RAMP
Regional Aquatics
Monitoring Program

2012 TECHNICAL REPORT

FINAL

REGIONAL AQUATICS MONITORING PROGRAM

2012 Technical Report

FINAL

Prepared for:

RAMP STEERING COMMITTEE

Prepared by:

The RAMP 2012 Implementation Team

Consisting of:

HATFIELD CONSULTANTS
KILGOUR AND ASSOCIATES LTD.
***and* WESTERN RESOURCE SOLUTIONS**

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The RAMP chairperson during the 2012 program year was Sarah Aho (Suncor). Rod Hazewinkel (AESRD) was chair of the Technical Program Committee, Ainslie Campbell (Shell) was chair of the Finance Subcommittee, National Public Relations served as Communications Coordinator for RAMP, and Hatfield Consultants managed and implemented the program on behalf of the Steering Committee.

RAMP is a multi-stakeholder environmental monitoring program that is composed of representatives from industry; municipal, provincial and federal governments, and a local Aboriginal group. Effective implementation of the RAMP requires a number of contributors. We would like to thank the following:

- Members of the RAMP Steering Committee, Technical Program Committee, Finance Subcommittee, and the Communications Subcommittee;
- Syncrude, Canadian Natural, Suncor, Nexen, Shell, and Fisheries and Oceans Canada for their contribution towards the fish inventory program;
- AESRD for providing water quality data from their ongoing LTRN monitoring programs for inclusion in RAMP;
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- University of Alberta Limnological Laboratory (chemical analyses for ASL component); and
- Dr. John Gibson, University of Victoria (run-off estimates for ASL component).

2012 IMPLEMENTATION TEAM

The RAMP Implementation Team for 2012 included the following personnel from Hatfield Consultants Partnership (HCP), Kilgour and Associates Ltd. (KAL), and Western Resource Solutions (WRS):

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EXECUTIVE SUMMARY

OVERVIEW

The Regional Aquatics Monitoring Program (RAMP) was initiated in 1997 in association with mining development in the Athabasca oil sands region near Fort McMurray, Alberta. RAMP is an industry-funded, multi-stakeholder initiative that monitors aquatic environments in the Regional Municipality of Wood Buffalo. The intent of RAMP is to integrate aquatic monitoring activities so that long-term trends, regional issues, and potential cumulative effects related to oil sands development (surface mining and in situ extraction) can be identified and assessed. In 2012, RAMP was funded by Suncor Energy Inc., Syncrude Canada Ltd., Shell Canada Energy, Canadian Natural Resources Limited, Imperial Oil Resources, Nexen Inc., Husky Energy, Total E&P Canada Ltd., MEG Energy Corp., Dover Operating Corp., ConocoPhillips Canada, Devon Energy Corp., Teck Resources Ltd., Cenovus Energy, Japan Canada Oil Sands Ltd., Statoil Canada Ltd., and Hammerstone Corporation. Non-funding participants included municipal, provincial, and federal government agencies, and one Aboriginal group.

The original Regional Municipality of Wood Buffalo boundary (pre-2012) in northeastern Alberta represents the Regional Study Area (RSA) of RAMP. Within this area, a Focus Study Area (FSA) has been defined and includes those parts of the following watersheds where oil sands and other developments are occurring or planned:

- Lower Athabasca River;
- Major tributary watersheds/basins of the lower Athabasca River including the Clearwater River, Christina River, Hangingstone 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);
- Specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- A selected group of 50 regional acid-sensitive lakes.

The RAMP FSA also includes the Athabasca River Delta as the receiving environment of any oil sands developments occurring in the Athabasca oil sands region.

RAMP 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 in RAMP on monitoring sensitive biological indicators that reflect the overall condition of the aquatic environment. By combining both monitoring approaches, RAMP strives to achieve a more holistic understanding of potential effects on the aquatic environment related to oil sands development.

The scope of RAMP 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 RAMP FSA, 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, lakes and the Athabasca River Delta 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.

RAMP is funded by member companies that are constructing and operating oil sands projects in the RAMP FSA. However, there are other companies that are constructing or operating oil sands projects, but who are not members of RAMP. Therefore, the term "focal projects" is used in the RAMP 2012 Technical Report to define those projects owned and operated by the 2012 industry members of RAMP listed above that were under construction or operational in 2012 in the RAMP FSA. For 2012, these projects included a number of oil sands projects and a limestone quarry project.

2012 RAMP industry members do have other projects in the RAMP FSA that were in the application stage as of 2012, or had received approval in 2012 or earlier, but construction had not yet started as of 2012. These projects are noted throughout this technical report, but are not designated as focal projects, as these projects in 2012 would not have contributed to any possible influences on aquatic resources covered by RAMP components.

The term "other oil sands developments" is used in the RAMP 2012 Technical Report to define those oil sands projects operated by non-RAMP members located within the RAMP FSA.

A weight-of-evidence approach is used for the analysis of RAMP data by applying multiple analytical methods to interpret results and determine whether any changes have occurred due to focal projects and other 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 focal project EIAs, AESRD and CCME water quality and sediment quality guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in the measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources.

The RAMP 2012 Technical 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 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; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2012) or were (prior to 2012) 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.

Satellite imagery was used in 2012 in conjunction with more detailed maps of Athabasca oil sands operations provided by a number of RAMP industry members to estimate the type, location, and amount of land changed by focal projects and other development activities. As of 2012, it is estimated that approximately 105,700 ha of the RAMP FSA had undergone land change from focal projects and other oil sands developments. The percentage of the area of watersheds with land change as of 2012 varies from less than 1% for many watersheds (MacKay, Christina, Hangingstone, Horse, and Firebag rivers), to 1% to 5% for the Calumet, Ells, Poplar, and Steepbank watersheds, to 5% to 10% for the Upper Beaver watershed, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries from Fort McMurray to the confluence of the Firebag River.

ASSESSMENT OF 2012 MONITORING RESULTS

A tabular summary of the 2012 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge calculated from the observed *test* hydrograph were 0.6%, 1.8%, 0.3% and 1.0% lower, respectively, than from the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The results of the hydrologic assessment were essentially identical to results for the case in which focal projects plus other oil sands developments were considered.

Water Quality Differences in water quality in fall 2012 at all stations in the Athabasca River were classified as **Negligible-Low** compared to the regional *baseline* conditions, with the exception of the *test* station at the Muskeg River, on the east bank of the Athabasca River, which showed **Moderate** differences from regional *baseline* conditions due to high concentrations of TSS, organic carbon, nutrients, and associated particulate metals. Concentrations of water quality measurement endpoints at the *test* stations were generally similar to those at the upstream *baseline* stations at Donald Creek, on the east and west banks of the Athabasca River, and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded guidelines at all stations, while total boron showed an increasing trend at the *test* station downstream of all development, on the west bank of the Athabasca River, and both *test* stations at the Muskeg River, on the east and west banks of the Athabasca River.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2012:

1. Differences in measurement endpoints for benthic invertebrate communities in the Athabasca River Delta in Big Point Channel were classified as **Moderate** because there was an increase in equitability over time and abundance and richness were lower in 2012 compared to previous sampling years. In addition, abundance was extremely low in 2012 and lower than the range of historical conditions for all ARD reaches.

2. Differences in measurement endpoints for benthic invertebrate communities in Fletcher Channel were classified as **High** because of significant decreases in abundance and Correspondence Analysis (CA) Axis 2 scores over time and lower abundance, richness, diversity, and equitability in 2012 compared to the mean of previous sampling years. In

addition, abundance, richness, percent EPT (Ephemeroptera, Plecoptera, Trichoptera), equitability, and CA Axis 2 scores were outside the range of historical conditions for all ARD reaches. Abundance was much lower in 2012 compared to all previous years.

3. Differences in measurement endpoints for benthic invertebrate communities in Goose Island Channel were classified as **Moderate** because the CA Axis 2 scores showed a significant difference in 2012, reflecting a potential decrease in relative abundances of bivalves and gastropods. Mean values of all other measurement endpoints were within previously-measured values for this reach and within the range of historical conditions for the ARD.

4. Differences in measurement endpoints for benthic invertebrate communities in the Embarras River were classified as **Moderate** because richness and the percentage of the fauna as EPT taxa significantly decreased over time. In addition, Ephemeroptera were absent, although the benthic fauna was still considered to be in relatively good condition.

Total abundance of benthic invertebrate communities in all four channels of the ARD was negatively correlated with percent substrate as sand. The higher sand content in 2012 in the channels of the ARD was likely related to high discharge events in 2012 prior to the fall sampling period, potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints as **Moderate** (Big Point Channel, Goose Island Channel, Embarras River) and **High** (Fletcher Channel), the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in the channels of the ARD.

In fall 2012, sediment quality in channels of the ARD generally exhibited coarser characteristics with lower organic carbon and hydrocarbon concentrations, than in recent years. All stations were predominantly composed of sand, with the exception of the Embarras River where silt was dominant. Concentrations of sediment quality measurement endpoints at all five stations in the ARD showed concentrations that were generally similar to previously-measured concentrations. PAHs at all stations in fall 2012 were dominated by alkylated species, indicating a petrogenic origin of these compounds. From 1999 to 2010, an increase in concentrations of total PAHs was observed in Big Point Channel, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2012, the concentration of total PAHs in Big Point Channel was lower than the previously-measured minimum concentration. With the exception of the station on the Athabasca River at the confluence with the Embarras River, all stations in the ARD exhibited a decrease in TOC and total PAHs in fall 2012 relative to fall 2011, likely associated with the coarser substrate observed at all stations. The PAH Hazard Index for the Embarras River was above the potential chronic toxicity threshold value of 1.0 but below 1.0 at all other stations. Acute toxicity data for sediments exceeded previously-measured maximum values for *Hyalella* survival in Big Point Channel and *Chironomus* survival at the station on the Athabasca River at the confluence with the Embarras River. Samples collected from Fletcher Channel showed historically low growth of *Chironomus* relative to previously-measured minimum concentrations. SQI values for all stations indicated **Negligible-Low** differences from regional *baseline* conditions.

Fish Populations (fish inventory) As outlined in the RAMP Design and Rationale document, the Athabasca River fish inventory is generally considered to be a community-driven activity, primarily used for assessing general trends in abundance and populations variables for large-bodied species, rather than detailed community structure.

As of 2012, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, age-frequency distributions, and condition of fish among years. There has been a significant increase in the catch and CPUE of goldeye in the last two years (i.e., 2011 and 2012), which could be related to an increase in recruitment during the calm, warm spring seasons in the last two years in the lower Athabasca River. However, it is important to note that the despite the increase in goldeye in the river, the absolute abundances of other KIR species has not concomitantly decreased. More data are necessary to determine any trends and evaluate the cause of the increase in goldeye numbers.

The fish health assessment indicated that abnormalities observed in 2012 in all species were within the historical range and consistent with studies done prior to the major oil sands development in the upper Athabasca River, the ARD, and the Peace and Slave rivers.

Muskeg River Watershed

Hydrology The calculated mean open-water discharge and the annual maximum daily discharge were 5.2% and 6.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **Moderate.** The calculated mean winter discharge and the open-water period minimum daily discharge were 140.3% and 34.8% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **High.**

Water Quality Concentrations of many water quality measurement endpoints at the upper *baseline* station of Jackpine Creek were outside previously-measured concentrations and exceeded the 95th percentile of regional *baseline* conditions. Concentrations of water quality measurement endpoints at other locations of the Muskeg River watershed in fall 2012 were frequently within the range of previously-measured concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2012 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were **Negligible-Low,** with the exception of the upper *baseline* station of Jackpine Creek and the *test* station of Iyinimin Creek, which had **Moderate** differences from regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2012:

1. Differences in values of measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Muskeg River were classified as **Moderate** because there was a significant increase in total abundance and CA Axis 1 and 2 scores over time and significant differences in abundance, EPT taxa, and CA Axis 1 and 2 scores in 2012 relative to previous sampling years. The benthic invertebrate community; however, appeared to be in good condition, with high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies. The percentage of the fauna as worms (tubificids and naidids) was relatively similar to previous years indicating no significant change in the quality of the habitat.

2. Differences in measurement endpoints for benthic invertebrate communities at the middle *test* reach of the Muskeg River were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches and there was no evidence of a negative change over time in any measurement endpoints.

3. Differences in measurement endpoints for benthic invertebrate communities at the upper *test* reach of the Muskeg River were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches. In addition, there was little evidence of any negative changes and the relative abundance of tubificids were lower than 2011.

4. Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of Jackpine Creek were classified as **Negligible-Low** because although there were significant differences from the upper *baseline* reach (i.e., higher CA Axis 1 scores, abundance, and richness at the lower reach), the differences were not indicative of degraded habitat quality at the lower *test* reach. The strong statistical signal in CA Axis 1 scores was due to a lower abundance of tubificids in 2012 at the lower *test* reach, suggesting good habitat quality. The presence of sensitive taxa including mayflies, caddisflies, clams, and snails, also suggested that the lower *test* reach of Jackpine Creek had a benthic fauna indicative of good depositional habitat conditions.

5. Differences in measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Moderate** because of the significant decrease in percent EPT (i.e., particularly mayflies and caddisflies) and the increase in CA Axis scores compared to the period when Kearl Lake was designated as *baseline*. However, the benthic invertebrate community contained a diverse fauna and included several taxa that were typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and caddisflies). The relative abundance of ostracods, which has decreased since 2011, was still high compared to *baseline* lakes in the RAMP FSA and all measurement endpoints were within the range of values reported during the *baseline* period for Kearl Lake, with the exception of diversity. Simpson's Diversity was higher in 2012 than in the *baseline* period, indicating good or better habitat quality.

Sediment quality at all Muskeg River watershed stations sampled in fall 2012 was generally consistent with that of previous years and regional *baseline* conditions. Concentrations of total PAHs at these stations were within previously-measured concentrations, with a few exceptions where PAH concentrations were below previously-measured minimum concentrations. Differences in sediment quality in fall 2012 at all applicable stations in the Muskeg River watershed were assessed as **Negligible-Low** compared to regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages between the lower *test* reach of the Muskeg River and regional *baseline* conditions were classified as **Negligible-Low** given that most measurement endpoints were within the regional range of variation of *baseline* reaches. Differences in measurement endpoints for fish assemblages between the middle and upper *test* reaches of the Muskeg River and regional *baseline* conditions were classified as **Moderate** because all measurement endpoints were outside the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between the lower *test* reach of Jackpine Creek and regional *baseline* conditions were classified as **Moderate** because all measurement endpoints were below the regional range of variation of *baseline* reaches, likely related to the high flows observed in fall 2012.

Fish Populations (sentinel species) Given the small sample size of slimy sculpin captured at the lower *test* site of the Muskeg River, it was not possible to make statistical comparisons or compare the results to the effects criteria to provide a classification of results.

Steepbank River Watershed

Hydrology The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.31%, 0.32%, 0.32%, and 0.26% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of many water quality measurement endpoints in the Steepbank River watershed in fall 2012 were higher than previously-measured concentrations, particularly at the *test* station of the North Steepbank River and the upper *baseline* station of the Steepbank River.

When compared with regional *baseline* conditions, concentrations of water quality measurement endpoints were generally consistent and within the regional range. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2012 was similar to previous years. Differences in water quality in fall 2012 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed.

Benthic Invertebrate Communities Differences in measurement endpoints for the benthic invertebrate community at the lower *test* reach of the Steepbank River were classified as **Moderate** because total abundance, percent EPT, and CA Axis 1 and 2 scores were significantly lower at the lower *test* reach than the upper *baseline* reach. The benthic invertebrate community; however, was diverse and although it was dominated by somewhat tolerant tubificids, many other taxa were noted that require cool, clean water and not suggesting any degradation of habitat conditions at this reach.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages in fall 2012 between the lower *test* reach of the Steepbank River and regional *baseline* conditions were classified as **Negligible-Low** with all values of measurement endpoints within the range of regional *baseline* variability.

Fish Populations (sentinel species) The number of varying exceedances of effects criteria for slimy sculpin at *test* site SR-E compared to each *baseline* site suggests there was substantial variability in slimy sculpin populations among *baseline* sites, likely related to variability in habitat conditions. Accordingly, to minimize the range of *baseline* variability, the classification of results focused on comparisons between the lower (*test*) and upper (*baseline*) Steepbank River sites given both sites are part of the same river system and; therefore, share similar habitat characteristics. Based on the results of the 2012, which provided inconsistent response patterns in energy use (growth and gonadosomatic index [GSI]) in female and male slimy sculpin at the *test* site of the Steepbank River, the differences from the *baseline* site were classified as **Negligible-Low**. Although the lower GSI could be indicative of a negative change, the higher growth of slimy sculpin at the *test* site was not indicative of a negative change and could suggest an increase in food resources at this site.

Tar River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 28.0% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Water Quality Differences in water quality observed in fall 2012 between stations on the Tar River and regional *baseline* fall conditions were classified as **Negligible-Low**. Most water quality measurement endpoints at the lower *test* station and upper *baseline* station of the Tar River were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations. Higher concentrations of several ions (e.g., Ca, Ng, Na, P, Cl, SO_4) shifted the ionic composition of the lower *test* station to conditions with a greater anion contribution by chloride and sulphate.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Tar River were classified as **Negligible-Low** because although there were significant differences in measurement endpoints over time, the differences were not in a direction consistent with a negative change but rather suggested improvements in habitat quality and species diversity compared to previous years. Mean values of measurement endpoints for benthic invertebrate communities at both reaches of the Tar River were within the range of regional *baseline* conditions. Differences in sediment quality observed in fall 2012 between the lower *test* station of the Tar River and regional *baseline* conditions were classified as **Negligible-Low.** Concentrations of sediment quality measurement endpoints were within previously-measured concentrations in fall 2012, including total PAHs and predicted PAH toxicity; however, concentrations of benz[a]anthracene and benzo[a]pyrene represented maximum concentrations for the lower *test* station and also exceeded CCME guidelines.

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 although the Assemblage Tolerance Index (ATI) value exceeded the regional range of variation for *baseline* reaches, the exceedance was not in a direction consistent with a negative change. The ATI value was lower indicating that sensitive species in greater abundance were present at this reach compared to the range of regional *baseline* conditions.

MacKay River Watershed

Hydrology The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated from the observed *test* hydrograph were 0.004% lower from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2012 at the lower *test* and upper *baseline* stations of the MacKay River relative to regional *baseline* water quality conditions were classified as **Negligible-Low**, while differences in water quality at the middle *test* station of the MacKay River was classified as **Moderate**, likely due to very high flow conditions at the time of sampling, which resulted in high total suspended solids and total metals that are associated with particulates.

Benthic Invertebrate Communities Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the MacKay River were classified as **Moderate** because there was a decrease in EPT taxa below regional *baseline* conditions and significantly lower abundance of EPT taxa at the lower *test* reach compared to the upper *baseline* reach. In addition, CA Axis 1 scores were significantly lower at the lower *test* reach in 2012 compared to the upper *baseline* reach reflecting a difference in taxa composition, with fewer water mites. Differences in measurement endpoints for benthic invertebrate communities at the middle *test* reach of the MacKay River were classified as **Moderate** because the CA Axis 1 scores were significantly lower compared to the upper *baseline* reach.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower and middle *test* reaches of the MacKay River and regional *baseline* conditions were classified as **Negligible-Low** given there were was only one measurement endpoint for the lower *test* reach that exceeded the regional range of variation of *baseline* reaches. The increase in ATI at the lower *test* reach was due to the dominance of trout-perch captured at this reach, which has a high tolerance value.

Calumet River Watershed

Hydrology For the 2012 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge were estimated to be 0.2% lower than from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality In fall 2012, water quality at the lower *test* station and upper *baseline* station of the Calumet River showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of all water quality measurement endpoints at the lower *test* station and the upper *baseline* station were within the range of regional *baseline* concentrations in fall 2012. The ionic composition of water at the lower *test* station was consistent with previous years, and the ionic composition of the upper *baseline* station appeared to have returned to its historical range following a deviation in fall 2010.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Calumet River were classified as **Negligible-Low** because although there were significant differences in measurement endpoints compared to the upper *baseline* reach (e.g., higher diversity, EPT taxa, and lower equitability at the lower *test* reach), these differences were generally not in a direction consistent with a negative change or degraded habitat quality. In addition, mean values of measurement endpoints were within the range of variation for *baseline* depositional reaches and the benthic invertebrate ommunity at the lower *test* reach of the Calumet River was considered diverse and supported by good water quality. The benthic invertebrate community at the upper *baseline* reach was somewhat unusual relative to previous sampling years. The benthic invertebrate community was heavily dominated by nematodes and copepods, while several groups typically observed were not found in 2012 (e.g., Chaoboridae, Bivalvia, Ceratopogonidae). Concentrations of sediment quality measurement endpoints at both stations of the Calumet River in fall 2012 were generally within the range of previously-measured concentrations, with both stations comprised almost exclusively of sand substrate, with low concentrations of total organic carbon. Direct measurements of sediment toxicity indicated a survival ≥70% at both stations. Differences in sediment quality observed in fall 2012 between the upper *baseline* station and regional *baseline* conditions were classified as **Negligible-Low**. Differences in sediment quality between the lower *test* station of the Calumet River and regional *baseline* conditions were classified as **Moderate**.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower *test* reach of the Calumet River and regional *baseline* conditions were classified as **Negligible-Low** given that all measurement endpoints were within the regional range of variation of *baseline* reaches.

Firebag River Watershed

Hydrology The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated were 0.1% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. Water levels recorded for McClelland Lake, were, with the exception of a short period in November 2011 and May 2012, below the historical minimum for the duration of the 2012 WY.

Water Quality In fall 2012, water quality at the lower *test* and upper *baseline* stations of the Firebag River showed **Negligible-Low** differences from regional *baseline* water quality conditions. The ionic composition of water in fall 2012 at both Firebag River stations and McClelland Lake was consistent with previous sampling years. Concentrations of most water quality measurement endpoints at the lower *test* and upper *baseline* stations of the Firebag River were within the range of regional *baseline* concentrations in fall 2012. Concentrations of water quality measurement endpoints for McClelland and Johnson Lake were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. Many water quality measurement endpoints, primarily ions and select metals, exceeded previously-measured maximum concentrations at all stations in the Firebag River watershed.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities of McClelland Lake in 2012 were classified as **Negligible-Low** because total abundance was higher in the *test* period than the *baseline* period and although the percentage of fauna as EPT taxa was lower in 2012 than the mean of previous sampling years, it was consistent to 2002, 2003, and 2010. CA Axis 1 scores were significantly different from the *baseline* period and CA Axis 2 scores were different in 2012 than all previous sampling years; however, the composition of the community in terms of relative abundances, included fully aquatic forms and generally sensitive taxa including the mayfly *Caenis* and the caddisfly *Mystacides* suggesting that the community of McClelland Lake was still in good condition and generally similar to *baseline* conditions. The benthic invertebrate community Johnson Lake was indicative of good water and sediment quality conditions due to a the large relative abundance of permanent aquatic forms such as Amphipoda and bivalve clams, the presence of relatively sensitive and large aquatic insect larvae (Ephemeroptera: *Caenis*), and a low relative abundance of worms. Concentrations of sediment quality measurement endpoints for McClelland Lake frequently deviated from historical ranges in fall 2012, generally with lower concentrations of hydrocarbons. The coarser sediment composition and lower total organic carbon content observed in fall 2012 were likely a result of sampling variability and caused concentrations of total metals (normalized to percent fines) and total PAHs (normalized to total organic carbon) to exceed previously-measured maximum concentrations for this lake. Sediment toxicity to invertebrates was within previously-measured ranges for McClelland Lake. Fall 2012 represented the second year of sampling in Johnson Lake; sediment quality in Johnson Lake was generally similar to McClelland Lake, but had higher concentrations of hydrocarbons and total metals.

Ells River Watershed

Hydrology The mean winter discharge (November to March) was 0.01% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The calculated mean open-water discharge (May to October), the annual maximum daily discharge, and the open-water minimum daily discharge were 0.05% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2012 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at the lower and middle *test* stations, and were within the range of previously-measured concentrations and regional *baseline* conditions. Water quality at the upper *baseline* station in fall 2012 was similar to that at the other two stations and consistent with results since it was first sampled in 2010.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the Ells River were classified as **Moderate** because of the significant decrease in Simpson's Diversity and percent EPT taxa in 2012 compared to previous years, and a decrease in percentage of fauna as EPT taxa over time. Additionally, Simpson's Diversity was also lower than the range of *baseline* conditions for depositional reaches. Habitat at the lower *test* reach was of marginal quality for benthic invertebrate communities. The low diversity, high relative abundance of tubificid worms (>60% in 2012), absence of caddisflies and stoneflies, and low relative abundance of mayflies were indicative of an environment that was somewhat limiting to depositional fauna. Differences in measurement endpoints for benthic invertebrate communities at the middle *test* reach of the Ells River were classified as **Moderate** because there was a significant difference in abundance, richness, equitability, percent EPT, and CA Axis 1 and 2 scores between this reach and the upper *baseline* reach. In addition, abundance, and percent EPT were higher and lower, respectively at the middle *test* reach than the regional *baseline* range. Differences in sediment quality observed in fall 2012 between the lower *test* station of the Ells River and regional *baseline* conditions were classified as **Moderate**, and likely related to the exceedance of chrysene from previously-measured concentrations, and the concentration of total PAHs, which exceeded the regional *baseline* range. In addition, guideline exceedances were observed in concentrations of Fraction 2 and Fraction 3 hydrocarbons, pyrene, chrysene, and the potential chronic toxicity threshold.

Fish Populations Differences in fish assemblages observed in fall 2012 between both *test* reaches of the Ells River and regional *baseline* conditions were classified as **Negligible-Low** with all mean values of measurement endpoints within the range of regional *baseline* variability.

Clearwater River Watershed

Hydrology There was no land change in the Clearwater River watershed related to focal projects and other oilsands development in 2012. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

Water Quality In fall 2012, water quality at the *baseline* station of the High Hills River indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at the *test* and *baseline* stations on the Clearwater River indicated **Moderate** differences from regional *baseline* water quality conditions, with concentrations of several water quality measurement endpoints exceeding the range of previously-measured concentrations and the range of regional *baseline* conditions in 2012.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate community at the *baseline* reach of the High Hill River was diverse, including a high percentage of chironomids and EPT taxa that reflected good water quality. High Hills River was used as a regional *baseline* reach for comparisons to *test* reaches in the RAMP FSA. Sediment quality monitoring was not conducted on the High Hills River given it is an erosional river.

Fish Populations (fish inventory) Total fish captured in the Clearwater River during the fall fish inventory has varied across years, which can be partially attributed to variability in discharge. In lower flow years, the amount of available fish habitat and the accessibility of the river is limited. Species richness across reaches in spring 2012 was higher than previous years, with the exception of 2007 and 2008. Species richness in fall 2012 was also higher than previous sampling years. Species richness at the *test* reach was generally consistent to the *baseline* reaches across years for spring and summer. In fall, species richness was generally higher in the *baseline* reaches than the *test* reach. The relative abundance of fish species in the Clearwater River was variable without any clear trends observed over time. Similarly, there has been no marked shift in species dominance from year to year. Additionally, there have been no significant differences in condition of large-bodied KIR fish species in the *test* reach of the Clearwater River when compared to *baseline* data. It is important to note; however, that condition cannot necessarily be attributed to the environmental conditions in the capture location, as these fish populations are highly migratory throughout the region.

Fish Populations (fish tissue) Measurement endpoints used in the assessment included metals and tainting compounds in both individual and composite samples. In 2012, the mean concentration of mercury in northern pike was lower than in previous sampling years, with the exception of 2009. The mercury concentration in size classes of northern pike greater than 550 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) The fish assemblage at the *baseline* reach on the High Hills River was generally consistent with other *baseline* erosional reaches, with a much higher proportion of slimy sculpin. This species is typical of riffle habitat with faster flowing water and as noted above, is a sensitive species, which likely contributed to the lower ATI value observed for this reach.

Christina River Watershed

Hydrology The calculated mean open-water season (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge of the Christina River during the 2012 WY were 0.04% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The mean winter discharge was 0.11% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

Water Quality In fall 2012, water quality at *test* stations on the lower Christina River, Jackfish River, Sawbones Creek, and Sunday Creek indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at the upper *test* station of the Christina River indicated **High** differences from regional *baseline* water quality conditions. Concentrations of several water quality measurement endpoints (e.g., total and dissolved metals) were outside the range of previously-measured concentrations and regional *baseline* conditions in fall 2012 at the upper *test* station of the Christina River.

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 **Moderate** because abundance, richness, and the percentage of EPT taxa were lower in 2012 compared to previous years and diversity and abundance were below the range of variation for *baseline* depositional reaches. The benthic invertebrate community at the lower *test* reach has consistently been dominated by tubificid worms over time suggesting that the observed differences in 2012 may be due to natural variation. The reach also contained stoneflies (Plecoptera) suggesting reasonably good habitat quality. Differences in measurement endpoints for benthic invertebrate communities at the upper *test* reach of the Christina River were classified as **Negligible-Low** because the significantly higher percentage of EPT taxa in the *test* period compared to the *baseline* period was not consistent with a negative change. Differences in measurement endpoints for benthic invertebrate communities at the *test* reaches of Sawbones Creek, Sunday Creek, and Jackfish River were classified as **Negligible-Low** because almost all measurement endpoints including the CA Axis scores were either within or above regional *baseline* conditions. Differences in measurement endpoints for the benthic invertebrate community of Christina Lake in fall 2012 were classified as **Negligible-Low** given that the lake contained a diverse benthic fauna including several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies). In fall 2012, concentrations of sediment quality measurement endpoints at both stations of the Christina River were generally lower than previously-measured concentrations and a decreasing trend in concentrations of total PAHs was observed over time at the lower *test* station. Concentrations of sediment quality measurement endpoints at stations on tributaries to Christina Lake (i.e., Sawbones and Sunday creeks) were within regional *baseline* conditions. Sediment quality in fall 2012 showed **Negligible-Low** differences at all stations in the Christina River watershed, excluding Christina Lake, from regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages between the lower and upper *test* reaches of the Christina River and regional *baseline* conditions were classified as **Negligible-Low** because only abundance at the lower *test* reach was below the range of variation for regional *baseline* reaches. The lower catch was likely due to difficulties in effectively sampling the river in high water conditions in fall 2012. Regional information for this part of the RAMP FSA was limited; therefore, comparisons to regional *baseline* conditions were made with areas further to the north (i.e., reaches sampled by RAMP to the north of Fort McMurray). Differences in measurement endpoints for fish assemblages between the *test* reach of Sunday Creek and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured and not consistent with a negative change. Differences in measurement endpoints for fish assemblages between the *test* reach of Jackfish River and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within regional *baseline* range of variation. Differences in measurement endpoints for fish assemblages between the *test* reach of Sawbones Creek and regional *baseline* conditions were classified as **Moderate** because three of the four measurement endpoints were below the 5th percentile of regional *baseline* conditions. Given that historical data were limited for Sawbones Creek, a more complete assessment of fish assemblages in this creek will be conducted in fall 2013, once two years of data are acquired. A total of 784 fish from nine species were captured using the three methods during the fish assemblage survey in Christina Lake in summer 2012. Two species captured during the

RAMP 2012 survey had not been previously documented in either Christina Lake or its tributaries, including the Iowa darter (*Etheostoma exile*) and northern redbelly dace (*Phoxinus eos*).

Fish Populations (fish tissue) Mercury concentrations in northern pike and walleye from Gregoire Lake in 2012 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in fish from Gregoire Lake were near the lower end of the historical range of mercury concentrations in fish sampled from other regional lakes.

Hangingstone River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Pierre River Area

Water Quality Differences in water quality in fall 2012 between the *baseline* stations of Big Creek, Pierre River, Red Clay Creek, and Eymundson Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. The *baseline* station on Eymundson Creek differed from the other stations in its ionic composition, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 37.2% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph for Mills Creek. These differences were classified as **High**.

In the 2012 WY, lake levels of Isadore's Lake generally decreased from November 2011 to early March 2012, with levels in November and December near historical median values and levels from January to late March varying between the historical minimum and lower-quartile values. Lake levels increased during freshet in late March and April followed by decreasing levels until mid-May. Lake levels increased from late May through July in response to rainfall events, and generally remained between the historical maximum and upper quartile values until the end of the 2012 WY.

Differences in water quality in fall 2012 between Mills Creek and regional *baseline* conditions were classified as **Moderate**, likely due to relatively high concentrations of many ions and other dissolved species that exceeded the 95th percentile of regional *baseline* concentrations. The ionic compositions of test stations on 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 for the benthic invertebrate community of Isadore's Lake were classified as **Negligible-Low** because the significant (though subtle) increase in percent EPT over time and the higher percent EPT in 2012 than the mean of previous years does not suggest degrading conditions. The percentage of fauna as EPT has always been <1% (normally EPT are absent), but in 2012 EPT taxa accounted for about half a percent of the fauna. Further, all measurement endpoints were within the range of historical values for the lake. Historically, Isadore's Lake has had a unique benthic invertebrate community compared to other lakes in the area, having low diversity and high abundance of nematodes. While there has been very little negative change over time, the benthic invertebrate community in Isadore's Lake has been representative of a degraded system since sampling was initiated in 2006. Concentrations of most sediment quality measurement endpoints in fall 2012 in Isadore's Lake were within previously-measured concentrations with only a few exceptions (i.e., carbon-normalized PAHs and naphthalene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2012 at the *test* station of Shipyard Lake were within previously-measured concentrations with only a few exceptions (i.e., magnesium and total aluminum). The ionic composition of water of Shipyard Lake continued to exhibit an increase in sodium and chloride concentrations relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the Shipyard Lake watershed (the upper 93% of the Shipyard Lake watershed has been disturbed). A WQI was not calculated for lakes in 2012 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the limited *baseline* lake data.

Differences in measurement endpoints for the benthic invertebrate community of Shipyard Lake in 2012 were classified as **Negligible-Low**. The increasing trend over time of abundance and taxa richness were significant and were not indicative of degraded water or habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams, and snails, indicating generally good water and sediment quality. Concentrations of most sediment quality measurement endpoints in fall 2012 at the *test* station of Shipyard Lake were within previously-measured concentrations with only a few exceptions (i.e., TOC and benzo[a]pyrene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers.

Poplar Creek and Beaver River The calculated mean open-water discharge (May to October) was 1.6% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The annual maximum daily discharge and open-water minimum daily discharge were 1.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Concentrations of several water quality measurement endpoints, primarily ions and other dissolved species, exceeded regional *baseline* concentrations at the lower *test* station of the Beaver River, resulting in a **Moderate** difference from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at the lower *test* station of Poplar Creek and the upper *baseline* station of the Beaver River, differences in water quality in fall 2012 and regional *baseline* conditions were classified as **Negligible-Low**.

Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of Poplar Creek were classified as **Moderate** because of the significant and large differences in abundance, percentage of fauna as EPT taxa, and CA Axis scores compared to *baseline* reach BER-D2. The benthic invertebrate community at the lower *test* reach of Poplar Creek was in generally good condition, reflected by low relative abundances of worms and higher relative abundances of fingernail clams. The low relative abundance of mayflies and caddisflies, and lack of stoneflies potentially indicated some level of disturbance, but over time the percentage of EPT taxa has been increasing. Differences in sediment quality observed in fall 2012 at the lower *test* station of Poplar Creek and the upper *baseline* station of the Beaver River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of most sediment quality measurement endpoints were within the range of previously-measured concentrations and within the range of regional *baseline* conditions.

Differences in measurement endpoints for fish assemblages between the lower *test* reach of Poplar Creek and regional *baseline* conditions were classified as **Negligible-Low** because although the assemblage tolerance index (ATI) was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured, and not reflective of degrading conditions in Poplar Creek.

McLean Creek Concentrations of water quality measurement endpoints at the lower *test* station of McLean Creek were often higher than regional *baseline* concentrations in fall 2012. Concentrations of TSS, TDS, and many ions and dissolved species of water quality measurement endpoints were high relative to regional *baseline* conditions and exhibited guideline exceedances, indicating a **Moderate** difference from regional *baseline* concentrations.

Fort Creek The calculated mean open-water period (May to October) discharge volume was 11.7% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Moderate**. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed. This variability in daily flow was sufficiently large to adjust the expected flow characteristics previously evident at this station. The 2012 WY showed multiple precipitation-driven annual maximum daily discharges within the annual hydrograph, and did not display a defined open-water minimum daily flow following a sustained dry period as is typical in other systems.

Differences in water quality in fall 2012 between the lower *test* station of Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**. However, relatively high concentrations of several water quality measurement endpoints were observed, but were within the range of previously-measured concentrations. A large increase in the concentration of sulphate has been observed at the lower *test* station of Fort Creek since 2008 (not a statistically significant trend), which appeared to have occurred in the absence of other apparent changes in ionic composition.

Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of Fort Creek were classified as **High** because of the significantly lower abundance and richness during the *test* period compared to the *baseline* period. Additionally, four of the five measurement endpoints were outside of the range of variation for regional *baseline* depositional rivers. Although the percentage of fauna as EPT taxa has increased over time, this could be an artifact of the low overall abundance in the reach during many years of sampling (including 2012). Differences in sediment quality observed in fall 2012 between the lower *test* station of Fort Creek and regional *baseline* conditions were **Negligible-Low** with nearly all sediment quality measurement endpoints within the range of previously-measured concentrations and regional *baseline* concentrations.

Differences in measurement endpoints for fish assemblages between the lower *test* reach of Fort Creek and regional *baseline* conditions were classified as **Negligible-Low** given that the mean value all measurement endpoints were within the range of variation for regional *baseline* reaches.

Susan Lake Outlet Flows decreased after monitoring began in the outlet of Susan Lake, with the exception of two rainfall induced peaks on June 4 and June 24. Daily flows recorded in July showed multiple peak flows due to rainfall events from late June to mid-July. Flows generally decreased from late July through August to below the historical minimum values in mid-August. Rainfall events in late August and early September resulted in flows exceeding the historical maximum values. Following this peak, flows decreased through September before steadily increasing until monitoring ended on October 16, 2012.

Acid-Sensitive Lakes

Results of the analysis of the RAMP lakes in 2012 compared to historical data suggest that there was no significant change in the overall chemistry of the lakes across years that were attributable to acidification. Significant increases in pH, Gran alkalinity, sodium, TDS, conductivity, and sum of base cations were observed; however, these changes appeared to be the result of factors other than acidifying emissions (e.g., hydrology).

A summary of the state of the RAMP lakes in 2012 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of 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 general, data in 2012 were less variable than in 2011 resulting in fewer exceedances of the two standard deviation criterion. The highest number of exceedances (3) occurred in lakes in the Canadian Shield subregion, which are remote from emissions sources and considered *baseline* lakes. Exceedances were observed in base cation concentrations in two lakes, which are increasing due to factors other than acidification. Taking into account these factors, the subregions were all classified as having a **Negligible-Low** indication of incipient acidification.

Summary and Recommendations

The following table provides a summary of the 2012 RAMP monitoring program results, by watershed and component.

The report concluded with a number of recommendations directed towards refining the monitoring program and increasing the value of RAMP monitoring activities. These recommendations are for consideration during the design of monitoring in future years of RAMP:

- Continue to monitor existing climate and hydrometric stations to enhance record length and data availability.
- Expand the climate and hydrology monitoring network to support the provision of *baseline* and *test* hydrometric information and regional climate data.
- Evaluate additional hydrometric measurement endpoints and indicators (such as the timing and frequency of flow conditions) that would further support the RAMP assessment and understanding of aquatic conditions.
- Conduct water balance assessments as a consistent approach applicable to tributary watersheds, independent of the length of the data record, and, as possible, continue to refine inputs such as the time-step of industrial data and delay of releases reaching the measurement station.
- Delineate watershed areas for all RAMP hydrometric stations using updated topographic elevation data and assess if watershed areas need to be updated.
- Continue to add *baseline* stations for ongoing RAMP water quality sampling, particularly stations that are expected to remain *baseline* well into the future.
- Continue to expand seasonal or monthly sampling within the RAMP water quality program, particularly for larger tributaries, to better capture the range of conditions in these locations and allow better discrimination of natural versus anthropogenic changes in water quality in future.
- Consider the addition of deep-water benthic sampling in lakes in which a thermocline has had an opportunity to develop. Such sampling would ensure that any changes in deep-water habitats are detected, if they occur.
- Consider the use of sediment traps in some channels of the delta (especially Fletcher Channel), to estimate sediment deposition rates and also to specifically assess concentrations of hydrocarbons and metal in sediments deposited in the ARD in a given year.
- Continue to collaborate with Environment Canada and AESRD on lethal fish sampling in rivers and lakes in the region to minimize potential impacts on fish populations related to monitoring activities.

- Continue to work with AESRD and Environment Canada on fish monitoring activities to further harmonize fishing methods and data collection, which will eventually result in more efficient sampling in the region and increased data and information sharing to meet the objectives of all stakeholder needs.

- Continue to collect data on fish abnormalities to develop a better understanding of the prevalence of abnormalities in fish in Northern Alberta.

- Consider the use of an electrofishing boat for fish assemblage monitoring in the Athabasca River Delta, which will allow better spatial coverage and increased capture success such that data collected will more accurately represent the fish assemblage present in the delta.

- Evaluate the two basins of Christina Lake separately, if a fish survey is conducted again, to ensure adequate spatial coverage in both basins.

Summary assessment of RAMP 2012 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Fish Populations: Human Health Risk from Mercury in Fish Tissue[8]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[9]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Assemblages[5]	Sentinel Fish Species[6]	Species	Subs. Fishers	General Cons.	
Athabasca River	🟡	🟡 / 🟠	-	-	-	-	-			-
Athabasca River Delta	-	-	🟠 / 🟤	🟡	n/a	-	-			-
Muskeg River	🟤	🟡	🟠 / 🟡	🟡	🟡 / 🟠	-[7]	-			-
Jackpine Creek	nm	🟡	🟡	🟡	🟡	-	-			-
Kearl Lake	nm	🟡	🟠	n/a	-	-	-			-
Steepbank River	🟡	🟡	🟠	-	🟡	🟠	-			-
Tar River	🟤	🟡	🟡	🟡	-	-	-			-
MacKay River	🟡	🟡 / 🟠	🟠	-	🟡	-	-			-
Calumet River	🟡	🟡	🟡	🟠	🟡	-	-			-
Firebag River	🟡	🟡	nm	nm	nm	-	-			-
McClelland Lake	nm	n/a	🟠	n/a	-	-	-			-
Johnson Lake	-	n/a	n/a	n/a	-	-	-			-
Ells River	🟡	🟡	🟠	🟠	🟡	-	-			-
Christina River	🟡	🟡 / 🟤	🟠 / 🟡	🟡	-	-	-			-
Christina Lake	nm	n/a	n/a	n/a	n/a	-	-			-
Christina Lake Tributaries[10]	nm	🟡	🟡	🟡	🟠 / 🟡	-	-			-
Gregoire Lake	-	-	-	-	-	-	WALL NRPK	🟡	🟡	-
Clearwater River	nm	🟠	nm	nm	-	-	NRPK (>500mm)	🟤	🟠	-
High Hills River	-	🟡	n/a	-	n/a	n/a	-			-
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	-	🟡	-	-	-	-	-			-
Pierre River	-	🟡	-	-	-	-	-			-
Red Clay Creek	-	🟡	-	-	-	-	-			-
Eymundson Creek	-	🟡	-	-	-	-	-			-
Stony Mountains	-	-	-	-	-	-	-			🟡
West of Fort McMurray	-	-	-	-	-	-	-			🟡
Northeast of Fort McMurray	-	-	-	-	-	-	-			🟡
Birch Mountains	-	-	-	-	-	-	-			🟡
Canadian Shield	-	-	-	-	-	-	-			🟡
Caribou Mountains	-	-	-	-	-	-	-			🟡

Legend and Notes

🟡 Negligible-Low change

🟠 Moderate change

🟤 High change

"-" program was not completed in 2012.

nm - not measured in 2012.

n/a - classification could not be completed because there were no *baseline* conditions to compare against.

[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 are calculated for each watershed because of differing lengths of the hydrographic record for 2012, hydrology results above are for those measurement endpoints that were calculated.

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

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

Note: Water quality at all stations in the Athabasca River was assessed as Negligible-Low with the exception of station ATR-MR-E, which was assessed as Moderate.

Note: Water quality at the lower station of the MacKay River was assessed as Negligible-Low and water quality at the middle station was assessed as Moderate.

Note: Water quality at the lower station of the Christina River was assessed as Negligible-Low and water quality at the upper station was assessed as High.

[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 comparison to regional *baseline* conditions.

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

Note: Benthic invertebrate communities at the lower reach of the Muskeg River were assessed as Moderate and benthic invertebrate communities at the middle and upper reaches were assessed as Negligible-Low.

Note: Benthic invertebrate communities at the lower reach of the Christina River were assessed as Moderate and benthic invertebrate communities at the upper reach were assessed as Negligible-Low.

[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 3.2.4.3 for a detailed description of the classification methodology.

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

Note: Fish assemblages Sawbones Creek were assessed as Moderate and fish assemblages at Sunday Creek and Jackfish River were assessed as Negligible-Low.

[6] **Fish Populations (sentinel species):** Classification based on effects criteria established for Environment Canada's Environmental Effects Monitoring Program for pulpmills (Environment Canada 2010); see Section 3.2.4.4 for a description of the classification methodology.

[7] A classification of results could not be completed for the lower Muskeg River site given the low sample size of slimy sculpin captured for the sentinel species program.

[8] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. NRPK – northern pike; WALL – walleye; Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada.

[9] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2012 were more than twice the standard deviation from their long-term mean in each lake.

[10] Christina Lake tributaries include Sawbones Creek, Sunday Creek, and Jackfish River.

1.0 INTRODUCTION

This document is the 2012 Technical Report of the Regional Aquatics Monitoring Program (RAMP). RAMP is a joint environmental monitoring program that assesses the health of rivers and lakes in the Athabasca oil sands region of northeastern Alberta with participation from the oil sands industry, other industries active in the Athabasca oil sands region, regional stakeholders, Aboriginal communities, and local, provincial, and federal governments.

1.1 ATHABASCA OIL SANDS REGION BACKGROUND

With an estimated 293.1 billion m^3 (1.84 trillion barrels) of total reserves of bitumen (initial volume in place), 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 26.80 billion m^3 (168.7 billion barrels) of remaining established bitumen reserves[1] (ERCB 2012) being equivalent to 12.4% of the world's known reserves of conventional crude oil[2] (US Energy Information Administration 2012). 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 (ERCB 2012).

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 22.4% of the estimated established bitumen reserves in the Athabasca oil sands region were under active development as of the end of 2011, and 4.1% of the estimated established bitumen reserves of the Athabasca oil sands region had been extracted by the end of 2011 (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 2011		32,732
Mineable	30,966	
in situ	1,737	
Cumulative Production as of 31 December 2011		5,982
Mineable	5,158	
in situ	825	
Remaining Established Reserves		139,954

Data from ERCB (2012); all figures are as of December 31, 2011.

* Estimated, established reserves are 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.

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[1] Established bitumen reserves are defined as the amount of bitumen that is recoverable under current technology and present and anticipated economic conditions specifically proved by drilling, testing, or production, plus the portion of reserves that are interpreted to exist from geological, geophysical, or similar information with reasonable certainty (ERCB 2010). Remaining established bitumen reserves are established bitumen reserves less cumulative bitumen production.

[2] The world's known reserves of conventional crude oil are based on 2010 data as 2011 and 2012 data are not available (US Energy Information Administration 2012).

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. Environmental monitoring and research has been a prominent topic of discussion among regulators, media, and concerned stakeholders. The organizations involved in long-term environmental monitoring (i.e., for status and trends reporting and compliance or approval requirements) and surveillance monitoring (i.e., typically short-term to address specific questions) in the Athabasca oil sands region, in addition to RAMP, include (but are not limited to) (Dowdeswell et al. 2010):

Long-term Monitoring

- Cumulative Environmental Management Association (CEMA) – established in 2000, CEMA develops guidelines and management frameworks on how best to reduce cumulative environmental effects due to industrial development. CEMA's focus includes (but is not limited to): adaptive management of reclaimed terrestrial (CEMA 2010a [ToR]) and aquatic ecosystems (CEMA 2012 [ToR]); guidance for end-pit lake and wetland establishment, acid deposition; land capability; air contaminants; surface and ground water management; and traditional ecological knowledge (TEK).
- Wood Buffalo Environmental Association (WBEA) – monitors and provides information on air quality and air-related environmental impacts in the RMWB. The WBEA implements three programs:
    - Air quality monitoring and reporting, conducted via a network of fifteen air quality monitoring stations in the RMWB;
    - Terrestrial Environmental Effects Monitoring (TEEM) – a program designed to detect, characterize and quantify the extent to which air emissions affect terrestrial and aquatic ecosystems, and traditional resources in the Athabasca oil sands region; and
    - A human exposure monitoring program, initiated in 2005, designed to monitor human exposure to select air contaminants in the RMWB.
- Alberta Biodiversity Monitoring Institute (ABMI) – formally established in 2007, is an independent, not-for-profit organization that monitors plant and animal species and habitats at more than 1,600 sites across the province of Alberta, including 959 sites in the Boreal region where the Athabasca oil sands are situated.
- Government of Alberta – monitors the environment of the Athabasca oil sands region through the following ministries:
    - Alberta Environment and Sustainable Resource Development (AESRD) has been monitoring water quality of the Athabasca River since the 1970s and the Muskeg River since the 1990s. AESRD recently initiated intensive, integrated monitoring throughout the Muskeg River watershed as well as a contaminant loading study involving passive water quality samplers throughout the Athabasca oil sands region and historical sediment quality assessments (coring studies).
    - AESRD monitors and manages the fisheries resources in the Athabasca oil sands region; and

    - Alberta Health has implemented human health consumption guidelines for sportfish in several lakes and rivers within the lower Athabasca Region using mercury results collected by RAMP.

- Environment Canada – Environment Canada undertakes a number of monitoring activities in the oil sands region through the federal Water Act, Fisheries Act, and Canadian Environmental Protection Act. The Water Survey of Canada, which operates several hydrology stations in the area, is an example of one of the monitoring programs managed under Environment Canada. The Peace-Athabasca Delta Ecological Monitoring Program (PAD-EMP) is another Environment Canada initiative and falls under the jurisdiction of Parks Canada.
- Industry – individual oil sands companies, including both members and non-members of RAMP, undertake regular aquatic monitoring programs in streams and rivers near their operations to meet approval requirements stipulated by regulatory agencies such as AESRD, Fisheries and Oceans Canada, and Environment Canada.

Surveillance Monitoring and Research

- Alberta Water Research Institute (AWRI) – serves as a coordinator of research in support of Alberta's provincial water strategy, *Water for Life: A Strategy for Sustainability*. AWRI currently oversees eight projects focusing on water quality, quantity, recycling and management, and other water-related topics, in the Athabasca oil sands region.
- Canadian Oil Sands Network for Research and Development (CONRAD) – a network of companies, universities, and government agencies organized to facilitate collaborative research in science and technology for Alberta oil sands. The research focuses on the following areas: environmental research, in situ recovery, surface mining of oil sands, bitumen extraction, and bitumen and heavy oil upgrading.
- Carbon Dynamics, Food Web Structure, and Reclamation Strategies in Athabasca Oil Sands Wetlands (CFRAW) – a partnership between scientists at the universities of Alberta, Saskatchewan, Waterloo, and Windsor, and sponsoring industry partners. The research venture focuses on carbon dynamics, biological effects of oil sands process materials, and predicting changes in the environment and recommending reclamation strategies (Oilsands Advisory Panel 2010).
- Environment Canada is actively involved in monitoring and research in the oil sands region and has partnered with AESRD, universities, and other government departments on a number of projects. Areas of research include ecological flow needs, tailings pond management, and chemical profiling of hydrocarbons to distinguish those naturally occurring from industrial (Oilsands Advisory Panel 2010).

Finally, several universities, independent scientists, and government research agencies continue to undertake studies in the Athabasca oil sands region to better understand local aquatic resources and their response to regional development (Oilsands Advisory Panel 2010) including but not limited to:

- Natural Sciences and Engineering Research Council of Canada (NSERC);
- University of Alberta: David Schindler Laboratory;
- University of Alberta: Centre for Oil Sands Innovation (COSI);

- University of Saskatchewan – Toxicology Centre and Canada Research Chair in Environmental Toxicology; and
- University of Waterloo – headquarters for the Canadian Water Network (CWN), a program designed to connect Canadian and international water researchers with decision-makers and conduct contaminant fate research and graduate studies related to water management in the Athabasca oil sands region.

New Monitoring Initiatives

In 2012, Environment Canada and AESRD developed a joint integrated monitoring plan for the oil sands region. The provincial and federal governments are working together to develop a comprehensive program to assess cumulative environmental impacts on air, water, land, and biodiversity, which will build on the existing monitoring programs in the region (Government of Canada 2012). The new plan (Joint Canada-Alberta Implementation Plan) will be consistent with province-wide environmental monitoring in Alberta while also addressing specific issues related to oil sands development. Following a transition period of three years, this new plan will encompass current monitoring organizations and additional monitoring requirements to have one complete integrated monitoring program across all environmental components. Current monitoring organizations are working with both governments during the transition period to ensure all stakeholder concerns are met and the monitoring objectives will address the environmental concerns related to oil sands development.

In addition, the Government of Alberta has developed the Lower Athabasca Regional Plan (LARP), which is a management system that takes into account the cumulative effects of all activities and improves integration across economic, environmental, and social components (Government of Alberta 2012). The management system will align provincial policies on air, water, land, and biodiversity to balance economic development opportunities and social and environmental considerations. The LARP outlines management frameworks, strategies, actions, and tools that are required to achieve the desired objectives and outcomes on a long-term basis.

1.2 OVERVIEW OF RAMP

The Regional Aquatics Monitoring Program (the Program) is an industry-funded, multi-stakeholder environmental monitoring program initiated in 1997. The overall mandate of RAMP is to:

> *"…determine, evaluate, and communicate the state of the aquatic environment and any changes that may result from cumulative resource development within the Regional Municipality of Wood Buffalo."*

In order to fulfill this mandate, the Program integrates aquatic monitoring activities across different components of the aquatic environment, geographical locations, and Athabasca oil sands and other developments. This enables trends in the state of the aquatic environment to be determined, and any changes in the aquatic environment to be assessed and communicated. The coordination of monitoring efforts among RAMP members results in a comprehensive, regional, and publicly-available database[3] that may be used by operators for their environmental management programs, compliance with environmental requirements of regulatory approvals, assessments of proposed developments, as well as by other stakeholders interested in the health of the aquatic environment in the Athabasca oil sands region.

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[3] The database is available on the RAMP website http://www.ramp-alberta.org/ramp/data.aspx

1.2.1 Organization of RAMP

RAMP is governed by a multi-stakeholder Steering Committee. Membership in this decision-making body is comprised of oil sands companies and other industries, an Aboriginal representative, and government agencies (municipal, provincial, and federal) (Figure 1.2-1). RAMP also has a Technical Program Committee responsible for the development and review of the RAMP technical monitoring program from year to year. The Technical Program Committee is divided into discipline-specific sub-groups that develop and review their component for integration into the overall monitoring program. Investigators (the Hatfield RAMP Team, consisting in 2012 of Hatfield Consultants Partnership, Kilgour and Associates Ltd., and Western Resource Solutions) primarily carry out the fieldwork, data analysis, and reporting as defined by the Program. A Finance Sub-committee focuses on issues related to the budget and funding for the annual monitoring. Finally, RAMP has a Communications Sub-Committee for the purpose of presenting information and monitoring results to local stakeholders and the scientific community.

Figure 1.2-1 RAMP organizational structure[1].

STEERING COMMITTEE		
Industry	**Stakeholders**	**Government**
Alberta Pacific Forest Industries Inc. Canadian Natural Resources Ltd. Cenovus Energy Inc. ConocoPhillips Canada Devon Energy Corp. Dover Operating Corp. Hammerstone Corp. Husky Energy Imperial Oil Resources Japan Canada Oil Sands Limited MEG Energy Corp. Nexen Inc. Shell Canada Energy Statoil Canada Ltd. Suncor Energy Inc. Syncrude Canada Ltd. Teck Resources Ltd.[2] Total E&P Canada Ltd. (Secretary: Hatfield Consultants)	Fort McKay First Nation Fort McKay Métis Local No. 63 Fort McMurray First Nation	Alberta Energy Resources Conservation Board Alberta Environment and Sustainable Resource Development Alberta Health Fisheries and Oceans Canada Environment Canada Health Canada Regional Municipality of Wood Buffalo

Finance Sub-Committee	Technical Program Committee	Communications Sub-Committee	Investigators
All funding participants	Representatives from industry, communities, government, and investigators	Representatives from industry, communities, government, and investigators	Consultants, Aboriginal community representatives, industry representatives, and government

Technical Program Implementation	Communication Plan Implementation
Preparation of technical program for review by Steering Committee; technical workshops.	Open house events and other community activities, etc.

[1] Composition of Steering Committee as of December 2012.

[2] Formerly known as SilverBirch Energy Ltd.

In 2012, RAMP was funded by Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude), Shell Canada Energy (Shell), Canadian Natural Resources Ltd. (Canadian Natural), Imperial Oil Resources (Imperial Oil), Nexen Inc. (Nexen), Husky Energy (Husky), Total E&P Canada Ltd. (Total E&P), Hammerstone Corp. (Hammerstone), MEG Energy Corp. (MEG Energy), Devon Energy Corp. (Devon), ConocoPhillips Canada (ConocoPhillips), Dover Operating Corp., Japan Canada Oil Sands Ltd. (JACOS), Teck Resources Ltd. (Teck), Cenovus Energy Inc. (Cenovus), and Statoil Canada Ltd. (Statoil).

1.2.2 RAMP Objectives

The objectives of RAMP are to:

- 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;
- collect data that assists with the monitoring requirements of company-specific community agreements with associated funding;
- recognize and incorporate traditional knowledge into monitoring and assessment activities;
- communicate monitoring and assessment activities, results and recommendations to communities in the RMWB, regulatory agencies, and other interested parties;
- continuously review and adjust the program to incorporate monitoring results, technological advances and community concerns and new or changed approval conditions; and
- conduct a periodic peer review of the Program's objectives against its results, and to recommend adjustments necessary for the program's success.

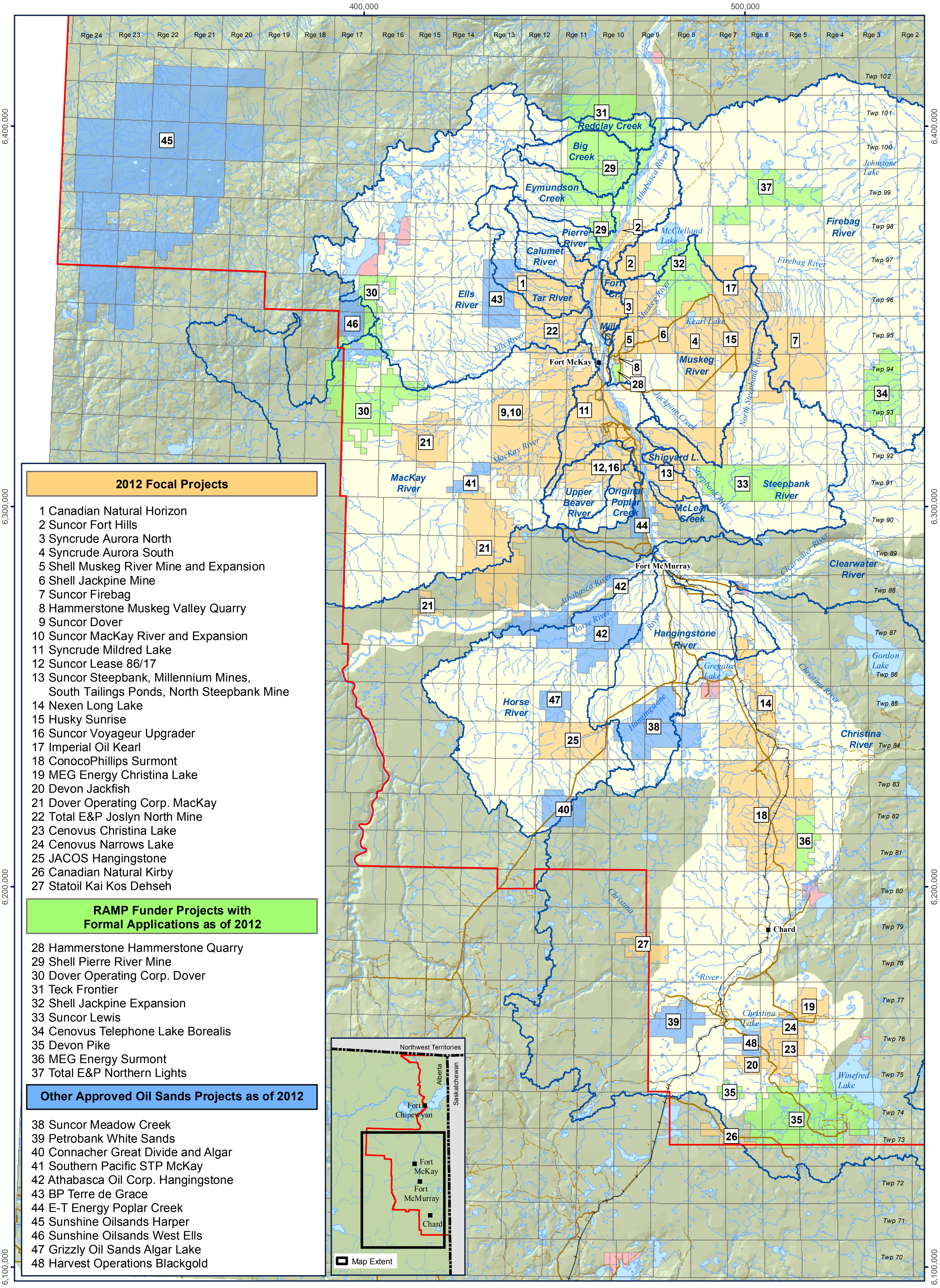
These objectives guide the scope, management and implementation of the Program over time.

1.3 RAMP STUDY AREAS

The RMWB, prior to changes made in 2012, in northeastern Alberta defines the RAMP Regional Study Area (RSA, Figure 1.3-1). The RMWB, prior to 2012, covered an area of 68,454 km^2 and, according to the 2012 Municipal Census, had a population of 119,496 persons of which 76,009 persons were residents of Fort McMurray and surrounding towns, and 39,271 persons were in work-camps (RMWB 2012). The original RMWB border was maintained as the RSA boundary given that it encompassed new members to the south of Fort McMurray. The RAMP RSA is bounded by the Alberta-Saskatchewan border on the east, the Alberta-Northwest Territories border on the north, Wood Buffalo National Park on the northwest, various demarcations on the west including the Athabasca River, and the Cold Lake Air Weapons Range on the south.

Within the RSA, a Focus Study Area (FSA) is defined by the watersheds in which oil sands development is occurring or is planned, as well as those parts of the Athabasca and Clearwater River channels within the RSA (Figure 1.3-1). Much of the Program's intensive monitoring activity is conducted within the RAMP FSA.

Figure 1.3-1 RAMP study areas.



2012 Focal Projects

1 Canadian Natural Horizon
2 Suncor Fort Hills
3 Syncrude Aurora North
4 Syncrude Aurora South
5 Shell Muskeg River Mine and Expansion
6 Shell Jackpine Mine
7 Suncor Firebag
8 Hammerstone Muskeg Valley Quarry
9 Suncor Dover
10 Suncor MacKay River and Expansion
11 Syncrude Mildred Lake
12 Suncor Lease 86/17
13 Suncor Steepbank, Millennium Mines, South Tailings Ponds, North Steepbank Mine
14 Nexen Long Lake
15 Husky Sunrise
16 Suncor Voyageur Upgrader
17 Imperial Oil Kearl
18 ConocoPhillips Surmont
19 MEG Energy Christina Lake
20 Devon Jackfish
21 Dover Operating Corp. MacKay
22 Total E&P Joslyn North Mine
23 Cenovus Christina Lake
24 Cenovus Narrows Lake
25 JACOS Hangingstone
26 Canadian Natural Kirby
27 Statoil Kai Kos Dehseh

RAMP Funder Projects with Formal Applications as of 2012

28 Hammerstone Hammerstone Quarry
29 Shell Pierre River Mine
30 Dover Operating Corp. Dover
31 Teck Frontier
32 Shell Jackpine Expansion
33 Suncor Lewis
34 Cenovus Telephone Lake Borealis
35 Devon Pike
36 MEG Energy Surmont
37 Total E&P Northern Lights

Other Approved Oil Sands Projects as of 2012

38 Suncor Meadow Creek
39 Petrobank White Sands
40 Connacher Great Divide and Algar
41 Southern Pacific STP McKay
42 Athabasca Oil Corp. Hangingstone
43 BP Terre de Grace
44 E-T Energy Poplar Creek
45 Sunshine Oilsands Harper
46 Sunshine Oilsands West Ells
47 Grizzly Oil Sands Algar Lake
48 Harvest Operations Blackgold

Legend

🟦	Lake/Pond
〰	River/Stream
〰	Watershed Boundary
〰	Major Road
〰	Secondary Road
〰	Railway
🟥	First Nations Reserve
🟥	RAMP Regional Study Area Boundary
▨	RAMP Focus Study Area

2012 Focal Projects are those projects within the RAMP FSA that were active in 2012 and were operated by 2012 RAMP funders. Boundaries on this map for approved projects under construction or operation consist of oil sands leases owned by 2012 RAMP funders in which land change was detected in 2012 (described in Section 2.0). Boundaries for other projects reflect oil sands lease boundaries contained in EIAs and on project websites.

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 from the Cumulative Management Association (CEMA).
d) Oil Sands Project Boundaries Derived from Alberta Energy Oil Sands Lease Agreements.

Township and Range designations are relative to W4M.

0 5 10 20 km

N

Scale: 1:1,000,000

Projection: NAD 1983 UTM Zone 12N

RAMP Regional Aquatics Monitoring Program

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_A_StudyArea_20130418.mxd

The Athabasca River is the dominant waterbody within the RAMP FSA and hydrologically links the upper (southern) portion of the RAMP FSA 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 Athabasca River forms part of the western border of the RAMP RSA before flowing east to Fort McMurray, where it once again flows north, draining the lower portion of the RAMP FSA. The Athabasca River is one of the focal rivers in the Alberta Water for Life Initiative and an assessment of the ecological health of the water quality, sediment quality, and non-fish biota was conducted as part of the Healthy Aquatic Ecosystems component of the initiative (Alberta Environment 2007a). More recently, AESRD has conducted a preliminary assessment of the current state of the surface water quality for the management of transboundary waters between Alberta and the Northwest Territories (Hatfield 2009) as well as an analysis of the water quality conditions and long-term trends on the Athabasca River (Hebben 2009).

The southern portion of the RAMP FSA 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 and the 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 RAMP FSA has little relief and is poorly-drained.

The northern portion of the RAMP FSA, 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 RAMP FSA and is characterized by an undulating sandy plain containing mixed boreal forest. Approximately 50% of this portion of the RAMP FSA 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 through the RAMP FSA, several smaller tributary streams and rivers join and contribute to the overall flow. Figure 1.3-2 is a hydrologic schematic of the RAMP FSA 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 size in the RAMP FSA; 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 existing in situ oil sands developments in the southern portion of the RAMP FSA including the Cenovus Christina Lake and Narrow Lake, ConocoPhillips Surmont, Devon Jackfish, MEG Energy Christina Lake, Statoil

Kai Kos Dehseh, and Nexen Long Lake projects and a portion of the Canadian Natural Kirby Project;

- Hangingstone River – a river originating in the southwestern portion of the RAMP FSA, joining the Clearwater River immediately upstream of Fort McMurray, and whose watershed includes portions of the JACOS in situ Hangingstone and Nexen Long Lake projects;
- Horse River – a river originating in the southwestern portion of the RAMP FSA, joining the Athabasca River upstream of Fort McMurray, and whose watershed includes the JACOS Hangingstone Project;
- Steepbank River – joins the Athabasca River from the east and whose watershed includes Suncor's existing Steepbank/Project Millennium mines and extensions, the Suncor North Steepbank Mine, part of the Suncor in situ Firebag Project and part of the Husky in situ Sunrise Thermal Project;
- 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, Syncrude Aurora North Mine, a portion of the Suncor in situ Firebag Project, a portion of the Suncor Fort Hills Project, Imperial Oil Kearl Project, Husky in situ Sunrise Thermal Project, Hammerstone Muskeg Valley Quarry, and Hammerstone Quarry;
- MacKay River – flows from the west and the watershed includes the Suncor in situ MacKay River development and expansion and Suncor Dover Project, Dover Operating Corp. MacKay Project and portions of Syncrude Mildred Lake Project area;
- Ells River – flows from the west and whose watershed includes the Total E&P Joslyn North Mine Project, and a small portion of the Canadian Natural Horizon Project, and the Dover Operating Corporation Dover development; this river is also the drinking water source for Fort McKay;
- Tar River – flows from the west and whose watershed contains most of the Canadian Natural Horizon Project, and portions of the Total E&P Joslyn North Mine;
- Calumet River – also flows from the west and whose watershed is partly within the Canadian Natural Horizon Project; and
- Firebag River – a river flowing from Saskatchewan whose watershed includes most of the Suncor in situ Firebag Project, the Suncor Fort Hills Project, and portions of the Husky in situ Sunrise Project, and the Imperial Oil Kearl Project.

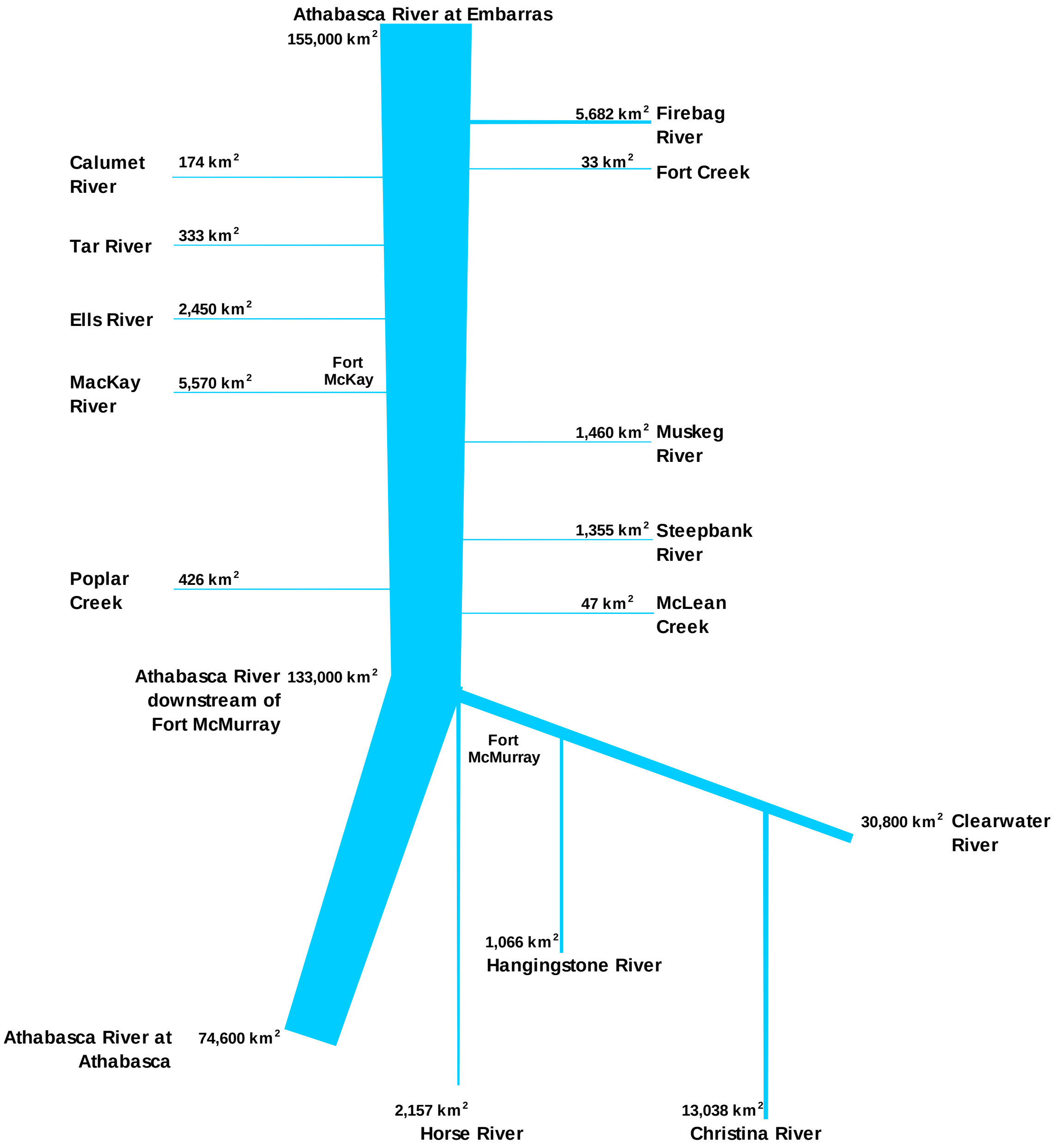
Other waterbodies monitored under RAMP and within existing or proposed oil sands developments include:

- 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, and Beaver River) that contain parts of a number of oil sands projects, including the Syncrude Mildred Lake development (Beaver River), Suncor Fort Hills Project (Fort Creek), Dover Operating Corp. MacKay Project, Shell Pierre River Mine (in application), Teck Frontier (in application), JACOS Hangingstone Project, Shell Muskeg River Mine and expansion, Suncor (Lease 86/17) and Syncrude Mildred Lake oil sands developments on the west side of the Athabasca River (Poplar Creek);

- specific lakes and wetlands such as Isadore's Lake, Shipyard Lake, McClelland Lake, Kearl Lake, Christina Lake, and Johnson Lake;
- a set of regional lakes important from a fisheries perspective; and
- a set of lakes throughout the RAMP RSA for the purpose of assessing lake sensitivity to acidifying emissions.

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

Figure 1.3-2 Hydrologic schematic of RAMP Focus Study Area.



