	2012	2013	2014	2009	2011	2012	2013	2014	2009	2011	2012	2013	2014
brassy minnow	BRMN	-	-	1	-	-	-	-	-	-	-	0	0	2.4	0	0	0	0	0	0	0
brook stickleback	BRST	1	2	8	18	5	4	-	-	-	-	3.3	6.1	19.0	24.7	5.8	20.0	0	0	0	0
burbot	BURB	-	-	-	-	-	-	-	-	18	4	0	0	0	0	0	0	0	0	22.5	5.1
fathead minnow	FTMN	2	2	4	15	7	-	-	2	-	-	7	6.1	9.5	20.5	8.1	0	0	11.1	0	0
finescale dace	FNDC	-	-	-	2	-	-	2	-	-	1	0	0	0	2.7	0	0	7.7	0	0	1.3
lake chub	LKCH	10	-	20	26	65	1	-	9	37	32	33.3	0	47.6	35.6	75.6	5.0	0	50.0	46.3	41.0
longnose sucker	LNSC	-	-	1	-	1	-	15	4	15	20	0	0	2.4	0	1.2	0	57.7	22.2	18.8	25.6
northern pike	NRPK	-	-	-	-	-	1	-	-	2	2	0	0	0	0	0	5.0	0	0	2.5	2.6
pearl dace	PRDC	-	28	2	-	-	-	4	-	-	-	0	84.8	4.8	0	0	0	15.4	0	0	0
spoonhead sculpin	SPSC	-	-	-	-	-	1	-	-	-	-	0	0	0	0	0	5.0	0	0	0	0
trout-perch	TRPR	2	-	-	-	-	5	-	-	-	-	6.7	0	0	0	0	25.0	0	0	0	0
walleye	WALL	-	-	-	-	-	4	-	-	1	5	0	0	0	0	0	20.0	0	0	1.3	6.4
white sucker	WHSC	15	-	5	8	8	4	5	2	7	12	50.0	0	11.9	11.0	9.3	20.0	19.2	11.1	8.8	15.4
yellow perch	YLPR	-	-	-	-	-	-	-	1	-	2	0	0	0	0	0	0	0	5.6	0	2.6
sucker sp. *		-	1	1	4	-	-	-	-	-	-	0	3.0	2.4	5.5	0	0	0	0	0	0
Total Count		**30**	**33**	**42**	**73**	**86**	**20**	**26**	**18**	**80**	**78**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**3**	**7**	**6**	**5**	**7**	**4**	**5**	**6**	**8**	**5**	**3**	**7**	**6**	**5**	**7**	**4**	**5**	**6**	**8**
Electrofishing Effort (secs)		**1,678**	**1,412**	**1,618**	**1,192**	**1,292**	**1,534**	**1,003**	**1,535**	**1,312**	**1,686**	-	-	-	-	-	-	-	-	-	-

* Unknown species not included in total count.

Underline denotes *baseline* reach.

Table 5.13-32 Summary of fish assemblage measurement endpoints (± 1SD) for reaches of Poplar Creek and the Beaver River, 2009 and 2014.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BER-F2	2009	0.10	-	5	5.00	-	0.62	-	7.04	-	1.96	-
	2011	0.22	0.39	4	1.20	0.84	0.13	0.22	7.74	3.63	3.05	5.27
	2012	0.19	0.13	7	3.20	1.10	0.58	0.11	6.45	0.96	2.53	1.70
	2013	0.29	0.30	5	3.40	1.14	0.39	0.10	7.22	0.50	6.04	5.91
	2014	0.29	0.09	5	3.40	1.14	0.39	0.10	6.09	0.18	6.62	1.77
POC-F1	2009	0.07	-	7	7.00	-	0.81	-	8.29	-	1.19	-
	2011	0.17	0.22	4	1.40	1.34	0.30	0.28	6.01	3.33	1.91	2.63
	2012	0.09	0.09	6	2.00	1.23	0.43	0.24	6.41	1.10	1.16	1.13
	2013	0.27	0.17	6	4.20	0.84	0.64	0.09	4.78	0.52	6.21	3.93
	2014	0.27	0.16	8	4.20	0.84	0.64	0.09	4.77	0.53	4.77	2.99

* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

Underline denotes *baseline* reach.

Table 5.13-33 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for Poplar Creek.

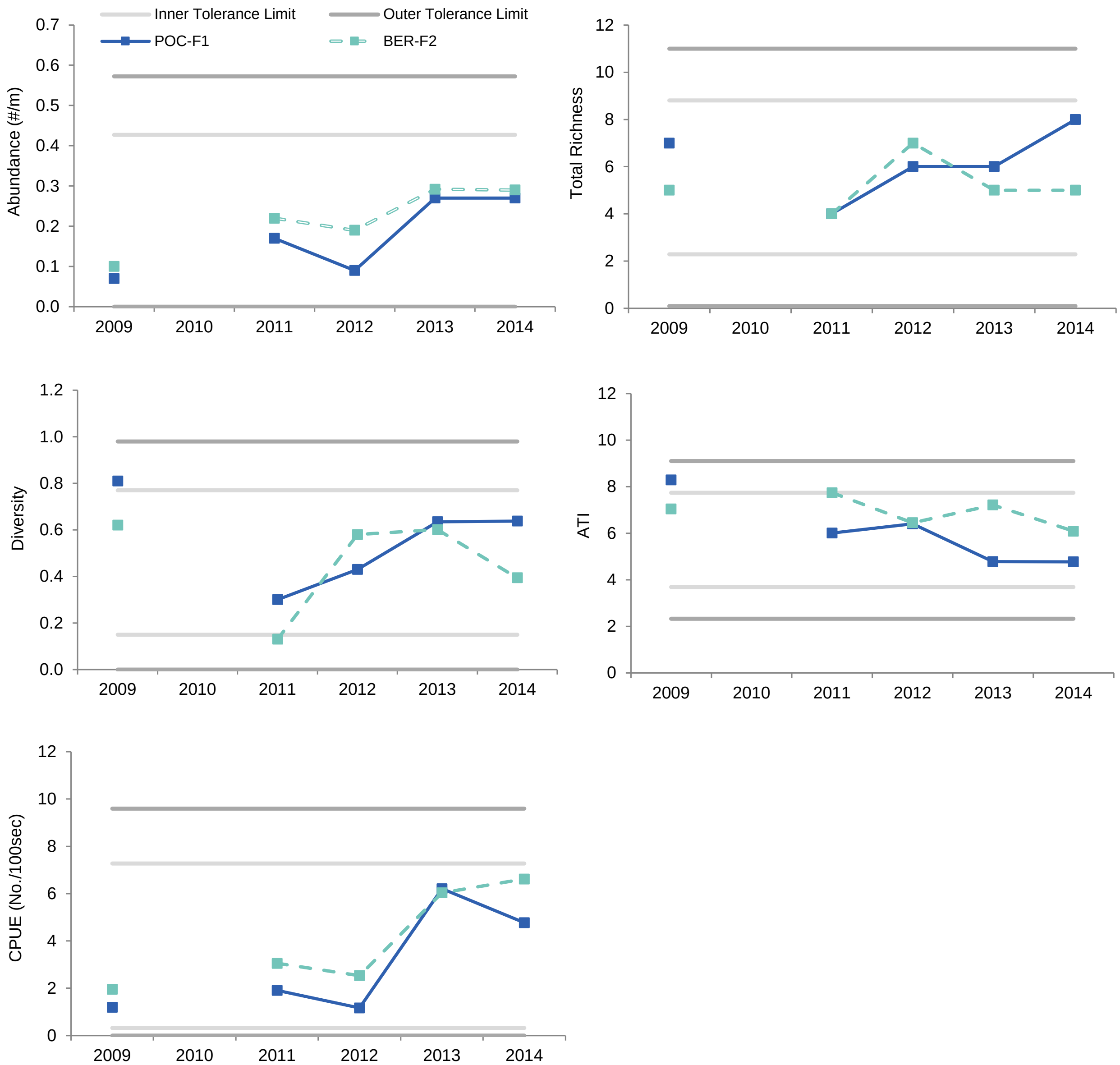
Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Reach)	*Test* Reach vs. *Baseline* Reach	
Abundance	0.190	0.960*	20	1	No change.
Richness	**<0.001**	0.370	63	2	Increasing over time.
Diversity	**0.006**	0.110*	41	7	Increasing over time.
ATI	**<0.001***	0.490*	75	1	Decreasing over time.
CPUE (No./100 sec)	**0.001***	0.970*	45	1	Increasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in temporal and spatial comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

* denotes data were ranked transformed to meet assumptions of ANOVA.

Figure 5.13-24 Variation in fish assemblage measurement endpoints for reaches of the upper Beaver River (*baseline* reach BER-F2) and Poplar Creek (*test* reach POC-F1) from 2009 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Note: A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Note: Although *baseline* reach BER-F2 is not part of *baseline* cluster 2, the data were graphed to provide comparison to *test* reach POC-F1.

Table 5.13-34 Concentrations of water quality measurement endpoints, McLean Creek (*test* station MCC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	15	8.0	8.3	8.6
Total suspended solids	mg/L	-	4.0	15	<3.0	10	83
Conductivity	µS/cm	-	725	15	289	407	1,220
Nutrients							
Total dissolved phosphorus	mg/L	-	0.009	15	0.005	0.016	0.048
Total nitrogen	mg/L	-	0.784	15	0.700	**1.16**	**1.52**
Nitrate+nitrite	mg/L	3	<0.054	15	<0.050	<0.100	<1.00
Dissolved organic carbon	mg/L	-	25.5	15	4.90	25.5	35.0
Ions							
Sodium	mg/L	-	78.5	15	10.3	43.0	182
Calcium	mg/L	-	57.4	15	37.9	48.7	81.7
Magnesium	mg/L	-	16.3	15	10.3	13.4	21.0
Chloride	mg/L	120	42.2	15	4.75	44.0	**220**
Sulphate	mg/L	429	<u>86.2</u>	15	3.17	16.5	76.4
Total dissolved solids	mg/L	-	469	15	218	320	743
Total alkalinity	mg/L	-	216	15	141	176	319
Selected metals							
Total aluminum	mg/L	0.1	**0.200**	15	0.070	**0.352**	**2.58**
Dissolved aluminum	mg/L	0.05	0.008	15	0.003	0.009	0.020
Total arsenic	mg/L	0.005	0.0010	15	0.0006	0.0010	0.0014
Total boron	mg/L	1.2	0.168	15	0.024	0.059	0.220
Total molybdenum	mg/L	0.073	<u>0.00107</u>	15	0.00012	0.00020	0.00092
Total mercury (ultra-trace)	ng/L	5, 13	1.35	11	<1.20	1.30	4.10
Total strontium	mg/L	-	0.245	15	0.110	0.180	0.331
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	3.90	3	0.700	1.33	7.94
Oilsands Extractable	mg/L	-	3.90	3	1.19	2.32	11.9
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.210	3	<8.756	<14.13	<15.16
Retene	ng/L	-	0.684	3	1.140	<2.071	5.100
Total dibenzothiophenes	ng/L	-	<u>16.71</u>	3	23.57	32.28	140.5
Total PAHs	ng/L	-	<u>122.8</u>	3	163.3	302.3	629.1
Total Parent PAHs	ng/L	-	<u>15.34</u>	3	24.53	25.58	26.71
Total Alkylated PAHs	ng/L	-	<u>107.5</u>	3	138.8	276.7	602.4
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.004**	15	**0.002**	**0.008**	**0.025**
Total iron	mg/L	0.3	**0.591**	15	**0.360**	**0.660**	**3.46**
Total phenols	mg/L	0.004	**0.005**	15	0.001	**0.007**	**0.012**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Figure 5.13-25 Piper diagram of ion balance in McLean Creek and Fort Creek.

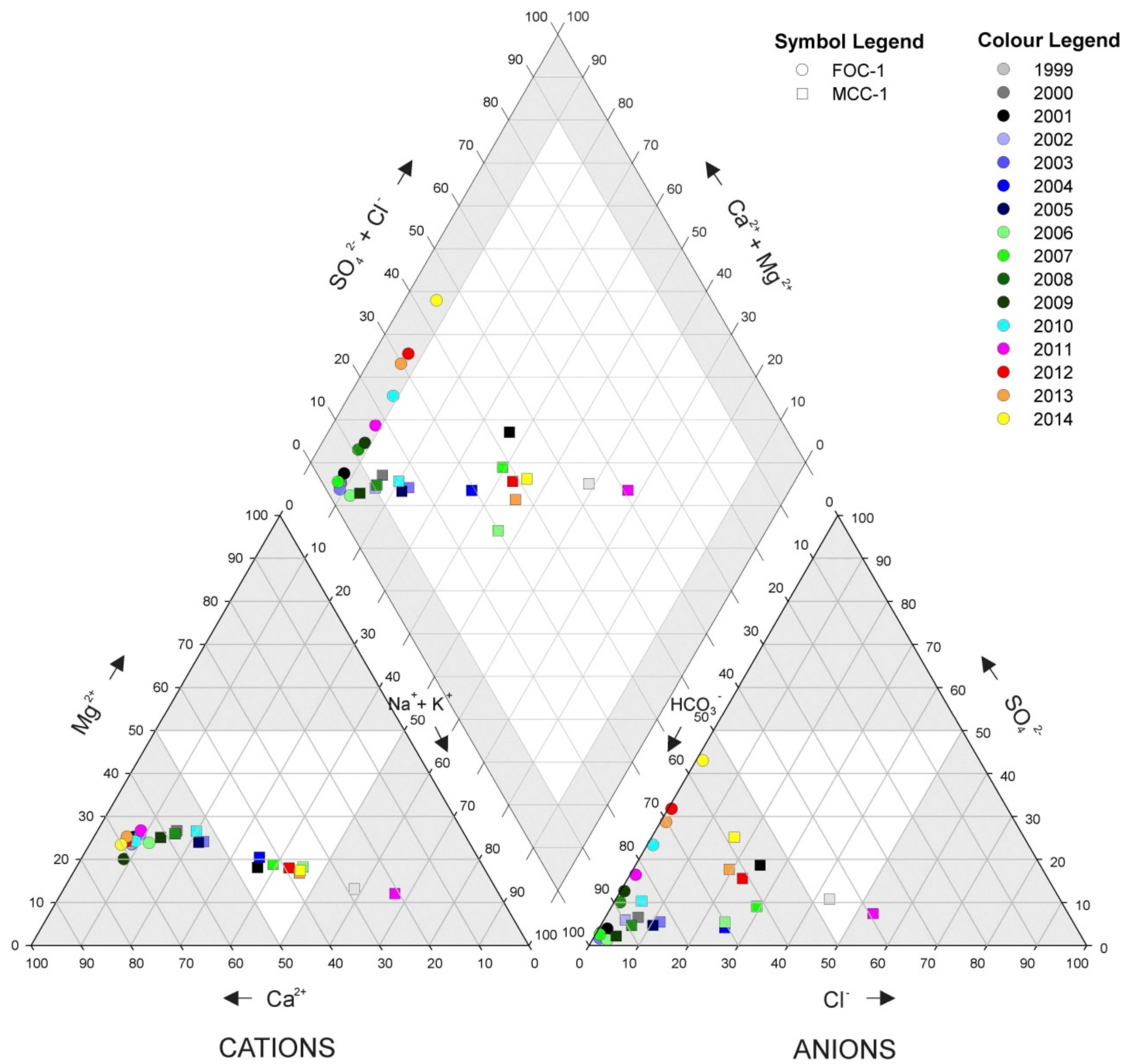
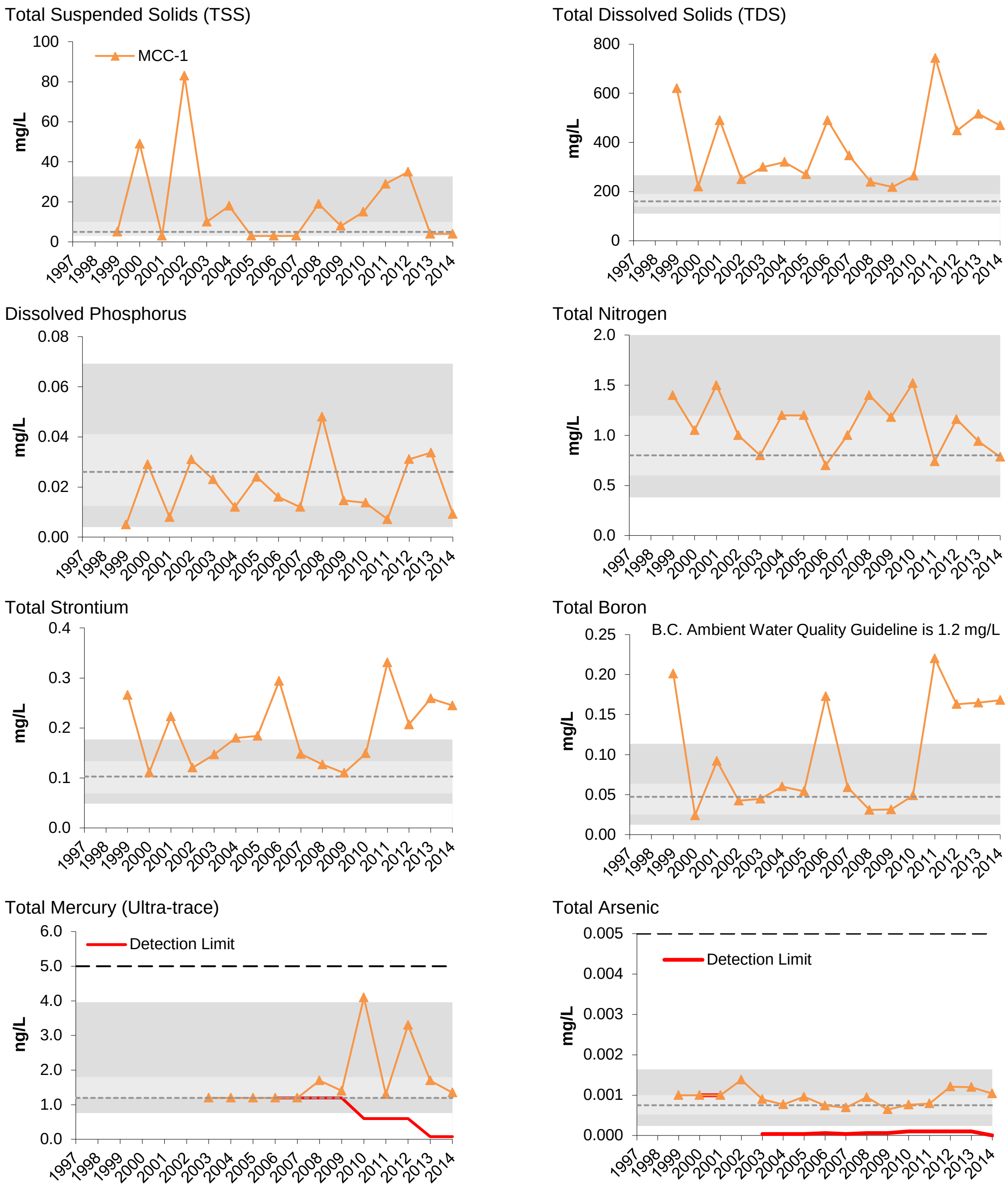


Figure 5.13-26 Concentrations of selected water quality measurement endpoints in McLean Creek (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



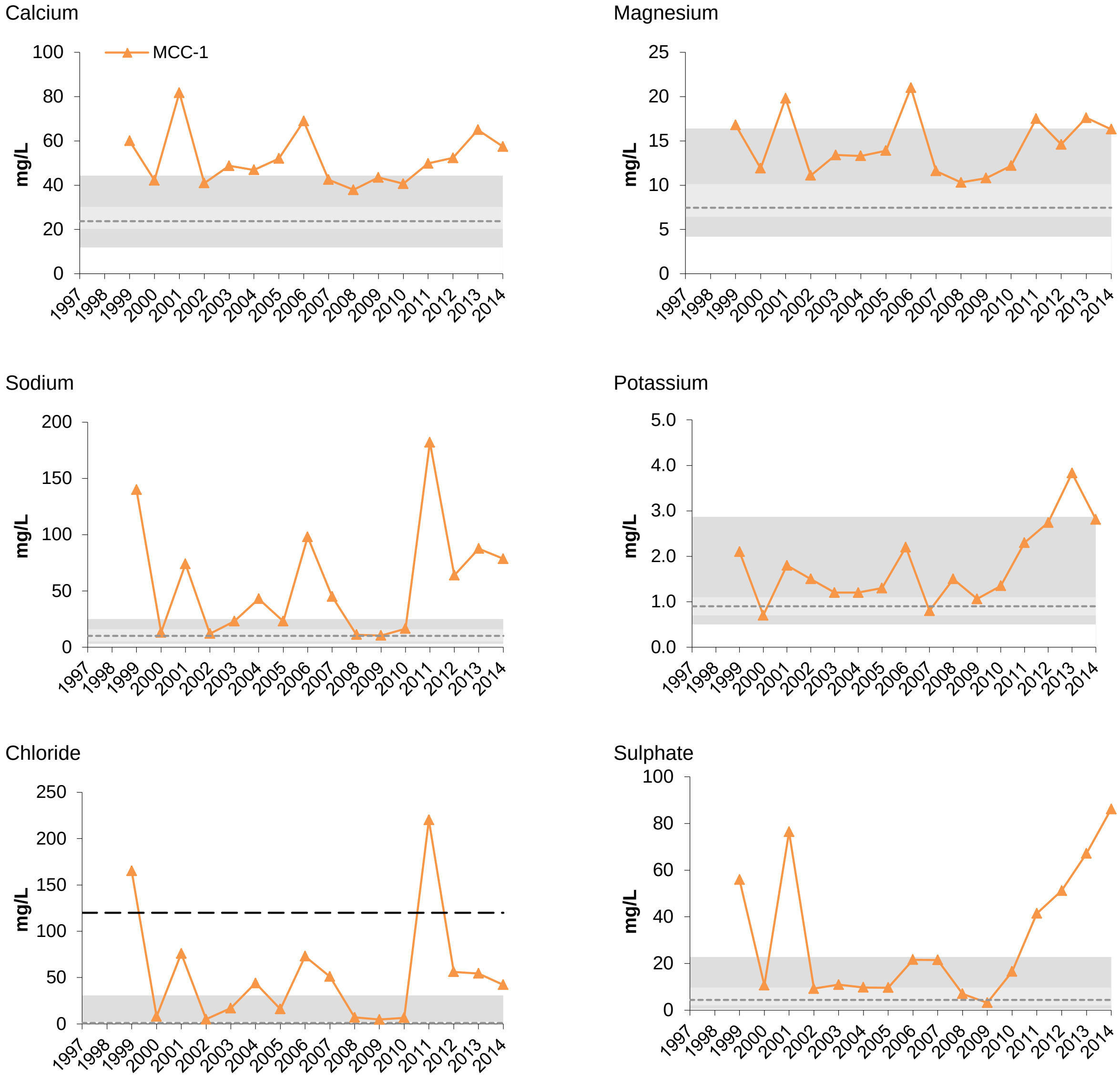
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-26 (Cont'd.)



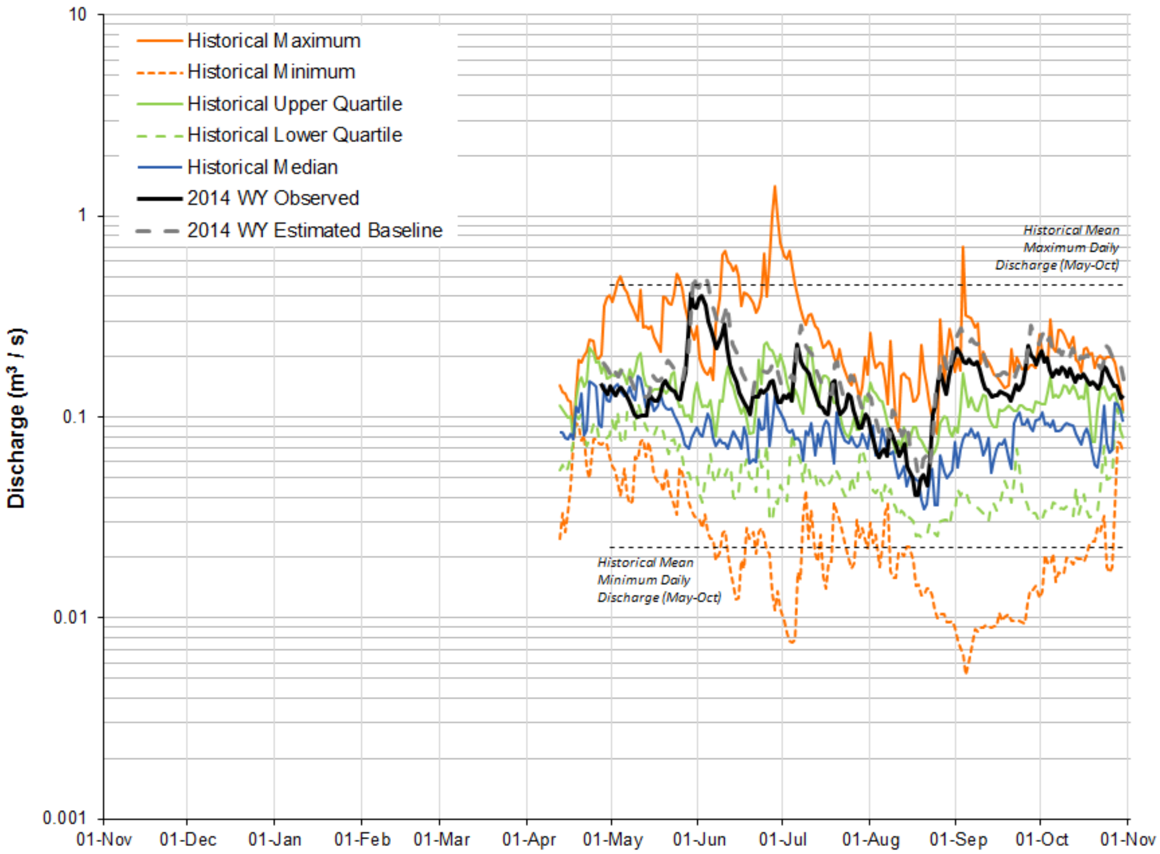
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-27 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Fort Creek in the 2014 WY, compared to historical values.