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

1.4 GENERAL RAMP MONITORING AND ANALYTICAL APPROACH

1.4.1 Focal Projects

While most of the 2012 industry members of RAMP are companies that are constructing and operating oil sands projects in the RAMP FSA, other industry members of RAMP, such as Hammerstone, are companies constructing and operating other types of projects in the RAMP FSA. Therefore, the term "focal projects" is used in the 2012 Technical Report and is defined as those projects owned by 2012 industry members of RAMP (Section 1.2.1) that were under construction or operational in 2012 in the RAMP FSA. For 2012, these projects include a number of oil sands projects and a limestone quarry project (the Hammerstone Muskeg Valley Quarry Project); the focal projects are listed and described in Section 2.

2012 industry members of RAMP do have other projects in the RAMP FSA that were in the application stage as of 2012, or that received approval in 2012 or earlier, but that had not yet started construction as of 2012. These projects are noted throughout this technical report but are not designated as focal projects.

1.4.2 Overall RAMP Monitoring Approach

RAMP 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 focal 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 from RAMP 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 RAMP 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, RAMP strives to achieve a more holistic understanding of potential effects on the aquatic environment related to the development of focal projects.

1.4.3 RAMP Components

RAMP in 2012 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 RAMP FSA, 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** – monitoring of water quality in regional lakes in order to assess potential changes in water quality as a result of acidification.

1.4.4 Definition of Terms

The analysis for each RAMP 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 one or more focal projects; 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 2012) or were (prior to 2012) upstream of all focal projects; 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 the focal projects to allow for long-term comparison of trends between *baseline* and *test* stations.

1.4.5 Monitoring Approaches for RAMP Components

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

1.4.5.1 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 as part of RAMP to:

- provide a basis for verifying EIA predictions of hydrologic changes;
- facilitate the interpretation of data collected by the other RAMP 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;
- support regulatory applications and requirements of regulatory approvals; and
- support calibration and verification of regional hydrologic models that form the basis of environmental impact assessments, operational water management plans, and closure reclamation drainage designs.

The RAMP 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 RAMP Climate and Hydrology component has gradually expanded geographically to include watersheds affected, or expected to be affected, by focal projects in the area around Fort McMurray. Some watersheds that do not contain focal projects 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 RAMP 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. RAMP also monitors winter (November to April) flows on some streams that Environment Canada and AESRD monitor during the open-water season.

1.4.5.2 Water Quality

RAMP monitors water quality 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 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:

- develop a water quality database to verify EIA predictions, support regulatory applications, and to meet requirements of regulatory approvals;
- 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, including the focal projects.

A range of characteristics are measured in the Water Quality component, including: conventional variables, major ions, nutrients, biological oxygen demand, other organics, and total and dissolved metals. Sublethal toxicity bioassays are conducted using ambient river water from selected stations to assess potential chronic effects on different aquatic organisms.

RAMP water quality stations are located throughout the RAMP FSA, 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 located in waterbodies already monitored by RAMP 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.

1.4.5.3 Benthic Invertebrate Communities and Sediment Quality

Benthic invertebrate communities are a commonly-used indicator of aquatic environmental conditions and are included as a component of RAMP 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 RAMP Benthic Invertebrate Communities component are to:

- collect scientifically defensible *baseline* and historical data to characterize variability in benthic invertebrate communities in the Athabasca oil sands region;
- monitor aquatic environments in the Athabasca oil sands region to detect and assess cumulative effects and regional trends; and
- collect data against which predictions contained in environmental impact assessments can be verified.

RAMP focuses on characterizing benthic invertebrate communities on the basis of total abundance, taxonomic richness, and diversity in areas downstream of focal projects relative to benthic invertebrate communities upstream of focal projects.

The Benthic Invertebrate Communities component focuses on tributaries of the Athabasca River and regional wetlands (shallow lakes). Historically, sampling was also conducted on the mainstem Athabasca River but was discontinued in 1998 because of problems related to the transient/shifting nature of bottom sediments in the river. Samples are collected from four areas within the Athabasca River Delta (ARD) because that is an area of significant sediment deposition and an area in the RAMP FSA that is considered to have the potential to be affected by long-term development.

With an increasing number of focal projects, 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 component of 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, as in past years, to:

- develop a sediment quality database to verify EIA predictions, support regulatory applications and to meet requirements of regulatory approvals;

- 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 (polycyclic aromatic hydrocarbons); 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.

1.4.5.4 Fish Populations

The goal of the RAMP 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 focal projects. 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:

- collect fish population data to characterize natural or *baseline* variability, assess EIA predictions, and meet requirements of regulatory approvals;

- 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; and

- assess the suitability of fisheries resources in the Athabasca oil sands region for human consumption.

The first two objectives derive from the overall objectives of RAMP. The third objective addresses local community and Aboriginal concerns regarding the safety of consuming fish and the quality of consumed fish that are captured in the Athabasca oil sands region.

To meet the specific component objectives, RAMP conducts 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 (as of 2008 in the Athabasca and 2009 in the Clearwater), 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;

- 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 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 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 focal projects relative to fish assemblages upstream of focal projects. 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 - 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.

1.4.5.5 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 1999a). 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 RAMP for aquatic receptors.

The Acid-Sensitive Lakes (ASL) component of RAMP was initiated in 1999 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 alkalinity and Gran alkalinity (acid-neutralizing capacity); base cations; sulphate; chloride; nitrates; dissolved organic carbon; dissolved inorganic carbon; and chlorophyll.

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 RAMP FSA.
2. For scientific validity, the lake selection includes lakes in the Caribou Mountains and 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 fall season. While fall sampling captures a picture of lake water chemistry after conditions have stabilized after 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 focal projects and the possibility that they might be low in alkalinity and; therefore, more sensitive to acid deposition.

1.4.6 Alignment with the JOSM Plan

Where similarities exist in monitoring, RAMP has been working with the JOSM Plan to align monitoring activities and collaborate on field surveys.

1.4.7 Overall Analytical Approach for 2012

The overall analytical approach for the 2012 RAMP Technical Report is a weight-of-evidence approach that builds on analytical approaches used in RAMP in previous years and are described in the RAMP Technical Design and Rationale (RAMP 2009b) (Figure 1.4-1). Key features of the overall analytical approach are as follows.

First, the analysis for each RAMP component uses a set of measurement endpoints (Table 1.4-1) representing the health and integrity of valued environmental resources within the component. These are the same measurement endpoints that were used in the RAMP 2004 to 2011 Technical Reports (RAMP 2005, RAMP 2006, RAMP 2007, RAMP 2008, RAMP 2009a, RAMP 2010, RAMP 2011, and RAMP 2012).

Second, the analysis of RAMP results for 2012 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 between: (i) *test* stations; and (ii) *baseline* conditions outside of the range of natural variability (Table 1.4-1).

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 1.4-1 Overall analytical approach for RAMP 2012.

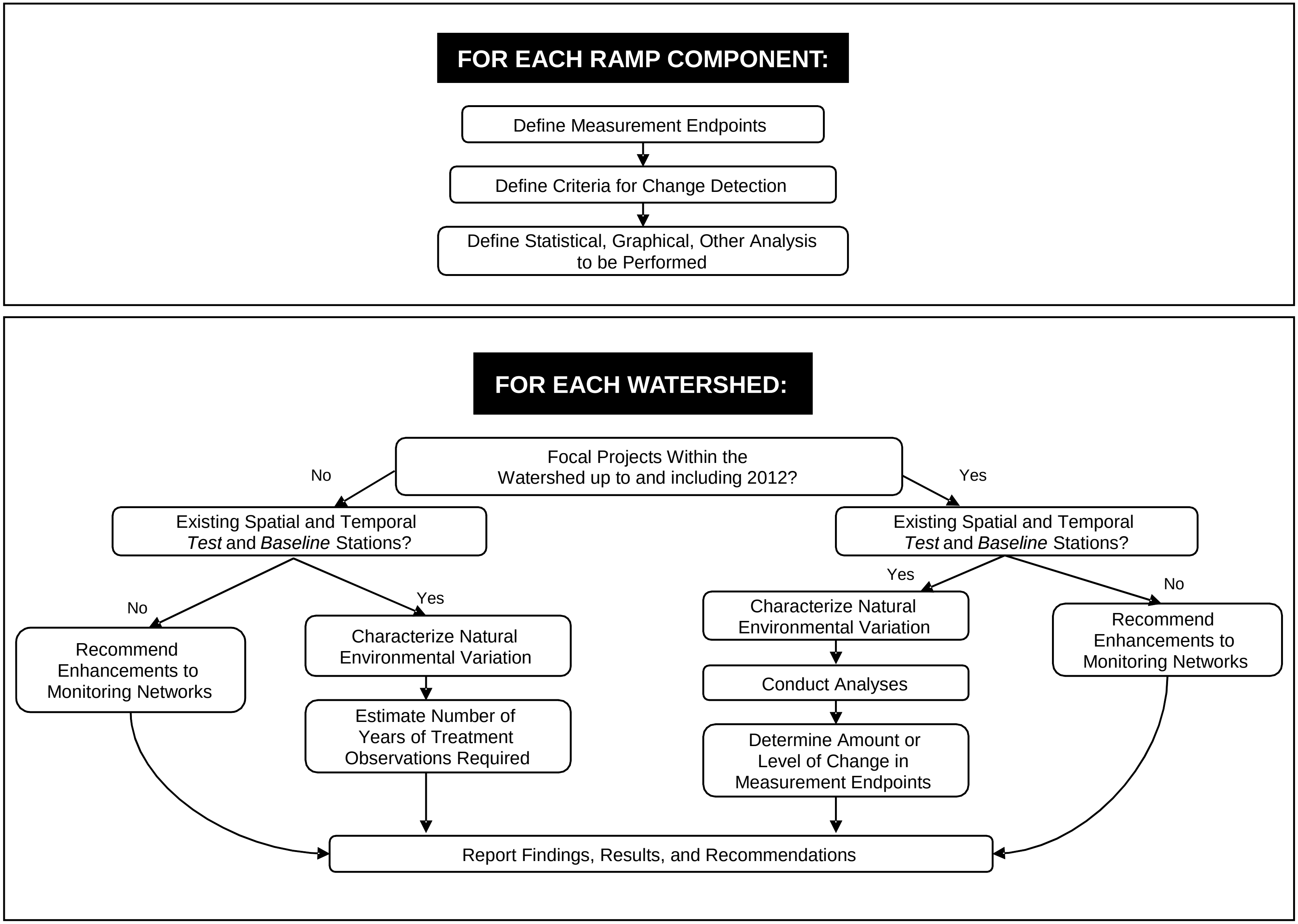


Table 1.4-1 Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2012 Technical Report.

RAMP Component	Measurement Endpoints Used in 2012 Technical Report[1]	Criteria for Determining Change Used in 2012 Technical 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 focal projects and other 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) Simpson's Diversity Equitability 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 $\bar{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* reaches/lakes as compared to *baseline* reaches/lakes; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes 2. Moderate: strong statistically significant difference in one any measurement endpoint between *test* and *baseline* reaches/lakes, with low "noise" in the statistical test, but no measurement endpoint outside *baseline* range of natural variation 3. High: statistically significant difference in one 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
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

[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 1.4-1 (Cont'd.)

RAMP Component	Measurement Endpoints Used in 2012 Technical Report	Criteria for Determining Change Used in 2012 Technical Report
Fish Populations: Fish Inventory	Relative abundance (catch per unit effort) Age-frequency Percent composition Condition factor	The RAMP 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 focal project activities.
Fish Populations: Fish Assemblage Monitoring	Abundance Richness (number of taxa) Simpson's Diversity Assemblage Tolerance Index	Exceedance of at least three measurement endpoints from the regional range of *baseline* variability based on the mean and standard deviation, with regional range defined as $\bar{X} \pm 2SD$: 1. Negligible-Low: no exceedances of any measurement endpoint from the range of baseline variability. 2. Moderate: exceedances of at least three of the four measurement endpoints from the range of baseline variability. Statistical comparisons were not completed given that there are only two years of data for more reaches.
Fish Populations: Fish Tissue	Mercury concentration in fish muscle tissue	Risk to Human Health Negligible-Low: Fish tissue concentrations for mercury below USEPA and Health Canada criteria for recreational and subsistence fishers and the general consumer. High (subsistence): Fish tissue concentrations for mercury above USEPA and Health Canada criteria for subsistence fishers, but below criteria for recreational fishers and general consumers. High (general consumer): Fish tissue concentrations for mercury above USEPA and Health Canada criteria for general consumers, and recreational and subsistence fishers.
Fish Populations: Sentinel Species Monitoring	Age Growth Gonadosomatic Index (GSI) Condition Factor Liversomatic Index (LSI)	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, GSI, and LSI of fish at the *test* reach relative to fish condition at the *baseline* reach. Negligible-Low: no exceedance greater than ± 10% in condition, ± 25% in age, growth, GSI, or LSI of fish at *test* site compared to condition of fish at *baseline* site Moderate: exceedance greater than ± 10% in condition, ± 25% in age, growth, GSI, or LSI of fish at *test* site compared to condition of fish at *baseline* site, but not in two consecutive years of sampling including the current year High: exceedance greater than ± 10% in condition ± 25% in age, growth, GSI, or LSI of fish at *test* site compared to condition of 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 2012 within each subregion with endpoint values greater than two standard deviations from the mean is calculated. Negligible-Low: subregion has <2% of endpoint-lake combinations exceeding ± 2SD criterion. Moderate: subregion has 2% to 10 % of endpoint-lake combinations exceeding ± 2SD criterion. 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.

1.5 ORGANIZATION OF THE RAMP 2012 TECHNICAL REPORT

Together with this Introduction, the RAMP 2012 Technical Report contains nine sections within which the results of the 2012 RAMP monitoring program developed by the RAMP Technical Program Committee and implemented by the Hatfield Team are presented.

Section 2: Activities in the RAMP Focus Study Area in 2012 – This section contains:

- a description of the activities in 2012 for each of the focal projects;
- a list of projects owned by 2012 industry members of RAMP that were in the application stage as of 2012, or which received approval in 2012 (or earlier) but were not in the construction phase as of 2012;
- a list of active oil sands projects in the RAMP study areas owned or operated by companies that were not members of RAMP in 2012;
- a list of report focal project water withdrawal and discharge locations; and
- a summary of land change occurring up to 2012 as a result of development of focal projects.

This provides a synthesis of information related to development activities that may be influencing aquatic environmental resources within the RAMP FSA.

Section 3: 2012 RAMP Monitoring Activities – This section of the report contains concise descriptions of the RAMP monitoring program that was conducted in 2012 for each RAMP component, and includes:

- an overview of the 2012 program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, 2012 industry members of RAMP, RAMP stakeholders, and other 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 2011 field program;
- a description of the challenges and issues encountered during 2012 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 RAMP 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 RAMP FSA in 2012 – This section of the report describes the 2012 water year (WY) (November 1, 2011 to October 31, 2012) and how the 2012 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 2012 Results – This is the main results section of the RAMP 2012 Technical Report, consisting of two major parts:

- Section 5.1 is the report of 2012 findings for the mainstem Athabasca River and the Athabasca River Delta;
- Sections 5.2 to 5.13 are watershed-level reports of the 2012 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations; and
- Section 5.14 is the report of 2012 findings for the Acid-Sensitive lakes component.

Each of these sections presents the RAMP 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 focal projects.

Section 6: Special Studies – This section of the report contains studies that are not part of the core monitoring program but have been initiated to aid in improving the monitoring program or to gain additional information on aquatic resource monitoring in relation to oil sands development.

Section 7: Conclusions and Recommendations – This section of the report contains a summary of the findings, conclusions, and recommendations from RAMP 2012. The recommendations include proposed changes to the RAMP monitoring network for future years based on the results for 2012.

The main report concludes with **Section 8: References** and **Section 9: 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 RAMP component.

All RAMP data are publicly available on the RAMP website (www.ramp-alberta.org). The database is updated each year following the completion of the RAMP Technical Report.

2.0 SUMMARY OF FOCAL PROJECT ACTIVITIES IN 2012

This section provides information on oil sands and other developments in the Focus Study Area (FSA) of the Regional Aquatics Monitoring Program (RAMP) needed to support the assessment of the 2012 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. Five sets of information are looked at: development status of focal projects; development status of other oil sands projects in the RAMP FSA; summary of focal project activities in 2012; summary of focal project water withdrawals and discharges from surface water sources; and RAMP FSA land change analysis for 2012.

2.1 DEVELOPMENT STATUS OF FOCAL PROJECTS

The development status of all RAMP industry member projects, as of the end of 2012 in the RAMP FSA, is presented in Table 2.3-1. In the RAMP FSA, areas downstream of focal projects 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 of the RAMP FSA that are upstream of focal projects or downstream of focal projects 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 2.3-1 is used to interpret the 2012 monitoring results for all RAMP components.

2.2 DEVELOPMENT STATUS OF OTHER OIL SANDS PROJECTS

There were nine approved oil sands projects active in the RAMP FSA in 2012 whose operators were not members of RAMP in 2012 (Table 2.3-2). This information is used in specific analyses conducted in the Water Quality component (Section 3.2.2.2, Table 3.2-3) and Benthic Invertebrate Communities component (Section 3.2.3.1).

2.3 SUMMARY OF FOCAL PROJECT ACTIVITIES IN 2012

The information, with respect to any changes to watercourses within a watershed that might influence water and sediment quality, and benthic invertebrate and fish habitat, provided in this section is used to interpret the 2012 monitoring results for all RAMP components. Water discharge and withdrawal information provided in this section is used for the analysis, assessment, and reporting in the Climate and Hydrology component (Section 3.2.1.4). The information provided in this section reflects changes within the 2012 Water Year (i.e., November 1, 2011 to October 31, 2012) for consistency with analyses conducted for the Climate and Hydrology Component.

2.3.1 Suncor Energy Inc.

As of 2012, development activities were underway for 12 of Suncor's 22 focal projects (i.e., projects with a specified first year of disturbance, Table 2.3-1). Suncor focal project activities and related use/discharge of water in 2012 included:

- Millennium and Voyageur Mines – discharge of approximately 0.16 million m^3 of water from holding ponds and site drainage at the Voyageur Upgrader, and withdrawal of 27.02 million m^3 from the Athabasca River;

Table 2.3-1 Status and activities of developments owned by 2012 industry members of RAMP in the RAMP Focus Study Area.

2012 RAMP Industry Member	Development	Focal Projects	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2012 Status
Suncor Energy	Lease 86/17	√	92-10-W4M	mine	280,000	1964	1967	Closed in 2002
	Steepbank Mine	√	91,92-9-W4M	mine	294,000	1996	1997	Operational
	Millennium Mine	√	91,92-9-W4M	mine		1998	2000	Operational
	Steepbank Debottleneck Phase 3	√		mine	4,000		2007	Operational
	North Steepbank Mine Extension	√	92,93-9-W4M	mine	180,000	2006	2007	Operational
	Millennium Debottlenecking	√		mine	23,000		2008	Operational
	Voyageur: Voyageur Upgrader 3 Phase 1	√	91,92-10-W4M	mine	127,000	2005	–	Approved
	Voyageur: Voyageur Upgrader 3 Phase 2	√		mine	63,000		–	Approved
	Voyageur: South Phase 1	√		mine	120,000	2007	–	Application
	Firebag (Stage 1 and 2, and expansion)	√	93,94,95,96-4,5,6,7-W4M	in situ	95,000	2000	2002	Operational
	Firebag Stage 3	√		in situ	42,500	–	2004	Operational
	Firebag Stage 4	√		in situ	42,500	–	2011	Operational
	Firebag Stage 5	√		in situ	62,500	–	–	Approved
	Firebag Stage 6	√		in situ	62,500	–	–	Approved
	Firebag Stages 3-6 Debottlenecking	√		in situ	23,000	–	–	Application
	Fort Hills Phase 1	√	96-11-W4M, 97,98-10-W4M	mine	165,000	2001	2005	Approved
	Fort Hills Debottleneck	√		mine	25,000	–	–	Approved
	Lewis Phase 1 and 2		91-6,7,8-W4M	in situ	80,000	–	–	Application
	MacKay River Phase 1	√	92, 93-12-W4M	in situ	33,000	1998	2000	Operational
	MacKay River Expansion (MR2)	√	92, 93-12-W4M	in situ	40,000	2005	–	Application
	Meadow Creek Phase 1 and 2		84,85-8,9,10-W4M	in situ	80,000	2001	–	Approved
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	1973	Operational
	Mildred Lake and Aurora North Stage 3 Expansion	√	6-93-10-W4M; 96-9,10,11-W4M	mine	116,300	2001	–	Operational
	Aurora South Train 1 and 2	√		mine	200,000	–	2012	Approved
Shell Canada Energy	Muskeg River Mine Commercial	√	95-10-W4M	mine	155,000	1997	2000	Operational
	Muskeg River Mine Expansion & Debottlenecking	√	95-8,9-W4M, 94-10-W4M	mine	115,000	2005	2009	Approved
	Jackpine Mine Phase 1A	√	95-8-W4, 95-9-W4	mine	100,000	2002	2006	Operational
	Jackpine Mine Phase 1B	√		mine	100,000	–	–	Approved
	Jackpine Mine Expansion	√	96,97-8,9-W4M	mine	100,000	2007	2017	Application
	Pierre River Mine Phase 1 and 2	√	97,98,99-10,11-W4M	mine	200,000	2007	2018	Application
Canadian Natural	Horizon Phase 1	√	96-11/12-W4M, 96-13-W4M, 97-11-W4M, 97-12-W4M, 97-13-W4M	mine	135,000	2002	2004	Operational
	Horizon Phase 2A	√		mine	10,000	–	2014	Construction
	Horizon Phase 2B	√		mine	45,000	–	–	Approved
	Horizon Phase 3	√		mine	80,000	–	–	Approved
	Horizon Tranche 2	√		mine	5,000	–	2010	Operational
	Kirby North Phase 1	√	73,74,75-7,8,9-W4M	in situ	40,000	–	2016	Application
	Kirby North Phase 2	√		in situ	40,000	–	–	Application
	Kirby South Phase 1	√		in situ	40,000	–	–	Construction
	Kirby South Phase 2	√		in situ	20,000	–	–	Application
Imperial Oil Resources	Kearl Lake Phase 1	√	95,96,97-6,7,8-W4M	mine	110,000	2005	2009	Construction
	Kearl Lake Phase 2	√		mine	110,000	–	–	Construction
	Kearl Lake Phase 3 Debottleneck	√		mine	70,000	–	–	Approved
Nexen	Long Lake Project Phase 1	√	85-6-W4M	in situ	72,000	2000	2003	Operational
	Long Lake Project Phase 2	√		in situ	72,000	2000	–	Approved
	Long Lake Project Phase 3	√		in situ	72,000	–	–	Application
	Long Lake South Project (Kinosis) Phase 1	√	84-7-W4M	in situ	80,000	2006	–	Approved
	Long Lake South Project (Kinosis) Phase 2	√						Approved

Notes: Information in this table obtained from Dowdeswell et al. (2010), Government of Alberta (2012), ERCB (2012), Energy Resources Conservation Board (ERCB) project approvals, project environmental impact assessment (EIA) documents, and company websites.

SAGD is steam-assisted gravity drainage.

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

Table 2.3-1 (Cont'd.)

2012 RAMP Industry Member	Development	Focal Projects	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2012 Status
Total E&P Joslyn	Joslyn, SAGD Phase I	√	94,95,96-11-W4M, 94-12-W4M	in situ	2,000	unknown	2003	Suspended
	Joslyn, SAGD Phase II	√		in situ	10,000	2004	2005	Suspended
	Joslyn North Mine Project Phase 1	√		mine	100,000	2006	2011	Approved
	Northern Lights		98,99-5,6,7-W4M	mine	115,000	2006	–	On Hold
Husky Energy	Sunrise Phase 1	√	94-97-6,7-W4M	in situ	60,000	–	–	Construction
	Sunrise Phase 2-4	√			150,000	–	–	Approved
Hammerstone	Muskeg Valley Quarry	√	94,95-10-W4M	quarry	limestone product, 7 million t/yr	2004	2005	Operational
	Hammerstone Quarry	√	94-10-W4M	quarry	limestone product, 18 million t/yr	2006	–	Application
Cenovus Energy	Telephone Lake Borealis Phase A and B	√	94,95-3-W4M	in situ	90,000	–	–	Application
	Christina Lake Phase 1A and 1B	√	75,76-5,6-W4M	in situ	18,800	–	2002	Operational
	Christina Lake Phase C	√		in situ	40,000	–	–	Operational
	Christina Lake Phase D	√		in situ	40,000	–	–	Operational
	Christina Lake Phase E	√		in situ	40,000	2009	–	Construction
	Christina Lake Phase F and G	√		in situ	100,000	2009	–	Approved
	Narrows Lake Phase 1	√	76,77-6,7-W4M	in situ	45,000	2010	–	Construction
	Narrows Lake Phase 2 and 3	√		in situ	85,000	2010	–	Approved
ConocoPhillips	Surmont Phase 1	√	81,82,83-5,6,7-W4M	in situ	27,000	2001	2004	Operational
	Surmont Phase 2	√		in situ	109,000	–	2010	Construction
	Pilot	√		in situ	1,200	–	1997	Operational
Devon Energy	Jackfish Phase 1	√	75,76-6,7-W4M	in situ	35,000	2003	2005	Operational
	Jackfish Phase 2	√		in situ	35,000	2006	2008	Operational
	Jackfish Phase 3	√		in situ	35,000	2010	2011	Construction
	Pike 1A, 1B, and 1C	√	73,74,75-4,5,6,7,8-W4M	in situ	105,000	–	–	Application
MEG Energy	Christina Lake Phase 1 Pilot	√	76,78-4,6-W4M	in situ	3,000	2004	2005	Operational
	Christina Lake Phase 2A	√		in situ	22,000	2005	2007	Operational
	Christina Lake Phase 2B	√		in situ	35,000	2007	2007	Construction
	Christina Lake Phase 3A	√		in situ	50,000	2008	–	Approved
	Christina Lake Phase 3B	√		in situ	50,000	2009	–	Approved
	Christina Lake Phase 3C	√		in situ	50,000	2011	–	Approved
	Surmont Phase 1-3	√	81,82-5-W4M	in situ	123,000	2012	–	Application
JACOS	Hangingstone Pilot	√	84-10,11,12-W4M	in situ	11,000	–	1999	Operational
	Hangingstone Expansion	√		in situ	35,000	–	2014	Application
Dover Operating Corp.	MacKay River Phase 1	√	92, 93-12-W4M	in situ	35,000	2010	2010	Construction
	Mackay River Phase 2-4	√		in situ	115,000	2010	2010	Approved
	Dover North Phase 1 and 2	√	87,88,89,90,91-12-W4M	in situ	100,000	2010	2010	Application
	Dover South Phase 3-5	√		in situ	150,000	2010	2010	Application
Teck Resources Ltd.	Frontier Phase 1-3 and Phase 4 Equinox	√	99-11, 100,101-9,10,11-W4M	mine	275,000	2011	2020	Application
Statoil Canada Ltd.	Kai Kos Dehseh Corner	√	19 to 21, 26, 28, 29 to 33-78-9-W4M	in situ	40,000			Approved
	Kai Kos Dehseh Corner Expansion	√		in situ	40,000			Application
	Kai Kos Dehseh Hangingstone	√		in situ	20,000			Application
	Kai Kos Dehseh Leismer	√		in situ	10,000			Approved
	Kai Kos Dehseh Leismer Demonstration	√		in situ	10,000			Operational
	Kai Kos Dehseh Leismer Expansion	√		in situ	20,000			Approved
	Kai Kos Dehseh Leismer Northwest	√		in situ	20,000			Approved
	Kai Kos Dehseh Leismer South	√		in situ	20,000			Approved
	Kai Kos Dehseh Thornbury	√		in situ	40,000			Application
	Kai Kos Dehseh Thornbury Expansion	√		in situ	20,000			Application

Notes: Information in this table obtained from Dowdeswell et al. (2010), Government of Alberta (2012), ERCB (2012), 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.

- Firebag In Situ Project – discharge to the Firebag River watershed of 0.03 million m^3 of water for water management activities and water withdrawals of 0.07 million m^3 from the Muskeg River watershed to support dust suppression activities;
- MacKay In Situ Project – water withdrawals from various locations in the MacKay River watershed, totaling 0.01 million m^3; and
- Steepbank Mine – water withdrawals of approximately 0.02 million m^3 from a location in the northern area of the Steepbank River watershed to support activities including dust suppression.

Table 2.3-2 Approved oil sands projects within the RAMP FSA operated by non-RAMP members, as of 2012.

Operator	Project	Location (Township-Range-Meridian)	Type of Operation
Petrobank Energy and Resources Ltd.	Whitesands Experimental Pilot Project	76,77-8,9-W4M	in situ
Southern Pacific Resource Corp.	STP McKay	91-14,15-W4M	in situ
Connacher Oil and Gas Ltd.	Great Divide and Algar	82,83-11,12-W4M	in situ
N-Solv Corp.	Dover Demonstration[1]	93-12-W4M	in situ
Athabasca Oil Corp.	Hangingstone Phase 1	86,87,88-10,11,12,13-W4M	In situ
BP p.l.c.	Terre de Grace Pilot	95,96,97-13,14-W4M	in situ
E-T Energy Ltd.	Poplar Creek Experimental Pilot	90-9,10-W4M	in situ
Sunshine Oilsands Ltd.	Harper	95,96,97,98,99,100,101,102 -20,21,22,23,24,25-W4M	in situ
Sunshine Oilsands Ltd.	West Ells	94,95,96-17,18-W4M	
Grizzly Oil Sands ULC.	Algar Lake Phase 1 and 2	85-12-W4M	in situ
Harvest Operations Corp.	BlackGold Phase 1	76-7-W4M	in situ

[1] N-Solv Corp. Dover Demonstration project is located on the Suncor Dover lease.

Information obtained from OSDG (2012), Government of Alberta (2012), ERCB (2012), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

2.3.2 Syncrude Canada Ltd.

Syncrude's operational focal projects in 2012 included the Mildred Lake and Aurora North Stage 1 and 2 Expansion and the Mildred Lake and Aurora North Stage 3 Expansion (Table 2.3-1). Other approved projects included the Aurora South trains 1 and 2. Syncrude focal project activities' use and discharge of water in 2012 included:

- water withdrawal of 39.1 million m^3 from the Athabasca River;
- discharge of 0.29 million m^3 of treated domestic wastewater to the Athabasca River;
- discharge of 0.51 million m^3 to Poplar Creek via the Poplar Creek Spillway; and

- discharge of 5.50 million m^3 of water from surface runoff, muskeg dewatering, or basal water to Stanley Creek as part of the Aurora Clean Water Diversion system.

2.3.3 Shell Canada Energy

Shell Canada Energy focal projects in 2012 included the Muskeg River Mine and the Jackpine Mine Phase 1A (Table 2.3-1). Approved projects included the Muskeg River Mine Expansion and Debottlenecking operations and the Jackpine Mine Phase 1B (Table 2.3-1). The Jackpine Mine Expansion and Pierre River Mine project are still in the application phase (Table 2.3-1). Shell Canada Energy focal project activities' use and discharge of water in 2012 included:

- Muskeg River Mine – water withdrawals from the Athabasca River of 6.08 million m^3; and

- Jackpine Mine – water withdrawals of 8.68 million m^3 from the Athabasca River.

2.3.4 Canadian Natural Resources Ltd.

As of 2012, the Canadian Natural Horizon project was operational; the Kirby South Phase 1 project was in the construction stage; and the Kirby North Phase 1 was in the application stage (Table 2.3-1). Water use and discharge activities in 2012 included:

- Horizon Project – water withdrawals of 22.31 million m^3 from the Athabasca River; and

- Kirby Project – water withdrawals of approximately 0.01 million m^3 from the Christina River watershed for drilling and ice road construction activities.

2.3.5 Nexen Inc.

The Nexen Inc. Long Lake Project Phase 1 was operational in 2012, Phase 2 of the project was approved, and Phase 3 was in the application phase (Table 2.3-1). The Long Lake South (Kinosis) Project phases 1 and 2 were approved in 2012 (Table 2.3-1). The Long Lake Phase 1 project activities in 2012 included water withdrawals of approximately 0.077 million m^3 from surface water sources in the Christina River watershed for dust suppression and other project activities.

2.3.6 Imperial Oil Resources

The Imperial Oil Resources Kearl Project Phase 1 and Phase 2 were under construction in 2012 and the Kearl Phase 3 Debottleneck was approved (Table 2.3-1); Kearl project activities related to water use and discharge in 2012 included:

- discharges of 0.68 million m^3 to the Athabasca River; and

- water withdrawals of 11.15 million m^3 from the Athabasca River.

2.3.7 Total E&P Canada Ltd.

The Total E&P Joslyn North Mine Project Phase 1 received approval in 2012 (Table 2.3-1). Activities for the Joslyn North Mine project in 2012 included:

- water diversions of approximately 0.01 million m^3 from six locations within the Ells River watershed to support winter drilling and construction activities;
- water withdrawals of 64 m^3 from the MacKay River watershed for drilling and construction activities;
- water withdrawals of approximately 0.01 million m^3 of water from three locations within Tar River watershed to support winter drilling and construction activities; and
- water discharges of 0.02 million m^3 to the Athabasca River from sedimentation ponds.

2.3.8 Husky Energy

The Husky Energy Sunrise project Phase 1 was under construction in 2012, and phases 2, 3, and 4 were approved (Table 2.3-1). Project activities included water discharges of approximately 0.01 million m^3 from the Sunshine project treatment plant.

2.3.9 Hammerstone Corp.

The Hammerstone Muskeg Valley Quarry project was operational and the Hammerstone Quarry project was in the application phase in 2012 (Table 2.3-1). The Muskeg Valley Quarry project did not require surface water withdrawals for production and had no direct discharges to surface waterbodies.

2.3.10 ConocoPhillips Canada

The ConocoPhillips Surmont Pilot and Phase 1 projects were operational in 2012 (Table 2.3-1) and diverted approximately 0.051 million m^3 of water from various lakes in the Christina River watershed, for drilling purposes. The Surmont Phase 2 Project was under construction in 2012.

2.3.11 Devon Energy Canada

The Devon Canada Jackfish Phase 1 and Phase 2 projects were operational in 2012 and the Phase 3 project was in the construction stage (Table 2.3-1), but did not require surface water withdrawals for production and had no direct discharges to surface waterbodies.

2.3.12 Dover Operating Corp.

In 2012, the Dover Operating Corp. MacKay River Project Phase 1 was under construction and phases 2 to 4 were approved (Table 2.3-1). The Dover North and South projects were in the application phase in 2012 (Table 2.3-1).

2.3.13 MEG Energy Corp.

The MEG Energy Christina Lake Project Phase 1 Pilot and Phase 2A were operational in 2012; Phase 2B was under construction; and phases 3A, 3B, and 3C were approved (Table 2.3-1). In 2012, water withdrawals included approximately 0.07 million m^3 from within the Christina River watershed.

2.3.14 Japan Canada Oil Sands Limited (JACOS)

The Japan Canada Oil Sands Limited (JACOS) Hangingstone Pilot Project was operational in 2012 and the Expansion project was in the application phase (Table 2.3-1). The JACOS project did not require surface water withdrawals for production and had no direct discharges to surface waterbodies.

2.3.15 Teck Resources Ltd.

The Teck Resources Ltd. Frontier Project phases 1 to 3 and Phase 4 Equinox were in the application phase in 2012.

2.3.16 Cenovus Energy Inc.

As of 2012, the Cenovus Energy Inc. Christina Lake Project phases 1A, 1B, C, and D were operational, Phase E was under construction, and Phases F and G were approved (Table 2.3-1). The Narrows Lake Project Phase 1 was under construction in 2012 and Phases 2 and 3 were approved. The Telephone Lake Borealis Project Phases A and B were in the application phase. In 2012, The Christina Lake Project did not require surface water withdrawals for production and had no direct discharges to surface waterbodies.

2.3.17 Statoil Canada Ltd.

Statoil Canada Limited (Statoil) became a new member of RAMP in 2012. The Leismer Demonstration Project was operational in 2012; the Corner, Leismer Commercial, and Leismer Expansion projects were approved; and the Corner Expansion, Hangingstone, Leismer Northwest, Leismer South, Thornbury, and Thornbury Expansion projects were in the application phase. Water withdrawals were approximately 0.012 million m^3 from the Christina River watershed in 2012 for drilling activities at the Leismer Demonstration Project.

2.4 WATER USE RELATED TO FOCAL PROJECT ACTIVITIES IN 2012

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 RAMP Climate and Hydrology Component, water withdrawal and discharge data were collected from RAMP industry members 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. The source of water withdrawals and location of discharge points in the RAMP FSA for each focal project are provided in Figure 2.5-1.

2.5 LAND CHANGE AS OF 2012 RELATED TO DEVELOPMENT ACTIVITIES

Land change, as of 2012 related to development activities, was estimated with satellite imagery in conjunction with more detailed maps provided by a number of RAMP industry members. Thirteen SPOT-5 10-m resolution images (seven north of Fort McMurray and six south of Fort McMurray) taken on June 7, June 21, June 26, July 7, July 8, August 18, and September 3, 2012 and two Landsat-7 30-m resolution images (one south and one north of Fort McMurray) taken on June 26, and September 28, 2012 were obtained. A land change classification protocol was developed and applied to the imagery to identify and delineate two types of land change in 2012 from the projects listed in Table 2.3-1 and Table 2.3-2. Developed areas where there is no natural exchange of water with the rest of the watershed (e.g., tailings ponds) are designated as hydrologically closed-circuited. Developed areas where there is natural exchange of water with the rest of the watershed (e.g., cleared land) are designated as not hydrologically closed-circuited.

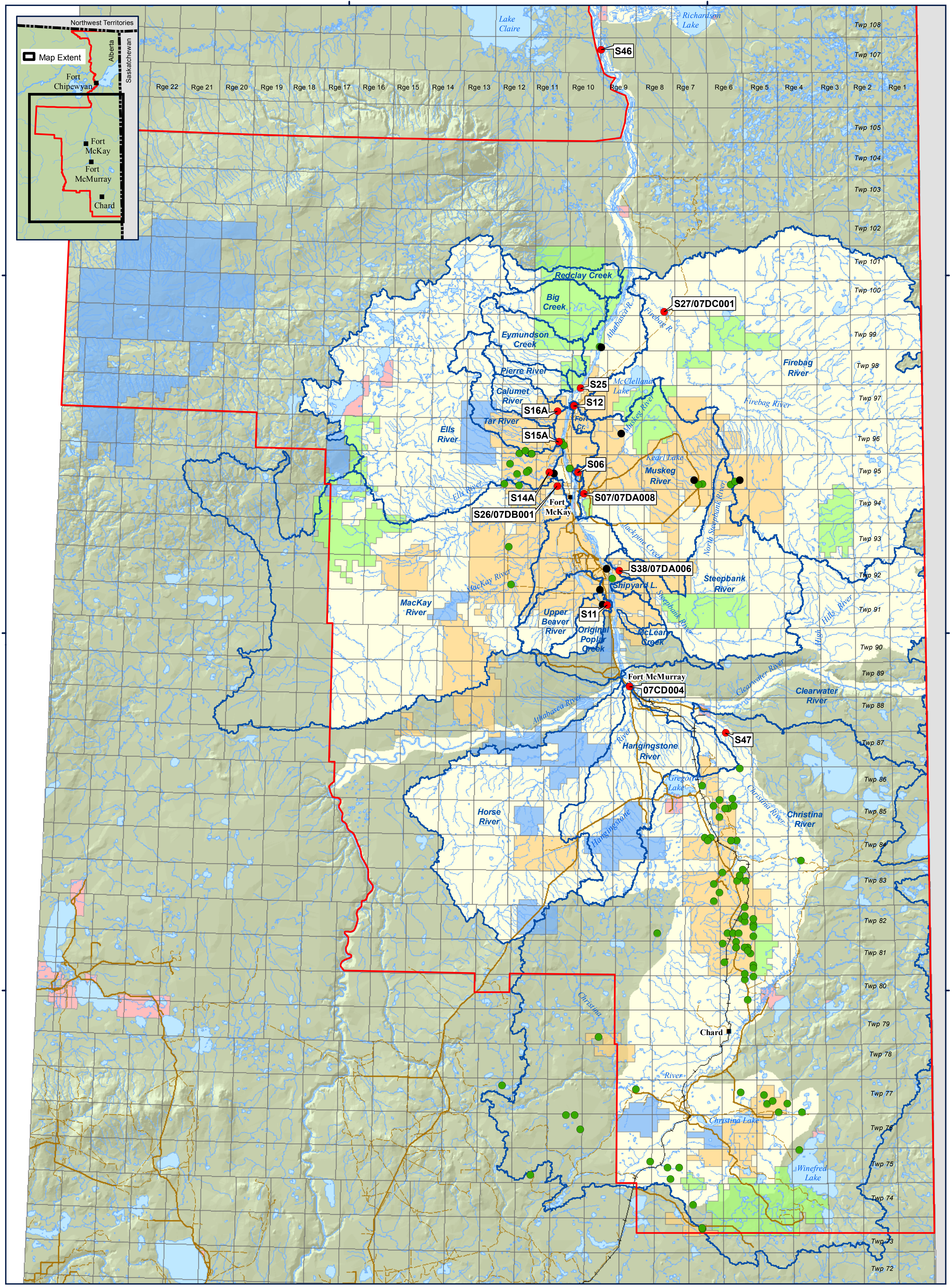
Because of the resolution of the satellite imagery, SAGD well pads were about the smallest oil sands development entity that was delineated. Details of the land change estimation procedure are provided in Appendix A. Drafts of the land change maps were provided to RAMP members for review, and recommendations for revision of the maps were used to produce the final set of 2012 land change maps.

Land change area as of 2012 is presented in Figure 2.5-2 and Figure 2.5-3 for north and south of Fort McMurray, respectively.

Table 2.5-1 and Table 2.5-2 provide tabular summaries of the total and percent land change in each of the main watersheds by each land change type, for focal projects, and non-RAMP oil sands projects within the RAMP FSA. Land change as of 2012 within the RAMP FSA was estimated at approximately 105,700 ha for focal projects and approximately 400 ha for oil sands projects operated by companies who were not members of RAMP in 2012, for a total of approximately 106,100 ha. The land change area for focal projects increased from 93,500 ha in 2011, but the land change area for oil sands projects operated by companies who were not RAMP members has decreased from 700 ha in 2011. This decrease reflects the addition of Statoil as a new member of RAMP in 2012; thereby adding the land change from Statoil’s development to the total focal project land change area. The total area of land change represented approximately 3.0% of the RAMP FSA. The percentage of the area of watersheds with land change as of 2012 varies from less than 1% for many watersheds (MacKay, Christina, Hangingstone, Horse, and Firebag rivers), to 1% to 5% for the Calumet, Ells, Poplar, and Steepbank watersheds, to 5% to 10% for the Upper Beaver watershed, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries from Fort McMurray to the confluence of the Firebag River.

Land change area within the city of Fort McMurray in 2012 was estimated at approximately 4,700 ha. Approximately half of this land change was in watersheds of smaller tributaries of the Athabasca River, with the other half in the Hangingstone and Horse River watersheds. The land change area within the city of Fort McMurray increased from approximately 4,600 ha in 2011.

Figure 2.5-1 Locations of surface water withdrawals and discharges from focal project activities used in the RAMP water balance calculations, 2012 Water Year.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- 🟥 First Nations Reserve
- 🟥 RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- 🟧 2012 Focal Projects
- 🟩 RAMP Funder Projects with Formal Applications as of 2012
- 🟦 Other Approved Oil Sands Projects as of 2012
- ● Hydrometric Station for Water Balance Analysis
- ● Water Withdrawal Location
- ● Water Discharge Location

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 Modified from Cumulative Environmental Management Association (CEMA).
d) Oil Sands Project Boundaries Derived from Alberta Energy Oil Sands Lease Agreements.

Township and Range designations are relative to W4M.

0 5 10 20 km
N

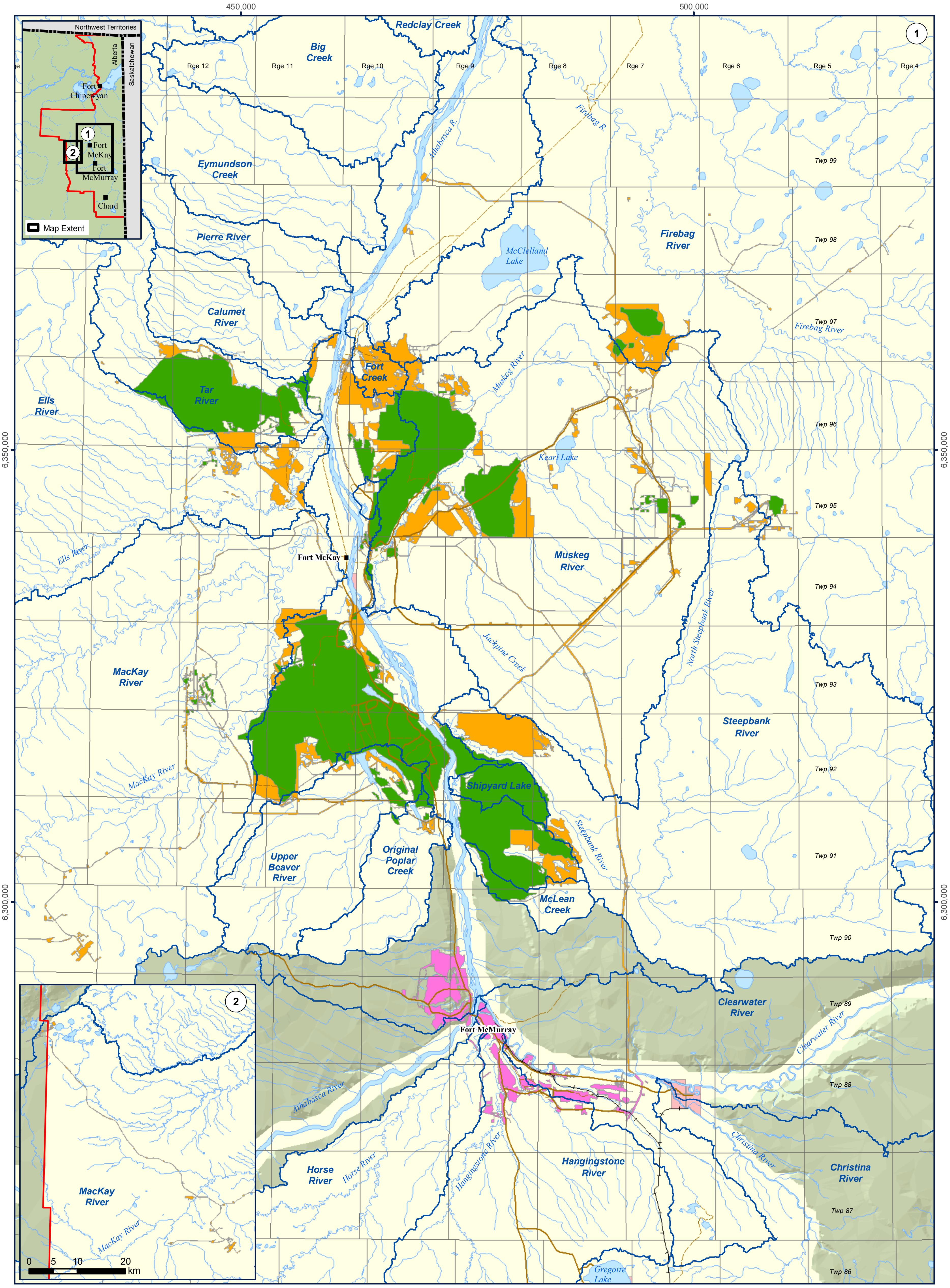
Scale: 1:1,100,000

Projection: NAD 1983 UTM Zone 12N

Regional Aquatics Monitoring Program

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_C_DischargeWithdrawal_20130418.mxd

Figure 2.5-2 RAMP land change classes derived from SPOT-5 (June and July 2012) and Landsat-7 (June and September 2012) satellite imagery, north of Fort McMurray.



Legend

- 🟦 Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- 🟥 First Nations Reserve
- 🟥 RAMP Regional Study Area Boundary
- ▨ RAMP Focus Study Area
- 🟪 Town of Fort McMurray

Land Change Area as of 2012[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 Modified from Cumulative Environmental Management Association (CEMA).

d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

0 2 4 8 km

N

Scale: 1:425,000

Projection: NAD 1983 UTM Zone 12N

RAMP Regional Aquatics Monitoring Program

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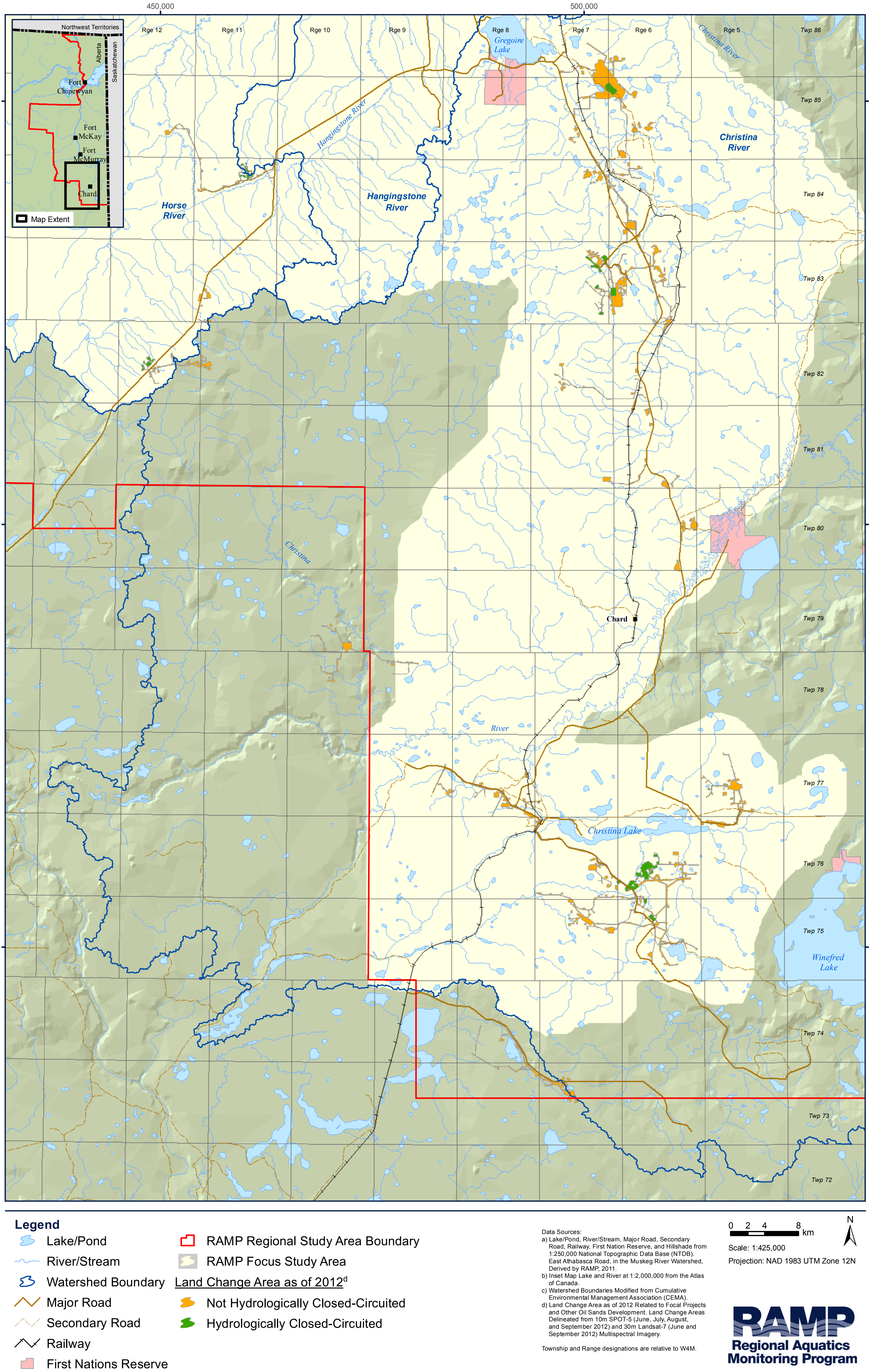
Figure 2.5-3 RAMP land change classes derived from SPOT-5 (June, July, August, and September 2012) and Landsat-7 (June and September 2012) satellite imagery, south of Fort McMurray.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

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Table 2.5-1 Area of watersheds with land change in 2012.

Watershed	Total Watershed Area (ha)	Watershed Area with Land Change (ha)							
		Focal Projects		Other Oil Sands Projects		Total		Watershed Total (ha and %)	
		Not-Closed Circuited (ha)	Closed-Circuited (ha)	Not-Closed Circuited (ha)	Closed-Circuited (ha)	Not-Closed Circuited (ha)	Closed-Circuited (ha)		
Muskeg	146,000	8,854	12,619			8,854	12,619	21,473	14.71
Steepbank	135,491	4,529	488			4,529	488	5,017	3.70
MacKay	557,000	3,185	619			3,185	619	3,804	0.68
Tar	33,261	1,248	9,576			1,248	9,576	10,825	32.54
Calumet	17,354	130	68			130	68	198	1.14
Firebag	568,174	3,995	1,360			3,995	1,360	5,355	0.94
Ells	245,000	2,273	342			2,273	342	2,614	1.07
Christina	1,303,805	6,507	785	158		6,665	785	7,450	0.57
Hangingstone	106,641	9	47			9	47	56	0.05
Mills Creek	890	58	235			58	235	293	32.93
Shipyard Lake	4,047	15	3,739			15	3,739	3,753	92.75
Fort Creek	3,193	2,042	33			2,042	33	2,075	64.99
Horse	215,741	232	38	163	76	395	114	509	0.24
McLean	4,712	146	1,109			146	1,109	1,255	26.64
Original Poplar[1]	13,856	182	310			182	310	492	3.55
Upper Beaver[1]	28,711	861	1,928			861	1,928	2,790	9.72
Minor Athabasca River Tributaries[2]	160,730	7,423	30,715			7,423	30,715	38,137	23.73
Total	**3,544,606**	**41,688**	**64,013**	**322**	**76**	**42,009**	**64,089**	**106,098**	**2.99**
Slave[3]	863,473	378				378	0	378	0.04

[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 Slave watershed was added in 2011 given that a portion of the Canadian Natural Kirby project is located within this watershed. The Slave watershed is not part of the RAMP FSA.

Table 2.5-2 Percent of total watershed areas with land change in 2012.

Watershed	Total Watershed Area (ha)	Watershed Area with Land Change (%)						
		Focal Projects		Other Oil Sands Projects in RAMP FSA		Total		Watershed Total (%)
		Not-Closed Circuited (%)	Closed-Circuited (%)	Not-Closed Circuited (%)	Closed-Circuited (%)	Not-Closed Circuited (%)	Closed-Circuited (%)	
Muskeg	146,000	6.06	8.64	-	-	6.06	8.64	14.71
Steepbank	135,491	3.34	0.36	-	-	3.34	0.36	3.70
MacKay	557,000	0.57	0.11	-	-	0.57	0.11	0.68
Tar	33,261	3.75	28.79	-	-	3.75	28.79	32.54
Calumet	17,354	0.75	0.39	-	-	0.75	0.39	1.14
Firebag	568,174	0.70	0.24	-	-	0.70	0.24	0.94
Ells	245,000	0.93	0.14	-	-	0.93	0.14	1.07
Christina	1,303,805	0.50	0.06	0.01	-	0.51	0.06	0.57
Hangingstone	106,641	0.01	0.04	-	-	0.01	0.04	0.05
Mills Creek	890	6.52	26.41	-	-	6.52	26.41	32.93
Shipyard Lake	4,047	0.37	92.38	-	-	0.37	92.38	92.75
Fort Creek	3,193	63.95	1.04	-	-	63.95	1.04	64.99
Horse	215,741	0.11	0.02	0.08	0.04	0.18	0.05	0.24
McLean	4,712	3.10	23.54	-	-	3.10	23.54	26.64
Original Poplar[1]	13,856	1.32	2.24	-	-	1.32	2.24	3.55
Upper Beaver[1]	28,711	3.00	6.72	-	-	3.00	6.72	9.72
Minor Athabasca River Tributaries[2]	160,730	4.62	19.11	-	-	4.62	19.11	23.73
Total	**3,544,606**	**1.18**	**1.81**	**0.01**	**0.00**	**1.19**	**1.81**	**2.99**
Slave[3]	863,473	0.04	-	-	-	0.04	-	0.04

[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 Slave watershed was added in 2011 given that a portion of the Canadian Natural Kirby project is located within this watershed. The Slave watershed is not part of the RAMP FSA.

3.0 2012 RAMP MONITORING ACTIVITIES

This section contains a description of RAMP monitoring conducted in 2012 and includes the following for each RAMP component:

- Summary of 2012 monitoring activities and field methods;
- Description of any other information obtained (i.e., information from regulatory agencies, owners and operators of the 2012 focal projects, knowledge obtained from local communities, and other sources);
- Description of changes in the monitoring network from the 2011 program;
- Description of the challenges and issues encountered during 2012 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 RAMP data.

Monitoring activities for all RAMP components in 2012 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 under RAMP in 2012. Appendix B contains a detailed description of the QA/QC procedures used for RAMP monitoring in 2012.

All 2012 monitoring data collected under RAMP have been added to the RAMP database, which is located on the RAMP website.

3.1 FIELD DATA COLLECTION

3.1.1 Climate and Hydrology Component

The 2012 RAMP Climate and Hydrology monitoring network included:

- 18 *baseline* streamflow stations;
- 13 streamflow stations with less than 5% of the watershed affected by land change due to oil sands development;
- 17 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.

The following sections describe the 2012 monitoring activities related to the Climate and Hydrology monitoring network.

3.1.1.1 Overview of 2012 Monitoring Activities

Climate and Hydrology monitoring in 2012 consisted of:

- climate monitoring (Table 3.1-1, Figure 3.1-1):
    - 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 Kearl Lake and McClelland Lake stations; and
    - measuring rainfall, from May 1 to October 31, at five hydrometric monitoring stations;
- snow survey monitoring (Figure 3.1-1):
    - Snowcourse surveys conducted during the months of February, March, and April; covering four distinct bio-geographic land cover types in four representative regions of the RAMP study area;
- streamflow monitoring (Table 3.1-1, Figure 3.1-2):
    - 24 year-round stations;
    - 17 open-water stations;
    - six winter-only stations jointly operated with Water Survey of Canada (WSC), which monitors during the open-water season;
    - monitoring water temperature at 41 streamflow stations; and
    - measuring total suspended solids (TSS) throughout the open-water season at all streamflow stations during each visit;
- water level monitoring at four lake/wetland stations (Table 3.1-1, Figure 3.1-2).

Appendix C provides specific station information for all climate and hydrology stations in the 2012 program.

3.1.1.2 Field Methods

Field methods are described in this section and cover the topics of 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 2012 for the Climate and Hydrology component:

- Five field visits during the open-water season at the RAMP year-round and open-water stations; and
- Five visits during the winter season to all year-round RAMP stations and three visits to the winter-only WSC stations, three of five winter visits included a regional snowcourse survey.

Table 3.1-1 RAMP climate and hydrometric stations operating in 2012.

RAMP Station	UTM Coordinates (Easting, Northing)	Operating Season	Variables Measured and Telemetry Type[5]
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 Lake	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[2]	water level, water temperature (G)
S2 Jackpine Creek at Canterra Road	474971, 6344091	all year	level, discharge, water temperature (C)
S3 Iyinimin Creek above Kearl Lake	489423, 6345196	open-water	level, discharge, rainfall, water temperature (C)
S5 Muskeg River above Stanley Creek	479761, 6356759	all year	level, discharge, water temperature (C)
S5A Muskeg River above Muskeg Creek	476042, 6351803	all year	level, discharge, barometric pressure, water temperature (C)
S6 Mills Creek at Highway 63	463755, 6344927	all year	level, discharge, water temperature (C)
S7 Muskeg River near Fort McKay (07DA008)	465552, 6338804	winter[1]	level, discharge, water temperature (C)
S9 Kearl Lake Outlet	483983, 6347020	all year	level, discharge, water temperature (C)
S10 Wapasu Creek	488573, 6358554	all year[3]	level, discharge, water temperature (C)
S11 Poplar Creek at Highway 63 (07DA007)	471972, 6307825	all year	level, discharge, water temperature (C)
S12 Fort Creek at Highway 63	462620, 6363554	open-water	level, discharge, water temperature (C)
S14A Ells River at the Canadian Natural Bridge	455738, 6344944	all year	level, discharge, water temperature (C)
S15A Tar River near the mouth	458458, 6353439	open-water	level, discharge, water temperature (C)
S16A Calumet River near the mouth	458096, 6362020	open-water	level, discharge, water temperature (C)
S19 Tar River Lowland Tributary near the mouth	457326, 6352850	open-water	level, discharge, water temperature, rainfall (C)
S20 Muskeg River Upland	492107, 6355709	open-water	level, discharge, water temperature (C)
S22 Muskeg Creek near the mouth	480969, 6349071	open-water	level, discharge, water temperature (C)

[1] WSC monitors water level and discharge at these stations during the open-water season.

[2] Station was installed May 2012

[3] S10 station was relocated to a site 3 km downstream in August 2012 and given the designation S10A.

[4] S50 Station was relocated to a site 3 km upstream in April 2012 and given the designation S50A.

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

Table 3.1-1 (Cont'd.)

RAMP Station	UTM Coordinates (Easting, Northing)	Operating Season	Variables Measured and Telemetry Type[5]
S24 Athabasca River below Eymundson Creek	466305, 6372764	all year	level, discharge, water temperature (C)
S25 Susan Lake Outlet	464513, 6368477	open-water	level, discharge, water temperature (R-C)
S26 MacKay River near Fort McKay (07DB001)	458019, 6341008	winter[1]	discharge
S27 Firebag River near the mouth (07DC001)	487914, 6389855	winter[1]	discharge
S29 Christina River near Chard (07CE002)	508211, 6187940	winter[1]	discharge
S31 Hangingstone Creek at North Star Road	469812, 6236089	open-water	level, discharge, water temperature, rainfall (C)
S32 Surmont Creek at Highway 881	490250, 6254524	open-water	level, discharge, water temperature (C)
S33 Muskeg River at the Aurora North/Muskeg River Mine Boundary	474878, 6350204	all year	level, discharge, water temperature (C)
S34 Tar River above Canadian Natural Lake	440745, 6361662	all year	level, discharge, water temperature (C)
S36 McClelland Lake Outlet above Firebag River	490635, 6384056	open-water	level, discharge, water temperature (G)
S37 East Jackpine Creek near the 1,300 m contour	487850, 6325416	open-water	level, discharge, water temperature
S38 Steepbank River near Fort McMurray (07DA006)	475296, 6317398	winter[1]	discharge
S39 Beaver River above Syncrude (07DA018)	465560, 6311437	winter[1]	discharge
S40 MacKay River at Petro-Canada Bridge	444949, 6314178	all year	level, discharge, water temperature, rainfall (C)
S42 Clearwater River above Christina River (07DC005)	504427, 6279666	winter[1]	discharge
S43 Firebag River upstream of Suncor Firebag	531704, 6354796	all year	level, discharge, water temperature, rainfall (G)
S44 Pierre River near Fort McKay (formerly 07DA013)	460769, 6369299	open-water	level, discharge, water temperature (C)
S45 Ells River above Joslyn Creek Diversion	440325, 6342418	all year	level, discharge, water temperature (C)
S46 Athabasca River near Embarras Airport	470241, 6463209	all year	level, discharge, water temperature (G)
S47 Christina River near the mouth	505048, 6272065	all year	level, discharge, water temperature (G)
S48 Big Creek	470817, 6389113	open-water	level, discharge, water temperature (R-C)
S49 Eymundson Creek near the mouth	465473, 6372694	open-water	level, discharge, water temperature (C)
S50A Red Clay Creek	474954, 6396094	open-water[4]	level, discharge, water temperature (R-C)
S51 High Hills River near the mouth	532571, 6290998	all year[2]	level, discharge, water temperature (G)
S53 Dover River near the mouth (07DB002)	451453, 6337017	all year[2]	level, discharge, water temperature (R-C)
S54 Dunkirk River near Fort McKay (07DB003)	395815, 6302067	all year[2]	level, discharge, water temperature (G)
S55 Gregoire River near the mouth	510185, 6259986	all year[2]	level, discharge, water temperature (R-C)
S56 Jackfish River below Christina Lake (07CE005)	493753, 6169685	all year[2]	level, discharge, water temperature (C)
S57 Sunday Creek above Christina Lake	506227, 6158403	all year[2]	level, discharge, water temperature (C)
S58 Sawbones Creek above Christina Lake	511444, 6167182	open-water[2]	level, discharge, water temperature (C)

[1] WSC monitors water level and discharge at these stations during the open-water season.

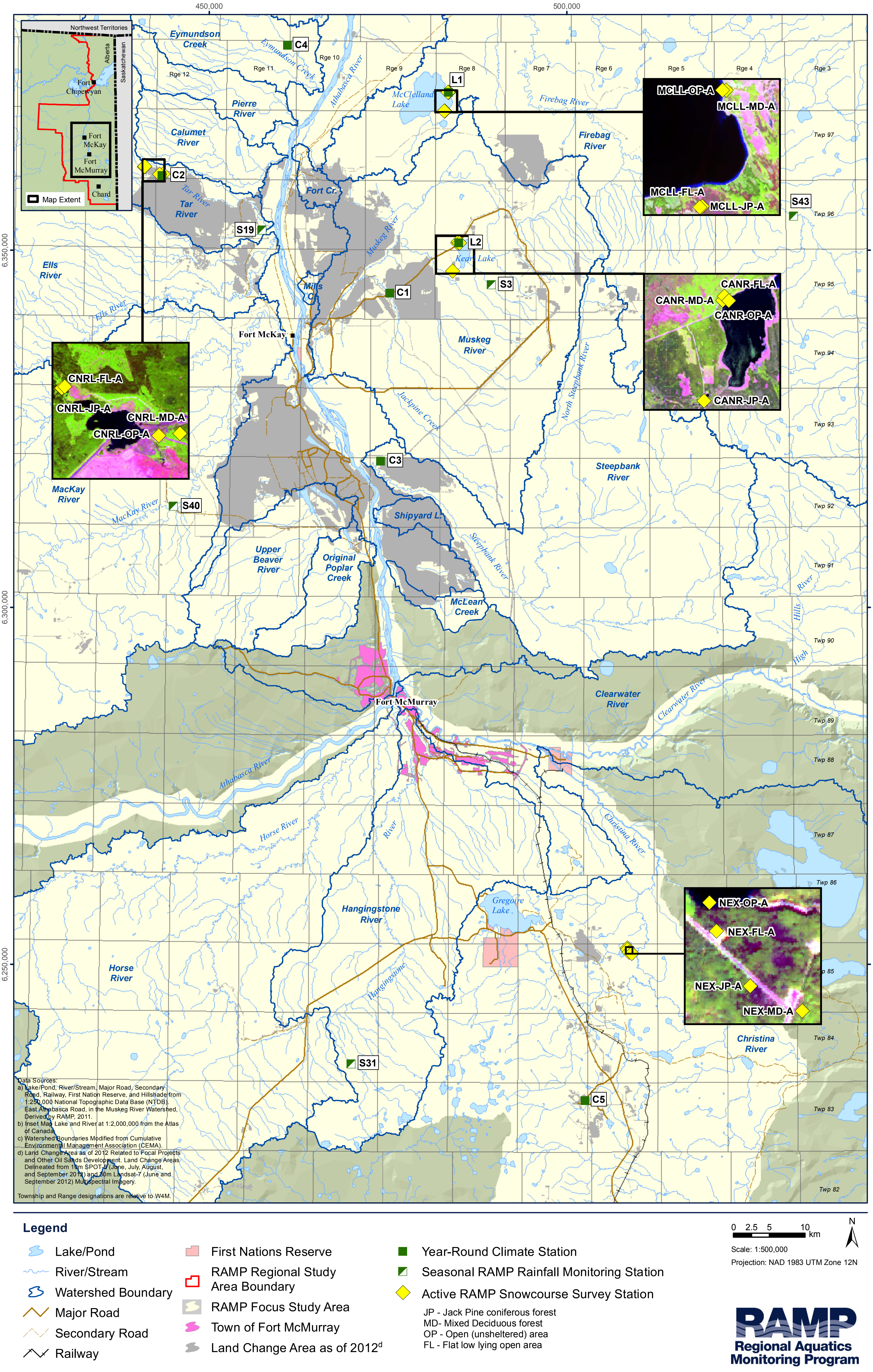
[2] Station was installed May 2012

[3] S10 station was relocated to a site 3 km downstream in August 2012 and given the designation S10A.

[4] S50 Station was relocated to a site 3 km upstream in April 2012 and given the designation S50A.

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

Figure 3.1-1 Locations of RAMP climate stations and snowcourse survey stations, 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

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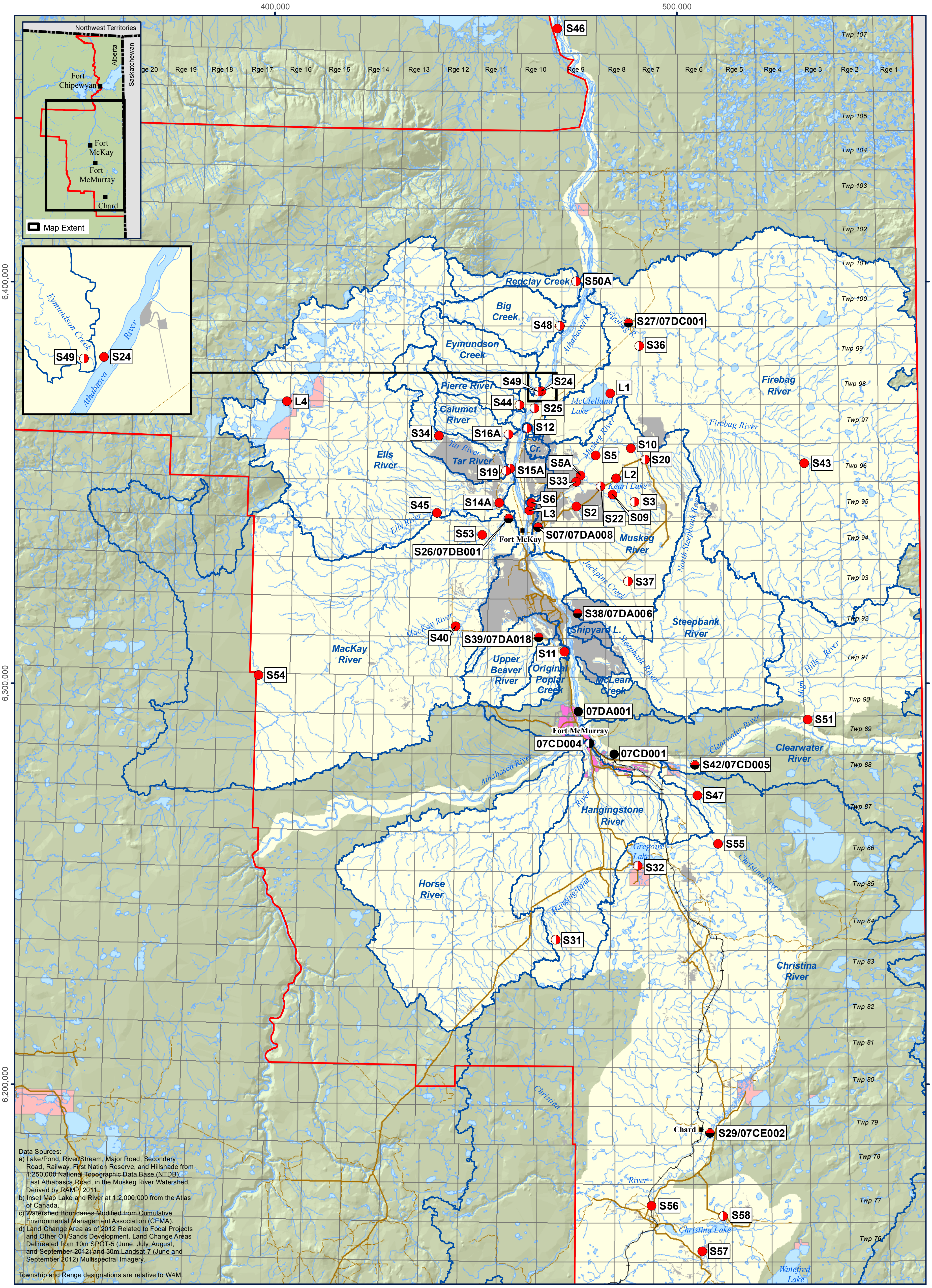
Figure 3.1-2 Locations of hydrometric stations operated by RAMP and Water Survey of Canada, 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).

d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- Town of Fort McMurray
- Land Change Area as of 2012[d]

Hydrometric Station

- ● Year-Round RAMP
- ◐ Seasonal RAMP
- ● Year-Round RAMP/Water Survey of Canada
- ● Year-Round Water Survey of Canada
- ◑ Seasonal Water Survey of Canada

0 5 10 20 km

N

Scale: 1:950,000

Projection: NAD 1983 UTM Zone 12N

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Regional Aquatics Monitoring Program

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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.

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.

Measurement standards are summarized below:

- Number of verticals: minimum of 20, or at a spacing of 0.05 m in small streams;
- Number of velocity observations for an open-water measurement:
    - Where depth is 0.75 m or less, one observation is made at 60% of the depth below the surface;
    - For depths greater than 1.0 m, velocity is observed once at 20% and once at 80% of the depth; and
    - Where water depths are between 0.75 m and 1.0 m, the operator chose whether one or two velocity observations best suited that vertical;
- Number of vertical readings for a measurement under ice: the same procedure was 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 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 0.9 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 (Marsh McBirney Flo-Mate 2000).

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):

- 40 snow depths were measured in each study plot;
- 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 2011

New Monitoring Stations

- Namur Lake, located northwest of Fort McKay, is a lake with importance to local communities. Station L4, Namur Lake, located at the northeast end of the lake near the outlet, was installed and became operational in May 2012. This station provides *baseline* monitoring of water level and water temperature.
- To monitor *baseline* hydrometric conditions in the oil sands region, Station S51, High Hills River near the mouth, was established in May 2012. This river is a south aspect tributary to the Clearwater River east of Fort McMurray and the station monitors discharge, water level, and water temperature on a year-round basis.
- Stations S53, Dover River near the mouth (07DB002), and Station S54, Dunkirk River near Fort McKay (07DB003), became operational in May 2012. These two stations were installed to characterize the hydrologic conditions within the MacKay River watershed and to continue monitoring of WSC stations, which were operated in the 1970s. Stations S53 and S54 are year-round monitoring stations collecting discharge, water level, and water temperature data.
- Station S55, Gregoire River near the mouth, was installed to monitor oil sands development in the Gregoire River drainage area. The hydrometric station was installed in May 2012 and monitors year-round discharge, water level, and water temperature.
- Three hydrometric stations were established in the Christina Lake drainage area to characterize the hydrologic conditions of Christina Lake. Station S56, Jackfish River below Christina Lake (07CE005), is located at the discontinued WSC station (the WSC station was discontinued in 1995). Station S57, Sunday Creek above Christina Lake, and Station S56 are operated year-round while Station S58, Sawbones Creek above Christina Lake, is monitored during the open-water season only. All three stations monitor discharge, water level, and water temperature and became operational in May 2012.

Modified Stations

The following modifications and field equipment upgrades were made in 2012 to support station function and reliability of data collection:

- Station S47, Christina River near the mouth, was moved to a site 6 km upstream in an effort to find a location with deeper flow and reduce the potential for the pressure transducer to be encased in ice in winter. The new station was designated as Station S47A.

- Station S10, Wapasu Creek at Canterra Road, was moved to a site 3 km downstream of the current location to avoid influences of beaver activity.
- A Sontek-IQ continuous velocity probe was deployed at Station S36, McClelland Lake Outlet above the Firebag River, to provide continuous discharge and velocity measurements, and assist with data analysis.
- Benchmarks at hydrometric and lake/wetland monitoring stations were upgraded in 2012. Each station was upgraded to have a minimum of three benchmarks.
- Eight stations were upgraded with calibrated pressure transducers and sensors based on a two-year exchange cycle for all year-round monitoring stations. The upgraded stations included the Aurora climate station (Station C1); the Steepbank climate station (Station C3); Station S5 Muskeg River above Stanley Creek; Station S5A Muskeg River above Muskeg Creek; Station S6 Mills Creek at Hwy 63; Station S7 Muskeg River near Fort McKay; Station S24 Athabasca River below Eymundson Creek; Station S34 Tar River above Canadian Natural Lake; and Station S46 Athabasca River near Embarras Airport.

Near-Real-Time RAMP Monitoring Network

Forty RAMP hydrometric monitoring stations were upgraded with telemetry equipment in 2012. A combination of cellular communications, radio-cellular relays, and GOES communication systems were used as follows (see Table 3.1-1 for equipment used at each station):

- Twenty-nine stations were operated with cellular telemetry. Data files were transmitted once daily during a two-hour timeframe (12:00 – 14:00 MST).
- Six stations utilized a radio-cellular relay station to transmit data files. These stations were located in a depression where cellular signals cannot be reached. Data files were transmitted via spread spectrum RF radio from the hydrometric station to the relay station, then via cellular modem. Data transmissions occurred during a two-hour timeframe (12:00 – 14:00 MST).
- Seven stations utilized Geostationary Operational Environmental Satellite (GOES) telemetry. These stations were located in remote locations where there is no cellular service. Data were transmitted on an hourly basis from the hydrometric station to the GOES satellite, and sent by AESRD to the RAMP database.

3.1.1.4 Challenges Encountered and Solutions Applied

Wildlife and Environmental Challenges

The following wildlife and environmental challenges were addressed by the RAMP Climate and Hydrology component in 2012:

- The pressure transducer at Station S47, Christina River near the mouth, was encased in ice from November 5, 2011 to April 26, 2012. Water level monitoring resumed when the ice around the pressure transducer thawed.
- During the spring freshet the pressure transducer at Station S15A, Tar River near the mouth, was damaged by ice. The pressure transducer was replaced and the station was reinstated in May 2012.

- The power supply at Station S33, Muskeg River at the Aurora North/Muskeg River Mine Boundary, was found disconnected. Station monitoring was disrupted on July 15, 2012 and reinstated on August 6, 2012.
- Station S51, High Hills River near the mouth, was damaged by wildlife on September 27, 2012. The pressure transducer was disconnected from the data logger and caused a disruption to station monitoring. The station was reinstated on October 25, 2012 during the next field visit.
- The pressure transducer cable was pulled out of the data logger by wildlife at Station S54, Dunkirk River near Fort McKay, on June 1, 2012. The station was reinstated on June 14, 2012 during the next field visit.
- Station S45, Ells River above Joslyn Creek diversion, was damaged by wildlife on October 23, 2012. The solar panel and enclosure were damaged, and the power supply was disconnected. The station was reinstated on November 13, 2012.

Data Logger Malfunctions and Attrition

The following data logger malfunctions and equipment challenges were addressed by the RAMP Climate and Hydrology component in 2012:

- The operation of Station S11, Poplar Creek at Hwy 63, was disrupted due to a faulty battery on July 25, 2012. The station was reinstated during the next field visit on August 8, 2012.
- A faulty power supply caused Station S56, Jackfish River below Christina Lake, to lose power on June 23, 2012. The power supply was replaced on July 4, 2012 and the station was reinstated. A faulty solar panel was replaced at this station on August 11 2012.

3.1.1.5 Other Information Obtained

Streamflow data from WSC were obtained and incorporated into the RAMP database for stations that are jointly operated by RAMP and WSC. 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 Alberta Government Station, Christina Lake near Winfred Lake, were used in the preparation of the 2012 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 for RAMP. Additional climate data can be obtained from the following sources: Wood Buffalo Environmental Association (WBEA), Environment Canada (EC), and the Alberta Government are available 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 RAMP data available for the Climate and Hydrology component, 1997 to 2012. (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				2012
	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	n/a
Athabasca River near Embarras Airport (S46)																																																											2	2	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	>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	>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	>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	<5% Land Change
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	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	>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	>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	>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	>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	>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	>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	>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	>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	>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	>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	>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	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	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	<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	<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	<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	<5% Land Change
Firebag River upstream of Suncro Firebag (S43)																																																		2	2	2		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	n/a
Pierre River near Fort McKay (formerly 07DA013, S44)																																																		2	2	2		2	2	2		2	2	2		2t	2t	2t	Baseline
Big Creek (S48)																																																										2	2	2		2t	2t	2t	Baseline
Eymundson Creek near the mouth (S49)																																																										2	2	2		2t	2t	2t	Baseline
Red Clay Creek (S50/S50A)																																																										2	2	2		2t	2t	2t	Baseline

Legend

a = rainfall
b = rainfall and snowfall, or total precipitatior
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 groun
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				2012
	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)																																																													1t	1t	1t	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 CNRL 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	<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	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	<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	Baseline
Dover River near the mouth (S53)																																																													2t	2t	2t	Baseline
Dunkirk River near Fort McKay (S54)																																																													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	n/a
Tar River near the mouth (S15)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2																									
Tar River near the mouth (S15A)																																										2	2	2		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	>5% Land Change
Tar River above CNRL 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	Baseline
Calumet River Basin																																																																	
Calumet River near the mouth (S16)																		2	2	2		2g	2g	2g	be	2tbe	2tbe	2tbe	e	2be	2be	2tbe	be	be	e																														
Calumet River near the mouth (S16A)																																																						2	2	2		2	2	2		2t	2t	2t	Baseline
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 (07DA007, 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	<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	Baseline
Clearwater River Tributaries																																																																	
Surmont Climate Station (C5)																																																											gd	gd	gd	gd	gd	n/a
Christina River near Chard (07CE002, 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	>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	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	Baseline
Clearwater River above Christina River (07CD005, S42)																																																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	Baseline
Christina River near the mouth (S47/S47A)																																																										2t	2t	2t	2t	2t	2t	<5% Land Change
High Hills River near the mouth (S51)																																																														2t	2t	2t	Baseline
Gregoire River near the mouth (S55)																																																														2t	2t	2t	<5% Land Change
Jackfish River below Christina Lake (S56)																																																														2t	2t	2t	<5% Land Change
Sunday Creek above Christina Lake (S57)																																																														2t	2t	2t	<5% Land Change
Sawbones Creek above Christina Lake (S58)																																																														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																																																			
CNRL Area Snowcourse Survey																		c				c				c																																							
Wide-Area Snowcourse Survey																													c				c				c				c				c				c				c				c				c				n/a

Legend

a = rainfall
b = rainfall and snowfall, or total precipitatior
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 groun
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)

3.1.2 Water Quality Component

3.1.2.1 Overview of 2012 Monitoring Activities

Monitoring activities for the Water Quality component were conducted in four sampling campaigns in 2012: winter (March 14 and 15); spring (May 19 to 22); summer (July 11 to 16); and fall (September 4 to 14).

Water quality sampling focused on the Athabasca River and its major tributaries in the RAMP FSA, as well as regionally important lakes and wetlands. Additional data were contributed by AESRD. Water quality was sampled at 56 RAMP stations in 2012. Table 3.1-3 summarizes the location of 2012 water quality sampling stations, seasonal distribution of the sampling effort, and water quality variables measured at each station. Figure 3.1-3 provides the locations of water quality sampling in 2012. Sampling intensity was greatest during the fall campaign, with samples collected from all 2012 RAMP monitoring stations in that season. RAMP's standard protocol for newly-established water quality stations is to sample seasonally for three years and then to sample once in fall in subsequent years (Table 3.1-3).

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), temperature, pH and conductivity 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 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 exception to this was the total hydrocarbons (oil and grease) and BTEX samples, 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 in the river/lake ice drilled 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. Samples collected for analysis of dissolved organic carbon (DOC) were filtered in the field through a disposable, 0.45-µm filter. All water quality samples taken in 2012 were analyzed for the RAMP standard variables (Table 3.1-4) in all sampling seasons, which included the addition of CCME fractionated hydrocarbons and PAHs in 2011. 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 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. 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.

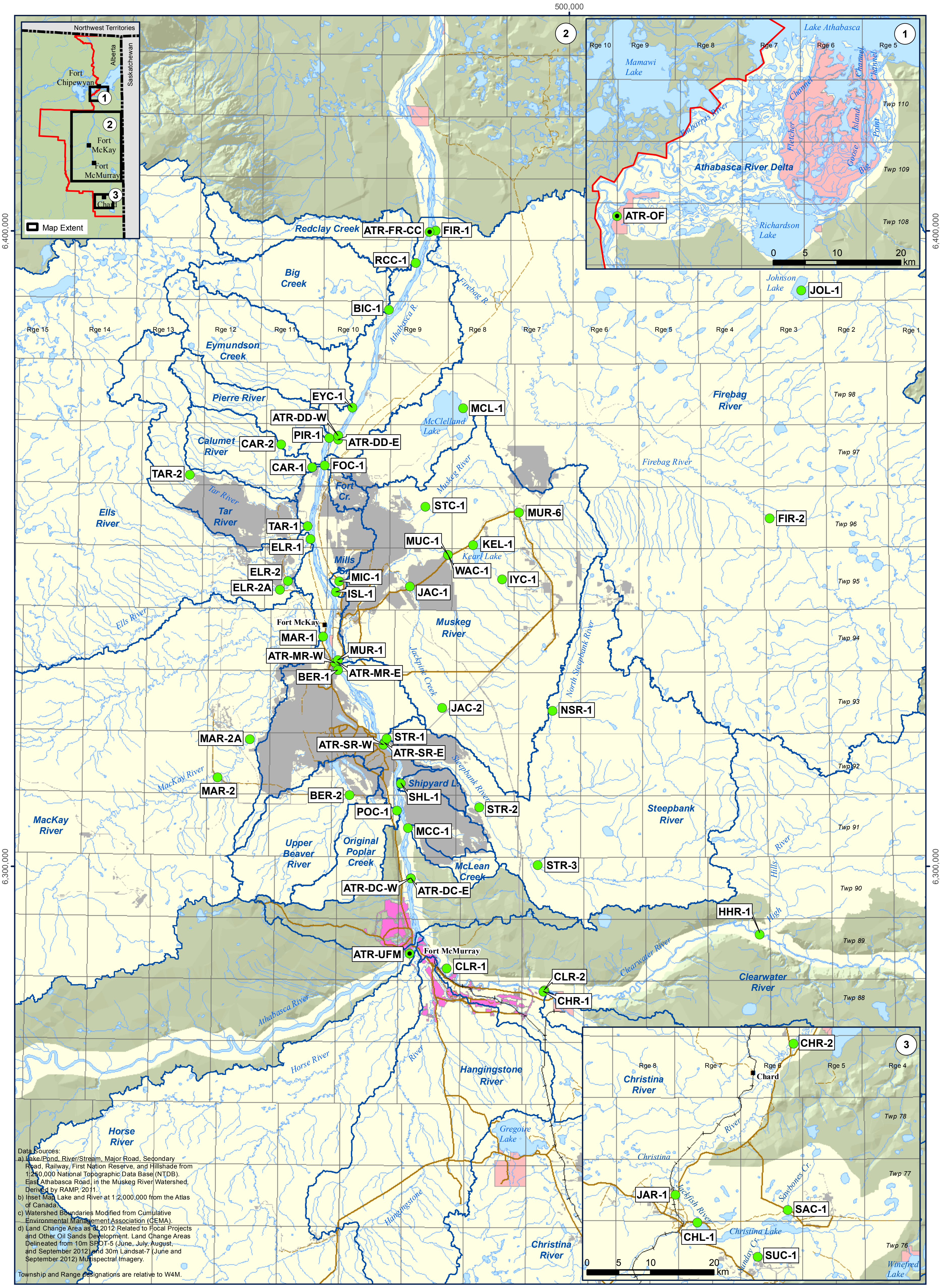
Blank Correction of Detection Limits for Ultra-trace PAHs

Ultra-trace analysis of PAHs in water was introduced to RAMP in the 2011 program, with analysis conducted by AXYS Analytical Ltd. (AXYS) using low-resolution mass spectrometry (LRMS). Results for 43 parent and alkylated PAH homologues were reported in 2011 and 2012, 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 species (ranging from 0.13 to 0.85 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-wise, consistent, detection limits for each PAH species. This allowed for consistent comparisons of all PAH data collected by RAMP in 2012. This blank-correction procedure followed methods developed in conjunction with AXYS for the RAMP 2011 data (RAMP 2012) so that all results measured by RAMP for a given PAH species 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 species) were generated by calculating DLs for each species equal to 2x the standard deviation of concentrations of that species measured in all project trip blanks.

Where mean RLs were 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 species, typically of less than one order of magnitude. However, for some species, the DL increased by over an order of magnitude. Both species-specific RLs and associated, blank-corrected DLs are provided in Table 3.1-5.

Figure 3.1-3 Locations of RAMP water quality stations, 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- Town of Fort McMurray
- Land Change Area as of 2012^d
- ● RAMP Water Quality Station
- ● AESRD Water Quality Station

0 2.5 5 10 km

Scale: 1:600,000

Projection: NAD 1983 UTM Zone 12N

N

RAMP
Regional Aquatics Monitoring Program

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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 species 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 2011

The 2012 monitoring network for the Water Quality component was the same as the 2011 monitoring network with the following exceptions:

- *Baseline* station ELR-2A was planned to be move further upstream to a new location (*baseline* station ELR-3) given the increase in development in the Ells River watershed; however, to be consistent with sampling under the JOSM Plan, the station was not moved in 2012. Therefore, *baseline* station ELR-2A was sampled in winter and fall in 2012;

- Four new *test* stations were established south of Fort McMurray in the Christina River watershed, including Christina Lake (CHL-1), Sunday Creek (SUC-1), Sawbones Creek (SAC-1), and Jackfish River (JAR-1), to acquire data for RAMP southern operators; and

- Shelley Creek, a *test* station (SHC-1) in the Muskeg River watershed, was removed from the sampling program, given there is currently no water flowing in the creek.

3.1.2.4 Changes in Analytical Chemistry Methods from 2011

No changes were made in analytical chemistry methods from 2011 to 2012.

3.1.2.5 Challenges Encountered and Solutions Applied

During the fall sampling program, high rain events created potentially hazardous sampling conditions. Extra safety precautions were taken while sampling and when needed sampling was delayed until weather conditions improved. All scheduled sampling occurred.

3.1.2.6 Other Information Obtained

All sampling for the Water Quality component in 2012 was conducted by the RAMP 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 provided to RAMP 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 differs from RAMP 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 by RAMP are summarized in Table 3.1-6. Table 3.1-6 does not include all data collected by AESRD, only the data provided to RAMP for analysis.

Table 3.1-3 Summary of sampling for the RAMP 2012 Water Quality component.

Station Identifier and Location		UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	Winter	Spring	Summer	Fall	
Athabasca River								
ATR-DC-E	Athabasca River upstream of Donald Creek (east bank)	475120	6298154	3	3	3	3	East bank grab
ATR-DC-W	Athabasca River upstream of Donald Creek (west bank)	475102	6298152	3	3	3	3	West bank grab
ATR-DD-E	Athabasca River downstream of all development (east bank)	463709	6367189	3	3	3	3	East bank grab
ATR-DD-W	Athabasca River downstream of all development (west bank)	463709	6367819	3	3	3	3	West bank grab
ATR-MR-E	Athabasca River upstream of the Muskeg River (east bank)	463504	6332230	-	-	-	3	East bank grab
ATR-MR-W	Athabasca River upstream of the Muskeg River (west bank)	463195	6332090	-	-	-	3	West bank grab
ATR-SR-E	Athabasca River upstream of the Steepbank River (east bank)	470932	6319461	-	-	-	3	East bank grab
ATR-SR-W	Athabasca River upstream of the Steepbank River (west bank)	470785	6319199	-	-	-	3	West bank grab
Tributaries to the Athabasca River (Southern)								
Clearwater River								
CLR-1	Clearwater River upstream of Fort McMurray	480735	6283997	-	-	-	3	Mid-channel grab
CLR-2	Clearwater River upstream of Christina River	496094	6280541	-	-	-	3	Mid-channel grab
Christina River and Tributaries								
CHR-1	Christina River upstream of Fort McMurray	495968	6280327	-	-	-	3	Mid-channel grab
CHR-2	Christina River upstream of Janvier	512360	6193385	-	-	-	3	Mid-channel grab
JAR-1	Jackfish River	493797	6169546	-	3	3	3	Mid-channel grab
SUC-1	Sunday Creek	506716	6159804	-	3	3	3	Mid-channel grab
SAC-1	Sawbones Creek	511453	6167195	-	3	3	3	Mid-channel grab
High Hills Creek								
HHR-1	High Hills River (mouth)	529938	6289299	3	3	3	3	Mid-channel grab
Tributaries to the Athabasca River (Eastern)								
FOC-1	Fort Creek	461549	6363105	-	-	-	3	Mid-channel grab
MCC-1	McLean Creek (mouth)	474637	6306051	-	-	-	3	Mid-channel grab
Steepbank River								
NSR-1	North Steepbank River	497367	6324536	-	-	-	3	Mid-channel grab
STR-1	Steepbank River (mouth)	471320	6320145	3	-	-	3	Mid-channel grab
STR-2	Steepbank River upstream of Suncor Millennium	485845	6309326	-	-	-	3	Mid-channel grab
STR-3	Steepbank River upstream of North Steepbank River	495011	6300231	-	-	-	3	Mid-channel grab

Legend

1 = standard water quality parameters (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 (routine paramters and arsenic)
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 parameters (conventional parameters, major ions, nutrients and total metals)
12 = AESRD routine parameters + RAMP standard parameters
13 = AESRD routine parameters + PAHs
14 = AESRD routine parameters + DataSonde
15 = AESRD routine parameters + PAHs + DataSonde
16 = standard water quality + chlorophyll-a
17 = standard water quality + chlorophyll-a + PAHs
* = Sampling was scheduled but didn’t occur (station was frozen to depth, dry or couldn’t be sampled due to another circumstance)

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	
Muskeg River and Muskeg River Tributaries								
MUR-1	Muskeg River (mouth)	463643	6332490	-	-	-	3	Mid-channel grab
MUR-6	Muskeg River upstream of Wapasu Creek	492093	6355679	-	-	-	3	Mid-channel grab
JAC-1	Jackpine Creek (mouth)	474982	6344048	-	-	-	3	Mid-channel grab
JAC-2	Jackpine Creek (upstream)	480050	6324945	-	-	-	3	Mid-channel grab
MUC-1	Muskeg Creek (mouth)	480967	6349070				3	Mid-channel grab
IYC-1	Iyinimin Creek	489421	6345190	-	-	-	3	Mid-channel grab
STC-1	Stanley Creek (mouth)	477402	6356617	-	-	-	3	Mid-channel grab
WAC-1	Wapasu Creek at Canterra Road crossing	480969	6349062	-	-	-	3	Mid-channel grab
Firebag River								
FIR-1	Firebag River (mouth)	479033	6400124	-	-	-	3	Mid-channel grab
FIR-2	Firebag River upstream of Suncor Firebag	531527	6354782	-	-	-	3	Mid-channel grab
Tributaries to the Athabasca River (Western)								
BER-1	Beaver River (mouth)	463640	6330910	-	-	-	3	Mid-channel grab
POC-1	Poplar Creek (mouth)	472958	6308822	-	-	-	3	Mid-channel grab
BER-2	Beaver River (upper)	465489	6311275	-	-	-	3	Mid-channel grab
CAR-1	Calumet River (mouth)	459586	6362803	-	-	-	3	Mid-channel grab
CAR-2	Calumet River (upper river)	454710	6366441	-	-	-	3	Mid-channel grab
ELR-1	Ells River (mouth)	459304	6351517	-	-	-	3	Mid-channel grab
ELR-2	Ells River (upstream)	455756	6344917	-	-	-	3	Mid-channel grab
ELR-2A	Ells River (upstream of Fort McKay Water Intake)	454471	6343543	3	-	-	3	Mid-channel grab
TAR-1	Tar River (mouth)	458854	6353551	-	-	-	3	Mid-channel grab
TAR-2	Tar River upstream of Canadian Natural Horizon	440357	6361662	-	-	-	3	Mid-channel grab
PIR-1	Pierre River (mouth)	462291	6367440	3*	3	3	3	Mid-channel grab
EYC-1	Eymundson Creek (mouth)	465933	6372234	3	3	3	3	Mid-channel grab
BIC-1	Big Creek (mouth)	471687	6387679	3*	3	3	3	Mid-channel grab
RCC-1	Red Clay Creek (mouth)	475878	6395027	3*	3	3	3	Mid-channel grab

Legend

1 = standard water quality parameters (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 (routine paramters and arsenic)
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 parameters (conventional parameters, major ions, nutrients and total metals)
12 = AESRD routine parameters + RAMP standard parameters
13 = AESRD routine parameters + PAHs
14 = AESRD routine parameters + DataSonde
15 = AESRD routine parameters + PAHs + DataSonde
16 = standard water quality + chlorophyll-a
17 = standard water quality + chlorophyll-a + PAHs
* = Sampling was scheduled but didn't occur (station was frozen to depth, dry or couldn't be sampled due to another circumstance)

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	
MacKay River								
MAR-1	MacKay River (mouth)	461314	6336214	-	-	-	3	Mid-channel grab
MAR-2	MacKay River upstream of Suncor MacKay	444731	6314041	-	-	-	3	Mid-channel grab
MAR-2A	MacKay River upstream of Suncor Dover	449746	6320067	3	3	3	3	Mid-channel grab
Lakes and Wetlands								
ISL-1	Isadore's Lake	463356	6343198	-	-	-	17	Mid-lake grab
KEL-1	Kearl Lake	484850	6350577	-	-	-	17	Mid-lake grab
MCL-1	McClelland Lake	483309	6372106	-	-	-	17	Mid-lake grab
SHL-1	Shipyard Lake	473558	6313093	-	-	-	17	Mid-lake grab
JOL-1	Johnson Lake	536465	6390715	17	17	17	17	Mid-lake grab
CHL-1	Christina Lake	497226	6165178	-	17	17	17	Mid-lake grab
Tributaries to Lakes								
MIC-1	Mills Creek, tributary to Isadore's Lake	463842	6344880	-	-	-	3	Mid-channel grab
QA/QC[1]								
-				3	3	3	3	Trip and field blanks, split, duplicate
Government and Industry Monitoring Stations Contributing Data to RAMP								
ATR-UFM	Athabasca River upstream of Fort McMurray (monthly)	474901	6286327	13	11	13	11	AESRD sampling
ATR-OF	Athabasca River at Old Fort (monthly)	470205	6474330	12	12	12	12	AESRD sampling
ATR-FR-CC	Athabasca River upstream of the Firebag River	478031	6377868	13	13	13	13	AESRD sampling

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard w.q. + chronic toxicity testing (Pseudokirchneriella subcapitata, *Ceriodaphnia dubia, Pimephales promelus fathead minnow)*
3 = standard water quality + PAHs
4 = standard water quality + chronic tox testing + PAHs
5 = standard water quality for OPTI lakes (routine paramters and arsenic)
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 parameters (conventional parameters, major ions, nutrients and total metals)
12 = AESRD routine parameters + RAMP standard parameters
13 = AESRD routine parameters + PAHs
14 = AESRD routine parameters + DataSonde
15 = AESRD routine parameters + PAHs + DataSonde
16 = standard water quality + chlorophyll *a*
17 = standard water quality + chlorophyll *a* + PAHs
* = Sampling was scheduled but didn't occur (station was frozen to depth, dry or couldn't be sampled due to another circumstance)

Table 3.1-4 RAMP standard water quality variables.

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	5	APHA 4500-H, 2510, 2320	10165	ALS
	Total Dissolved Solids	mg/L	12	APHA 2540 C	-	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	101278	ALS
	CCME Fraction 1 (BTEX)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	-	ALS
	CCME Fraction 1 (C6-C10)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	-	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	-	ALS
	m+p-Xylene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	-	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		ALS
	Toluene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	101279	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	101281	ALS
Major ions	Bicarbonate (HCO_3)	mg/L	5	APHA 4500-H, 2510, 2320	6201	ALS
	Calcium (Ca)	mg/L	0.5	APHA 3120 B-ICP-OES	104394	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 3120 B-ICP-OES	104407	ALS
	Potassium (K)	mg/L	0.5	APHA 3120 B-ICP-OES	104416	ALS
	Sodium (Na)	mg/L	1	APHA 3120 B-ICP-OES	104423	ALS
	Sulphate (SO_4)	mg/L	0.5	APHA 4110 B-ION CHROMATOGRAPHY	98228	ALS
	Sulphide	mg/L	0.002	APHA 4500 -S E-Auto-Colorimetry	16003	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	-	ALS
	Nitrate+Nitrite	mg/L	0.071	CALCULATION	103392	ALS
	Nitrite	mg/L	0.05	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	0.003	ICP/MS by DRC-II	103999	AITF
	Antimony	mg/L	0.00005	ICP/MS by DRC-II	80043	AITF
	Arsenic	mg/L	0.0001	ICP/MS by DRC-II	80020	AITF
	Barium	mg/L	0.0001	ICP/MS by DRC-II	80022	AITF
	Beryllium	mg/L	0.0001	ICP/MS by DRC-II	80023	AITF
	Bismuth	mg/L	0.0001	ICP/MS by DRC-II	80024	AITF
	Boron	mg/L	0.0008	ICP/MS by DRC-II	80021	AITF
	Cadmium	mg/L	0.00001	ICP/MS by DRC-II	80026	AITF
	Calcium	mg/L	0.1	ICP/MS by DRC-II	80025	AITF
	Chlorine	mg/L	0.3	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	0.0003	ICP/MS by DRC-II	80029	AITF
	Cobalt	mg/L	0.0001	ICP/MS by DRC-II	80028	AITF
	Copper	mg/L	0.0001	ICP/MS by DRC-II	80030	AITF
	Iron	mg/L	0.004	ICP/MS by DRC-II	80031	AITF
	Lead	mg/L	0.0001	ICP/MS by DRC-II	80041	AITF
	Lithium	mg/L	0.0002	ICP/MS by DRC-II	80034	AITF
	Manganese	mg/L	0.0001	ICP/MS by DRC-II	80036	AITF
	Mercury	mg/L	0.00005	ICP/MS by DRC-II	80032	AITF
	Mercury (Hg), ultra-trace	ng/L	0.6	ICP/MS by DRC-II	101979	AITF
	Molybdenum	mg/L	0.0001	ICP/MS by DRC-II	80037	AITF
	Nickel	mg/L	0.0001	ICP/MS by DRC-II	80039	AITF
	Selenium	mg/L	0.0003	ICP/MS by DRC-II	80044	AITF
	Silver	mg/L	0.00001	ICP/MS by DRC-II	103998	AITF
	Strontium	mg/L	0.0001	ICP/MS by DRC-II	80047	AITF
	Sulphur	mg/L	2	ICP/MS by DRC-II	80042	AITF
	Thallium	mg/L	0.0001	ICP/MS by DRC-II	80053	AITF
	Thorium	mg/L	0.0001	ICP/MS by DRC-II	80048	AITF
	Tin	mg/L	0.0001	ICP/MS by DRC-II	80046	AITF
	Titanium	mg/L	0.0001	ICP/MS by DRC-II	80049	AITF
	Uranium	mg/L	0.0001	ICP/MS by DRC-II	80054	AITF
	Vanadium	mg/L	0.0001	ICP/MS by DRC-II	80055	AITF
	Zinc	mg/L	0.0002	ICP/MS by DRC-II	80056	AITF
Dissolved Metals	Aluminum	mg/L	0.001	ICP/MS by DRC-II	103927	AITF
	Antimony	mg/L	0.00005	ICP/MS by DRC-II	103951	AITF
	Arsenic	mg/L	0.0001	ICP/MS by DRC-II	103928	AITF
	Barium	mg/L	0.0001	ICP/MS by DRC-II	103930	AITF
	Beryllium	mg/L	0.0001	ICP/MS by DRC-II	103931	AITF
	Bismuth	mg/L	0.0001	ICP/MS by DRC-II	103932	AITF
	Boron	mg/L	0.0008	ICP/MS by DRC-II	103929	AITF
	Cadmium	mg/L	0.00001	ICP/MS by DRC-II	103934	AITF
	Calcium	mg/L	0.1	ICP/MS by DRC-II	103933	AITF
	Chlorine	mg/L	0.3	ICP/MS by DRC-II	103935	AITF
	Chromium	mg/L	0.0003	ICP/MS by DRC-II	103937	AITF
	Cobalt	mg/L	0.0001	ICP/MS by DRC-II	103936	AITF
	Copper	mg/L	0.0001	ICP/MS by DRC-II	103938	AITF
	Iron	mg/L	0.004	ICP/MS by DRC-II	103939	AITF
	Lead	mg/L	0.0001	ICP/MS by DRC-II	103949	AITF
	Lithium	mg/L	0.0002	ICP/MS by DRC-II	103942	AITF
	Manganese	mg/L	0.0001	ICP/MS by DRC-II	103944	AITF
	Mercury	mg/L	0.00005	ICP/MS by DRC-II	103940	AITF
	Molybdenum	mg/L	0.0001	ICP/MS by DRC-II	103945	AITF
	Nickel	mg/L	0.0001	ICP/MS by DRC-II	103947	AITF
	Selenium	mg/L	0.0003	ICP/MS by DRC-II	103952	AITF
	Silver	mg/L	0.00001	ICP/MS by DRC-II	103926	AITF
	Strontium	mg/L	0.0001	ICP/MS by DRC-II	103955	AITF
	Sulphur	mg/L	2	ICP/MS by DRC-II	103950	AITF
	Thallium	mg/L	0.0001	ICP/MS by DRC-II	103958	AITF
	Thorium	mg/L	0.0001	ICP/MS by DRC-II	103956	AITF
	Tin	mg/L	0.0001	ICP/MS by DRC-II	103954	AITF
	Titanium	mg/L	0.0001	ICP/MS by DRC-II	103957	AITF
	Uranium	mg/L	0.0001	ICP/MS by DRC-II	103959	AITF
	Vanadium	mg/L	0.0001	ICP/MS by DRC-II	103960	AITF
	Zinc	mg/L	0.0002	ICP/MS by DRC-II	103961	AITF

Table 3.1-5 RAMP PAH variables measured in water.

Group	Analyte	Units	Average Reporting Limit	Blank-Corrected Detection Limit	Analytical Method	Lab
PAHs	Biphenyl	ng/L	0.144	2.046	LR GC/MS	AXYS
	C1-Biphenyls	ng/L	0.138	19.294	LR GC/MS	AXYS
	C2-Biphenyls	ng/L	0.625	86.336	LR GC/MS	AXYS
	Naphthalene	ng/L	0.294	8.756	LR GC/MS	AXYS
	C1-Naphthalenes	ng/L	0.228	3.071	LR GC/MS	AXYS
	C2-Naphthalenes	ng/L	0.280	3.883	LR GC/MS	AXYS
	C3-Naphthalenes	ng/L	0.202	2.689	LR GC/MS	AXYS
	C4-Naphthalenes	ng/L	0.498	5.805	LR GC/MS	AXYS
	Acenaphthylene	ng/L	0.131	0.343	LR GC/MS	AXYS
	Acenaphthene	ng/L	0.250	0.619	LR GC/MS	AXYS
	C1-Acenaphthenes	ng/L	0.174	0.327	LR GC/MS	AXYS
	Fluorene	ng/L	0.113	0.304	LR GC/MS	AXYS
	C1-Fluorenes	ng/L	0.379	8.435	LR GC/MS	AXYS
	C2-Fluorenes	ng/L	0.378	1.712	LR GC/MS	AXYS
	C3-Fluorenes	ng/L	0.326	3.761	LR GC/MS	AXYS
	Phenanthrene	ng/L	0.132	1.072	LR GC/MS	AXYS
	Anthracene	ng/L	0.149	0.186	LR GC/MS	AXYS
	C1-Phenanthrenes/Anthracenes	ng/L	0.148	1.733	LR GC/MS	AXYS
	C2-Phenanthrenes/Anthracenes	ng/L	0.204	1.915	LR GC/MS	AXYS
	C3-Phenanthrenes/Anthracenes	ng/L	0.274	0.968	LR GC/MS	AXYS
	C4-Phenanthrenes/Anthracenes	ng/L	0.849	5.273	LR GC/MS	AXYS
	Retene	ng/L	0.837	0.509	LR GC/MS	AXYS
	Dibenzothiophene	ng/L	0.132	0.210	LR GC/MS	AXYS
	C1-Dibenzothiophenes	ng/L	0.202	5.591	LR GC/MS	AXYS
	C2-Dibenzothiophenes	ng/L	0.287	26.420	LR GC/MS	AXYS
	C3-Dibenzothiophenes	ng/L	0.178	1.135	LR GC/MS	AXYS
	C4-Dibenzothiophenes	ng/L	0.557	1.947	LR GC/MS	AXYS
	Fluoranthene	ng/L	0.116	0.653	LR GC/MS	AXYS
	Pyrene	ng/L	0.117	0.570	LR GC/MS	AXYS
	C1-Fluoranthenes/Pyrenes	ng/L	0.464	1.004	LR GC/MS	AXYS
	C2-Fluoranthenes/Pyrenes	ng/L	0.359	1.621	LR GC/MS	AXYS
	C3-Fluoranthenes/Pyrenes	ng/L	0.676	0.998	LR GC/MS	AXYS
	Benz[a]anthracene	ng/L	0.140	0.291	LR GC/MS	AXYS
	Chrysene	ng/L	0.146	0.432	LR GC/MS	AXYS
	C1-Benzo[a]anthracenes/Chrysenes	ng/L	0.212	0.579	LR GC/MS	AXYS
	C2-Benzo[a]anthracenes/Chrysenes	ng/L	0.511	0.378	LR GC/MS	AXYS
	Benzo[b,j,k]fluoranthene	ng/L	0.182	0.168	LR GC/MS	AXYS
	Benzo[a]pyrene	ng/L	0.286	0.229	LR GC/MS	AXYS
	C1-Benzofluoranthenes/Benzopyrenes	ng/L	0.375	0.706	LR GC/MS	AXYS
	C2-Benzofluoranthenes/Benzopyrenes	ng/L	0.389	1.063	LR GC/MS	AXYS
	Indeno[1,2,3-c,d]-pyrene	ng/L	0.181	0.232	LR GC/MS	AXYS
	Dibenz[a,h]anthracene	ng/L	0.173	0.319	LR GC/MS	AXYS
	Benzo[g,h,i]perylene	ng/L	0.170	0.187	LR GC/MS	AXYS

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Table 3.1-6 Summary of RAMP data available for the Water Quality component. (Page 1 of 2)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012			
		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 (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	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	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		1	1	1																				3				3				1				1	1			1				1																				
(west bank) [b]	ATR-DC-W								1								1				3				1				1				1				1				1				1	1			1	1			1	1	1	1	1	1	3	3	3	3	3	3	3
(east bank) [b]	ATR-DC-E								1								1				3				1				1				1				1				1				1	1			1	1			1	1	1	1	1	1	3	3	3	3	3	3	3
(middle)	ATR-DC-M																1																																																
Upstream of the Steepbank River (middle)	ATR-SR-M																1																																																
(west bank)	ATR-SR-W																1				1				1				1				1				1				1				1				1				1				1				3				3
(east bank)	ATR-SR-E																1				1				1				1				1				1				1				1				1				1				1				3				3
Upstream of the Muskeg River (middle)	ATR-MR-M																1																																																
(west bank) [b,c]	ATR-MR-W								1								1				1				1				1				1				1				1				1				1				1				1				3				3
(east bank) [b,c]	ATR-MR-E								1								1				1				1				1				1				1				1				1				1				1				1				3				3
Upstream Fort Creek (cross channel)	ATR-FC-CC-D		1	1	1																																																												
(west bank) [b,c]	ATR-FC-W								1								1				3				1				1																																				
(east bank) [b,c]	ATR-FC-E								1								1				3				1				1																																				
(middle)	ATR-FC-M																1																																																
Downstream of all development (cross channel)	ATR-DD-CC																					1	1	1	3	1,1	1	1	3	1,1	1	1	3	1,1	1	1	1																												
(east bank)	ATR-DD-E																																	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	3	3	3	3	3	3	3
(west bank)	ATR-DD-W																																	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	3	3	3	3	3	3	3
Upstream of mouth of Firebag River	ATR-FR-CC																								1				1				1				1				1				1				1				1				1				3				3
Upstream of the Embarras River (cross channel)	ATR-ER									1							1				3												1																																
Embarras River	EMR-1																												1																																				
At Old Fort (grab) [d]	ATR-OF													11	11	11	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	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				1								1				1																																
Athabasca River tributaries (Eastern)																																																																	
McLean Creek (mouth)	MCC-1											6	7		6	6	9		6	6	9		6	6	7		6	6	7		6	6	9		7	7	9		6	6	9				9				1				1				1				3				3
(100 m upstream)	MCC-2											6	6																																																				
Steepbank River (mouth)	STR-1	3	1	1	1		1	1	1	1							1				1	1			1				1				1				1				1				1	1			1	1			1	1			1	1			3	3			3
(upstream of Project Millennium)	STR-2																					1			1				1				1				1				1				1				1				1				1				3				3
(upstream of Nt. Steepbank)	STR-3																													1	1	1	1	1	1	1	1		1	1	1	1	1	1	1				1				1				1				3				3
North Steepbank River (upstream of Suncor Lewis)	NSR-1																						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1				1				1				3				3
Fort Creek (mouth)	FOC-1														7		7		6	6	7		6	6	7		6	6	7										6	6	7				7		6	6	7		6	6	7				1				3				3
Muskeg River																																																																	
Mouth [f]	MUR-1			1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1				1				1				1				1				1				1				1				1				3				3
Upstream of Wapasu Creek	MUR-6								1,2		7	7	7		6	6	9		6	6	7		6	6	7		6	6	7		6	6	7		6	6	7		6	6	7				7		6	6	7				1				1				3				3
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	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				1		1	1	1				1				1				1				1				1				2				3				3
(upper)	JAC-2																																																1				1				2				3				3
Shelley Creek (mouth)	SHC-1								11				11,1																												1				1								1								3				
Muskeg Creek (mouth)	MUC-1								11,2				11,1				1				1				1				1	1	1	1	1				1				1				1	1	1	1	1												3				3
Stanley Creek (mouth)	STC-1								11				11,1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1				1				1				3				3
Iyinimin Creek (mouth)	IYC-1																																											1	1				1								1				3				3
Wapasu Creek (Canterra Road Crossing)	WAC-1								11,2	1			11,1																				1				1				1				1				1				1				1				3				3

Legend

1 = standard water quality parameters (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 (routine paramters and arsenic)
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 parameters (conventional parameters, major ions, nutrients and total metals)
12 = AESRD routine parameters + RAMP standard parameters
13 = AESRD routine parameters + PAHs
14 = AESRD routine parameters + DataSonde
15 = AESRD routine parameters + 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 and an unnamed side channel
[f] All testing, with the exception of thermographs, is conducted by individual industry
[g] AENV 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

🟦 *Test* (downstream of focal projects)
🟩 *Baseline* (upstream of focal projects)
🟩 *Baseline* (excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities)
🟪 *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				2006				2007				2008				2009				2010				2011				2012			
		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 (Western)																																																																	
Poplar Creek (mouth)	POC-1																1				1				1				1				1				1				1				1				1				1				1				3				3
Beaver River (mouth)	BER-1																											1	1			1	1			1	1				1				1	1			1				1				1				3				3
(upper)	BER-2																																														1	1	1	1	1	1	1	1	1	1	1				3				3
MacKay River (mouth)	MAR-1								1								1				1	1			1				1	1	1	1	1				1				1				1	1	1	1	1	1	1	1	1				1				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
(upstream of Suncor MacKay)	MAR-2																					1			1	1	1	1	1				1				1				1				1	1	1	1	1	1	1	1	1				1				3				3
Dunkirk River (Fish program support)	DUR-1																																																				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				1				1				1				1				1				3				3
(upstream of Total Joslyn Mine)	ELR-2														11	11	11	14												1	1	1	2	1	1	1	1	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
Tar River (mouth)	TAR-1						1	1	1														1	1	2	1	1	1	2	1	1	1	1	1	1	1	1				1				1				1		1	1	1				1				3				3
(upstream of Canadian Natural Horizon)	TAR-2																													1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2				1		1	1	1				1				3				3
Calumet River (mouth)	CAR-1																						1	1	2	1	1	1	2	1	1	1	2	1	1	1	2				1				1				1				1				1				3				3
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2																																	1	1	1	2	1	1	1	2	1	1	1	2				1				1				1				3				3
Firebag River (mouth)	FIR-1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1				1				1				3				3
(upstream of Suncor Firebag)	FIR-2																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1				1				1				3				3
Pierre River (mouth)	PIR-1																																																									1	3	3	3	3	3	3	3
Eymundson Creek (mouth)	EYC-1																																																									1	3	3	3	3	3	3	3
Big Creek (mouth)	BIC-1																																																									1	3	3	3	3	3	3	3
Red Clay Creek (mouth)	RCC-1																																																									1	3	3	3	3	3	3	3
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	1	7	7	7		7	7	7				1				1				1				3				3
(upstream of Christina River)	CLR-2																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7		6	6	7		6		7				1				1				1				3				3
Christina River (upstream of Fort McMurray)	CHR-1																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1				1				1				3				3
(upstream of Janvier)	CHR-2																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1				1				1				3				3
(mid)	CHR-2A																																									1			1																				
Jackfish River (outlet of Christina Lake)	JAR-1																																																														3	3	3
Sunday Creek (inlet to Chistina Lake)	SUC-1																																																														3	3	3
Sawbones Creek (inlet to Chistina Lake)	SAC-1																																																														3	3	3
Hangingstone River (upstream of Fort McMurray)	HAR-1																													1	1	1	1	1	1	1	1	1	1	1	1		1	1	1				1																
Horse River (Fish program support)	HOR-1																																																				1												
High Hills River (mouth)	HHR-1																																																									1	3	3	3	3	3	3	3
Lake Tributaries																																																																	
Mills Creek	MIC-1																																																								1				3				3
Wetlands (Lakes)																																																																	
Kearl Lake	KEL-1							16+3	16+3								16+3			16	16				1	1			1			16	16			16	16				16			16	16				16				16				16				17				17
Isadore's Lake	ISL-1							16									16			16	16											16	16			16	16			16	16			16	16			16	16				16				16				17				17
Shipyard Lake	SHL-1							16			1	16	1			16	1			16	16			16	16			1	1			16	16			16	16			16	16			16	16			16	16				16				16				17				17
McClelland Lake	MCL-1																16			1	16				1				1												16				16				16				1				16				17				17
Johnson Lake	JOL-1																																																									16	17	17	17	17	17	17	17
Christina Lake	CHL-1																																																														17	17	17
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		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	1	1	1	1,1	1	1	1	1,1				1,1

Legend

1 = standard water quality parameters (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 (routine paramters and arsenic)

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 parameters (conventional parameters, major ions, nutrients and total metals)

12 = AESRD routine parameters + RAMP standard parameters

13 = AESRD routine parameters + PAHs

14 = AESRD routine parameters + DataSonde

15 = AESRD routine parameters + 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 and an unnamed side channel

[f] All testing, with the exception of thermographs, is conducted by individual industry

[g] AENV 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

🟦 *Test* (downstream of focal projects)
🟩 *Baseline* (upstream of focal projects)
🟩 *Baseline* (excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities)
🟪 *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 2012 Monitoring Activities for the Benthic Invertebrate Communities Component

Benthic invertebrate communities were sampled from September 1 to 16, 2012. A total of 319 samples were collected from 21 river reaches and six lakes (Figure 3.1-4, Table 3.1-7). As in previous years, river-reach samples were collected in the dominant habitat type found in each reach (Table 3.1-7). Habitats were defined as being either depositional (dominated by fine sediment deposits and low to no current) or erosional (dominated by rocky substrates and frequent riffle areas). These habitat classes do not change from year to year within a reach, so sampling methods used within any reach are the same from year to year.

Field Methods

Benthic invertebrates communities were sampled according to standard methods used in previous years (Golder 2003b, 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 and was deployed using a rope and messenger in lakes.

Ten replicate samples were collected from within pre-established 2 to 4 km long river reaches. Five replicate samples were collected from ARD channels. Samples were selected from within the reach, based on habitat availability and approximately equal spacing. Ten replicate samples were randomly selected in lakes from littoral areas based on a controlled depth range of 0.5 m to 3 m. Samples collected at depositional stations were sieved in the field using a 250-µm screen, 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 only);
- Field water quality measurements – dissolved oxygen, conductivity, temperature, and pH. The instrument used to measure conductivity and pH was calibrated according to manufacturer’s instructions; dissolved oxygen was measured by field titrations;
- Current 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.

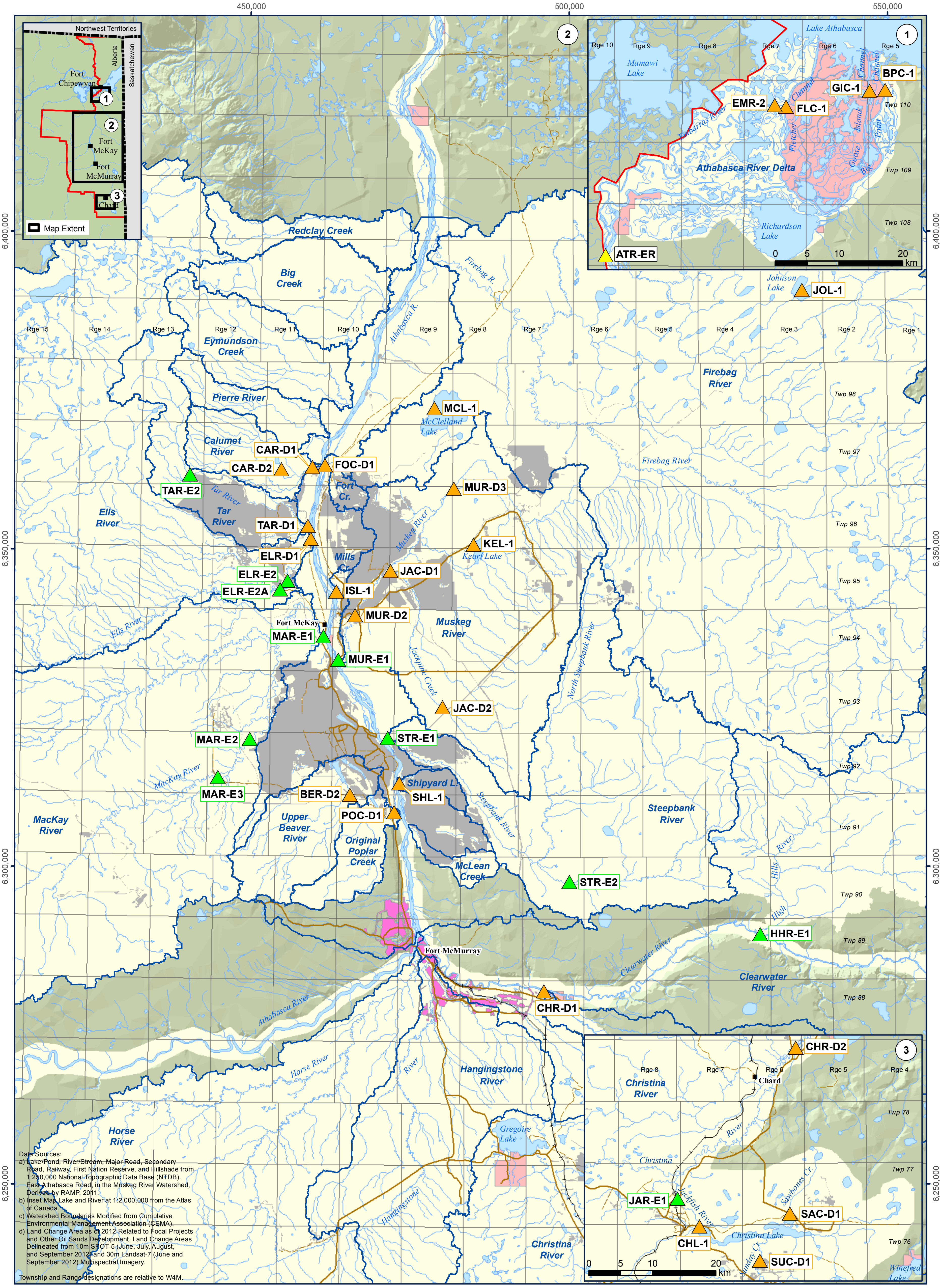
Table 3.1-7 Summary of sampling locations for the RAMP 2012 Benthic Invertebrate Communities component.

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	BPC-1	509619	6494139	509599	6494120
Big Point Channel	depositional	FLC-1	512003	6494367	511952	6494450
Fletcher Channel	depositional	GIC-1	496439	6491668	496455	6491683
Embarras River	depositional	EMR-2	494674	6491928	494684	6491920
Steepbank River						
Lower Reach	erosional	STR-E1	471407	6320187	471522	6320290
Upper Reach	erosional	STR-E2	499959	6297575	501116	6297774
Muskeg River						
Lower Reach	erosional	MUR-E1	463640	6332494	464707	6332336
Middle Reach	depositional	MUR-D2	466300	6339494	466588	6340504
Upper Reach	depositional	MUR-D3	480075	6357945	482128	6360073
Jackpine Creek						
Lower Reach	depositional	JAC-D1	471849	6436449	473076	6346332
Upper Reach	depositional	JAC-D2	480064	6324951	480775	6324643
Beaver River						
Upper Reach	depositional	BER-D2	465474	6311282	465208	6311027
Poplar Creek						
Lower Reach	depositional	POC-D1	473020	6308782	472372	6308495
MacKay River						
Lower Reach	erosional	MAR-E1	461314	6336214	460466	6337478
Middle Reach	erosional	MAR-E2	449746	6320067	448659	6319278
Upper Reach	erosional	MAR-E3	444731	6314041	443351	6314113
Tar River						
Lower Reach	depositional	TAR-D1	458854	6353551	458561	6353560
Upper Reach	erosional	TAR-E2	440357	6361662	439870	6362093
Ells River						
Lower Reach	depositional	ELR-D1			458903	6351738
Middle Reach	erosional	ELR-E2	455643	6344955	455744	6344134
Upper Reach	erosional	ELR-E2A	454471	6343543	453554	6344169
Calumet River						
Lower Reach	depositional	CAR-D1	459586	6362803	459595	6302806
Upper Reach	depositional	CAR-D2	454710	6362441	454678	6362386
High Hills River						
Lower Reach	erosional	HHR-E1	529936	6289300	530062	6290132
Fort Creek						
Lower Reach	depositional	FOC-D1	461548	6363105	461731	6363065
Jackfish River						
Lower Reach	erosional	JAR-E1	493812	6169529	494198	6168855
Christina River						
Lower Reach	depositional	CHR-D1	495968	6280327	497736	6278503
Upper Reach	depositional	CHR-D2	512360	6193385	511905	6192474
Sawbones Creek						
Lower Reach	depositional	SAC-D1	511453	6167195	511492	6167892
Sunday Creek						
Lower Reach	depositional	SUC-D1	506716	6159804	506257	6159707
Lakes[2]						
Kearl Lake	lake	KEL-1	484850	6350577	484817	6350913
McClelland Lake	lake	MCL-1	483192	6372106	483360	6372191
Shipyard Lake	lake	SHL-1	473558	6313093	473558	6313093
Christina Lake	lake	CHL-1	497200	6162168	497226	6165178
Johnson Lake	lake	JOL-1	536465	6390715	537215	6390977
Isadore’s Lake	lake	ISL-1	463356	6343198	403733	6343429

[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 RAMP benthic invertebrate community reaches and sediment quality stations, 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).

d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- Town of Fort McMurray
- Land Change Area as of 2012[d]
- ▲ Benthic Invertebrate Communities Reach
- ▲ Benthic Invertebrate Communities Reach and Sediment Quality Station
- ▲ Sediment Quality Station

0 2.5 5 10 km

Scale: 1:600,000

Projection: NAD 1983 UTM Zone 12N

N

Regional Aquatics Monitoring Program

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_G_BenthosSed_20130418.mxd

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 6X to 10X. 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.

Changes in Monitoring Network from 2011

The 2012 monitoring network for the Benthic Invertebrate Communities component was the same as the 2011 monitoring network with the following exceptions:

- The Christina River (*test* reach CHR-D1 and *test* reach CHR-D2) was sampled in 2012, following the rotating panel design of the program;
- The Calumet River (*test* reach CAR-D1 and *baseline* reach CAR-D2) was sampled in 2012, following the rotating panel design of the program;
- The Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2) was not sampled in 2012, following the rotating panel design of the program;
- *Test* reaches on Jackfish River (JAR-E1), Sawbones Creek (SAC-D1), and Sunday Creek (SUC-D1), which are tributaries to Christina Lake, were added to the program given the increase in RAMP membership in the southern oil sands area; and
- A *test* station on Christina Lake (CHL-1) was added to the program to compare to data acquired from tributaries flowing in and out of the lake and given that the lake is important to stakeholders in the area.

Challenges Encountered and Solutions Applied

During the fall sampling program, extreme rain events created high water levels in many watersheds, which made sampling difficult or impossible. In the erosional rivers, the water was often too deep to sample using the Hess cylinder and some replicates were not sampled. Hydrographs were monitored so that sampling could be conducted if water levels dropped to appropriate levels. This did not occur within the fall sampling period; therefore, some stations did not have all replicates sampled completely. Reaches that were affected included the lower Ells River (*test* reach ELR-D1), where only seven replicates were collected; the lower Steepbank River (*test* reach STR-E1), where only two replicates were collected; and the upper Steepbank River (*baseline* reach STR-E2), where only six replicates were collected.

Other Information Obtained

There was no additional information obtained for the Benthic Invertebrate Communities component in 2012.

Summary of Component Data Now Available

As of 2012, 2,927 benthic invertebrate community samples have been collected under RAMP. 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 2012 Monitoring Activities for the Sediment Quality Component

Sediment samples were collected from September 1 to 15, 2012 at the most downstream replicate sampling location in each depositional reach sampled for benthic invertebrate communities (total of 19 depositional reaches), one station on the Athabasca River downstream of the Embarras distributary, and six 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, jetboat, all-terrain vehicle, or four-wheel drive 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 a metal-free soap (i.e., Liquinox), 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, particle size, and TOC analyses, 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.

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 RAMP standard sediment quality variables (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 by RAMP in 2012 are provided in Table 3.1-10.

Changes in Monitoring Network from 2011

Given the three-year sampling rotation for some stations, *test* station CHR-D1 (lower reach on the Christina River), *test* station CHR-D2 (upper 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 2012, and not in 2011 or 2010. *Test* station CLR-D1 (lower reach on the Clearwater River) and *baseline* station CLR-D2 (upper reach on the Clearwater River) were not sampled in 2012. *Test* stations CHL-1 (Christina Lake), SUC-D1 (Sunday Creek), and SAC-D1 (Sawbones Creek) were added to the sediment sampling network in 2012. *Test* station EMR-2 (lower Embarras River) was sampled in 2012, whereas *test* station EMR-1 (upper Embarras River) was not sampled in 2012.

Table 3.1-8 Summary of RAMP data available for the Benthic Invertebrate Communities component. (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			
				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	ATRFLC,GIC,BPC																								1 🟦				1 🟦				1 🟦				1 🟦								1 🟦				1 🟦				1 🟦				1 🟦				1 🟦				1 🟦
Embarras River	1	depositional	EMR-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 🟦
Middle Reach	1	erosional	CHR-E2A																																												1 ■																				
Upper Reach	1	depositional	CHR-D2																								1 ■				1 ■				1 ■				1 ■				1 ■												1 ■												1 🟦
Clearwater River																																																																	
Downstream of Christina River	1	depositional	CLR-D1																				1 🟩				1 🟦				1 🟦				1 🟦				1 🟦												1 🟦												1 🟦				
Upstream of Christina River	1	depositional	CLR-D2																				1 🟩				1 🟩				1 🟩				1 🟩				1 🟩												1 🟩												1 🟩				
Ells River																																																																	
Lower Reach	1	depositional	ELR-D1																												1 🟦				1 🟦				1 🟦				1 🟦				1 🟦												1 🟦				1 🟦				1 🟦
Middle Reach	1	erosional	ELR-E2																												1 🟩				1 🟩				1 🟩				1 🟩																								1 🟦
Upper Reach	2	erosional	ELR-E2A																																																								1 🟩				1 🟩				1 🟩
Firebag River																																																																	
Lower Reach	1	depositional	FIR-D1																												1 🟦				1 🟦				1 🟦				1 🟦				1 🟦												1 🟦								
Upper Reach	1	erosional	FIR-E2																												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 🟦
Hangingstone River																																																																	
Lower Reach	1	erosional	HAR-E1																																1 ■				1 ■				1 ■				1 ■				1 ■																
High Hills River																																																																	
Lower Reach	1	erosional	HHR-E1																																																												1 🟩				1 🟩
Jackpine Creek																																																																	
Lower Reach	1	depositional	JAC-D1																								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 🟩
MacKay River																																																																	
Lower Reach	1	erosional	MAR-E1																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 🟦
Upper Reach	1	erosional	MAR-E3																																																						1 🟩				1 ■				1 ■
Muskeg River																																																																	
Lower Reach	1	erosional	MUR-E1																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 🟦
Upper Reach	1	depositional	MUR-D3																								1 🟩				1 🟩				1 🟩				1 🟩				1 🟩				1 🟩				1 🟦				1 🟦				1 🟦				1 🟦				1 🟦
Steepbank River																																																																	
Lower Reach	1	erosional	STR-E1																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 🟩

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 focal projects)

🟩 Baseline (upstream of focal projects)

■ Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

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

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			
				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
Historical Upper Reach	1	erosional	TAR-E1																												🟩 1				🟩 1				🟩 1				🟩 1																								
Upper Reach	1	erosional	TAR-E2																																																				🟩 1				🟩 1				🟩 1				🟩 1
Beaver River																																																																	
Lower Reach	1	depositional	BER-D2																																																🟩 1				🟩 1				🟩 1				🟩 1				🟩 1
Poplar Creek																																																																	
Lower Reach	1	depositional	POC-D1																																																🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Jackfish River																																																																	
Lower Reach	1	erosional	JAR-E1																																																																🟦 1
Sawbones Creek																																																																	
Lower Reach	1	depositional	SAC-D1																																																																🟦 1
Sunday Creek																																																																	
Lower Reach	1	depositional	SUC-D1																																																																🟦 1
Wetlands and Lakes																																																																	
Isadore's Lake	1	lake	ISL-1																																								🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Johnson Lake	1	lake	JOL-1																																																														🟩 1				🟩 1
Kearl Lake	1	lake	KEL-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
Shipyard Lake	1	lake	SHL-1																🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Christina Lake	1	lake	CHL-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																																																						

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 focal projects)
🟩 Baseline (upstream of focal projects)
■ Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

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

Table 3.1-9 Summary of sampling for the RAMP Sediment Quality component, September 2012.

Station Identifier and Location		UTM Coordinates (NAD83, Zone12)		Analytical Package
		Easting	Northing	
Athabasca River				
ATR-ER	Athabasca River at Embarras River	468066	6468279	2
Athabasca Delta				
FLC-1	Fletcher Channel	496439	6491668	2
GIC-1	Goose Island Channel	509619	6494139	2
BPC-1	Big Point Channel	512046	6494274	2
Embarras River				
EMR-2	Embarras River	494674	6491928	2
Tributaries to the Athabasca River (Eastern)				
FOC-D1	Fort Creek	461548	6363105	2
Tributaries to the Athabasca River (Western)				
BER-D2	Beaver River (upper reach)	465482	6311279	2
ELR-D1	Ells River (lower reach)	459304	6351517	2
TAR-D1	Tar River (lower reach)	458854	6353551	2
POC-D1	Poplar Creek (lower reach)	472426	6308509	2
CAR-D1	Calumet River (lower reach)	459595	6362806	2
CAR-D2	Calumet River (upper reach)	454710	6362441	2
Tributaries to the Athabasca River (Southern)				
CHR-D1	Christina River (lower reach)	495968	6280327	2
CHR-D2	Christina River (upper reach)	512360	6193385	2
SUC-D1	Sunday Creek (lower reach)	506716	6159804	2
SAC-D1	Sawbones Creek (lower reach)	511453	6167195	2
Muskeg River				
MUR-D2	Muskeg River (middle reach)	466297	6339500	1
MUR-D3	Muskeg River (upper reach)	481822	6359425	1
JAC-D1	Jackpine Creek (lower reach)	471849	6346446	2
JAC-D2	Jackpine Creek (upper reach)	480023	6325008	2
Regional Lakes				
KEL-1	Kearl Lake	484850	6350577	2
MCL-1	McClelland Lake	478757	6372046	2
SHL-1	Shipyard Lake	473261	6313030	2
ISL-1	Isadore's Lake	463356	6343198	2
JOL-1	Johnson Lake	536465	6390715	2
CHL-1	Christina Lake	497200	6165168	2
QA/QC				
-	Two sets of split and duplicate samples			1
-	Two rinsate blanks			metals, PAHs

Legend to Analytical Packages:

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

Challenges Encountered and Solutions Applied

No challenges were encountered during the Sediment Quality component sampling program in fall 2012.

Other Information Obtained

No additional sediment quality information for 2012 was obtained.

Summary of Component Data Now Available

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

Table 3.1-10 RAMP standard sediment quality variables.

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	SSIR-51 Method 3.2.1	ALS
	% Moisture	%	0.1	Oven dry 105C-Gravimetric (VMV 10042)	ALS
	% Sand	%	0.1	SSIR-51 Method 3.2.1	ALS
	% Silt	%	0.1	SSIR-51 Method 3.2.1	ALS
	$CaCO_3$ Equivalent	%	0.8	SSSA (1996) P455-456	ALS
	Inorganic Carbon	%	0.1	SSSA (1996) P455-456 (VMV 50303)	ALS
	Texture		-	SSIR-51 Method 3.2.1	ALS
	Total Carbon by Combustion	%	0.1	SSSA (1996) P. 973-974 (VMV 6075)	ALS
	Total organic carbon	%	0.1	SSSA (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	200	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 varies 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	100	EPA 200.2/6020A	ALS
	Potassium (K)	mg/kg	100	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 varies 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 (*Chirononmus 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 (*Chirononmus 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 (*Chirononmus 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 (*Chirononmus 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 RAMP data available for the Sediment Quality component.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007				2008				2009				2010				2011				2012			
		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
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
Goose Island Channel	GIC-1																				🟦 2				🟦 2				🟦 2								🟦 1								🟦 1				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Fletcher Channel	FLC-1																				🟦 2				🟦 2				🟦 2								🟦 1								🟦 1				🟦 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
Athabasca River Tributaries (South of Fort McMurray)																																																																	
Clearwater River (upstream of Fort McMurray)	CLR-1/CLR-D1																				🟩 1				🟦 2				🟦 2																				🟦 2												🟦 2				
(upstream of Christina River)	CLR-2/CLR-D2																				🟩 1				🟩 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
benthic reach at upper Christina River)	CHR-D2																																								🟦 2												🟦 2												🟦 2
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																🟩 2				🟩 2																												
Sunday Creek	SUC-D1																																																																🟦 2
Sawbones Creek	SAC-D1																																																																🟦 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
Poplar Creek (mouth)	POC-1/POC-D1				🟦 1																				🟦 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																																

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			
		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 🟦
(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 🟦
(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 🟦
Firebag River (mouth)	FIR-1																								2 🟦				2 🟦				1 🟦																																
(benthic reach at mouth)	FIR-D1																																								2 🟦				1 🟦												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 🟦
(benthic reach - upstream of Stanley Creek)[f]	MUR-D3																												2 🟩				2 🟩				2 🟩				2 🟩				2 🟩				2 🟦				1 🟦				1 🟦				1 🟦				1 🟦
Muskeg River Tributaries																																																																		
Jackpine Creek (mouth)	JAC-1				1 🟩																												2 🟩																																
(benthic reach at mouth)	JAC-D1																																								2 🟦				1 🟦				2 🟦				2 🟦				2 🟦				2 🟦				2 🟦
(benthic reach at upper Jackpine Creek)	JAC-D2																																								2 🟩				1 🟩				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 🟦
Isadore's Lake (composite)	ISL-1																				1 🟦																				2 🟦				2 🟦				2 🟦				1 🟦				1 🟦				1 🟦				2 🟦
Shipyard Lake (composite)	SHL-1																				1 🟦				2 🟦				1 🟦				2 🟦								2 🟦				2 🟦				2 🟦				1 🟦				1 🟦				1 🟦				2 🟦
McClelland Lake (composite)	MCL-1																								1 🟩				1 🟩												2 🟩				2 🟩				2 🟩				1 🟩				1 🟦				1 🟦				2 🟦
Johnson Lake (composite)	JOL-1																																																														1 🟩				2 🟩
Christina Lake (composite)	CHL-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

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)

3.1.4 Fish Populations Component

3.1.4.1 Overview of 2012 Monitoring Activities

The following monitoring activities were conducted in 2012 for the Fish Populations component:

- Spring, summer, and fall fish inventories on the Athabasca and Clearwater rivers;
- Tissue analyses on northern pike in the Clearwater River;
- Fish assemblage monitoring (FAM) on tributaries to the Athabasca and Clearwater rivers, and the Athabasca River Delta (see Section 6);
- Fish assemblage survey on Christina Lake;
- Sentinel species monitoring (slimy sculpin) using lethal sampling methods on the Steepbank, Muskeg, Dunkirk, Horse, and High Hills rivers; and
- Tissue analyses on target fish species (walleye and northern pike) in Gregoire Lake.

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 2012 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 2012, spring, summer, and fall inventories of the fish community focusing on the following RAMP 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 14 and May 30, 2012, July 23 and August 4, 2012, and September 17 and September 28, 2012, respectively. Approximately six 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 specifically established for the RAMP fish inventory (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).

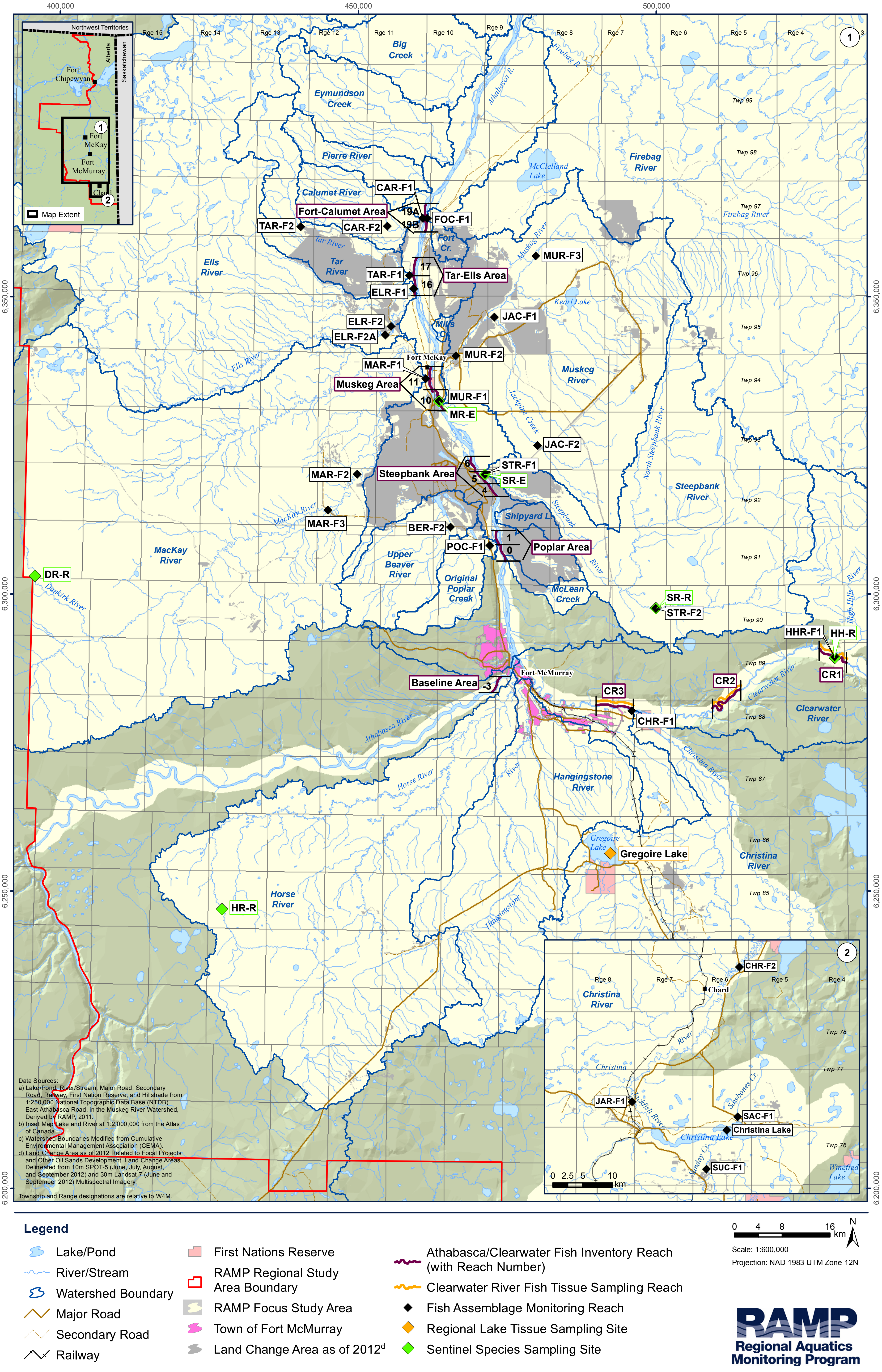
Sampling was conducted on both rivers in areas conducive to electrofishing, primarily in shallow river margins deep enough to be accessible by boat.

Fish were sampled using a Smith-Root model SR-18 electrofishing boat equipped with a 5.0 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 RAMP fish monitoring activities, 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_H_Fish_20130418.mxd

Table 3.1-12 Locations of fish inventory areas on the Athabasca and Clearwater rivers, 2012.

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 2012, based on a rotating panel design for the *baseline* reaches. The *test* reaches are sampled every year.

Fish Tag Return Assessment

Tagging of sportfish species has been a part of the Fish Populations component since 1999. RAMP 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.

Clearwater River Tissue Study

Northern pike was the target species for the 2012 fish tissue study on the Clearwater River. Tissue samples were acquired from fish captured in all three sampling areas of the Clearwater River in September 2012 (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.

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. These size classes were selected in order to:

- ensure adequate representation of typical size ranges for northern pike observed in the fall during past inventories on the river (RAMP 2005, 2007, 2008, 2010);
- ensure an even distribution of tissue samples across a wide range of fish sizes and ages; and
- ensure consistency with past tissue programs on the river (RAMP 2005, 2007, 2008, 2010) to allow comparisons with historical data.

Muscle tissue was sampled non-lethally from each northern pike for mercury analysis using a clean, unused 4-mm dermal biopsy punch (Acuderm Inc.), a method that was first adopted by RAMP in 2005 (RAMP 2006). 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.

Following mercury tissue sampling, all northern pike not designated for lethal dissections were released immediately into the calm margins of the river to limit additional handling and confinement stress. 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.

Lethal Dissections and Tissue Analysis for Tainting Compounds and Metals A target of ten northern pike (five males and five females) (target fork length: 450 mm to 500 mm for males and 500 to 550 mm for females) was set for dissection and comprehensive tissue sampling for tainting compounds (organics) and metals analysis. Captured fish of these sizes classes were stored in cold water and transported back to an indoor facility to minimize contamination from precipitation, wind and debris. 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 2005, 2007, 2008, 2010).

The distribution of fish captured for tissue analysis for tainting compounds is provided in Table 3.1-13. Because of difficulties capturing female northern pike within the target size class, male northern pike from the "female" target size class were also collected to ensure sufficient tissue for analyses (Table 3.1-13).

Table 3.1-13 Sex/length combinations of northern pike captured for fish tissue analyses of metals and organics, Clearwater River 2012.

Species	Sex	Size Class	Number Captured
Northern pike	male	450-500 mm (target)	3
	female	500-550 mm (target)	1
	male	500-550 mm (additional)	6

Each captured fish was measured for fork length and weight, given an external health assessment, and sampled for mercury analysis as described above. Each fish was then 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), gonad weight (± 0.01 g), and carcass weight (total weight minus the internal organs, ± 1 g) were recorded. Ageing structures (cleithra and two leading rays from the anal fin) were then collected, dried, and stored in labeled coin envelopes to be sent to NorthSouth Consultants Inc. (Winnipeg, MB) for analysis.