Note: Observed 2014 WY hydrograph based on Fort Creek at Highway 63, JOSMP Station S12. The upstream drainage area is 63.8 km^2. Historical values from April 12 to October 31 were calculated using data from 2000 to 2002 and from 2006 to 2013.

Table 5.13-35 Estimated water balance at Station S12, Fort Creek at Highway 63, 2014 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**2.350**	**Observed discharge, obtained from JOSMP Station S12**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.924	Estimated 20.0 km^2 of the Fort Creek watershed is closed-circuited as of 2014 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.328	Estimated 35.5 km^2 of the Fort Creek watershed with land change from oil sands developments as of 2014 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Fort Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Fort Creek watershed, relative to the estimated *baseline* hydrograph	-	Not used in water balance model
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**2.947**	**Estimated *baseline* discharge at JOSMP Station S12**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-0.596	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	**20.241**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: All values in this table are presented to three decimal places.

Table 5.13-36 Calculated change in hydrologic measurement endpoints for the Fort Creek at Highway 63, 2014 WY.

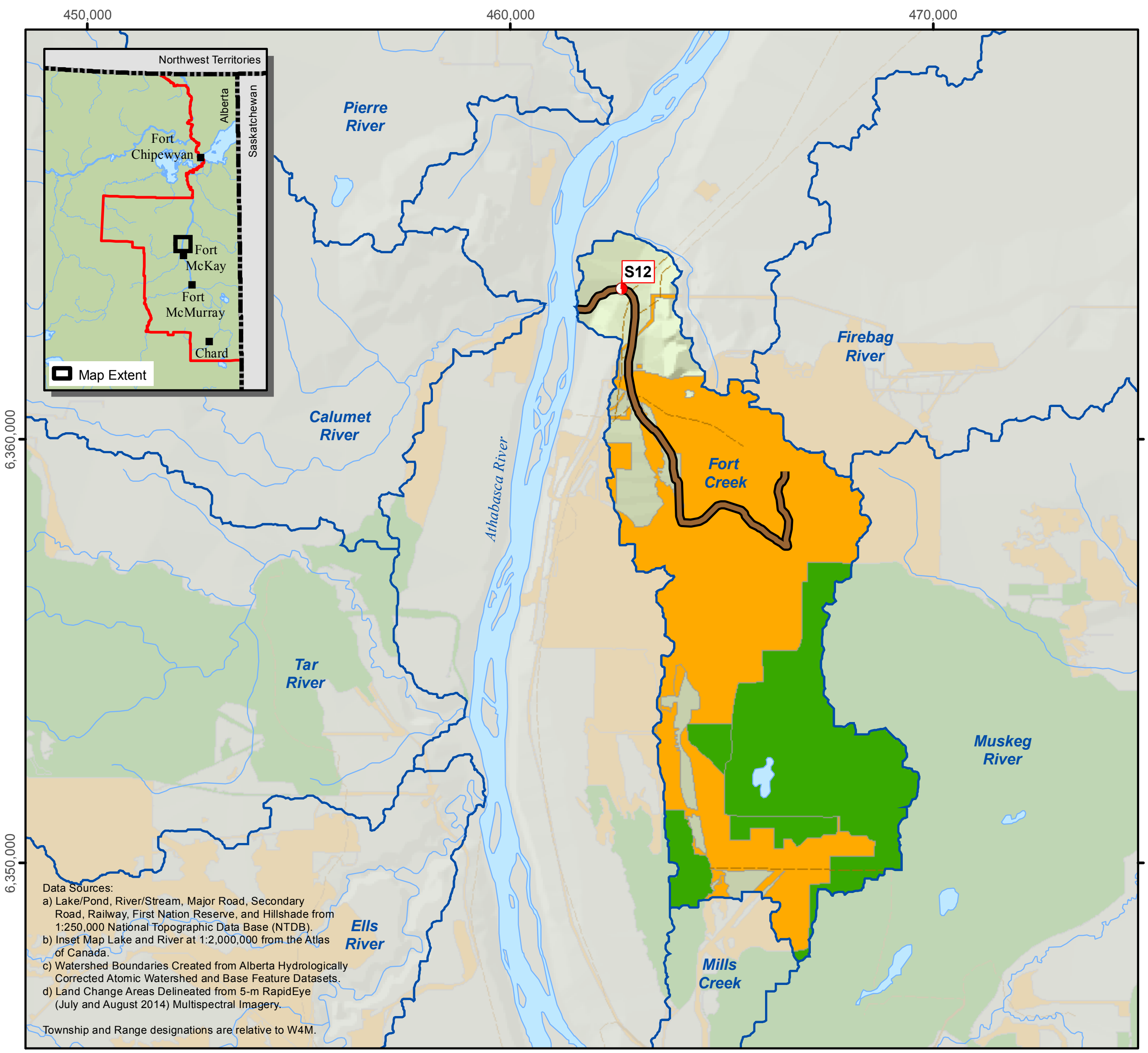
Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.148	0.185	-20.241%
Mean winter discharge	not measured	not measured	-
Open-water maximum daily discharge	0.412	0.516	-20.241%
Open-water season minimum daily discharge	0.041	0.051	-20.241%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31.

Figure 5.13-28 Hydrologic change classification of the Fort Creek, 2014 WY.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road

Land Change Area as of 2014[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Hydrometric Station

- JOSMP Seasonal

Hydrologic Change Classification

- High

0 1 2 4 km N

Scale: 1:150,000

Projection: NAD 1983 UTM Zone 12N

Hatfield CONSULTANTS

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Table 5.13-37 Concentrations of water quality measurement endpoints, Fort Creek (*test* station FOC-1), fall 2014.

Measurement Endpoint	Units	Guideline[a]	September 2014	1997-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.21	12	8.10	8.31	8.42
Total suspended solids	mg/L	-	6.80	12	<3.0	11.5	35.5
Conductivity	µS/cm	-	<u>743</u>	12	432	566	694
Nutrients							
Total dissolved phosphorus	mg/L	-	0.008	12	0.005	0.010	0.019
Total nitrogen	mg/L	-	0.424	12	0.361	0.551	1.00
Nitrate+nitrite	mg/L	3	<0.054	12	<0.050	<0.086	<0.100
Dissolved organic carbon	mg/L	-	9.10	12	9.10	13.0	14.0
Ions							
Sodium	mg/L	-	10.7	12	9.0	11.4	18.0
Calcium	mg/L	-	115	12	69.4	84.1	117
Magnesium	mg/L	-	23.3	12	14.6	18.4	26.3
Chloride	mg/L	120	4.25	12	2.00	2.92	7.00
Sulphate	mg/L	429	<u>167</u>	12	3.70	20.3	109
Total dissolved solids	mg/L	-	<u>509</u>	12	260	360	458
Total alkalinity	mg/L	-	<u>225</u>	12	231	279	309
Selected metals							
Total aluminum	mg/L	0.1	**0.138**	12	0.031	0.079	**0.850**
Dissolved aluminum	mg/L	0.05	0.0011	12	<0.0010	0.0016	0.0500
Total arsenic	mg/L	0.005	0.00023	12	0.00020	0.00028	<0.0010
Total boron	mg/L	1.2	0.0729	12	0.0380	0.0539	0.0731
Total molybdenum	mg/L	0.073	<u>0.00015</u>	11	<0.00001	0.00010	0.00010
Total mercury (ultra-trace)	ng/L	5, 13	1.28	9	0.480	<1.20	1.40
Total strontium	mg/L	-	0.245	12	<0.00001	0.195	0.260
Total hydrocarbons							
BTEX	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	3	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>1.00</u>	3	0.25	0.40	0.90
Oilsands Extractable	mg/L	-	1.80	3	0.58	1.64	1.92
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<7.21	3	<8.756	<14.13	<15.16
Retene	ng/L	-	7.820	3	<0.958	2.071	8.790
Total dibenzothiophenes	ng/L	-	339.0	3	42.54	52.33	445.2
Total PAHs	ng/L	-	948.6	3	233.6	298.1	1,529
Total Parent PAHs	ng/L	-	23.60	3	22.55	24.99	36.29
Total Alkylated PAHs	ng/L	-	925.0	3	208.6	275.6	1492
Other variables that exceeded CCME/AESRD guidelines in fall 2014							
Sulphide	mg/L	0.002	**0.0022**	12	0.0005	**0.0026**	**0.0060**
Total iron	mg/L	0.3	**0.653**	12	0.065	**0.662**	**1.94**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.13-38 Average habitat characteristics of benthic invertebrate sampling locations in Fort Creek, fall 2014.

Variable	Units	FOC-D1 Lower *Test* Reach
Sample date	-	Sept 4, 2014
Habitat	-	Depositional
Water depth	m	0.4
Current velocity	m/s	0.36
Field Water Quality		
Dissolved oxygen	mg/L	10.3
Conductivity	µS/cm	176
pH	pH units	8.0
Water temperature	°C	7.2
Sediment Composition (mean ± 1SD)		
Sand	%	87±13
Silt	%	8±9
Clay	%	4±4
Total Organic Carbon	%	2.2±0.6

Table 5.13-39 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community in Fort Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach FOC-D1		
	2001	2002-2013	2014
Nematoda	2	1 to 24	3
Oligochaeta (indet.)	-	0 to 2	15
Naididae	1	0 to 3	3
Tubificidae	-	<1 to 66	13
Enchytraeidae	1	0 to 2	3
Lumbricidae	-	7	-
Erpobdellidae	-	0 to <1	-
Glossiphoniidae	-	0 to <1	-
Hydracarina	<1	0 to 2	-
Gastropoda	<1	0 to 3	9
Bivalvia	5	0 to 8	3
Ceratopogonidae	<1	0 to 8	-
Chironomidae	80	18 to 95	48
Diptera (misc.)	9	0 to 14	-
Ephemeroptera	<1	0 to 1	-
Plecoptera	-	0 to 7	2
Trichoptera	-	0 to <1	-
Heteroptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	91	13 to 1,603	19
Richness	15	4 to 14	7
Equitability	0.50	0.30 to 0.80	0.69
% EPT	<1	0 to 9	2

Table 5.13-40 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in lower Fort Creek (*test* reach FOC-D1).

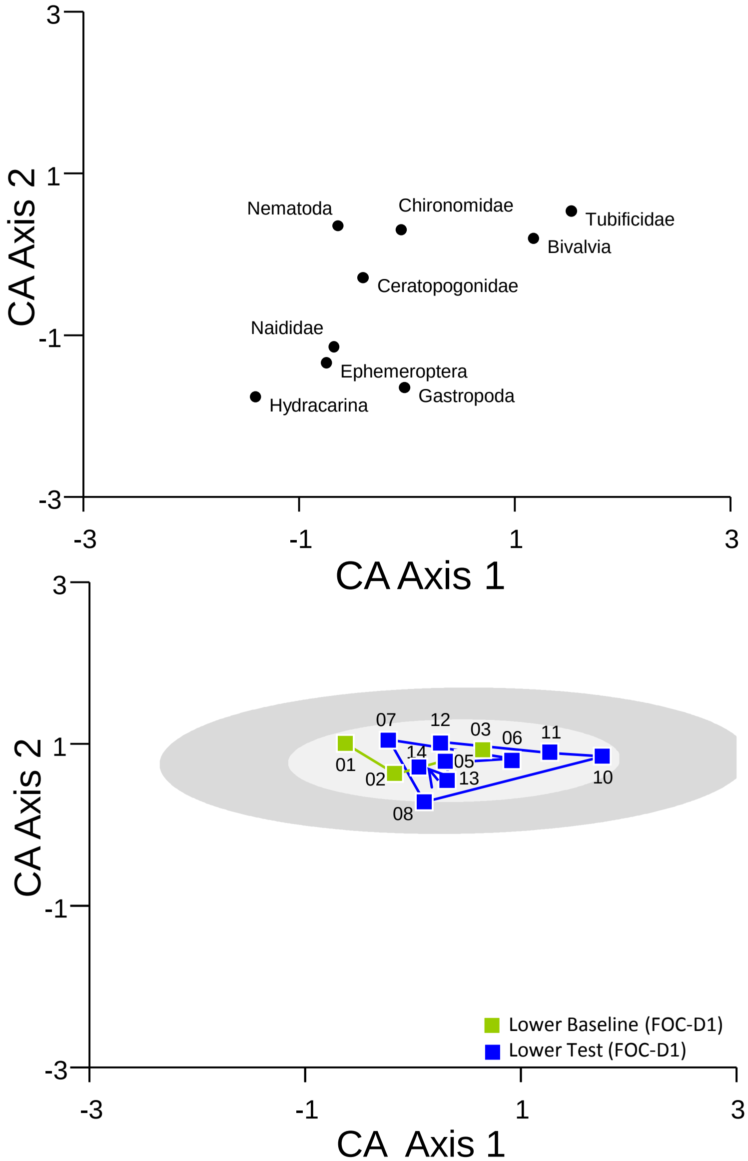
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Test Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	*Test* Period vs. *Baseline* Period	Time Trend (*Test* Period)	2014 vs. *Baseline* Years	2014 vs. Previous Years	
Log of Abundance	**<0.001**	0.391	**0.006**	0.413	42	2	24	2	Lower in *test* period; lower in 2014 than mean of baseline years.
Log of Richness	**0.002**	0.326	0.179	0.498	31	3	5	1	Lower in *test* period.
Equitability	**0.006**	0.412	**0.016**	0.320	25	2	19	3	Higher in *test* period; higher in 2014 than mean of *baseline* years.
Log of EPT	0.457	0.411	0.596	0.906	6	7	3	0	No change.
CA Axis 1	0.127	0.890	0.868	0.372	15	0	0	5	No change.
CA Axis 2	0.772	0.892	0.778	0.891	3	1	3	1	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

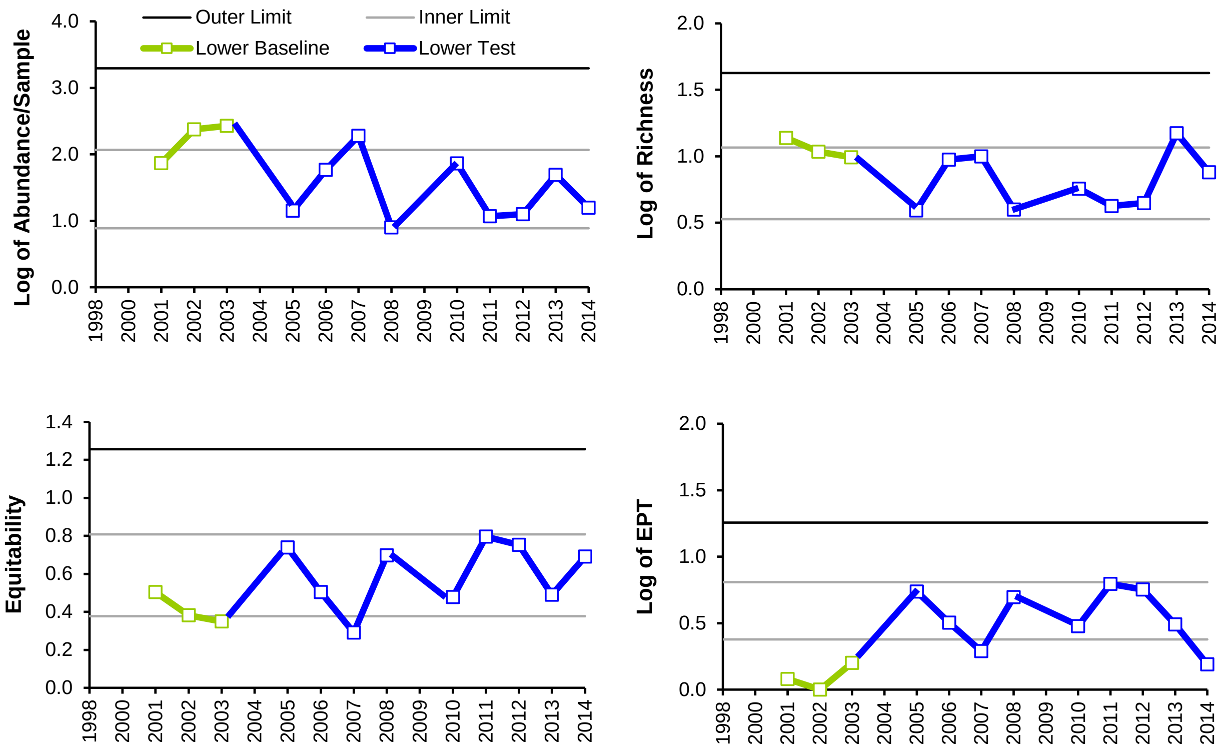
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-29 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Fort Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner 5th and outer 95th percentiles for previous years at *test* reach FOC-D1.

Figure 5.13-30 Variation in benthic invertebrate community measurement endpoints in Fort Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years (2001 to 2013).

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.13-41 Concentrations of sediment quality measurement endpoints, Fort Creek (*test* station FOC-D1), fall 2014.

Variables	Units	Guideline	September 2014	2001-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.7	7	0.98	3.8	15
Silt	%	-	24.3	7	1.04	4.8	29
Sand	%	-	64	7	56	91.4	97.9
Total organic carbon	%	-	3.2	9	1.48	2.92	7.1
Total hydrocarbons							
BTEX	mg/kg	-	<20	6	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	6	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	100	6	16	110	**311**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,550**	6	**440**	**2,160**	**2,930**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	1,390	6	450	1,740	2,330
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0039	9	0.0006	0.0029	0.017
Retene	mg/kg	-	0.107	9	0.033	0.081	0.679
Total dibenzothiophenes	mg/kg	-	1.34	9	0.16	1.85	3.22
Total PAHs	mg/kg	-	6.19	9	1.85	9.28	14.26
Total Parent PAHs	mg/kg	-	0.287	9	0.159	0.274	0.874
Total Alkylated PAHs	mg/kg	-	5.91	9	1.69	9.01	13.38
Predicted PAH toxicity[3]	H.I.	1.0	0.55	8	0.42	0.65	**1.50**
Metals that exceeded CCME guidelines in 2014							
none							
Other analytes that exceeded CCME guidelines in 2014							
Chrysene	mg/kg	0.0571	**0.091**	9	0.018	**0.095**	**0.230**
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.0118**	9	0.0039	**0.0126**	**0.068**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	8	3.2	9.0	10
Chironomus growth - 10d	mg/organism	-	2.26	8	1.24	2.22	3.30
Hyalella survival - 14d	# surviving	-	8.8	8	6.0	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.26	8	0.1	0.18	0.28

Values in **bold** indicate concentrations exceeding guidelines.

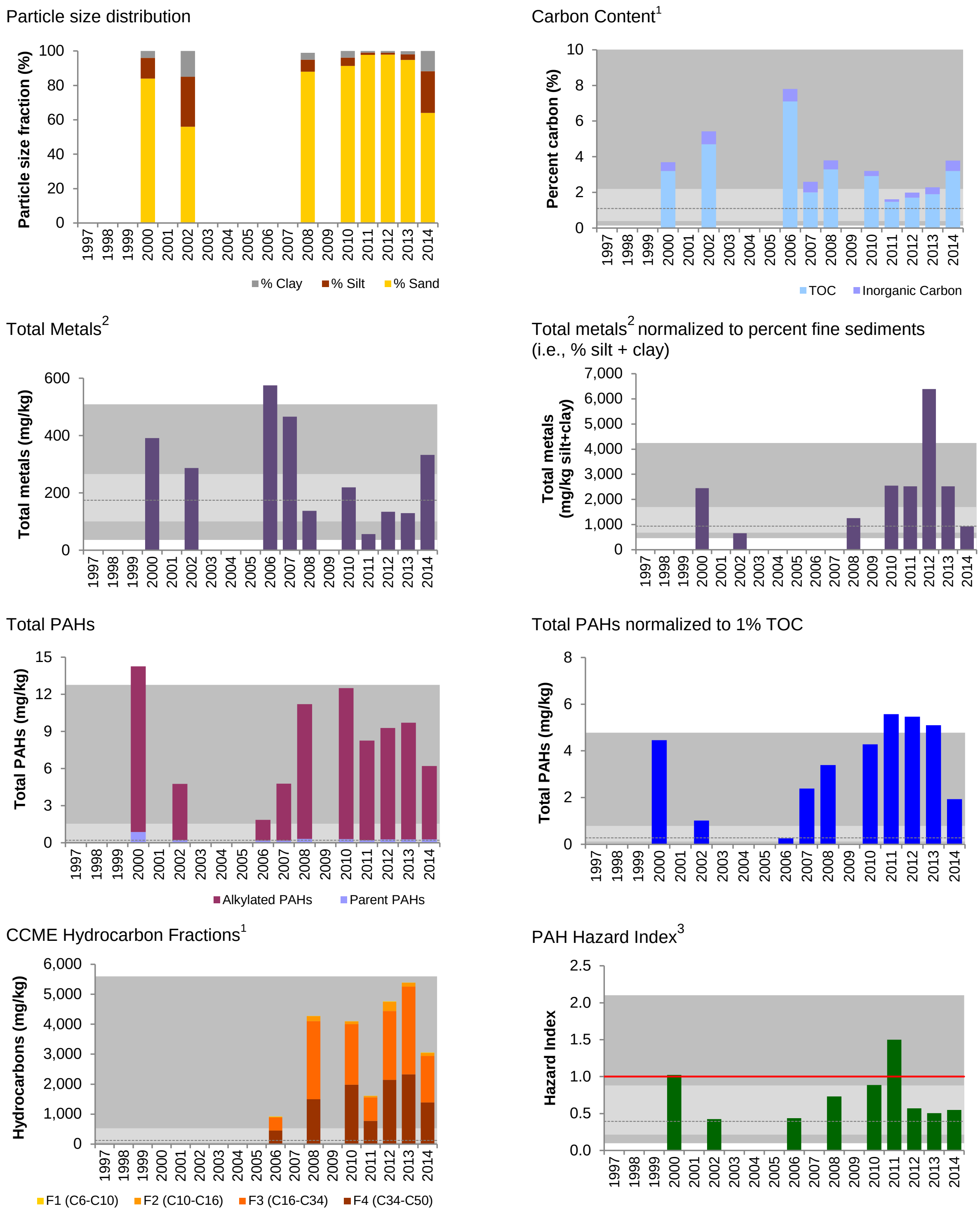
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-31 Variation in sediment quality measurement endpoints in Fort Creek, *test* station FOC-D1.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-42 Average habitat characteristics of the fish assemblage monitoring location of Fort Creek, fall 2014.

Variable	Units	FOC-F1 Lower *Test* Reach
Sample date	-	Sept 4, 2014
Habitat type	-	riffle/run
Maximum depth	m	0.76
Mean depth	m	0.64
Bankfull channel width	m	6.8
Wetted channel width	m	2.8
Substrate		
Dominant	-	sand
Subdominant	-	fines
Instream cover		
Dominant	-	small woody debris
Subdominant	-	undercut banks
Field water quality		
Dissolved oxygen	mg/L	9.2
Conductivity	µS/cm	617
pH	pH units	7.86
Water temperature	^{0}C	12.3
Water velocity		
Left bank velocity	m/s	0.32
Left bank water depth	m	0.33
Centre of channel velocity	m/s	0.42
Centre of channel water depth	m	0.33
Right bank velocity	m/s	0.46
Right bank water depth	m	0.40
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	overhanging vegetation

Table 5.13-43 Total number and percent composition of fish species captured at *test* reach FOC-F1 of Fort Creek, 2011 to 2014.