Tissue samples 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 3.1-14. All remaining tissue samples were archived at the testing laboratory for additional analyses, if required.

Table 3.1-14 Methods of analyses and detection limits for mercury, metals, and tainting compounds analyzed in fish tissues from the Clearwater River, 2012.

Variable	Detection Limit (mg/kg)	Method of Analysis
Metals		
Aluminum (Al)	2	EPA 200.3/200.8-ICPMS
Antimony (Sb)	0.05	EPA 200.3/200.8-ICPMS
Arsenic (As)	0.01	APHA 3114 C-AAS – Hydride
Barium (Ba)	0.1	EPA 200.3/200.8-ICPMS
Beryllium (Be)	0.2	EPA 200.3/200.8-ICPMS
Boron (B)	2	EPA 200.3/200.8-ICPMS
Cadmium (Cd)	0.01	EPA 200.3/200.8-ICPMS
Chromium (Cr)	0.1	EPA 200.3/200.8-ICPMS
Cobalt (Co)	0.1	EPA 200.3/200.8-ICPMS
Copper (Cu)	0.05	EPA 200.3/200.8-ICPMS
Iron (Fe)	5	EPA 200.3/200.7-ICPOES
Lead (Pb)	0.02	EPA 200.3/200.8-ICPMS
Lithium (Li)	0.5	EPA 200.3/200.8-ICPMS
Manganese (Mn)	0.5	EPA 200.3/200.7-ICPOES
Mercury (Hg)[1]	0.002	Cold Vapor Atomic Fluorescence Spectraphotometry (CVAFS)
Molybdenum (Mo)	0.05	EPA 200.3/200.8-ICPMS
Nickel (Ni)	0.02	EPA 200.3/200.8-ICPMS
Selenium (Se)	0.002	APHA 3114 C-Auto Continuous Hydride[3]
Silver (Ag)	0.02	EPA 200.3/200.8-ICPMS
Strontium (Sr)	0.05	EPA 200.3/200.8-ICPMS
Thallium (Tl)	0.05	EPA 200.3/200.8-ICPMS
Tin (Sn)	0.1	EPA 200.3/200.8-ICPMS
Titanium (Ti)	0.05	EPA 200.3/200.7-ICP-OES
Vanadium (V)	0.006	EPA 200.3/200.8-ICPMS
Zinc (Zn)	0.5	EPA 200.3/200.8-ICPMS
Tainting Compounds (PAHs)		
1,3,5-Trimethylbenzene	0.01	EPA 5021/8260-Headspace GC/MS
M+P-Xylenes	0.01	EPA 5021/8260-Headspace GC/MS
Naphthalene[2]	0.05	EPA 3540/8270-GC/MS
Thiophene	0.01	EPA 5021/8260-Headspace GC/MS
Toluene	0.01	EPA 5021/8260-Headspace GC/MS

[1] Analyzed by Flett Research (all other variables analyzed by ALS).

[2] 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.

[3] APHA is the American Public Health Association.

Regional Fish Tissue – Gregoire Lake

In 2012, tissue studies were performed on target fish (lake whitefish, walleye, and northern pike) captured during AESRD's fall walleye index netting program (FWIN) in Gregoire Lake, south of Fort McMurray (Figure 3.1-5).

Sampling in the lake took place between September 10 and September 14, 2012 by AESRD. A target of 25 walleye, 25 northern pike, and 25 lake whitefish was set for mercury tissue analysis, with a specific target 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. These five length classes were selected in order to ensure consistency with those size classes targeted in past tissue programs for these species in other regional lakes. These classes were originally selected based on typical size ranges observed for each species during past lake inventories, and were therefore considered to be representative of a wide range of fish sizes and ages within the population of each species. The distribution of fish captured from Gregoire Lake for tissue analysis for mercury is provided in Table 3.1-15. There were no lake whitefish captured during the survey.

Fish were collected by AESRD using experimental multi-mesh gill nets, sacrificed, measured for fork length (± 1 mm) and total weight (± 1 g), and evaluated for sex and stage of maturity. The tail sections (between the last rib and end of the caudal peduncle) were then removed, placed on dry ice, and transported to Hatfield (Fort McMurray) where they were stored in a deep-freeze and later sampled for mercury analysis. Ageing structures (otoliths) were taken from each individual fish and analyzed by personnel at AESRD.

Skinless, boneless, interior muscle tissues were sampled from each fish peduncle for mercury analysis using clean, stainless steel dissection equipment. Tissues from each fish were collected individually in sterile, pre-labeled, pre-weighed (± 0.001 g) 4 mL externally-threaded cryovials. Tissue sample wet weights were recorded (± 0.001 g) for the calculation of total mercury concentration, and samples were held in the Hatfield deep-freeze (Fort McMurray) before being shipped on dry ice to Flett Research Ltd. (Winnipeg, Manitoba) for mercury analysis. All sampling equipment was rinsed using metals-free soap and distilled water, hexane, then acetone, and re-rinsed with de-ionized water in between each fish to avoid cross contamination.

Table 3.1-15 Number of walleye and northern pike captured in each size class for fish tissue analyses of mercury, Gregoire Lake, September 2012.

	Size Class (mm)				
Species	**201-300**	**301-400**	**401-500**	**501-600**	**601-700**
Northern pike	2	1	8	0	0
Walleye	1	5	9	0	0

Lethal Tributary Sentinel Species Monitoring

The objective of the sentinel species monitoring program in 2012 was to monitor potential changes in fish populations due to stressors resulting from focal project development by assessing growth, reproduction and survival. Sentinel species monitoring in fall 2012 was carried out at a total of six sites on tributaries of the Athabasca River (Table 3.1-16, Figure 3.1-5). Two of these sites on the lower Steepbank River (site STR-E) and lower Muskeg River (site MR-E), were designated as *test,* while the remaining four sites, the upper Steepbank River (site STR-R), Horse River (site HR-R), Dunkirk River (site DR-R), and High Hills River (HH-R) were designated as *baseline*. Slimy sculpin (*Cottus cognatus*) was the selected sentinel species, with a target of 40 males and 40 females to be captured per site.

Table 3.1-16 Location and general description of each site sampled for sentinel fish species monitoring, 2012.

Watershed	Site Code	Location Description	UTM Coordinates (NAD83, Zone 12)[1]
Steepbank River	SR-E	*Test* site approximately 0.3 to 1.0 km upstream of the confluence with the Athabasca River.	471163 E / 6320073 N
	SR-R	*Test* site approximately 15 km upstream of the confluence with the Athabasca River.	501053 E / 6332222 N
Muskeg River	MR-E	*Test* site approximately 0.2 to 0.6 km upstream of the confluence with the Athabasca River.	463478 E / 6332415 N
Horse River	HR-R	*Baseline* site approximately 140 km upstream of the confluence with the Athabasca River.	427070 E / 6246983 N
Dunkirk River	DR-R	*Baseline* site approximately 25 km upstream of the confluence with the MacKay River.	395647 E / 6303046 N
High Hills River	HH-R	*Baseline* site approximately 0.2 km upstream of the confluence with the Clearwater River	529925 E / 6289260 N

[1] D/S-downstream end of reach; reach lengths varied depending on capture efficiency.

Fish Sampling Fish sampling was conducted between September 17 and October 10, 2012, with assistance from Environment Canada personnel given that sentinel species monitoring was also under the JOSM plan. All fish sampling was carried out by a four-person field crew using a Smith-Root 12B-POW battery-powered electrofishing unit and three standard dip nets, which were deployed downstream of the anode prior to and during the application of electrical current. The dip nets were fitted with a fine mesh net (32 mm) to ensure that slimy sculpin of all sizes could be captured. Fish sampling was conducted from one wetted bank to the other within each site, where water levels permitted backpack electrofishing, until approximately 40 adult fish (i.e., > 60 mm) were captured.

All captured sculpin were identified to species and brought back in aerated holding containers to a contained laboratory facility for dissecting. Each fish was measured for total length (± 1.0 mm) and weight (± 0.01 g) using an electronic balance that was calibrated prior to each measurement. The internal organs were removed, and the gonads (± 0.001 g) and liver (± 0.001 g) were weighed. Otoliths were removed from each fish for ageing. Internal and external pathology examinations were also performed on each fish.

Fish Habitat Assessments Habitat assessments were completed at each site including measurements of variables relating to channel morphology, substrate, water quality, and stream cover. Water quality variables including temperature (°C), dissolved oxygen (mg/L), and specific conductivity (µS/cm) were measured either with a hand-held probe (LaMotte Tracer Pocketester) (temperature, conductivity, pH) or a titration kit (LaMotte Winkler) (DO).

Christina Lake Fish Assemblage Survey

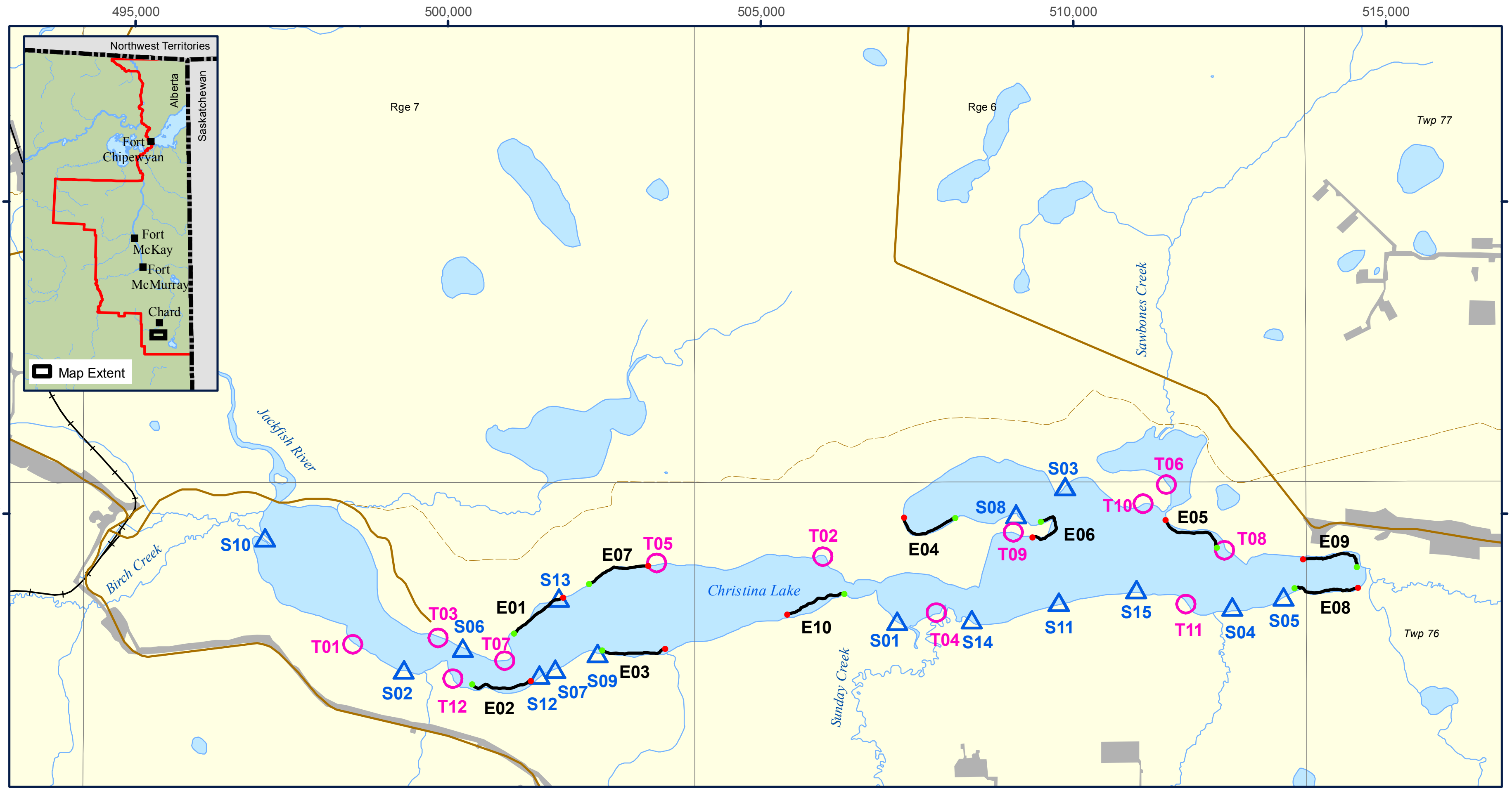
Sampling on Christina Lake was conducted for the first time in August 2012 given the increase in membership in RAMP of operators in that area. Sampling was undertaken using hoopnets, boat electrofishing, and seine nets based on methodology outlined in GOA (2011).

Fish Sampling Sample locations were chosen randomly by placing a 100 m UTM grid overlay on a map of the lake. Given that Christina Lake is oriented east-west, random easting coordinates were generated to determine the easting and then a random shore (north or south) was chosen. The process was repeated for each of the three types of fishing methods; hoopnets, seine nets, and boat electrofishing. The final sampling design consisted of fifteen seine net locations, twelve hoop net locations, and eight electrofishing transects (Table 3.1-17).

Table 3.1-17 Locations of sampling locations for the fish assemblage survey of Christina Lake, August 2012.

Fishing Method	Site	NAD 83, Zone 12 UTM Coordinates (Easting, Northing)
Electrofishing	E01	500374 E / 6162268 N
	E02	501055 E / 6163074 N
	E03	502480 E / 6162793 N
	E04	508106 E / 6164942 N
	E05	512284 E / 6164472 N
	E06	509481 E / 6164876 N
	E07	502249 E / 6163874 N
	E08	513550 E / 6163807 N
	E09	514535 E / 6161416 N
	E10	506335 E / 6163714 N
Seine Netting	S01	506184 E / 6163281 N
	S02	499287 E / 6162497 N
	S03	509866 E / 6165435 N
	S04	512547 E / 6163506 N
	S05	513353 E / 6163663 N
	S06	500231 E / 6162849 N
	S07	501717 E / 6162511 N
	S08	509082 E / 6164993 N
	S09	502384 E / 6162763 N
	S10	497067 E / 6164626 N
	S11	509769 E / 6163579 N
	S12	501464 E / 6162414 N
	S13	501777 E / 6163651 N
	S14	508371 E / 6163306 N
	S15	511006 E / 6163789 N
Hoop Nets	T01	498476 E / 6162893 N
	T02	505995 E / 6164311 N
	T03	499840 E / 6163001 N
	T04	507805 E / 6163407 N
	T05	503330 E / 6164197 N
	T06	511494 E / 6165466 N
	T07	500912 E / 6162633 N
	T08	512429 E / 6164411 N
	T09	509036 E / 6164696 N
	T10	511118 E / 6165160 N
	T11	511809 E / 6163537 N
	T12	500082 E / 6162350 N

Figure 3.1-6 Locations of sampling sites for the fish assemblage survey of Christina Lake, August 2012.



Legend

- Lake/Pond
- River/Stream
- Major Road
- Secondary Road
- Railway
- RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- Land Change Area as of 2012^{c}
- Hoop Net
- Seine Net
- Electrofishing (Start is Green, Finish is Red)

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, and Railway from 1:50,000 National Topographic Data Base (NTDB).
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

0 0.5 1 2 km

N

Scale: 1:100,000

Projection: NAD 1983 UTM Zone 12N

RAMP
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Electrofishing was done using a custom electrofishing boat equipped with a Coffelt 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. Each electrofishing transect was 1,000 m in length and conducted parallel to shore at depths between 0.8 and 1.2 m. All fish were held until in the aerated live well until the each transect was completed

Hoopnets were 90 cm in diameter and 3.5 m long with a 50 mm mesh. Each net had two, 1.8 m long wing nets of the same mesh size. Nets were set facing perpendicular to the shore at each location and a 10 m seine net (8 mm mesh) was stretched from the mouth of the net towards the shore. The opening of each net was placed in 0.8 m of water and the hoop was stretched away from the shore. All hoopnets were set overnight.

Seine netting was used to capture small-bodied fish species. At each seine net location, a line perpendicular to shore was followed until the 1 m depth contour was reached. The area within the net was adjusted as needed to ensure that boulders, large woody debris, and excessive (>75% submerged and/or >10% emergent) vegetation would not influence the efficacy of seining. The seine net was 15 m long, 1.2 m deep, with 8 mm mesh and attached to wooden poles. Two crew members approached each site being careful not to disturb the sampling area. The crew stood 5 m apart and allowed the net to settle to the bottom. While maintaining the 5 m spacing, the crews walked 10 m parallel to the shore keeping the net as close as possible to the bottom. At the end of the 10 m, the bottom of the net was quickly drawn up to the surface. Fish were removed from the net and placed in a bucket of water.

All fish captured 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.

Fish Habitat Assessments Habitat assessments were completed at each sampling location including measurements of variables relating to substrate, water quality, and instream cover. Visual estimates of substrate composition and cover were recorded (%).

In situ water quality variables including temperature, dissolved oxygen (DO), and conductivity were measured using a Hanna hand-held probe (temperature, conductivity, pH) and a LaMotte Winkler titration kit (DO) at each fish sampling location. For the hoopnets, water quality was measured at the time of set and the time of retrieval.

A depth profile of the lake was completed at the deepest location in the lake (approx. 30 m) as determined from published bathymetry (Prepas and Mitchell 1990). An YSI multimeter was used to measure temperature (ºC), dissolved oxygen (mg/L), and conductivity (µS/cm). Measurements were taken at 1 m intervals from the surface of the lake to the 20 m depth, then at 2 m intervals from depths between 20 m to 30 m.

Fish Assemblage Monitoring Program

Following a two-year pilot study conducted in 2009 and 2010, fish assemblage monitoring (FAM) in tributaries to the Athabasca and Clearwater rivers was incorporated into RAMP in 2011; 2012 was the second year of the monitoring program. The objective of this monitoring component was to evaluate fish assemblages in reaches where water quality, sediment quality and benthic invertebrate communities were also assessed. Accordingly, fish assemblage monitoring was conducted at all benthic invertebrate sampling reaches on tributaries surveyed in fall, 2012 (Table 3.1-18). The FAM study was conducted from September 5 to September 16, 2012 to assess changes in the fish assemblage of rivers that may potentially be influenced by focal projects.

The methods used to develop the FAM program for RAMP 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 RAMP FSA and outline protocols to collect measurements describing physical habitat, the fish community, water and sediment chemistry, and benthic invertebrate communities.

Table 3.1-18 Locations of reaches surveyed for the fish assemblage monitoring program, September 2012.

Watershed	Reach	Habitat Type	Reach Designation	UTM Coordinates (NAD 83, Zone 12)	
				Downstream Boundary	Upstream Boundary
Muskeg River	MUR-F1	erosional	*test*	463543 E / 6332450 N	463718 E / 6332499 N
	MUR-F2	depositional	*test*	466399 E / 6340037 N	466553 E / 6340424 N
	MUR-F3	depositional	*test*	479743 E / 6356818 N	479786 E / 6357048 N
Jackpine Creek	JAC-F1	depositional	*test*	472857 E / 6346559 N	472965 E / 6346495 N
	JAC-F2	depositional	*baseline*	480068 E / 6324970 N	480023 E / 6324916 N
Steepbank River	STR-F1	erosional	*test*	471251 E / 6320112 N	471515 E / 6320299 N
	STR-F2	erosional	*baseline*	499907 E / 6297577 N	500020 E / 6297611 N
Ells River	ELR-F1	depositional	*test*	459277 E / 6351314 N	458461 E / 6351403 N
	ELR-F2	erosional	*test*	455473 E / 6344969 N	455744 E / 6344924 N
	ELR-F2A	erosional	*baseline*	454470 E / 6343542 N	454458 E / 6343323 N
MacKay River	MAR-F1	erosional	*test*	461324 E / 6336203 N	461142 E / 6336410 N
	MAR-F2	erosional	*test*	449746 E / 6320158 N	449623 E / 6319969 N
	MAR-F3	erosional	*baseline*	444816 E / 6314082 N	444592 E / 6314057 N
Tar River	TAR-F1	depositional	*test*	458566 E / 6353567 N	458351 E / 6353416 N
	TAR-F2	erosional	*baseline*	440330 E / 6361738 N	440238 E / 6361804 N
Calumet River	CAR-F1	depositional	*test*	460802 E / 6363190 N	460648 E / 6363183 N
	CAR-F2[1]	depositional	*baseline*	454831 E / 6361829 N	-
High Hills River	HHR-F1	erosional	*baseline*	529931 E / 6289376 N	529884 E / 6289523 N
Christina River	CHR-F1	depositional	*test*	495882 E / 6280335 N	497734 E / 6278477 N
	CHR-F2	depositional	*baseline*	511761 E / 6192370 N	510842 E / 6192020 N
Jackfish River	JAR-F1	erosional	*test*	493789 E / 6169731 N	493973 E / 6169389 N
Sunday Creek	SUC-F1	depositional	*test*	506299 E / 6158407 N	506315 E / 6158289 N
Sawbones Creek	SAC-F1	depositional	*test*	511465 E / 6167189 N	511511 E / 6167316 N
Beaver River	BER-F2	depositional	*baseline*	465488 E / 6311280 N	465585 E / 6311111 N
Poplar Creek	POC-F1	depositional	*test*	472048 E / 6308166 N	472058 E / 6307891 N
Fort Creek	FOC-F1	depositional	*test*	461548 E / 6363109 N	461693 E / 6363060 N

[1] Downstream coordinate is the middle of a beaver impoundment. The upper Calumet River was not a defined channel.

Fish Sampling Each reach was approximately 20 times the wetted width, which was divided into five sub-reaches to assess variability within a reach. 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.

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 3.1-19);
- 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 3.1-20);
- Substrate (dominant and subdominant particle size) (Table 3.1-21);
- Bank slope (°);
- Bank height (m); and
- Large and small woody debris (count of debris in length/size classes).

In situ water quality variables including temperature, DO, and conductivity 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 3.1-19 Habitat type and code used for the fish assemblage monitoring program (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 3.1-20 Percent cover rating for instream and overhead cover at each transect used for the fish assemblage monitoring program (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 3.1-21 Substrate size class codes used for the fish assemblage monitoring program (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 2011

The 2012 monitoring activities for the Fish Populations component differed from those carried out in 2011 in the following ways:

- Fish assemblage reaches were added to the program based on the benthic sampling design; the program was expanded to include new *test* reaches on tributaries to the south of Fort McMurray (i.e., Jackfish River, and Sawbones and Sunday creeks), two reaches on the Christina River (*test* reaches CHR-F1 and CHR-F2), and two reaches on the Calumet River (*test* reach CAR-F1 and *baseline* reach CAR-F2);
- Given the three-year sampling rotation of the fish tissue sampling program, fish tissue sampling was conducted on the Clearwater River (last completed in 2009). There was no fish tissue sampling on the Athabasca River given that program was last conducted in 2011;
- A fish assemblage survey was conducted on Christina Lake for the first time by RAMP. The survey was undertaken in response to local community interest and increasing RAMP membership of companies surrounding the lake;
- The regional lakes fish tissue program was conducted on Gregoire Lake in fall 2012. This lake was previously sampled in 2002 and 2007; and
- Given the three-year sampling rotation, a lethal sentinel monitoring program for slimy sculpin was conducted in 2012. The program was last completed in 2009.

3.1.4.4 Challenges Encountered and Solutions Applied

During the fall fish assemblage monitoring program, high rain events caused water levels to increase in most tributaries. The higher water levels made it difficult to effectively backpack electrofish in a safe manner. Given these conditions, the capture success for the sentinel species and fish assemblage program was affected by difficulties in accessing the water column using an electrofisher. Despite the high water levels, all 2012 monitoring activities were completed successfully, although only a limited number of female northern pike from the 500 to 550 mm size class were captured during the Clearwater River fish tissue program. Male walleye of the target “female” size class were collected to supplement the target sample size.

3.1.4.5 Other Information Obtained

A pilot fish assemblage study was conducted at reaches in the Athabasca River Delta (ARD). The results of this study are presented in Section 6.0.

3.1.4.6 Summary of Component Data Now Available

Fish Populations component data collected to date by RAMP are summarized in Table 3.1-22.

Table 3.1-22 Summary of RAMP data available for the Fish Population component.

WATERBODY AND LOCATION	Site ID	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012			
		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	-3																																																										1	1	1		1	1	1
Poplar Area	0/1		1	1,5	1,5		1,6	1,5	1,3,6														1								1		1		1		1		1		1		1		1		1	1	1,6		1	1	1		1	1	1		1	1	1		1	1	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				6		1		1		1		1,6		1		1		1		1		1	1	1,6		1	1	1		1	1	1		1	1	1,6		1	1	1
Muskeg Area	10/11		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6				6		1		1		1		1,6		1		1		1		1		1	1	1,6		1	1	1		1	1	1		1	1	1,6		1	1	1
Tar-Ells Area	16/17		1	1,5	1,5		1,6	1	1,3,6									7					1								1		1		1		1		1		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	1
CNRL/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				10															3	3												3								
Reference site between STP and Suncor	ATR-2												1,3												3				10															3	3												3								
Downstream of Suncor's Discharge	ATR-3												1,3												10,3				10															3	3												3								
Below Muskeg River	ATR-4												1,3												10,3				10															3	3												3								
Downstream of Development (near Firebag River)	ATR-5																												10,6															3	3												3								
Athabasca River Delta																																																																	
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																																																																10
Embarras River	EMR-F2																																																																10
Athabasca River Tributaries (northern)																																																																	
Fort Creek (mouth)	FOC-F1														1,8,5,9	1																																													10				10
Poplar Creek (mouth)	POC-F1																																																				10								10				10
Beaver River (upper)	BER-F2																																																				10								10				10
Athabasca River Tributaries (southern)																																																																	
High Hills River (mouth)	HH-R/HHR-F1																																																				10								10				3,10
Clearwater River Reach	CR1																										1		1		1		1,6		1		1		1		1,6		1		1,6		1		1		1	1	1,6		1	1	1		1	1			1	1	1,6
Clearwater River Reach	CR2																										1		1		1				1				1		1,6		1		1,6		1		1		1	1	1,6		1	1	1		1	1			1	1	1,6
Clearwater River Reach	CR3																										1	10	1		1				1				1		1,6		1		1,6		1		1		1	1	1,6		1	1	1		1	1	1		1	1	1,6
Christina River (mouth)	CHR-F1																																																																10
Christina River (upstream of Janvier)[i]	CHR-F2																																1																																10
Jackfish River	JAR-F1																																																																10
Sunday Creek	SUC-F1																																																																10
Sawbones Creek	SAC-F1																																																																10
Ells River																																																																	
Upper Ells River[j,h]	ELR-F2A												1,3																		4		3		4		3							3	3												10				10				10
Middle Ells River	ELF-F2																																																															10
Lower Ells River[j,h]	ELF-F1												1,3																		4		3		4		3							3	3												10				10				10
MacKay River																																																																	
Lower reach (mouth) [j]	MAR-F1		1																				1					10			4																						10								10				10
Mid-River (upstream of Suncor MacKay)	MAR-F2																																																												10				10
Upper MacKay River reach	MAR-F3																																																												10				10
Horse and Dunkirk rivers	HR-R/DR-R																3				3												3							3	3											3	3,10												3
Tar River																																																																	
Lower Tar River	TAR-F1												1,3																																								10								10				10
Upper Tar River	TAR-F2												1,3																																																10				10
Calumet River																																																																	
Lower Calumet River	CAR-F1																																																																10
Upper Calumet River	CAR-F2																																																																10
Muskeg River																																																																	
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1												1,3						4		3		4		4		4						3						4	3	3										4	3	3,10				10				10				3,10
Lower 35 km below Jackpine Creek confluence	MUR-F2			1			4						1,3		2,8	2	2	2	2	1	6			1	6							1	6							1	6												10								10				10
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																						1,4		1,4																																				10				10
Muskeg River Tributaries																																																																	
Alands Drain																																																																	
Jackpine Creek (upper portion of the creek)	JAC-F2																																																				10				10				10				10
Jackpine Creek (accessable areas of lower creek)	JAC-F1														8					1				1								1																					10				10				10				10
Shelley Creek																																																																	
Muskeg Creek (Canterra road crossing)[e]																							1,4		1,4																																								
Stanley Creek																																																																	
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																																3							3	3											3	3,10				10				10				3,10
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												3																																
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2																																							3	3											3	3								10				3,10
Regionally-Important Lakes																																																																	
Christina Lake	CHL-F1																																																																10
Various lakes in water/air emissions pathway																													6				6											6	6				6				6				6								6

Legend

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)
2002-2012: 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

🟦 *Test* (downstream of focal projects)

🟩 *Baseline* (upstream of focal projects)

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. Needs to be done prior to Kearl Project.

[f] Located from 3 to 11 km upstream of the confluence with the Athabasca River.

[g] Reference site located approximately 21 km upstream of confluence with Athabasca River; sampling done by Environment Canada, NWRI, Burlington, Ontario

[h] 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.

[i] Reconaissance inventory carried out in the Christina River upstream and downstream of the Hwy 881 bridge crossing.

[j] In 2004 a fish fence reconnaissance was carried out on the Ells and MacKay rivers.

3.1.5 Acid-Sensitive Lakes Component

3.1.5.1 Overview of 2012 Monitoring Activities

The 2012 Acid-Sensitive Lakes (ASL) component consisted of monitoring 50 lakes and ponds within and beyond the RAMP study area for water quality variables in August, 2012. The location of each lake is presented in Figure 3.1-7. The 50 lakes are located in four physiographic regions:

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

The date of sampling and the UTM coordinates for each lake are presented in Table 3.1-23. The unique identification number listed in Table 3.1-23 is that ascribed to each lake by the NO_xSO_x Management Working Group (NSMWG) lake sensitivity mapping program (WRS 2004). The current AESRD name of each lake is also included in Table 3.1-23.

The sampling design for the ASL component reflects the natural geographic distribution of lakes within the study region, which limits the ability to apply a more statistically robust stratified sampling design. The 50 lakes represent a majority of the major lakes within the RAMP 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 lakes include a large number of small ponds that are less than 0.5 km^2 in area. Beaver ponds were not considered to be permanent lakes. Low alkalinity lakes are represented in the upland areas (Birch Mountains, Stony Mountains). Lakes to the northwest and northeast of the oils sands region in the Caribou Mountains and Canadian Shield are remote from emission sources of NO_xSO_x and were selected as *baseline* lakes.

Timing of Sampling

Sampling was conducted during the late summer, from August 14 to 31, 2012, 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 and the lake chemistry changes dramatically. Large decreases in pH and increases in Gran alkalinity are observed during the winter accompanied by low oxygen levels and high levels of sulphide (strong sulphide odour). In spring, the lakes recover from the low pH and high alkalinities as the water melts and oxygen is re-introduced. Detecting a decrease in pH or decrease in alkalinity in the spring during this recovery period was not possible in the CEMA/AESRD study. A more detailed study of the spring acid pulse phenomenon was initiated by RAMP in 2012 and the results are reported in Section 6.0.

Summary of Field Methods

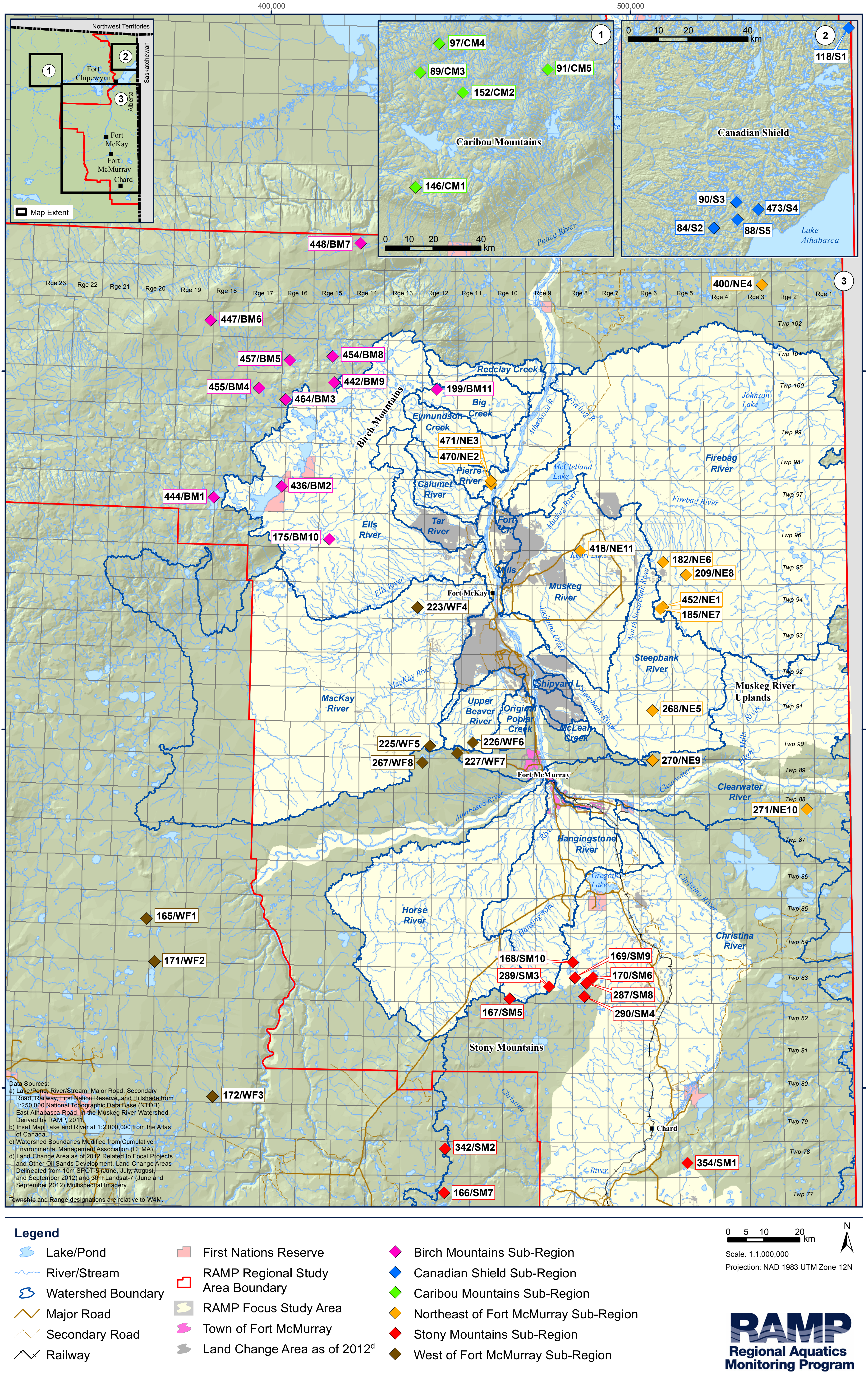
AESRD provided the sampling equipment and logistical support for the lake sampling. A float plane was used to access the majority of study lakes while a helicopter with floats was used to reach the smaller lakes. AESRD water quality sampling protocols were used as the basis for the field methods (AENV 2006). 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, temperature, conductivity, 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 were shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection, and analyzed for the water quality variables listed in Table 3.1-24.

One field blank was collected using de-ionized water from the Limnology Laboratory, University of Alberta. Three field replicates were sampled and analyzed by the University of Alberta laboratory. The field and quality control samples were analyzed for the water quality variables listed in Table 3.1-24 (Appendix B). The analytical methods for each water quality variable are described in the RAMP database available on the RAMP website.

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.

Figure 3.1-7 Locations of Acid-Sensitive Lakes sampled in 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_J_ASL_20130418.mxd

Table 3.1-23 Lakes sampled in 2012 for the Acid-Sensitive Lakes component.

Lake Identification			Lake Area (km^2)	UTM Coordinates (NAD83, Zone12)		Sampling Date month/day/year
Unique ID[1]	Original Name	AESRD Name		Easting	Northing	
Stony Mountains Sub-Region						
168	A21	SM 10	1.38	483819	6235130	08/30/12
169	A24	SM 9	1.45	484387	6230872	08/30/12
170	A26	SM 6	0.71	489502	6230877	08/30/12
167	A29	SM 5	1.05	466180	6224950	08/30/12
166	A86	SM 7	1.44	448014	6170896	08/30/12
287	25	SM 8	2.18	487594	6229281	08/30/12
289	27	SM 3	1.83	477248	6228400	08/30/12
290	28	SM 4	0.54	487068	6225576	08/30/12
342	82	SM 2	1.97	448271	6183205	08/30/12
354	94	SM 1	2.50	515689	6179207	08/30/12
Birch Mountains Sub-Region						
436	L18/Namur	BM 2	43.39	402704	6368016	08/31/12
442	L23/Otasan	BM 9	3.44	417321	6396959	08/31/12
444	L25/Legend	BM 1	16.80	383849	6364923	08/31/12
447	L28	BM 6	1.30	382996	6414339	08/31/12
448	L29/Clayton	BM 7	0.65	424694	6435790	08/28/12
454	L46/Bayard	BM 8	1.20	416941	6404239	08/31/12
455	L47	BM 4	4.37	396500	6395456	08/31/12
457	L49	BM 5	2.61	404995	6403111	08/31/12
464	L60	BM 3	0.91	403796	6392247	08/31/12
175	P13	BM 10	0.38	416003	6353212	08/14/12
199	P49	BM 11	2.61	446002	6394961	08/27/12
Northeast of Fort McMurray Sub-Region						
452	L4 (A-170)	NE 1	0.61	508990	6334305	08/27/12
470	L7	NE 2	0.33	515029	6327465	08/27/12
471	L8	NE 3	0.56	524390	6322556	08/27/12
400	L39/E9/A-150	NE 4	1.12	536495	6424234	08/29/12
268	E15	NE 5	1.87	506092	6305335	08/27/12
182	P23	NE 6	0.28	509000	6346712	08/14/12
185	P27	NE 7	0.09	508300	6333712	08/14/12
209	P7	NE 8	0.15	515399	6343212	08/14/12
270	4	NE 9	3.44	506113	6291421	08/27/12
271	6	NE 10	4.31	549064	6277789	08/27/12
418	Kearl	NE 11	5.34	485939	6349881	08/27/12
West of Fort McMurray Sub-Region						
165	A42	WF 1	3.20	365015	6247322	08/30/12
171	A47	WF 2	0.47	367321	6235430	08/30/12
172	A59	WF 3	2.06	383467	6197733	08/30/12
223	P94	WF 4	0.03	440557	6334112	08/14/12
225	P96	WF 5	0.21	444002	6295513	08/14/12
226	P97	WF 6	0.16	456002	6296463	08/14/12
227	P98	WF 7	0.08	451762	6293513	08/14/12
267	1	WF 8	2.22	441917	6290884	08/30/12
Caribou Mountains Sub-Region						
146	E52/ Fleming	CM 1	1.60	243692	6522556	08/28/12
91	O-1/E55	CM 5	2.70	298955	6571856	08/28/12
97	O-2/E67	CM 4	0.56	253582	6582654	08/28/12
152	E59/Rocky I.	CM 2	9.53	263546	6562225	08/28/12
89	E68 Whitesand	CM 3	2.46	245596	6570610	08/28/12
Canadian Shield Sub-Region						
473	A301	S 4	1.40	525150	6559733	08/29/12
118	L107/Weekes	S 1	3.73	555469	6620456	08/29/12
84	L109/Fletcher	S 2	1.29	510321	6553552	08/29/12
88	O-10	S 5	0.70	518279	6556260	08/29/12
90	R1	S 3	0.55	517889	6562197	08/29/12

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

Table 3.1-24 Water quality variables analyzed in 2012 in lake water sampled for the Acid-Sensitive Lakes component.

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

3.1.5.2 Changes in Monitoring Network from 2012

All 50 lakes were sampled in 2012. There was no change in sampling design or its implementation.

3.1.5.3 Challenges Encountered and Solutions Applied

There were no exceptional challenges encountered in implementing the ASL field program in 2012.

3.1.5.4 Other Information Obtained

AESRD collected additional water samples for metals analyses from each ASL component lake surveyed during the 2012 field season (Table 3.1-23). These water samples were sent to Alberta Innovates Technology Futures (AITF), Vegerville, Alberta for analysis of the total and dissolved fractions of the metals listed in Table 3.1-25. The results of the metals analyses are reported in Appendix F. For the first time in 2012, samples for low level mercury were collected and reported.

Table 3.1-25 Metals analyzed in 2012 in lake water sampled for the Acid-Sensitive Lakes component.

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

3.1.5.5 Summary of Component Data Now Available

The selection of lakes sampled during the fourteen years of the ASL component is summarized in Table 3.1-26.

Table 3.1-26 Summary of lakes sampled for the Acid-Sensitive Lakes component, 1999 to 2012.

NO$_x$SO$_x$ GIS No.	Original RAMP Designation	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
168	A21	+	+	+	+	+	+	+	+	+	+	+	+	+	+
169	A24	+	+	+	+	+	+	+	+	+	+	+	+	+	+
170	A26	+	+	+	+	+	+	+	+	+	+	+	+	+	+
167	A29	+	+	+	+	+	+	+	+	+	+	+	+	+	+
166	A86	+	+		+	+	+	+	+	+	+	+	+	+	+
287	25 (287)				+	+	+	+	+	+	+	+	+	+	+
289	27 (289)				+	+	+	+	+	+	+	+	+	+	+
290	28 (290)				+	+	+	+	+	+	+	+	+	+	+
342	82 (342)				+	+	+	+	+	+	+	+	+	+	+
354	94 (354)				+	+	+	+	+	+	+	+	+	+	+
165	A42	+	+	+	+	+	+	+	+	+	+	+	+	+	+
171	A47	+	+	+	+	+	+	+	+	+	+	+	+	+	+
172	A59	+	+	+	+	+	+	+	+	+	+	+	+	+	+
223	P94 (223)				+	+	+	+	+	+	+	+	+	+	+
225	P96 (225)				+	+	+	+	+	+	+	+	+	+	+
226	P97 (226)				+	+	+	+	+	+	+	+	+	+	+
227	P98 (227)				+	+	+	+	+	+	+	+	+	+	+
267	1 (267)				+	+	+	+	+	+		+	+	+	+
452	L4	+	+	+	+	+	+	+	+	+	+	+	+	+	+
470	L7	+	+	+	+	+	+	+	+	+	+	+	+	+	+
471	L8	+	+	+	+	+	+	+	+	+	+	+	+	+	+
400	L39	+	+	+	+	+	+	+	+	+	+	+	+	+	+
268	E15 (268)		+	+	+	+	+	+	+	+	+	+	+	+	+
182	P23 (182)				+	+	+	+	+	+	+	+	+	+	+
185	P27 (185)				+	+	+	+	+	+	+	+	+	+	+
209	P7 (209)				+	+	+	+	+	+	+	+	+	+	+
270	4 (270)				+	+	+	+	+	+	+	+	+	+	+
271	6 (271)				+	+	+	+	+	+	+	+	+	+	+
418	Kearl Lake					+	+	+	+	+	+	+	+	+	+
+436	L18 Namur	+	+	+	+	+	+	+	+	+	+	+	+	+	+
442	L23 Otasan	+	+	+	+	+	+	+	+	+	+	+	+	+	+
444	L25 Legend	+	+	+	+	+	+	+	+	+	+	+	+	+	+
447	L28	+	+	+	+	+	+	+	+	+	+	+	+	+	+
448	L29 Clayton	+		+	+	+	+	+	+	+	+	+	+	+	+
454	L46 Bayard	+	+	+	+	+	+	+	+	+	+	+	+	+	+
455	L47	+	+	+	+	+	+	+	+	+	+	+	+	+	+
457	L49	+	+	+	+	+	+	+	+	+	+	+	+	+	+
464	L60	+	+	+	+	+	+	+	+	+	+	+	+	+	+
175	P13 (175)				+	+	+	+	+	+	+	+	+	+	+
199	P49 (199)				+	+	+	+	+	+	+	+	+	+	+
473	A301			+	+	+	+	+	+		+	+	+	+	+
118	L107 Weekes		+	+	+	+	+	+	+	+	+	+	+	+	+
84	L109 Fletcher	+	+	+	+	+	+	+	+	+	+	+	+	+	+
88	O-10	+	+	+	+	+	+	+	+		+	+	+	+	+
90	R1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
146	E52 Fleming	+	+	+	+	+	+	+	+	+	+	+	+	+	+
152	E59 Rocky Is.	+	+	+	+	+	+	+	+	+	+	+	+	+	+
89	E68 Whitesand		+	+	+	+	+	+	+	+	+	+	+	+	+
91	O-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
97	O-2	+	+	+	+	+	+	+	+	+	+	+	+	+	+
428	L1	+													
83	O3/E64	+													
85	R2	+													
86	R3	+													
310	A300			+											

3.2 ANALYTICAL APPROACH

A weight-of-evidence approach is used for the analysis of RAMP 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 RAMP 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 spatially;
- A comparison of the monitoring data to published guidelines to assess whether any exceedances in variables measured have occurred;
- A comparison of the 2012 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 RAMP Technical Design and Rationale document (RAMP 2009b) outlines the following measurement endpoints to be used in the water balance analysis of the hydrologic data:

- Mean open-water season (May 1, 2012 to October 31, 2012) discharge;
- Mean winter (November 1, 2011 to March 31, 2012) discharge;
- Annual maximum daily (November 1, 2011 to October 31, 2012) discharge; and
- Open-water season minimum daily discharge.

These measurement endpoints are hydrologic measurement endpoints used in various oil sands project EIAs (RAMP 2009b) that can be computed from one year of data, and were selected for the analysis of the 2012 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 climate and hydrometric station, records for the 2012 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 RAMP FSA. 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 is provided when describing the temporal context of the 2012 WY observations and calculated *baseline* conditions using the EDA approach.

3.2.1.3 Comparison to *Baseline* Conditions

The 2012 hydrologic data were analyzed using a water balance approach consistent with previous analytical methods from 2004 to 2011. The water balance approach was used to develop *baseline* and *test* hydrographs for each watershed with focal projects. 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 focal projects. This approach identified the influence of focal projects on the 2012 hydrograph. Additional details regarding this analytical approach are found in RAMP (2008) and Appendix C of this report.

The RAMP 2012 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 2.7, Aquatic Informatics ™);
- estimating the 2012 *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*) scenarios.

Estimation of 2012 Baseline Hydrograph

The 2012 WY *baseline* hydrographs were defined for this analysis as the hydrographs that would have been observed in the 2012 WY had there been no focal projects in the watershed. Additional influences may be incorporated in the 2012 WY *baseline* hydrograph due to development activities from other oil sands developments in the watershed. Therefore, the *baseline* hydrograph was derived for the purpose of assessing any change due to focal projects, and should not be considered as a fully naturalized hydrograph. The equation provided below describes the method used to calculate the 2012 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 2012 WY;

Q_{obs} is the *test* hydrograph which was observed in the 2012 WY;

Q_w are the focal project withdrawals from the watercourse;

Q_r are the focal project releases to the watercourse;

Q_{HI} is the natural runoff that would have occurred in the watershed, but was intercepted or closed-circuited by focal projects in the 2012 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 in the RAMP FSA. 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, the Climate and Hydrology Component subgroup under the RAMP Technical Program Committee established that this approach would assume 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 4 years after harvesting indicated minor increases in annual runoff from the Rocky Creek watershed" (AENV 2000). Within the RAMP FSA, 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 are cleared and contributing is 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.

- The RAMP Climate and Hydrology Component subgroup under the RAMP Technical Program Committee will continue to assess the 20% assumption in light of current/available research.

The Climate and Hydrology Component subgroup under the RAMP Technical Program Committee is currently investigating additional hydrologic indicators that could further describe regional hydrologic flow conditions including methods to assess potential changes in timing and frequency of flow conditions. These methods require considerable hydrometric record lengths. This approach is; therefore, being evaluated for locations where the record length is approaching the requirements of the methodologies under investigation. The water balance approach, as described above, is applicable for all stations within the RAMP FSA with 2012 WY flow records and associated land use and industrial flow data. The water balance approach thereby provides a consistent approach for the 2012 WY for all watersheds in the RAMP FSA.

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).

3.2.2 Water Quality Component

The analytical approach used in 2012 for the Water Quality component 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 2012 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 2003a);
- 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
- discussions within the RAMP Technical Program Committee about:
    - the importance of various water quality variables to assist in interpreting results of the Benthic Invertebrate Communities and the Fish Populations components; and
    - appropriate analytical strategies for the Water Quality component.

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

Table 3.2-1 Potential water quality measurement endpoints.

Group	RAMP (2009b) Variables Listed in EIAs	CEMA Variables of Concern (CEMA 2004a)	RAMP 5-year Report (Golder 2003a)	Variables to Support Other RAMP 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)
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 RAMP except those in **bold**.

Note: RAMP 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 2012 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 focal projects 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 2003a). 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 RAMP FSA (RAMP 2004) and which 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 to RAMP water quality 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 the 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 fall data using the program WQStat Plus, with a level of significance of α=0.05. Values were not flow-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 RAMP sampling (1997 to 2012), to assess trends potentially related to development between the two stations during this time period.

Ion Balance

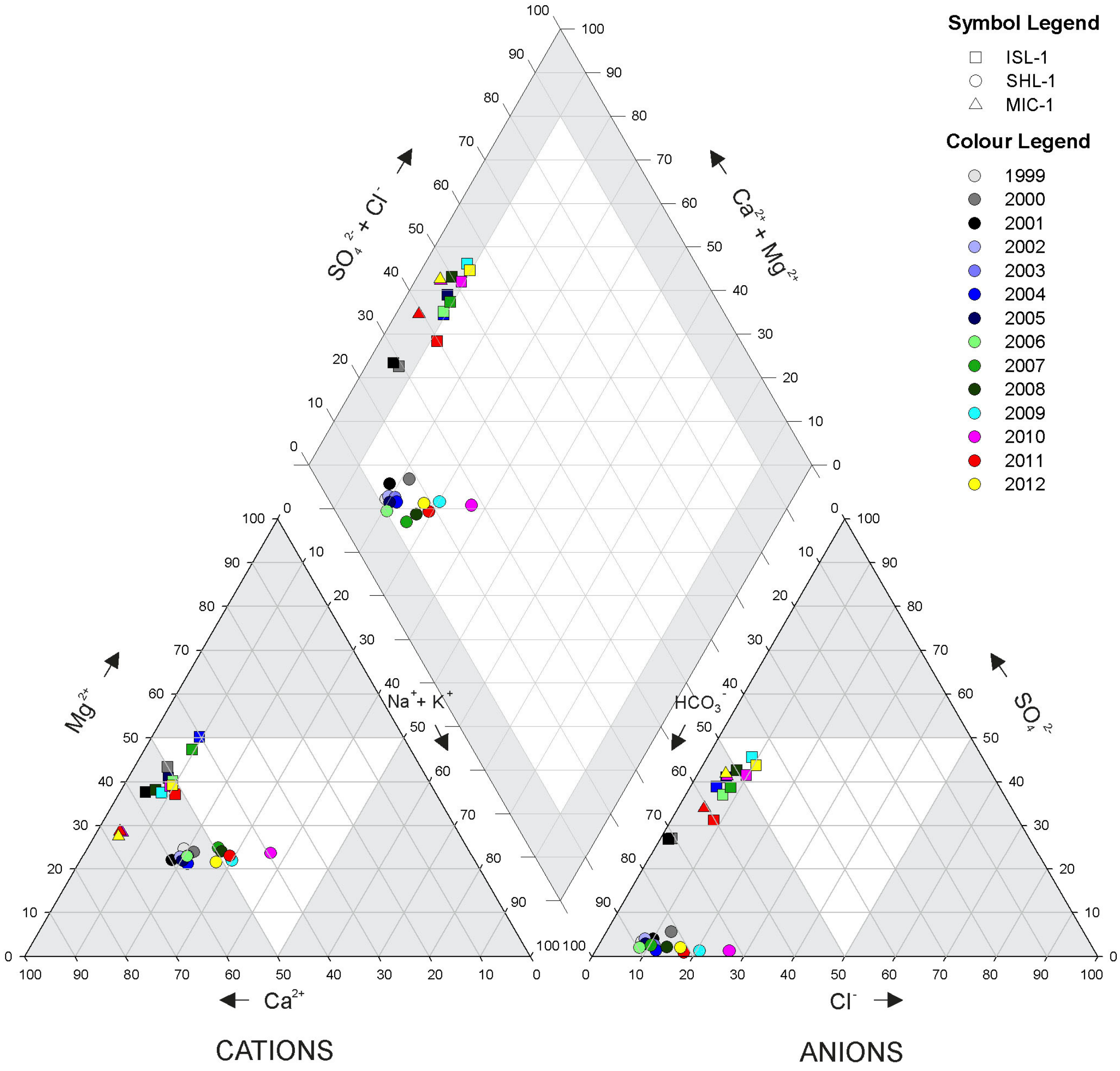
Piper diagrams were used to examine ion balance at each station or at multiple stations within a watershed, to assess temporal or spatial differences in the ionic composition of water. Piper diagrams display the relative concentrations of major cations and anions on two separate ternary (triangular) 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 fall 2012 value 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 2012 (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 2012.

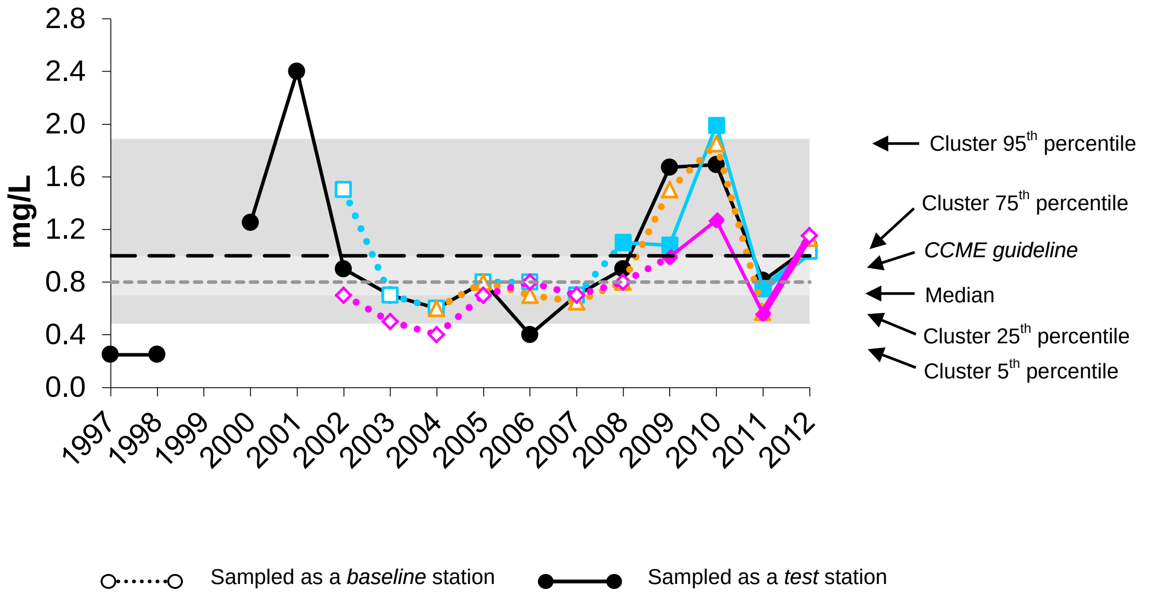


Comparison to Regional Baseline Concentrations

To allow for a regional comparison, untransformed data for 14 of the 21 water quality measurement endpoints from all *baseline* stations sampled by RAMP from 1997 to 2012 (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 (Figure 3.2-2, Table 3.2-2, Table 3.2-3, Table 3.2-4). The number of observations varied by cluster for each of the fourteen selected water quality measurement endpoints (Table 3.2-3). 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 by the RAMP Water Quality Component in 2012, 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 the fifteen 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 by RAMP 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 RAMP data from a specific watershed against regional *baseline* concentrations and water quality guidelines, in this case, total nitrogen in the Steepbank River watershed.



Development of Regional *Baseline* Concentrations Descriptions of regional *baseline* water quality conditions were developed from existing data collected by RAMP 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 2012, 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 RAMP Benthic Invertebrate Communities component, and incorporates elements of control charting (Morrison 2008), which also is a feature of the RAMP 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% 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 RAMP *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 2012, cluster analysis confirmed overall patterns previously seen in the data: stations generally group together based on geographical location rather than sampling year. However, since the inclusion of data from 2011 and 2012, these clearly defined regional clusters have become less well defined, perhaps due to the historically dry and wet conditions experienced at several RAMP stations in the two most recent years. Rank and scale transformations of the data produced different cluster memberships for approximately 20% of the stations, suggesting that clustering based on water quality data—especially within tributaries—was based on weak relationships, likely due to the large amount of variability present in the data. 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, 2. Eastern Tributaries, and 3. Western and Southern Tributaries. Stations included in each group of *baseline* data, and those compared against these groups, appear in Table 3.2-2. Ranges of regional *baseline* values calculated for each group of stations and used for comparisons appear 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]	*Test* Stations (2012) Compared Against Regional *Baseline*
1. Athabasca	ATR-DC-CC, ATR-DC-E, ATR-DC-M, ATR-DC-W	ATR-DC-E, ATR-DC-W, ATR-SR-E, ATR-SR-W, ATR-MR-E, ATR-MR-W, ATR-DD-E, ATR-DD-W
2. Southern and western tributaries, McLean Creek, and Mills Creek	BER-2, BIC-1, CAR-1, CAR-2, CLR-1, CLR-2, DUR-1, ELR-1, ELR-2, ELR-2A, EYC-1, HHR-1, HAR-1[2], HOR-1, MAR-1, MAR-2, PIR-1, RCC-1, TAR-1, TAR-2	BER-1, BER-2, BIC-1, CAR-1, CAR-2, CHR-1, CHR-2, CLR-1, CLR-2, ELR-1, ELR-2, ELR-2A, EYC-1, HHR-1, JAR-1, MAR-1, MAR-2, MAR-2A, PIR-1, POC-1, REC-1, SAC-1, SUC-1, TAR-1, TAR-2
3. Eastern tributaries, Muskeg River, and Steepbank River	FIR-2, FOC-1, IYC-1, JAC-1, JAC-2, MUC-1, MUR-6, NSR-1, SCH-1, STC-1, STR-2, STR-3, WAC-1	FIR-1, FIR-2, FOC-1, IYC-1, JAC-1, JAC-2, MCC-1, MIC-1, MUC-1, MUR-1, MUR-6, NSR-1, STC-1, STR-1, STR-2, STR-3, WAC-1

[1] See Table 3.1-6 for classification of station status by year. Where station status changed from *baseline* to *test* during 1997 to 2012, only *baseline* data were used in the determination of regional water quality characteristics.

[2] Station classified as *baseline* due to no focal projects upstream, but excluded from regional *baseline* range calculations due to other oil sands developments in upstream watershed.

Table 3.2-3 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2012, Group 1 Athabasca River.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	36	7.70	7.85	8.08	8.19	8.21	8.32	8.40
Total suspended solids	36	3.00	3.00	10.0	16.0	23.0	92.3	136
Conductivity	36	202	204	232	269	291	324	366
Nutrients								
Total dissolved phosphorus	36	0.003	0.005	0.007	0.011	0.018	0.028	0.030
Total nitrogen	36	0.250	0.288	0.451	0.500	0.700	0.808	0.901
Nitrate+nitrite	36	0.050	0.050	0.071	0.100	0.100	0.100	0.290
Dissolved organic carbon	36	1.50	2.88	5.80	7.00	9.63	14.5	17.1
Ions								
Sodium	36	8.00	8.50	9.75	11.5	17.0	21.4	28.0
Calcium	36	17.7	18.7	23.8	31.5	33.8	39.7	43.6
Magnesium	36	5.49	5.73	7.03	8.53	9.48	11.3	12.3
Chloride	36	1.86	2.00	3.00	6.00	17.3	25.0	36.0
Sulphate	36	5.67	6.48	11.3	24.1	29.1	38.0	50.2
Potassium	36	0.75	0.8	0.855	1.00	1.16	1.40	1.40
Total dissolved solids	36	40.0	87.5	155	168	179	240	282
Total alkalinity	36	62.9	68.3	84.0	99.5	110	126	145
Selected metals								
Total aluminum	36	0.030	0.138	0.423	0.568	1.12	2.27	3.76
Dissolved aluminum	36	0.006	0.007	0.010	0.012	0.029	0.123	1.10
Total arsenic	36	0.000	0.001	0.001	0.001	0.001	0.001	0.0017
Total boron	36	0.014	0.017	0.021	0.025	0.032	0.040	0.045
Total molybdenum	36	0.000	0.000	0.000	0.001	0.001	0.001	0.0011
Total mercury (ultra-trace)	25	0.600	1.20	1.20	1.20	2.00	5.62	12.9
Total strontium	36	0.090	0.097	0.134	0.201	0.254	0.288	0.295

Table 3.2-4 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2012, Group 2 southern/western tributaries.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	76	7.20	7.60	7.94	8.10	8.22	8.36	8.41
Total suspended solids	76	2.00	3.00	3.00	7.00	21.0	79.5	208
Conductivity	76	79.7	157	206	260	450	644	772
Nutrients								
Total dissolved phosphorus	76	0.004	0.008	0.017	0.026	0.056	0.122	0.305
Total nitrogen	76	0.300	0.389	0.543	0.961	1.4235	2.511	5.541
Nitrate+nitrite	76	0.050	0.066	0.071	0.071	0.100	0.100	0.100
Dissolved organic carbon	76	6.00	7.00	13.0	20.5	31.3	47.3	54.4
Ions								
Sodium	76	3.00	7.35	11.00	15.0	26.4	69.0	76.0
Calcium	76	10.0	11.7	21.7	29.7	44.9	63.7	68.6
Magnesium	76	2.86	4.05	6.90	9.37	13.8	20.5	26.6
Chloride	76	0.500	0.500	0.975	2.00	15.5	34.5	43.0
Sulphate	76	0.500	3.29	8.00	15.5	32.4	62.4	119
Potassium	76	0.500	0.600	0.900	1.20	2.19	3.63	5.00
Total dissolved solids	76	40.0	113	157	201	310	468	547
Total alkalinity	76	29.8	43.5	84.8	117	197	287	337
Selected metals								
Total aluminum	76	0.020	0.046	0.128	0.245	0.500	2.270	5.000
Dissolved aluminum	76	0.001	0.002	0.007	0.015	0.025	0.052	0.185
Total arsenic	76	0.0002	0.0005	0.0008	0.0010	0.0014	0.0027	0.0050
Total boron	76	0.014	0.023	0.046	0.062	0.088	0.150	0.424
Total molybdenum	76	0.0001	0.0001	0.0002	0.0005	0.0008	0.0015	0.0025
Total mercury (ultra-trace)	65	0.60	0.80	1.20	1.20	2.00	8.36	13.70
Total strontium	76	0.051	0.065	0.106	0.141	0.196	0.290	0.356

Table 3.2-5 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2012, Group 3 eastern tributaries.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	79	7.16	7.40	7.83	8.00	8.20	8.30	8.46
Total suspended solids	79	3.00	3.00	3.00	4.00	8.00	23.2	243
Conductivity	79	110	137	183	228	312	526	1,172
Nutrients								
Total dissolved phosphorus	80	0.006	0.011	0.014	0.020	0.034	0.061	0.096
Total nitrogen	79	0.300	0.490	0.700	0.800	1.00	1.67	3.90
Nitrate+nitrite	80	0.050	0.050	0.100	0.100	0.100	0.100	0.100
Dissolved organic carbon	79	6.00	10.8	15.0	20.0	24.0	29.1	33.0
Ions								
Sodium	79	2.00	2.90	4.00	8.00	12.0	23.1	96.2
Calcium	79	16.4	17.9	23.0	30.0	44.8	72.0	83.5
Magnesium	79	4.90	5.37	6.90	8.80	14.0	18.0	25.1
Chloride	79	0.500	0.500	1.00	2.00	2.00	4.16	80.2
Sulphate	79	0.500	0.828	1.90	3.00	4.60	8.08	22.6
Potassium	79	0.300	0.500	0.510	0.800	1.00	1.71	3.10
Total dissolved solids	79	109	110	150	180	234	331	500
Total alkalinity	79	55.0	67.6	93.0	114	180	289	354
Selected metals								
Total aluminum	80	0.007	0.015	0.029	0.050	0.090	0.539	2.84
Dissolved aluminum	80	0.001	0.002	0.005	0.009	0.013	0.044	0.170
Total arsenic	80	0.0001	0.0003	0.0005	0.0006	0.0010	0.0010	0.0016
Total boron	80	0.006	0.010	0.015	0.032	0.054	0.115	0.169
Total molybdenum	80	0.00003	0.00004	0.00010	0.00012	0.00020	0.00030	0.00640
Total mercury (ultra-trace)	54	0.600	1.13	1.20	1.20	1.20	2.58	8.80
Total strontium	80	0.028	0.048	0.069	0.090	0.122	0.201	0.435

3.2.2.3 Classification of Results

The following criteria were used for assess water quality results:

- **Trend Analysis**: Any significant ($\alpha=0.05$) trends over time in water quality measurement endpoints.
- **Comparison to Historical Concentrations**: Fall 2012 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 by RAMP in 2012 in any season were screened against Alberta acute and chronic water quality guidelines for the protection of aquatic life (AENV 1999b) 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**: 2012 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 RAMP monitoring station in fall 2012 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 to RAMP is described below.

Index calculations for RAMP 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 RAMP 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 by RAMP in fall since 1997 (n=574) yielded index values ranging from 41.3 to 100.0. It should be noted that historical index values calculated for specific observations may change annually, given 95th percentile values for individual variables included in the index may change with addition of new *baseline* data to the RAMP 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 RAMP components. A classification of a "Negligible-Low" difference from *baseline,* corresponds with CCME guideline-based index classes "Good" and "Excellent"; RAMP classification of a "Moderate" difference from *baseline* generally corresponds with CCME class "Fair"; and RAMP 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, as is done by RAMP, 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 (i.e., McClelland, Kearl, Isadore's, Shipyard, Johnson 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 by the RAMP Water Quality Component, 2012.

Water Quality Variable	Units	AESRD[b]		CCME[a]	Other Jurisdictions[c]
		Acute	Chronic		
Conventional variables		-	-	-	-
pH	pH units	-	-	6.5 to 9.0	-
Dissolved oxygen	mg/L	5.0 (min)	6.5 (7-day mean)[j]	5.5 to 9.5[k]	-
Temperature	°C	-	-	-	-
Suspended Solids	mg/L	-	> 10 mg/L[o]	-	-
Turbidity	NTU	-	-	-	-
Major ions		-	-	-	-
Sulphate	mg/L	-	-	-	100[c]
Sulphide (as H_2S)	mg/L	-	-	-	0.002[c]
Chloride (Cl)	mg/L	-	-	120	230 (BC), 860 (USEPA)
Nutrients		-	-	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-
Ammonia	mg/L	-	-	0.043 to 153[j]	-
Nitrate-N	mg/L	-	-	13	-
Nitrite-N	mg/L	-	-	0.060	-
Total Nitrogen	mg/L	-	1.0	-	-
Total Dissolved Phosphorus	mg/L	-	-	-	-
Total Phosphorus	mg/L	-	0.05	-	-
Organics		-	-	-	-
Total phenols	mg/L	-	0.005	0.0040	0.05[n]
Naphthenic acids	mg/L	-	-	-	-
Total and dissolved metals					
Aluminum (Al)	mg/L	-	-	0.005, 0.1[d]	0.05 (dissolved)[l]
Antimony (Sb)	mg/L	-	-	-	0.023
Arsenic (As)	mg/L	-	-	0.0050	-
Barium (Ba)	mg/L	-	-	-	5[c]
Beryllium (Be)	mg/L	-	-	-	-
Bismuth (Bi)	mg/L	-	-	-	-
Boron (B)	mg/L	-	-	-	1.2[c]
Cadmium (Cd)	mg/L	-	-	0.000017[e]	-
Calcium (Ca)	mg/L	-	-	-	-
Chromium III (Cr^{3+})	mg/L	-	-	0.0089	-
Chromium VI (Cr^{6+})	mg/L	-	-	0.0010	-
Cobalt (Co)	mg/L	-	-	-	0.11[c]
Copper (Cu)	mg/L	-	-	0.002 to 0.004[f]	-
Iron (Fe)	mg/L	-	-	0.300	-
Lead (Pb)	mg/L	-	-	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	-	-
Molybdenum (Mo)	mg/L	-	-	0.073	-
Nickel (Ni)	mg/L	-	-	0.025 to 0.150[i]	-
Phosphorus (P)	mg/L	-	-	-	-
Potassium (K)	mg/L	-	-	-	-
Selenium (Se)	mg/L	-	-	0.0010	-
Silver (Ag)	mg/L	-	-	0.0001	-
Sodium (Na)	mg/L	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-
Sulphur (S)	mg/L	-	-	-	-
Thallium (Tl)	mg/L	-	-	0.0008	-
Tin (Sn)	mg/L	-	-	-	-
Titanium (Ti)	mg/L	-	-	-	0.1[c]
Uranium (U)	mg/L	0.033	0.15	-	-
Vanadium (V)	mg/L	-	-	-	-
Zinc (Zn)	mg/L	-	-	0.030	-
Polycyclic Aromatic Hydrocarbons (PAHs)					**[BC Chronic]**
Acenaphthene	ng/L	-	-	5800	6000
Anthracene	ng/L	-	-	12	4000
Benzo(a)anthracene	ng/L	-	-	18	100
Benzo(a)pyrene	ng/L	-	-	15	10
Fluoranthene	ng/L	-	-	40	4000
Fluorene	ng/L	-	-	3000	12000
Naphthalene	ng/L	-	-	1100	1000
Phenanthrene	ng/L	-	-	400	300
Pyrene	ng/L	-	-	25	-

a: CCME (2011).

b: AENV (1999b).

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

d: 0.005 at pH<6.5; $[Ca^{2+}]$<4 mg/L; DOC<2 mg/L; 0.100 at pH>=6.5; $[Ca^{2+}]$>=4 mg/L; DOC>=2 mg/L

e: Hardness-dependant. Guideline = $10^{(0.86[\log(\text{hardness})]-3.2)}$/1000

f: Hardness-dependant. Guideline = $10^{(0.8545*[\ln(\text{hardness})]-1.465)}$/1000. 0.002 at $[CaCO_3]$=0 to 120 mg/L; 0.003 at $[CaCO_3]$=120 to 180 mg/L; 0.004 at $[CaCO_3]$>180 mg/L

g: Hardness-dependant. Guideline = $10^{(1.273*[\ln(\text{hardness})]-4.705)}$/1000. 0.001 at $[CaCO_3]$=0 to 60 mg/L; 0.002 at $[CaCO_3]$=60 to 120 mg/L; 0.004 at $[CaCO_3]$=120 to 180 mg/L

h: for inorganic mercury

i: Hardness-dependant. Guideline = $10^{(0.76*[\ln(\text{hardness})]+1.06)}$/1000. 0.025 at $[CaCO_3]$=0 to 60 mg/L; 0.065 at $[CaCO_3]$=60 to 120 mg/L; 0.110 at $[CaCO_3]$=120 to 180 mg/L; 0.150 at $[CaCO_3]$>180 mg/L

j: Guidelines for total ammonia are temperature and pH dependent; see CCME (2007) 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 $e^{1.6-3.327*\text{median } pH+0.402*pH2}$

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

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

o: Concentration should not be increased by more than 10 mg/L over background value.

3.2.3 Benthic Invertebrate Communities and Sediment Quality

3.2.3.1 Benthic Invertebrate Communities Component

The analytical approach used in 2012 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 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; and
    - control charts to indicate when a reach was shifting from *baseline* conditions;
- 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:

- Abundance (total number of individuals/m^2);
- Taxon richness (number of distinct taxa);
- Simpson's Diversity Index (D), where

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

  and p_i is the proportion that taxon i contributes to the total number of invertebrates in a sample;
- 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 that 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 computed for all RAMP 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. 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 hypothesis:

- H_1: No time trend in mean values of measurement endpoints during the period of sampling.

RAMP has collected data for some reaches, such as lower Jackpine Creek (JAC-D1), during both the *baseline* period for that reach and now when it is classified as a *test* reach. For those reaches, linear contrasts were developed that test the following null hypotheses:

- H_2: No change in mean values of measurement endpoints from before to after exposure to oil sands development.

Where a *test* reach can also be compared with an upstream *baseline* reach, evidence of an effect is derived as a change in the difference of a measurement endpoint between *test* and *baseline* reaches, from before to after exposure to oil sands development. Linear contrasts were thus used to test the following specific hypotheses where the data allowed:

- H_3: No change from before to after exposure in the difference between *baseline* and *test* reach in mean values of a measurement endpoints.

- H_4: No change in time trends during the period of exposure to oil sands development.

For completeness, additional analyses were carried out to determine changes in the current year of data, 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. The current year data were also compared to the mean of all historical data for that reach.

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, Simpson's Diversity, and percent EPT and an increase in equitability, would each be considered a negative change or difference. An increase or decrease in abundance could be considered a positive or negative change. Excessively high abundances (i.e., on the order of 100's of thousands of organisms per m^2) 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 RAMP benthic data has suggested that changes are more easily interpreted when the change accounts for at least 20% of the variation, so that additional criterion was used to identify interpretable changes.

Comparison to Published Literature

There are no conventional "guidelines" *per se* against which to judge observed differences in measurement endpoints of benthic invertebrate communities given *baseline* ranges of variation tend to depend on local or regional climatic, hydrological, and geological conditions. The RAMP *baseline* reach database and published literature; therefore, provides (de facto) the most appropriate set of regional *baseline* conditions and information against which to assess differences observed in *test* reaches.

Determination of Regional Baseline Conditions

Regional *baseline* conditions were defined as the range of variability for measurement endpoints across all *baseline* reaches. The range of variability was used for benchmarks in control charts as part of the assessment of measurement endpoints of benthic invertebrate community.

Control charts are conventionally used in the assessment of industrial process using the following general rules of thumb which indicate when a process is "out of control": (i) two sequential observations falling outside of $\bar{x} \pm 2SD$; (ii) four sequential observations falling outside of $\bar{x} \pm 1SD$; and (iii) a trend over time in the last six observations (Westgard et al. 1981).