Common Name	Code	Total Species Catch				Percent of Total Catch			
		2011	2012	2013	2014	2011	2012	2013	2014
brook stickleback	BRST	8	-	-	-	9.8	0	0	0
burbot	BURB	-	-	18	3	0	0	62.1	23.1
fathead minnow	FTMN	-	4	-	-	0	6.6	0	0
finescale dace	FNDC	23	-	-	-	28.0	0	0	0
lake chub	LKCH	33	1	3	6	40.2	1.6	10.3	46.2
longnose sucker	LNSC	16	15	5	3	19.5	24.6	17.2	23.1
northern pike	NRPK	-	-	2	-	0	0	6.9	0
northern redbelly dace	NRDC	-	22	1	-	0	36.1	3.4	0
pearl dace	PRDC	-	7	-	-	0	11.5	0	0
slimy sculpin	SLSC	1	2	-	-	1.2	3.3	0	0
spottail shiner	SPSH	-	7	-	-	0	11.5	0	0
trout-perch	TRPR	-	1	-	-	0	1.6	0	0
white sucker	WHSC	1	2	-	1	1.2	3.3	0	7.7
Total Catch		**82**	**61**	**29**	**13**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**9**	**5**	**4**	**6**	**9**	**5**	**4**
Electrofishing effort (secs)		**1,097**	**1,255**	**834**	**1,260**	**-**	**-**	**-**	**-**

Table 5.13-44 Summary of fish assemblage measurement endpoints (± 1SD) for the lower reach of Fort Creek, 2011 to 2014.

Year	Abundance		Richness			Diversity		ATI		CPUE	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2011	0.67	0.36	6	3.40	1.14	0.52	0.16	6.44	1.07	7.59	4.92
2012	0.41	0.25	9	3.80	2.28	0.50	0.29	6.70	0.70	4.82	2.98
2013	0.15	0.07	5	2.50	1.29	0.39	0.26	3.27	0.89	3.46	1.52
2014	0.05	0.02	4	2.00	0.82	0.41	0.29	4.68	0.67	1.29	0.38

SD = standard deviation across sub-reaches within a reach.

Table 5.13-45 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for lower Fort Creek (*test* reach FOC-F1).

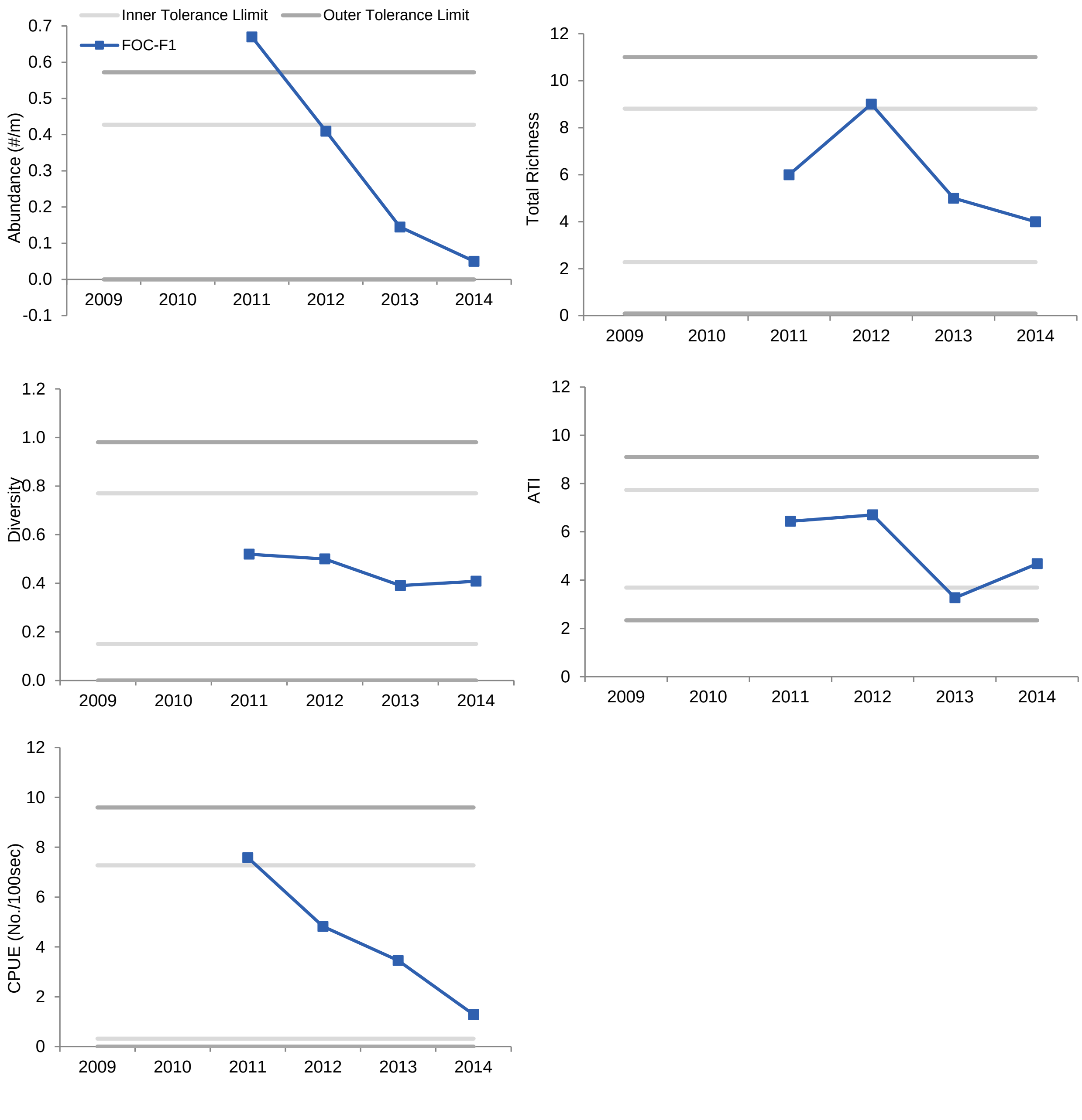
Variable	Time Trend P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**<0.001***	57.2	Decreasing over time.
Richness	**0.030***	19.5	Decreasing over time.
Diversity	0.190	41.9	No change.
ATI	0.006	39.0	No change.
CPUE (No./100 sec)	**0.001***	42.2	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

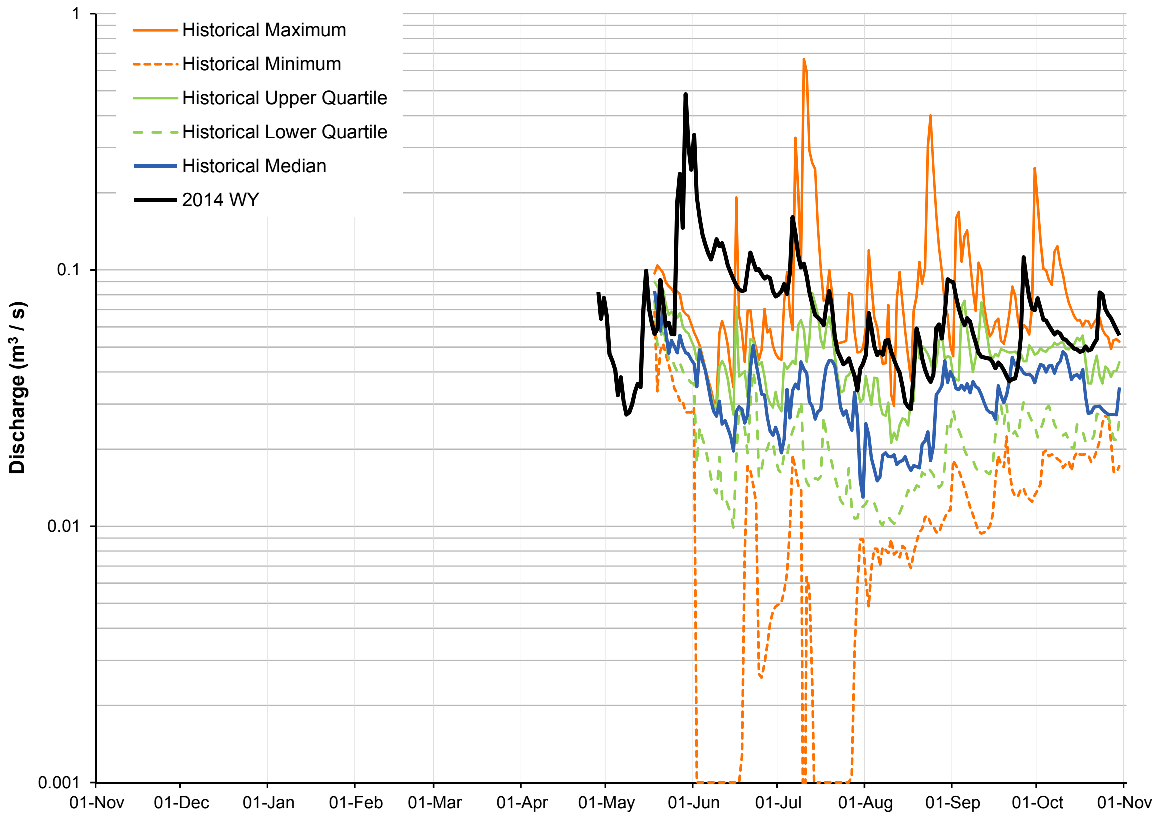
* denotes data were ranked transformed to meet assumptions of ANOVA.

Figure 5.13-32 Variation in fish assemblage measurement endpoints for the lower reach of Fort Creek from 2011 to 2014, relative to regional *baseline* conditions (cluster 2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 2 (see Table 3.2-14 and Table 3.2-15).

Figure 5.13-33 Observed hydrograph for Susan Lake Outlet (JOSMP Station S25) for the 2014 WY, compared to historical values.



5.14 ACID-SENSITIVE LAKES

This section presents the results of the Acid-Sensitive Lakes (ASL) component of the JOSMP for 2014.

5.14.1 General Characteristics of the ASL Component Lakes in 2014

The lakes monitored for the ASL component (referred to as the "ASL lakes") are typically small and shallow with a median area of 1.32 km^2 and depth of only 1.83 m (Table 5.14-1). Given the shallow depth of these lakes, a large proportion of the water volume in many of the lakes freezes to depth each winter. Freezing to depth results in large changes in lake chemistry (e.g., anoxia, decreases in pH, and increases in alkalinity) that reverse when melting occurs in spring (See Appendix H in RAMP 2008).

The water chemistry variables measured in the 45 ASL lakes from 1999 to 2014 are summarized in Table 5.14-2 (the five lakes previously sampled in the Caribou Mountains were removed from the program in 2014). The ASL lakes cover a large variety of lake types from soft water to hard water and from acidic to alkaline. Historically, the pH of the lakes has ranged from 3.97 to 9.87, with a median of 6.84. The median pH in 2014 was 7.05, which was slightly higher than the historical median but similar to that recorded in 2013 (7.04).

Gran alkalinity in the ASL lakes has historically ranged from negative values to 2,023 µeq/L (median: 208 µeq/L). The median Gran alkalinity in 2014 was 247 µeq/L. The highest values of Gran alkalinity have been consistently observed in Kearl Lake, which peaked at 2,023 µeq/L in 2012. The value in 2014 (1,644 µeq/L) was similar to the historical mean for this lake (1,680 µeq/L).

Conductivity in the ASL lakes has historically ranged from 8.4 µS/cm to 196 µS/cm (median: 35.2 µS/cm). The median conductivity in 2014 was 35.3 µS/cm. Similar to Gran alkalinity, the highest values of conductivity have consistently been recorded in Kearl Lake with a maximum value of 196 µS/cm in 2012. Conductivity in Kearl Lake in 2014 (161 µS/cm) was similar to the historical mean for this lake (170 µeq/L).

Total dissolved solids (TDS) in the ASL lakes has historically ranged from 0.02 mg/L to 219 mg/L (median: 62.0 mg/L). In 2014, the median TDS was 61.0 mg/L, which was very close to the historical median value. In 2012, TDS and most of the base cations were unusually high and, in most cases, were the highest values recorded across all monitoring years (2009 to 2014). These high concentrations were attributed to hydrologic conditions, low precipitation, and runoff in that year.

The concentration of sulphate has been historically very low in the ASL lakes, ranging from non-detectable to 19.0 mg/L, with a median concentration of 1.03 mg/L. The median sulphate concentration in 2014 (0.68 mg/L) was slightly lower than the historical median.

By conventional standards, most of the ASL lakes are considered humic, with a median concentration of 21.7 mg/L for dissolved organic carbon (DOC) across all monitoring years (Kortelainen et al. 1989; Forsius et al. 1992; Driscoll et al. 1991). In 2014, the median DOC concentration (21.5 mg/L) was close to the historical median concentration. Extremely high concentrations of DOC in the ASL lakes were recorded in 2012, including 71 mg/L in Lake NE7/185 and 92.2 mg/L in Lake NE8/209, both located in the Northeast of Fort McMurray subregion.

The concentration of nitrates in the ASL lakes have been historically highly variable and have varied over two to three orders of magnitude, ranging from non-detectable concentrations to 733 µg/L (median: 3.0 µg/L). In 2014, nitrates were considerably lower than previous years, ranging from non-detectable to 23 µg/L, with a non-detectable median concentration. Lake sampling is normally conducted during the late summer and early fall when the lakes are well mixed and chemical variables are assumed to have stabilized. In 2014, sampling was conducted two to three weeks earlier than in previous years (i.e., August 17 to 20). Higher chlorophyll levels in 2014 (see below) suggested that nitrates may have been assimilated in the relatively large algal biomass at the time of sampling.

The concentration of chlorophyll *a* has historically ranged from 0.10 µg/L to 371 µg/L (median: 10.3 µg/L). In 2014, chlorophyll *a* was slightly higher than previous years, ranging from 2.5 µg/L to 313 µg/L (median: 18.2 µg/L).

The concentration of total phosphorus in the ASL lakes has historically ranged from 3 µg/L to 451 µg/L (median: 39 µg/L). The ASL lakes; therefore, cover the range of nutrient conditions from oligotrophic to hypereutrophic (Wetzel 2001). The median concentration of total phosphorus in 2014 was 35 µg/L, similar to the historical median. Dissolved phosphate in the ASL lakes has historically ranged from 1 µg/L to 197 µg/L (median: 11 µg/L). In 2014, the median was also 11µg/L. A large fraction of the phosphorus is bound to suspended particulates.

Metal concentrations are typically low with a large number of non-detectable values. The highest concentration of metals are found in the Birch Mountains upland region. Concentrations of metals in the ASL lakes are discussed in greater detail in Appendix F.

Lakes having "unusual" water chemistry were identified in 2014 as those below or above the 5^{th} and 95^{th} percentile for three measurement endpoints: pH, Gran alkalinity, and DOC (Table 5.14-3) and were generally the same lakes identified in previous years. Four lakes (SM9/169, WF3/172, SM8/287 and Clayton Lake/BM7) had very low pH and Gran alkalinity and were the most poorly buffered of the ASL lakes. These lakes are found in organic soils in upland regions including the Stony and Birch Mountains subregions, with the exception of Lake 172/WF3, which is located in the West of Fort McMurray subregion. The highest pH and Gran alkalinity were found in lakes NE6/182, NE9/270, NE10/271 and Kearl Lake/NE11, all located in mineral soils in the Northeast of Fort McMurray subregion. These represent the most acid-insensitive lakes of the 45 ASL component lakes. The lowest concentrations of DOC were found in two lakes in the Birch Mountains subregion (Namur Lake/BM2 and Legend Lake /BM1), and one lake in the Canadian Shield subregion (S1/Weekes Lake). The highest concentrations of DOC were found in lakes NE6/182 and WF4/223.

Unique to the ASL lakes are lakes such as Kearl Lake that are simultaneously high in pH and high in DOC. Most coloured (high DOC) lakes are typically low in pH (Kortelainen et al. 1989).

The water chemistry of the ASL lakes is discussed further in Appendix F.

5.14.2 Temporal Trends

5.14.2.1 Among-Year Comparisons of Measurement Endpoints using ANOVA

Results of the one-way ANOVA are summarized in Table 5.14-4. Nitrates was the only measurement endpoint showing a significant change (a decrease) across monitoring years (Figure 5.14-1). A decrease in nitrates is the opposite effect expected under an acidification scenario. Concentrations of nitrates are highly variable in the ASL lakes, both between lakes and between years within each lake. Nitrates are also nutrients that are essential to algal growth and are taken up by actively-growing algae. Both their high variability and eutrophying characteristics make it difficult to attribute changes in nitrate concentration in the ASL lakes to acidification from emission sources. As indicated in Section 5.14.1, nitrates were extremely low in the ASL lakes in 2014, possibly attributable to the high algal biomass at the time of sampling.

Significant increases over time were observed in concentrations of TDS and potassium across years. Changes in potassium were also observed in the ANOVA using the General Linear Model (GLM) discussed below.

5.14.2.2 Among-Year Comparisons of Measurement Endpoints using the General Linear Model

The GLM was applied to three separate cases:

- Case 1 – all 45 ASL lakes;
- Case 2 – the five *baseline* lakes from the Canadian Shield located outside of the area receiving acidifying deposition from oil sands development; and
- Case 3 – the 40 *test* lakes potentially exposed to acidifying emissions.

Table 5.14-4 presents the variables showing statistically significant changes across years, the direction of the change (slope as positive or negative), and the significance (or non-significance) of the interaction term (lake x year) for each variable. The percentage of the variability accounted for by each significant interaction term is presented in brackets. Significant differences in an interaction term accounting for more than 5% of the variability occurred for TDS, nitrates, and chlorophyll a in Case 1 (all 45 lakes); TKN and TP in Case 2 (*baseline* lakes); and TDS, chloride, nitrates, and chlorophyll *a* in Case 3 (*test* lakes). For these variables, the significant/non-significant designation for a time-related trend was; therefore, less reliable.

There was a significant increase in pH in all three cases from 2002 to 2014, which was the opposite effect expected under an acidification scenario. The fact that a significant increase in pH was observed in both the *baseline* lakes and the *test* lakes suggested that region-wide factors (e.g., changes to the regional hydrology) were responsible for the increased pH in these lakes.

There was a significant increase in Gran alkalinity in Case 1 and Case 2 in 2014. The effect was not significant for Case 3 (*test* Lakes) although the direction of change was still positive. In 2013, a significant increase in Gran alkalinity was observed in all three cases. As with pH, an increase in Gran alkalinity was inconsistent with an acidification scenario and the fact that the *baseline* lakes showed significant increases in Gran alkalinity suggested that regional factors were responsible.

There were no statistically significant changes in sulphate in the ASL lakes from 2002 to 2014 in all three cases, although the direction of change in all cases was a decrease in sulphate concentration. Sulphates and nitrates are the principal acidifying agents in oil sands emissions.

Consistent with the results of the one-way ANOVA, there were significant decreases in concentrations of nitrates in Case 1 (all lakes) and Case 3 (*test* lakes). There was also a decrease in nitrate concentrations in the *baseline* lakes (Case 2) although this decrease was not statistically significant. A decrease in concentration of nitrates was the opposite effect expected under an acidification scenario.

There were no significant changes in DOC across sampling years. The concentration of DOC was increasing (positive slope) in the *test* lakes, although these changes were also not statistically significant. However, colour, which is highly correlated with DOC, increased significantly in all the lakes (Case 1) and in the *test* lakes (Case 2). Under acidification, decreases in both DOC and colour are anticipated.

There was a significant increase in the sum of base cations (SBC) from 2002 to 2014 in the *baseline* lakes (Case 2). Base cations will increase under an acidification scenario as cations in soil are displaced by hydrogen ions. As the *baseline* lakes are remote from the main sources of acidifying emissions and the increase in SBC was not accompanied by decreases in Gran alkalinity or pH, factors other than acidifying emissions were likely causing the increase in SBC in these lakes.

There was no significant change in the concentration of dissolved aluminum across years in all three cases. An increase in aluminum was anticipated under an acidification scenario.

There were several significant changes in the ionic characteristics of the ASL lakes, including:

- an increase in potassium (Cases 1, 2, and 3);
- an increase in magnesium (Cases 1 and 2);
- an increase in bicarbonate (Cases 1, 2, and 3); and
- a decrease in chloride (Case 1).

In 2012, significant increases were observed in major ions including sodium, potassium, TDS, conductivity and sum of base cations (RAMP 2013). These changes were attributed to long-term changes in hydrologic conditions resulting in an increase in the proportion of the groundwater input (vs. surface runoff) to each lake. Changes in the ionic characteristics of the ASL lakes were less evident in 2013 and 2014 and likely reflected the return to more “typical” hydrologic conditions.

Chlorophyll *a* increased significantly in Case 1 and Case 3 but the variability attributed to the interaction term (lake vs. year) rendered these observations unreliable.

Although significant trends in measurement endpoints in the 45 ASL lakes were observed, they did not occur in a direction indicative of acidification. Significant changes in major cations and anions were also observed that likely reflected changing hydrological conditions over the monitoring period.

5.14.3 Critical Loads of Acidity and Critical Load Exceedances

The critical loads of acidity (CL) were calculated for each ASL lake for 2002 to 2014 using the Henriksen steady state water chemistry model modified to include the contribution of organic anions as both strong acids and weak organic buffers (WRS 2006; RAMP 2005). The critical load (CL) is an inherent property of each lake that defines the greatest load of acidifying substances that will not cause ecological damage to the lake. Therefore, the CL represents a measure of the acid-sensitivity of a lake, where a lower critical load represents greater sensitivity to acidification. Calculations of CL included the calculation of the original base cation concentrations from the current base cation concentrations using the F factor from Brakke et al. (1990) (See Section 3.2.5.3).

The runoff values to each lake, an influential term in the Henriksen model, are presented in Appendix F. As noted in Gibson et al. (2010) and RAMP (2012), water yields vary considerably between years with the highest values of yield logically occurring in years with high precipitation. Significant changes in the runoff to a lake result in changes to the critical load; therefore, the acid sensitivity of a lake may vary depending on the hydrologic regime.

Table 5.14-5 provides estimates of the critical loads of acidity for each individual lake from 2002 to 2014; summary statistics are provided in Table 5.14-6. In 2014, the critical loads ranged from -0.762 keq H^+/ha/yr to 3.619 keq H^+/ha/yr, with a median CL of 0.429 keq H^+/ha/y. The median and mean critical loads were lower in 2013 and 2014 than 2012. The median critical load for the 45 lakes appeared to be increasing over time as a result of increases in lake buffering capacity (Gran alkalinity) noted in Section 5.14.2.2.

Mean critical loads in 2014 in the five subregions are presented in Table 5.14-7. Similar to previous years, the lowest critical loads were found in lakes in the Stony Mountains subregion, followed by lakes in the West of Fort McMurray and the Birch Mountains subregions. Negative critical loads were calculated for many of the lakes, especially in the Stony Mountains subregion. Negative critical loads occur when the export of alkalinity to the lakes is less than the biological threshold assumed in the model to maintain the ecological integrity of the lake (See Section 3.5.5.3). The Stony Mountain lakes, having the lowest critical loads, were the most acid-sensitive of the ASL lakes.

5.14.4 Comparison of Critical Loads of Acidity to Modeled Net Potential Acid Input

The critical loads of acidity for each lake were compared to modeled rates of acid deposition for each lake conducted for Teck Energy's Frontier Project (Davies et al. 2015 provisional). Acid input was expressed as the Net Potential Acid Input (PAI), which corrects for nitrogen uptake by plants in the lake catchments (AENV 2007; CEMA 2004b). Nitrogen uptake by plants represents a eutrophying rather than acidifying effect of nitrogen on lake catchments and water chemistry. The 2015 PAI predictions provided new estimates of base cation deposition determined from mixed-bed ion exchange resin collectors deployed from 2009 to 2010 at CEMA TEEM study sites in the oil sands region (Fenn et al. 2015). Bulk base cation deposition rates from open study sites were used in the estimate of PAI rather than rates measured in "flow-through" sites representing deposition to the forest canopy. The open sites typically displayed lower rates of base cation deposition and; therefore, resulted in higher (more conservative) estimates of PAI. For the first time in 2014, the PAI modeling also included the deposition of reduced forms of nitrogen (ammonia and ammonium), and an "existing conditions" EIA emissions scenario was assumed in the modeling (Davies et al. 2015).

The 2015 PAI values changed the entire acidification scenario for the oil sands region. The reworked estimates of base cation deposition were much higher than previous estimates and, at most sites, neutralized the acidifying depositional components (S and N). The 2015 PAI values for the 45 lakes ranged from -1.569 keqH+/Ha/y to 0.049 keqH+/Ha/y, with a median of -0.222 keqH+/Ha/y (Table 5.14-5). As indicated by the negative PAI values in Table 5.14-5, the majority of lake catchments (31 of 45) were exposed to basic rather than acidic deposition. Most of the lakes exposed to acidifying deposition were found in the Birch Mountains and the Canadian Shield, which were regions with relatively low base cation deposition.

Comparison of the modeled PAI to the calculated critical load made little sense when the deposition to a catchment was basic rather than acidic. For those lakes exposed to acidifying deposition, only two lakes in the Birch Mountain subregion (BM6/447 and BM7/448 [Clayton Lake]) had modeled PAI values greater than the critical load (Table 5.14-5). In previous RAMP reports, when the PAI did not include the updated estimates of base cation deposition, 11 to 18 lakes had critical loads exceeded by the PAI. Table 5.14-8 summarizes the key chemical characteristics of the two Birch Mountain lakes. Both were high in DOC, very low in pH (5.49 and 4.4, respectively), and have very little buffering capacity (Gran alkalinity: 43.2 μeq/L and 3.00 μeq/L, respectively).

Four percent (2 of 45 lakes) of the ASL lakes had critical loads that exceeded the PAI in 2014 (Table 5.14-6). This percentage of CL exceedances was lower than the 8% reported in an earlier study on 399 regional lakes conducted for CEMA's NO_xSO_x Management Working Group (WRS 2006). The higher proportion of lakes having CL exceedances in the CEMA study reflected the lower base cation deposition rates incorporated in their PAI predictions. For comparison, Henriksen et al. (2002) reported that 11% to 26% of lakes in four sensitive regions of Ontario had levels of PAI exceeding the critical load.

A modeled PAI greater than the critical load of a lake does not mean that acidification is imminent but that there is a potential risk of acidification. Other factors, such as the influence of highly buffered groundwater seepage to each lake must also be considered in assessing the risks of acidification.

The results of this section indicated that most of the ASL component lakes were subjected to basic rather than acid deposition and are at little risk of acidification. Furthermore, it is the depositional rates of base cations that determined the risk of acidification to an individual lake. As a result of their lower rates of base cation deposition, the Birch Mountain lakes were more at risk to acidification than the Stony Mountain lakes, despite the higher acid sensitivity of the Stony Mountain lakes (See Section 5.14.3).

5.14.5 Mann-Kendall Trend Analysis on Measurement Endpoints

Table 5.14-9 presents the S or Z statistic for each measurement endpoint for each ASL component lake. A significant trend over time is indicated by the shading, with red denoting a direction indicative of acidification and green denoting the opposite direction. Directions of change that are consistent with lake acidification include the following:

- A decrease in pH;
- A decrease in Gran alkalinity;
- An increase in nitrates;

- A decrease in DOC;
- An increase in the sum of base cations; and
- An increase in the concentration of aluminum.

It is important to note that the Mann-Kendall test is a non-parametric test that subtracts successive values and ranks the differences as negative or positive. Small consistent increases or decreases in a variable that may not be ecologically significant or that fall within the range of analytical error can result in a false conclusion that a significant acidifying trend is occurring. The results of these analyses must; therefore, be interpreted carefully. In order to help interpret the results of the trend analyses, control charts of measurement endpoints have been prepared for those lakes where significant changes occurred in a direction indicative of acidification (Figure 5.14-2). The control charts examine changes in a variable in a particular lake in relation to its historical variability, which avoids the false conclusions that may arise from the Mann-Kendall analysis. The control charts were interpreted using the rules outlined in Section 3.2.5.2.

In 2014, there were fewer significant trends detected in measurement endpoints than in previous years (Table 5.14-9):

1. Only one lake (NE9/270) had a significant decrease in pH that suggested acidification. This trend was also observed in 2013. This is a highly buffered lake (Gran alkalinity: 1,088 µeq/L) located in mineral soils in the Northeast of Fort McMurray subregion. Given that the decrease in pH was not associated with a decrease in Gran alkalinity or an increase in sulphate, it is highly unlikely that acidification was the cause of the decrease. The control chart in Figure 5.14-2 shows that the pH in Lake NE9/270 has not deviated by more than 0.40 pH units from the mean with a standard deviation of only 0.20 pH units across all years of monitoring. In addition, the pH in Lake NE9 has remained relatively stable over the last five years. Application of the control chart rules indicated that there was no trend occurring in pH in this lake.

2. There were significant increases in pH in 20 of the 45 lakes, including SM5, SM7, SM3, WF1, WF2, WF7, NE1, NE2, NE3, NE8, BM2, BM9, BM1, BM7, BM4, and S1 to S5. An increase in pH is the opposite effect expected from an acidification scenario. Many of the lakes that showed an increasing trend in pH in 2014 also showed this trend in previous years. A statistical increase in pH over time was also detected using the general linear model of ANOVA for Case 2 (*baseline* lakes) and Case 3 (*test* lakes) (Section 5.12.2). The increase in pH appeared to be a regional phenomenon and was likely the result of changing hydrologic conditions in the ASL component lakes.

3. There were no significant decreases in the concentration of Gran alkalinity over time, indicative of acidification, in any of the ASL lakes. Gran alkalinity increased significantly in 14 lakes located in all of the subregions, including the Stony Mountains (Table 5.14-9). Lakes from the Stony Mountains are the most acid-sensitive and would likely show the earliest indications of acidification (See Section 5.14.3). A significant increase in Gran alkalinity over time was also detected using an ANOVA (Section 5.12.2) for Case 1 (all lakes) and Case 2 (*baseline* lakes). Similar to pH, changing hydrologic conditions were likely responsible for the observed increases in Gran alkalinity.

4. There was a significant increase in the concentration of sulphate over time in only one lake (WF4/223) in the West of Fort McMurray subregion. This lake is highly buffered with a mean Gran alkalinity of 777 µeq/L. There were no significant changes in any of the other measurement endpoints for this lake (including pH and Gran alkalinity) that suggested that acidification was occurring. The control chart for this lake showed increasing sulphate concentrations over time since 2009, reaching a peak in 2013 with a slight decrease in 2014 (Figure 5.14-2). Strict application of the control chart rules suggested that a trend was not yet occurring in sulphate in this lake (Section 3.2.5.2). However, given the increasing sulphate concentrations from 2009, monitoring of Lake WF4 should be continued to determine if a significant trend emerges.

5. There was a significant increase in the concentration of nitrates over time in Lake NE8/209 in the Northeast of Fort McMurray subregion. Lake NE8/209 is a small pond with an area of only 0.1 km^2 and a catchment area of 0.8 km^2. The concentration of nitrates was low but highly variable, with a mean of only 8 µg/L and concentration that was non-detectable in 2014 (Figure 5.14-2). The increase in nitrates in Lake NE8 was accompanied by significant increases (rather than decreases) in pH and Gran alkalinity. Application of the control chart rules indicated that there was no significant trend in nitrates occurring in this lake. The high variability of nitrates and the limitations of its use as a measurement endpoint were noted in previous reports (e.g., RAMP 2012).

6. There were significant decreases in DOC over time in lakes SM1/354 and SM2/342 in the Stony Mountains subregion and Lake NE9/270 in the Northeast of Fort McMurray subregion. These trends were also observed in these lakes in 2013. The decreases in DOC in lakes SM1 and SM2 were not associated with significant decreases in pH or Gran alkalinity. The decrease in DOC in SM2 was actually associated with a significant decrease in sulphate, the principal acidifying agent and decreases (rather than increases) in the sum of base cations. The decrease in DOC in Lake NE9 was associated with a significant decrease in pH although there was no significant change in Gran alkalinity, sulphates, or nitrates and there was a significant decrease in the sum of base cations. The control charts did not provide evidence to suggest that a significant decreasing trend in DOC was occurring in any of these lakes (Figure 5.14-2). The changes in DOC in these lakes were likely attributed to factors other than acidification.

7. There were significant increases in the sum of base cation concentrations over time in lakes WF2/171, WF6/226, WF7/227, located in the West of Fort McMurray subregion; Lake NE8/209 and Kearl Lake (NE11/418), located in the Northeast of Fort McMurray subregion; and Namur Lake (BM2/436) and Lake BM1/444 located in the Birch Mountains subregion. These trends were also identified in 2013 in these lakes. Acidification should initially result in an increase in SBC in a lake as these ions are stripped from soils in catchments receiving acid deposition, which would result is an increased loading of calcium and magnesium sulphate to the lake that reduces Gran alkalinity and pH. Alternatively, an increase in base cations can also occur when the balance between groundwater and surface runoff inputs to each lake is affected by natural changes in hydrology. For the seven lakes showing increases in SBC, there were no significant decreases in pH or Gran alkalinity indicative of acidification. Five of the seven lakes actually had significant increases in pH and/or Gran alkalinity. The control charts suggested that no significant increasing trend was occurring in any of these lakes (Figure 5.14-2). The increases in SBC in these seven

lakes can; therefore, be attributed to changes in hydrology resulting in increased loadings of alkalinity (calcium and magnesium bicarbonates) from their catchments rather than calcium and magnesium sulphate.

8. There was a significant increase in dissolved aluminum in Lake NE1/452, located in the Northeast of Fort McMurray subregion. Similar to nitrates, dissolved aluminum in the ASL lakes is highly variable both between lakes and among years within each lake. The increase in dissolved aluminum in this lake was associated with significant increases in pH and Gran alkalinity which suggested that these changes in dissolved aluminum were not attributed to acidification. The control chart for this lake showed an exceedance of the 2SD limit in 2013 followed by decrease in 2014 to the mean value (Figure 5.14-2). Therefore, the control chart does not indicate an acidifying trend in dissolved aluminum in this lake.

The results of the Mann-Kendall trend analyses did not indicate that acidification was occurring in any of the ASL component lakes. Changes in measurement endpoints were noted but were inconsistent with an acidification scenario and likely reflected hydrological changes in these lakes. However, monitoring of measurement endpoints should be maintained, particularly in Lake WF4 where an acidifying trend may be occurring.

5.14.6 Control Charting of ASL Measurement Endpoints in Lakes at Greatest Risk to Acidification

Of the 14 lakes exposed to acid deposition (nine lakes in the Birch Mountains subregion and five lakes in the Canadian Shield subregion, see Table 5.14-5), the five lakes most at risk to acidification were selected for control charting. An acidification risk factor was calculated from the ratio of PAI to the critical load (Table 5.14-10). The higher the ratio in a lake, the greater the risk of acidification. These five lakes were all found in the Birch Mountains subregion. If acidification was occurring, it would be evident first in these lakes.

Control charts for pH, SBC, sulphate, DOC, nitrates, Gran alkalinity, and dissolved aluminum are presented in Figure 5.14-3 to Figure 5.14-9. As the concentrations of nitrates in each lake were highly variable, a logarithmic scale was used (Figure 5.14-7). Potential trends identified in the control charts were examined using the rules outlined in Section 3.2.5.2. Similar to previous years, the control charts for all measurement endpoints showed isolated exceedances of ±2SD during the monitoring period. Some of these exceedances were in a direction consistent with acidification, while others were not. Two consecutive exceedances of the ±2SD limit in a direction consistent with acidification are required to indicate a significant trend.

The following measurement endpoints/lakes showed exceedances in a direction consistent with acidification at some point during the period of data record:

- pH – lakes BM3/464 (1999), BM9/442 (1999), and BM7/Clayton L. (1999);
- SBC – lakes BM3/464 (2012) and BM7/Clayton L. (2011);
- Sulphate – lakes BM3/464 (1999), BM5/457 (1999), BM9/442 (1999), BM6/447 (1999), and BM7/Clayton L. (2007);

- DOC – Lake BM6/447 (2010);
- Nitrates – lakes BM3/464 (2009), BM9/442 (2001), BM6/477 (2001), and BM7/Clayton L. (2011);
- Gran alkalinity – Lake BM6/447 (2005); and
- Dissolved aluminum – Lake BM3/464 (2009).

In all cases, the concentrations of the measurement endpoints returned to values within the 2SD limits in the following year. The concentration of nitrates actually exceeded the 3SD limit in Clayton Lake (BM7) in 2011, and then returned to normal values in the following years (Figure 5.14-7). An exceedance of this magnitude would indicate a trend; however, the Mann Kendall trend analysis suggested that pH and DOC were actually increasing in this lake (Table 5.14-9). Statistically, concentrations of nitrates are decreasing in all 45 ASL component lakes (Section 5.14.2) and, due to the high variability of this measurement endpoint, it may not be appropriate to use (See Section 5.14.2.2). Therefore, this exceedance was likely an anomaly rather than evidence of acidification in Clayton Lake. With the exception of the concentration of nitrates in Clayton Lake, the control charts did not indicate that acidification was occurring in any of these five lakes that were most at risk to acidification.

5.14.7 Classification of Results

Results of the analysis of the ASL lakes in 2014 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 45 lakes across years that could be attributed to acidification. These results were consistent with the revised estimates of potential acid input (PAI) suggesting that only 14 of the 45 lakes were actually exposed to acidifying deposition.

A summary of the state of the ASL lakes in 2014, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In 2014 there were no exceedances of the 2SD criterion for any of the measurement endpoints in any of the subregions. Therefore, all subregions were classified as having a **Negligible-Low** indication of incipient acidification.

Table 5.14-1 Morphometry statistics for the acid-sensitive lakes.

	Lake Area (km^2)	Catchment Area (km^2)	Maximum Depth (m)
Minimum	0.03	0.57	0.91
Maximum	44.00	166	27.40
Median	1.32	13.2	1.83

Table 5.14-2 Summary of chemical characteristics of the acid-sensitive lakes, 1999 to 2014.

Variable	Mean		Median		Minimum		Maximum		5th percentile 2014	95th percentile 2014	Coef. Variation 1999 to 2014
	1999 to 2014	2014	1999 to 2014	2014	1999 to 2014	2014	1999 to 2014	2014			
Lab pH	6.65	6.91	6.83	7.05	3.97	4.44	9.87	9.87	5.07	8.03	14.99
Total alkalinity (µeq/L)	346	372.4	226	275.2	0.00	25.0	2032	1664	25.0	1074	5.21
Gran alkalinity (µeq/L)	331	348.4	210	247.0	-57.20	3.0	2023	1643.6	7.68	1050	5.61
Specific conductivity (µS/cm)	46.3	45.2	35.2	35.3	8.40	9.57	196	161	10.7	115	80.8
Total dissolved solids (mg/L)	70.0	64.7	62.0	61.0	0.02	1.23	219	166	14.2	135	60.9
Turbidity (NTU)	4.61	5.02	2.31	2.87	0.010	0.53	53.0	31.9	0.744	18.2	122
Total suspended solids (mg/L)	7.58	4.52	2.50	1.50	0.00	0.025	175	48.9	0.025	18.4	191
Colour (TCU)	149	165	112	153	8.00	11.6	948	503	27.2	328	81.4
Sodium (mg/L)	2.15	1.605	1.44	0.860	0.02	0.150	12.4	8.810	0.228	5.65	96.5
Potassium (mg/L)	0.568	0.688	0.470	0.570	0.000	0.050	2.45	2.200	0.184	1.59	73.0
Calcium (mg/L)	5.87	6.18	4.67	5.26	0.0015	0.23	32.2	20.56	0.954	16.20	84.40
Magnesium (mg/L)	1.94	2.03	1.51	1.50	0.005	0.120	8.81	7.12	0.274	5.34	83.5
Bicarbonate (mg/L)	21.0	22.7	13.8	16.8	0.00	1.53	124	102	1.53	65.5	103
Chloride (mg/L)	0.34	0.252	0.17	0.110	0.02	0.015	2.64	2.20	0.032	0.926	139
Sulphate (mg/L)	2.35	1.90	1.03	0.680	0.02	0.02	19.0	17.09	0.02	9.04	145
Total dissolved nitrogen (µg/L)	853	846	740	798	105.4	307	3010	3010	365	1514	55.2
Ammonia (µg/L)	37.1	40.7	14.9	9.00	0.35	1.50	1509	1040	1.50	67.6	282
Nitrate + Nitrite (µg/L)	18.00	2.22	3.00	1.00	0.02	1.00	733	23.00	1.00	9.40	324
Total phosphorus (µg/L)	57	71.3	39	35.0	3.0	5.00	451	451	11.0	243	12
Dissolved phosphorous (µg/L)	21	26.7	11	11.0	1.0	2.00	197	197	4.00	87.8	13
Dissolved inorganic carbon (mg/L)	3.5	3.12	2.1	1.80	0.027	0.100	21.6	17.6	0.100	10.0	18.5
Dissolved organic carbon (mg/L)	23.6	22.5	21.7	21.5	6.82	7.30	92.2	45.9	9.90	33.0	11.93
Chlorophyll *a* (µg/L)	23.3	33.9	10.27	18.18	0.10	2.50	371	313.07	3.25	128	10.9
Iron (mg/L)	0.41	0.618	0.17	0.310	0.001	0.008	5.44	5.440	0.008	1.93	11.3
Total nitrogen (µg/L)	1229	1108	993	930	274	280	6558	4450	419	2560	14.0
Total Kjeldahl nitrogen (µg/L)	1210	1106	969	930	273	280	6552	4450	419	2542	13.9
Sum base cations (µeq/L)	560	563	450	445	32.2	32.2	2411	2015	88	1377	78.1
Dissolved aluminum (µg/L)	72.7	63.7	21.3	27.3	0.100	0.400	850	441	1.062	278	14.4

Grey shading denotes measurement endpoints for the ASL program. Yellow shading denotes values that are less than the detection limit with values equal to one half the detection limit.

Table 5.14-3 Acid-sensitive lakes with chemical characteristics either below the 5th or above the 95th percentile in 2014.

Lake	Subregion	pH	Gran Alkalinity (µeq/L)	DOC (mg/L)
5th percentile (2014)		5.07	7.7	9.9
95th percentile (2014)		8.03	1,050	33.0
S1/118 (Weekes L.)	Canadian Shield	7.72	476	9.3
SM9/169	Smoky Mountains	4.81	3.0	19.8
WF3/172	West of Fort McMurray	5.06	32.4	32.4
BM10/175	Birch Mountains	8.02	792	41.6
NE6/182	Northeast of Fort McMurray	9.87	895	24.0
WF4/223	West of Fort McMurray	7.56	777	45.9
NE9/270	Northeast of Fort McMurray	7.96	1,089	21.3
NE10/271	Northeast of Fort McMurray	8.03	1,208	19.9
SM8/287	Smoky Mountains	5.17	6.6	13.4
NE11/418 (Kearl L.)	Northeast of Fort McMurray	8.13	1,644	23.5
BM2/436 (Namur L.)	Birch Mountains	7.50	448	7.3
BM1/444 (Legend L.)	Birch Mountains	7.25	247	9.4
BM7/448 (Clayton L.)	Birch Mountains	4.44	3.0	21.5

Yellow shading denotes values below the 5th percentile in 2014.

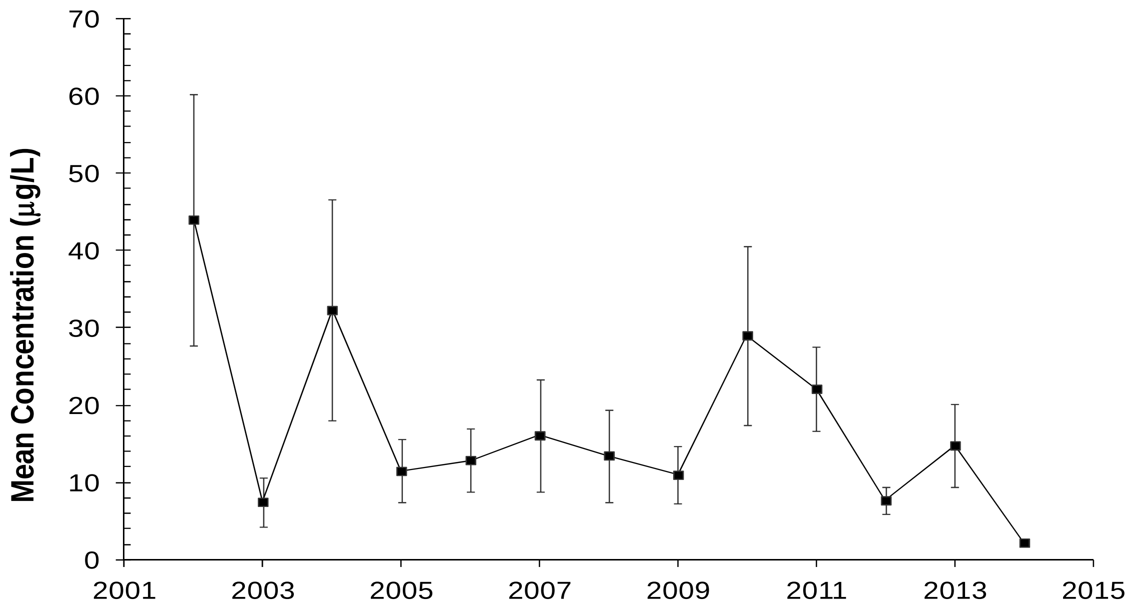
Green shading denotes values above the 95th percentile in 2014.

Table 5.14-4 Results of the one-way ANOVA and the GLM for all 45 acid-sensitive lakes, *baseline* lakes, and *test* lakes.

Variable	One-Way ANOVA/K-W All Lakes	GLM Case 1 – All Lakes			GLM Case 2 – *Baseline* Lakes			GLM Case 3 – *Test* Lakes		
	Significance	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term
pH	NS	S	Positive	S (1.2%)	S	Positive	NS	S	Positive	NS
Gran alkalinity	NS	S	Positive	S (1.2%)	S	Positive	NS	NS	Positive	S (1.1%)
Sum base cations	NS	NS	Positive	S (1.4%)	S	Positive	NS	NS	Positive	S (1.4%)
Conductivity	NS	NS	Negative	S (1.2%)	NS	Negative	NS	NS	Negative	S (1.2%)
TDS	S	NS	Positive	S (6.9%)	NS	Positive	NS	NS	Negative	S (7.0%)
Colour	NS	S	Positive	NS	NS	Positive	NS	S	Positive	NS
Sodium	NS	NS	Negative	NS	NS	Positive	NS	NS	Negative	NS
Potassium	S	S	Positive	NS	S	Positive	NS	S	Positive	NS
Calcium	NS	NS	Positive	NS	NS	Positive	NS	NS	Negative	NS
Magnesium	NS	S	Positive	S (1.6%)	S	Positive	NS	NS	Positive	S (1.5%)
Bicarbonate	NS	S	Positive	S (1.1%)	S	Positive	NS	S	Positive	S (1.1%)
Chloride	NS	S	Negative	S (1.7%)	NS	Negative	NS	S	Negative	S (24.7%)
Sulphates	NS	NS	Negative	S (1.8%)	NS	Negative	NS	NS	Negative	S (1.8%)
Nitrates	S	S	Negative	S (30.3%)	NS	Positive	NS	S	Negative	S (30.5%)
Total phosphorus	NS	NS	Positive	NS	NS	Positive	S (6.7%)	NS	Positive	NS
DOC	NS	NS	Positive	S (4.1%)	NS	Negative	NS	NS	Positive	S (4.6%)
Chlorophyll *a*	NS	S	Positive	S (10.2%)	NS	Positive	NS	S	Positive	S (10.4%)
Aluminum	NS	NS	Positive	NS	NS	Negative	NS	NS	Positive	NS

Note: S = statistically significant ($p<0.05$), NS = not statistically significant. Percentage of the variation attributed to the interaction between lake number and year is indicated in brackets when the term was significant. Shading denotes measurement endpoints for the ASL component. Kruskal Wallis (K-W) non-parametric test was used in the one-way ANOVA when the variances were significantly different.

Figure 5.14-1 Mean concentration of nitrates (± 1SE) in all 45 acid-sensitive lakes combined, 2002 to 2014.



Note: Error bars represent one standard error of the mean.

Table 5.14-5 Critical loads of acidity in the acid-sensitive lakes, 2002 to 2014.

NO_xSO_x GIS No.	Original AESRD Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y) using F to calculate BC_0													Net PAI (keqH+/Ha/y)
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Stony Mountains Subregion																	
168	A21	SM10	18.2	-0.071	-0.082	-0.099	-0.131	-0.101	-0.052	-0.117	-0.101	-0.140	-0.121	-0.121	-0.145	-0.130	-0.220
169	A24	SM9	8.3	-0.184	-0.141	-0.394	-0.519	-0.257	-0.078	-0.234	-0.206	-0.258	-0.422	-0.326	-0.383	-0.311	-0.269
170	A26	SM6	13.1	-0.016	-0.019	-0.029	-0.052	-0.042	-0.009	0.002	-0.026	-0.049	-0.035	-0.046	-0.060	-0.046	-0.309
167	A29	SM5	3.7	-0.078	-0.055	-0.014	0.004	0.090	-0.010	-0.257	0.042	-0.283	-0.096	-0.122	-0.281	-0.140	-0.245
166	A86	SM7	6.9	0.064	0.141	0.182	0.249	0.193	0.144	0.472	0.511	0.316	0.041	0.280	0.277	0.125	-0.454
287	25	SM8	9.6	-0.092	-0.135	-0.198	-0.284	-0.201	-0.026	-0.166	-0.215	-0.266	-0.199	-0.212	-0.265	-0.208	-0.310
289	27	SM3	7.4	0.034	0.071	0.079	0.126	0.076	0.088	0.092	0.115	0.001	0.057	0.115	0.066	0.151	-0.252
290	28	SM4	11.7	0.001	0.019	-0.004	-0.005	0.006	-0.007	0.001	0.000	-0.033	-0.007	-0.015	-0.022	-0.016	-0.344
342	82	SM2	15.4	0.064	0.059	0.117	0.155	0.118	0.012	0.115	0.139	0.140	0.095	0.107	0.096	0.080	-0.434
354	94	SM1	9.6	0.707	0.676	0.803	1.033	0.426	0.152	1.394	1.413	1.022	0.727	0.823	0.772	0.809	-0.750
West of Fort McMurray Subregion																	
165	A42	WF1	10.4	0.382	0.883	1.378	2.112	0.964	0.727	2.110	2.252	1.858	1.352	1.167	1.380	0.798	-0.217
171	A47	WF2	4.3	0.104	0.170	0.126	0.468	0.150	-	0.792	0.390	0.169	0.239	0.318	0.291	0.361	-0.222
172	A59	WF3	51.6	0.006	0.000	-0.001	-0.019	-0.027	-0.018	0.035	0.021	0.010	0.011	-0.013	-0.027	0.004	-0.297
223	P94	WF4	1.8	0.112	0.090	0.117	1.199	0.194	0.087	0.330	0.318	0.155	0.262	0.306	0.296	0.329	-0.270
225	P96	WF5	5.0	0.123	0.264	0.229	1.469	0.383	0.202	0.413	0.451	0.553	0.868	0.703	0.443	0.533	-0.167
226	P97	WF6	4.2	0.088	0.340	0.202	2.655	0.192	0.166	0.287	0.391	0.464	0.374	0.358	0.470	0.463	-0.008
227	P98	WF7	1.6	0.288	1.131	0.576	0.835	0.947	0.460	1.058	1.451	1.645	1.245	1.365	1.324	1.169	-0.051
267	1	WF8	23.1	0.197	0.400	0.349	0.934	0.415	0.147	-	0.758	0.348	0.517	0.522	0.410	0.429	-1.141
Northeast of Fort McMurray Subregion																	
452	L4	NE1	16.8	0.092	0.092	0.069	0.262	0.087	0.064	0.243	0.125	0.078	0.202	0.243	0.165	0.162	-1.091
470	L7	NE2	15.1	0.171	0.141	0.074	0.312	0.745	0.156	0.228	0.201	0.208	0.285	0.356	0.232	0.195	-0.966
471	L8	NE3	24.0	0.341	0.601	0.431	1.107	0.604	0.226	0.445	0.486	0.424	0.572	0.802	0.598	0.660	-0.793
400	L39	NE4	3.2	1.069	0.913	0.715	0.654	1.473	0.723	1.344	1.347	0.796	1.239	1.143	0.913	0.782	-0.004
268	E15	NE5	7.3	1.349	2.186	1.478	2.291	0.257	0.409	1.976	2.842	2.286	2.031	2.357	0.329	1.521	-0.919

Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2015, provisional) representing emissions from industrial sources that include all the existing sources and approved sources from 2008. The PAI is the net PAI after correction for nitrogen uptake by plants in the catchment (eutrophication). Runoff in all CL measurements estimated using the IMB method from data provided by Gibson et al. (pers. comms.).