In this assessment, the range of conditions was estimated using the data obtained from *baseline* reaches unexposed to oil sands development. Control charts were established separately for erosional and depositional reaches. Exploratory analysis has not identified any variable (apart from habitat class) as explaining substantial variation in temporal or spatial variation in measurement endpoints of benthic invertebrate communities, justifying the development of control charts for erosional and deposition reaches (RAMP 2009b). The lack of influence of other physical stream variables on composition was in large measure because baseline reaches were generally large tributaries.

Visual inspection of box and normal probability plots indicated that some measurement endpoints (reach means) were non-normally distributed among *baseline* reaches. The condition for *baseline* reach means was estimated; 5th and 95th percentiles as surrogates for $\overline{x} \pm 2SD$, and 25th and 75th percentiles as surrogates for $\overline{x} \pm 1SD$ (e.g., Figure 3.2-3). For the univariate measures, abundance, richness, Simpson's Diversity, equitability, and percent EPT, these ranges were developed for the individual measurement endpoints within both erosional and deposition habitat classes. The multivariate CA axis scores were treated somewhat differently. Biplots of *baseline* reach scores were generated within SYSTAT , which was also used to generate 1%, 5%, 25%, 50%, 75%, 95% and 99% ellipses (Figure 3.2-4). These ellipses were used to judge whether a reach was "in control" using the "rules of thumb". A test of time trends over the past six years for *test* reaches was computed using the Euclidean distances to the centroid of the *baseline* reach ellipse.

Figure 3.2-3 Example time trend chart for benthic invertebrate community taxa richness in relation to regional *baseline* conditions, in this case, for depositional reaches.

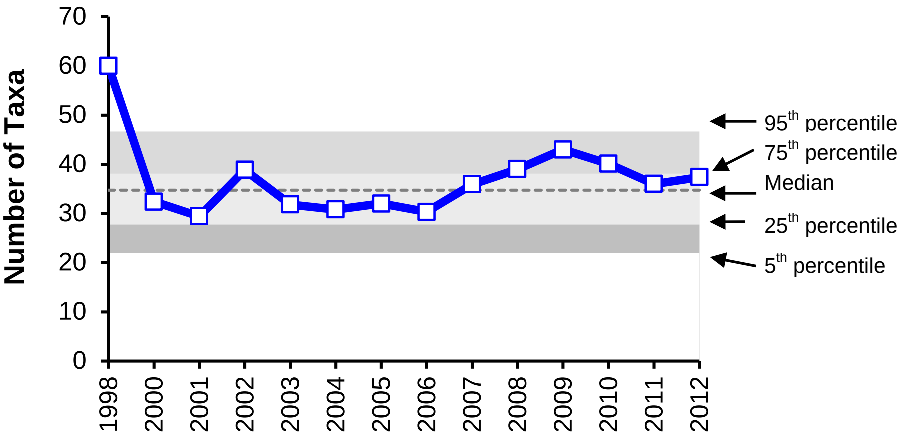
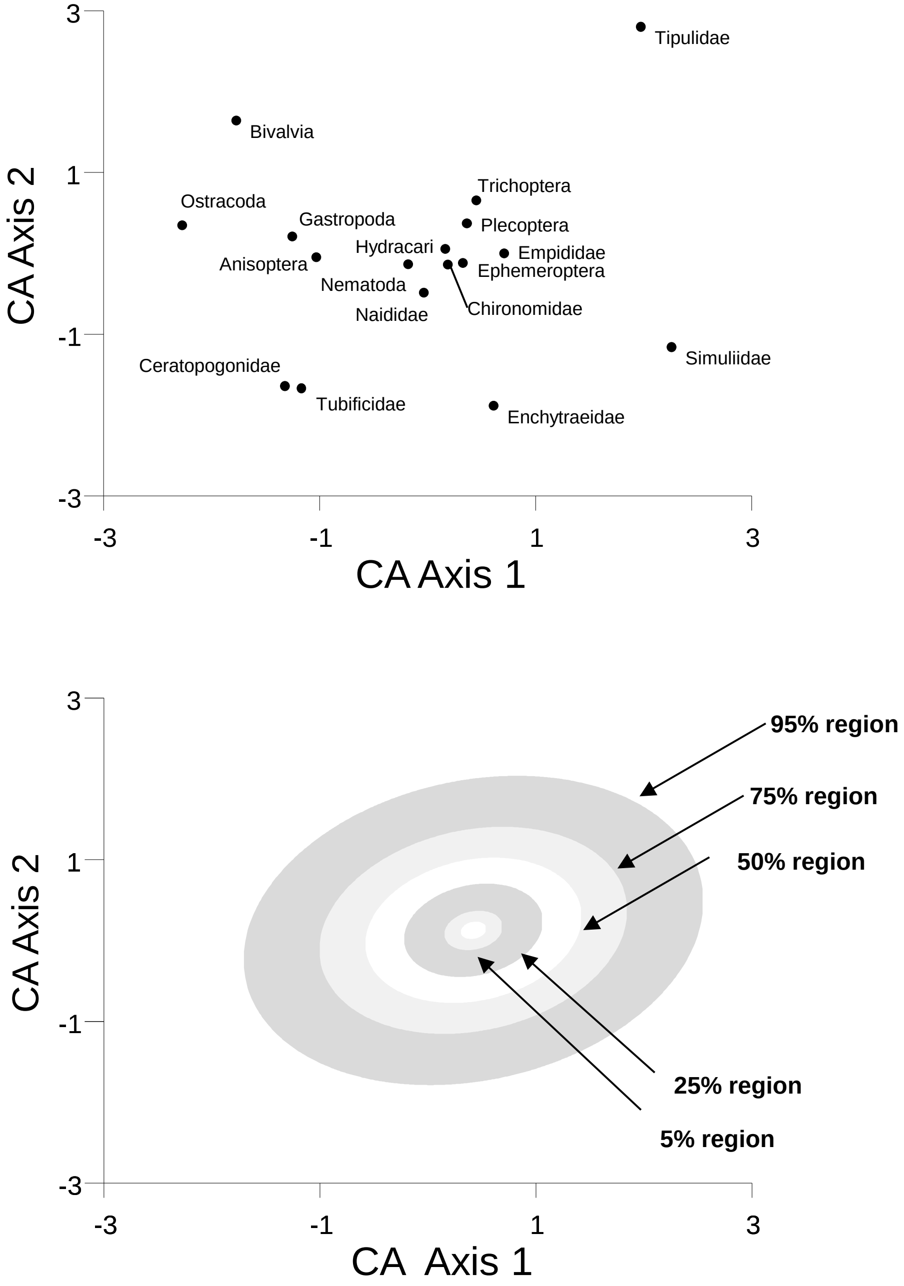


Figure 3.2-4 **Example bi-plot showing time trend of benthic invertebrate CA Axis scores in relation to regional *baseline* conditions, in this case, for samples from the middle reach of the Muskeg River (MUR-D2).**



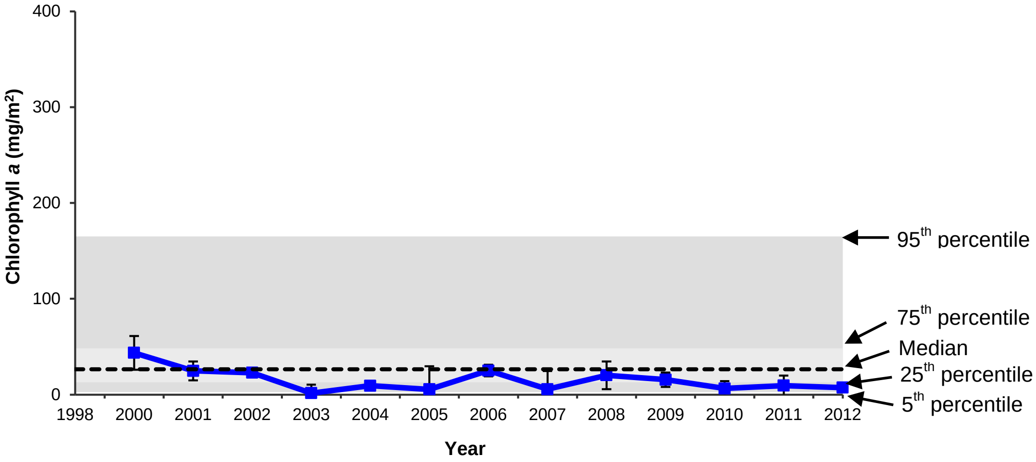
Environmental Variables

A number of environmental variables, including physical substrate condition and water temperature, chemistry, and flow velocities were measured at each reach (Section 3.1.3.1). 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 focal 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; AENV 1999b). Concentrations below this guideline are indicative of potential risks to aquatic life, especially if those concentrations are observed during the day, which is the typical time of sampling for RAMP; 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). The limits of the range of chlorophyll *a* values from reaches designated as *baseline* was determined (Appendix D) and is provided in figures that illustrate trends over time in chlorophyll *a* values.

Figure 3.2-5 Example of periphyton chlorophyll *a* data against the range of regional *baseline* concentrations, in this case, for the lower Muskeg River.



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, and 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 "significant" (i.e., interpretable) if the change explained > 20% of the variation in annual means. There are five core measurement endpoints for benthic invertebrate communities assessed (abundance, taxa richness, Simpson's Diversity, equitability, and percent EPT). If any one of those measurement endpoints produces a strong signal of a change, then this criterion will be considered to have been met. Allowing any one of the five measurement endpoints to trigger this criterion assumes that each measurement endpoint represents an attribute of the community that is important. The second criterion will be considered to be met (producing a "yes" in Table 3.2-7) if any measurement endpoint has fallen outside of regional *baseline* conditions for three years in a row. The criterion will also be considered to be met when values for three of the five measurement endpoints fall outside regional *baseline* conditions within the current year. This is particularly relevant for the assessment of waterbodies (reaches or lakes) for which there is at least a three-year data record.

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

Criterion	Classification			"Yes"
	Negligible-Low	Moderate	High	
Statistical significance	No	Yes	Yes	Strong statistical signal on any one of five measurement endpoints across time, with difference from *baseline* implying a negative change.
Exceed *baseline* range of variation	No	No	Yes	Any three of five measurement endpoints with values that violate a control charting criterion.

3.2.3.2 Sediment Quality Component

The analytical approach undertaken for the Sediment Quality component in 2012 was expanded relative to previous years and included:

- 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);
- tabular presentation of 2012 results, comparing 2012 concentrations of the sediment quality measurement endpoints to concentrations previously observed within the reach, where data were available, and sediment quality guidelines;
- graphical presentation of 2012 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
- analysis of the relationship between various sediment quality measurement endpoints and benthic invertebrate community measurement endpoints, using correlation analysis.

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 2003a);
- results of correlation analysis of the RAMP 1997 to 2004 sediment quality dataset indicating significant inter-correlation of various sediment quality variables; and
- discussions within the RAMP Technical Program Committee about:
    - the importance of various sediment quality variables to interpreting the results of the Benthic Invertebrate Communities component; and
    - approaches and appropriate analytical strategies for the Sediment Quality component.

Table 3.2-8 Potential sediment quality measurement endpoints.

Variable Group	EIA Review: Variables Listed in EIAs	RAMP 5-Year Report (Golder 2003a)	Variables to Support Other RAMP 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 by the RAMP Technical Program Committee and from 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 total arsenic (see below) and 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);
- *Total arsenic:* In analyses of sediment quality in the ARD (Section 5.1), data for total arsenic in sediments are presented, given stakeholder concerns regarding arsenic in regional sediments; 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 2012 Sediment Quality Results

The 2012 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 2012. 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 by presenting data for each station for all years of sampling by RAMP to allow assessment of any temporal trends.

Classification of Results

Sediment quality in each depositional benthic invertebrate sampling reach in fall 2012 was summarized using the CCME Sediment Quality Index calculator, (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 3.2.2.3), 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 RAMP sediment quality data used regional *baseline* conditions as benchmarks for comparison. All sediment quality data collected by RAMP 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 PAH species, 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 2012 (n=326), sediment quality index values of 67.7 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 2012 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) 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 2012 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. 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 on a river, for each season. Temporal and spatial comparisons were graphically presented in order to compare species composition and CPUE between 1987 and 2012 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. 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 among years (1987 to 2012) for each season using analysis of covariance (ANCOVA; $\alpha = 0.05$), 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 from 1986 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 2012 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, with the exception of lake whitefish for which only fall condition was evaluated over time due to insufficient sample sizes in summer. Spring condition 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 and AESRD Fish & Wildlife maintain records of tagged fish recaptured by anglers or during RAMP fish inventories. 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 RAMP program recaptures 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 2012.

Classification of Results

As indicated in Section 1.4.4.4, the RAMP 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 focal project activities 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 Clearwater River Fish Tissue Study

Selection of Measurement Endpoints

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

Whole-organism metrics (fork length, body weight and age) and mercury burden (both concentration and concentration standardized to fish length) were the measurement endpoints used to analyze fish tissues results from the Clearwater River.

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 northern pike collected during the tissue program on the Clearwater River.

Mercury Mercury results were reported for fish collected from the Clearwater 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 (2004, 2006, 2007, 2009, and 2012) for the Clearwater 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 length-weight regressions from different populations, 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 northern pike collected during the Clearwater River fish tissue program. Temporal comparisons of 2012 results were made with data from northern pike tissue studies previously completed on the Clearwater River (2004, 2006, 2007, 2009) by RAMP.

Comparison to Published Guidelines

Mercury measured in fish collected from the Clearwater 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 RAMP 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, INAC 2003, updated June 2006) (Table 3.2-10);
- Region III USEPA risk-based criteria for consumption of fish tissue for recreational and subsistence fishers (USEPA 2000, updated October 2007) (Table 3.2-10); and
- National USEPA risk-based screening values for consumption of fish tissue (USEPA 2000, updated November 2000) (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 RAMP FSA, developed through a risk assessment of fish mercury data collected through RAMP (GOA 2009). The consumption limits were established for fish species from specific waterbodies previously sampled by RAMP and AESRD, including the Clearwater 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 was reported for fish tissue samples collected by RAMP; 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, total arsenic concentrations 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 RAMP fish tissue measurement endpoints, including several total metals and 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 Criteria used for evaluating potential risk of fish consumption to human health for watercourses within the RAMP FSA (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 waterbodies that were sampled by RAMP and AESRD in 2012.

Table 3.2-10 Criteria 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						
Antimony (Sb)	mg/kg	nc	nc	nc	nc	0.54
Arsenic (As)[6]	mg/kg	nc	nc	0.026	0.00327	0.0021
Barium (Ba)	mg/kg	nc	nc	nc	nc	270
Beryllium (Be)	mg/kg	nc	nc	nc	nc	2.7
Cadmium (Cd)	mg/kg	nc	nc	nc	nc	1.4
Chromium (Cr)	mg/kg	nc	nc	nc	nc	4.1
Copper (Cu)	mg/kg	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	nc	nc	nc	nc	410
Lithium (Li)	mg/kg	nc	nc	nc	nc	27
Manganese (Mn)	mg/kg	nc	nc	nc	nc	190
Mercury (Hg)[7]	mg/kg	0.5	0.2	0.4	0.049	0.14
Molybdenum (Mo)	mg/kg	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	nc	nc	nc	nc	27
Selenium (Se)	mg/kg	nc	nc	20	2.457	6.8
Silver (Ag)	mg/kg	nc	nc	nc	nc	6.8
Strontium (Sr)	mg/kg	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	nc	nc	nc	nc	810
Vanadium (V)	mg/kg	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	nc	nc	nc	nc	410
Tainting Compounds						
Toluene	mg/kg	nc	nc	nc	nc	110

[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/pubs/mercur/merc_fish_poisson-eng.php

[3] Last updated June 2006; found at http://www.ainc-inac.gc.ca/nth/ct/ncp/pubs/hig/hil-eng.pdf

[4] Last updated November 2000; found at http://www.epa.gov/waterscience/fishadvice/volume1/index.html (see Chapter 5).

[5] Last updated May 2012; found at http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2012_FISH.pdf

[6] Criterion is for inorganic arsenic.

[7] Criteria are for total mercury and methyl-mercury, 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 RAMP 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 RAMP 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 Christina Lake Fish Assemblage Survey

Selection of Measurement Endpoints

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

- Relative Abundance – the total number of fish caught by each fishing method by the amount of effort (e.g., electrofishing seconds, trap-hours);
- Richness (S) – the total number of fish species collected in the lake. Higher richness values are typically used to infer a "healthier" fish assemblage; and
- Diversity – this measurement endpoint was computed for the lake 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.

Temporal Trends and Spatial Comparisons

Temporal comparisons to assess changes over time were conducted using fish data collected by AESRD during past FWIN (fall walleye index netting) programs and from the FWMIS database that comprises all fish data from studies conducted in Alberta. Comparisons in species richness were conducted over time; however, given the different objectives and fishing methods between the AESRD and RAMP surveys, it was not possible to conduct temporal comparisons of other 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, data from EIAs conducted for oil sands projects adjacent to the lake (e.g., Cenovus, MEG, and Devon projects), and data from AESRD provide the most appropriate set of regional *baseline* conditions and information against which to assess potential differences in the 2012 RAMP data.

Classification of Results

The fish assemblage survey on Christina Lake was conducted on behalf of RAMP southern operators to provide a *baseline* assessment of the lake prior to any major development in the area. The lake is important to stakeholders and communities in the region; therefore, a survey was conducted to assess general trends in abundance and population variables of fish species in the lake. Given that this is the first year that the survey was conducted, no criteria were used to classify the results of the Christina Lake fish assemblage survey but rather the survey was conducted to collect *baseline* data to test against future surveys.

3.2.4.4 Lethal Tributary Sentinel Species Monitoring

Selection of Measurement Endpoints

Measurement endpoints selected for sentinel species monitoring on the Steepbank, Muskeg, Horse, Dunkirk, and High Hills rivers are summarized in Table 3.2-15. These are based on Environment Canada's Environmental Effects Monitoring (EEM) guidelines developed for the metal mining and pulp and paper sectors (Environment Canada 2010).

The measurement endpoints for lethal sentinel species monitoring were calculated as follows:

- Age = mean age;
- Growth = size-at-age;
- Condition Factor (K) = 100*(body weight/length^3);
- Gonadosomatic index (GSI) = 100*(gonad weight/body weight); and
- Liversomatic index (LSI) = 100*(liver weight/body weight).

Table 3.2-13 Measurement endpoints for sentinel species monitoring on the tributaries in the oil sands region (Environment Canada 2010).

Response	Measurement Endpoints	Dependent Variable	Covariate
Age	Age	Age	None
Energy Use	Growth	Body weight	Age
	Gonad size (GSI)	gonad weight	Body weight
Energy Storage	Liver size (LSI)	Liver weight	Body weight
	Condition	Body weight	Fork length

Temporal Trends and Spatial Comparisons

Possible spatial and temporal differences in measurement endpoints of slimy sculpin were assessed by comparing each *test* site (MR-E and SR-E) against the *baseline* sites. The following comparisons were evaluated for 2012 and compared to the same comparisons made in 1999 and 2001:

- Between *baseline* sites (to determine variability across *baseline* sites) if no differences were observed, the *baseline* sites were pooled to perform statistical analyses;
- *Test s*ite MR-E versus *baseline* sites SR-R, HR-R, DR-R and HH-R; and
- *Test s*ite SR-E versus *baseline* sites SR-R, HR-R, DR-R and HH-R.

For testing for possible differences in age of slimy sculpin between *baseline* and *test* sites, mean age was compared among sites over time using ANOVA ($\alpha = 0.05$), where age represented the dependent variable and site the independent variable.

For testing for possible differences in growth of slimy sculpin between *baseline* and *test* sites, size-at-age was compared among sites over time using ANCOVA ($\alpha = 0.05$), where age represented the dependent variable, site the independent variable, and body weight the covariate.

For testing for possible differences in reproduction of slimy sculpin between *baseline* and *test* sites, relative gonad size was compared among sites over time using an ANCOVA ($\alpha = 0.05$), where gonad size represented the dependent variable, site the independent variable, and weight the covariate. Relative liver size was also compared among reaches, where liver size represented the dependent variable, site the independent variable, and body weight the covariate.

For testing for possible differences in condition of slimy sculpin between *baseline* and *test* sites, condition factor was compared among sites over time using ANCOVA ($\alpha = 0.05$), where body weight represented the dependent variable, site the independent variable, and length the covariate.

Power analysis was used to determine whether the sample size was adequate to effectively detect differences in measurement endpoints between *baseline* and *test* sites, assuming a 5% probability of committing a Type I error and a 95% probability of detecting the difference, and the unexplained variability (i.e., the population standard deviation). Power was calculated by re-arranging the following power equation (Green 1989):

$$n = \frac{2(t_\alpha + t_\beta)^2 \sigma^2}{\delta^2}$$

where,

n is the number of fish;

σ is the population standard deviation;

δ is the specified effect size;

t_α is the Students t statistic for a two-tailed test with significance level α; and

t_β is the Students t statistic for a one-tailed test with significance level β.

The estimated site-year standard deviation was the square-root of the pooled mean squared error term from the ANOVA or ANCOVA, separately generated for male and female slimy sculpin.

Comparison to Published Literature

There are many published articles on sentinel species monitoring for pulpmills and oil sands operations (e.g., Gibbons et al. 1998, Parrott et al. 2002, Tetreault et al. 2003), to provide context to the results from the 2012 slimy sculpin sentinel program.

Classification of Results

The selected criteria for determining change in a measurement endpoint for sentinel species monitoring was established for the Pulp and Paper Environmental Effects Monitoring (EEM) Program (Environment Canada 2010). The criteria are as follows:

- ± 25% difference in age of fish collected at a *test* site from age of fish collected at a *baseline* site;
- ± 25% difference in growth (size-at-age) in fish collected at a *test* site from growth (size-at-age) of fish collected at a *baseline* site;
- ± 25% difference in GSI in fish collected at a *test* site from GSI of fish collected at a *baseline* site;
- ± 25% difference in LSI in fish collected at a *test* site from LSI of fish collected at a *baseline* site; and
- ± 10% difference in condition in fish collected at a *test* site from condition of fish collected at a *baseline* site.

There are two steps in determining the classification of the effects criterion as Negligible-Low, Moderate, or High (Table 3.2-14):

- an exceedance of the effects criteria on any one of the three responses (age, energy use [weight-at-age, GSI], energy storage [LSI, K]) observed at a *test* site compared to the *baseline* sites in the current sampling year; and
- an exceedance at a *test* site in two consecutive years of sampling, including the current year.

Table 3.2-14 Classification of results for the sentinel species monitoring program.

Criteria	Negligible-Low	Moderate	High	"Yes"
Exceedance in current sampling year	No	Yes	Yes	Exceedance of the effects criteria on any one of the three responses at a *test* site compared to the *baseline* site.
Exceedance across sampling years	No	No	Yes	Exceedance of the effects criteria on any one of the three responses in two consecutive sampling years.

3.2.4.5 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);
- Richness (S) – 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 3.2-15). For species captured in the RAMP FSA, but not assessed by Whittier et al. (2007), a number was assigned based on species similarity to those with calculated values, as per RAMP (2011). With this index, lower tolerance values imply a species that is more sensitive to disturbance.

Table 3.2-15 Tolerance values for fish collected during the 2012 fish assemblage monitoring program (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]
finescale dace*	FNDC	7.0
fathead minnow*	FTMN	8.3
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/or across years within a reach. Given this was the second year of the fish assemblage monitoring program following a two-year pilot study at a subset of the reaches, statistical analyses were not conducted to assess temporal trends or spatial comparisons. However, as more data are collected over time, ANOVA will be used to test the following hypotheses:

- H_1: No linear time trend in mean values of measurement endpoints during the period of sampling; and
- H_2: No difference in mean values of measurement endpoints between an upstream *baseline* reach and a downstream *test* reach.

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, RAMP *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 Regional Baseline Conditions

To allow for a regional comparison, the first step was to determine which fish assemblage reaches were similar in habitat conditions in order to group reaches according to their similarities. A principal components analysis of the physical and chemical habitat data for each of the 59 reach x year combinations was carried out 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 indices of fish community composition. The PCA was conducted using the following suite of 22 variables: average water depth, bankfull width, wetted channel width, left bank height, right bank height, left bank angle, right bank angle, dissolved oxygen concentration, conductivity, pH, water temperature at the time of the sample, instream cover as attached algae, instream cover as macrophytes, in-stream cover as large woody debris (LWD), instream cover as small woody debris (SWD), in-stream cover as trees, in-stream cover as overhanging vegetation < 1 m from the water surface, instream cover as undercut banks, instream cover as boulders, sum of canopy scores, sum of understory scores, and sum of LWD scores.

Principal component axes explaining > 10% of the total variance in habitat features and 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 correlate with an axis can be considered at least somewhat redundant. The PCA; therefore, helps in identifying redundancies among the measured instream variables.

Variables considered here as explanatory variables included:

- Substrate class (i.e., erosional or depositional);
- Vegetation class (i.e., dominant vegetation in the riparian zone; deciduous, coniferous, mixed);

- Habitat type (i.e., run, pool or riffle);
- Average bankfull width; and
- Average water depth.

Sources of *baseline* variability in measurement endpoints of fish assemblages among the 20 *baseline* reaches (across years) were explored using general linear models (see Appendix E). Substrate texture was demonstrated to explain significant variation in ATI values. No other physical variable explained variation in any measurement endpoint. The range of variation for abundance, richness, and diversity were, therefore, calculated using data from all 19 reaches. *Baseline* ranges for ATI were calculated separately for depositional and erosional reaches. As more data are collected over time, analysis of habitat variables and the influence on fish assemblages will be refined.

The range of variation for each measurement endpoint was calculated as:

$$\overline{X}_r \pm 2SD_r$$

where:

$\overline{X}_r$ is the mean value for a measurement endpoint across all *baseline* reaches (or within the erosional or depositional groups of reaches for ATI); and

SD_r is the standard deviation of the mean value of a measurement endpoint. The range defined by the mean ± 2SD includes approximately 95% of possible observations (Kilgour et al. 1998).

The range of variation for *baseline* depositional and erosional reaches is provided in Table 3.2-16. The 5th and 95th percentiles were used to judge whether a reach was consistent with regional *baseline* conditions.

Table 3.2-16 Range of variation for each fish assemblage measurement endpoint within *baseline* reaches.

Reach	Statistic	Abundance	Richness	Diversity	ATI
All	Median	0.22	3.20	0.52	
	Mean	0.32	3.26	0.43	
	SD	0.26	1.61	0.24	
	5th	0.02	0.59	0.00	
	95th	0.72	5.05	0.70	
Depositional	Median				6.72
	Mean				6.65
	SD				1.24
	5th				4.82
	95th				8.06
Erosional	Median				5.34
	Mean				5.07
	SD				1.65
	5th				3.06
	95th				6.93

Classification of Results

Criteria used for classifying results of fish assemblages focused on whether or not the core measurement endpoints for the fish assemblage at a *test* reach either exceeded regional *baseline* conditions, 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 core measurement endpoints for fish assemblages (Table 3.2-17). There are four core measurement endpoints assessed for fish assemblages (abundance, richness, Simpson's Diversity, and the assemblage tolerance index). If any one of those measurement endpoints produced a significant change, then this criterion was considered to have been met. 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. The second criterion was considered to be met (producing a "yes" in Table 3.2-17) if any measurement endpoint had fallen outside of regional *baseline* conditions for three years in a row. The criterion was also considered to be met when values for three of the five measurement endpoints fell outside regional *baseline* conditions within the current year. This was particularly relevant for the assessment of reaches for which there was at least a three-year data record.

Given this was only the second year of the fish assemblage monitoring program, the first criterion to classify results could not be used given there were not enough data to conduct statistical analyses; however, the second criterion was used to assess the fish assemblage at a given reach designated as *test* by determining whether any of the five measurement endpoints exceeded the range of variability in *baseline* reaches.

Table 3.2-17 Classification of results for the fish assemblage monitoring program.

Criterion	Classification			"Yes"
	Negligible-Low	Moderate	High	
Statistical significance	No	No	Yes	Strong statistical signal on any one of four measurement endpoints across time, with difference from *baseline* implying a negative change.
Exceed *baseline* range of variation	No	Yes	Yes	Any three of four measurement endpoints with values that are outside of the range of variation in *baseline* reaches.

Note: only the second criterion was used in the 2012 analyses given the limited data available.

3.2.5 Acid-Sensitive Lakes Component

The analytical approach used in 2012 for the ASL component was in accordance with methods outlined in the RAMP Technical Design and Rationale (RAMP 2009b). The analytical approach consisted of:

- selecting ASL measurement endpoints;
- developing criteria to be used in detecting changes in ASL measurement endpoints; and
- detailed data analysis of 2012 results.

Minor changes and additions to the analyses described in the RAMP Technical Design and Rationale document are included in Section 3.2.5.4.

3.2.5.1 Selection of Measurement Endpoints

The measurement endpoints for the ASL component in 2012 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). Sulphate has also found to be sequestered and immobilized within the individual catchment basins (Whitfield et al. 2010).

3.2.5.2 Temporal Trends

The emphasis in the data analysis was placed on the detection and evaluation of potential temporal trends in the ASL measurement endpoints in the RAMP study lakes that would indicate incipient acidification in the lakes. In this regard, four specific data analyses were conducted.

Among-Year Comparisons of Measurement Endpoints A one-way Analysis of Variance (ANOVA) was conducted to determine whether there have been any significant changes in the mean concentrations of each ASL measurement endpoint in the 50 RAMP lakes during the eleven years of monitoring when all 50 lakes were sampled (2002 to 2012). 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.

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 50 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 over all the lakes. The GLM was applied to the population of 50 lakes as well as subsets of the 50 lakes that included the various physiographic regions and those lakes determined as most likely to undergo acidification (high potential acid input (PAI)/low critical load (CL); see below).

Mann–Kendall Trend Analysis on Measurement Endpoints in Individual Lakes Potential trends in measurement endpoints were examined in all 50 lakes using 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 is applied to calculate the test statistic Z. 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 Individual Lakes deemed 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. Ten lakes were selected for control charting on the basis of the ratio of modeled PAI to CL. The higher the ratio in a given lake, the greater is 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 on the previous years' data (1999 to 2011). A trend in the value of a measurement endpoint was determined on the basis of the criteria described below. As there was a low probability (1% or less) that these criteria would be violated in a truly random population of a measurement endpoint, there was a high probability of detecting a true trend in a measurement endpoint over time. The visual presentation of the data in 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".

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".

3.2.5.3 Calculation of Critical Loads of Acidity and Comparison to Modeled Potential Acid Input

The Critical load (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; it represents a measure of a lake's sensitivity to acidification. CLs for the RAMP lakes in

2012 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 exp(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 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 (WRS 2004).

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 applying the Henriksen model, 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:

1. 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 there was an insignificant difference between the current and calculated original base cation concentrations in all 50 lakes (See Appendix F).

2. 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.

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 6.0 is 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 with levels of the potential acid input (PAI) to each lake basin summarized in the Teck Frontier EIA (Teck 2011) and CEMA (2010b). In both cases, a maximum emissions scenario was assumed to represent existing emission sources as well as emissions from industrial sources that have been approved but not yet occurring. The ability of nitrates to be assimilated and used as a nutrient by plants within the 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 2007b).

3.2.5.4 Supporting Analyses

The following supporting data analyses were also conducted on the RAMP 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 RAMP lakes in 2012 to the range of chemical characteristics of lakes within the oil sands region;
- Classification of lake chemistry in Piper plots; and
- Analysis of metals in the individual lakes.

Update of the ASL Database, Summary Statistics and Comparisons of RAMP ASL Chemistry to Regional Lake Chemistry The chemical data from 2012 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 RAMP 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 comparison was used to determine how typical the study lakes are of lakes within the oil sands region. Comparisons involved:

- examination of the ranges, medians and mean values of key chemical variables for 2012 in the RAMP lakes relative to the regional dataset;
- graphical presentation of both datasets in box-plots; and
- statistical comparison of chemical variables between the RAMP study lakes and the regional dataset.

Classification of the RAMP Study Lakes in Piper Plots Piper plots were used to characterize the waters 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 are described below:

- 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 RAMP Lakes The total and dissolved metal fractions from 11 years of monitoring by AESRD (2001, 2003 to 2012) 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 2010b, AENV 1999b). The lakes and physiographic regions having the highest metal concentrations were identified and plotted on regional maps.

In 2012, additional analyses were conducted to detect potential changes in metals concentrations attributable to acidification. These analyses included:

- Comparison of metal concentrations between physiographic regions using Analysis of Variance;
- Comparison of metals concentrations between *baseline* and *test* lakes using Analysis of Variance;
- Comparison of metal concentrations in lakes situated <50 km, 50 to 100 km, 100 to 200 km and greater than 200 km from the major sources of acidifying emissions; and
- Plotting of metals concentrations as a function of radial distance from the major sources of acidifying emissions.

3.2.5.5 Classification of Results

A summary of the state of the RAMP lakes in 2012 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); aluminum (upwards).

For each lake, the mean and standard deviation were calculated for each measurement endpoint over all monitoring years. The number of lakes in 2012 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 such endpoint-lake exceedances was expressed as a percentage of the total number of lake-endpoint combinations for each subregion. The results were classified as follows:

- Negligible-Low: subregion has <2% endpoint-lake combinations exceeding ± 2 SD criterion;
- Moderate: subregion has 2% to 10% endpoint-lake combinations exceeding ± 2 SD criterion; and
- High: subregion has > 10% of endpoint-lake combinations exceeding ± 2 SD criterion.

4.0 CLIMATE AND HYDROLOGIC CHARACTERIZATION OF THE ATHABASCA OIL SANDS REGION IN 2012

4.1 INTRODUCTION

The following characterization of the 2012 climate and hydrology of the Athabasca oil sands region and comparison with long-term climate and hydrology information provides context for the results of the 2012 Regional Aquatics Monitoring Program (RAMP) monitoring program. 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; however, it also relies on a number of the RAMP climate and snowpack monitoring stations for additional regional context.

The following discussion is based on the 2012 water year (WY), from November 1, 2011 to October 31, 2012.

4.2 CLIMATE CHARACTERIZATION

Since 1945, daily precipitation and air temperature data have been collected at the Fort McMurray airport at four stations maintained by Environment Canada (EC). The data record for the different stations spans 68 years (1945 to 2012). Through the years these stations were either decommissioned or upgraded, but essentially the data recorded at these stations are representative of the same climate conditions at this location. Therefore, for purposes of the analyses conducted in this report all precipitation and air temperature records from these stations were consolidated into one long-term data series from 1945 to 2012. This data series will be referred hereafter as the Fort McMurray data set.

A summary of the details for each EC station is presented in Table 4.2-1.

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 2013	✓	✓
Fort McMurray CS	3062696	486919	6278571	368.8	1999 to 2013	✓	✓

[1] Unique seven digit identifier assigned by Environment Canada.

4.2.1 Precipitation

Total precipitation measured at Fort McMurray in the 2012 WY was 460.1 mm (Figure 4.2-1), which was approximately 6% higher than the long-term annual mean of 433.9 mm for Fort McMurray (calculated from the 1945 WY to the 2011 WY). Conditions observed in the 2012 WY were a departure from drier than normal conditions observed for the previous eight years. The wetter than normal conditions observed in 2012 were largely influenced by precipitation in summer and early fall. The wettest months in the 2012 WY were July and September with total precipitation amounting to 130.8 mm and 116.9 mm, respectively, representing an increase from the historical mean by 69% and 141%, respectively (Figure 4.2-2). Conversely, total precipitation from November 1, 2011 to April 30, 2012 was 76 mm and approximately 34% below the historical mean of 115.7 mm for this period.

Figure 4.2-1 Historical annual precipitation at Fort McMurray, 1945 WY to 2012 WY.

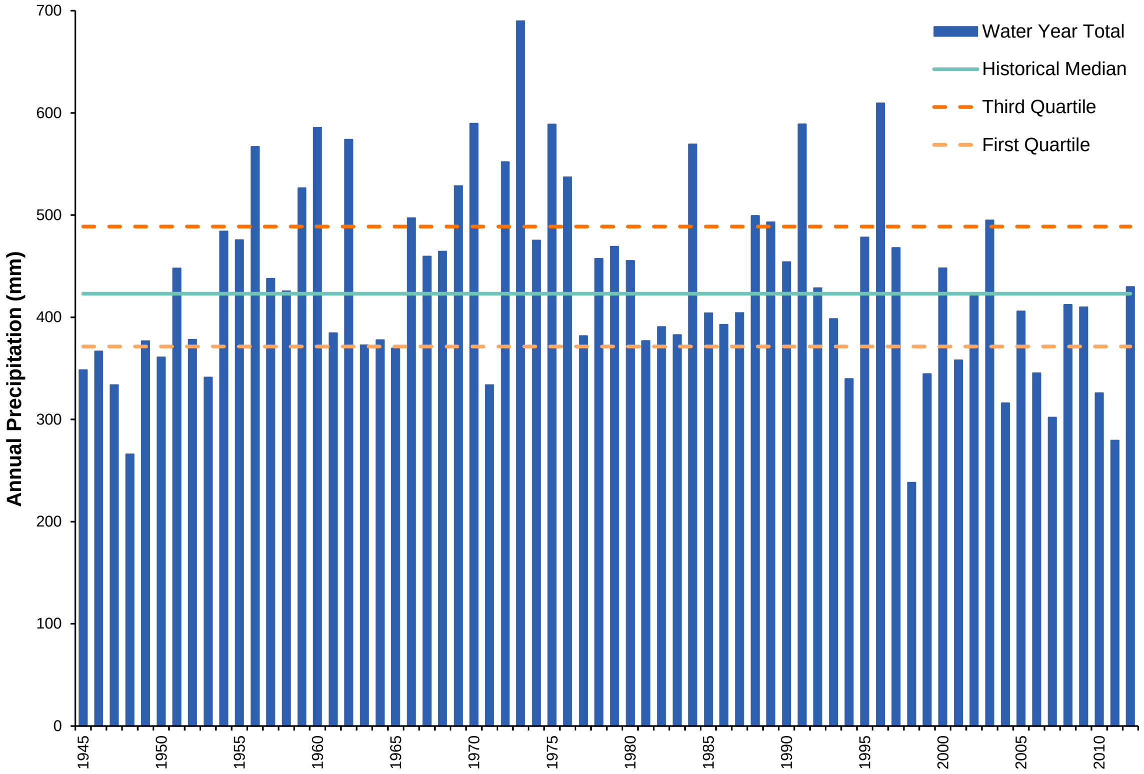
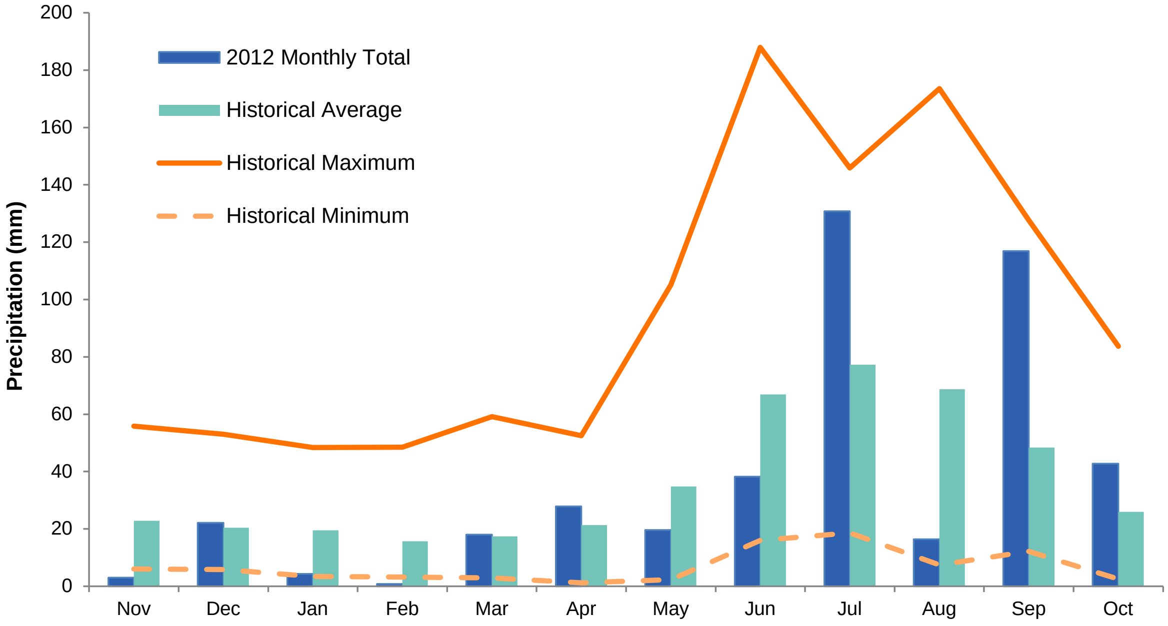
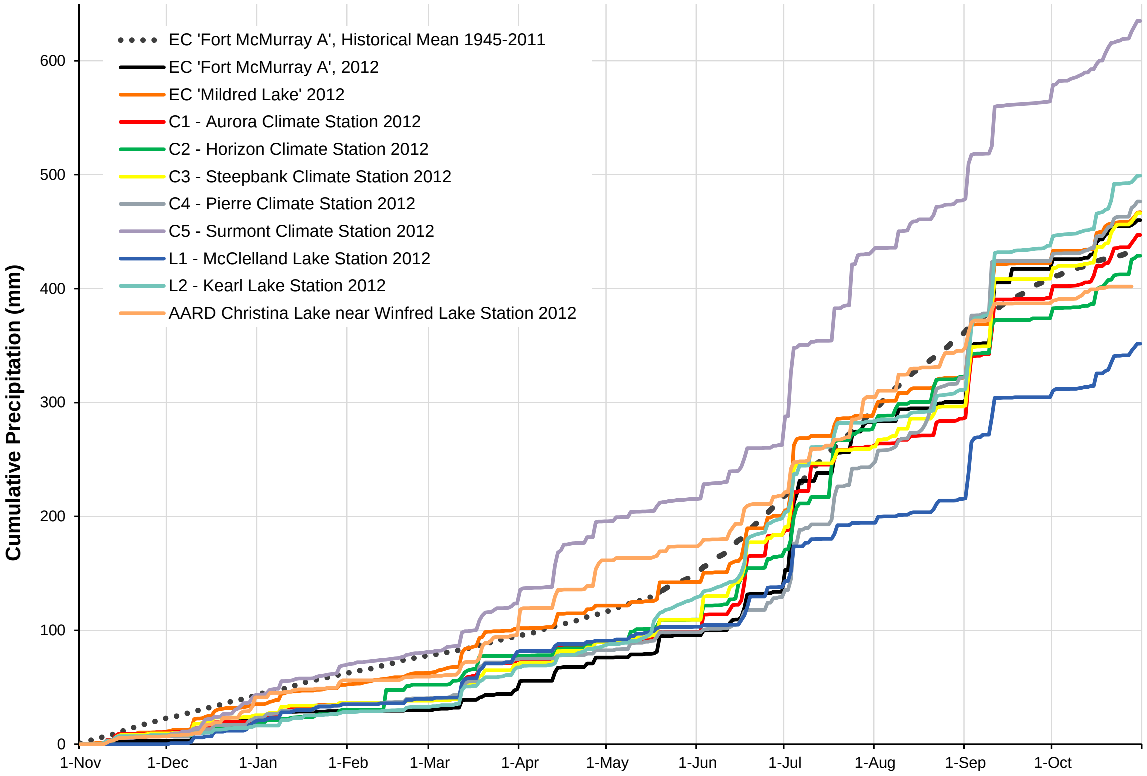


Figure 4.2-2 Monthly precipitation at Fort McMurray in 2012.



Precipitation records for EC Mildred Lake station (ID# 3064528), Alberta Agriculture and Rural Development (AARD) Christina Lake near Winefred Lake station (ID# 3061580), and RAMP stations C1–Aurora, C2–Horizon, C3-Steepbank, C5-Surmont, L1–McClelland Lake, and L2–Kearl Lake provided additional information to characterize conditions throughout the region in 2012 (Figure 4.2-3). In general, the 2012 WY cumulative precipitation recorded at these stations was above the historical mean of 433.9 mm for Fort McMurray. At most stations, annual precipitation was approximately 7% above the historical mean but 46% and 15% above the historical mean for stations C5-Surmont and L2-Kearl Lake, respectively. Drier than normal conditions were observed at the C2-Horizon climate station (428 mm), L1-McClelland Lake station (352 mm), and AARD Christina Lake station (402 mm). Most stations recorded cumulative precipitation below the historical mean for the first half of the 2012 WY (November 2011 to mid-June 2012), with the exception of the C5-Surmont climate station where observed cumulative precipitation was consistently above the historical mean throughout the 2012 WY.

Figure 4.2-3 Cumulative total precipitation at climate stations in the Athabasca oil sands region in 2012.

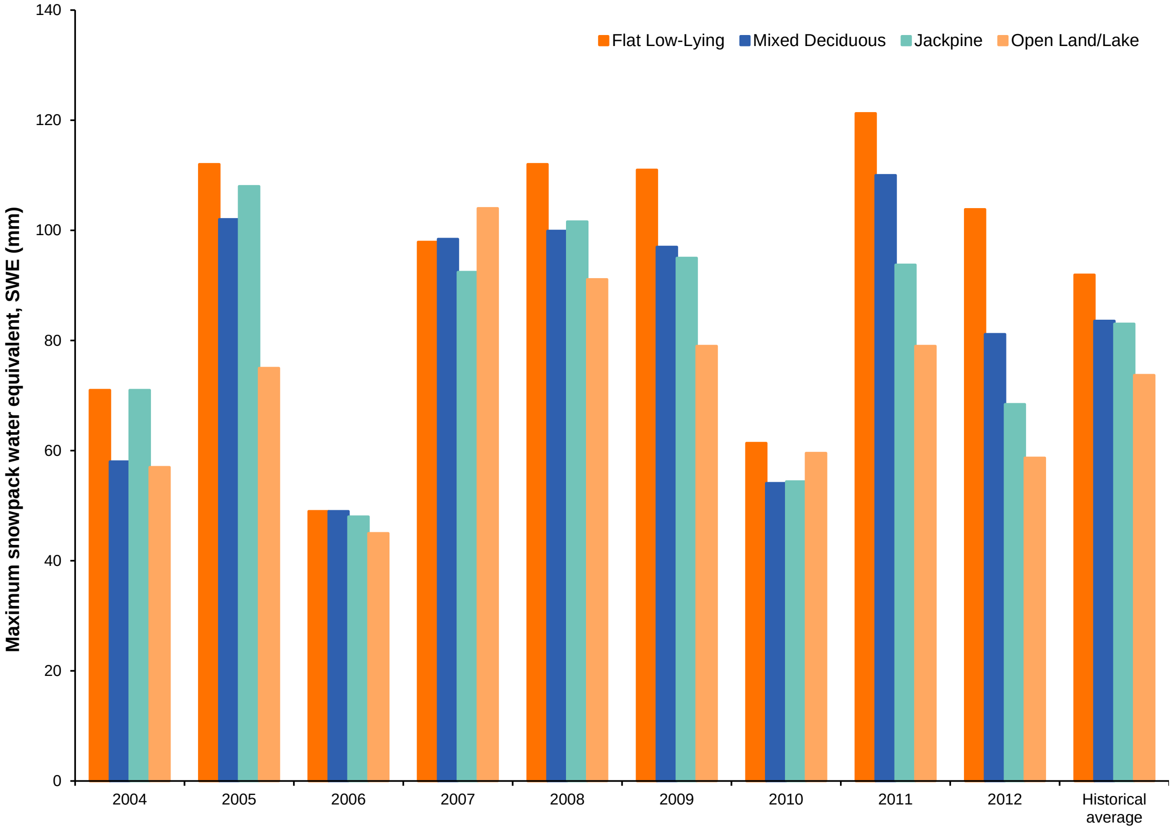


4.2.2 Snowpack

Snowpack amounts (in terms of mm snow water equivalent or SWE) were measured at 16 locations during the period of February 9 to 16, March 8 to 16, and March 26 to April 4, 2012, in each of four land category types (i.e., flat low-lying, mixed deciduous, jackpine, and open land/lake). The maximum mean SWE value recorded for each land category is presented in Figure 4.2-4. Historical maximum mean SWE values for the period of 2004 to 2011 were also included for comparison. Similar to previous years, mean SWE values were highest in flat low-lying terrain, with a decreasing trend through mixed deciduous, jackpine, and open land/lake terrain. The mean SWE value in 2012 for the flat low-lying terrain was higher than the eight-year historical mean, and ranked as the fifth highest on record. In contrast, the mean SWE values in 2012 for the mixed deciduous, jackpine, and open/lake terrains were all below historical mean values.

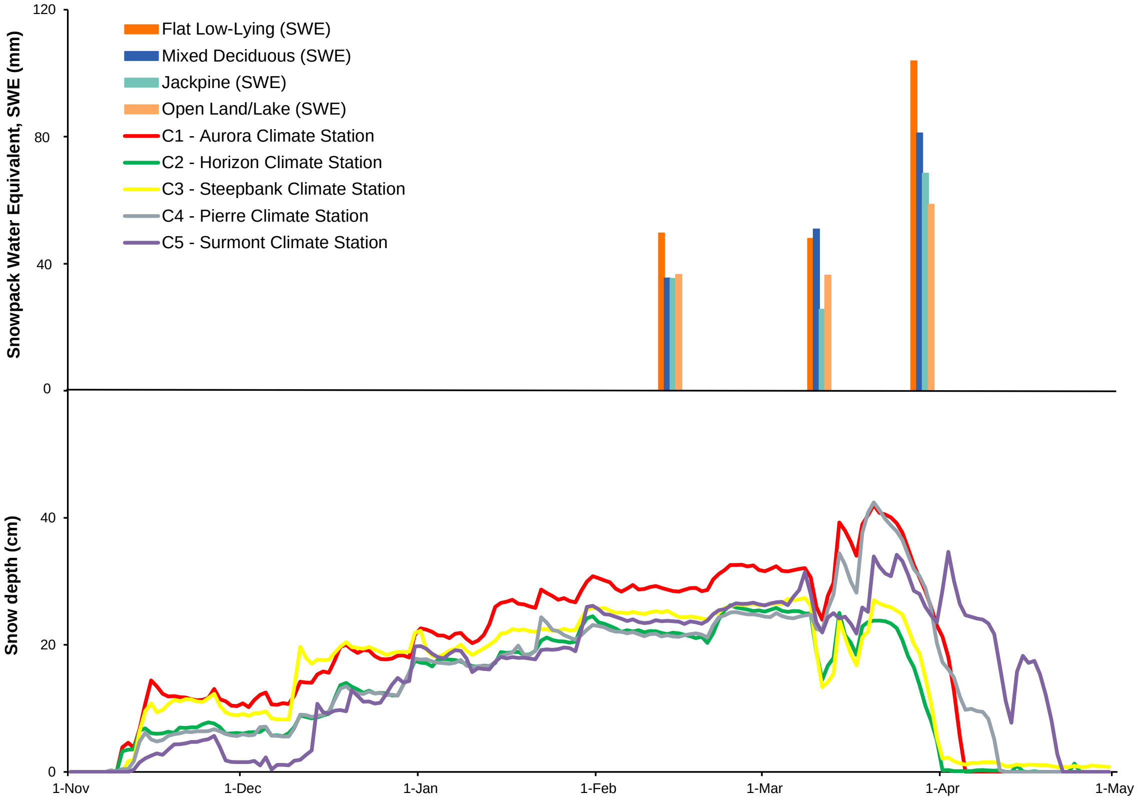
Mean SWE by land category type corresponded well with snow depths measured at the C1-Aurora, C2-Horizon, C3-Steepbank, and C4-Pierre climate stations (Figure 4.2-5). Snow water equivalent measurements were collected at appropriate sampling intervals to characterize the snowpack trend for the 2012 WY. At most stations the snow pack had melted by early to mid-April; however, the snowpack persisted well into late April at the C5-Surmont station (Figure 4.2-5). Detailed information for the 2012 snow surveys conducted at each station is included in Appendix C.

Figure 4.2-4 **Maximum measured snowpack amounts in the Athabasca oil sands region, 2004 to 2012.**



Note: Data from RAMP regional snowcourse surveys. Four snowcourses were sampled in each of four land categories (Figure 3.1-1), usually in February, March and April of each winter. Mean snow water equivalent (SWE) values shown here represent the maximum monthly mean values recorded for each land category and year.

Figure 4.2-5 **Comparison of snowpack depth (cm) and snow water equivalent (SWE, mm) observed at RAMP climate stations.**



4.2.3 Air Temperature

Daily mean air temperatures measured at Fort McMurray for the 2012 WY were generally between historical lower quartile and historical maximum values (Figure 4.2-6). Winter air temperatures, from November to February, were more variable than the remainder of the year and were generally above the historical median and followed a similar pattern as the historical upper quartile. Temperatures from March to October followed the historical median until temperatures in October fell below the historical lower quartile on two occasions.

The monthly mean air temperatures in winter (December to February) for the 2012 WY were generally warmer than the historical mean by approximately 7.0 °C (Figure 4.2-7). During the spring months of the 2012 WY, mean air temperatures were warmer than the historical mean in March and May but colder in April. Air temperature in summer and early fall of the 2012 WY was above historical mean values, while mean temperatures in October were below the historical mean by approximately 2.6 °C.

Figure 4.2-6 **2012 WY daily mean air temperature at Fort McMurray compared to historical values (1945 to 2011).**

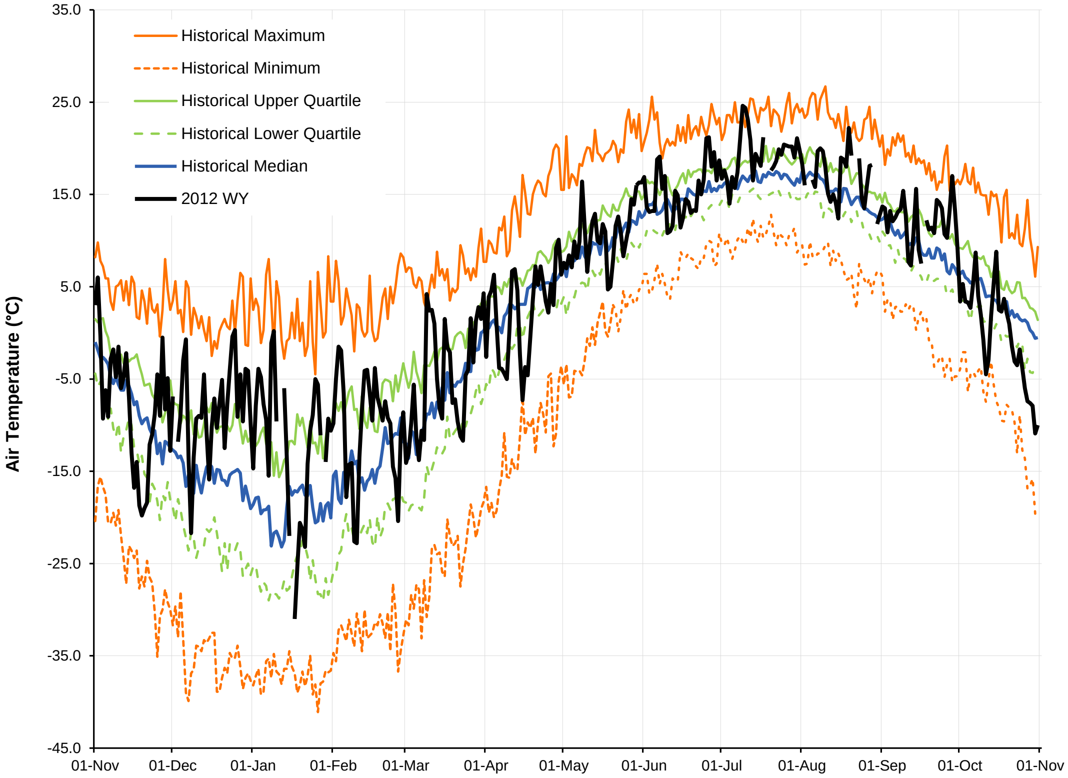
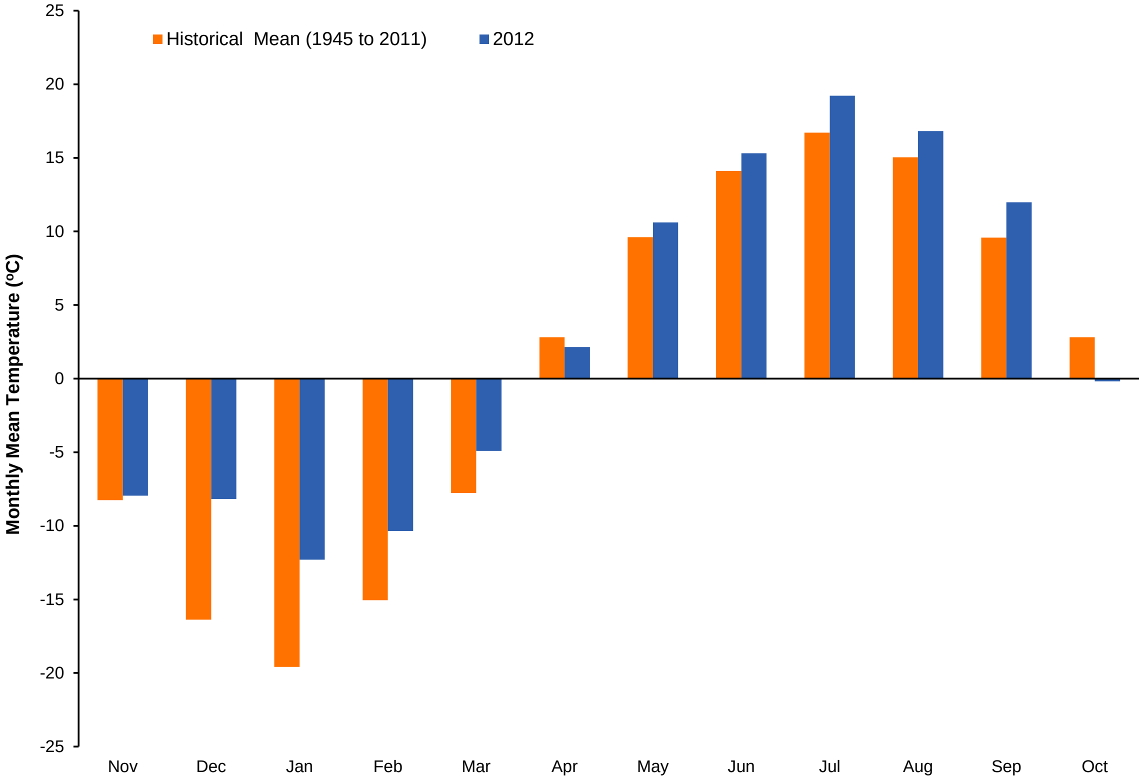


Figure 4.2-7 **Comparison of historical (1945 to 2011) and 2012 WY monthly mean air temperatures at Fort McMurray.**



Note: Daily mean air temperatures for Fort McMurray were averaged for each month for the period 1945 to 2011. These values are compared to monthly means for the 2012 WY.

4.3 HYDROLOGIC CHARACTERIZATION

Daily discharge hydrographs were developed for four long-term Water Survey of Canada (WSC) stations and compared to their respective 2012 WY provisional data. The four stations are located on the Athabasca, Muskeg, MacKay, and Christina rivers. Each station represents four primary areas of interest in the RAMP Focus Study Area (FSA). A summary of each WSC station is presented in Table 4.3-1.

Table 4.3-1 Long-term discharge data available from select Water Survey of Canada stations located in the 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 mineable area	132,585	1957 to 2012
Muskeg River near Fort McKay	07DA008	Eastern tributary of the Athabasca River	1,457	1974 to 2012
MacKay River near Fort McKay	07DB001	Western tributary of the Athabasca River	5,569	1972 to 2012
Christina River near Chard	07CE002	South of Fort McMurray	4,863	1982 to 2012

4.3.1 Athabasca River

The total annual flow volume for the Athabasca River measured at WSC Station 07DA001, Athabasca River below McMurray, was 20,496 million m^3 for the 2012 WY (Table 4.3-2). This was 5% greater than the historical mean flow volume of 19,476 million m^3 over the station's 53-year period of record (1958 to 2011). The 2012 WY was the fifth year since 1991 to have exceeded the historical mean WY runoff volume; the other years were 1996, 1997, 2005, and 2011 (Figure 4.3-1).

The flows measured at this station during the 2012 WY were near the historical minimum in November 2011 and close to the lower quartile range for the months of December 2011 and January, February, and March 2012. During the summer months (June to August), recorded flows were close to the historical upper quartile range, while flows recorded in fall (September to November) were near the historical median (Figure 4.3-2). The minimum flow for the 2012 open-water period (May to October) was 390 m^3/s recorded on October 31, 2012, which was below the historical median by approximately 35 m^3/s (Table 4.3-2). The spring snowmelt and freshet conditions in the Athabasca River resulted in flows below the historical upper quartile range in the 2012 WY. Flows in mid-June were near the historical maximum and exceeded the historical maximum in late July. The annual maximum discharge of 3,680 m^3/s, which occurred on July 29, 2012, was greater than the mean historical maximum discharge by approximately 1,200 m^3/s.

The two high runoff events observed in mid-June and late July at the Athabasca River station below Fort McMurray were not observed in basins north of Fort McMurray (i.e., Muskeg and MacKay rivers). These events were observed at the WSC station Athabasca River at Athabasca (07BE001) indicating that these peak flows were a result of weather conditions upstream of the town of Athabasca.

Figure 4.3-1 Historical annual runoff volume in the Athabasca River basin, 1958 to 2012.

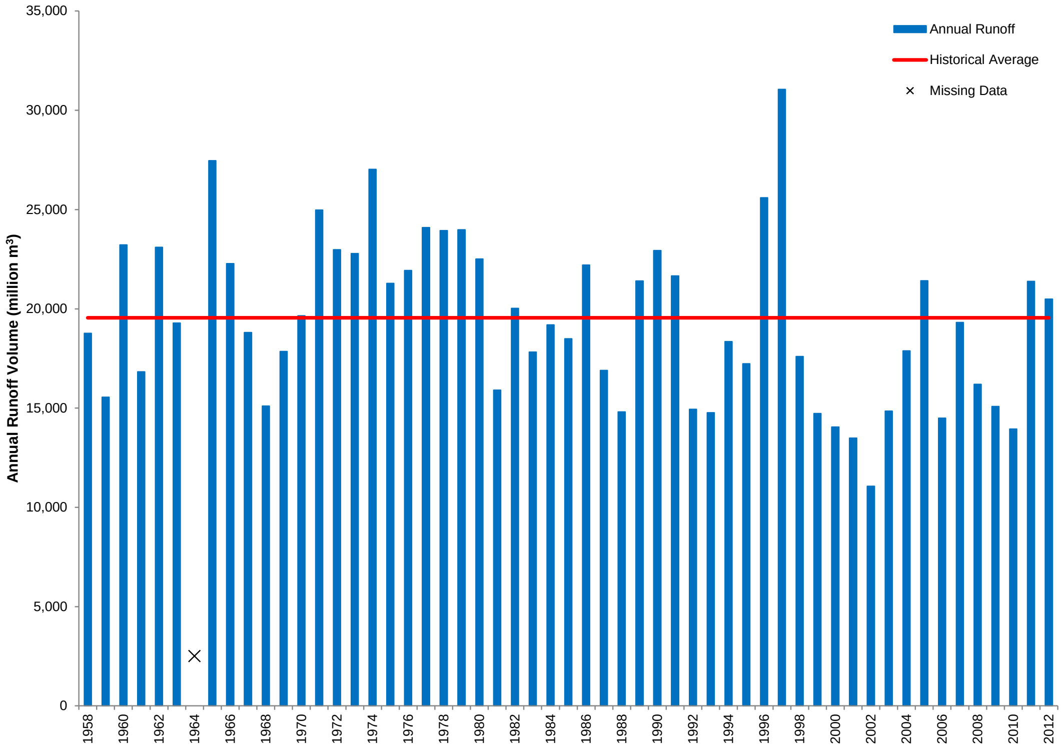


Figure 4.3-2 The 2012 WY Athabasca River hydrograph compared to historical values.

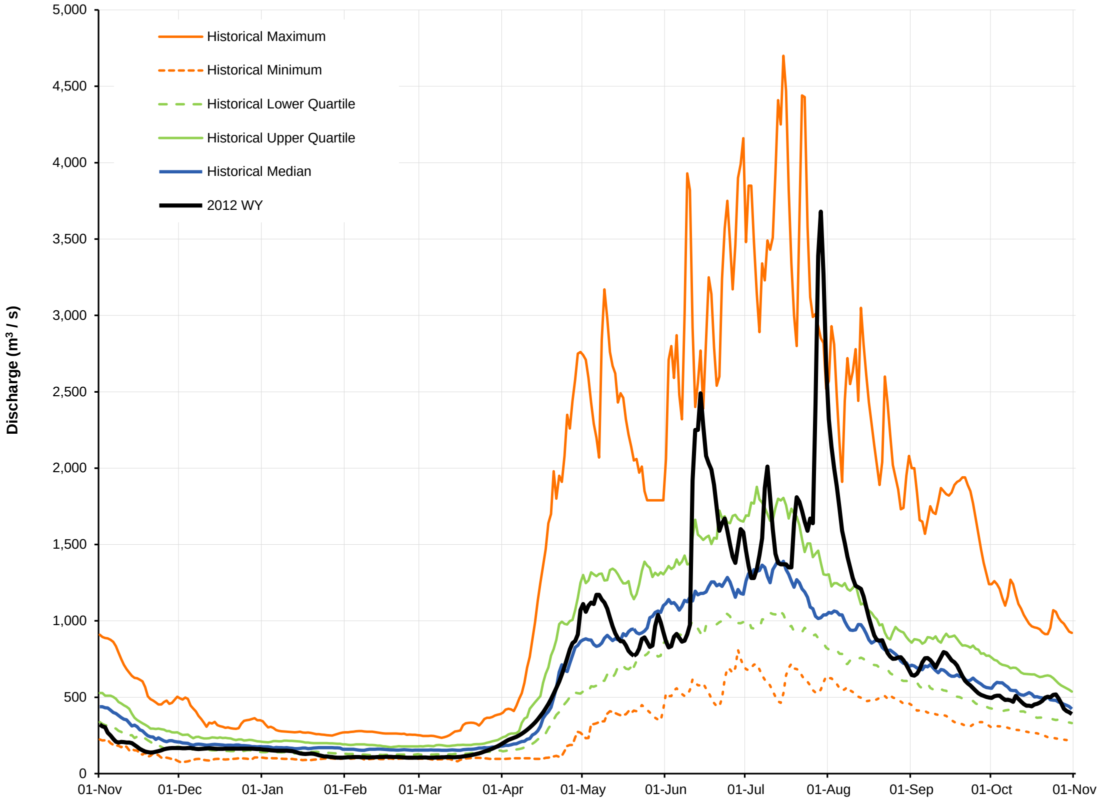


Table 4.3-2 Summary of 2012 hydrologic variables compared to historical values measured in the Athabasca oil sands region.

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 2012	1974 to 2012	1973 to 2012	1983 to 2012
Runoff Volume[1]				
Historical[2] mean (million m^3)	19,476	115	423	428
2012 (million m^3)	20,496	106.5	230.4	460.8
Maximum Daily Discharge[1]				
Historical mean (m^3/s)	2,497	25.2	113.2	83.2
2012 (m^3/s)	3,680	29.4	33.3	60.8
Minimum Daily Discharge[3]				
Historical mean (m^3/s)	425.6	1.1	3.6	6.5
2012 (m^3/s)	390	0.4	4.2	12.9

[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 2011 WY.

[3] Open-water season is based on values from May to October.

4.3.2 Muskeg River

The 2012 seasonal (March to October) runoff volume for the Muskeg River watershed recorded at WSC Station 07DA008, Muskeg River near Fort McKay, was 106.5 million m^3 (Table 4.3-2). This was approximately 7% lower than the long-term mean seasonal runoff volume of 115 million m^3, based on the station's 39-year period of record (Figure 4.3-3). The hydrograph at this location for the 2012 WY was dominated by rainfall-generated flows that occurred in early July and mid- to late September (Figure 4.3-4). This pattern does not conform to typical conditions for this location, where the highest flows in the year are usually generated by snowmelt during the spring freshet period. Flows in the 2012 WY were below historical lower quartile values during the freshet period and approached the historical maximum in late September. The peak flow for the 2012 WY was 29.4 m^3/s on September 20, 2012. The 2012 open-water season (May to October) minimum daily flow of 0.4 m^3/s recorded on September 1 was 58% lower than the historical mean minimum daily flow of 1.1 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 2012.

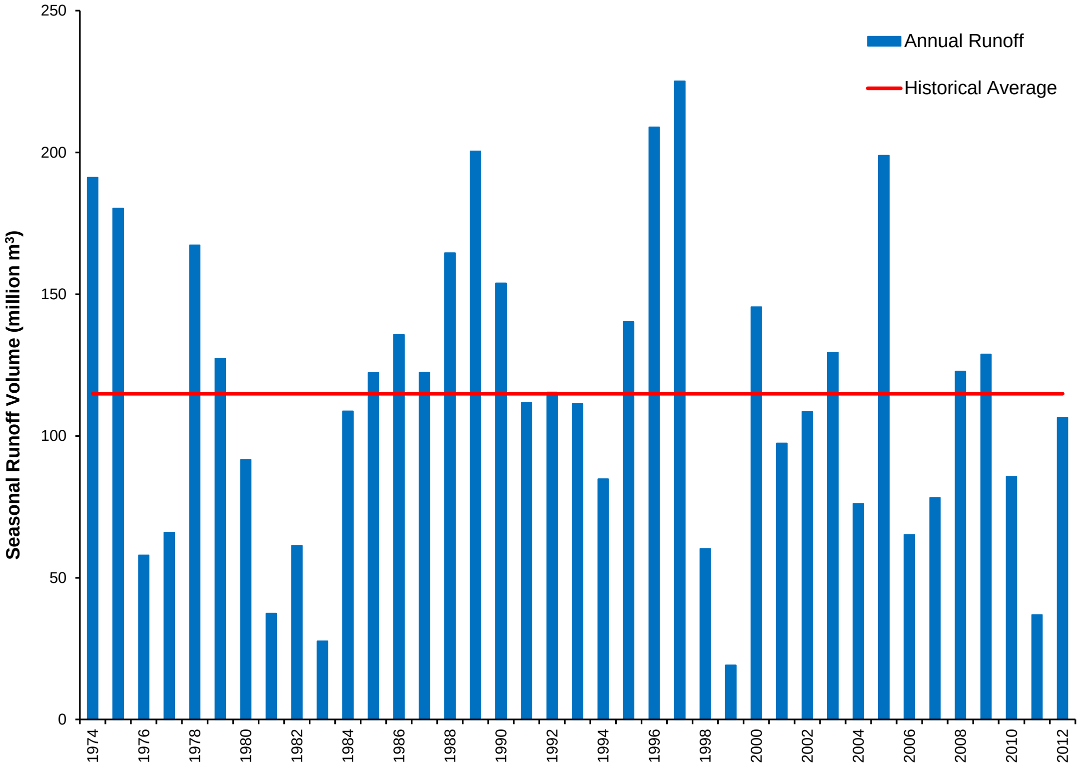
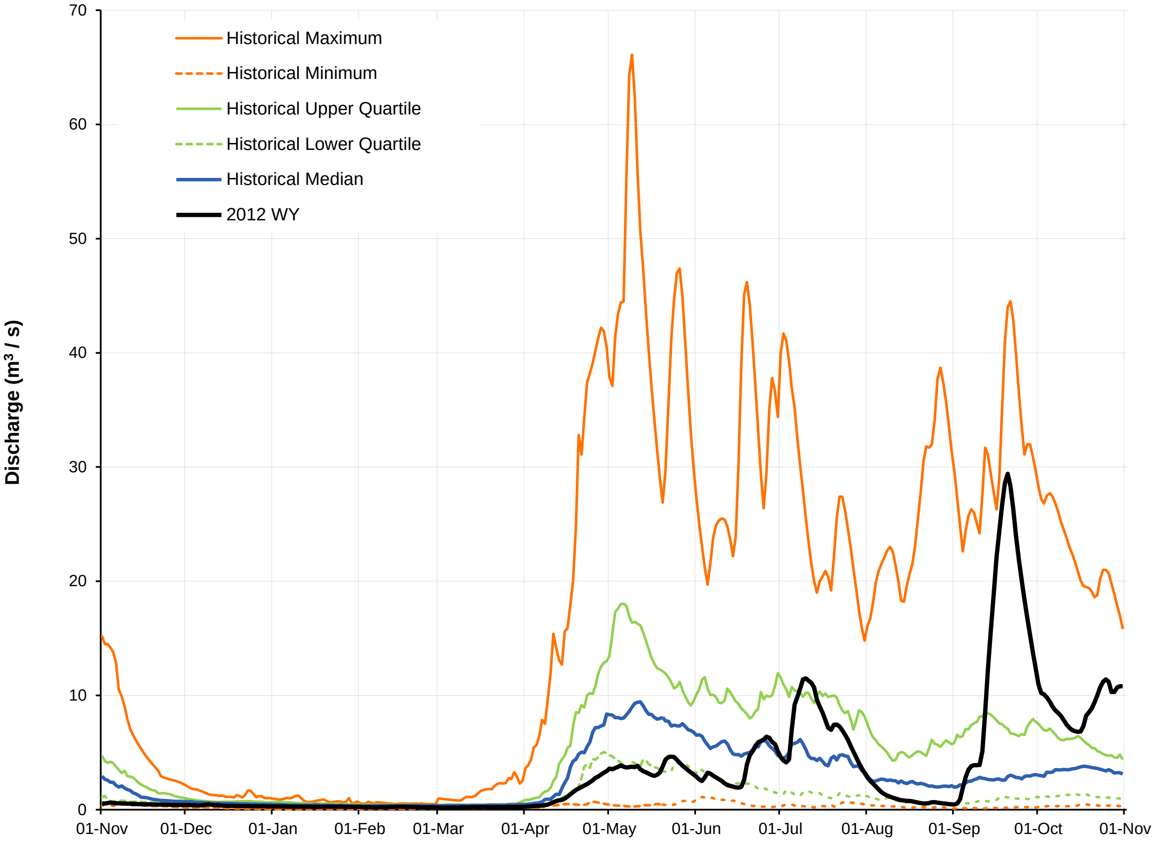


Figure 4.3-4 The 2012 WY Muskeg River hydrograph compared to historical values.



4.3.3 MacKay River

The 2012 seasonal (March to October) runoff volume for the MacKay River watershed recorded at WSC Station 07DB001, MacKay River near Fort McKay, was 230.4 million m^3 (Table 4.3-2). This was approximately 46% lower than the long-term mean seasonal runoff volume of 423 million m^3 (Figure 4.3-5, Table 4.3-2), based on a 39-year period of record. Discharge levels in the 2012 WY approached the historical lower quartile during the spring freshet and continued to mid-June. The annual peak of 33.3 m^3/s on July 8, 2012 approached the historical upper quartile but was well below the mean historical maximum of 113.2 m^3/s (Figure 4.3-6). Unlike the Muskeg River, a response to rainfall events in mid- to late September was less pronounced at this station. Discharge levels for the remainder of the summer and fall were near the historical median. The 2012 open-water season (May to October) minimum daily flow of 4.17 m^3/s occurred on August 24, and was approximately 14% higher 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 2012.

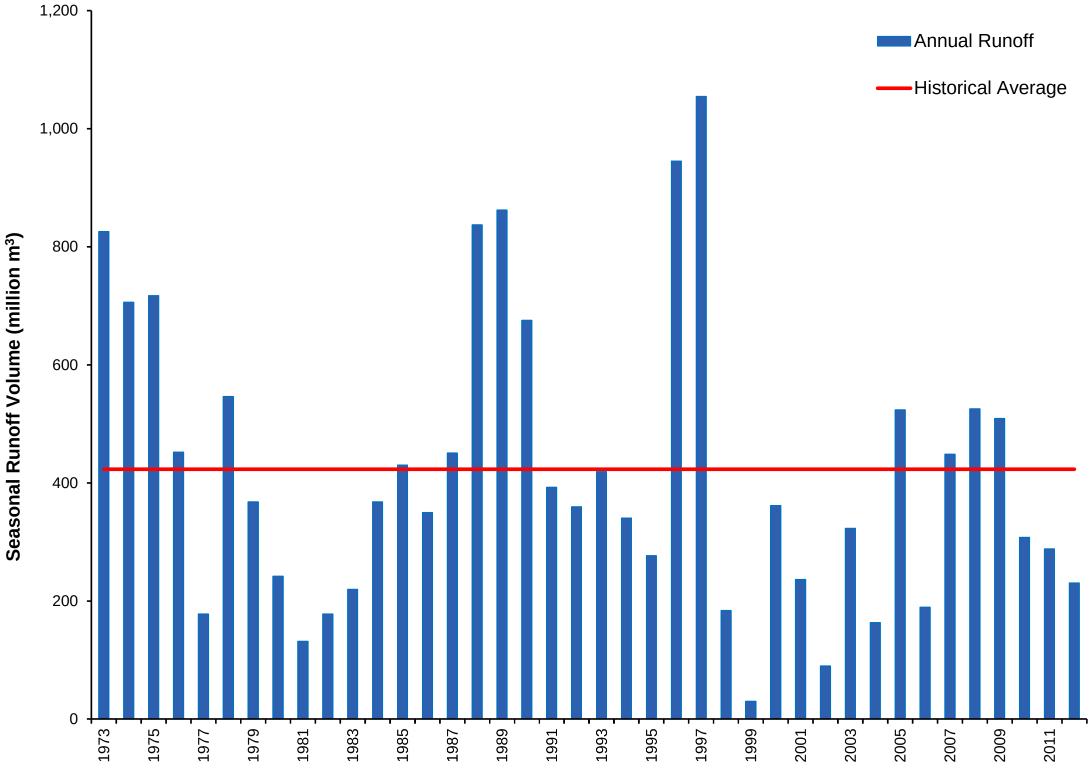
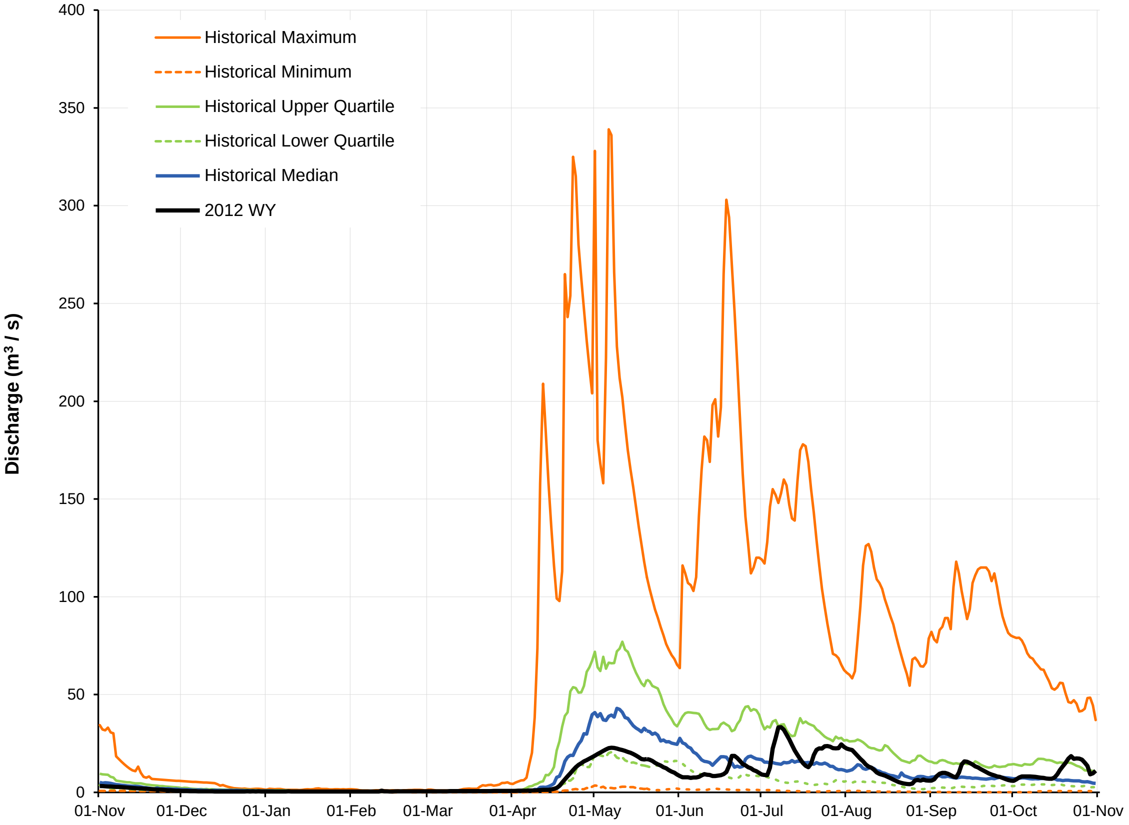


Figure 4.3-6 The 2012 WY MacKay River hydrograph compared to historical values.



4.3.4 Christina River

The 2012 seasonal (March to October) runoff volume for the Christina River watershed recorded at WSC station 07CE002, Christina River near Chard, was 460.8 million m^3 (Table 4.3-2). This was approximately 8% higher than the long-term mean seasonal runoff volume of 428 million m^3 over the 31-year period of record. The 2012 WY was the ninth consecutive year where seasonal flow volumes were above the mean recorded at this station (Figure 4.3-7).

Unlike the Muskeg and MacKay rivers, the highest flows at this station occurred during the spring freshet period. The freshet peak of 60.8 m^3/s was recorded on May 3, 2012 and exceeded historical upper quartile levels (Figure 4.3-8). Similar to the Muskeg River watershed, the Christina River watershed experienced elevated runoff levels in response to high precipitation in July and early to mid-September. Flows in September exceeded upper quartile levels and were near the historical maximum. After mid-September, daily discharges decreased to historical upper quartile levels. The daily minimum discharge in the 2012 WY of 12.9 m^3/s occurred on July 2, and was approximately twice as high as the historical minimum (Table 4.3-2).

Figure 4.3-7 Historical seasonal (March to October) runoff volume in the Christina River basin, 1983 to 2012.

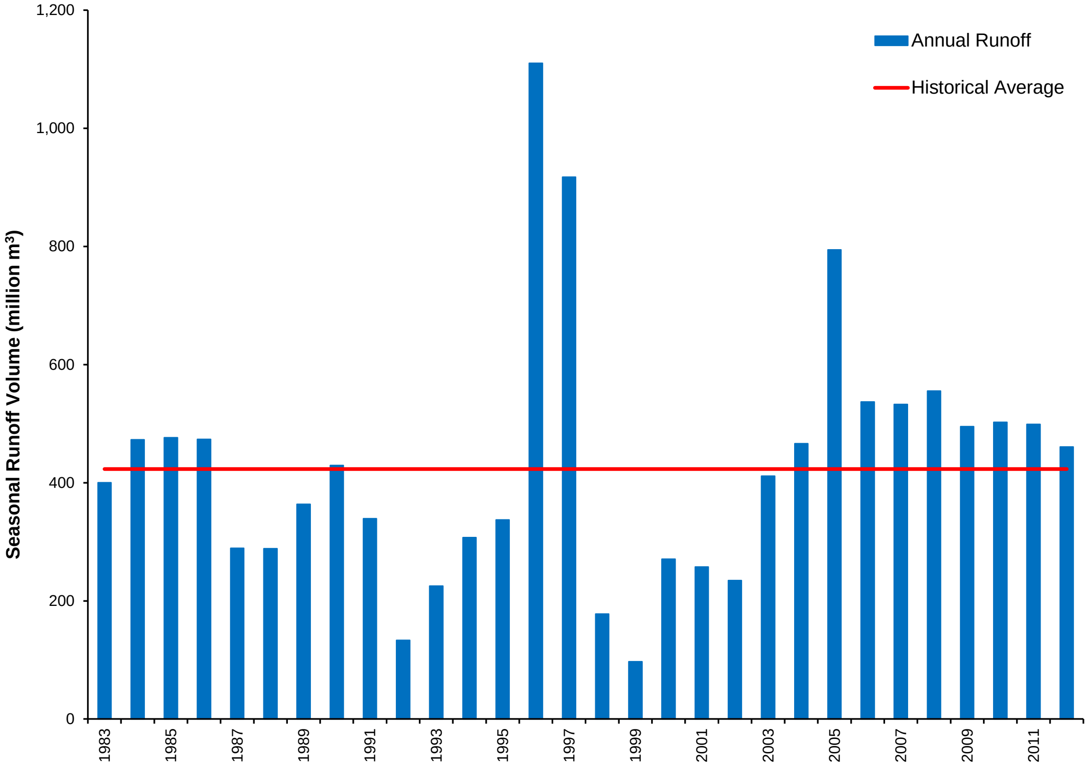
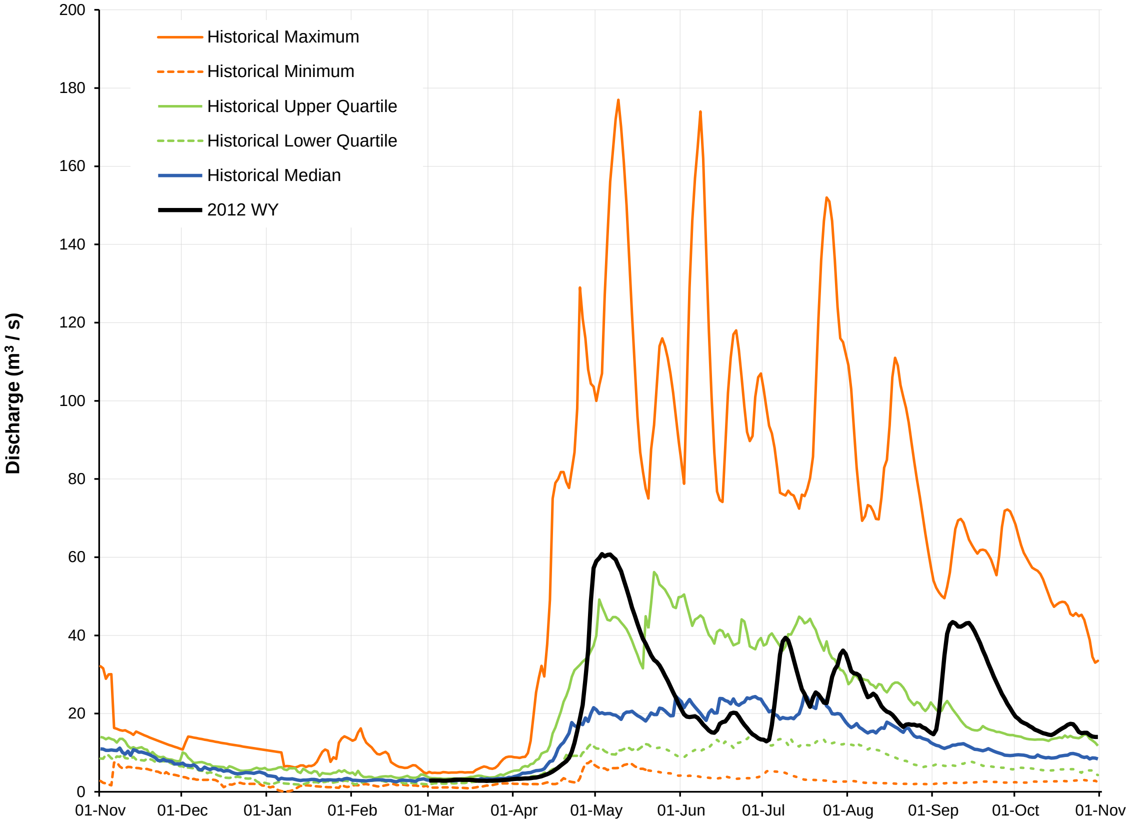


Figure 4.3-8 The 2012 WY Christina River hydrograph compared to historical values.



4.4 SUMMARY

In summary, climate and hydrology in the RAMP FSA in the 2012 WY was characterized by the following conditions:

1. The 2012 WY represented a departure from drier than normal conditions observed in the previous eight years. Annual precipitation measured at Fort McMurray was approximately 6% higher than the historical mean. The wettest months were July and September with precipitation amounts of 69% and 141% above the historical mean, respectively. Conversely, precipitation during the winter months was approximately 34% lower than the historical mean. Most of the RAMP climate stations were consistent with this pattern, with the exception of the C5-Surmont and L2-Kearl Lake station, which recorded cumulative totals exceeding the historical mean by 46% and 15%, respectively.

2. Mean daily air temperatures in the 2012 WY were generally warmer across all months, with greater increases above the historical mean values in the winter months. In late October, observed temperatures were below the historical mean by approximately 2.6°C.

3. The runoff volume for WSC Station 07DA001, Athabasca River below Fort McMurray, recorded flows above the mean for the fifth year in the last two decades. In the 2012 WY, the annual flow volume of 18,934 million m^3 was 10% higher than the historical mean for this station.

4. Seasonal (March to October) runoff volumes were approximately 7% and 46% lower than historical mean values for the Muskeg and MacKay rivers, respectively, but 8% higher for the Christina River.

5. Annual maximum daily flows in the 2012 WY were largely influenced by rainfall events that occurred in late summer and early fall in the Athabasca, Muskeg, and MacKay rivers. In contrast, the hydrograph for the Christina River was dominated by snowmelt during the spring freshet period.

5.0 2012 RAMP RESULTS

The following chapter consists of two parts. The first part focuses on detailed monitoring results specific to individual watersheds within the RAMP Focus Study Area (FSA). 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 of RAMP and focuses on water quality monitoring at 50 lakes and ponds located throughout the RAMP Regional Study Area (RSA).

For the watershed analyses, Section 5.1 presents 2012 results for the Athabasca River and the Athabasca River Delta (ARD); Sections 5.2 to 5.12 present 2012 watershed results for the major tributaries of the Athabasca River within the RAMP FSA; and Section 5.13 contains the results for miscellaneous aquatic systems that were monitored in 2012. 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 RAMP 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	5-96	5-181	5-233	5-267	5-301	5-334	5-369	5-408	5-463	5-546	5-553	5-566	-
Water Quality	5-9	5-97	5-182	5-234	5-268	5-302	5-335	5-371	5-408	5-466	-	5-553	5-566	-
Benthic Invertebrate Communities	5-13	5-101	5-184	5-235	5-270	5-303	5-337	5-372	5-410	5-468	-	-	5-566	-
Sediment Quality	5-18	5-107	5-184	5-237	5-272	5-306	5-339	5-374	5-411	5-472	-	-	5-566	-
Fish Populations	5-20	5-109	5-186	5-238	5-272	5-307	5-340	5-376	5-411	5-474	-	-	5-566	-

Definitions for Monitoring Status

The RAMP 2012 Technical 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 focal projects; 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 2012) or were (prior to 2012) 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 the 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.

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 2012 Conditions												
	Athabasca River								*Athabasca River Delta*				
Climate and Hydrology													
Criteria							**S46** Athabasca River near Embarras Airport		no stations sampled				
Mean open-water season discharge							🟡						
Mean winter discharge							🟡						
Annual maximum daily discharge							🟡						
Minimum open-water season discharge							🟡						
Water Quality													
Criteria	**ATR-DC-E** upstream of Donald Creek (east bank)	**ATR-DC-W** upstream of Donald Creek (west bank)	**ATR-SR-E** upstream of Steepbank River (east bank)	**ATR-SR-W** upstream of Steepbank River (west bank)	**ATR-MR-E** upstream of Muskeg River (east bank)	**ATR-MR-W** upstream of Muskeg River (west bank)	**ATR-DD-E** downstream of all development (east bank)	**ATR-DD-W** downstream of all development (west bank)	no stations sampled				
Water Quality Index	🟡	🟡	🟡	🟡	🟠	🟡	🟡	🟡					
Benthic Invertebrate Communities and Sediment Quality													
Criteria	no reaches sampled								**FLC** Fletcher Channel	**GIC** Goose Island Channel	**BPC** Big Point Channel	**ATR-ER** Athabasca River downstream of Embarras River	**EMR-2** Embarras River
Benthic Invertebrate Communities									🟤	🟠	🟠	ns	🟠
Sediment Quality Index									🟡	🟡	🟡	🟡	🟡
Fish Populations													
No fish tissue or fish assemblage activities conducted in 2012													

Legend and Notes

🟡 Negligible-Low	*baseline*
🟠 Moderate	*test*
🟤 High	

n/a – not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

ns – not sampled

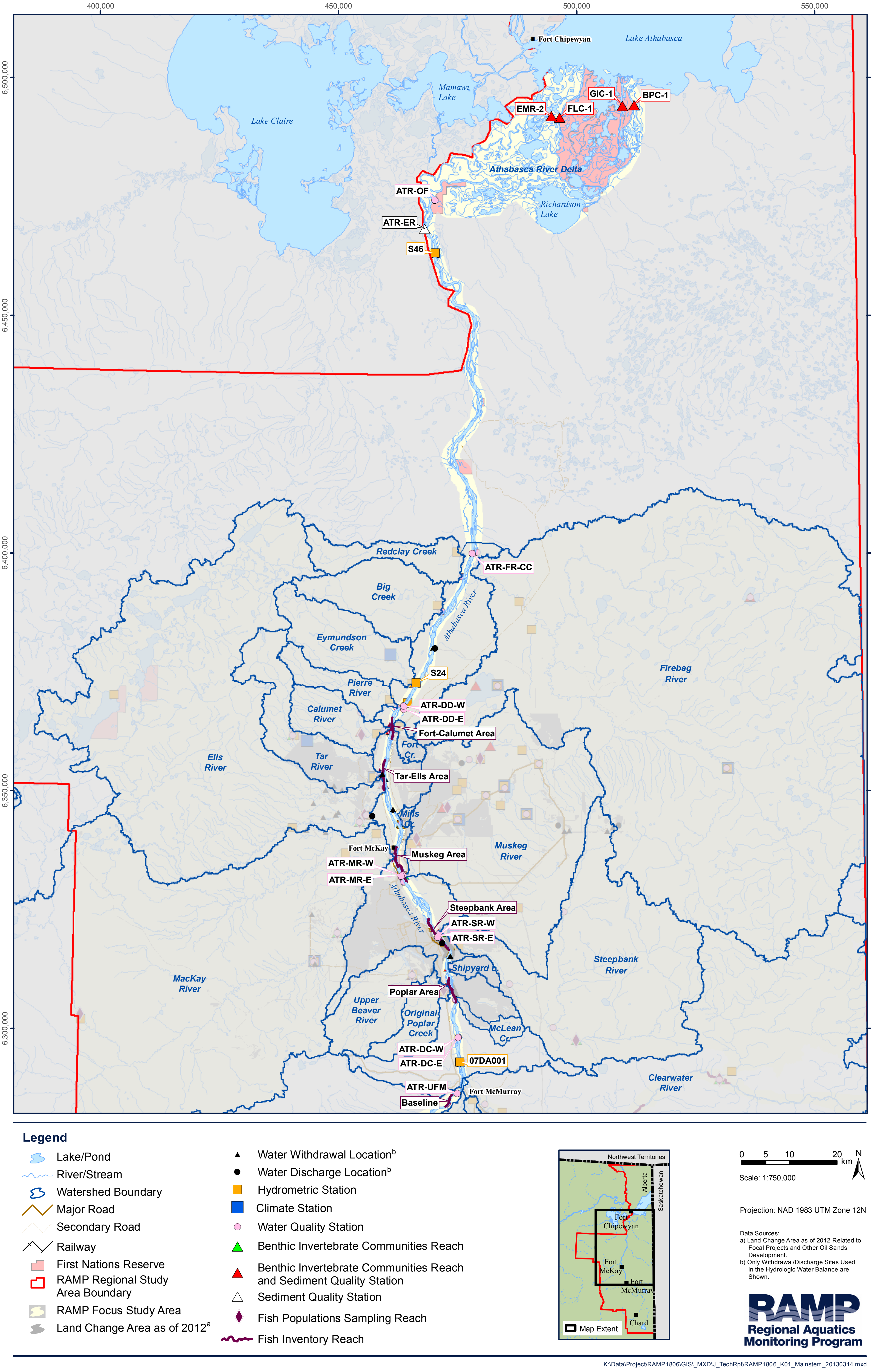
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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* areas 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.

Figure 5.1-1 Athabasca River and Athabasca River Delta.



Scale: 1:750,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K01_Mainstem_20130314.mxd

Figure 5.1-2 Representative monitoring stations of the Athabasca River and Athabasca River Delta, fall 2012.

Hydrology Station S24: Athabasca River below Eymundson Creek

Benthic and Sediment Quality Station FLC-1: Athabasca River Delta – Fletcher Channel

Benthic and Sediment Quality Station ATR-ER: Athabasca River downstream of Embarras River

Hydrology Station S46: Athabasca River near Embarras Airport

Water Quality Station ATR-DC-W: Athabasca River at Donald Creek

Benthic and Sediment Quality Station GIC-1: Athabasca River Delta – Goose Island Channel

Water Quality Station ATR-MR-W: Athabasca River downstream of Muskeg River

Water Quality Station ATR-MR-E: Athabasca River downstream of Muskeg River

5.1.1 Summary of 2012 Conditions

As of 2012, approximately 3.0% (106,098 ha) of the RAMP FSA had undergone land change from focal projects and other oil sands developments (Table 2.5-2). Approximately 23.7% (38,137 ha) of the minor Athabasca River tributary watersheds had undergone land change as of 2012 from focal projects and other oil sands developments (Table 2.5-2). For 2012, 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 2012 assessment for the Athabasca River and Athabasca River Delta, while Figure 5.1-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations, and the land change area for 2012. Figure 5.1-2 contains fall 2012 photos of a number of monitoring stations in the Athabasca River and Athabasca River Delta.

Hydrology The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge calculated from the observed *test* hydrograph were 0.6%, 1.8%, 0.3% and 1.0% lower, respectively, than from the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The results of the hydrologic assessment were essentially identical to results for the case in which focal projects plus other oil sands developments were considered.

Water Quality Differences in water quality in fall 2012 at all stations in the Athabasca River were classified as **Negligible-Low** compared to the regional *baseline* conditions, with the exception of *test* station ATR-MR-E, which showed **Moderate** differences from regional *baseline* conditions due to high concentrations of TSS, organic carbon, nutrients, and associated particulate metals. Concentrations of water quality measurement endpoints at the *test* stations were generally similar to those at the upstream *baseline* stations (ATR-DC-E and ATR-DC-W) and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded guidelines at all stations, while total boron showed an increasing trend at *test* stations ATR-DD-W, ATR-MR-E, and ATR-MR-W.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities in the Athabasca River Delta at *test* reach BPC-1 were classified as **Moderate** because there was an increase in equitability over time and abundance and richness were lower in 2012 compared to previous sampling years. In addition, abundance was very low in 2012 than all previous sampling years and lower than the range of historical conditions for all ARD reaches.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **High** because of significant decreases in abundance and CA Axis 2 scores over time and lower abundance, richness, and diversity, and higher equitability in 2012 compared to the mean of previous sampling years. In addition, abundance, richness, percent EPT, equitability, and CA Axis 2 scores were outside the range of historical conditions for all ARD reaches.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach GIC-1 were classified as **Moderate** because the CA Axis 2 scores showed a significant difference in 2012, reflecting a potential decrease in relative abundances of bivalves and gastropods. Values of all other measurement endpoints were within previously-measured values for this reach and within the range of historical conditions for all ARD reaches.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach EMR-2 were classified as **Moderate** because richness and the percentage of the fauna as EPT taxa significantly decreased over time. In addition, Ephemeroptera were absent, although the benthic fauna at *test* reach EMR-2 in 2012 was still considered to be in relatively good condition.

Total abundance of benthic invertebrate communities in all four channels of the ARD was negatively correlated with percent substrate as sand. The higher sand content in 2012 in the channels of the ARD was likely related to high discharge events in 2012 prior to the fall sampling period, potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints as **Moderate** for *test* reaches BPC-1, GIC-1, and EMR-2 and **High** for *test* reach FLC-1, the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in the channels of the ARD.

In fall 2012, sediment quality in channels of the ARD generally exhibited coarser characteristics with lower organic carbon and hydrocarbon concentrations, than in recent years. All stations were predominantly composed of sand, with the exception of EMR-2 where silt was dominant. Concentrations of sediment quality measurement endpoints at all five stations in the ARD were generally similar to previously-measured concentrations. PAHs at all stations in fall 2012 were dominated by alkylated species, indicating a petrogenic origin of these compounds. From 1999 to 2010, an increase in concentrations of total PAHs was observed at *test* station BPC-1, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2012, the concentration of total PAHs at *test* station BPC-1 was lower than the previously-measured minimum concentration. With the exception of *test* station ATR-ER, all stations in the ARD exhibited a decrease in TOC and total PAHs in fall 2012 relative to fall 2011, likely associated with the courser substrate observed at all stations. The PAH Hazard Index at *test* station EMR-2 was above the potential chronic toxicity threshold value of 1.0 but below 1.0 at all other stations. Acute toxicity data for sediments exceeded previously-measured maximum values for *Hyalella* survival at *test* station BPC-1 and *Chironomus* survival at *test* station ATR-ER. Samples collected from *test* station FLC-1 showed historically low growth of *Chironomus* relative to previously-measured minimum concentrations. SQI values for all stations indicated **Negligible-Low** differences from regional *baseline* conditions.

Fish Populations (fish inventory) As outlined in the RAMP Design and Rationale document, the Athabasca River fish inventory is generally considered to be a community-driven activity, primarily used for assessing general trends in abundance and populations variables for large-bodied species, rather than detailed community structure.

As of 2012, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, age-frequency distributions, and condition of fish among years. There has been a significant increase in the catch and CPUE of goldeye in the last two years (i.e., 2011 and 2012), which could be related to an increase in recruitment during the calm, warm spring seasons in the last two years in the lower Athabasca River. However, it is important to note that the despite the increase in goldeye in the river, the absolute abundances of other KIR species has not concomitantly decreased. More data are necessary to determine any trends and evaluate the cause of the increase in goldeye numbers.

The fish health assessment indicated that abnormalities observed in 2012 in all species were within the historical range and consistent with studies done prior to the major oil sands development in the upper Athabasca River, the ARD, and the Peace and Slave rivers.

5.1.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Athabasca River was conducted at RAMP Station S46, Athabasca River near Embarras Airport, which was used for the water balance analysis instead of RAMP Station S24, Athabasca River below Eymundson Creek, which was used in previous years. This change was undertaken because the S46 station was located further downstream than the S24 station and encompassed all development in the RAMP FSA. The water balance analysis was conducted using both stations for the 2012 WY to determine if a bias was present between the two stations and if the results calculated from S46 represented the same level of effect as the calculations conducted using the S24 station from past years. Results from this assessment indicated that the level of effect was the same between the two stations and the results across years were comparable. Additional hydrometric data for the Athabasca River were available from stations S24, Athabasca River below Eymundson Creek and 07DA001, Athabasca River below Fort McMurray. Details for the RAMP Station S24 can be found in Appendix C.

Continuous hydrometric data have been collected for Station S46 since August 16, 2011. Historical continuous annual data were available for the WSC Station 07DD001, Athabasca River at Embarras Airport from 1971 to 1976 and seasonal data from May to October were available from 1977 to 1984. In the 2012 WY, the annual and open-water runoff volumes were 23,418 million m^3 and 18,759 million m^3, respectively. The 2012 WY annual runoff volume was 3.3% lower than the historical mean annual runoff (1971 to 1976 WY), and the open-water runoff volume was 0.4% higher than the historical mean open-water runoff (1971 to 1986). Flows decreased from November 2011 to March 2012 and were below the historical median values, with the exception of early December when flows exceeded the historical upper quartile values (Figure 5.1-3). In late March and early April, flows increased during spring freshet to a peak of 1,381 m^3/s on April 25, which was 4% higher than the historical maximum value recorded for this time of the year. In mid-May, flows generally decreased until early June when flows increased again and remained at or above the historical mean until mid-August. Flows in mid-June and mid-July exceeded the historical upper quartile and in late August flows exceeded the historical maximum value. The annual maximum daily flow of 3,178 m^3/s recorded on July 31 was 18% higher than the historical mean maximum daily flow. Flows decreased following this peak until mid-October to the lowest open-water flow of 502 m^3/s on October 16, 2012. This value was 12% lower than the historical open-water mean minimum daily flow of 570 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at Station S46 in the 2012 WY is presented for two different cases in Table 5.1-2. The first case considered changes from focal projects and the second case considered changes from focal projects plus other oil sands developments. The second case can be considered as the cumulative hydrologic assessment in the 2012 WY for all oil sands developments in the Athabasca River watershed upstream of Station S46.

A summary of the inputs to the water balance model for the Athabasca River for the focal projects is provided below and in Table 5.1-2:

1. The closed-circuited land area from focal projects as of 2012 in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River and Upper Beaver River was estimated to be 375 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 57.098 million m^3.

2. As of 2012, the area of land change from focal projects 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 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 2.640 million m^3.
3. Water withdrawals directly from the Athabasca River by focal projects in the 2012 WY were 114.348 million m^3.
4. Water discharges directly to the Athabasca River by focal projects in the 2012 WY were 1.158 million m^3.
5. The 2012 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 7.156 million m^3 less than the discharge would have been in the absence of focal projects in those watersheds.

The estimated cumulative effect was a loss of flow of 174.803 million m^3 at Station S46 from what the estimated *baseline* flow would have been in the absence of focal projects. The estimated observed *test* and estimated *baseline* hydrographs are presented in Figure 5.1-3. The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge calculated from the observed *test* hydrograph were 0.6%, 1.8%, 0.3% and 1.0% lower, respectively, than from the estimated *baseline* hydrograph (Table 5.1-3). These differences were all classified as **Negligible-Low** (Table 5.1-1).

In the second case, inputs from both focal and non-focal oil sands developments were considered. The non-focal oil sands developments occurred within the Horse River and Christina River watersheds. These were the only two watersheds in the RAMP FSA that contained non-focal oil sands developments under construction or operational as of 2012 (Table 2.5-1). The estimated cumulative effect of focal plus non-focal oil sands developments was a loss of flow of 174.843 million m^3 at Station S46 from the estimated *baseline* flow that would have occurred in the absence of these projects and developments (Table 5.1-2). This value was 0.04 million m^3 different from the first case. The values of the hydrologic measurement endpoints were essentially identical for the two cases (Table 5.1-3).

5.1.3 Water Quality

In 2012, water quality samples were taken on the Athabasca River at:

- *baseline* stations ATR-DC-E and ATR-DC-W, east and west banks, upstream of Donald Creek in winter, spring, summer, and fall (data available most years from 1997 to 2012);
- *test* stations ATR-SR-E and ATR-SR-W, east and west banks, upstream of the Steepbank River in fall (data available from 2000 to 2012);

- *test* stations ATR-MR-E and ATR-MR-W, east and west banks, upstream of the Muskeg River in fall (data available most years from 1998 to 2012); and
- *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 2002 to 2012).

In addition, monthly water quality sampling of the Athabasca River is 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 by RAMP in fall, and was called "ATR-FR-CC" (data available from 2002 to 2010).

Temporal Trends The following significant (α=0.05) trends in fall concentrations (typically 2000 to 2012) of water quality measurement endpoints at RAMP stations were detected:

- Decreasing concentrations of calcium, sulphate, and total strontium, and increasing concentrations of total suspended solids and total nitrogen at *baseline* station ATR-DC-E;
- A decreasing concentration of chloride, and increasing concentrations of total suspended solids, total boron, and total nitrogen at *test* station ATR-MR-E;
- Increasing concentrations of total arsenic and total boron at *test* station ATR-MR-W;
- An increasing concentration total dissolved solids at *test* station ATR-DD-E; and
- An increasing concentration of total boron at *test* station ATR-DD-W.

Trends were generally consistent among stations along the river's east bank (i.e., decreasing ions and increasing TSS and TDS) and west bank (i.e., increasing metals), and were observed in stations upstream (-DC) and downstream (-SR, -MR, -DD) of watersheds with oil sands development (i.e., McLean, Poplar, and Steepbank, Muskeg, MacKay, and Tar rivers). The increase in concentrations of total arsenic and total boron over time at *test* station ATR-MR-W was not observed at other stations. Concentrations of these metals at *test* station ATR–MR-W in fall 2012; however, were within the range of previously-measured concentrations at all stations and similar to concentrations from previous years. No significant trends from 1998 to 2012 were observed at *baseline* station ATR-DC-W and *test* stations ATR-SR-E and ATR-SR-W.

Water quality data was 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 between 1997 and 2012. The following significant trends (α=0.05) in concentrations of water quality measurement endpoints were detected from the monthly data for the Athabasca River mainstem:

- Increasing concentrations of total nitrogen and total Kjeldahl nitrogen, and decreasing concentrations of total phosphorous and total boron at *baseline* station ATR-UFM (upstream of Fort McMurray and upstream of oil sands development); and
- Increasing pH and concentrations of total nitrogen, total Kjeldahl nitrogen, sulphate, and total aluminum, and a decreasing concentration of total molybdenum at *test* station ATR-OF (near the Athabasca delta, downstream of oil sands development).

2012 Results Relative to Historical Concentrations Relative to previous years, water quality in the Athabasca River in September 2012 generally exhibited higher suspended solids and nutrients and lower ion concentrations. However, concentrations of most water quality measurement endpoints in fall 2012 were within the range of previously-measured concentrations at the Athabasca River stations, with the following exceptions (Table 5.1-4):

- total dissolved phosphorus, with a concentration that exceeded the previously-measured maximum concentration (0.029 mg/L) and dissolved organic carbon (2.5 mg/L versus previous minimum of 4 mg/L), magnesium (5.49 mg/L versus previous minimum of 5.7 mg/L), and sulphate (5.67 mg/L versus previous minimum of 6.4 mg/L), with concentrations that were lower than previously-measured minimum concentrations at *baseline* station ATR-DC-E;
- dissolved organic carbon (1.5 mg/L versus previous minimum of 3.0 mg/L), with a concentration that was lower than the previously-measured minimum concentration at *baseline* station ATR-DC-W;
- total suspended solids (209 mg/L versus previous historical high of 117 mg/L), with a concentration that exceeded the previously-measured maximum concentration, and sodium (7.8 mg/L versus previous low of 11 mg/L) and chloride (2.47 mg/L versus historical low of 8 mg/L), with concentrations that were lower than previously-measured minimum concentrations at *test* station ATR-SR-E;
- total suspended solids (136 mg/L versus previous historical high of 81 mg/L), with a concentration that exceeded the previously-measured maximum concentration at *test* station ATR-SR-W;
- dissolved organic carbon (18.1 mg/L versus 15.4 mg/L), total arsenic (0.083 mg/L versus 0.078 mg/L), dissolved aluminum (0.098 mg/L versus 0.06 mg/L), and total boron (0.048 mg/L versus 0.032 mg/L), with concentrations that exceeded previously-measured maximum concentrations and total molybdenum (0.0003 mg/L versus 0.0004 mg/L), total strontium (0.128 mg/L versus 0.15 mg/L), sulphate (14.3 mg/L versus 15.5 mg/L), calcium (23.2 mg/L versus 24.5 mg/L), and magnesium (6.35 mg/L versus 7.2 mg/L), with concentrations that were lower than previously-measured minimum concentrations at *test* station ATR-MR-E;
- dissolved aluminum (0.0419 mg/L versus 0.0322 mg/L) and total mercury (ultra-trace) (7.8 mg/L versus 5.8 mg/L), with concentrations that exceeded the previously-measured maximum concentrations and sodium (9.9 mg/L versus 10 mg/L), with a concentration that was lower than the previously-measured minimum concentration at *test* station ATR-MR-W;
- total boron (0.0311 mg/L versus 0.0303 mg/L), with a concentration that exceeded the previously-measured maximum concentration, and sodium (9.3 mg/L and 12 mg/L) and chloride (6.22 mg/L versus 7.0 mg/L), with concentrations that were lower than previously-measured minimum concentrations at *test* station ATR-DD-E; and
- sodium (9.7 mg/L versus 10.8 mg/L) and chloride (5.56 mg/L versus 5.83 mg/L), with concentrations that were lower than previously-measured minimum concentrations at *test* station ATR-DD-W.

Ion Balance The ionic composition in fall 2012 at all Athabasca River stations was consistent with ionic composition at these stations since 1997, and dominated by calcium and bicarbonate (Figure 5.1-4 to Figure 5.1-6). Water collected from the east bank of the Athabasca River tended to have a greater proportion of sodium and chloride ions than water from the west side, which was most evident at *baseline* station ATR-DC-E and likely related to the incomplete mixing of the Clearwater River into the Athabasca River mainstem upstream of *baseline* station ATR-DC-E (see Section 5.9 for a description of the ionic composition of water from the Clearwater River).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints were below water quality guidelines in fall 2012 (Table 5.1-4), with the exception of total aluminum at all stations in the Athabasca River mainstem and total mercury (ultra-trace) at *baseline* station ATR-DC-E and *test* stations ATR-SR-E, ATR-MR-E, and ATR-MR-W.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Athabasca River mainstem in fall 2012 (Table 5.1-5):

- Total iron and total chromium at all stations;
- Dissolved iron at *baseline* station ATR-DC-E and *test* station ATR-MR-E;
- Total phosphorus at *baseline* stations ATR-DC-E and ATR-DC-W and *test* stations ATR-SR-E, ATR-SR-W, ATR-MR-E, ATR-MR-W, and ATR-DD-E;
- Total phenols at *baseline* stations ATR-DC-E and ATR-DC-W and *test* stations ATR-MR-E, ATR-MR-W, and ATR-DD-E;
- Total copper at *test* stations ATR-SR-W, ATR-MR-E, and ATR-MR-W; and
- Benzo[a]pyrene at *test* station ATR-SR-W.

Concentrations of water quality measurement endpoints that exceeded relevant water quality guidelines in other seasons are listed in Table 5.1-5.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of the following water quality measurement endpoints exceeded the 95th percentile of regional *baseline* concentrations in fall 2012 (Figure 5.1-7 to Figure 5.1-9):

- Dissolved phosphorus and total arsenic at *baseline* station ATR-DC-E;
- Total suspended solids, total arsenic, and total mercury (ultra-trace) at *test* stations ATR-MR-E and ATR-MR-W;
- Total nitrogen and total boron at *test* station ATR-MR-E;
- Total suspended solids and total mercury (ultra-trace) at *test* station ATR-SR-E; and
- Total suspended solids and total arsenic at *test* station ATR-SR-W.

Concentrations of the following water quality measurement endpoints that were below the 5th percentile of regional *baseline* concentrations in fall 2012 (Figure 5.1-7 to Figure 5.1-9):

- sulphate at *baseline* station ATR-DC-E; and
- sodium at *test* stations ATR-SR-E and ATR-SR-W.

Water Quality Index The WQI values at all stations in the Athabasca River mainstem in fall 2012 indicated **Negligible-Low** differences from regional *baseline* water quality conditions, with the exception of *test* station ATR-MR-E (WQI: 74.0), which indicated a **Moderate** difference from regional *baseline* conditions (Table 5.1-6). The WQI value for all other stations on the Athabasca River ranged from 84.7 to 100 (Table 5.1-6). The lower WQI value at *test* station ATR-MR-E was driven primarily by the high concentrations of total suspended solids (TSS), dissolved organic carbon (DOC), total organic carbon (TOC), total phosphorous, total Kjeldahl nitrogen, and various total metals typically associated with particulates (i.e., Al, As, Ba, B, Cr, Co, Fe, Pb, Li, Mn, Hg, Ti, V) relative to the historical range of concentrations measured at the upstream *baseline* stations (ATR-DC-E/W), which were used to represent regional *baseline* conditions for the Athabasca River.

Classification of Results Differences in water quality in fall 2012 at all stations in the Athabasca River were classified as **Negligible-Low** compared to the regional *baseline* conditions, with the exception of *test* station ATR-MR-E which showed **Moderate** differences from regional *baseline* conditions due to high concentrations of TSS, organic carbon, nutrients, and associated particulate metals. Concentrations of water quality measurement endpoints at the *test* stations were generally similar to those at the upstream *baseline* stations (ATR-DC-E and ATR-DC-W) and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded guidelines at all stations, while total boron showed an increasing trend at *test* stations ATR-DD-W, ATR-MR-E, and ATR-MR-W.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities in the Athabasca River Delta

Benthic invertebrate community samples were collected from four depositional reaches in the ARD in fall 2012:

- Depositional *test* reach BPC-1 in Big Point Channel, sampled from 2002 to 2005 and 2007 to 2012;
- Depositional *test* reach FLC-1 in Fletcher Channel, sampled from 2002 to 2005 and 2007 to 2012;
- Depositional *test* reach GIC-1 in Goose Island Channel, sampled from 2002 to 2005 and 2007 to 2012; and
- Depositional *test* reach EMR-2 in the Embarras River, sampled in 2010 and 2012.

2012 Habitat Conditions Samples were collected at depths between 2.5 and 4 m. Water at *test* reaches BPC-1, GIC-1, FLC-1, and EMR-2 was neutral/basic, with high dissolved oxygen (> 8.5 mg/L), moderate conductivity (~250 µS/cm), and water temperatures around 16°C (Table 5.1-7). The substrate in the four channels was fine and typically dominated by sand and silt (Table 5.1-7). The substrate in the Embarras River was more equally distributed between sand/silt/clay than the other reaches (Table 5.1-7). Total organic carbon content of sediments was low at all reaches (<1%), with the exception of the Embarras River where it was slightly higher (2.3 %) (Table 5.1-7).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate communities at *test* reach BPC-1 in fall 2012 were dominated by chironomidae (63%) and tubificid worms (27%), with sub-dominant taxa consisting of Copepoda (3%) and Cladocera (3%) (Table 5.1-8). Chironomids at *test* reach BPC-1 were primarily of the genera *Procladius*, *Stempellina*, and *Paracladopelma*. A single bivalve (*Pisidium*) and mayflies (Ephemeroptera: *Ametropus neavei*) were found in low relative abundances at *test* reach BPC-1. The total abundance at *test* reach BPC-1 was extremely low in fall 2012 (791 organisms/m^2) compared to previous years (4,757 to 103,982 organisms/m^2).

The benthic invertebrate communities at *test* reach FLC-1 in fall 2012 were dominated by chironomids (79%), with subdominant taxa including tubificids (11%), Ceratopogonidae (8%), and Copepoda (3%) (Table 5.1-8). Chironomids at *test* reach FLC-1 consisted of seven taxa, and were primarily of the genera *Paracladopelma*. EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa were not found at *test* reach FLC-1 in fall 2012 and neither were bivalves or gastropods. The total abundance at *test* reach FLC-1 was extremely low in fall 2012 (330 organisms/m^2) compared to previous years (8,327 to 118,413 organisms/m^2).

The benthic invertebrate communities at *test* reach GIC-1 were dominated by tubificid worms (48%) and chironomids (31%), with subdominant taxa consisting of copepods (15%) (Table 5.1-9). There were many other taxa present in very low relative abundance (Table 5.1-9). The chironomids at *test* reach GIC-1 were primarily of the forms *Paracladopelma* and *Beckidia zabolotskyi.* Mayflies (*Ametropus neavei*) were present in low relative abundances in some replicates at *test* reach GIC-1 (Table 5.1-9).

The benthic invertebrate communities at *test* reach EMR-2 were dominated by Ostracoda (30%) and chironomids (29%), with subdominant taxa consisting of Ceratopogonidae (16%), Nematoda (12%), and Bivalvia (*Pisidium/Sphaerium:* 7%) (Table 5.1-9). Chironomids were primarily from the genera *Procladius*, *Polypedilum*, *Tanytarsus*, and *Stempellinella*. Mayflies (Ephemeroptera) were absent, but a few caddisflies (*Oecetis* and *Neureclipsis*) were found in some of the replicates.

Big Point Channel

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 Big Point Channel.

Temporal comparisons for *test* reach BPC-1 included testing for:

- Changes over time (Hypothesis 1, Section 3.2.3.1); and
- Changes between 2012 values and the mean of all previous years of sampling.

Equitability increased over time at *test* reach BPC-1, explaining >20% of the variance in annual means (Table 5.1-10). Abundance and richness were lower and equitability was higher in 2012 than the mean of previous sampling years, explaining >20% of the variance in annual means (Table 5.1-10).

CA Axis 2 scores decreased over time at *test* reach BPC-1 and were lower in 2012 than the mean of all previous years, explaining >60% of the variance in annual means for both cases (Table 5.1-10). The shift in axis scores reflected a decrease in the relative abundance of tubificids in 2012.

Comparison to Published Literature The relative abundance of tubificid worms (27%) at *test* reach BPC-1 decreased significantly from 2011 (75%). Griffiths (1998) considers a community with >30% worms to be potentially indicative of degraded conditions. Tubificidae accounted for just <30% in 2012 compared to 75% in 2011. The composition of the benthic invertebrate community in 2012 was what would be expected in a shifting sand environment (Barton and Smith 1984).

2012 Results Relative to Historical Conditions Values of measurement endpoints for benthic invertebrate communities at *test* reach BPC-1 in fall 2012 were within the range of historical conditions, defined by the range of data from previous sampling years for all ARD reaches up to 2011, with the exception of abundance, which was very low and below the 5th percentile of the historical range (Figure 5.1-10). The number of taxa (7) was below the median value for the ARD while diversity, equitability, and percentage of the fauna as EPT taxa were above the median value. The CA Axis 2 scores were outside the range of historical conditions observed in the delta reflecting an absence of bivalves, gastropods, and a lower relative abundance of tubificids in 2012 (Figure 5.1-11). The decrease in percentage of the fauna as Oligochaeta (i.e., Tubificidae) was most likely related to a change in sediment grain size given that it was determined that total benthic abundance (and abundance of tubificids) seemed to covary with substrate texture, with abundances increasing in siltier sediments (RAMP 2012). Sediments in 2012 were sandier than they were in 2011, likely explaining the marked decrease in total numbers (Figure 5.1-12).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities in the Athabasca River Delta at *test* reach BPC-1 were classified as **Moderate** because there was an increase in equitability over time and abundance and richness were lower in 2012 compared to previous sampling years. In addition, abundance was very low in 2012 than all previous sampling years and lower than the range of historical conditions for all ARD reaches. Total abundance of benthic invertebrate communities in Big Point Channel was negatively correlated with percent substrate as sand (Figure 5.1-12). The higher sand content in 2012 in Big Point Channel was likely related to high discharge events in 2012 prior to the fall sampling period (Figure 5.1-3), potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints at *test* reach BPC-1 as **Moderate**, the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in Big Point Channel.

Fletcher Channel

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 Fletcher Channel.

Temporal comparisons for *test* reach FLC-1 included testing for:

- Changes over time (Hypothesis 1, Section 3.2.3.1); and
- Changes between 2012 values and the mean of all previous years of sampling.

Equitability increased over time and was higher in 2012 than the mean of previous sampling years at *test* reach FLC-1, explaining 27% and 65% of the variance in annual means, respectively (Table 5.1-11). Abundance, richness, and CA Axis 2 scores were lower in 2012 at *test* reach FLC-1 than the mean of previous sampling years, explaining >20% of the variance in annual means in all cases (Table 5.1-11). The decrease in CA

Axis 2 scores potentially reflected a decreased in the relative abundance of bivalves (Figure 5.1-11).

Comparison to Published Literature The benthic invertebrate community at *test* reach FLC-1 in fall 2012 was somewhat unusual compared to what was typically reported for shifting-sand riverine environments (Barton and Smith 1984). Shifting sands typically support chironomids, worms, and ceratopogonids, which were present at this reach. Shifting sand environments also typically contain mayflies (Ephemeroptera), which were absent in 2012, though can be problematic to collect in shifting sands (e.g., *Ametropus neavei*) (Barton and Lock 1979).

2012 Results Relative to Historical Conditions Total abundance (~300 organisms per m^2) was very low in 2012, with abundance generally between 5,000 and 10,000 organisms per m^2 in the delta. Taxa richness and percent EPT were also below the range of variation for ARD reaches, while equitability exceeded the historical range for ARD reaches (Figure 5.1-10). CA Axis 2 scores were outside the historical ranges for ARD reaches (Figure 5.1-11), potentially reflecting an absence of bivalves and gastropods at this reach in 2012.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **High** because of a significant decrease in abundance over time and lower abundance, richness, and diversity, and higher equitability in 2012 compared to the mean of previous sampling years. In addition, abundance, richness, percent EPT, equitability, and CA Axis 2 scores were outside the range of historical conditions for all ARD reaches. Total abundance of benthic invertebrate communities in Fletcher Channel was negatively correlated with percent substrate as sand (Figure 5.1-12). The higher sand content in 2012 in Fletcher Channel was likely related to high discharge events in 2012 prior to the fall sampling period (Figure 5.1-3), potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints at *test* reach FLC-1 as **High**, the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in Fletcher Channel.

Goose Island Channel

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 Goose Island Channel.

Temporal comparisons for *test* reach GIC-1 included testing for:

- Changes over time (Hypothesis 1, Section 3.2.3.1); and
- Changes between 2012 values and the mean of all previous years of sampling.

CA Axis 2 scores were lower in 2012 than the mean of previous years, explaining 35% of the variance in annual means (Table 5.1-12). The lower CA Axis 2 scores reflected a decrease in the relative abundances of tubificids and bivalves and an absence of gastropods (Figure 5.1-11).

Comparison to Published Literature The benthic invertebrate community at *test* reach GIC-1 in 2012 was what would be expected of a shifting-sand riverine environment (Barton and Smith 1984). Shifting sands typically support chironomids, worms and ceratopogonids, which were present at this reach as well as mayflies such as *A. neavei*, which was also present in 2012, and can be difficult to collect, with reported numbers often not reflecting their true abundance (Barton and Lock 1979).

2012 Results Relative to Historical Conditions Values of measurement endpoints for benthic invertebrate communities at *test* reach GIC-1 were within the range of historical conditions for all reaches in the ARD (Figure 5.1-10). CA Axis 2 scores were at the lower edge of the 95th percentile of historical conditions (Figure 5.1-11).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach GIC-1 were classified as **Moderate** because the CA Axis 2 scores showed a significant difference in 2012, reflecting a potential decrease in relative abundances of bivalves and gastropods. Values of all other measurement endpoints were within previously-measured values for this reach and within the range of historical conditions for all reaches in the ARD. Total abundance of benthic invertebrate communities in Goose Island Channel was negatively correlated with percent substrate as sand (Figure 5.1-12). The higher sand content in 2012 in Goose Island Channel was likely related to high discharge events in 2012 prior to the fall sampling period (Figure 5.1-3), potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints at *test* reach GIC-1 as **Moderate**, the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in Goose Island Point Channel.

Embarras River

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 Embarras River.

Temporal comparisons for *test* reach EMR-2 included testing for:

- Changes over time (Hypothesis 1, Section 3.2.3.1); and
- Changes between 2012 values and the mean of all previous years of sampling.

Richness and percent EPT decreased over time at *test* reach EMR-2, explaining >20% of the variance in annual means (Table 5.1-13). CA Axis 1 scores were lower in 2012 than the mean of previous sampling years, explaining 77% of the variance in annual means (Table 5.1-13) and reflecting an increase in the relative abundance of ceratopogonids and a decrease in the relative abundance of chironomids (Figure 5.1-11).

Comparison to Published Literature The benthic invertebrate community at *test* reach EMR-2 was typical for a shifting-sand environment, with a low relative abundance of tubificid worms (4%) and higher relative abundances of chironomids, ostracods, and ceratopogonids (75% of the community). Bivalves (*Pisidium/Sphaerium*) were present at this reach but Ephemeroptera were absent in 2012. The benthic fauna at *test* reach EMR-2 was typical for rivers in good condition (Hynes 1960, Griffiths 1998).

2012 Results Relative to Historical Conditions Values of measurement endpoints for benthic invertebrate communities at *test* reach EMR-2 were within the range of historical conditions for the ARD reaches (Figure 5.1-10). The percentage of the fauna as EPT taxa decreased from 2010 and was near the minimum value for historical conditions for the ARD (Figure 5.1-10). CA Axis 1 and 2 scores were within the range of historical conditions for the ARD (Figure 5.1-11).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach EMR-2 were classified as **Moderate** because richness and the percentage of the fauna as EPT taxa significantly decreased over time. In addition, Ephemeroptera were absent, although the benthic fauna at *test* reach EMR-2 in 2012 was still considered to be in relatively good condition. Total abundance of benthic invertebrate communities in the Embarras River was negatively correlated with percent substrate as sand (Figure 5.1-12). The higher sand content in 2012 in the Embarras River was likely related to high discharge events in 2012 prior to the fall sampling period (Figure 5.1-3), potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints at *test* reach EMR-2 as **Moderate**, the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in the Embarras River.

5.1.4.2 Sediment Quality

In fall 2012, sediment quality was sampled in the ARD at:

- *test* station BPC-1 in Big Point Channel, sampled from 1999 to 2003, 2005, and 2007 to 2012;
- *test* station FLC-1 in Fletcher Channel, sampled from 2001 to 2003, 2005, and 2007 to 2012;
- *test* station GIC-1 in Goose Island Channel, sampled from 2001 to 2003, 2005, and 2007 to 2012;
- *test* station EMR-2 in the Embarras River, previously sampled in 2005 and 2010; and
- *test* station ATR-ER, in the Athabasca River mainstem immediately upstream of the Embarras River, sampled from 2000 to 2005 and 2007 to 2012.

Temporal Trends Decreasing concentrations of total metals, total arsenic, total parent PAHs, and total C1 hydrocarbons were detected at *test* station ATR-ER.

No significant trends in sediment quality measurement endpoints were detected at *test* stations BPC-1, FLC-1, and GIC-1. Trend analysis could not be conducted for *test* station EMR-2 because of limited available data (n=3).

2012 Results Relative to Historical Concentrations Concentrations of sediment quality measurement endpoints at all five stations in fall 2012 were within previously-measured concentrations (Table 5.1-14 to Table 5.1-18 and Figure 5.1-13 to Figure 5.1-17), with the exception of the following:

- Sediments at all five stations in fall 2012 were dominated by silt and/or sand, with sand exceeding previously-measured maximum concentrations and fine fractions (silt and clay) below previously-measured minimum concentrations at *test* stations FLC-1 and BPC-1 (Table 5.1-14 to Table 5.1-18). Both stations had higher total metals normalized to percent fines in 2012 than previously-measured maximum concentrations;
- Concentrations of total metals, total PAHs, total parent PAHs, total alkylated PAHs, naphthalene, and retene were lower than previously-measured minimum concentrations at *test* station BPC-1;

- Concentrations of total PAHs, total dibenzothiophenes, total parent PAHs, and total alkylated PAHs were lower than previously-measured minimum concentrations at *test* station FLC-1;
- The concentration of naphthalene was lower than the previously-measured minimum concentration at *test* station GIC-1;
- The concentration of total organic carbon was lower than the previously-measured minimum concentration at *test* station EMR-2;
- Potential chronic toxicity of PAHs in sediments were lower than previously-measured minimum values as a result of lower concentrations of PAHs contributing to the hazard index calculation at *test* stations FLC-1 and GIC-1;
- Direct measures of sediment toxicity to invertebrates indicated good survival (i.e., ≥80%) of the amphipod *Hyalella* at all five *test* stations. Survival was higher than any previously-measured maximum value at *test* station BPC-1, which could be related to the lowest concentrations of various PAHs observed in 2012 at this station. In addition, survival of the midge *Chironomus* exceeded 80% survival at all stations, with the exception of *test* stations GIC-1 (72%) and EMR-2 (74%), with survival that was higher than the previously-measured maximum value at *test* station ATR-ER; and
- Ten-day growth of the midge *Chironomus* and 14-day growth of the amphipod *Hyalella* were within the range of previously-measured values at all stations, with the exception of *test* station FLC-1, where *Chironomus* growth was lower than the previously-measured minimum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No hydrocarbon fractions, specific PAHs, or total metals measured exceeded relevant sediment or soil quality guidelines at any station in fall 2012, with the exception of potential chronic toxicity of PAHs in sediments at *test* station EMR-2 (Table 5.1-18), which exceeded the potential chronic toxicity threshold value of 1.0.

Sediment Quality Index The SQI values for all stations in the ARD in fall 2012 indicated **Negligible-Low** differences in sediment quality from regional *baseline* conditions (Table 5.1-19). SQI values ranged from 83.2 at *test* station EMR-2 to 100.0 at *test* stations FLC-1 and ATR-ER.

Classification of Results In fall 2012, sediment quality in channels of the ARD generally exhibited coarser characteristics with lower organic carbon and hydrocarbon concentrations, than in recent years. All stations were predominantly composed of sand, with the exception of EMR-2 where silt was dominant. Concentrations of sediment quality measurement endpoints at all five stations in the ARD showed concentrations that were generally similar to previously-measured concentrations. PAHs at all stations in fall 2012 were dominated by alkylated species, indicating a petrogenic origin of these compounds. From 1999 to 2010, an increase in concentrations of total PAHs was observed at *test* station BPC-1, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2012, the concentration of total PAHs at *test* station BPC-1 was lower than the previously-measured minimum concentration. With the exception of *test* station ATR-ER, all stations in the ARD exhibited a decrease in TOC and total PAHs in fall 2012 relative to fall 2011, likely associated with the courser substrate observed at all stations. The PAH Hazard Index at *test* station EMR-2 was above the potential chronic toxicity threshold value of 1.0 but below 1.0 at all other stations. Acute toxicity data for sediments exceeded previously-measured maximum values for *Hyalella* survival at *test* station BPC-1 and *Chironomus* survival at *test* station ATR-ER. Samples collected from *test* station FLC-1 showed historically low growth of *Chironomus* relative to previously-measured minimum concentrations. SQI values for all stations indicated **Negligible-Low** differences from regional *baseline* conditions.

5.1.5 Fish Populations

Fish population monitoring in 2012 on the Athabasca River consisted of a spring, summer, and fall fish inventory, and a fish tag return assessment.

5.1.5.1 Fish Inventory

Temporal and Spatial Comparisons

Temporal comparisons to assess changes over time and by season, as well as spatial comparisons among areas of the river, were conducted for the following measurement endpoints: species composition, species richness, catch per unit effort (as a measure of relative abundance), age-frequency distributions, size-at-age, and condition factor.

Total Catch and Species Richness A total of 5,656 fish were captured in the 14 standardized reaches in six areas of the Athabasca River during the spring, summer, and fall fish inventories in 2012 (Table 5.1-20, Figure 5.1-18), of which:

- 1,539 fish representing 12 species were caught in spring;
- 8,50 fish representing 14 species were caught in summer; and
- 3,266 fish representing 16 species were caught in fall.

A comparison of total catch and species richness in 2012 by season and area is provided in Table 5.1-21 and Figure 5.1-19.

A temporal comparison of seasonal species richness and total number of fish captured is presented in Figure 5.1-18. A total of 19 species were captured in 2012 compared to 20 species in 2011 and 2010, 16 species in 2009, and 22 species in 1997 (i.e., the lowest and highest species richness documented to date). Species richness in each season in 2012 was lower than 2011 but within the historical range. Total catch was lower in spring but higher in summer and fall compared to 2011.

Species Composition Key features of the species composition of the Athabasca River in 2012 and comparison to previous years are as follows (Figure 5.1-20):

1. The most abundant large-bodied fish species captured in 2012 was walleye and goldeye in spring; goldeye and walleye in summer; and goldeye and walleye in fall. In summer, a shift was observed in the second most dominant species from goldeye in 2011 to walleye in 2012.

2. In 2012, trout-perch was the most abundant small-bodied fish species in spring; however, in summer and fall emerald shiner and flathead chub, respectively, were the most abundant.

3. In spring, the number of goldeye captured was within the historical range, but in summer and fall the number of goldeye captured was amongst the higher values observed to date.

4. In 2012, the composition of large-bodied KIR fish species in summer showed a shift from walleye in 2010 and 2011 to goldeye in 2012.

5. Similar to 2011, the composition of large-bodied KIR fish species in fall 2012 was dominated by goldeye.

Catch Per Unit Effort To provide a standardized comparison across time, catch per unit effort (CPUE), as a measure of relative abundance, was calculated only for reaches that are currently sampled by RAMP (i.e., the 14 reaches in the 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., lake whitefish, walleye, northern pike) given their importance to stakeholders and their suitability for assessing localized conditions in the river (i.e., white sucker, longnose sucker are bottom feeders, and trout-perch is a non-migratory sentinel species).

In 2011, a new *baseline* reach, upstream of Fort McMurray (-03B), was added to assess the fish community in an area upstream of oil sands development. Total CPUE for each species by area and season in 2012 is provided in Figure 5.1-21. Mean CPUE for each KIR fish species in 2012 was compared by area and season to three historical sampling periods: 1987 to 1996, designated as pre-RAMP; 1997 to 2004, designated as RAMP prior to enhanced standardization of sampling reaches; and 2005 to 2012, designated as RAMP post-reach standardization (Figure 5.1-22 to Figure 5.1-28). From 2005 onwards, an effort has been made to target the whole fish community and ensure consistent sampling methodology across reaches; therefore, CPUE has generally been higher during this time period (i.e., 2005 to 2012).

Spatial comparisons were conducted to assess changes in CPUE of KIR fish species over time between each reach area of the Athabasca River. A trend analysis was conducted on KIR fish species for each area from 1997 to 2012 to assess whether CPUE was exhibiting increasing or decreasing trends over time ($p<0.05$) (Table 5.1-22). Species-specific results for 2012 are as follows:

- CPUE of goldeye was lower at all *test* areas (i.e., downstream of development), compared to the *baseline* area (upstream of Fort McMurray) in spring. In summer, goldeye CPUE in the *test* areas was consistent to the *baseline* area; however, in fall, CPUE in *test* areas was higher than the *baseline* area (Figure 5.1-22). Goldeye showed a significant increase in CPUE at the Poplar, Muskeg, and Steepbank areas of the Athabasca River from 1997 to 2012 ($p=0.02$, 0.04, 0.02, respectively).

- Lake whitefish were only captured in fall when the adult spawning population was in the Athabasca River. In fall, CPUE of lake whitefish was higher in all *test* areas compared to the *baseline* area (Figure 5.1-23). Lake whitefish exhibited a significant increase in CPUE at the Poplar, Muskeg, and Steepbank areas from 1997 to 2012 ($p=0.01$, 0.03, $p<0.001$, respectively).

- CPUE of longnose sucker was lower in all seasons at the *test* areas compared to the *baseline* area, with the exception of Steepbank area in fall; no significant trends in CPUE were observed over time ($p>0.05$) (Figure 5.1-24).

- Northern pike were only captured in the *baseline* area in spring and fall. In spring, CPUE of northern pike was low across all *test* areas, with the exception of the Poplar and Tar-Ells areas. In fall, CPUE was lower across all *test* areas with the exception of Tar-Ells and Fort-Calumet areas (Figure 5.1-25). CPUE of northern pike did not show any significant trends in any area over time ($p>0.05$).

- CPUE of trout-perch was generally higher at all *test* areas compared to the *baseline* area in all seasons (Figure 5.1-26). Although trout-perch were only continuously surveyed in most reaches since 2002, a trend analysis indicated that CPUE of trout-perch was significantly increasing at all areas over time ($p<0.05$).
- In spring, CPUE of walleye was higher in the *baseline* area compared to all *test* areas, likely due to preferred habitat conditions for spawning (i.e., hard substrate, fast-flowing water [Scott and Crossman 1973]) in the *baseline* area. In summer, CPUE was lower and variable across all areas than in the other two seasons. In fall, CPUE was higher at the *test* areas and highest in the most downstream area (Fort-Calumet), likely due to fish moving back downstream to overwintering grounds (Figure 5.1-27). Walleye exhibited a significant increasing trend in CPUE at the Poplar and Muskeg areas over time ($p<0.001$ and 0.03, respectively).
- White sucker were only caught in summer and fall in the *baseline* area. In summer, CPUE for white sucker was lower across *test* areas compared to the *baseline* area, with the exception of Steepbank and Fort-Calumet areas. In fall, CPUE was lower across *test* areas than the *baseline* area, with the exception of the Muskeg area (Figure 5.1-28). In previous years, CPUE of white sucker was been highest in the Muskeg area in spring given that they tend to spawn in the Muskeg River; however, in 2012, CPUE was low in this area but higher in the Tar-Ells and Fort-Calumet area. The reason for this shift is uncertain by may suggest that there has been a shift in preferred spawning grounds or the fish inventory was conducted before white sucker began to stage at the mouth of the Muskeg River prior to upstream migration. White sucker exhibited an increasing trend in CPUE at the Muskeg, Steepbank, and Tar-Ells areas over time ($p<0.001$, 0.04, and <0.05, respectively) (Table 5.1-22).

Age-Frequency Distributions Relative age-frequency distributions and size-at-age relationships for large-bodied KIR fish species for all seasons combined are presented in Figure 5.1-29 to Figure 5.1-34. The average relative age-frequency distributions were grouped for the periods: 1987 to 1996 (pre-Ramp); 1997 to 2004 (RAMP prior to enhanced standardization of reaches and fishing methods); 2005 to 2011 (RAMP post-standardization of reaches and fishing methods); and 2012, for each large-bodied KIR fish species. Statistical differences in size-at-age between 2012 and previous years were tested using analysis of covariance (ANCOVA). Only large-bodied KIR fish species with adequate samples sizes ($n\geq20$) were included and only significant differences were reported. The species-specific results are as follows:

1. The dominant age class of goldeye in 2012 was five years, which was slightly older than the dominant age class in 2011 of four years. The dominant age class of goldeye from 1997 to 2004 was three years, indicating a continuing shift to older age classes. Similar to 2011, the relationship between length and age in 2012 was relatively strong ($R^2=0.72$) (Figure 5.1-29).
2. Similar to 2011, the dominant of lake whitefish age class in 2012 was eight years. The dominant age class of lake whitefish from 1997 to 2004 was six years. The shift to an older dominant age class could indicate poor recruitment to the population of young individuals. Similar to 2011, the relationship between

length and age was low ($R^2=0.38$), whereas from 1997 to 2004 it was a moderate relationship ($R^2=0.56$) possibly indicating slower growth in more recent years (Figure 5.1-30).

3. The co-dominant age classes of longnose sucker in 2012 were six and seven years. The relationship between length and age of longnose sucker in 2012 was moderate ($R^2=0.46$) and higher than 2011 ($R^2=0.22$) (Figure 5.1-31).
4. In 2012 a larger sample size of ageing data was collected for northern pike compared to previous years. The dominant age class for northern pike in 2012 was five years. Similar to 1997 to 2004, and contrary to 2011, the relationship between length and age in 2012 was strong ($R^2=0.70$) (Figure 5.1-32). There was a significant increase in size-at-age in northern pike captured in 2012 compared to individuals captured in 1999 (p=0.106, 0.005), indicating greater growth in northern pike in 2012.
5. Similar to 2011, the dominant age class for walleye in 2012 was six years. In 2012, there was an increase in individuals from younger age classes. Similar to previous years, the relationship between length and weight of walleye in 2012 was moderate ($R^2=0.63$) (Figure 5.1-33).
6. The dominant age class of white sucker shifted from eight years in 2011, to four years in 2012. Contrary to a weak relationship between length and age that was observed in 2011, there was a moderate relationship between length and age of walleye in 2012 ($R^2=0.52$) and a significant difference in the length-age relationship between 2011 and 2012 (p=0.905/0.042), indicating greater growth in white sucker in 2012 (Figure 5.1-34).

Condition Factor Mean condition factor for KIR fish species captured in the Athabasca River from 1997 to 2012 in summer and fall were compared to the mean condition of fish from 1987 to 1996 (pre-RAMP) (Figure 5.1-35 to Figure 5.1-41). The species-specific results are as follows:

1. The mean condition of goldeye in summer and fall 2012 was lower than 2011 and the mean condition of goldeye from 1987 to 1996.
2. The mean condition of lake whitefish in 2012 for fall was higher than 2011 and greater than the mean condition of lake whitefish captured from 1987 to 1996.
3. The mean condition of longnose sucker in summer and fall was lowest across all years and below the mean condition of longnose from 1987 to 1996, with the exception of fall 2005.
4. The mean condition of northern pike for 2012 in summer was higher than 2011 and greater than the mean condition of northern pike captured from 1987 to 1996. In fall, the mean condition of northern pike in 2012 was similar to 2011 and lower than the mean condition of northern pike captured from 1987 to 1996.
5. The mean condition of walleye for 2012 in summer was similar to 2010 and 2011 and below the mean condition for 1987 to 1996; however, the mean condition in fall 2012 was higher than 2010 and 2011 and higher than the mean condition of walleye captured from 1987 to 1996.

6. The mean condition of white sucker for 2012 in summer was lower than previous years, with the exception of 2008, and lower than the mean condition of captured white sucker from 1987 to 1996. Mean condition of walleye in fall 2012 was lower than 2010 and 2011, but greater than the mean condition from 1987 to 1996.

Statistical differences between 2012 and *baseline* data collected from 1987 to 1996 for summer and fall were tested using analysis of covariance (ANCOVA). Only large-bodied KIR fish species with adequate samples sizes ($n \geq 20$) were included and only significantly different results were reported. Fish captured in spring were excluded from calculations of somatic condition as most species are known to be spring spawners and, as such, condition would be strongly influenced by advanced gonadal development of pre-spawning fish or reduced gonad size of spent fish. The same reasoning was applied to lake whitefish in fall during their spawning period. There were very few statistically significant differences among years in condition, with the exception of goldeye, which had significantly lower condition in fall 2012 than fish captured during the *baseline* years (1987 to 1996) ($p=0.311/<0.001$), although only slightly lower than the *baseline* mean value.

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 2012, 5.2%, 4.7%, and 1.7% of fish captured in spring, summer, and fall, respectively, were found to have some type of external abnormality. The incidences of external abnormalities in 2012 were higher than 2011 with the exception of fall, but lower than previous sampling years.

A total of 38 of 5,656 (0.7%) fish captured exhibited some form of external pathological abnormality such as parasites, growths, lesions (open sores) or body deformities. A summary of the percentage of fish by year for all seasons combined exhibiting some form of pathology is provided in Table 5.1-23. For each type of external pathology, there has been no increasing trend observed over time (Figure 5.1-42). External pathology was primarily observed in white sucker and walleye accounting for 3.29% and 1.70%, respectively, of fish with some type of external pathology in 2012; the percent of external pathology was within the historical range for white sucker (1.7% to 26.4%) and walleye (0.43% to 5.24%). Other species for which pathological abnormalities were recorded, mostly due to their higher catch frequency and relative abundance compared to other species in the river, included emerald shiner, goldeye, lake chub, lake whitefish, northern pike, trout-perch, and walleye.

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 RAMP 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 were conducted on the Wapiti, Smoky and Peace rivers documented 33% of burbot captured with some type of external abnormality (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

As outlined in the RAMP Design and Rationale document, the Athabasca River fish inventory is generally considered to be a community-driven activity, primarily used for assessing general trends in abundance and populations variables for large-bodied species, rather than detailed community structure.

As of 2012, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, age-frequency distributions, and condition of fish among years. There has been a significant increase in the catch and CPUE of goldeye in the last two years (i.e., 2011 and 2012) and although it is uncertain what has caused the observed increase in goldeye numbers in the Athabasca River, it could be related to the warm, calm spring seasons that have occurred in the last two years, which are favourable conditions for goldeye recruitment (Paul 2013). However, it is important to note that the despite the increase in goldeye in the river, the absolute abundances of other KIR species has not concomitantly decreased More data are necessary to determine any trends and evaluate the cause of the increase in goldeye numbers.

The fish health assessment indicated that abnormalities observed in 2012 in all species were within the historical range and consistent with studies done prior to the major oil sands development in the upper Athabasca River, the ARD, and the Peace Slave rivers.

5.1.5.2 Fish Tag Return Assessment

Angler Returns

A total of three RAMP Floy tags from walleye and northern pike were submitted to Alberta Environment and Sustainable Resource Development (AESRD), Fort McMurray office, by anglers in 2012. A summary of the RAMP tag returns in 2012 during the RAMP fish inventories and from anglers is provided in Table 5.1-24 and a cumulative summary of the RAMP tags returned to date is presented in Table 5.1-25 for comparisons by species. Figure 5.1-43 shows the location of first capture and tagging by RAMP and the location of the recapture by the angler. Given the location of the initial capture and the tag return are not always on the same river, tag returns for both the Athabasca and Clearwater are provided in this section.