Table 5.14-5 (Cont'd.)

NO_xSO_x GIS No.	Original AESRD Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y) using F to calculate BC_0													
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Net PAI (keqH+/Ha/y)
Northeast of Fort McMurray Subregion (Cont'd.)																	
182	P23	NE6	8.3	0.352	1.251	1.443	4.085	0.347	2.000	0.065	2.360	3.172	2.817	2.570	1.426	3.060	-0.997
185	P27	NE7	5.9	0.037	0.015	-0.072	0.279	-0.029	0.031	0.047	0.016	0.046	0.088	-0.146	-0.004	0.118	-1.107
209	P7	NE8	0.8	0.852	0.781	0.348	0.600	0.416	0.413	2.472	0.836	1.267	0.945	0.705	1.611	1.211	-0.935
270	4	NE9	11.2	3.371	4.488	4.986	8.031	4.567	1.331	3.932	6.714	5.356	4.528	4.236	3.414	3.619	-0.672
271	6	NE10	17.1	2.446	2.659	6.395	7.347	3.557	2.317	3.067	4.905	3.638	3.994	3.901	3.486	3.273	-0.626
418	Kearl L.	NE11	77.2		2.759	2.316	5.097	1.715	0.801	2.588	2.739	2.046	2.984	3.169	2.624	2.593	-1.569
Birch Mountains Subregion																	
436	L18	BM2	165.5	1.382	2.067	1.715	2.194	1.726	1.077	2.356	2.283	2.185	2.056	2.093	2.104	2.029	0.031
442	L23	BM9	33.3	0.260	0.353	0.267	0.362	0.308	0.295	0.427	0.437	0.233	0.113	0.394	0.427	0.378	0.040
444	L25	BM1	58.7	0.491	0.819	0.772	0.854	0.901	0.560	1.092	1.301	0.847	0.933	1.177	1.231	1.221	0.044
447	L28	BM6	13.7	-0.123	-0.179	-0.012	-0.340	-0.242	-0.017	0.001	-0.184	0.115	-0.084	-0.080	-0.204	-0.177	0.028
448	L29	BM7	4.7	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.312	-1.015	-0.761	-0.762	0.041
454	L46	BM8	32.5	0.433	0.590	0.351	0.855	0.409	0.328	0.514	0.618	0.348	0.517	0.607	0.492	0.674	0.032
455	L47	BM4	37.3	0.572	0.735	1.640	1.436	0.807	0.406	0.854	1.321	0.871	1.086	1.003	1.117	0.886	0.026
457	L49	BM5	30.6	0.457	0.664	0.417	0.883	0.501	0.227	0.565	0.714	0.438	0.414	0.638	0.533	0.578	0.049
464	L60	BM3	29.8	0.336	0.634	0.490	0.736	0.375	0.237	0.549	0.579	0.436	0.570	0.789	0.579	0.616	0.035
175	P13	BM10	5.2	0.393	0.345	0.662	1.455	0.618	0.298	0.813	2.806	0.520	0.932	0.972	0.655	0.715	-0.015
199	P49	BM11	0.6	0.110	0.150	0.168	0.196	0.209	0.079	0.139	0.143	0.103	0.152	1.830	0.124	0.139	-0.005
Canadian Shield Subregion																	
473	A301	S4	114.6	0.105	0.130	0.102	0.327	0.165	-	0.213	0.196	0.147	0.196	0.218	0.191	0.175	0.008
118	L107	S1	13.4	2.042	2.265	1.785	2.679	1.998	1.431	2.706	2.156	2.228	2.290	2.383	2.335	2.350	0.008
84	L109	S2	112.6	0.181	0.208	0.147	0.333	0.156	-	0.244	0.318	0.165	0.278	0.308	0.265	0.258	0.008
88	O-10	S5	4.5	0.273	0.312	0.204		0.282	-	0.400	0.544	0.209	0.328	0.375	0.374	0.281	0.008
90	R1	S3	37.9	0.346	0.479	0.351	0.550	0.444	0.547	0.608	0.587	0.460	0.544	0.590	0.581	0.558	0.008

Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2015, provisional) representing emissions from industrial sources that include all the existing sources and approved sources from 2008. The PAI is the net PAI after correction for nitrogen uptake by plants in the catchment (eutrophication). Runoff in all CL measurements estimated using the IMB method from data provided by Gibson et al. (pers. comms.).

Table 5.14-6 Summary of critical loads (CL) of acidity in the acid-sensitive lakes, 2002 to 2014.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
No. of lakes	49	50	50	49	50	46	49	50	50	50	50	50	45
Minimum CL	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.422	-1.015	-0.761	-0.762
Maximum CL	3.371	4.488	6.395	8.728	4.567	2.317	3.932	6.714	5.356	4.528	4.236	3.613	3.619
Average CL	0.429	0.637	0.645	1.339	0.597	0.428	0.809	0.984	0.803	0.816	0.872	0.724	0.700
Median CL	0.260	0.349	0.262	0.736	0.361	0.232	0.432	0.527	0.386	0.517	0.598	0.457	0.429
No. of lakes in which the PAI is greater than the CL	2	2	2	2	2	2	2	2	1	2	2	2	2

Table 5.14-7 Mean critical loads of acidity for lakes within each subregion in 2014.

Subregion	Critical Load keq H^+/ha/y
Stony Mountains	0.031
West of Fort McMurray	0.511
Northeast of Fort McMurray	1.563
Birch Mountains	0.573
Canadian Shield	0.724

Table 5.14-8 Chemical characteristics of acid-sensitive lakes having the modeled potential acid input (PAI) greater than the critical load in 2014.

NO_xSO_x GIS No.	AESRD ID	Subregion	pH	Gran Alkalinity (µeq/L)	Conductivity (µS/cm)	DOC (mg/L)	Lake Area (km^2)
447	L28/BM6	Birch Mts.	5.49	43.2	18.28	29.4	1.30
448	L29/BM7 (Clayton L.)	Birch Mts.	4.44	3.0	15.48	21.5	0.65

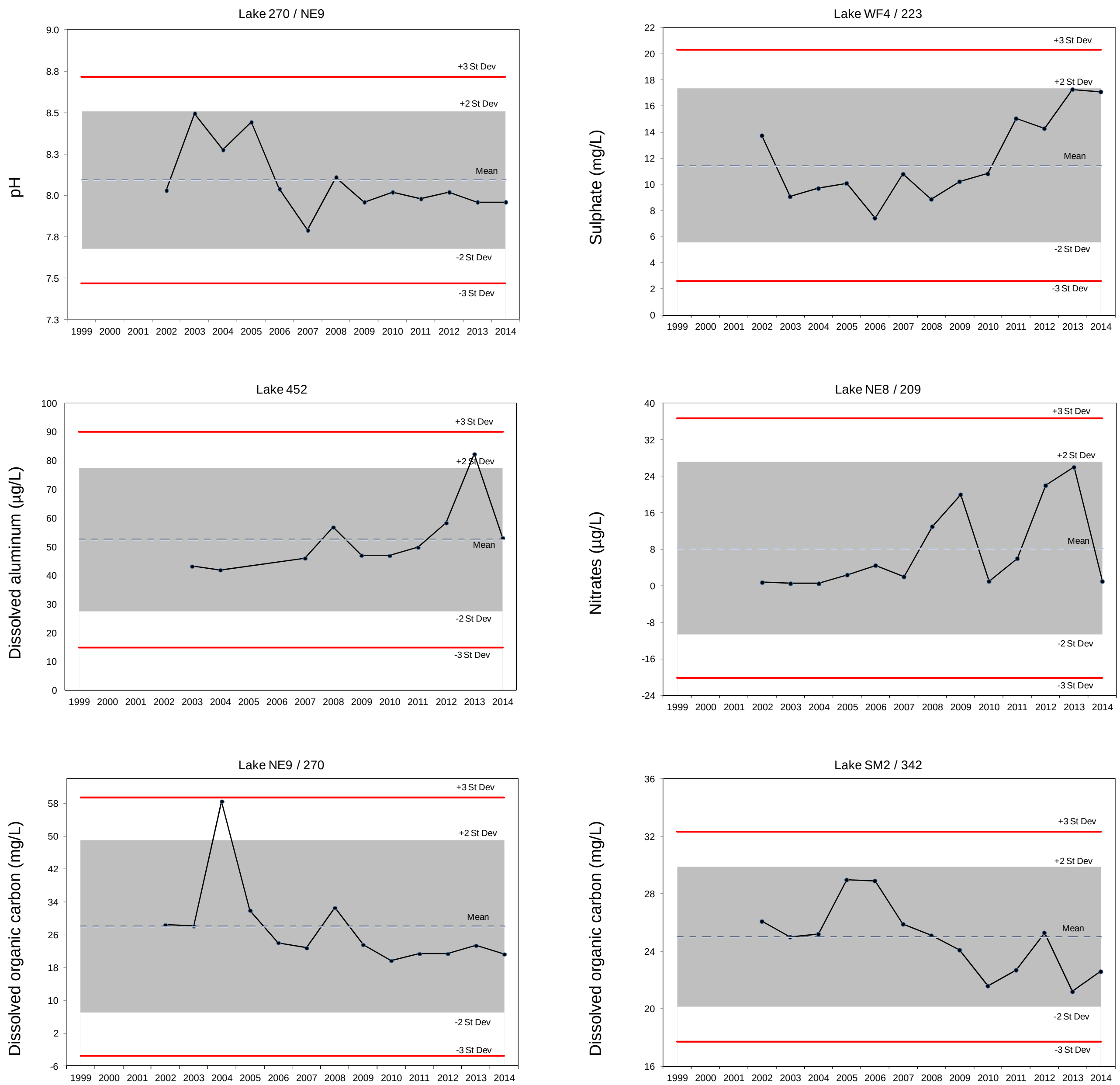
Table 5.14-9 Results of Mann-Kendall trend analyses on measurement endpoints for the acid-sensitive lakes, 2014.

AESRD ID	NO_XSO_X ID	pH	Gran Alkalinity (μeq/L)	Sulphate mg/L	Nitrates (μg/L)	Diss. Organic Carbon (mg/L)	SBC (μeq/L)	Aluminum (μeq/L)		Potential Acid Input (keq H+/ha/y)
		Z	Z	Z	Z	Z	Z	S	Z	
SM10	168	1.08	0.40	-3.56	-0.14	-1.04	-2.93		-1.33	0.134
SM9	169	1.04	-0.10	-2.21	-0.18	0.95	-1.94		0.16	0.121
SM6	170	0.23	2.28	-2.57	-0.63	0.27	-2.03		0.47	0.125
SM5	167	2.34	2.77	-1.40	0.41	-0.72	-1.04		0.78	0.105
SM7	166	2.13	2.19	-1.48	0.50	-0.10	0.99		0.00	0.043
SM8	287	0.06	1.40	-1.28	0.18	-1.65	-2.26		-0.72	0.120
SM3	289	2.01	2.26	-0.55	1.43	0.00	0.00		0.16	0.118
SM4	290	0.86	0.31	-2.32	-1.47	-1.40	-2.26		-0.86	0.115
SM2	342	0.00	-1.47	-2.96	-0.68	-2.38	-3.36		-1.56	0.027
SM1	354	1.59	-1.40	-1.53	-0.12	-2.20	-2.14		-0.39	0.043
WF1	165	3.06	0.20	-2.30	1.00	-1.58	0.00		-0.16	0.044
WF2	171	2.57	2.28	-1.04	-1.04	0.23	2.48		-1.71	0.082
WF3	172	-0.54	-0.69	-1.22	-0.05	-0.18	-0.14		-1.87	0.049
WF4	223	-0.49	-1.59	2.50	-0.93	0.37	0.67		1.61	0.151
WF5	225	1.34	0.00	0.31	-0.31	0.31	0.18		0.27	0.172
WF6	226	1.16	0.92	0.79	0.18	1.53	2.14		-0.99	0.240
WF7	227	2.75	1.28	-2.01	-0.25	0.06	2.62		0.45	0.209
WF8	267	0.55	-0.48	-2.06	1.10	1.17	-0.48		-0.27	0.161
NE1	452	2.21	2.08	-0.23	0.68	1.31	1.58		2.50	0.188
NE2	470	1.98	1.09	-0.86	0.27	0.14	0.59		-0.36	0.166
NE3	471	2.21	-0.74	-0.77	-1.27	0.99	-0.41		0.00	0.145
NE4	400	1.63	0.99	-0.32	0.72	1.35	-1.13		0.54	0.059
NE5	268	1.14	-0.49	-1.19	-0.30	0.20	-0.99		-0.78	0.163
NE6	182	1.65	1.16	-1.40	1.23	1.22	1.16		0.36	0.251
NE7	185	1.41	1.77	0.79	-0.24	0.79	0.79	0.00		0.189
NE8	209	2.14	2.50	-0.73	2.27	0.79	2.14		0.36	0.178
NE9	270	-2.28	-1.89	-0.92	0.13	-2.57	-2.14		1.87	0.137
NE10	271	-0.12	-1.10	-1.47	0.00	-1.22	-1.16		-1.43	0.064
NE11	418	1.10	1.44	-1.99	0.35	0.75	1.99		1.71	0.618
BM2	436	3.24	3.76	1.44	-0.95	-1.67	2.21		1.09	0.066
BM9	442	3.02	1.73	-1.85	1.68	0.05	-0.68		1.25	0.056
BM1	444	3.15	2.97	-0.99	-0.10	-0.18	2.75		-0.78	0.067
BM6	447	1.58	2.08	-1.22	-0.18	1.62	0.14		0.93	0.050
BM7	448	2.33	-0.06	-3.17	0.40	2.38	-0.99		-0.99	0.046
BM8	454	0.14	0.49	-1.76	0.32	1.85	-0.86		-0.31	0.053
BM4	455	1.98	1.29	-0.54	-1.04	1.31	0.59		-0.08	0.054
BM5	457	-0.63	-1.58	-0.72	-1.13	1.44	-2.12		1.25	0.052
BM3	464	1.13	2.18	-1.76	0.09	2.52	1.76		0.47	0.055
BM10	175	0.18	-1.28	-2.87	-0.37	-1.04	-1.16		0.00	0.084
BM11	199	0.55	0.79	-0.43	0.98	0.55	-0.18		1.53	0.086
S4	473	2.69	2.26	0.18	0.18	-1.16	1.28	2.00		0.014
S1	118	3.37	3.02	0.00	-0.05	0.15	1.39		0.54	0.007
S2	84	2.97	1.29	-1.35	-0.68	0.95	1.49		0.36	0.014
S5	88	2.52	0.92	-0.82	0.55	0.99	-0.77	-14.00		0.014
S3	90	3.38	2.28	-0.32	0.54	-1.13	1.85		0.81	0.014

Note: Numbers represent the S or Z statistic used in the analysis. Negative values represent overall decreases in a variable and positive values represent increases.

Note: Shaded values are statistically significant – yellow in a direction consistent with an acidification scenario, and green in a direction inconsistent with acidification.

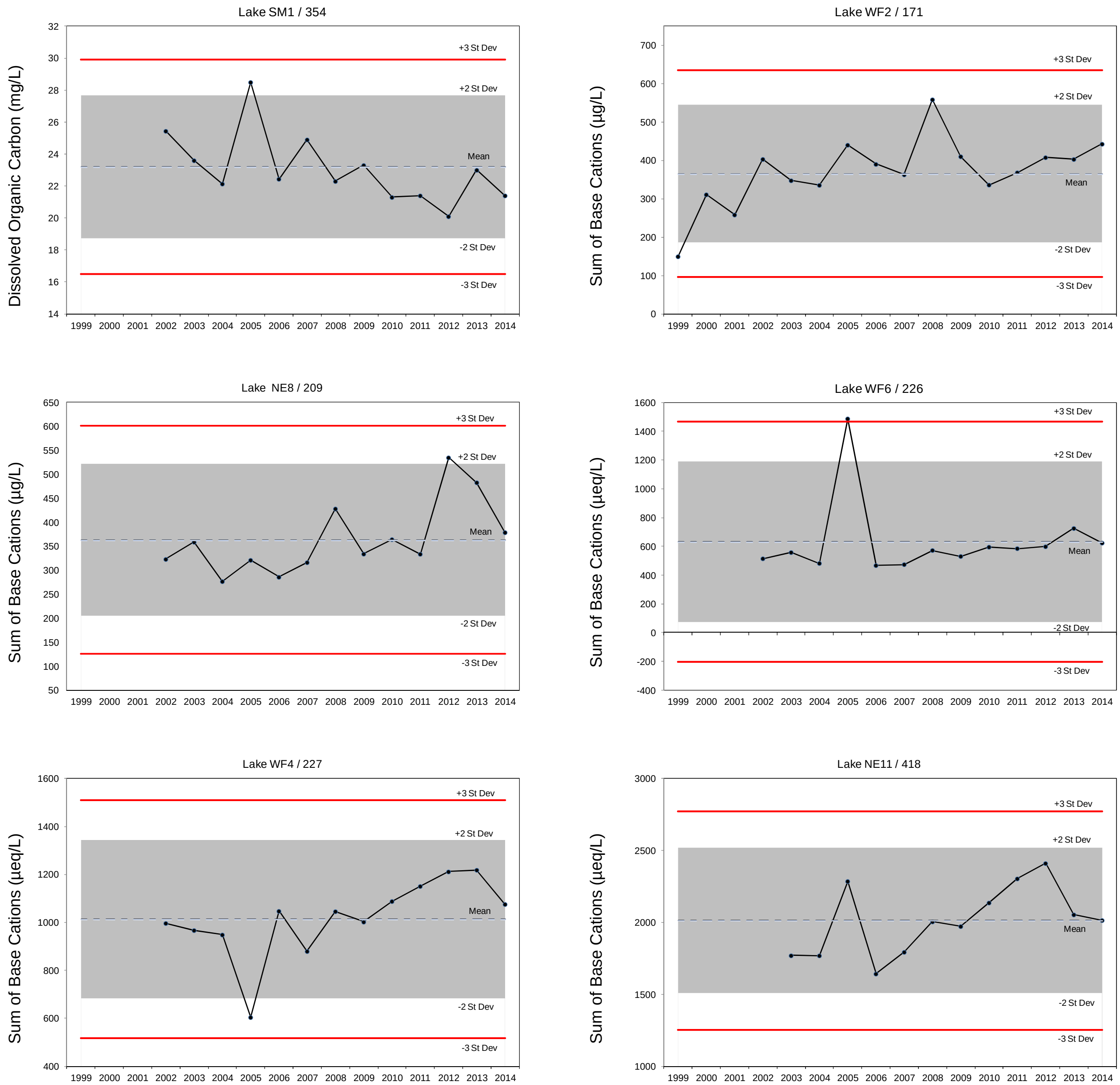
Figure 5.14-2 Control charts for acid-sensitive lakes showing significant trends in measurement endpoints using Mann-Kendall trend analysis.



Note: Only significant trends in a direction indicative of acidification are presented.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

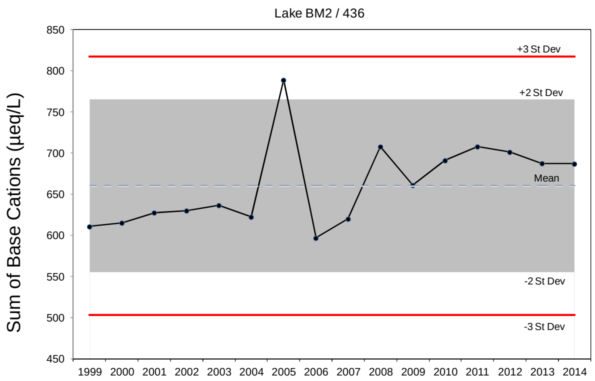
Figure 5.14-2 (Cont'd.)

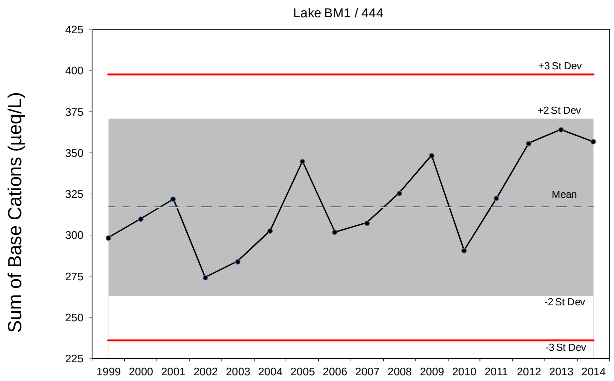


Note: Only significant trends in a direction indicative of acidification are presented.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Figure 5.14-2 (Cont'd.)





Note: Only significant trends in a direction indicative of acidification are presented.

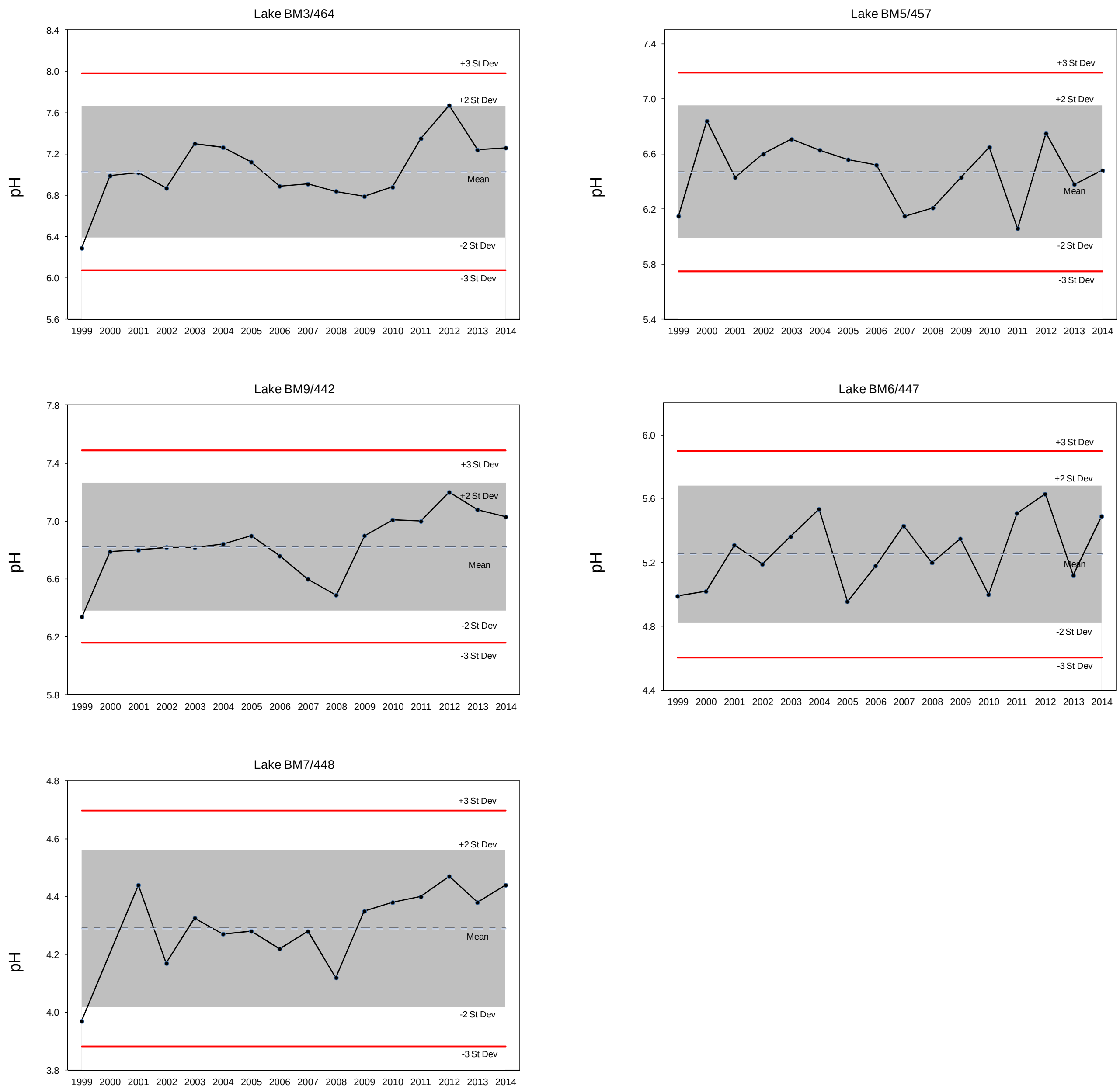
Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Table 5.14-10 Acidification risk factor for individual acid-sensitive lakes.