Fish Inventory Returns

Walleye and northern pike were tagged during RAMP fish inventory programs. During the 2012 Athabasca River fish inventory, 11 fish were recaptured during the Athabasca River fish inventories that were previously tagged, including nine walleye and two northern pike:

- Two northern pike were recaptured in the same areas of the river (i.e., Tar-Ells and Muskeg) in spring and fall 2012 where they were originally tagged in fall 2003 and summer 2012, respectively;

- Six walleye were recaptured in the same river reach in 2012 where they were originally tagged (Poplar, Fort Calumet, Muskeg and Steepbank); two walleye were originally captured in fall 2003 and spring 2006, and four in spring and summer 2011;

- One walleye that was originally tagged in the Poplar reach in spring 2012 was recaptured in Lake Athabasca in winter 2012; and

- Three walleye were recaptured in 2012; however, two tag numbers were not clear and one tag was missing; therefore, original capture data was not determined.

During the Clearwater River 2012 fish inventory, 12 fish were recaptured that had been previously tagged during Clearwater River inventories, including two walleye and ten northern pike:

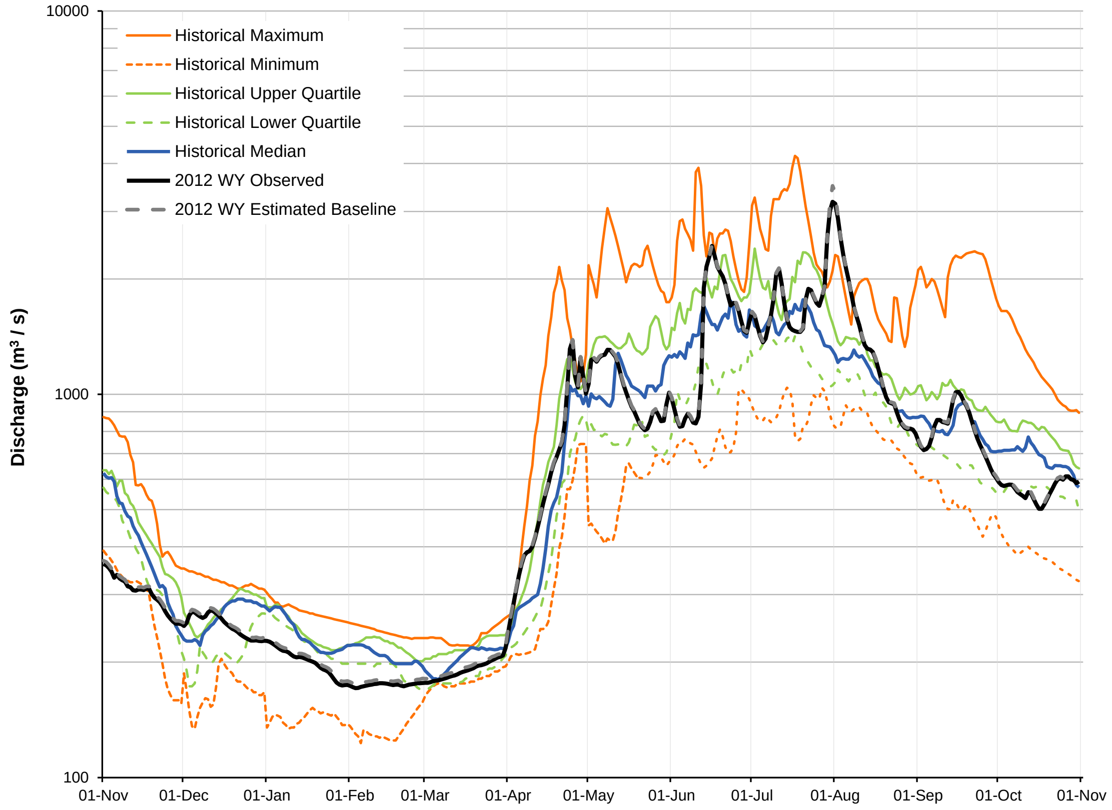
- Nine northern pike were recaptured in the same river reach in spring, summer, and fall 2012 where they were originally tagged (CR1, CR2, and CR3). Northern pike was originally captured in spring 2004 (1), 2006 (1), 2009 (1), 2010 (1), 2011 (1), 2012 (2); summer 2011 (1), and fall 2008 (1);

- One northern pike recaptured in 2012 was retagged due to loss of the original tag; therefore, no original capture data was determined;

- One walleye was recaptured in spring 2012 in the same river reach (CR3) where it was originally tagged in fall 2010; and

- One walleye was recaptured in 2012; however, the tag had fallen off and original capture data could not be determined.

Figure 5.1-3 Athabasca River: 2012 WY hydrograph and historical context.



Note: Based on 2012 WY provisional data from Athabasca River near Embarras Airport, Station S46. The upstream drainage area is 155,455 km^2. Historical values were calculated for the period 1971 to 1984 from Athabasca River near Embarras Airport, WSC Station 07DD001.

Note: For clarity, the estimated *baseline* flow resulting from focal projects in the Athabasca River watershed is only shown here; differences between this and the estimated *baseline* hydrograph resulting from other oil sands developments in the Athabasca River watershed are negligible and not detectable on this graph.

Table 5.1-2 Estimated water balance at Station S46, Athabasca River near Embarras Airport, 2012 WY.

Component	Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus Other Oil Sands Developments	
Observed *test* hydrograph (total discharge)	**23,476.579**		**Sum of observed daily discharges obtained from Athabasca River near Embarras Airport, RAMP Station S46**
Closed-circuited area water loss from the observed hydrograph	-57.098	-57.213	376.1 km^2 (375.3 km^2 focal projects only) of land estimated to have been closed-circuited as of 2012 (Table 2.5-1), in the cumulative area upstream of S46, including (from Table 2.4-1): minor Athabasca River tributaries, McLean Creek, Upper Beaver River, Shipyard Lake and Horse River.
Incremental runoff form land clearing (not closed-circuited area)	+2.640	+2.690	88.4 km^2 (86.8 km^2 focal projects only) of land estimated to have undergone land change as of 2012 but are not closed-circuited (Table 2.5-1), in the cumulative area upstream of S46, including (from Table 2.4-1): minor Athabasca River tributaries, McLean Creek, upper Beaver River, Shipyard Lake and Horse River.
Water withdrawals from the Athabasca River watershed from focal projects	-27.018		Withdrawals by Suncor (daily values provided).
	-39.105		Withdrawals by Syncrude (daily values provided).
	-14.761		Withdrawals by Shell (daily values provided).
	-22.313		Withdrawals by Canadian Natural (daily values provided).
	-11.152		Withdrawals by Imperial (daily values provided).
Water releases in the Athabasca River watershed from focal projects	+0.160		Releases by Suncor (daily values provided).
	+0.294		Releases by Syncrude (daily values provided).
	+0.683		Releases by Imperial (daily values provided).
	+0.022		Releases by Total E&P (daily values provided).
The difference between *test* and *baseline* hydrographs on tributary streams	-7.156	-7.129	Net sum of incremental volume results from the major tributaries as listed in Section 5.2 to Section 5.11[1].
Estimated *baseline* hydrograph (total discharge)	**23,651.382**	**23,651.421**	**Estimated *baseline* discharge at Athabasca River near Embarras Airport, RAMP Station S46.**
Incremental flow (change in total discharge)	-174.803	-174.843	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-0.739%**	**-0.739%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Data and assumptions are discussed in Section 3.2.1.4.

Note: Based on the provisional 2012 WY data for Athabasca River near Embarras Airport, Station S46.

Note: Some rounding of results occurs due to the use of a maximum of one decimal point.

[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, and so the incremental changes of the Beaver Creek diversion on the Athabasca River mainstem flows are assumed to be zero.

[2] The Horse and Christina River watersheds are the only watersheds in the RAMP FSA that contained other oil sands developments under construction or operation as of 2012 (Table 2.5-1).

Table 5.1-3 Calculated change in hydrologic measurement endpoints for the Athabasca River in the 2012 WY, for focal project and cumulative assessment cases[1].

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	1,190.4	1,183.7	-0.6%
Mean winter discharge	228.3	224.1	-1.8%
Annual maximum daily discharge	3,499.1	3,488.2	-0.3%
Open-water season minimum daily discharge	507.1	502.3	-1.0%

Note: Based on the provisional 2012 WY data for Athabasca River near Embarras Airport, Station S46.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are 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.

[1] Assessment results for both cases, focal project and focal project plus other oil sands developments, are essentially the same and only appear different when presented at three decimal places for *baseline* values and relative change values. The values presented in the above table are; therefore, applicable to both assessment cases.

Table 5.1-4 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2012.

Measurement Endpoint	Units	Guideline[a]	Upstream of Donald Creek		Upstream of Steepbank River		Upstream of Muskeg River		Downstream of Development	
			(ATR-DC-E, ATR-DC-W)[d]		(ATR-SR-E, ATR-SR-W)[d]		(ATR-MR-E, ATR-MR-W)[d]		(ATR-DD-E, ATR-DD-W)[e]	
			East[1]	West	East	West	East	West	East	West
Physical variables										
pH	pH units	6.5-9.0	8.0	8.2	8.5	8.0	8.1	8.1	8.1	8.1
Total suspended solids	mg/L	-	89	87	209	136	153	108	209	136
Conductivity	µS/cm	-	218	291	278	281	233	284	257	276
Nutrients										
Total dissolved phosphorus	mg/L	0.05	0.030	0.009	0.010	0.010	0.005	0.011	0.014	0.010
Total nitrogen	mg/L	1.0	0.70	0.47	0.47	0.53	0.93	0.59	0.52	0.51
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	2.5	1.5	8.5	8.0	18.1	12.4	13.3	14.5
Ions										
Sodium	mg/L	-	14.1	8.2	7.8	7.7	11.8	9.9	9.3	9.7
Calcium	mg/L	-	18.1	33	31.2	32.1	23.2	30.3	29.2	31.3
Magnesium	mg/L	-	5.5	8.6	8.0	8.3	6.4	7.9	7.8	8.3
Chloride	mg/L	120	15.4	2.7	2.5	2.3	7.8	4.0	6.2	5.6
Sulphate	mg/L	270	5.67	27.1	24.3	25.8	14.3	22.9	18.4	22.4
Total dissolved solids	mg/L	-	156	187	180	182	181	168	175	165
Total alkalinity	mg/L	-	84	119	114	115	87.7	110	103	111
Selected metals										
Total aluminum	mg/L	0.1	**1.75**	**1.34**	**2.14**	**2.64**	**4.83**	**3.30**	**1.41**	**1.01**
Total arsenic	mg/L	0.1	0.0014	0.0011	0.0014	0.0017	0.0016	0.0014	0.0011	0.0009
Dissolved aluminum	mg/L	0.1	0.0256	0.0180	0.0190	0.0181	0.0978	0.0419	0.0189	0.0185
Total boron	mg/L	1.2	0.039	0.025	0.027	0.025	0.048	0.036	0.031	0.032
Total molybdenum	mg/L	0.073	0.00026	0.00073	0.00071	0.00062	0.00030	0.00056	0.00058	0.00067

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 13 years of fall data (1998 to 2011).

[e] Historical comparison to seven years of fall data (2005 to 2011).

Table 5.1-4 (Cont'd.)

Measurement Endpoint	Units	Guideline[a]	Upstream of Donald Creek		Upstream of Steepbank River		Upstream of Muskeg River		Downstream of Development	
			(ATR-DC-E, ATR-DC-W)[d]		(ATR-SR-E, ATR-SR-W)[d]		(ATR-MR-E, ATR-MR-W)[d]		(ATR-DD-E, ATR-DD-W)[e]	
			East[1]	West	East	West	East	West	East	West
Selected metals (Cont'd.)										
Total mercury (ultra-trace)	ng/L	5, 13	**5.3**	4.2	**7.7**	4.9	**8.8**	**7.8**	3.9	3.4
Total strontium	mg/L	-	0.108	0.198	0.178	0.196	0.128	0.187	0.175	0.182
Total hydrocarbons										
BTEX	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25	0.67	<0.25	<0.25	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25	0.60	<0.25	<0.25	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.10	0.07	0.03	0.08	0.06	0.03	0.04	0.02
Oilsands extractable	mg/L	-	0.41	0.19	0.23	0.09	0.37	0.27	0.17	0.17
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	11.3	<8.8	<8.8	10.4	<8.8	<8.8	<8.8	<8.8
Retene	ng/L	-	8.9	3.4	2.8	20.2	28.7	10.4	6.4	2.5
Total dibenzothiophenes	ng/L	-	71.2	41.8	49.6	170.0	722.8	88.1	62.1	44.1
Total PAHs[c]	ng/L	-	409.6	254.0	343.7	1297.9	2469.2	536.4	347.6	260.2
Total Parent PAHs[c]	ng/L	-	24.8	18.4	25.4	137.8	70.3	32.2	21.6	18.8
Total Alkylated PAHs[c]	ng/L	-	384.8	235.7	318.3	1160.1	2399.0	504.1	326.1	241.4
Other variables that exceeded CCME/AESRD guidelines in 2012										
Benzo[a]pyrene	ng/L	15	-	-	-	**17.8**	-	-	-	-
Dissolved iron	mg/L	0.3	**0.482**	-	-	-	**0.333**	-	-	-
Total chromium	mg/L	0.001	**0.00280**	**0.00202**	**0.00297**	**0.00396**	**0.00528**	**0.00384**	**0.00168**	**0.00137**
Total copper	mg/L	0.002[b]	-	-	-	**0.00358**	**0.00381**	**0.00320**	-	-
Total iron	mg/L	0.3	**3.08**	**1.71**	**2.75**	**3.65**	**4.26**	**3.07**	**1.53**	**1.21**
Total phenols	mg/L	0.004	**0.0079**	**0.0042**	-	-	**0.0066**	**0.0045**	**0.0050**	-
Total phosphorus	mg/L	0.05	**0.120**	**0.0693**	**0.141**	**0.138**	**0.127**	**0.103**	**0.065**	-

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 13 years of fall data (1998 to 2011).

[e] Historical comparison to seven years of fall data (2005 to 2011).

Figure 5.1-4 Piper diagram of ion concentrations in Athabasca River mainstem (*test* stations ATR-SR versus *baseline* stations ATR-DC), fall 1997 to 2012.

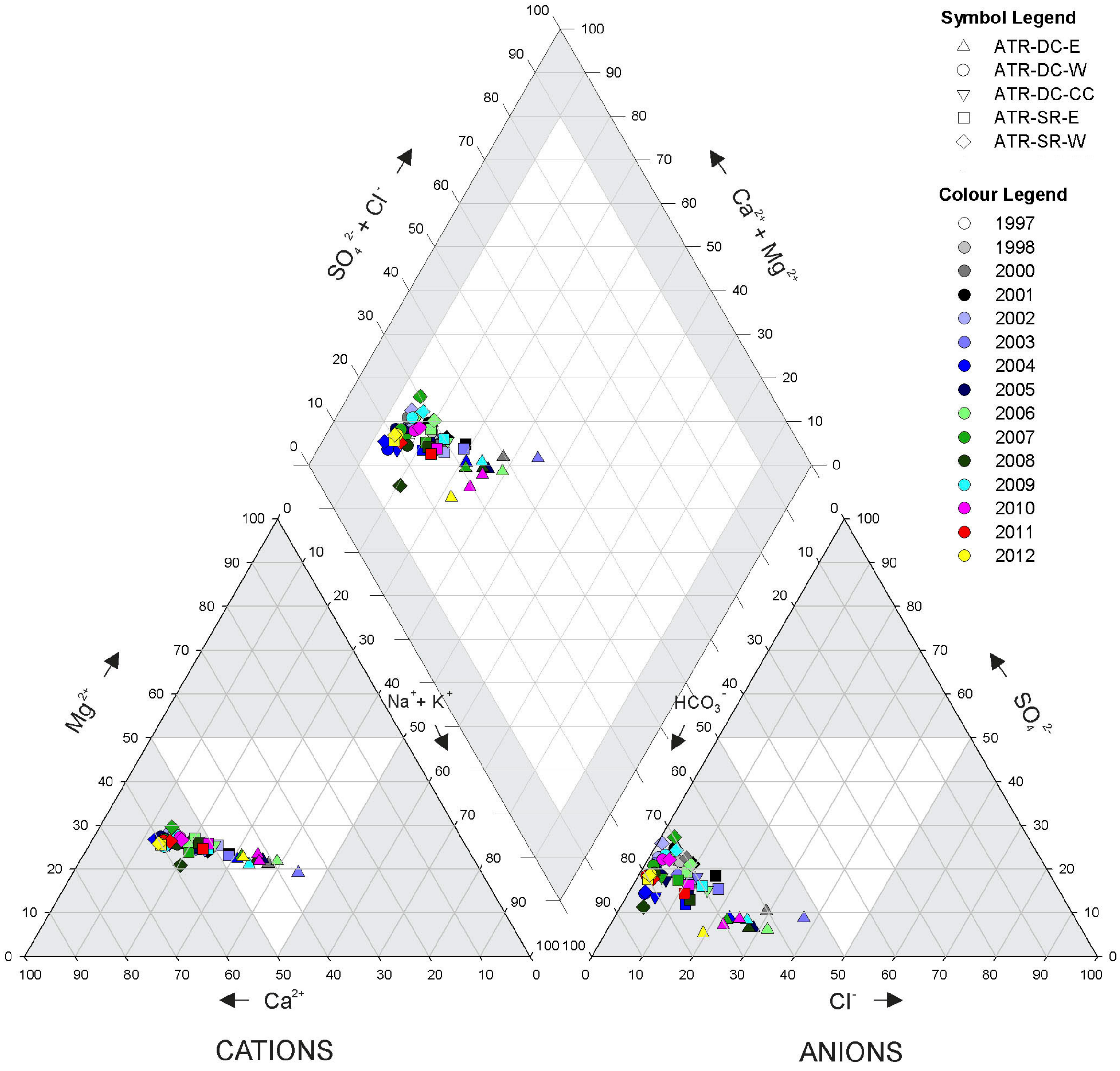


Figure 5.1-5 Piper diagram of ion concentrations in Athabasca River mainstem (*test* stations ATR-MR versus *baseline* stations ATR-DC), fall 1997 to 2012.

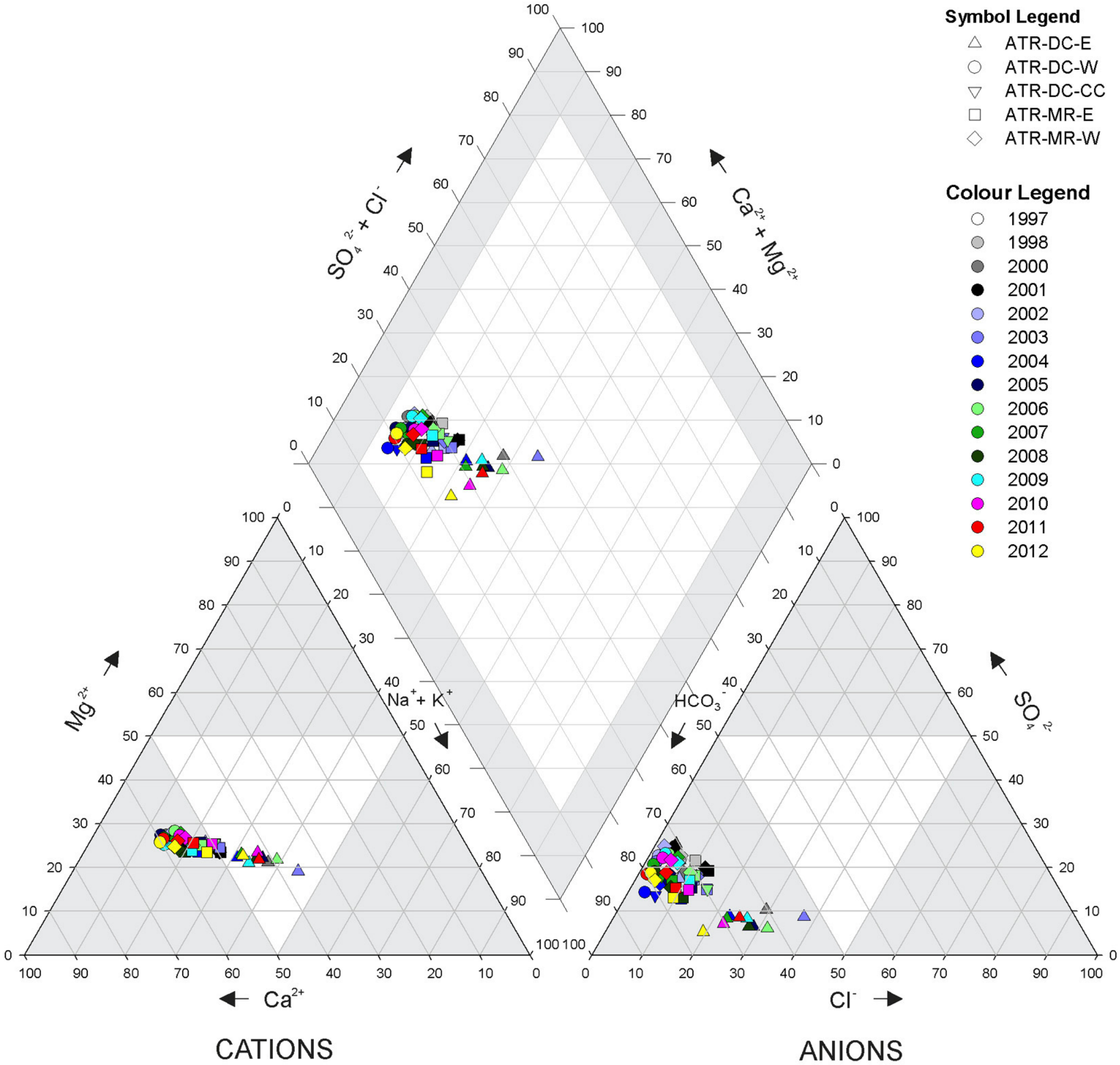


Figure 5.1-6 Piper diagram of ion concentrations in Athabasca River mainstem *test* stations ATR-DD versus *baseline* stations ATR-DC), fall 1997 to 2012.

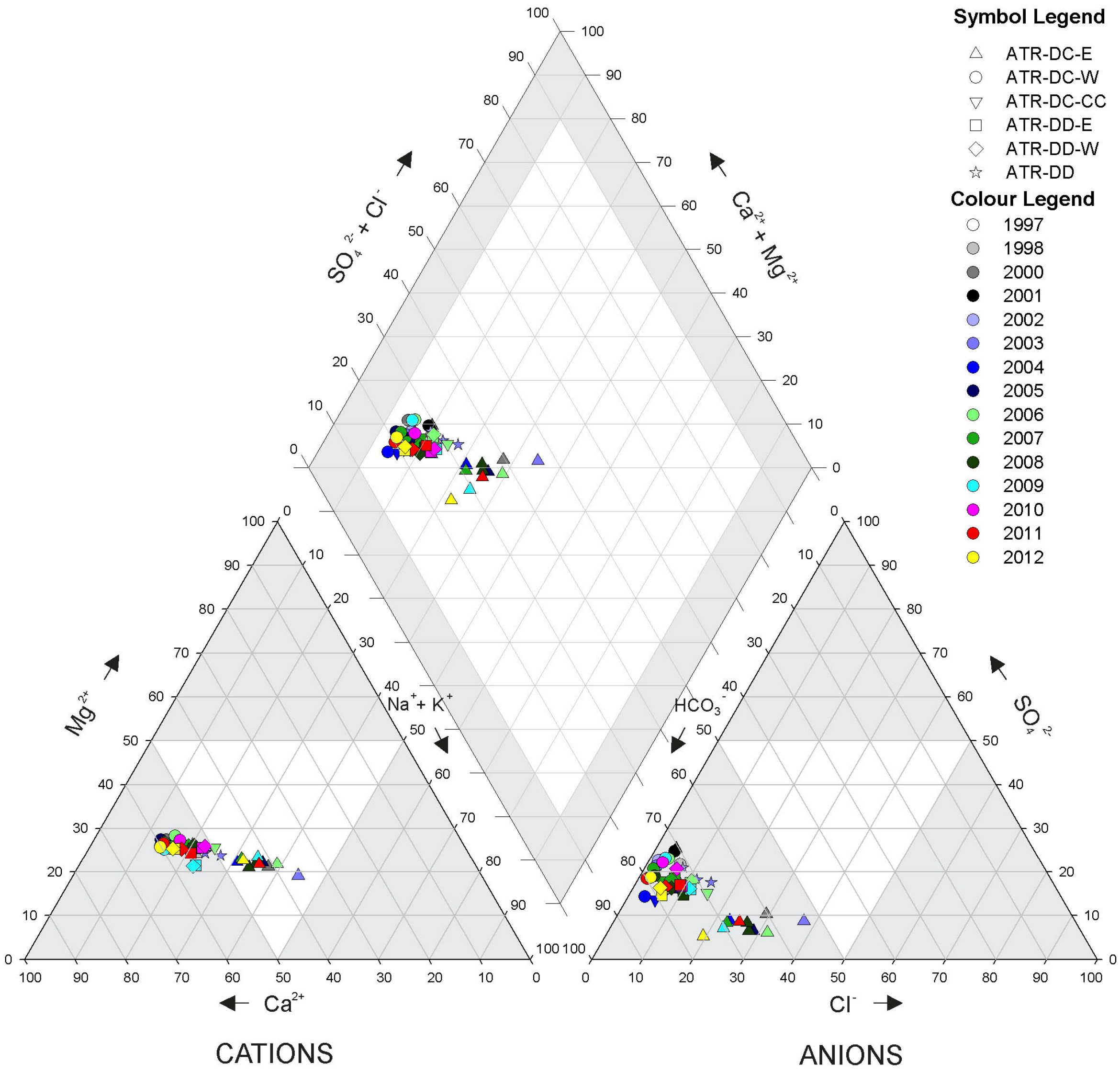


Table 5.1-5 Water quality guideline exceedances in the Athabasca River mainstem, downstream of development (ATR-DD), 2012.

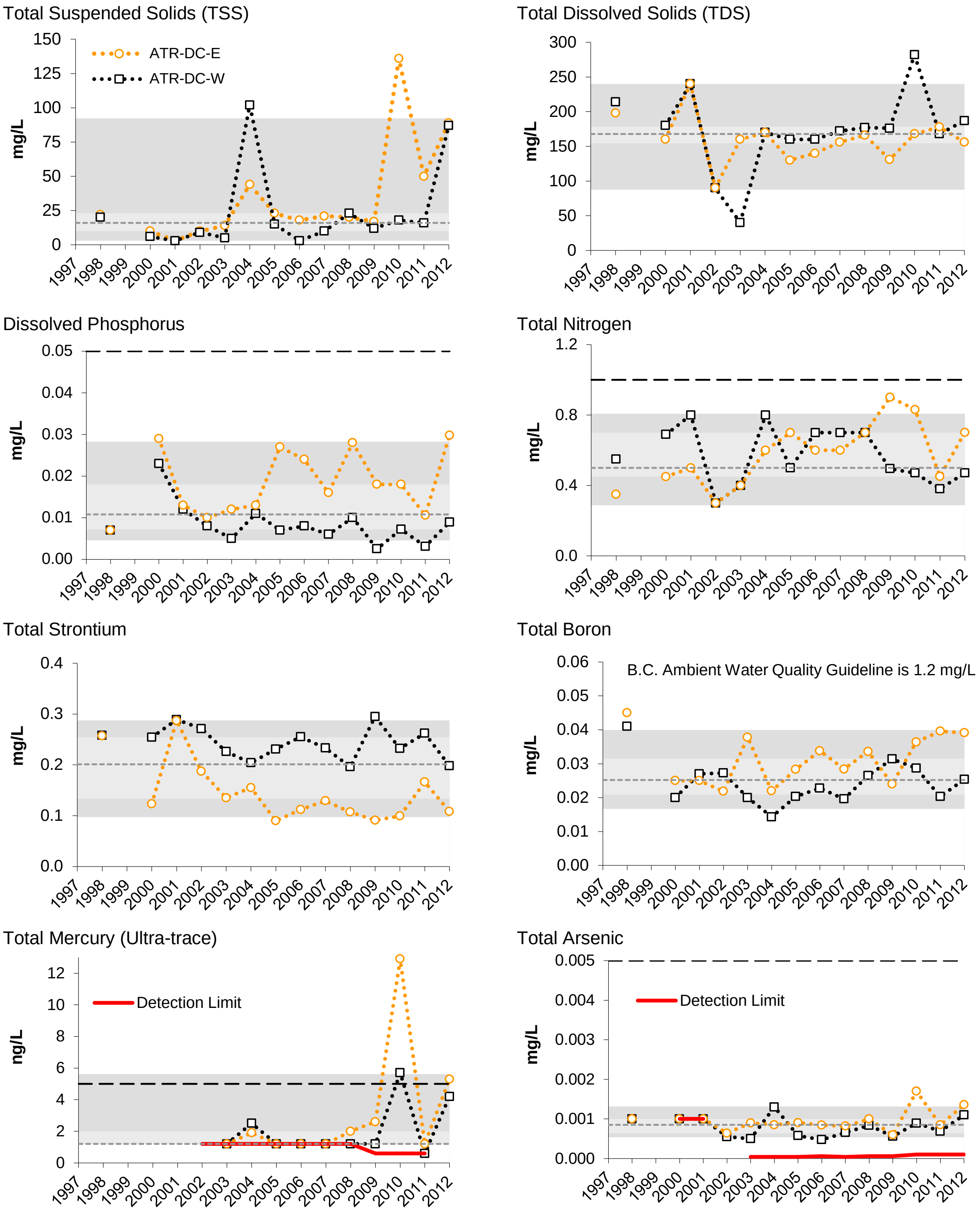
Parameter	Units	Guideline[a]	Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)		Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)		Downstream of Development (ATR-DD-E, ATR-DD-W)	
			East[1]	West	East	West	East	West	East	West
Winter										
Nitrite	mg/L	0.06	-	0.124	ns	ns	ns	ns	-	-
Sulphide	mg/L	0.002	0.0028	-	ns	ns	ns	ns	-	-
Total aluminum	mg/L	0.1	-	0.136	ns	ns	ns	ns	0.123	0.126
Total iron	mg/L	0.3	-	-	ns	ns	ns	ns	0.33	0.33
Total nitrogen	mg/L	1	-	3.940	ns	ns	ns	ns	-	-
Total phenols	mg/L	0.004	-	0.017	ns	ns	ns	ns	-	-
Spring										
Dissolved aluminum	mg/L	0.1	-	-	ns	ns	ns	ns	0.115	-
Dissolved iron	mg/L	0.3	0.33	-	ns	ns	ns	ns	0.34	-
Sulphide	mg/L	0.002	0.0047	0.0029	ns	ns	ns	ns	0.0038	0.0029
Total aluminum	mg/L	0.1	1.4	0.7	ns	ns	ns	ns	0.8	0.6
Total chromium	mg/L	0.001	0.0017	-	ns	ns	ns	ns	0.0011	-
Total copper	mg/L	0.002[b]	0.0022	-	ns	ns	ns	ns	-	-
Total iron	mg/L	0.3	2.9	1.3	ns	ns	ns	ns	1.6	1.4
Total lead	mg/L	0.00155[b]	0.0016	-	ns	ns	ns	ns	-	-
Total mercury (ultra-trace)	mg/L	5, 13	8.0	5.9	ns	ns	ns	ns	-	-
Total phenols	mg/L	0.004	0.0043	0.0057	ns	ns	ns	ns	0.0155	0.0120
Total phosphorus	mg/L	0.05	0.15	0.08	ns	ns	ns	ns	0.09	0.08
Summer										
Sulphide	mg/L	0.002	0.01	-	ns	ns	ns	ns	0.00	0.00
Total aluminum	mg/L	0.1	1.70	2.53	ns	ns	ns	ns	2.16	4.68
Total chromium	mg/L	0.001	0.003	0.004	ns	ns	ns	ns	0.003	0.007
Total copper	mg/L	0.002-0.0025[b]	0.002	0.004	ns	ns	ns	ns	0.003	0.006
Total iron	mg/L	0.3	2.39	3.45	ns	ns	ns	ns	2.34	4.65
Total lead	mg/L	0.0032[b]	-	-	ns	ns	ns	ns	-	0.004
Total mercury (ultra-trace)	mg/L	5, 13	5.4	9.3	ns	ns	ns	ns	10.8	11.8
Total phenols	mg/L	0.004	0.009	-	ns	ns	ns	ns	0.008	0.007
Total phosphorus	mg/L	0.05	0.10	0.14	ns	ns	ns	ns	0.16	0.23
Fall										
Benzo[a]pyrene	ng/L	15	-	-	-	17.8	-	-	-	-
Dissolved iron	mg/L	0.3	0.482	-	-	-	0.333	-	-	-
Total aluminum	mg/L	0.1	1.75	1.34	2.14	2.64	4.83	3.30	1.41	1.01
Total chromium	mg/L	0.001	0.0028	0.0020	0.0030	0.0040	0.0053	0.0038	0.0017	0.0014
Total copper	mg/L	0.002[b]	-	-	-	0.0036	0.0038	0.0032	-	-
Total iron	mg/L	0.3	3.08	1.71	2.75	3.65	4.26	3.07	1.53	1.21
Total mercury (ultra-trace)	ng/L	5. 13	5.3	-	7.7	-	8.8	7.8	-	-
Total phenols	mg/L	0.004	0.0079	0.0042	-	-	0.0066	0.0045	0.0050	-
Total phosphorus	mg/L	0.05	0.120	0.069	0.141	0.138	0.127	0.103	0.065	-

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 5.1-7 Concentrations of selected water quality measurement endpoints (fall data) relative to historical concentrations and regional *baseline* fall concentrations, Athabasca River mainstem, upstream of Donald Creek (ATR-DC).



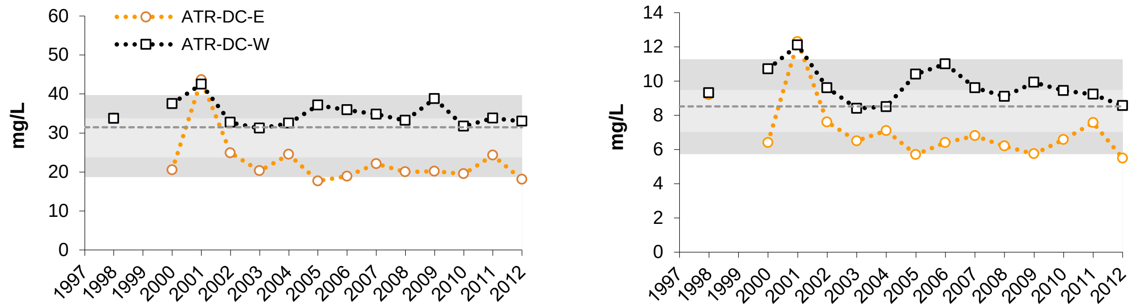
Non-detectable values are shown at the detection limit.

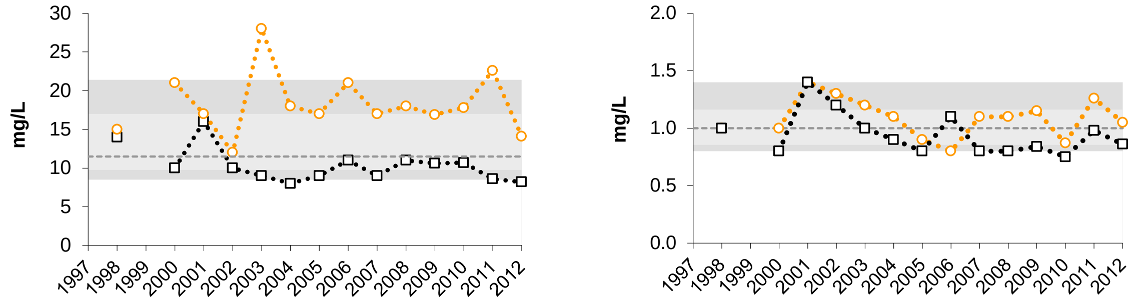
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

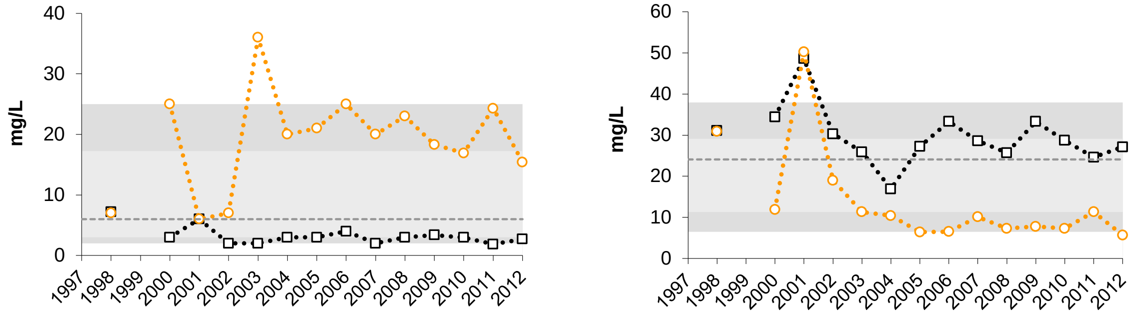
○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.1-7 (Cont'd.)


Calcium
Magnesium


Sodium
Potassium


Chloride
Sulphate

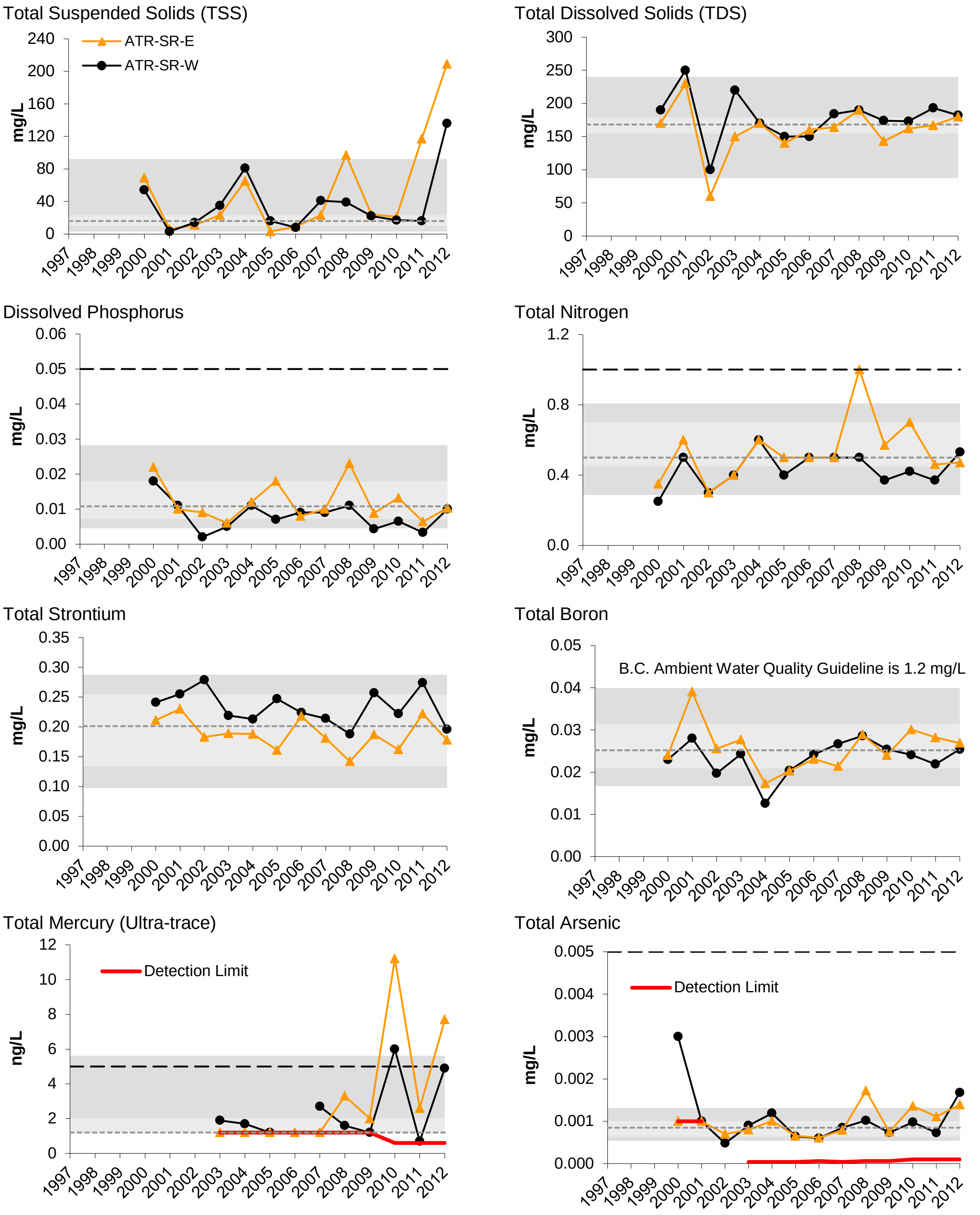
Non-detectable values are shown at the detection limit.

– – – – – 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.1-8 Concentrations of selected water quality measurement endpoints (fall data) relative to historical concentrations and regional *baseline* fall concentrations, Athabasca River mainstem, upstream of the Steepbank River (ATR-SR).



Non-detectable values are shown at the detection limit.

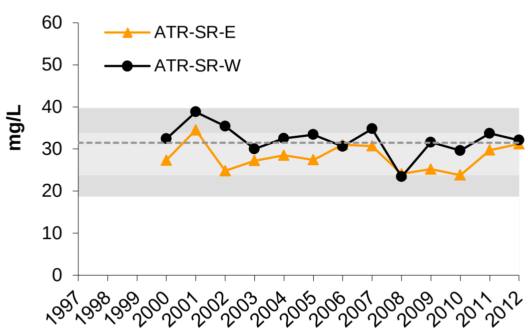
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

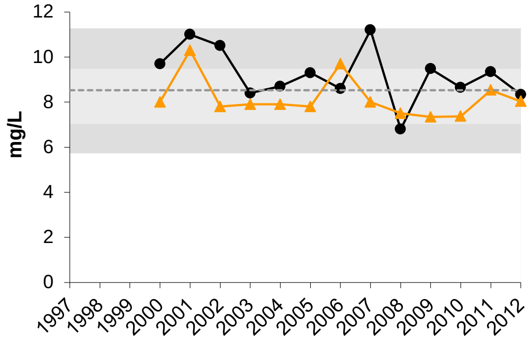
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.1-8 (Cont'd.)

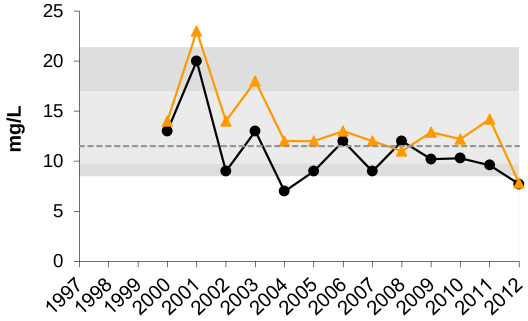
Calcium



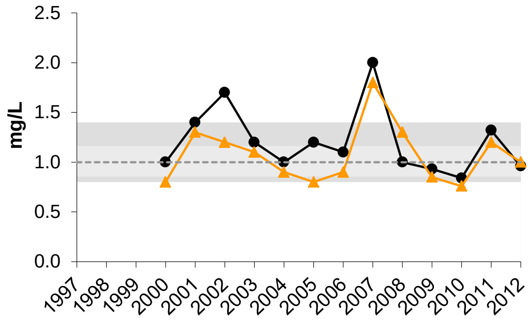
Magnesium



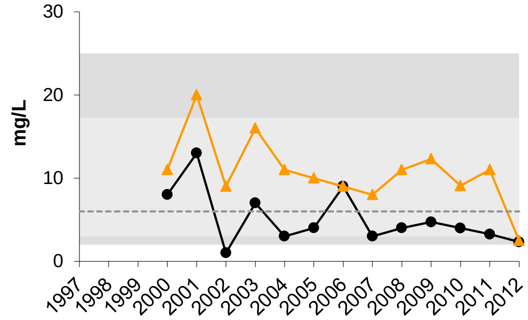
Sodium



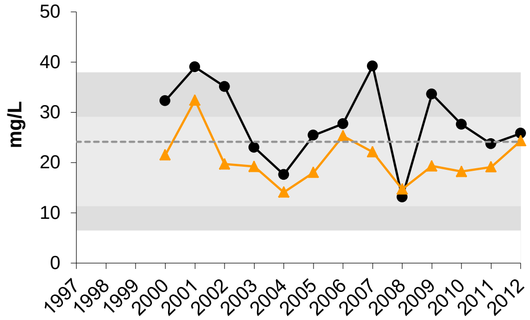
Potassium



Chloride



Sulphate



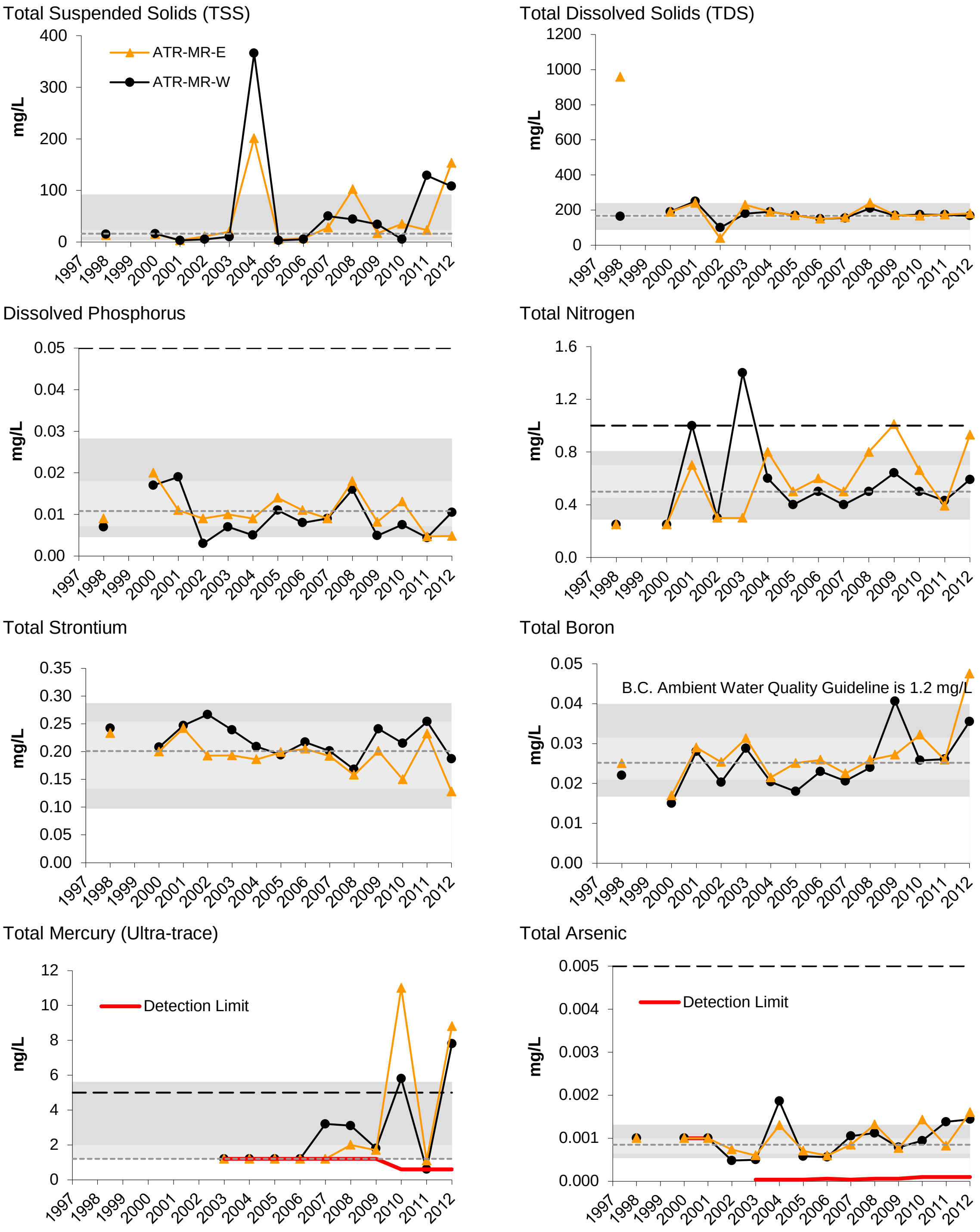
Non-detectable values are shown at the detection limit.

– – – – – 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.1-9 Concentrations of selected water quality measurement endpoints (fall data) relative to historical concentrations and regional *baseline* fall concentrations, Athabasca River mainstem, upstream of the Muskeg River (ATR-MR).


Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

Total Arsenic

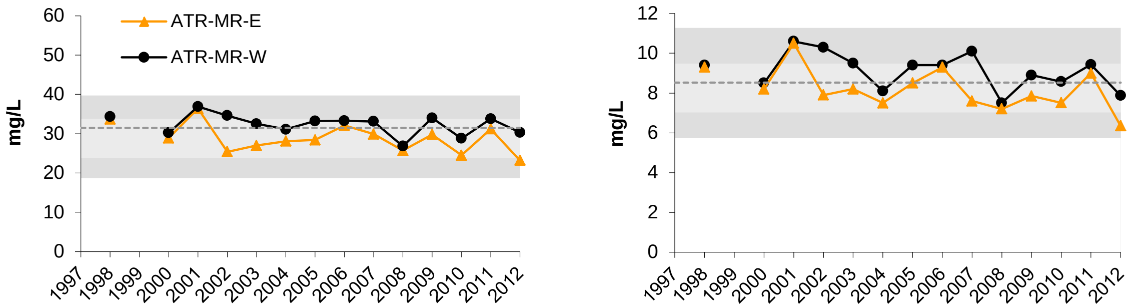
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

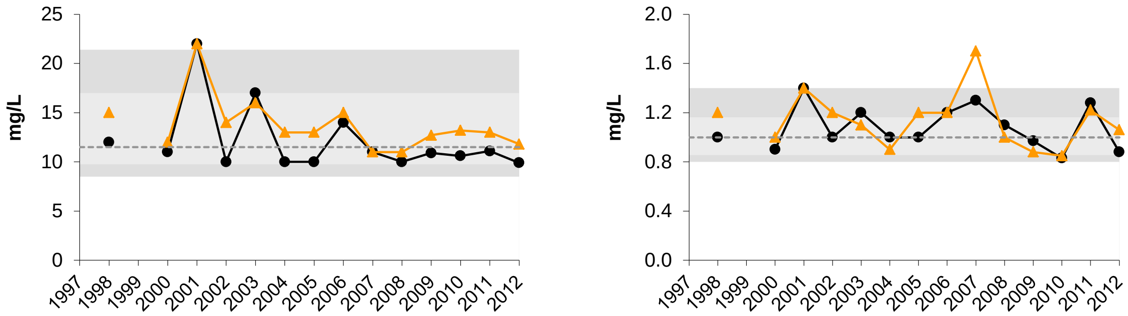
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

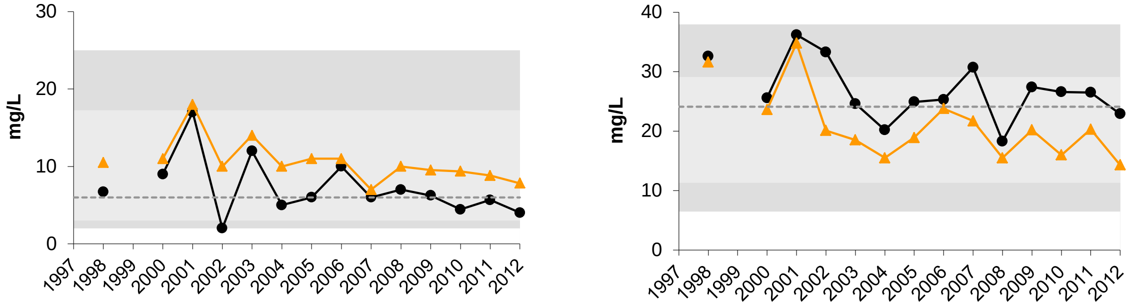
Figure 5.1-9 (Cont'd.)


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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.1-6 Water quality index (fall 2012) for Athabasca River mainstem stations.

Station	Location	2012 Designation	Water Quality Index	Classification
ATR-DC-E	Upstream of Donald Creek, East Bank	*baseline*	93.7	Negligible-Low
ATR-DC-W	Upstream of Donald Creek, West Bank	*baseline*	98.7	Negligible-Low
ATR-SR-E	Upstream of the Steepbank River, East Bank	*test*	87.2	Negligible-Low
ATR-SR-W	Upstream of the Steepbank River, West Bank	*test*	84.7	Negligible-Low
ATR-MR-E	Upstream of the Muskeg River, East Bank	*test*	74.0	Moderate
ATR-MR-W	Upstream of the Muskeg River, West Bank	*test*	84.8	Negligible-Low
ATR-DD-E	Downstream of all development, East Bank	*test*	100.0	Negligible-Low
ATR-DD-W	Downstream of all development, West Bank	*test*	100.0	Negligible-Low

Table 5.1-7 Average habitat characteristics of benthic invertebrate community sampling locations of the Athabasca River Delta, fall 2012.

Variable	Units	Big Point Channel (BPC-1)	Fletcher Channel (FLC-1)	Goose Island Channel (GIC-1)	Embarras River (EMR-2)
Sample date	-	01-Sept-2012	01-Sept-2012	01-Sept-2012	01-Sept-2012
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	3.8	3.1	2.5	3.8
Current velocity	m/s	0.13	-	-	-
Dissolved oxygen	mg/L	8.7	8.6	8.1	8.3
Conductivity	µS/cm	249	246	245	249
pH	pH units	7.84	8.10	8.00	8.20
Water temperature	°C	16.7	17.6	17.2	17.9
Sand	%	82	74	78	32
Silt	%	12	3	14	46
Clay	%	5	3	7	23
Total Organic Carbon	%	0.61	0.34	0.72	2.25

Table 5.1-8 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in *test* reaches BPC-1 and FLC-1 of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Big Point Channel (BPC-1)			Fletcher Channel (FLC-1)		
	2003	2004 to 2011	2012	2002	2003 to 2011	2012
Nematoda	<1	<1 to 7	1	5	0 to 22	
Erpobdellidae		0 to <1				
Naididae	1	0 to 7	0	<1	0 to 15	
Tubificidae	75	46 to 75	27	2	10 to 81	11
Hydracarina	<1	0 to <1			0 to <1	
Amphipoda		0 to 2				
Ostracoda	<1	0 to 7	2	3	0 to 7	
Macrothricidae				<1	0 to <1	
Cladocera			3			
Copepoda		0 to 1	3		0 to <1	3
Gastropoda	4	0 to 12		1	0 to 14	
Bivalvia	10	<1 to 37		1	<1 to 13	
Ceratopogonidae	1	<1 to 7		2	<1 to 10	8
Chaoboridae						
Chironomidae	6	3 to 40	63	86	4 to 52	79
Empididae		0 to 4		<1		
Tabanidae					0 to <1	
Tipulidae	<1	0 to <1				
Ephemeroptera	<1	0 to 2	2	<1	0 to 2	
Anisoptera	<1	0 to <1			0 to <1	
Plecoptera		0 to <1			0 to 1	
Trichoptera	1	0 to 4			0 to 2	
Heteroptera	<1	0 to <1			0 to <1	
Megaloptera		0 to <1				
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	11,552	4,757 to 103,982	791	11,897	8,327 to 118,413	330
Richness	11	10 to 15	7	12	5 to 12	4
Simpson's Diversity	0.42	0.39 to 0.73	0.69	0.53	0.29 to 0.78	0.55
Equitability	0.17	0.15 to 0.43	0.6	0.20	0.13 to 0.59	0.89
% EPT	1	0 to 19	2	1	0 to 6	0

Table 5.1-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in *test* reaches GIC-1 and EMR-2 of the Athabasca River Delta.

Taxon	**Percent Major Taxa Enumerated in Each Year**				
	Goose Island Channel (GIC-1)			**Embarras River (EMR-2)**	
	2002	**2003 to 2011**	**2012**	**2010**	**2012**
Nematoda	5	0 to 2	1	1	12
Erpobdellidae					<1
Glossiphoniidae					1
Oligochaeta					
Naididae		0 to 7		<1	<1
Tubificidae	<1	23 to 62	48	1	4
Lumbriculidae		0 to <1			
Hydracarina	<1	0 to <1		<1	
Amphipoda		0 to <1			
Ostracoda	1	2 to 39	<1	19	30
Cladocera			<1		
Macrothricidae	<1	0 to 2			
Copepoda	<1	0 to 2	15	<1	
Gastropoda	5	0 to 24		<1	<1
Bivalvia	13	<1 to 4	<1	29	7
Ceratopogonidae	1	1 to 17	1	4	16
Chaoboridae			1		
Chironomidae	74	13 to 64	31	41	29
Empididae		0 to <1	<1		
Tipulidae		0 to <1			
Ephemeroptera		0 to 1	1	<1	
Anisoptera	<1	0 to <1	<1		
Trichoptera	<1	0 to 2		3	<1
Heteroptera		0 to <1			
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	36,000	2,914 to 35,776	5,313	56,463	22,323
Richness	14	8 to 12	11	23	13
Simpson's Diversity	0.54	0.61 to 0.79	0.67	0.86	0.74
Equitability	0.18	0.24 to 0.52	0.35	0.33	0.35
% EPT	<1	0 to 2	1	3	<1

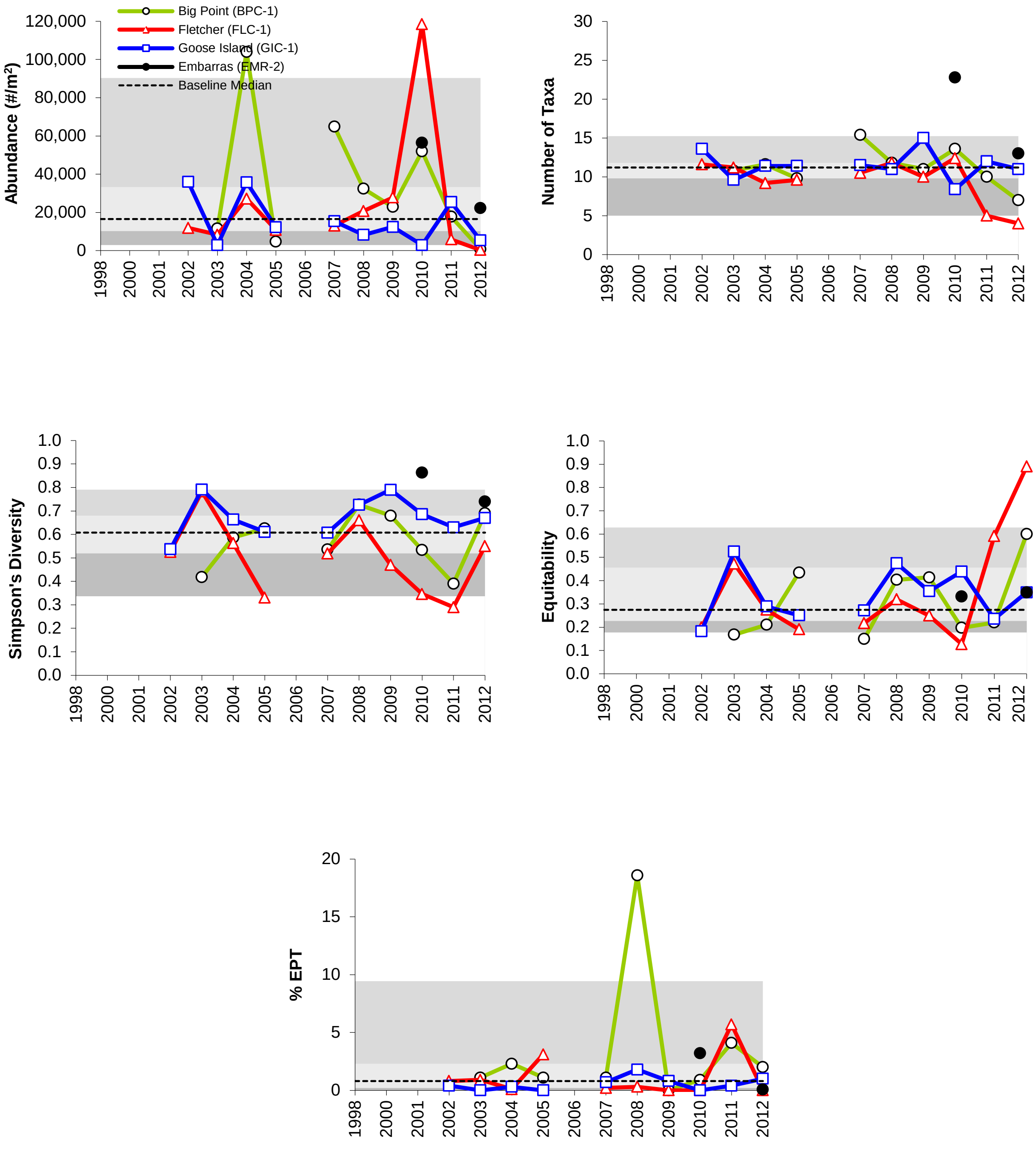
Table 5.1-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Big Point Channel of the Athabasca River Delta.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	**0.012**	**<0.001**	0	49	Decreasing over time; lower in 2012 than the mean of previous years.
Richness	0.053	**0.001**	20	66	Lower in 2012 than the mean of previous years.
Simpson's Diversity	0.403	**0.077**	3	13	Higher in 2012 than the mean of previous years.
Equitability	**0.015**	**<0.001**	20	47	Increasing over time; higher in 2012 than the mean of previous years.
EPT	1.000	0.472	0	2	No change.
CA Axis 1	0.374	0.159	2	4	No change.
CA Axis 2	**<0.001**	**0.001**	66	61	Decreasing over time; lower in 2012 than the mean of previous years.

Bold values indicate significant difference ($p<0.05$).

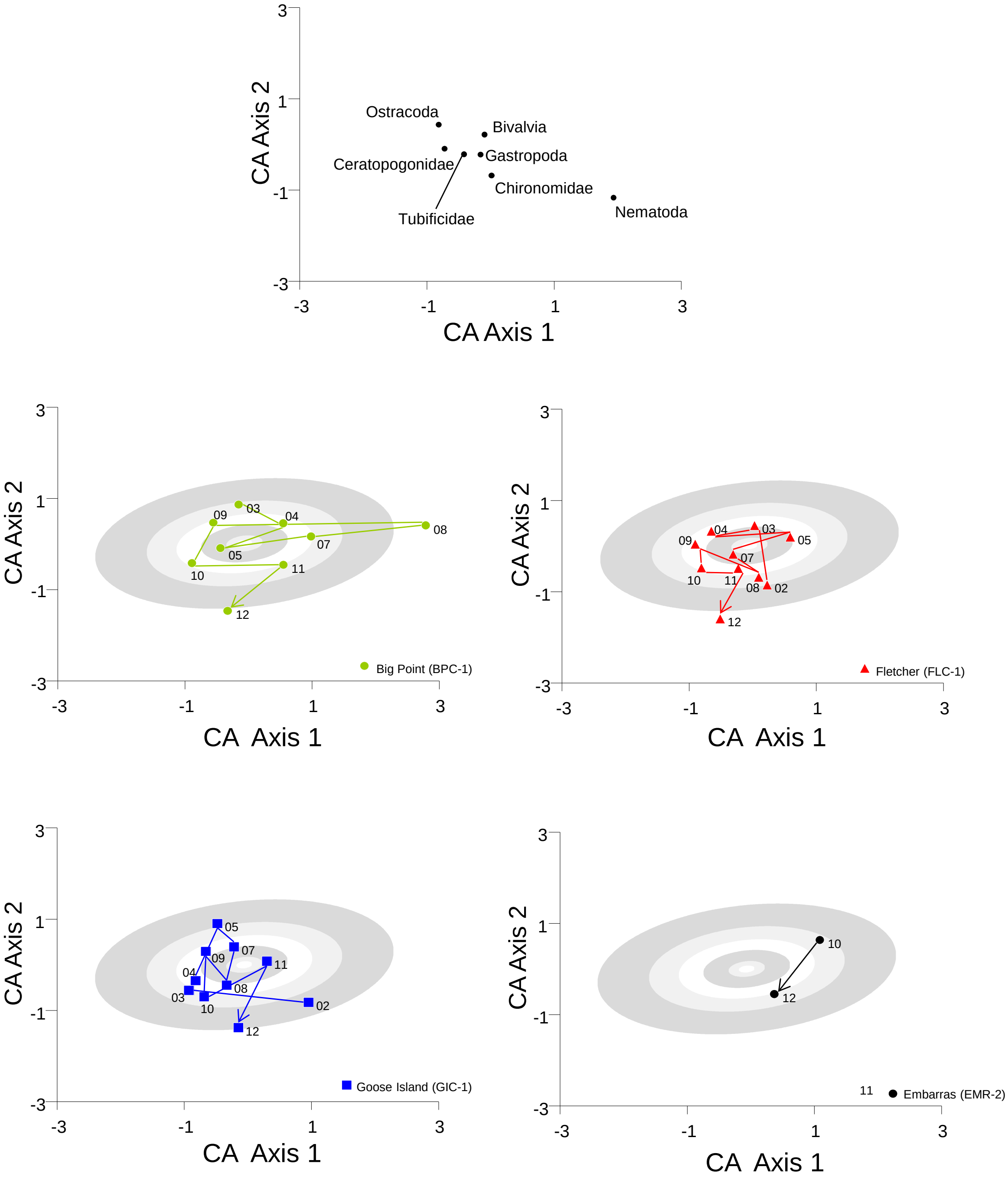
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.1-10 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta, 2002 to 2012.



Note: Historical *baseline* ranges represented by pooled results for all ARD reaches prior to 2012.

Figure 5.1-11 **Ordination (Correspondence Analysis) of benthic invertebrate communities in the Athabasca River Delta.**



Note: The upper left panel is the scatterplot of taxa scores while the other four panels are the sample scores. The ellipses represent the range of CA axis scores that the four ARD reaches have produced from 1997 to 2011 and serves as a range of values against which to compare the 2012 data.

Figure 5.1-12 **Relationship between total abundance (#/m^2) of benthic invertebrate communities and percent sand as substrate in channels of the Athabasca River Delta, 2002 to 2012.**

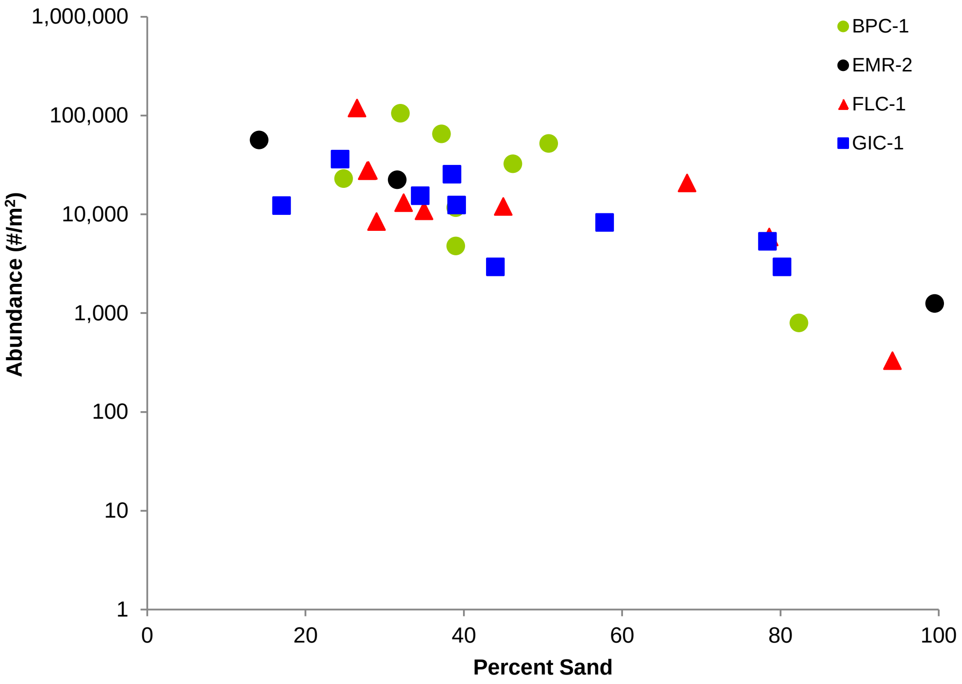


Table 5.1-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Fletcher Channel of the Athabasca River Delta.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	**<0.001**	**<0.001**	21	50	Decreasing over time; lower in 2012 than mean of previous years.
Richness	<0.001	**<0.001**	46	62	Decreasing over time; lower in 2012 than mean of previous years.
Simpson's Diversity	**0.021**	0.602	21	1	Decreasing over time.
Equitability	**<0.001**	**<0.001**	27	65	Increasing over time; higher in 2012 than mean of previous years.
EPT	0.623	0.223	1	9	No change.
CA Axis 1	0.038	0.418	26	4	Decreasing over time.
CA Axis 2	**0.034**	**0.006**	29	51	Decreasing over time; lower in 2012 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).

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.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	**0.013**	0.085	13	6	Decreasing over time.
Richness	0.384	0.437	6	4	No change.
Simpson's Diversity	0.449	0.850	4	0	No change.
Equitability	0.544	0.606	1	0	No change.
EPT	0.535	0.838	6	1	No change.
CA Axis 1	0.807	0.606	0	1	No change.
CA Axis 2	0.381	**<0.001**	2	35	Lower in 2012 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).

Table 5.1-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Embarras River of the Athabasca River Delta.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	**0.030**	**0.013**	6	8	Decreasing over time; lower in 2012 than mean of previous years.
Richness	**<0.001**	0.632	21	0	Decreasing over time.
Simpson's Diversity	0.099	0.884	22	0	No change.
Equitability	0.843	0.304	1	18	No change.
EPT	**0.012**	0.633	65	2	Decreasing over time.
CA Axis 1	0.095	**0.019**	34	77	Lower in 2012 than mean of previous years.
CA Axis 2	**0.008**	0.220	13	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 3.2-6).

Table 5.1-14 Concentrations of sediment quality measurement endpoints, Athabasca River mainstem upstream of Embarras River (ATR-ER).

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1.2	11	0.5	12.0	22.0
Silt	%	-	1.4	11	0.5	32.0	42.0
Sand	%	-	97	11	36	57	99
Total organic carbon	%	-	0.2	11	<0.1	1.0	1.7
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	7	11	20	39
Fraction 3 (C16-C34)	mg/kg	300[1]	31	7	<20	220	**570**
Fraction 4 (C34-C50)	mg/kg	2800[1]	28	7	24	180	340
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0007	11	0.0005	0.0077	**0.0370**
Retene	mg/kg	-	0.010	11	0.002	0.040	0.081
Total dibenzothiophenes	mg/kg	-	0.030	11	0.012	0.225	0.749
Total PAHs	mg/kg	-	0.214	11	0.075	1.107	2.482
Total Parent PAHs	mg/kg	-	0.015	11	0.005	0.089	0.156
Total Alkylated PAHs	mg/kg	-	0.199	11	0.070	1.017	2.355
Predicted PAH toxicity[3]	H.I.	1.0	0.804	11	0.335	0.913	**1.500**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>9.0</u>	7	3.4	7.4	8.6
Chironomus growth - 10d	mg/organism	-	1.47	7	1.15	2.09	3.50
Hyalella survival - 14d	# surviving	-	8.2	7	6.8	9.2	10.0
Hyalella growth - 14d	mg/organism	-	0.16	7	0.05	0.25	0.29

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 5.1-15 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC-1).

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3	10	9	19	32
Silt	%	-	5	10	20	47	58
Sand	%	-	92	10	10	37	71
Total organic carbon	%	-	0.6	10	<0.1	1.2	2.2
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	<8	<21
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	<8	<21
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	<5	<21	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	111	6	110	184	**307**
Fraction 4 (C34-C50)	mg/kg	2800[1]	102	6	33	110	199
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.003	10	0.005	0.009	0.024
Retene	mg/kg	-	0.024	10	0.035	0.052	0.096
Total dibenzothiophenes	mg/kg	-	0.104	10	0.150	0.254	0.358
Total PAHs	mg/kg	-	0.72	10	1.05	1.37	2.03
Total Parent PAHs	mg/kg	-	0.050	10	0.077	0.107	0.209
Total Alkylated PAHs	mg/kg	-	0.668	10	0.945	1.26	1.88
Predicted PAH toxicity[3]	H.I.	1.0	0.891	10	0.830	**1.22**	**2.59**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.6	9	3.2	7.0	9.0
Chironomus growth - 10d	mg/organism	-	1.85	9	0.89	1.82	3.60
Hyalella survival - 14d	# surviving	-	10.0	9	6.6	8.0	9.0
Hyalella growth - 14d	mg/organism	-	0.18	9	0.05	0.12	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic 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 5.1-16 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC-1).

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	9	8	14	23
Silt	%	-	3	9	14	38	72
Sand	%	-	93	9	11	47	79
Total organic carbon	%	-	0.6	9	0.6	1.3	2.2
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	10	30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	10	30
Fraction 2 (C10-C16)	mg/kg	150[1]	21	6	<5	22	30
Fraction 3 (C16-C34)	mg/kg	300[1]	208	6	68	200	**430**
Fraction 4 (C34-C50)	mg/kg	2800[1]	190	6	49	130	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.002	8	0.002	0.008	0.016
Retene	mg/kg	-	0.028	9	0.020	0.044	0.105
Total dibenzothiophenes	mg/kg	-	0.089	9	0.111	0.185	0.591
Total PAHs	mg/kg	-	0.586	9	0.594	1.213	2.745
Total Parent PAHs	mg/kg	-	0.041	9	0.048	0.100	0.160
Total Alkylated PAHs	mg/kg	-	0.545	9	0.546	1.11	2.61
Predicted PAH toxicity[3]	H.I.	1.0	0.400	9	0.488	0.883	**5.357**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.5	7	3.4	6.0	9.4
Chironomus growth - 10d	mg/organism	-	1.08	7	1.29	2.29	3.60
Hyalella survival - 14d	# surviving	-	9.2	7	8.0	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.27	7	0.10	0.19	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic 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 5.1-17 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC-1).