NO_xSO_x GIS No.	Original AESRD Designation	Current AESRD Designation	Subregion	Critical Load (keq/Ha/y) IMB	PAI	Acidification Risk Factor PAI/CL
118	L107	S1	Canadian Shield	2.350	0.008	0.003
90	R1	S3	Canadian Shield	0.558	0.008	0.014
436	L18	BM2	Birch Mountains	2.029	0.031	0.015
88	O-10	S5	Canadian Shield	0.281	0.008	0.029
455	L47	BM4	Birch Mountains	0.886	0.026	0.029
84	L109	S2	Canadian Shield	0.258	0.008	0.031
444	L25	BM1	Birch Mountains	1.221	0.044	0.036
473	A301	S4	Canadian Shield	0.175	0.008	0.046
454	L46	BM8	Birch Mountains	0.674	0.032	0.047
464	L60	BM3	Birch Mountains	0.616	0.035	0.057
457	L49	BM5	Birch Mountains	0.578	0.049	0.085
442	L23	BM9/Otasan	Birch Mountains	0.378	0.040	0.106
447	L28	BM6	Birch Mountains	-0.177	0.028	28.0
448	L29	BM7/Legend	Birch Mountains	-0.762	0.041	41.0

Shading denotes those lakes most at risk to acidification.

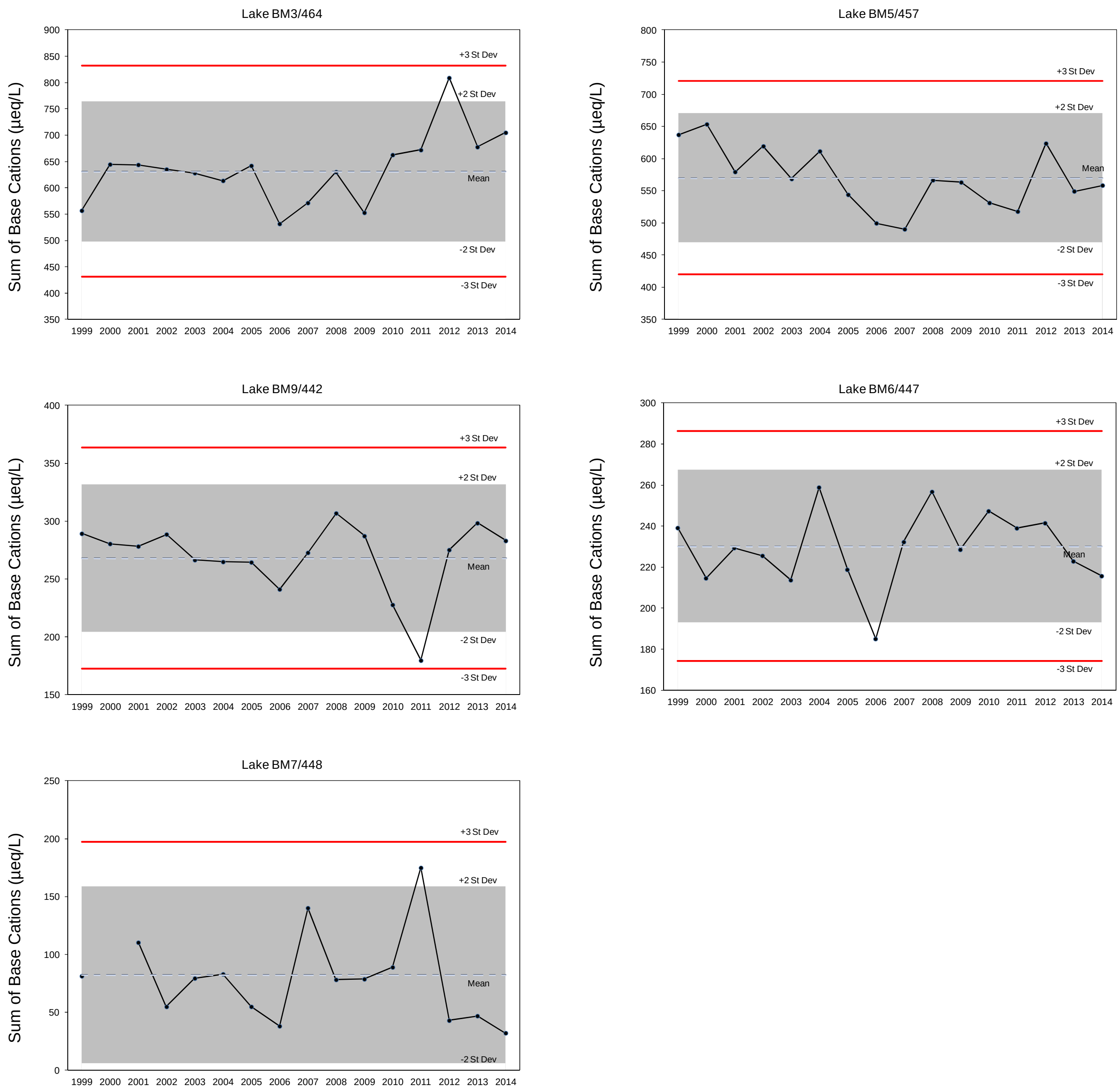
Figure 5.14-3 Control charts of pH in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

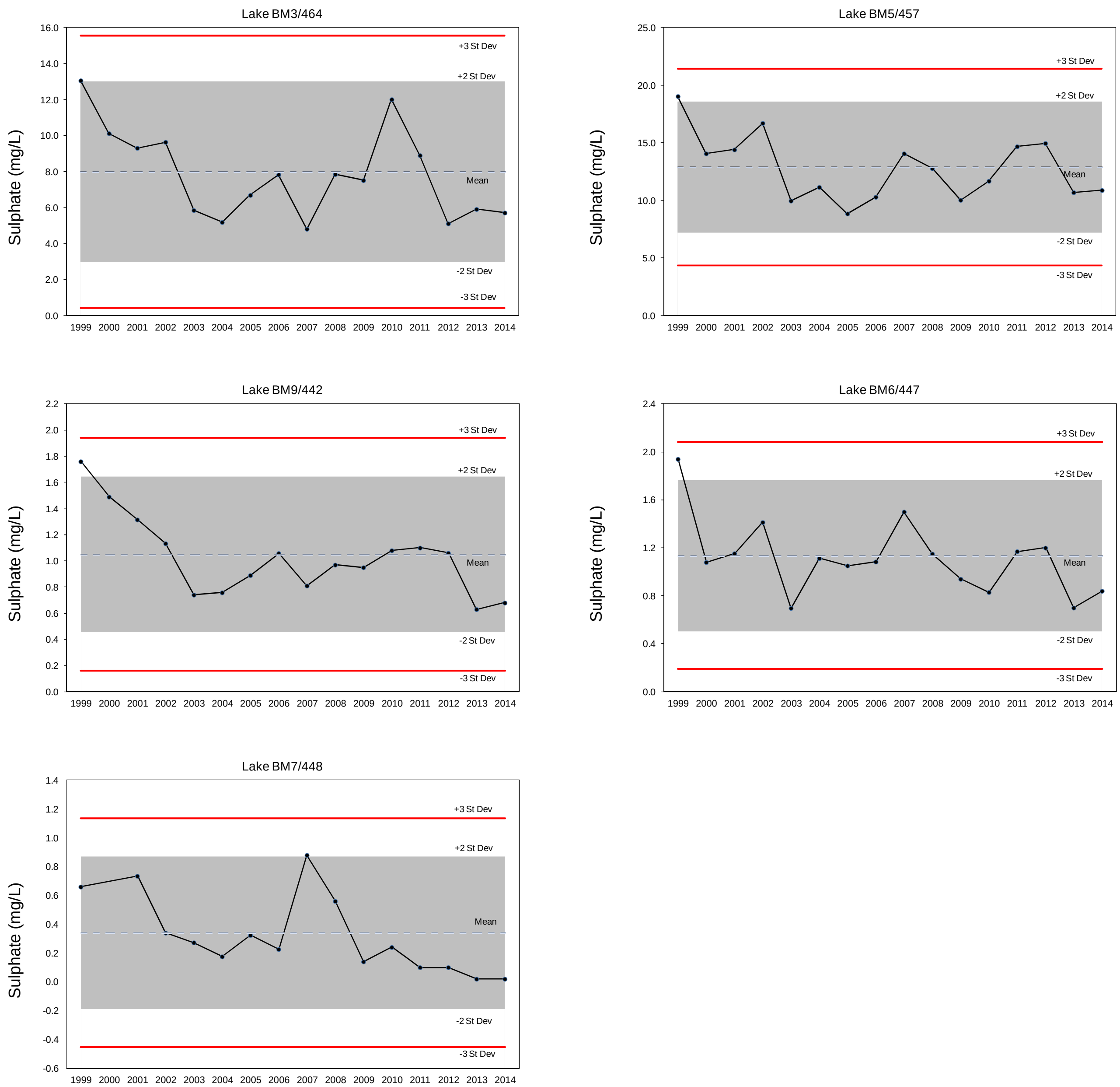
Figure 5.14-4 Control charts of the sum of base cations in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

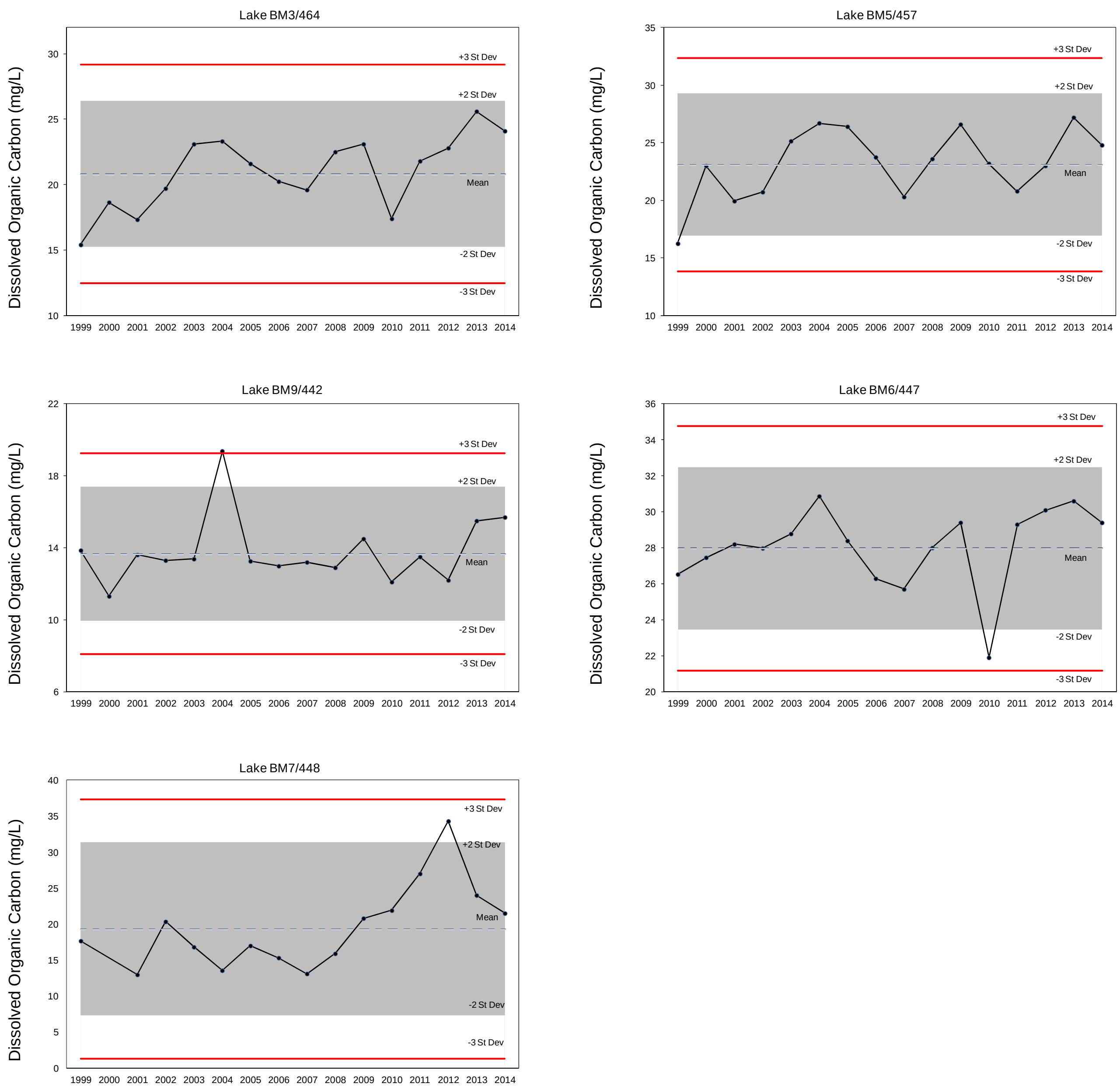
Figure 5.14-5 Control charts of sulphate in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

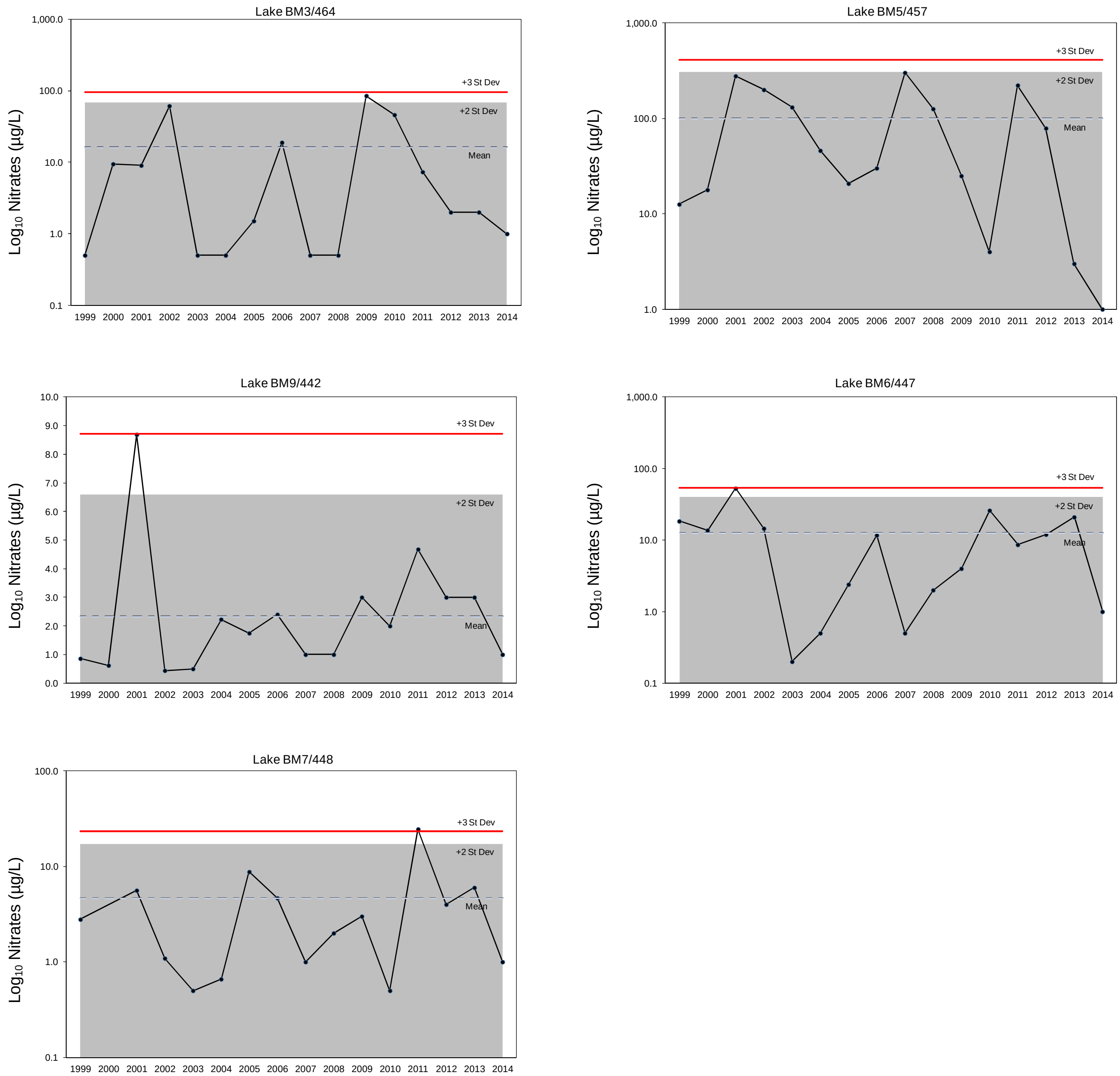
Figure 5.14-6 Control charts of dissolved organic carbon in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

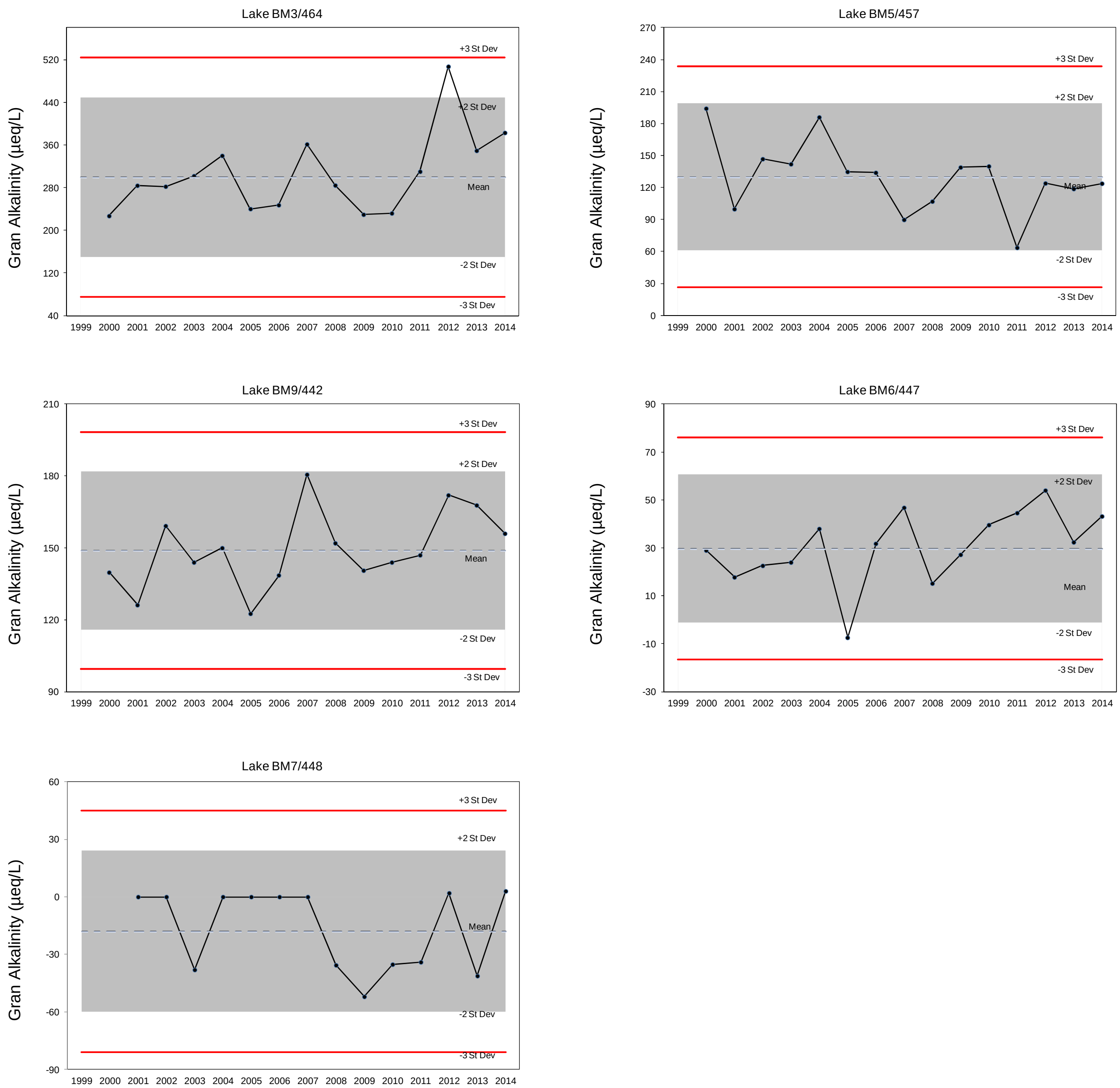
Figure 5.14-7 Control charts of nitrates in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

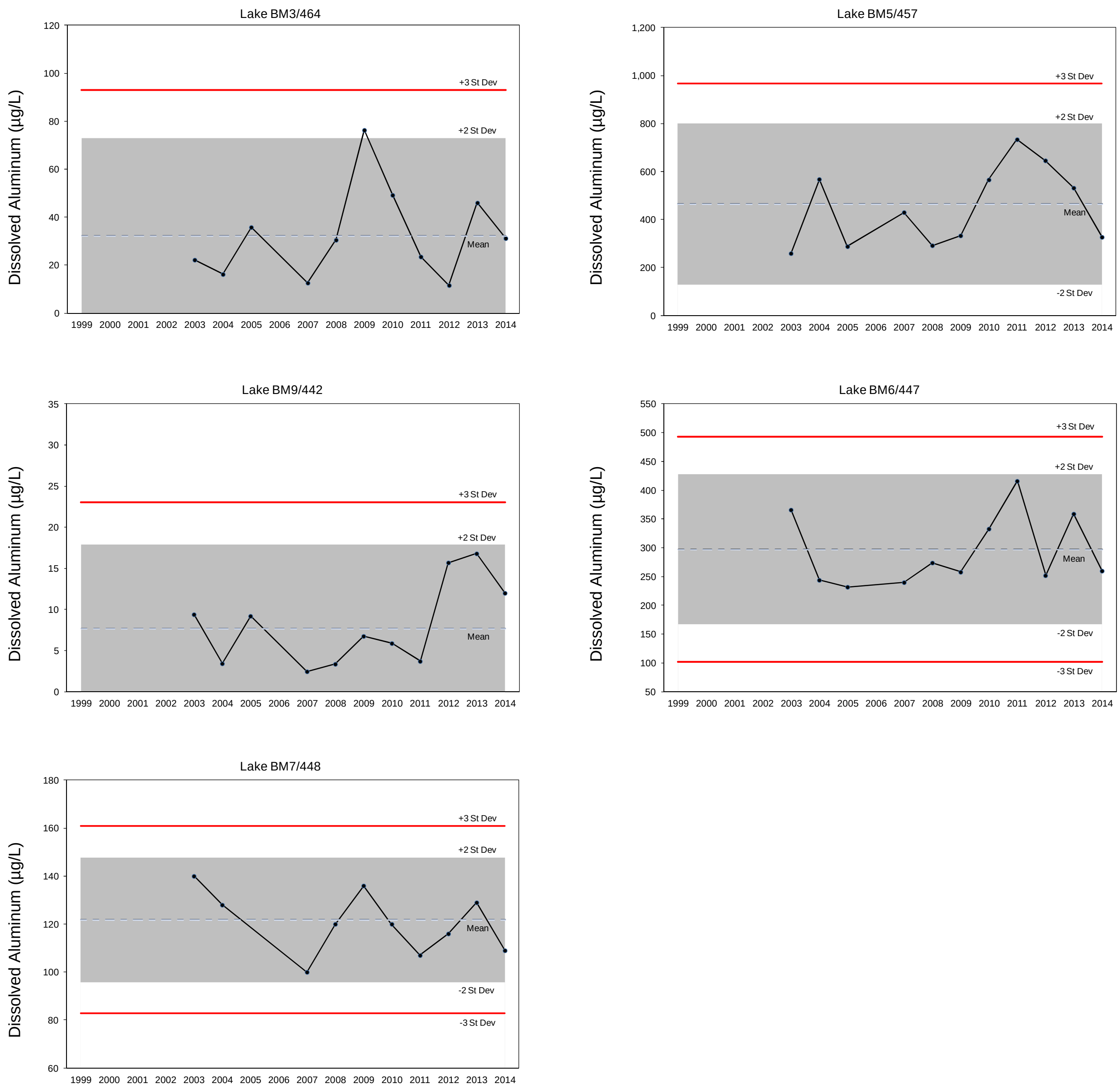
Figure 5.14-8 Control charts of Gran alkalinity in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Figure 5.14-9 Control charts of dissolved aluminum in five lakes in the Birch Mountains most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

6.0 SYNTHESIS OF 2014 RESULTS

The 2014 aquatic monitoring program results have been discussed in detail in Section 5. This section provides a summary of results for each monitoring component. Based on results presented in Section 5, Table 6.1-1 is a compilation of the 2014 results by watershed and by component. In addition, overall conclusions and general comments for each component are presented in the following sections.

6.1 CLIMATE AND HYDROLOGY

6.1.1 Summary of 2014 Results

Hydrologic changes in the Athabasca oil sands region during the 2014 WY were assessed as **Negligible-Low** in eight of the 13 watersheds that were assessed. Exceptions to the **Negligible-Low** assessment included the Muskeg River, Tar River, Mills Creek, Poplar Creek, and Fort Creek watersheds, where at least one of the four measurement endpoints was classified as **Moderate** or **High** (Table 6.1-2). In the 2014 WY, the activities related to oil sands development that contributed to hydrologic changes, in order of decreasing water volumes, were:

- industrial water withdrawals, releases, and diversions;
- closed-circuited land area resulting in a loss of flow to natural watercourses that would have occurred in the absence of oil sands developments; and
- land area that is cleared and not closed-circuited thereby contributing to increased flows to natural watercourses that would not have occurred in the absence of oil sands developments.

The cumulative effect of oil sands development on the surface hydrology was assessed using the Athabasca River mainstem. Relative changes from *baseline* to *test* conditions for all four measurement endpoints (i.e., mean open-water season discharge, mean winter discharge, annual maximum daily discharge, and open-water season minimum daily discharge) were classified as **Negligible-Low** at Station S46, Athabasca River near Embarras Airport, for the 2014 WY (Table 6.1-2). For each of these measurement endpoints, the observed *test* hydrograph value was lower than the estimated *baseline* hydrograph value that would have occurred in the absence of oil sands development.

Temporal changes on the cumulative effect of oil sands development on the surface hydrology was assessed by plotting the measurement endpoints for Station S24, Athabasca River below Eymundson Creek, from 2004 to 2011 and Station S46, Athabasca River near Embarras Airport, from 2012 to 2014 over time (Figure 6.1-1). The percent change in all measurement endpoints from 2004 to 2014 showed no discernible trend be2tween *baseline* and *test* conditions.

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Table 6.1-1 Summary assessment of 2014 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions: Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Assemblages[5]	Fish Populations: Human Health Risk from Mercury in Fish Tissue[6]: Species	Subsistence Fishers	General Consumers	Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[7]
Athabasca River	Negligible-Low	Negligible-Low	-	-	-	LKWH	Negligible-Low	Negligible-Low	-
						WALL	High	High	
Athabasca River Delta	-	-	Negligible-Low / Moderate / High	Negligible-Low	n/a		-		-
Muskeg River	Moderate	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low / Moderate / High		-		-
Jackpine Creek	nm	Negligible-Low	Negligible-Low	Negligible-Low	High		-		-
Kearl Lake	nm	Moderate / Negligible-Low	Negligible-Low	n/a	-		-		-
Steepbank River	Negligible-Low	Moderate	Moderate	-	High		-		-
Tar River	High	Negligible-Low	High	Negligible-Low	Negligible-Low		-		-
MacKay River	Negligible-Low	Negligible-Low	Moderate / Negligible-Low	-	Moderate / Negligible-Low		-		-
Calumet River	Negligible-Low	Negligible-Low	nm	nm	nm		-		-
Firebag River	Negligible-Low	Negligible-Low	-	-	-		-		-
McClelland Lake	nm	n/a	Negligible-Low	n/a	-		-		-
Johnson Lake	-	n/a	n/a	n/a	-		-		-
Ells River	Negligible-Low	Negligible-Low	Moderate	Negligible-Low	Moderate		-		-
Gardiner Lake	-	-	n/a	n/a	-				
Namur Lake	-	-	-	-	-		-		-
Clearwater River	nm	Negligible-Low	Negligible-Low	Negligible-Low	-		-		-
High Hills River	-	Negligible-Low	n/a	-	n/a		-		-
Christina River	Negligible-Low	Negligible-Low / Moderate	Negligible-Low	Negligible-Low	-		-		-
Christina Lake	nm	n/a	Moderate	n/a	-		-		-
Gregoire Lake	nm	n/a	Negligible-Low	n/a	-				
Gregoire River	nm	Moderate	Negligible-Low	n/a	Negligible-Low				
Jackfish River	nm	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low		-		-
Sawbones Creek	nm	Negligible-Low	Negligible-Low	Negligible-Low	High		-		-
Sunday Creek	nm	Negligible-Low	Moderate	Negligible-Low	Negligible-Low		-		-
Birch Creek	nm	Negligible-Low	n/a	Negligible-Low	n/a		-		-
Unnamed Creeks (east and south of Christina Lake)	nm	Negligible-Low	Negligible-Low	Negligible-Low	High / High		-		-
Hangingstone River	Negligible-Low	Moderate	-	-	-		-		-
Fort Creek	High	Negligible-Low	Moderate	Negligible-Low	Moderate		-		-
Beaver River	-	Moderate	-	-	-		-		-
McLean Creek	-	Moderate	-	-	-		-		-
Mills Creek	High	Moderate	-	-	-		-		-
Isadore's Lake	nm	n/a	Negligible-Low	n/a	-		-		-
Poplar Creek	High	Moderate	Negligible-Low	Negligible-Low	Negligible-Low		-		-
Shipyard Lake	-	n/a	Negligible-Low	n/a	-		-		-
Big Creek	-	Negligible-Low	n/a	Negligible-Low	n/a		-		-
Pierre River	-	Negligible-Low	n/a	Negligible-Low	n/a		-		-
Red Clay Creek	-	Negligible-Low	n/a	Negligible-Low	n/a		-		-
Eymundson Creek	-	Negligible-Low	n/a	Negligible-Low	n/a		-		-
Stony Mountains	-	-	-	-	-		-		Negligible-Low
West of Fort McMurray	-	-	-	-	-		-		Negligible-Low
Northeast of Fort McMurray	-	-	-	-	-		-		Negligible-Low
Birch Mountains	-	-	-	-	-		-		Negligible-Low
Canadian Shield	-	-	-	-	-		-		Negligible-Low

Legend and Notes

- Negligible-Low change
- Moderate change
- High change

"-" program was not completed in 2014; nm – not measured in 2014.

n/a – classification could not be completed because there were no *baseline* conditions to compare against or reach was sampled to add to the regional *baseline* dataset.

[1] **Hydrology:** Calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% – Negligible-Low; ± 15% – Moderate; > 15% – High.

Note: As not all hydrology measurement endpoints were calculated for each watershed because of differing lengths of the hydrographic record for 2014, hydrology results were for those measurement endpoints that were calculated.

Note: Mean Open-Water Season Discharge and Annual Maximum Daily Discharge in the Muskeg River were assessed as Moderate; Mean Winter Discharge was assessed as Negligible-Low, and Minimum Open-Water Season Discharge was assessed as High.

Note: Mean Open-Water Season Discharge, Mean Winter Discharge, and Annual Maximum Daily Discharge in Poplar Creek were assessed as Negligible-Low; Mean Open-Water Discharge was assessed as High.

[2] **Water Quality:** Classification based on adaptation of CCME water quality index.

Note: Water Quality in the Steepbank River was assessed as Moderate at the lower station, and Negligible-Low at all other stations.

[3] **Benthic Invertebrate Communities:** Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches or between *baseline* and *test* periods or trends over time for a reach as well as comparisons to regional *baseline* conditions.

Note: Benthic invertebrate communities in the Athabasca River Delta were assessed as Negligible-Low at Big Point Channel and the Embarras River, Moderate at Fletcher Channel, and High at Goose Island Channel.

[4] **Sediment Quality:** Classification based on adaptation of CCME sediment quality index.

[5] **Fish Populations (fish assemblages):** Classification based on exceedances of measurement from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Note: Fish assemblages in the Muskeg River were assessed as Moderate at the lower reach, Negligible-Low at the middle reach, and High at the upper reach.

Note: Fish assemblages in the MacKay River were assessed as High at the lower reach and Negligible-Low at the middle reach.

[6] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. LKWH – lake whitefish; WALL – walleye; Subsistence fishers and General consumers as defined by Health Canada (see Section 3.2.4.2).

[7] **Acid-Sensitive Lakes:** Classification based the frequency in each subregion with which values of seven measurement endpoints in 2014 were more than twice the standard deviation from their long-term mean in each lake.

Table 6.1-2 Summary assessment of the 2014 WY hydrologic monitoring results.

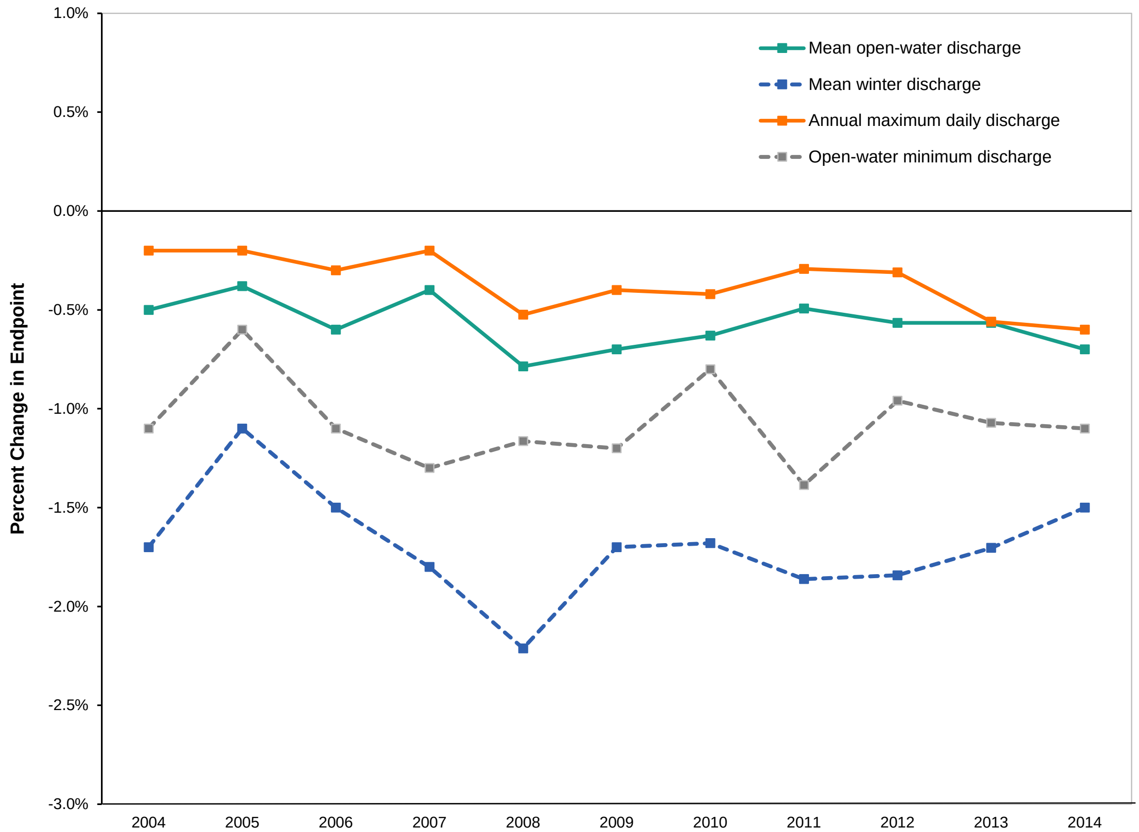
Watershed	Hydrologic Measurement Endpoint			
	Mean Open-Water Season Discharge	Mean Winter Discharge	Annual Maximum Daily Discharge	Minimum Open-Water Season Discharge
Athabasca River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Muskeg River	Negligible-Low	Moderate (-)	Moderate (-)	High (+)
Steepbank River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Tar River	High (-)	not measured	High (-)	High (-)
MacKay River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Calumet River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Firebag River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Ells River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Christina River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Hangingstone River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Poplar Creek	High (+)	Negligible-Low	Negligible-Low	Negligible-Low
Mills Creek	High (-)	High (-)	High (-)	High (-)
Fort Creek	High (-)	not measured	High (-)	High (-)

Assessments based on comparisons of calculated incremental change in hydrologic measurement endpoints with criteria used in Section 5: Negligible-Low: ± 5%; Moderate: ±15%; High: > ± 15%.

"not measured" means hydrologic information was not obtained for times of year for which the measurement endpoint was applicable.

Direction indicators (+ or -) indicate a calculated increase or decrease in discharge in observed *test* conditions as compared to estimated discharge in estimated *baseline* conditions. Direction indicators were shown only for differences of 5% or greater (i.e., Moderate or High).

Figure 6.1-1 Changes in values of hydrologic measurement endpoints in the Athabasca River as a result of oil sands developments.



Note: Measurement endpoints were calculated from estimated *baseline* and observed *test* hydrographs at Station S24, Athabasca River below Eymundson Creek, from 2004 to 2011 and Station S46, Athabasca River near Embarras Airport, from 2012 to 2014. A comparison of water balances from both stations, using 2013 WY data, indicated essentially no difference in the value of measurement endpoints (RAMP 2014).

6.2 WATER QUALITY

6.2.1 Summary of 2014 Results

Water quality at all stations in most of the larger watersheds (i.e., Athabasca, Muskeg, Ells, Firebag, Clearwater) that were assessed in fall 2014 was typical of historical and regional *baseline* observations in the Athabasca oil sands region. However, fall water quality measured at the lower Steepbank River and in several smaller watersheds exhibited differences from regional *baseline* conditions or historical conditions, or significant temporal trends in water quality measurement endpoints. These stations included the following:

- **Lower Steepbank River** – *Test* station STR-1 was classified as **Moderate** due to exceedances of concentrations of total metals, ions, and physical variables from the 95th percentile of regional *baseline* conditions, although concentrations of most of these variables were within historical ranges previously observed at this station.

- **Lower Hangingstone River** – Differences in water quality in fall 2014 between *test* stations HAR-1 and HAR-1A of the lower Hangingstone River (stations are influenced by urban development as well as upstream oil sands activities) and regional *baseline* fall conditions were classified as **Moderate** because of higher concentrations of ions and dissolved metals relative to regional *baseline* concentrations.

- **Lower Gregoire River** – At *test* station GRR-1, a **Moderate** difference from regional *baseline* water quality conditions was observed, which was related to concentrations of several water quality measurement endpoints (mostly total metals, perhaps related to high suspended solids in samples) that exceeded regional *baseline* concentrations.

- **Poplar Creek and Lower Beaver River** – *Test* stations POC-1 and BER-1 indicated **Moderate** differences from regional *baseline* concentrations, related to high ion concentrations.

- **McLean Creek** – *Test* station MCC-1 indicated **Moderate** differences from regional *baseline* water quality conditions, primarily be attributed to high levels of dissolved ions and metals.

- **Fort Creek** – Although water quality at *test* station FOC-1 showed **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2014, this station exhibited significant increasing trends over time in concentrations of calcium, magnesium, potassium, total boron, total dissolved solids, total strontium, and sulphate.

- **Lower Calumet River** – In fall 2014, water quality at *test* station CAR-1 indicated overall **Negligible-Low** differences from regional *baseline* conditions. However, concentrations of many hydrocarbons (i.e., CCME fractions and PAHs) were substantially greater than previously observed at this station and relative to *baseline* station CAR-2 in 2014. Significantly higher flows in 2014 in the Calumet River in May and June 2014 contributed to bank erosion near this station may have increased TSS, PAHs, and hydrocarbons from bank sediments.

- **Mills Creek and Isadore's Lake** – Differences in water quality in fall 2014 between Mills Creek and regional *baseline* fall conditions were classified as **High**, due to relatively high concentrations of many ions and other dissolved species that exceeded regional *baseline* concentrations. Water quality in Isadore's Lake, where Mills Creek flows into, exhibited similar water quality to Mills Creek and showed increasing trends in several measurement endpoints, including chloride, sodium, sulphate, total boron, total dissolved solids, and total strontium.

- **Shipyard Lake** – The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, with significant increasing trends in chloride, potassium, sodium, and total boron.

Definitive conclusions could not be drawn from monthly water quality sampling programs undertaken in the Muskeg, MacKay, Poplar, Clearwater, Christina, and Steepbank rivers, given that 2014 was the first or second year of complete monthly sampling. However, similar decreases of alkalinity and other base cations (i.e., chloride, sulphate) across stations during the spring melt/freshet period suggested that most of the observed decrease in alkalinity was related to base-cation dilution (i.e., volume of snowmelt) rather than consumption of alkalinity by a source of acid in surface runoff. Collection and analysis of additional years of comprehensive monthly water quality data will help to clarify and quantify sources of seasonal variation in ion concentrations.

6.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

6.3.1 Benthic Invertebrate Communities

6.3.1.1 Summary of 2014 Results

The Benthic Invertebrate Communities component characterizes changes in river reaches and lakes that are considered most likely to be affected by oil sands development. Within the major tributaries, samples were collected in lower reaches where changes from all upstream developments are anticipated to be the most significant. Differences in the lower reaches are in part judged against observations from previous years, from upper reaches that are classified as *baseline*, or from regional *baseline* conditions. Differences in measurement endpoints within reaches (and lakes) are judged using analyses of variance. Where changes are statistically significant, the magnitude of the observed change was considered, as is the nature of the change (i.e., in a positive or negative direction). The environmental tolerances of the biota are used to aid the interpretation of whether changes indicate degradation of habitat quality. A summary of the key findings from 2014 are provided below.

Athabasca River Delta Differences in benthic invertebrate communities varied across channels of the ARD. Differences in measurement endpoints in Big Point Channel and Embarras River were classified as **Negligible-Low**; **Moderate** for Fletcher Channel, and **High** for Goose Island Channel. Data collected from Fletcher Channel; however, were indicative of a stable community including higher richness than usual and the presence of EPT taxa. The total number benthic organisms was low in Goose Island Channel, while the relative abundance of tubificid worms was high (potentially reflecting high silt content in the sediments). The percentage of the fauna as EPT taxa was higher in Goose Island Channel in 2014 than previously recorded.

Lakes Differences in measurement endpoints for benthic invertebrate communities of lakes in the oil sands region have been difficult to classify in the past because there is a general lack of information on *baseline* lake conditions. In 2014, two new *baseline* lakes (Gardiner Lake and Namur Lake) were added to the sampling program; so that there are now three *baseline* lakes, including Johnson Lake, in the JOSMP. Until an adequate amount of *baseline* data are available, differences in lakes in 2014 were assessed against observations from previous years of sampling and from *baseline* years when available (e.g., McClelland Lake). Statistical tests for lakes were carried out using measurement endpoints that had been adjusted to a common depth of 2 m, based on a model developed using data from all years up to, and including the current year (2014) for all lakes.

Differences in measurement endpoints for benthic invertebrate communities at all *test* lakes sampled by JOSMP (i.e., Kearl, McClelland, Isadore's, Shipyard, Gregoire, and Christina lakes) were classified as **Negligible-Low** because measurement endpoint values in 2014 were not indicative of degradation of habitat conditions.

Rivers The analysis of benthic invertebrate communities in river reaches in 2014 focused on the comparison of lower *test* reaches to their historical range of variability (up to and including 2013), to an upper *baseline* reach (when available), or to a regional *baseline* range of variability.

Differences in measurement endpoints for benthic invertebrate communities of the following *test* reaches were classified as **High**:

- **Lower Tar River** – Abundance, richness, and equitability differed between the *baseline* period and *test* period for this reach. A significant time trend was noted for the CA Axis 1 scores, which suggested a change in taxa composition over time with fewer water mites and mayflies present in more recent years. Abundance and richness were below the normal range of variation for regional *baseline* depositional reaches. Diversity and the percentage of EPT taxa have decreased since 2009. Mayflies and caddisflies, which were present during the *baseline* period and in most of the previous sampling years, were absent in both 2013 and 2014.

Changes in benthic invertebrate communities of the following *test* reaches were classified as **Moderate**:

- **Lower Fort Creek** – There were statistically significant and large variations in abundance, richness, and equitability. The percentage of EPT taxa was below the inner tolerance limit for previous sampling years, but higher than was observed during the *baseline* years (2001 to 2003). Lower richness and higher equitability during the *test* years are potentially suggestive of moderate influences, but the presence of clams, snails, and particularly stoneflies suggested that habitat quality was not significantly perturbed. The fauna of Fort Creek has typically had low diversity including during the *baseline* period, and the community in 2014 was consistent with previous observations.

- **Lower Ells River** – There were significant and large decreases in abundance, percentage of EPT taxa, and richness over time. Abundance was slightly higher in 2014 compared to 2013, but still lower than normal with an average of 11 individuals per sample. Most of the major groups of 'larger' organisms (e.g., clams, snails, mayflies, caddisflies) were sparse in 2014 and EPT taxa were absent. All of the 'smaller' and previously-abundant organisms remained abundant in 2014 samples. Chironomids were dominated by sensitive genera.

- **Lower Steepbank River** – Abundance, richness, CA Axis 1 and 2 scores, and the percentage of EPT taxa were significantly different between *test* reach STR-E1 and *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach.

- **Lower Sunday Creek** – Abundance, richness, the percentage of EPT taxa, and CA Axis 2 scores were lower than the upper *baseline* reach. Those differences indicated that the *test* reach was of lower quality than the upper *baseline* reach. However, taxa richness and the percentage of EPT taxa have increased over the three years of data collection, indicating improving conditions at the lower *test* reach. In addition, all measurement endpoints for the lower *test* reach have been within the normal range of variation for *baseline* depositional reaches, indicating generally acceptable conditions at this reach.

Differences in benthic invertebrate communities of the following *test* reaches were classified as **Negligible-Low** because there were no significant differences in measurement endpoints indicative of degraded conditions and few exceedances of historical or regional *baseline* variability:

- Muskeg River (lower, middle, and upper);
- Jackpine Creek;
- MacKay River (lower and middle);
- Jackfish River;
- Christina River (lower, middle, upper);
- Gregoire River;
- Sawbones Creek;
- Unnamed Creeks (east and south of Christina Lake);
- Clearwater River; and
- Poplar Creek.

6.3.2 Sediment Quality

6.3.2.1 Summary of 2014 Results

Sediments in rivers and lakes of the Athabasca oil sands region naturally contain concentrations of hydrocarbons and PAHs that may exceed environmental-quality guidelines. In fall 2014, sediment quality at all sampled stations were generally similar to historical observations at all sampling locations and showed **Negligible-Low** differences in sediment quality from regional *baseline* conditions.

Significant decreasing trends over time in concentrations of total PAHs were observed in sediments at *test* stations CHR-D1 and CHR-D2 (Christina River), KEL-1 (Kearl Lake), and MUR-D2 (middle Muskeg River), while a significant increasing trend was observed at Shipyard Lake (SHL-1). However, when normalized to percent-TOC, no station showed a significant trend in PAHs, with the exception of the lower Christina River (CHR-D1), where a decreasing trend was observed.

6.4 FISH POPULATIONS

The 2014 Fish Populations component consisted of:

- seasonal fish inventories on the Athabasca and Clearwater rivers;
- a fish tissue program on the Athabasca River targeting walleye and lake whitefish; and
- fall fish assemblage monitoring on tributaries to the Athabasca and Clearwater rivers and on channels of the Athabasca Delta.

6.4.1 Summary of 2014 Results

6.4.1.1 Fish Inventory

In 2014, the analysis of the Athabasca River and Clearwater River fish inventories focused on seasonal and spatial trends over time of catch per unit effort (CPUE), fish condition, and age-frequency distributions for Key Indicator Resource (KIR) fish species.

Fish inventories on the Athabasca River and the Clearwater River are generally considered to be a community-driven activity, primarily suited for assessing general trends in abundance and population variables for KIR fish species, rather than detailed community structure. A summary of the key findings from the 2014 results are provided below.

Athabasca River

Total catch in summer and fall 2014 was much lower compared to 2013 whereas the catch was similar in spring to 2013. The record low numbers in the fall total catch were attributed largely to the timing of sampling with respect to the migration of lake whitefish from Lake Athabasca to spawning grounds in the Athabasca River upstream of Fort McMurray. Due to restrictions stated in the Fish Research License issued by AESRD, sampling could not occur during the spawning period, as it has in previous years. Therefore, fishing was conducted prior to the migration period when the number of lake whitefish in the sampled section of the Athabasca River was much lower. Lower water levels were also observed in fall 2014, limiting habitat availability as well as boat access and fishing efficiency. These factors also may have contributed to the reduction in total catch and richness observed in 2014.

Walleye were not captured in fall at the *baseline* area, while white sucker were not captured in any season in the *baseline* area. There was a decrease in CPUE of white sucker in 2014 compared to 2013 in spring. However, the highest CPUE of white sucker continued to be observed in the Muskeg area, which is a river that white sucker use for spawning.

The dominant age class of northern pike in 2013 and 2014 was one and two years, respectively; dominance was most pronounced at five years from 1997 to 2012. The increased frequency of catch of younger northern pike in the Athabasca River may be an indication of higher levels of recruitment, or the loss of older individuals, perhaps related to increasing fishing pressure.

Overall, the 2014 fish health assessment indicated that abnormalities observed among all species were within the historical range (1987 to 2013) despite the higher than average incidence of abnormalities observed in northern pike (14.8%) primarily related to fin erosion. These findings were also consistent with previously cited studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Clearwater

Spring and summer total catch in 2014 decreased by 440 and 420 fish, respectively, relative to 2013. Comparisons were unable to be carried out in fall because the *baseline* reaches were not sampled due to low water levels.

The abundance of goldeye in spring 2014 was the highest recorded since 2009. This increase may be related to an increase in survival rates among the population given that the dominant age class in 2011 was five years which has shifted to an older age class of seven years in 2013 and 2014.

The dominant age classes for northern pike have been two and three years since 2012, which has been a shift towards a younger age class. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

The percentage of external abnormalities increased considerably in 2014 from 2013, with the majority of abnormalities observed in white sucker and a higher percentage of overall abnormalities observed in summer. The increase in abnormalities was primarily driven by the increase in parasites on fish, which was higher than 2013.

6.4.1.2 Fish Tissue Monitoring

In 2014, the potential risk to human health related to mercury concentrations in fish was assessed using muscle samples of walleye and lake whitefish collected from the Athabasca River.

Measurement endpoints used in the assessment for the Athabasca River fish tissue program included concentrations of metals and tainting compounds in fish tissue of both individual and composite samples. Potential human health risks from contaminated fish tissue were predicted from both individual and composite samples. In 2014, the mean concentration of mercury in lake whitefish was slightly higher than 2011, but within the range of concentrations observed in previous sampling years. The mean mercury concentration across all size classes of lake whitefish were below the Health Canada guideline for subsistence fishers indicating a **Negligible-Low** risk to human health. The mean concentration of mercury in walleye was higher in 2014 compared to previous years. The mean mercury concentration in size classes of walleye greater than 300 mm exceeded the subsistence fishers guideline for consumption indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

6.4.1.3 Fish Assemblage Monitoring

In 2014, fish assemblage monitoring was conducted on major tributaries in the oil sands region and channels of the Athabasca River Delta. The objective of this monitoring component was to evaluate fish assemblages in reaches were water quality, and benthic invertebrate communities and sediment quality were also assessed. A summary of the key findings from the 2014 results are provided below (Table 6.1-1).

Athabasca River Delta In 2012, the tributary fish assemblage monitoring program was expanded to channels of the Athabasca River Delta where benthic invertebrate communities and sediment were sampled. This expansion increased harmonization of RAMP monitoring activities in the delta and further aligned the RAMP activities with proposed monitoring outlined in the JOSMP. Results of the 2014 fish assemblage monitoring in the ARD indicated a decrease in abundance across all reaches. Water temperatures during the 2013 fish assemblage monitoring program in the ARD ranged from 19.5˚C to 20.4˚C with a mean of 19.8˚C, whereas water temperatures during the 2014 monitoring program were higher ranging from 20.4˚C to 23.4˚C, with a mean of 22.1˚C. The higher temperatures in 2014 could have resulted in fish being in deeper, cooler waters, where boat electrofishing was not effective.

Rivers Fish assemblage monitoring characterizes changes in river reaches that are considered most likely to be affected by oil sands projects. Within the major tributaries of the oil sands region, sampling was conducted in lower reaches where changes from all upstream developments are anticipated to be the most significant. Differences in the lower reaches are in part judged against observations in upper reaches that are classified as *baseline* or against regional *baseline* conditions. Differences within reaches are used to judge changes over time. Where changes are observed, differences among reaches of a similar nature are used to put those changes into context.

Differences in measurement endpoints (abundance, CPUE, species richness, diversity, and the assemblage tolerance index) for fish assemblages were classified as **Negligible-Low** compared to regional *baseline* conditions at the following *test* reaches:

- Tar River;
- Christina River (above Jackfish River);
- Sunday Creek;
- Jackfish River;
- MacKay River (middle);
- Muskeg River (middle and upper); and
- Poplar Creek.

Differences in measurement endpoints for fish assemblages were classified as **Moderate** at the following *test* reaches given that at least three of the five measurement endpoints exceeded the range of variability for *baseline* reaches or there was a statistical change in any one measurement endpoints, in a direction suggesting negative change:

- Muskeg River (lower);
- Ells River;
- Fort Creek;
- MacKay River (lower).

Differences in measurement endpoints for fish assemblages were classified as **High** at the following *test* reaches given that at least three of the five measurement endpoints exceeded the range of variability for *baseline* reaches or there was a statistical change in three of the five measurement endpoints, in a direction suggesting a negative change:

- Jackpine Creek;
- Steepbank River;
- Sawbones Creek; and
- Unnamed Creek east of Christina Lake.

6.5 ACID-SENSITIVE LAKES

6.5.1 Summary of 2014 Results

Concentrations of chemical variables monitored in the ASL program in 2014 remained similar to historical levels. In among-year comparisons, pH, Gran alkalinity, potassium, magnesium, colour, and bicarbonate increased significantly over time, and often in both *baseline* and *test* lakes. However, decreases rather than increases in pH and Gran alkalinity are expected under an acidification scenario. There were no significant changes in sulphates while nitrates appeared to be decreasing over time. Nitrates and sulphates are the principal acidifying species from NO_xSO_x emissions. There was no significant increases in aluminum or decreases in DOC. The sum of base cations increased significantly but only in the *baseline* lakes. These significant trends suggested that acidification was not occurring in the ASL lakes. Changes in conservative ions such as potassium and magnesium were most likely due to hydrologic changes over time involving a possible increase in the role of surficial groundwater in determining lake chemistry.

Critical loads of acidity in the 45 lakes ranged from -0.762 keq H^+/ha/yr to 3.619 keq H^+/ha/yr, with a median value of 0.429 keq H^+/ha/y. Critical loads in the ASL component lakes were generally increasing over time consistent with increases in lake buffering capacity (i.e., Gran alkalinity). The lowest critical loads were found in lakes in the upland regions including the Stony Mountains, Birch Mountains, and Canadian Shield subregions. Lakes in the Stony Mountains, having the lowest critical loads, were the most acid-sensitive of the ASL component lakes.

In 2014, the critical loads of acidity for each individual lake were compared to modeled rates of acid deposition (Potential Acid Input) for each lake calculated for Teck Energy's Frontier Project (Davies et al. 2015). These PAI predictions reflected recent measurements of base cation deposition determined from field studies conducted in the oil sands region. Base cation deposition was much higher than in previous PAI estimates and, at most sites, neutralized the acidifying depositional components (S and N). The majority of the lake catchments (31 of 45) were exposed to basic rather than acidic deposition. Most of the lakes exposed to acidifying deposition were found in the Birch Mountains and the Canadian Shield subregions having relatively low base cation deposition. Only two lakes (BM6/447 and BM7/448 [Clayton Lake]), both in the Birch Mountains, had modeled PAI estimates exceeding their critical loads and were at potential risk of acidification.

Mann-Kendall trend analysis applied to the seven measurement endpoints in each of the 45 lakes identified 14 significant trends in a direction indicative of acidification; however, these trends were all inconsistent with any reasonable acidification scenario. For example, a significant increase in nitrates in

Lake NE8/209 was associated with significant increases (rather than decreases) in pH and Gran alkalinity in these lakes. The trends identified in the Mann-Kendall analysis were consistent with the results of the among-year comparisons (ANOVA) in showing significant increases in Gran alkalinity in 14 lakes and pH in 20 lakes.

Shewhart control charting was applied to the measurement endpoints in order to detect acidifying trends in the five individual lakes most at risk to acidification, which were located in the Birch Mountains subregion. While the control charts showed a number of isolated exceedances of the two standard deviation limits in individual lakes across years, these variables returned to normal in the following year. High variability was noted for nitrates both between lakes and among years within each lake. There was no evidence to suggest from the control charts that acidifying trends were occurring in these five lakes.

Results of the analysis of the ASL lakes in 2014 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 45 lakes across years that could be attributed to acidification. These results were consistent with the revised estimates of potential acid input (PAI) suggesting that only 14 of the 45 lakes were actually exposed to acidifying deposition.

A summary of the state of the ASL lakes in 2014, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In 2014 there were no exceedances of the criterion for any of the measurement endpoints in any of the subregions. Therefore, all subregions were classified as having a **Negligible-Low** indication of incipient acidification.

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8.0 GLOSSARY AND LIST OF ACRONYMS

8.1 GLOSSARY

Abundance	Number of organisms in a defined sampling unit, usually expressed as aerial coverage.
Acute	Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Ageing Structures	Parts of the fish which are taken for ageing analyses. These structures contain bands for each year of growth or maturity which can be counted. Some examples of these structures are scales, fin rays, otoliths and opercula. Most ageing structures can be taken with minimal effect on the fish and vary according to fish species.
Alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.
ANCOVA	Analysis of covariance. ANCOVA compares regression lines, testing for differences in either slopes or intercepts (adjusted means).
ANOVA	Analysis of variance. An ANOVA tests for differences among levels of one or more factors. For example, individual sites are levels of the factor site. Two or more factors can be included in an ANOVA (e.g., site and year).
Baseline	*Baseline* is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2010) or were (prior to 2010) upstream of all focal projects; data collected from these locations are to be designated as *baseline* for the purposes of data analysis, assessment, and reporting. The terms *test* and *baseline* depend solely on location of the aquatic resource in relation to the location of the focal projects to allow for long-term comparison of trends between *baseline* and *test* stations.

Benthic Invertebrates	Invertebrate organisms living on the bottom of lakes, ponds, and streams. Examples of benthic invertebrates include the aquatic insects such as caddisfly larvae, which spend at least part of their life on or in bottom sediments. Many benthic invertebrates are major food sources for fish.
Benthos	Organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes) of aquatic habitats for at least part of their life cycle. The term benthic is used as an adjective, as in benthic invertebrates.
Bioaccumulation	A general term meaning that an organism stores within its body a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate salt to survive in intertidal waters. Many toxicants, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.
Bioavailability	The amount of chemical that enters the general circulation of the body following administration or exposure.
Bioconcentration	A process where there is a net accumulation of a chemical directly from an exposure medium into an organism.
Biological Indicator (Bioindicator)	Any biological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomonitoring	The use of living organisms as indicators of the quality and integrity of aquatic or terrestrial systems in which they reside.
Bitumen	A highly viscous, tarry, black hydrocarbon material having an API gravity of about 9º (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80% to 85% of the elemental composition of bitumen, hydrogen – 10%, sulphur - 5%, and nitrogen, oxygen and trace elements the remainder.
BOD	Biochemical oxygen demand. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. Usually conducted as a 5-day test (i.e., BOD_5).

Bottom Sediments Substrates that lie at the bottom of a body of water. For example, soft mud, silt, sand, gravel, rock, and organic litter, that make up a river bottom.

Catch Per Unit Effort A measure which relates to the catch of fish, with a particular type of gear, per unit of time (number of fish/100 seconds). Results can be given for a particular species or the entire catch. The results can reflect both the density and/or the vulnerability of the gear utilized, of a species in a particular system.

Chronic Defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

CL Confidence limit. A set of possible values within which the true value will lie with a specified level of probability.

Colour True colour of water is the colour of a filtered water sample (and thus with turbidity removed), and results from materials which are dissolved in the water. These materials include natural mineral components such as iron and calcium carbonate, as well as dissolved organic matter such as humic acids, tannin, and lignin. Organic and inorganic compounds from industrial or agricultural uses may also add colour to water. As with turbidity, colour hinders the transmission of light through water, and thus 'regulates' biological processes within the body of water.

Community A set of taxa coexisting at a specified spatial or temporal scale.

Concentration Quantifiable amount of a chemical in environmental medium, expressed as mass of a substance per unit volume (e.g., mg/L), or per unit sample mass (e.g., mg/g).

Concentration Units

Concentration Units	Abbreviation	Units
Parts per million	ppm	mg/kg or µg/g or mg/L
Parts per billion	ppb	µg/kg or ng/g or µg/L
Parts per trillion	ppt	ng/kg or pg/g or ng/L
Parts per quadrillion	ppq	pg/kg or fg/g or pg/L

Condition Factor	A measure of the plumpness or fatness of aquatic organisms. For oysters and mussels, values are based on the ratio of the soft tissue dry weight to the volume of the shell cavity. For fish, the condition factor is based on weight-length relationships.
Conductivity	A measure of water's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.
Contaminant Body Burdens	The total concentration of a contaminant found in either whole-body or individual tissue samples.
Covariate	An independent variable; a measurement taken on each experimental unit that predicts to some degree the final response to the treatment, but which is unrelated to the treatment (e.g., body size [covariate] included in the analysis to compare gonad weights of fish collected from reference and exposed areas).
CWQG	Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.
Detection Limit	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level of a given method and representative matrix.
Development Area	Any area altered to an unnatural state. This represents all land and water areas included within activities associated with development of the oil sands leases.
Discharge	In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).
Diversity	The variety, distribution, and abundance of different plant and animal communities and species within an area.

DO — Dissolved oxygen, the gaseous oxygen in solution with water. At low concentrations it may become a limiting factor for the maintenance of aquatic life. It is normally measured in milligrams/litre, and is widely used as a criterion of receiving water quality. The level of dissolved oxygen which can exist in water before the saturation point is reached is primarily controlled by temperature, with lower temperatures allowing for more oxygen to exist in solution. Photosynthetic activity may cause the dissolved oxygen to exist at a level which is higher than this saturation point, whereas respiration may cause it to exist at a level which is lower than this saturation point. At high saturation, fish may contract gas bubble disease, which produces lesions in blood vessels and other tissues and subsequent physiological dysfunctions.

Drainage Basin — The total area that contributes water to a stream.

EC*p* — A point estimate of the concentration of test material that causes a specified percentage effective toxicity (sublethal or lethal). In most instances, the EC*p* is statistically derived by analysis of an observed biological response (e.g., incidence of nonviable embryos or reduced hatching success) for various test concentrations after a fixed period of exposure. EC25 is used for the rainbow trout sublethal toxicity test.

Ecological Indicator — Any ecological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress.

Ecosystem — An integrated and stable association of living and non-living resources functioning within a defined physical location.

Environmental Impact Assessment — A review of the effects that a proposed development will have on the local and regional environment.

Evenness — A measure of the similarity, in terms of abundance, of different species in a community. When there are similar proportions of all species then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value increases.

Exposure — The contact reaction between a chemical and a biological system, or organism.

Fauna — A term referring to an association of animals living in a particular place or at a particular time.

Fecundity — The number of eggs or offspring produced by a female.

Fecundity Index	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Filter-Feeders	Organisms that feed by straining small organisms or organic particles from the water column.
Forage Fish	Small fish that provide food for larger fish (e.g., trout-perch, fathead minnow).
Gonad	A male or female organ producing reproductive cells or gametes (i.e., female ovum, male sperm). The male gonad is the testis; the female gonad is the ovary.
Gonad Somatic Index (GSI)	The proportion of reproductive tissue in the body of a fish. It is calculated by expressing gonad weight as a percentage of whole body weight. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
GPS	Global Positioning System. This system is based on a constellation of satellites which orbit the earth every 24 hours. GPS provides exact position in standard geographic grid (e.g., UTM).
Habitat	The place where an animal or plant naturally or normally lives and grows, for example, a stream habitat or a forest habitat.
Hardness	Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre.
IC*p*	A point estimate of the concentration of test material that causes a specified percentage impairment in a quantitative biological test which measures a change in rate, such as reproduction, growth, or respiration.
Inorganics	Pertaining to a compound that contains no carbon.
KIRs	Key indicator resources are the environmental attributes or components identified as a result of a social scoping exercise as having legal, scientific, cultural, economic or aesthetic value.
LC_{50}	Median lethal concentration. The concentration of a substance that is estimated to kill half of a group of organisms. The duration of exposure must be specified (e.g., 96-hour LC_{50}).

Lesions	Pathological change in a body tissue.
Lethal	Causing death by direct action.
Littoral Zone	The zone in a lake that is closest to the shore.
Liver Somatic Index (LSI)	Calculated by expressing liver weight as a percent of whole body weight.
Macro-invertebrates	Those invertebrate (without backbone) animals that are visible to the eye and retained by a sieve with 500 µm mesh openings for freshwater, or 1,000 µm mesh openings for marine surveys (EEM methods).
Mean Annual Flood	The average of the series of annual maximum daily discharges.
Microtox®	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Negative Control	Material (e.g., water) that is essentially free of contaminants and of any other characteristics that could adversely affect the test organism. It is used to assess the 'background response' of the test organism to determine the acceptability of the test using predefined criteria.
NO_x	A measure of the oxides of nitrogen comprised of nitric oxide (NO) and nitrogen dioxide (NO_2).
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine-grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 µm), and a fines (>44 µm) fraction, consisting of silts and clays.
Operational	The term used to characterize data and information gathered from stations that are designated as exposed.
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCO_3$).
PAH	Polycyclic Aromatic Hydrocarbon. A series of petroleum-related chemicals composed of at least two fused benzene rings. Toxicity increases with molecular size and degree of alkylation.

PAI	The Potential Acid Input is a composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.
Pathology	The science which deals with the cause and nature of disease or diseased tissues.
Peat	A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
pH	A measure of the acid or alkaline nature of water or some other medium. Specifically, pH is the negative logarithm of the hydronium ion (H_30^+) concentration (or more precisely, activity). Practically, pH 7 represents a neutral condition in which the acid hydrogen ions balance the alkaline hydroxide ions. The pH of the water can have an important influence on the toxicity and mobility of chemicals in pulpmill effluents.
Population	A group of organisms belonging to a particular species or taxon, found within a particular region, territory or sampling unit. A collection of organisms that interbreed and share a bounded segment of space.
Quality Assurance (QA)	Refers to the externally imposed technical and management practices which ensure the generation of quality and defensible data commensurate with the intended use of the data; a set of operating principles that, if strictly followed, will produce data of known defensible quality.
Quality Control (QC)	Specific aspect of quality assurance which refers to the internal techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized.
Reach	A comparatively short length of river, stream channel, or shore. The length of the reach is defined by the purpose of the study.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Reference Toxicant	A chemical of quantified toxicity to test organisms, used to gauge the fitness, health, and sensitivity of a batch of test organisms.
Relative Abundance	The proportional representation of a species in a sample or a community.

Replicate	Duplicate analyses of an individual sample. Replicate analyses are used for measuring precision in quality control.
Riffle Habit	Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.
Run Habitat	Areas of swiftly flowing water, without surface waves, that approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Runoff Depth	Streamflow volume divided by catchment area.
Sediments	Solid fragments of inorganic or organic material that fall out of suspension in water, wastewater, or other liquid.
Sentinel Species	A monitoring species selected to be representative of the local receiving environment.
Simpson's Diversity Index	A calculation used to estimate species diversity using both species richness and relative abundance. A basic count of the number of species present in a community represents species richness. The number of individuals of each species occurring in a community is the species relative abundance.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species Richness	The number of different species occupying a given area.
Sportfish	Large fish that are caught for food or sport (e.g., northern pike, trout, walleye).
Stressor	An agent, a condition, or another stimulus that causes stress to an organism.
Sublethal	A concentration or level that would not cause death. An effect that is not directly lethal.

Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Test	***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of a focal project; data collected from these locations are designated as ***test*** for the purposes of analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against baseline conditions to assess potential changes.
Thalweg	The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.
Tolerance	The ability of an organism to subsist under a given set of environmental conditions. Organisms with high tolerance to pollution are usually indicators of poor water quality.
Total Dissolved Solids	The total concentration of all dissolved compounds solids found in a water sample. See filterable residue.
Toxic	A substance, dose, or concentration that is harmful to a living organism.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Transect	A line drawn perpendicular to the flow in a channel along which measurements are taken.
TSS	Total suspended solids (TSS) is a measurement of the oven dry weight of particles of matter suspended in the water which can be filtered through a standard filter paper with pore size of 0.45 micrometres.
Turbidity	Turbidity in water is caused by the presence of matter such as clay, silt, organic matter, plankton, and other microscopic organisms that are held in suspension.
VOC	Volatile Organic compounds include aldehydes and all of the hydrocarbons except for ethane and methane. VOCs represent the airborne organic compounds likely to undergo or have a role in the chemical transformation of pollutants in the atmosphere.

Watershed The entire surface drainage area that contributes water to a lake or river.

Wetlands Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, whether the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskeg, potholes, swales, glades, slashes, and overflow land of river valleys.

8.2 LIST OF ACRONYMS

ABMI	Alberta Biodiversity Monitoring Institute
ADC	Acoustic Digital Current
ADV	Acoustic Doppler Velocimeter
AED	Alberta Economic Development
AESRD	Alberta Environment and Sustainable Resource Development
AEMERA	Alberta Environmental Monitoring, Evaluation and Reporting Agency
AEP	Alberta Environment Protection
AITF	Alberta Innovates Technology Futures
ALPAC	Alberta-Pacific Forest Industries Inc.
ALS	ALS Laboratory Ltd.
ANC	Acid Neutralizing Capacity
ANC_{org}	ANC attributable to weak organic acids
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AOSERP	Alberta Oil Sands Environmental Research Program
APHA	American Public Health Association
ARD	Athabasca River Delta
ASL	Acid-Sensitive Lakes
ATI	Assemblage Tolerance Index
AWOS	Automated Weather Observing System
AWRI	Alberta Water Research Institute
AXYS	AXYS Analytical Services
BC MOELP	BC Ministry of Environment, Lands, and Parks
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CA	Correspondence Analysis
CABIN	Canadian Aquatic Biomonitoring Network
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CL	Critical Load

COC	chain of custody
COSI	Centre for Oil Sands Innovation
COSIA	Canada's Oil Sands Innovation Alliance
CPUE	Catch Per Unit Effort
CVAFS	Cold Vapor Atomic Fluorescence Spectraphotometry
CV	Coefficient of Variation
CWN	Canadian Water Network
CWQG	Canadian Water Quality Guidelines
CYMM	Fort McMurray Airport Code
DFO	Fisheries and Oceans Canada
DL	Detection Limit
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EC	Environment Canada
EDA	Exploratory Data Analysis
EEM	Environmental Effects Monitoring
EIA	Environmental Impact Assessment
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Priority Areas
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EROD	Ethoxyresorufin-O-deethylase
FAM	Fish Assemblage Monitoring
FWMIS	Fisheries and Wildlife Management Information System
FTIR	Fourier Transform Infrared
FWIN	Fall Walleye Index Netting
GC/MS	Gas Chromatography-Mass Spectrometry
GLM	General Linear Model
GOA	Government of Alberta
GPS	Global Positioning System

GPP	Generator Powered Pulsator
GSI	Gonad Somatic Index
HC	Health Canada
HI	Hazard Index
IBI	Index of Biotic Integrity
ICP/MS	Inductively Coupled Plasma Mass Spectroscopy
IFN	Instream Flow Needs
INAC	Indian and Northern Affairs Canada
IMB	Isotopic Mass Balance
ISQG	Interim Sediment Quality Guidelines
JACOS	Japan Canada Oil Sands Limited
JOSMP	Joint Oil Sands Monitoring Plan
KIR	Key Indicator Resource
LSI	Liver Somatic Index
LTRN	Long-term Regional Network
LWD	Large woody debris
MAKESENS	Mann-Kendall test for trend and Sen's slope estimates
MDL	Method Detection Limit
NAD	North American Datum
NRBS	Northern River Basins Study
NSMWG	NO_x and SO_x Management Working Group
OSE	Oil Sands Exploration
OSPW	Oil Sands Process Waters
OSTWAEO	Oil Sands Tailings Water Acid-extractable Organics
PAD-EMP	Peace-Athabasca Delta Ecological Monitoring Program
PAH	Polycyclic Aromatic Hydrocarbon
PAI	Potential Acid Input
PCA	Principal Component Analysis
PEL	Probable Effect Level
ppb	parts per billion
ppm	parts per million

ppq	parts per quadrillion
QA	Quality Assurance
QC	Quality Control
RAMP	Regional Aquatics Monitoring Program
RCA	Reference Condition Approach
RMCC	Research and Monitoring Coordinating Committee
RMWB	Regional Municipality of Wood Buffalo
RSDS	Regional Sustainable Development Strategy
SAGD	Steam Assisted Gravity Drainage
SD	Standard Deviation
SM	Surface Mine
SOP	Standard Operating Procedures
SQI	Sediment Quality Index
SSWQO	Site-specific Water Quality Objectives
STP	Sewage Treatment Plant
SWD	Small woody debris
SWE	Snow Water Equivalent
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TDS	total dissolved solids
TEEM	Terrestrial Environmental Effects Monitoring Committee
TEH	total extractable hydrocarbon
TEK	Traditional Ecological Knowledge
TIE	Toxicity Identification Evaluation
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
ToR	Terms of Reference
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
TSS	total suspended solids
USEPA	United States Environmental Protection Agency

WBEA	Wood Buffalo Environmental Association
WQI	Water Quality Index
WSC	Water Survey of Canada
WY	Water Year