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8	9	2	15	28
Silt	%	-	15	9	9	47	58
Sand	%	-	77	9	17	32	89
Total organic carbon	%	-	0.8	9	0.5	1.4	2.4
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	<8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	<8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	<5	19	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	157	6	39	198	**360**
Fraction 4 (C34-C50)	mg/kg	2800[1]	145	6	46	109	200
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.003</u>	9	0.004	0.008	0.015
Retene	mg/kg	-	0.021	9	0.006	0.044	0.078
Total dibenzothiophenes	mg/kg	-	0.109	9	0.043	0.223	0.412
Total PAHs	mg/kg	-	0.717	9	0.294	1.239	2.161
Total Parent PAHs	mg/kg	-	0.045	9	0.021	0.111	0.177
Total Alkylated PAHs	mg/kg	-	0.672	9	0.273	1.126	1.984
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.640</u>	9	0.800	**1.101**	**1.578**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.2	7	4.0	7.6	8.4
Chironomus growth - 10d	mg/organism	-	2.15	7	1.34	2.01	4.20
Hyalella survival - 14d	# surviving	-	8.8	7	7.0	9.0	10.0
Hyalella growth - 14d	mg/organism	-	0.23	7	0.10	0.17	0.30

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic 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 5.1-18 Concentrations of sediment quality measurement endpoints, Embarras River (EMR-2).

Variables	Units	Guideline	September 2012	2005-2010 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay[4]	%	-	35.7	2	32.4	37.7	43.0
Silt[4]	%	-	55	2	53	55	57
Sand[4]	%	-	9.3	2	4	7	10
Total organic carbon	%	-	2.41	2	2.58	2.59	2.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<5	<8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<5	<8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<32	2	<5	<19	<33
Fraction 3 (C16-C34)	mg/kg	300[1]	245	2	54	222	**390**
Fraction 4 (C34-C50)	mg/kg	2800[1]	164	2	36	113	190
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.011	2	0.018	0.021	0.025
Retene	mg/kg	-	0.116	2	0.072	0.101	0.130
Total dibenzothiophenes	mg/kg	-	0.278	2	0.483	0.488	0.492
Total PAHs	mg/kg	-	2.09	2	2.62	2.62	2.63
Total Parent PAHs	mg/kg	-	0.167	2	0.174	0.189	0.204
Total Alkylated PAHs	mg/kg	-	1.92	2	2.42	2.44	2.45
Predicted PAH toxicity[3]	H.I.	1.0	**1.34**	2	**1.29**	**3.63**	**5.96**
Metals that exceed CCME guidelines in 2012							
Total Arsenic	mg/kg	5.9	**8.1**	2	**7.0**	**7.6**	**8.2**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.40	1	6.80	6.80	6.80
Chironomus growth - 10d	mg/organism	-	2.04	1	1.62	1.62	1.62
Hyalella survival - 14d	# surviving	-	9.40	1	8.80	8.80	8.80
Hyalella growth - 14d	mg/organism	-	0.200	1	0.214	0.214	0.214

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

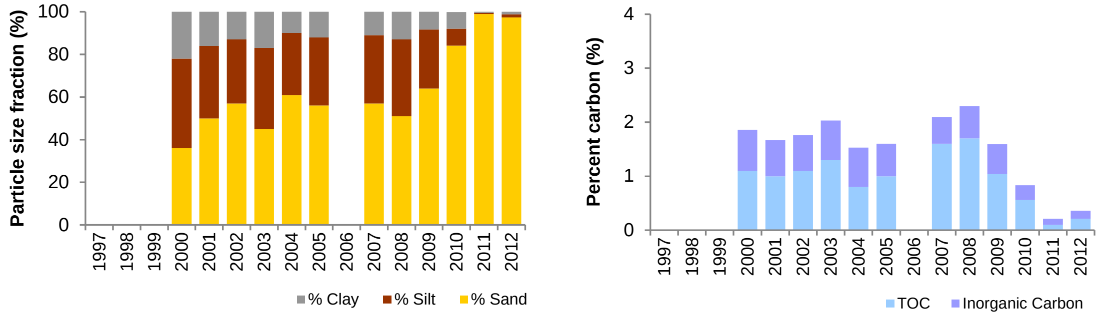
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

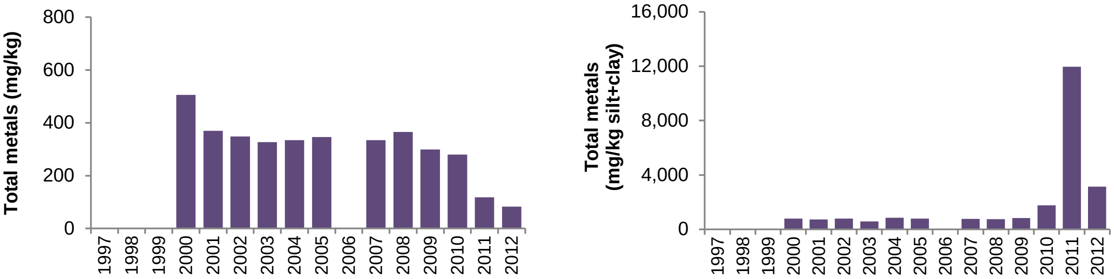
Table 5.1-19 Sediment quality index (fall 2012) for Athabasca River Delta stations.

Station	Location	2012 Designation	Sediment Quality Index	Classification
GIC-1	Athabasca River Delta, Goose Island Channel	*test*	97.8	Negligible-Low
BPC-1	Athabasca River Delta, Big Point Channel	*test*	98.9	Negligible-Low
FLC-1	Athabasca River Delta, Fletcher Channel	*test*	100.0	Negligible-Low
ATR-ER	Athabasca River downstream of Embarras River	*test*	100.0	Negligible-Low
EMR-2	Embarras River	*test*	83.2	Negligible-Low

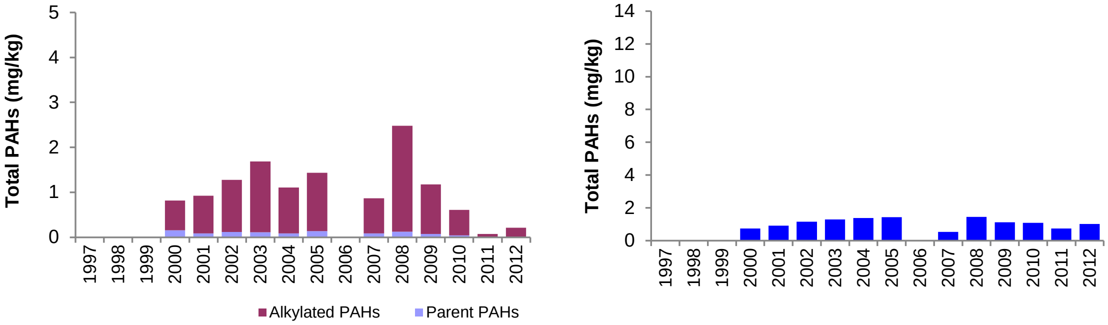
Figure 5.1-13 Characteristics of sediment collected in the Athabasca River upstream of Embarras River (ATR-ER), 2000 to 2012 (fall data only).


Particle size distribution

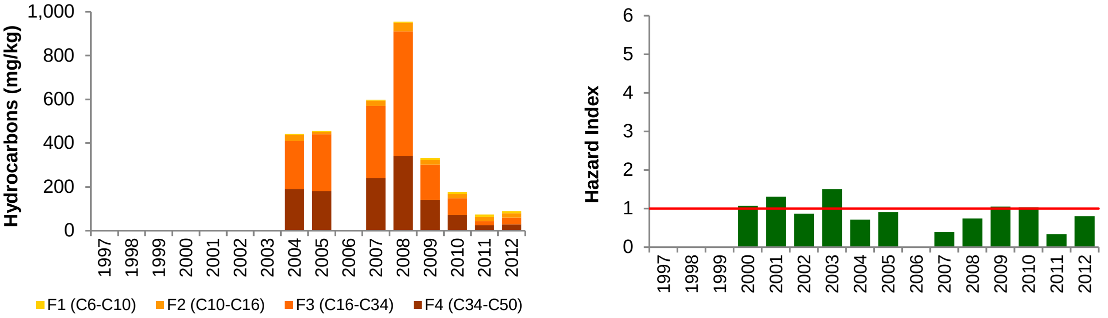
Carbon Content


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

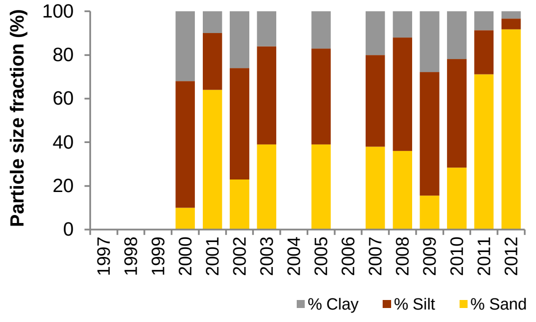
PAH Hazard Index[2]

[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).

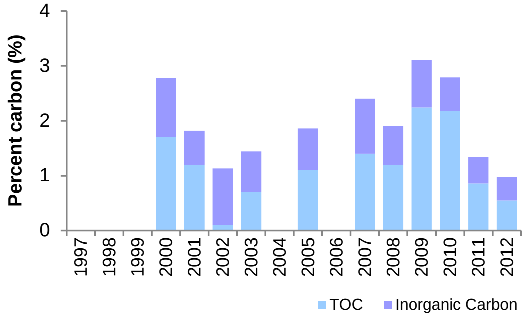
[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.1-14 Characteristics of sediment collected in Big Point Channel (BPC-1), 1999 to 2012 (fall data only).

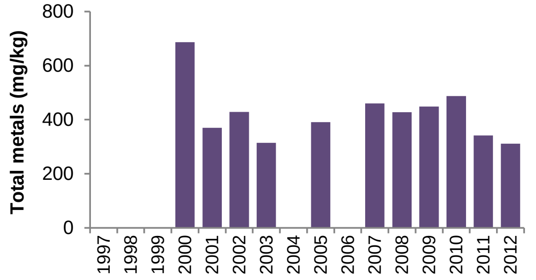
Particle size distribution



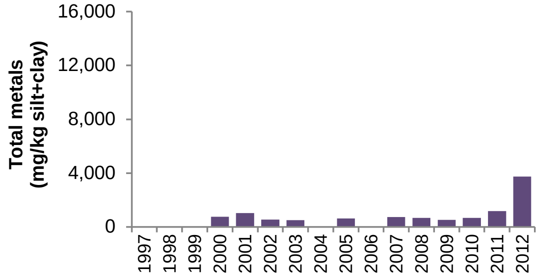
Carbon Content



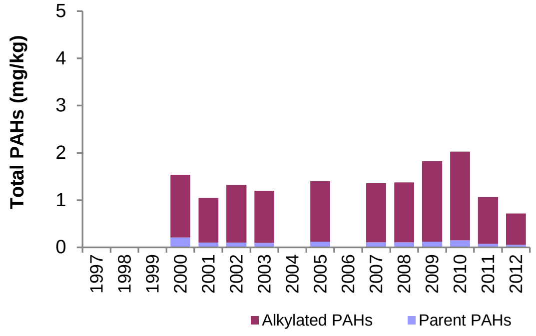
Total Metals[1]



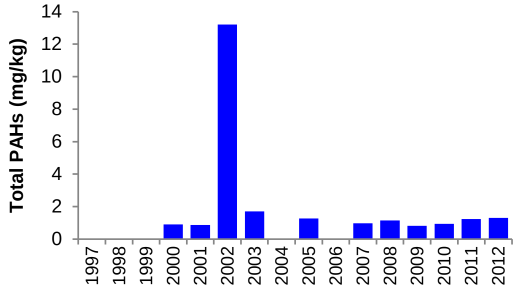
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



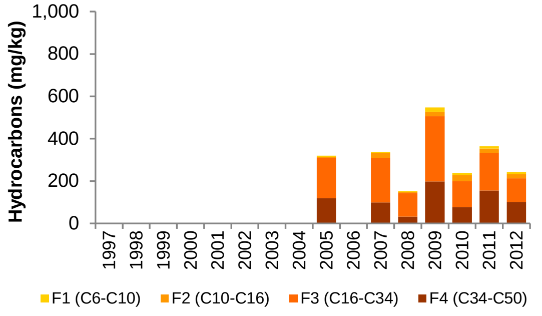
Total PAHs



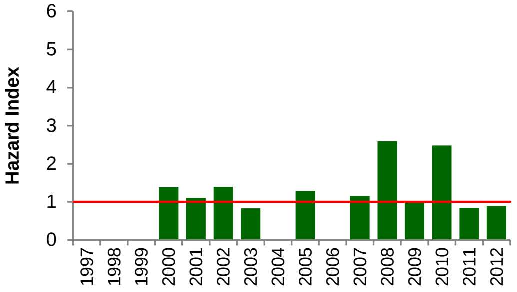
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]

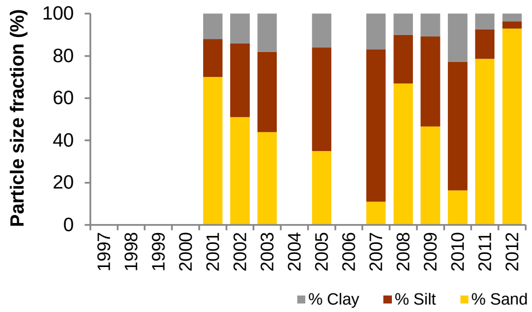


[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

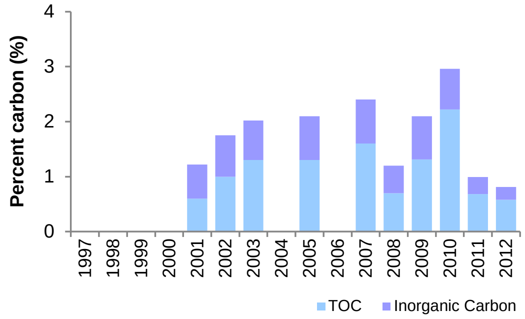
[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.1-15 Characteristics of sediment collected in Fletcher Channel (FLC-1), 2001 to 2012 (fall data only).

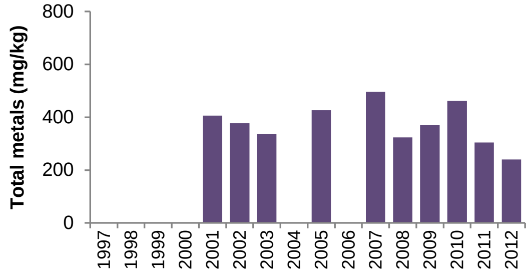
Particle size distribution



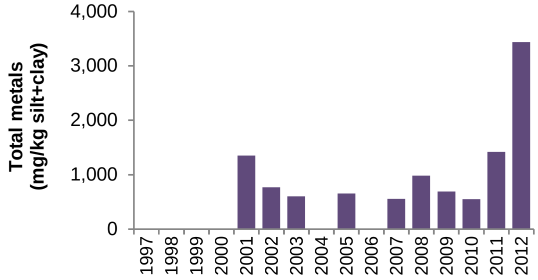
Carbon Content



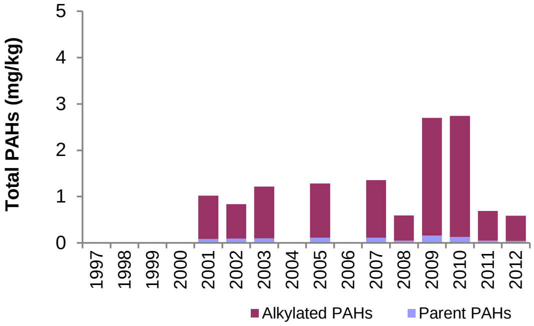
Total Metals[1]



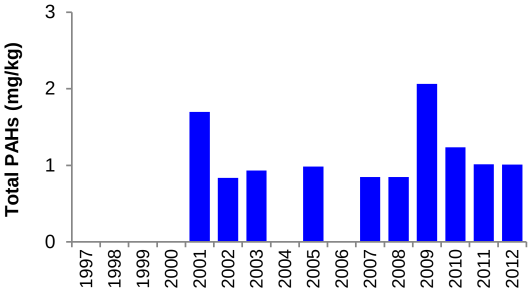
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



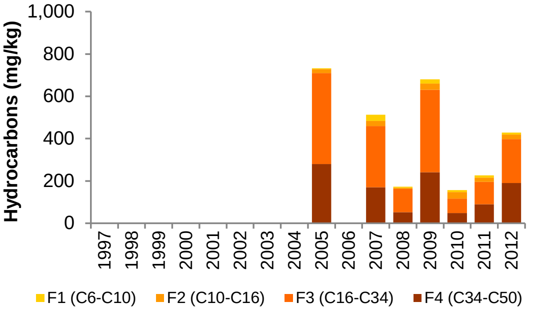
Total PAHs



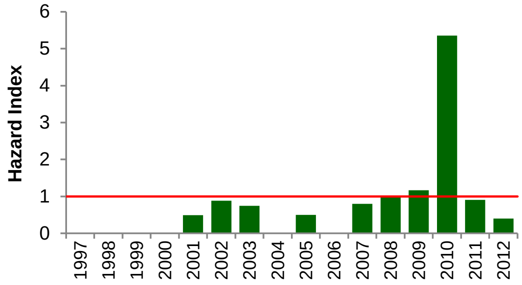
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



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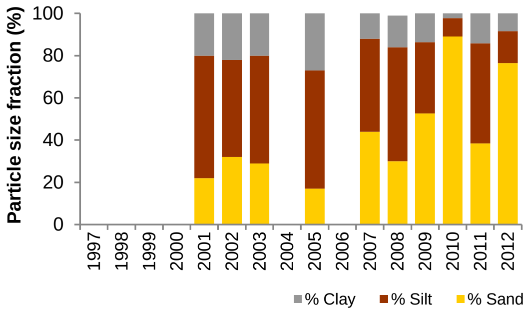
[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

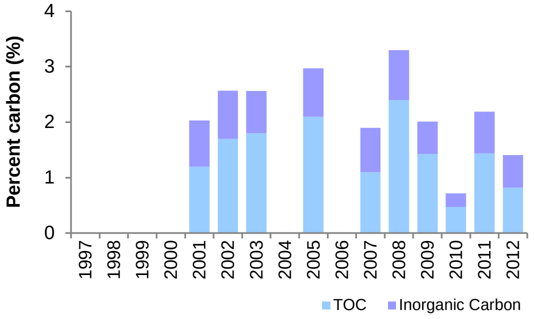
[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.1-16 **Characteristics of sediment collected in Goose Island Channel (GIC-1), 2001 to 2012 (fall data only).**

Particle size distribution

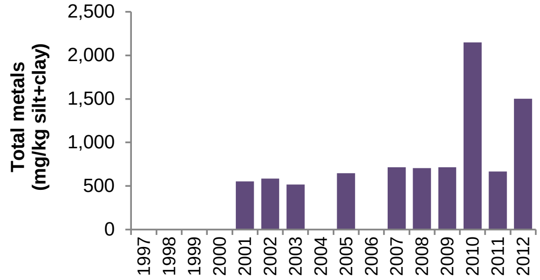


Carbon Content

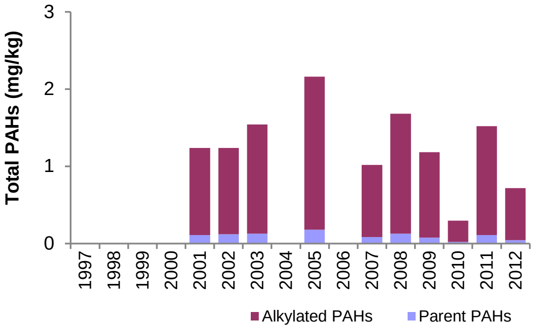


Total Metals[1]

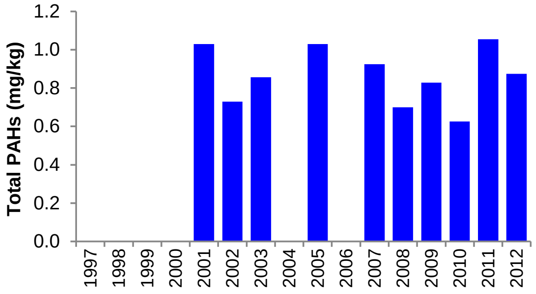
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



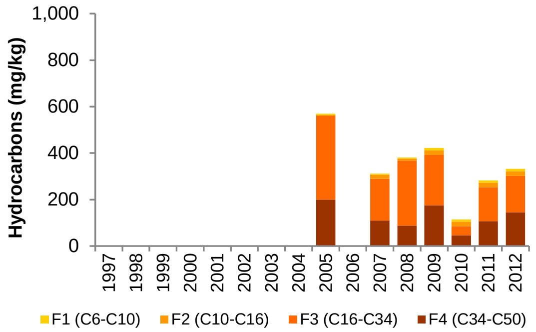
Total PAHs



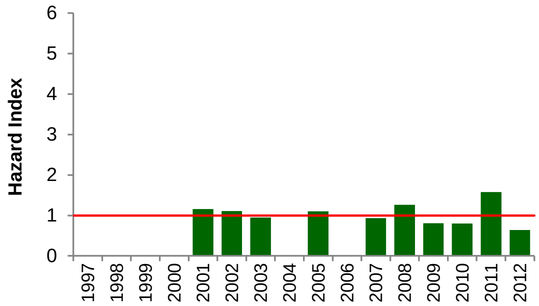
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]

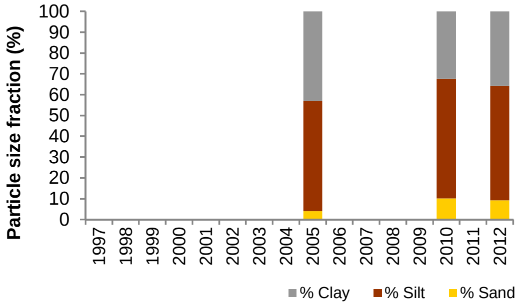


[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

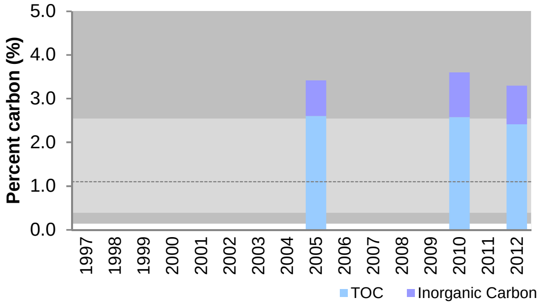
[2] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.1-17 Characteristics of sediment collected in the Embarras River (EMR-2), 2005, 2010, and 2012 (fall data only).

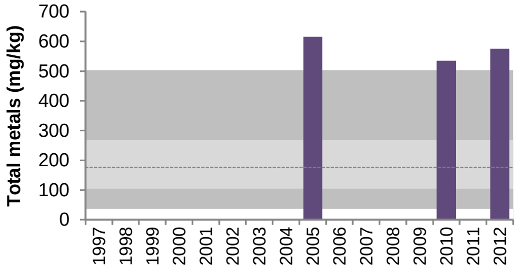
Particle size distribution



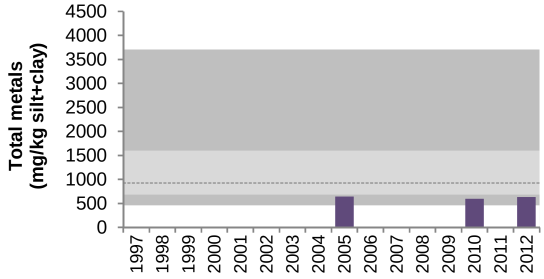
Carbon Content



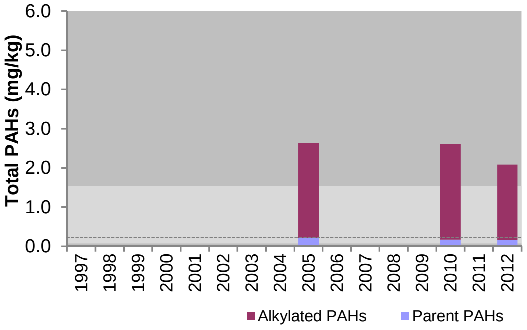
Total Metals[1]



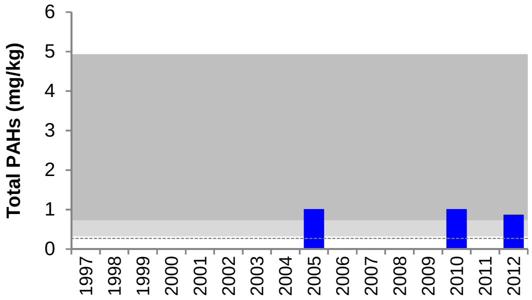
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



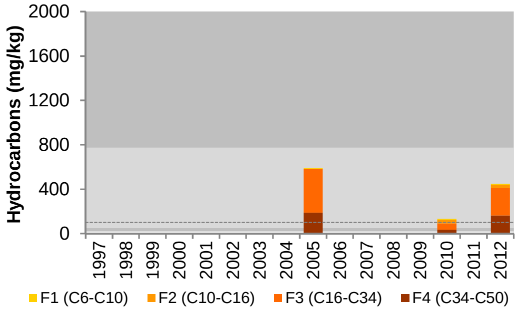
Total PAHs



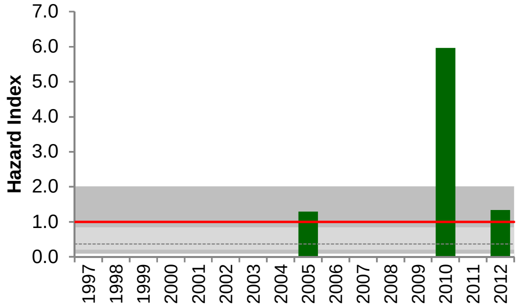
Total PAHs normalized to 1% TOC



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 5.1-20 Total number and percent composition of species in the Athabasca River captured during the spring, summer, and fall fish inventories, 2012.

Species	Spring		Summer		Fall	
	No.	%	No.	%	No.	%
burbot	8	0.5	11	1.3	-	-
cisco	-	-	-	-	3	0.1
emerald shiner	10	0.6	130	15.3	321	9.8
flathead chub	221	14.4	99	11.6	482	14.8
finescale dace	-	-	-	-	1	0.0
goldeye*	166	10.8	275	32.4	1,100	33.7
lake chub	14	0.9	1	0.1	12	0.4
lake whitefish*	4	0.3	8	0.9	366	11.2
longnose dace	-	-	-	-	-	-
longnose sucker*	34	2.2	48	5.6	65	2.0
mountain whitefish	-	-	2	0.2	3	0.1
ninespine stickleback	-	-	-	-	1	0.0
northern pike*	20	1.3	12	1.4	31	0.9
northern redbelly dace	-	-	-	-	2	0.1
spoonhead sculpin	-	-	1	0.1	-	-
spottail shiner	7	-	15	1.8	18	0.6
trout-perch*	623	40.5	101	11.9	397	12.2
walleye*	321	20.9	118	13.9	385	11.8
white sucker*	111	7.2	29	3.4	73	2.2
yellow perch	-	-	-	-	6	0.2
Total	**1,539**	**100**	**850**	**100**	**3,266**	**100**

* Key Indicator Resource (KIR) species

Figure 5.1-18 Species richness and total catch in the Athabasca River during spring, summer and fall fish inventories, 1987 to 2012.

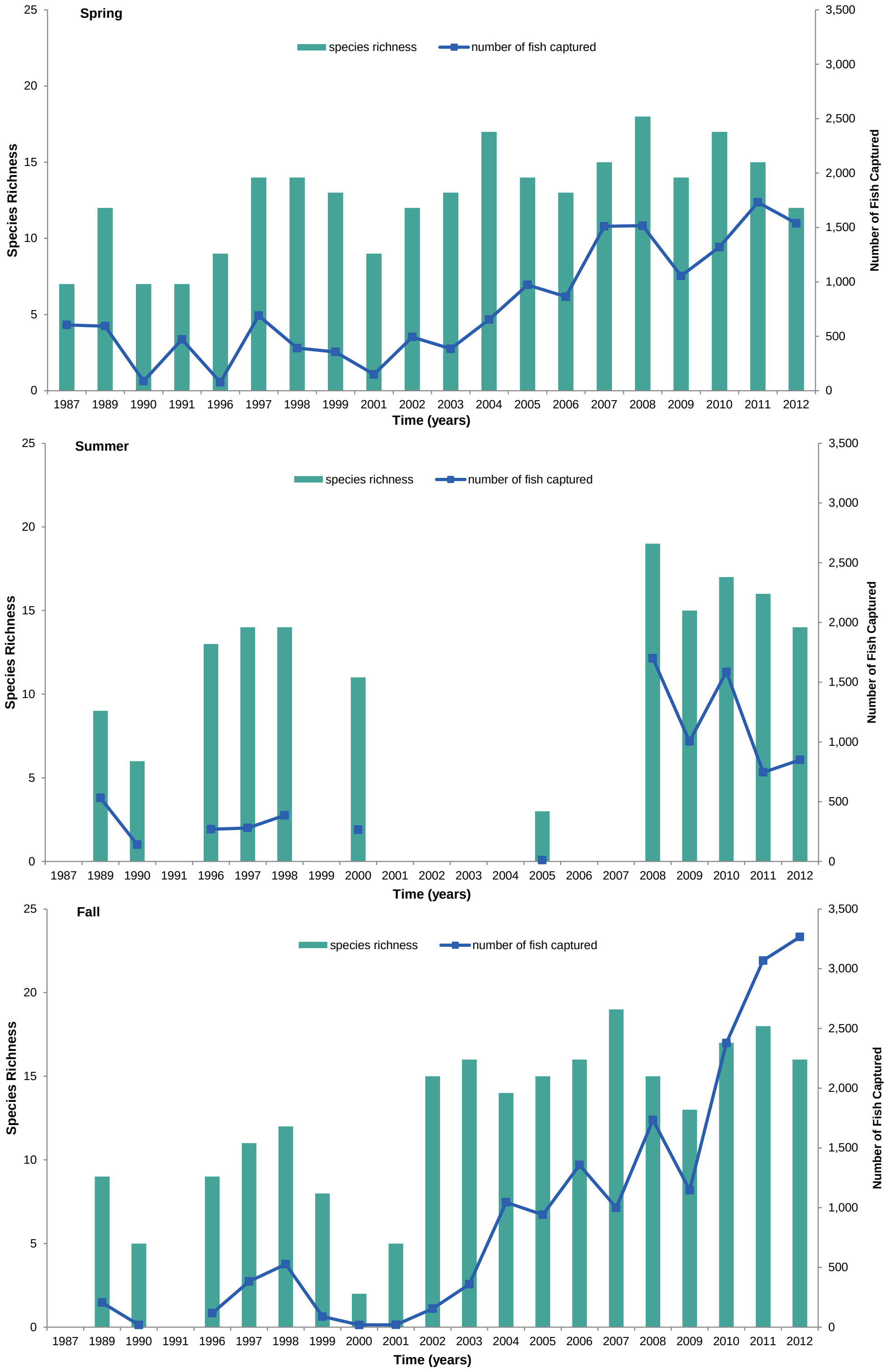


Table 5.1-21 Percent composition of species in the Athabasca River captured in each area during the spring, summer, and fall fish inventories, 2012.

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	4.7	-	0.9	-	1.3	-	6.5	-	1.2	-	1.2	1.2	-	-	-	-	-	-
cisco	-	-	-	-	-	-	-	-	-	-	-	-	1.5	-	-	0.2	-	-
emerald shiner	-	-	1.4	0.8	1.3	0.5	1.3	0.7	21.6	22.9	20.6	10.3	4.5	5.0	11.5	7.7	16.5	8.3
flathead chub	4.7	22.3	15.4	13.6	7.6	14.1	32.5	28.7	4.5	4.3	7.9	5.8	29.9	24.4	6.6	5.3	10.4	21.7
finescale dace	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-
goldeye*	18.6	6.8	21.9	7.2	22.2	5.2	20.8	19.1	29.4	51.4	32.7	40.2	22.4	39.5	25.8	33.7	45.7	26.8
lake chub	-	1.5	0.5	1.5	0.6	0.5	-	-	-	-	0.6	-	3.0	0.2	0.3	-	0.4	0.3
lake whitefish*	-	-	-	0.3	-	0.7	-	0.7	41.0	0.7	1.8	2.3	2.2	6.4	28.2	12.2	6.5	6.0
longnose dace	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
longnose sucker*	4.7	2.7	6.5	1.3	1.9	0.2	23.4	1.5	6.5	3.6	3.0	2.3	7.5	4.6	1.9	1.2	0.9	0.7
mountain whitefish	-	-	-	-	-	-	-	-	0.8	-	-	-	0.8	-	0.3	-	-	-
ninespine stickleback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-
northern pike*	1.2	0.8	1.4	1.5	3.8	0.5	-	2.2	0.8	1.4	1.8	2.3	1.5	0.2	0.8	1.2	1.3	1.1
northern redbelly dace	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	-
spoonhead sculpin	-	-	-	-	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-
spottail shiner	-	-	0.5	1.0	1.3	-	-	7.4	0.4	1.4	1.2	-	-	0.9	0.5	1.0	0.6	0.1
trout-perch*	1.2	38.6	22.8	49.2	10.8	61.5	1.3	14.7	18.4	2.9	16.3	4.6	11.9	7.4	13.1	25.6	8.7	9.3
walleye*	65.1	24.6	26.5	15.6	26.0	9.6	11.7	23.5	11.0	8.6	11.5	21.8	10.5	9.7	5.1	8.7	7.8	24.6
white sucker*	-	2.7	2.3	8.0	23.4	7.3	1.3	1.5	4.9	2.9	1.2	9.2	4.5	1.6	5.1	2.6	0.9	0.9
yellow perch	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.3	-	0.3	0.1
Total # of species	**7**	**8**	**11**	**11**	**11**	**10**	**9**	**10**	**12**	**10**	**12**	**10**	**12**	**12**	**15**	**11**	**12**	**12**
Total Count	**86**	**264**	**215**	**390**	**158**	**426**	**77**	**245**	**175**	**140**	**165**	**87**	**134**	**565**	**624**	**492**	**691**	**760**

* Key Indicator Resource (KIR) species

Figure 5.1-19 **Number of species captured in each sampling area of the Athabasca River captured during the spring, summer and fall fish inventories, 2009 to 2012.**

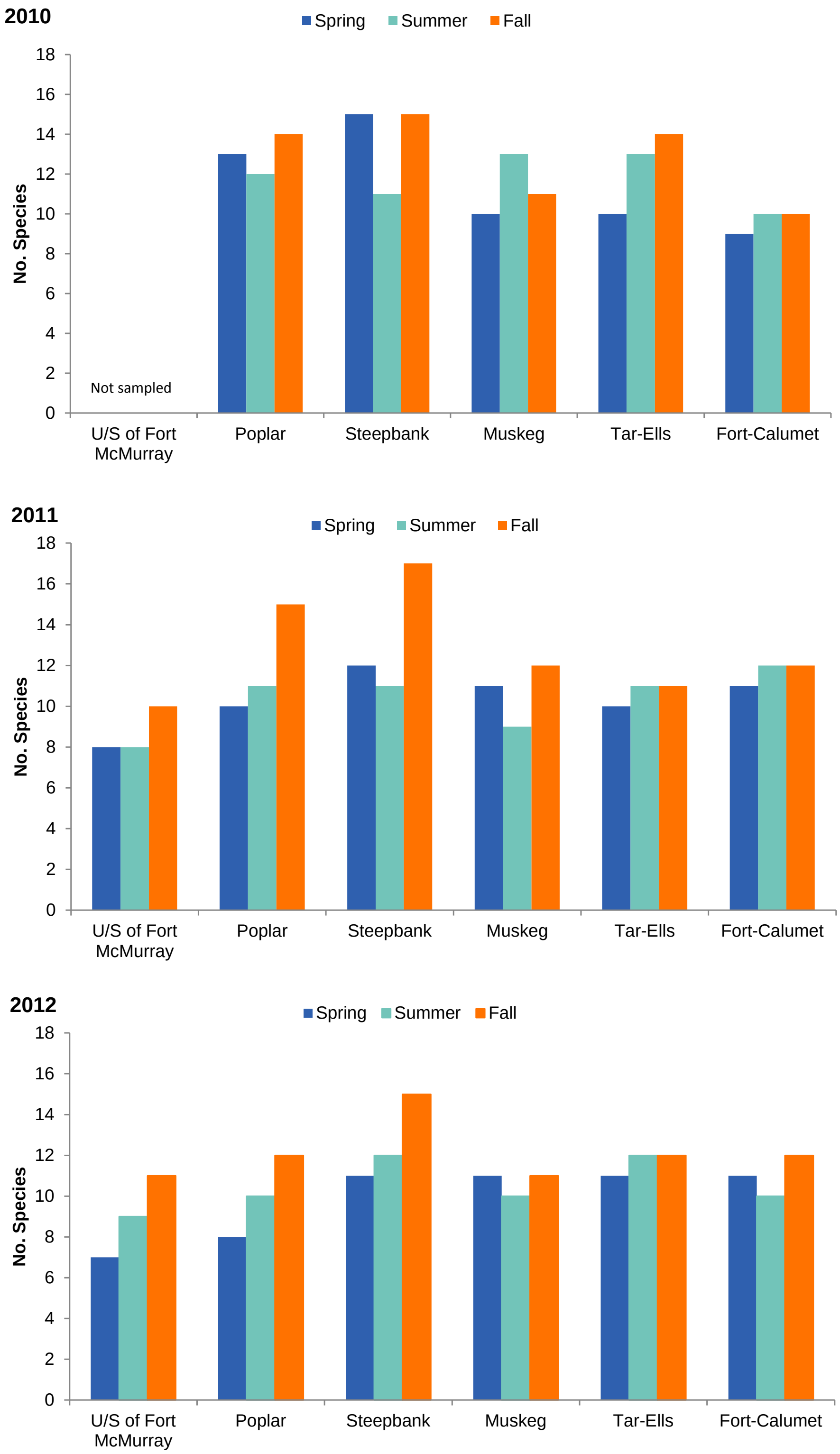


Figure 5.1-20 Percent composition of large-bodied KIR species caught during the Athabasca River spring, summer and fall fish inventories, 1987 to 2012.

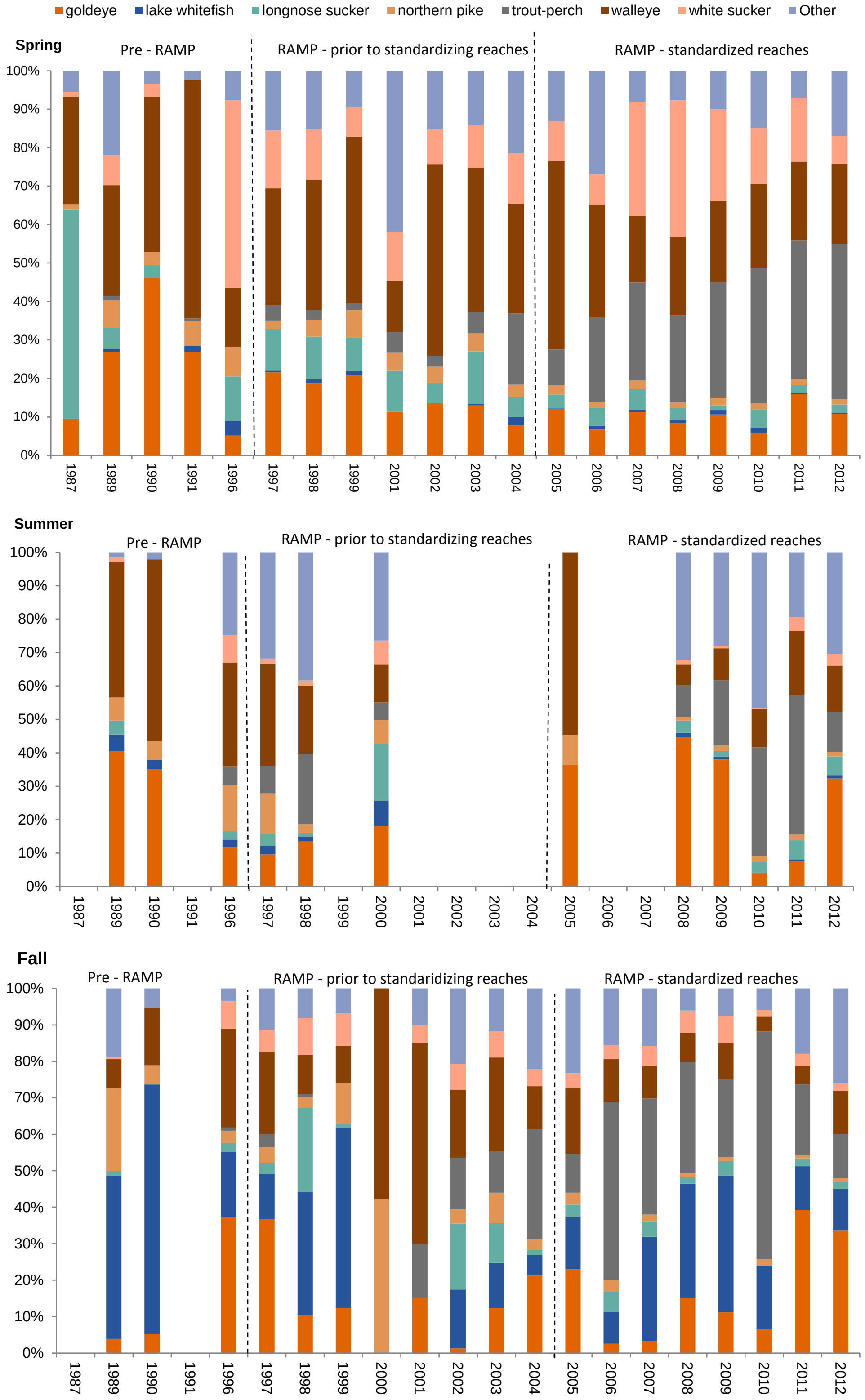
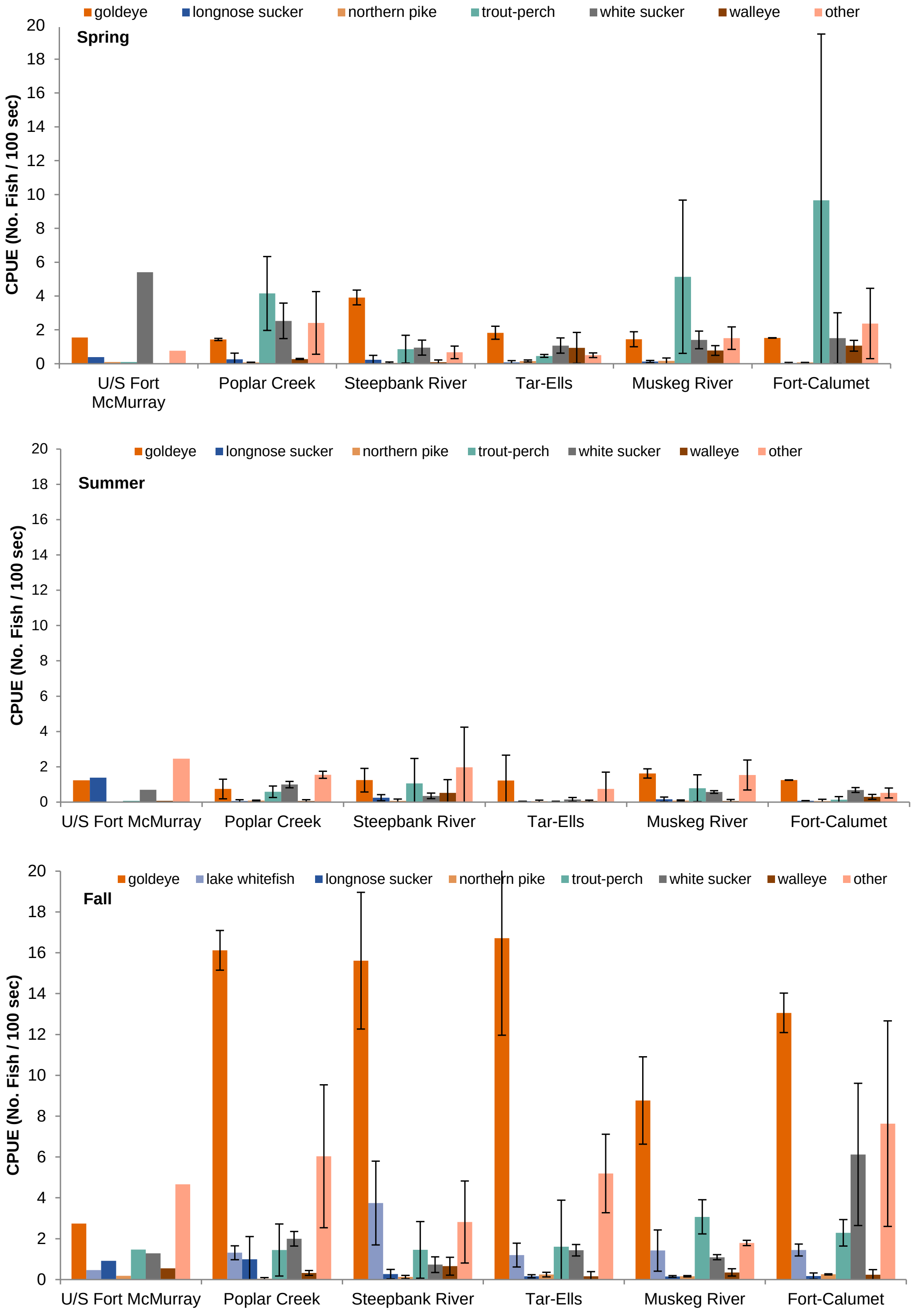


Figure 5.1-21 Total CPUE (±1SD) for KIR fish species in the Athabasca River during spring, summer, and fall fish inventories in 2012.



Note: standard deviations denote the variability across reaches within an area of the river. There is only one reach in the U/S of Fort McMurray area.

Figure 5.1-22 CPUE (±1SD) for goldeye from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

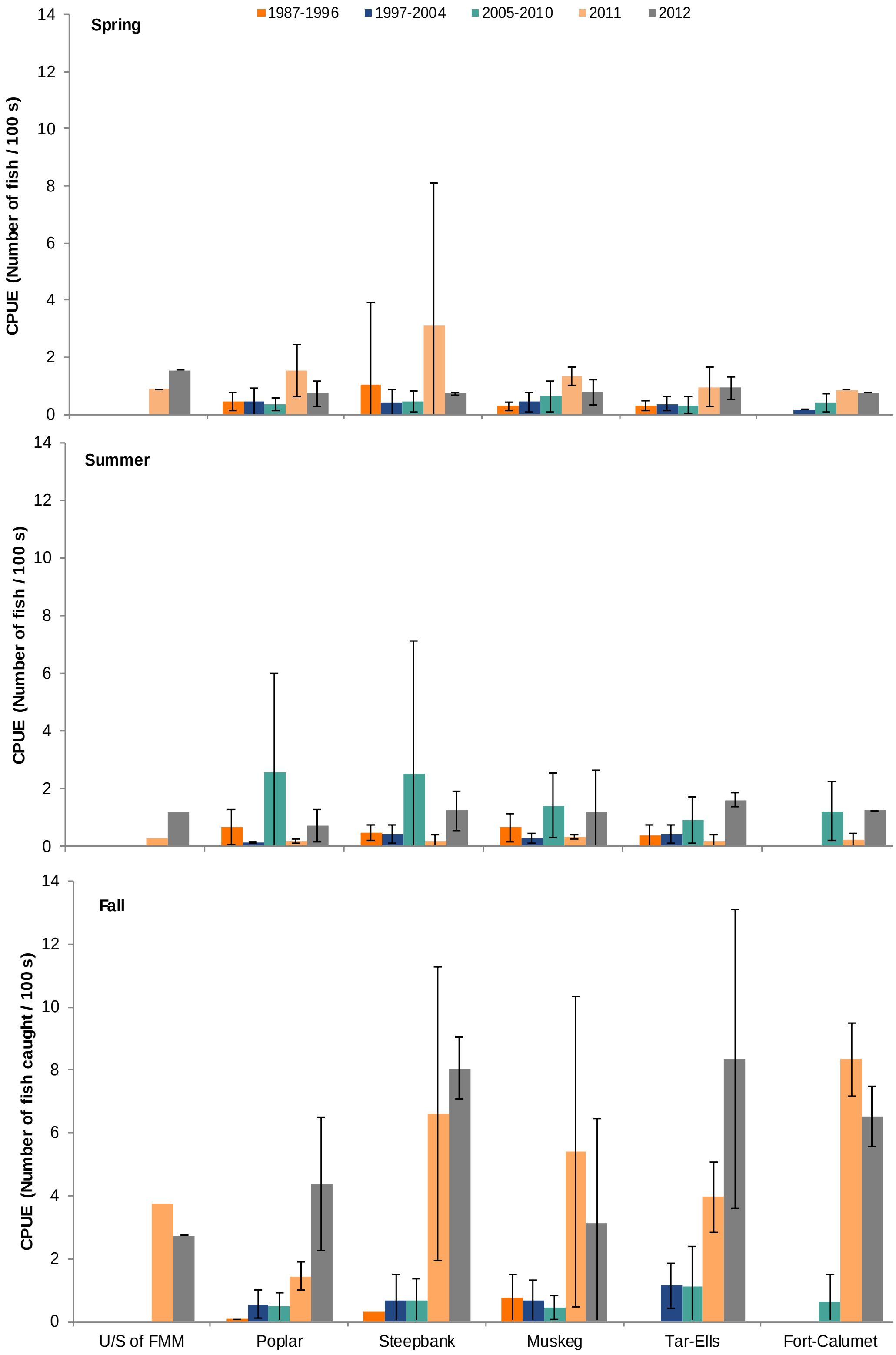


Figure 5.1-23 CPUE (±1SD) for lake whitefish from 1987 to 2012 during the fall fish inventory on the Athabasca River.

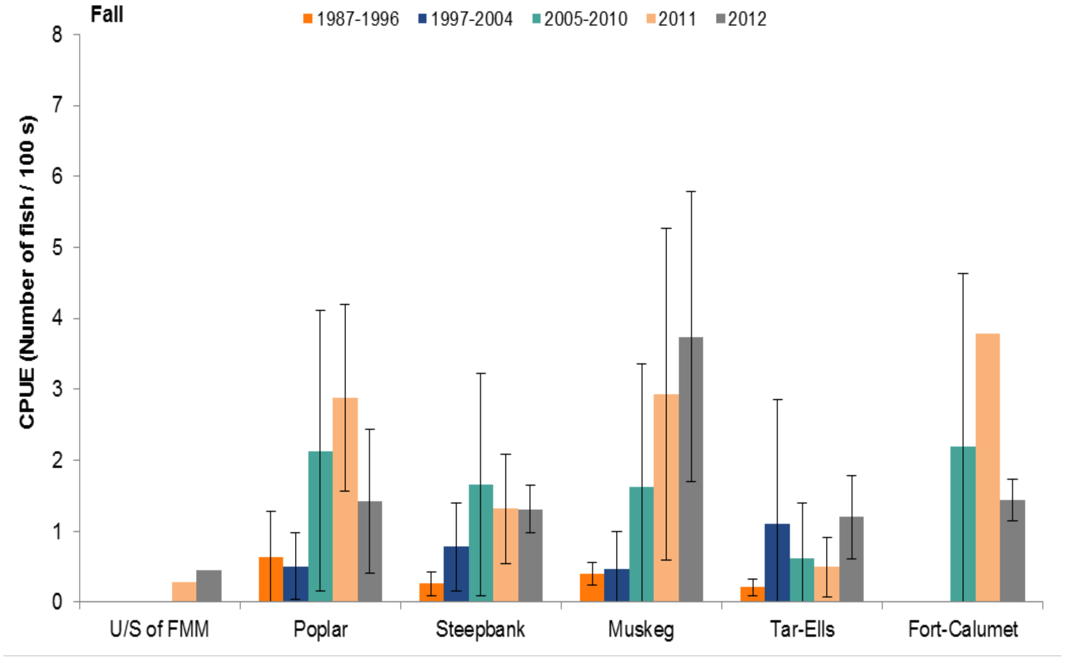


Figure 5.1-24 CPUE (±1SD) for longnose sucker from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

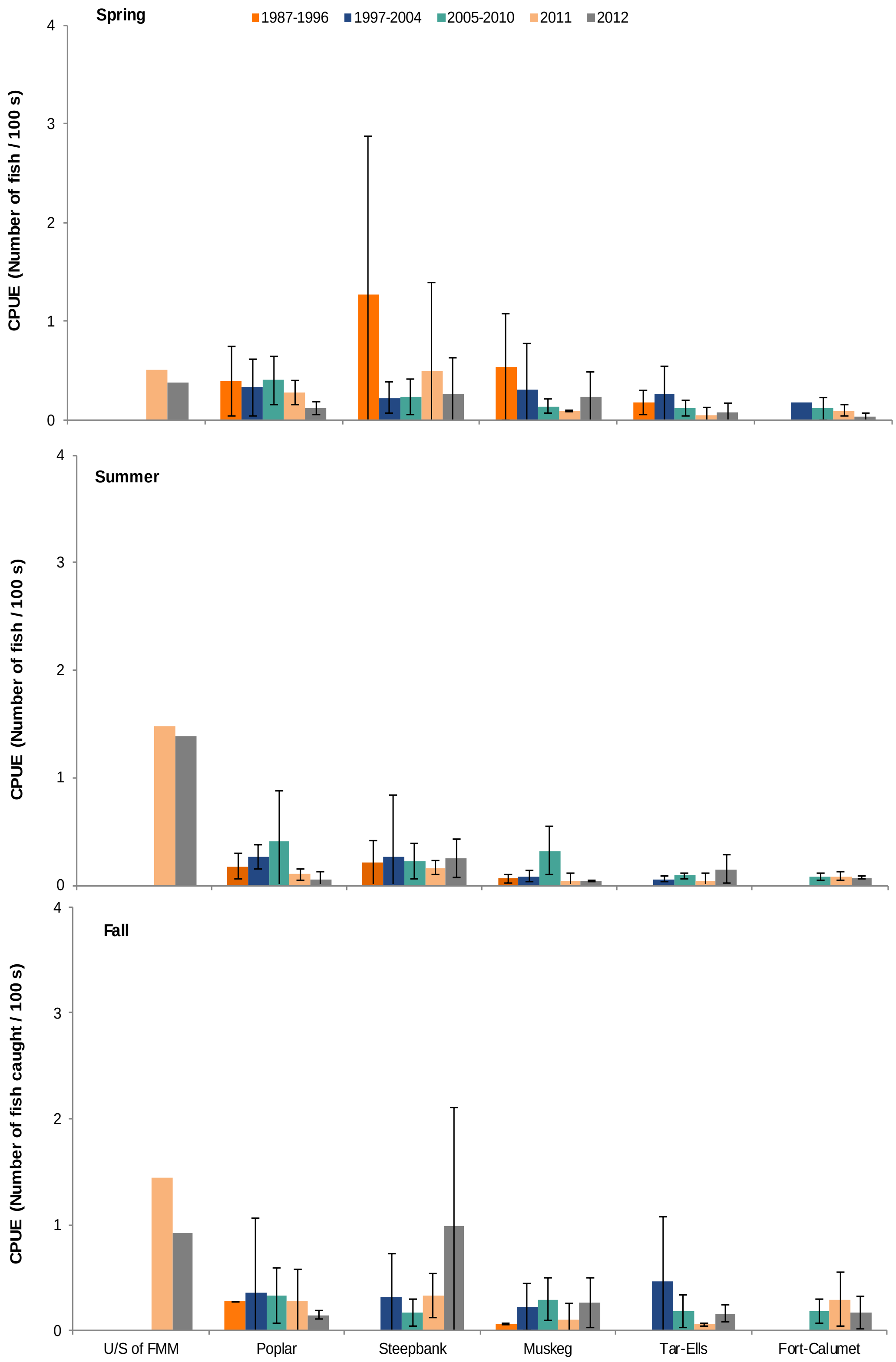


Figure 5.1-25 CPUE (±1SD) for northern pike from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

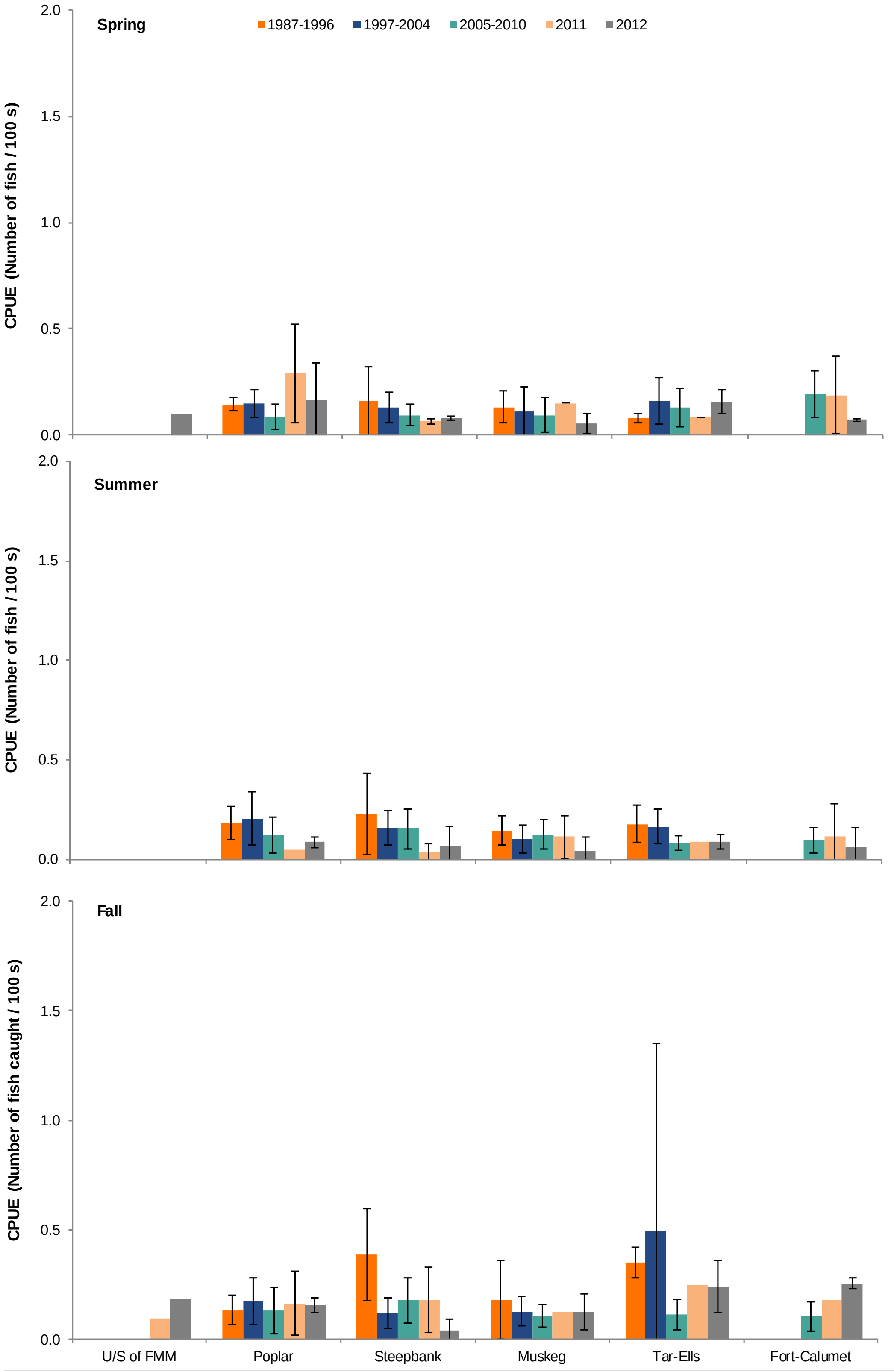


Figure 5.1-26 CPUE (±1SD) for trout-perch from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

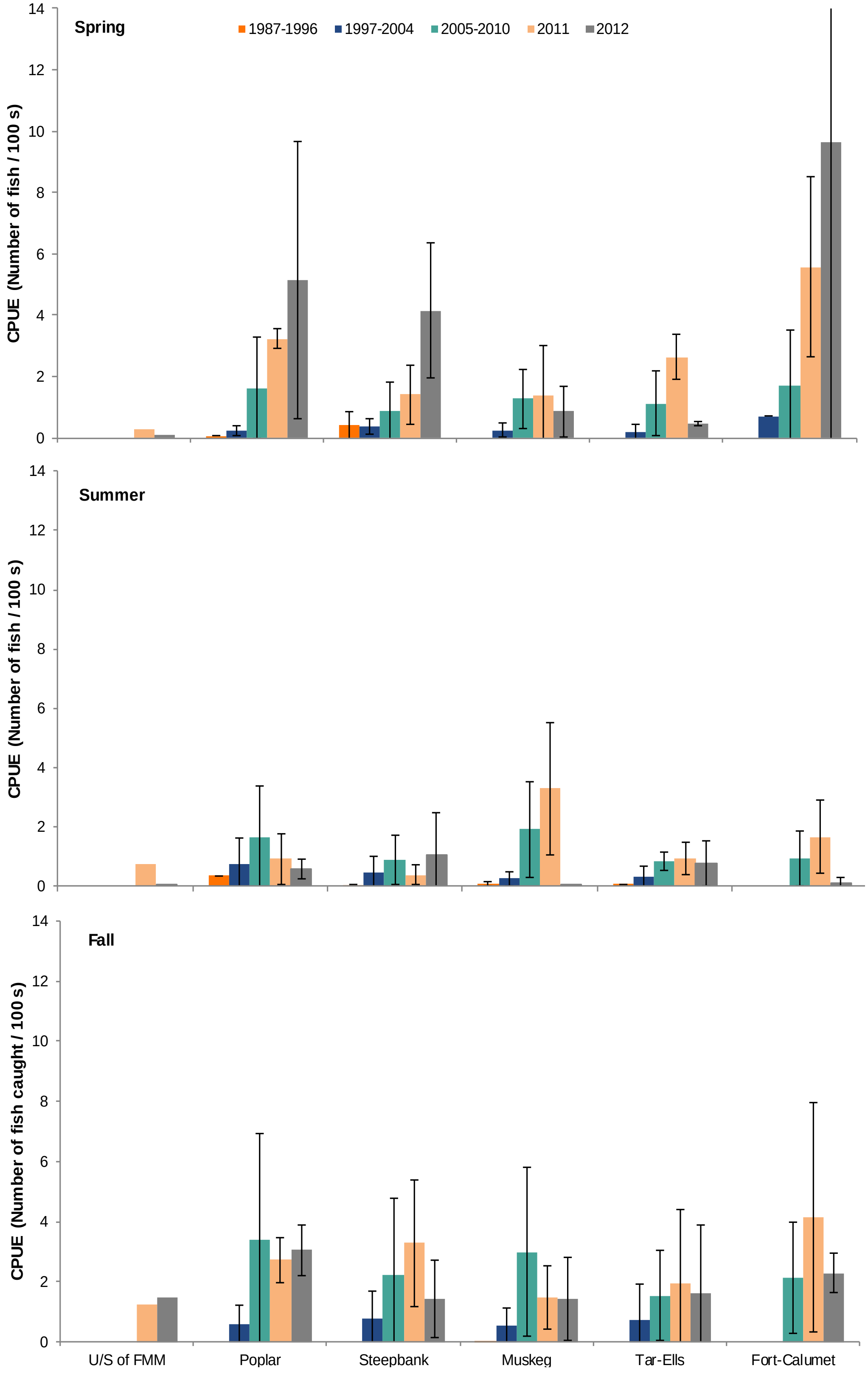


Figure 5.1-27 CPUE (±1SD) for walleye from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

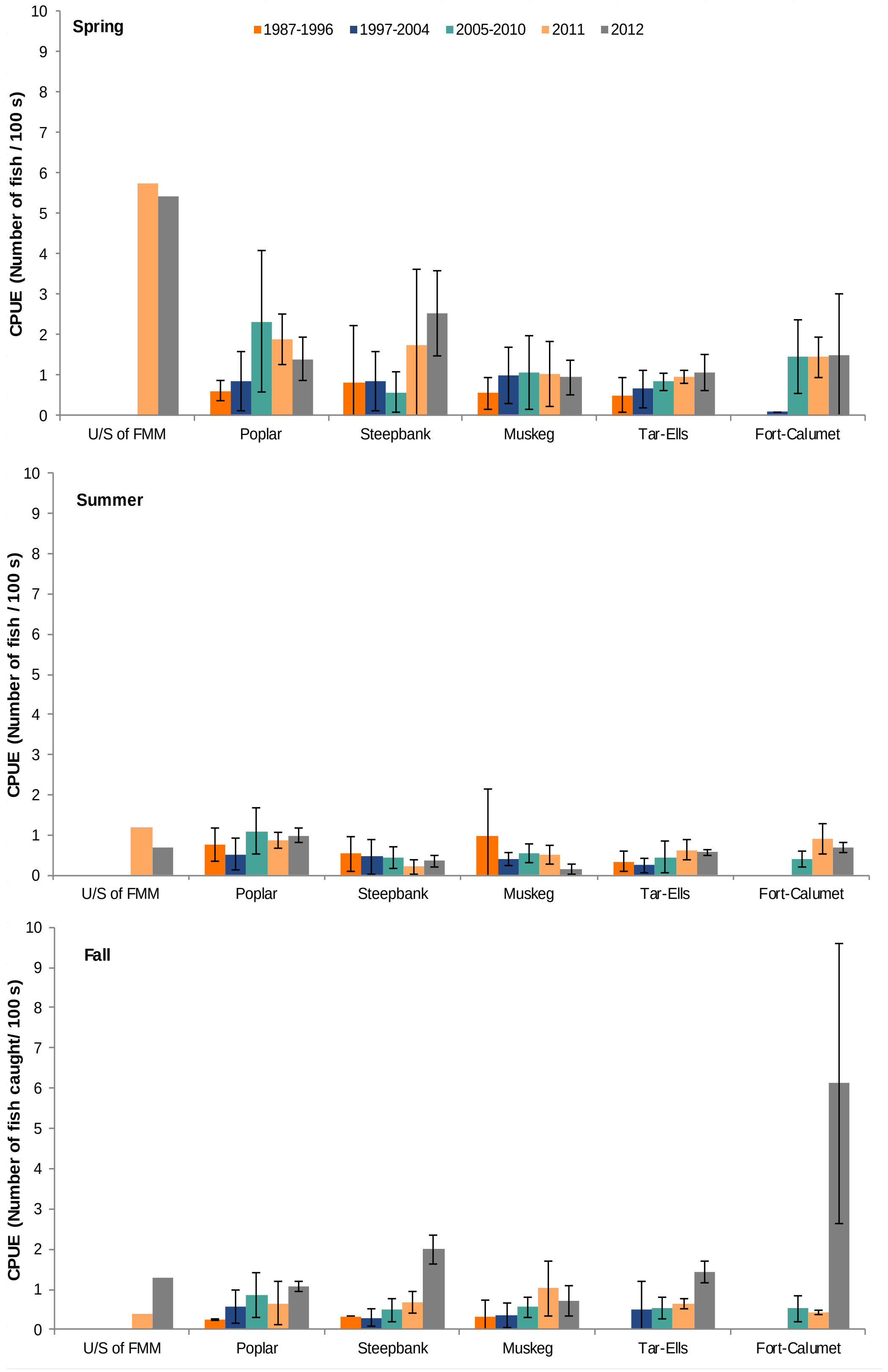


Figure 5.1-28 CPUE (±1SD) for white sucker from 1987 to 2012 during spring, summer, and fall fish inventories on the Athabasca River.

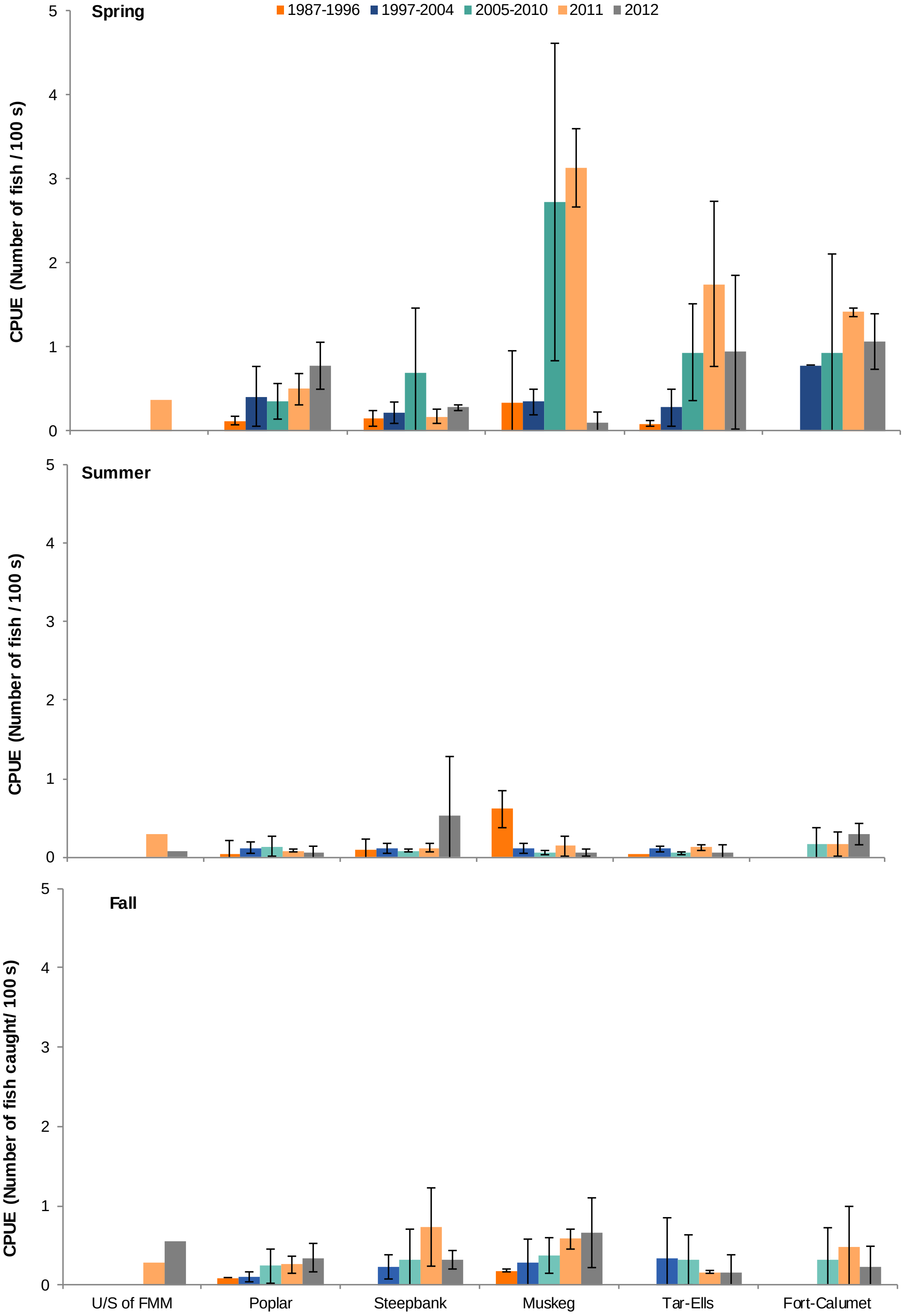


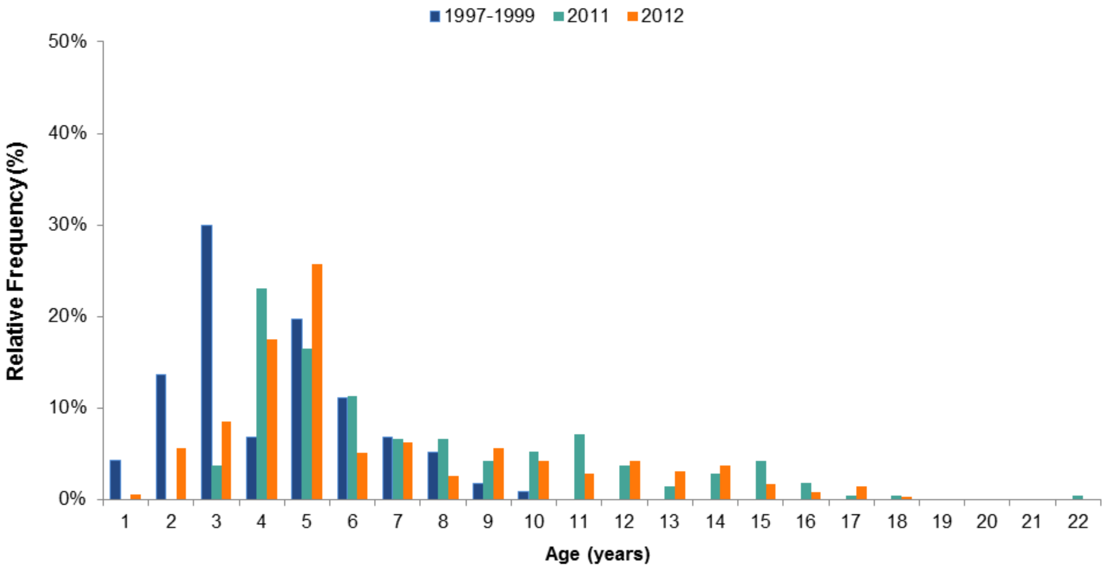
Table 5.1-22 Results of temporal trend analyses in CPUE for KIR fish species in the Athabasca River by area, 1997 to 2012.

Reach Area	GOLD	LKWH	LNSC	NPRK	TRPR	WALL	WHSC
Poplar	**0.020**	**0.012**	0.090	0.435	**<0.001**	**0.002**	0.056
Muskeg	**0.038**	**0.034**	0.425	0.260	**<0.001**	**0.026**	**0.001**
Steepbank	**0.024**	**0.002**	0.403	0.460	**<0.001**	0.131	**0.042**
Tar-Ells	0.302	0.136	0.909	0.463	**<0.001**	0.085	**0.047**
Fort Calumet	0.070	0.071	0.510	0.870	**0.005**	0.621	0.188

Note: All significant trends were assessed to be increasing.

Bolded values denotes significant trend ($p<0.05$).

Figure 5.1-29 Relative age-frequency distributions and size-at-age relationship for goldeye captured in the Athabasca River from 1987 to 2012.



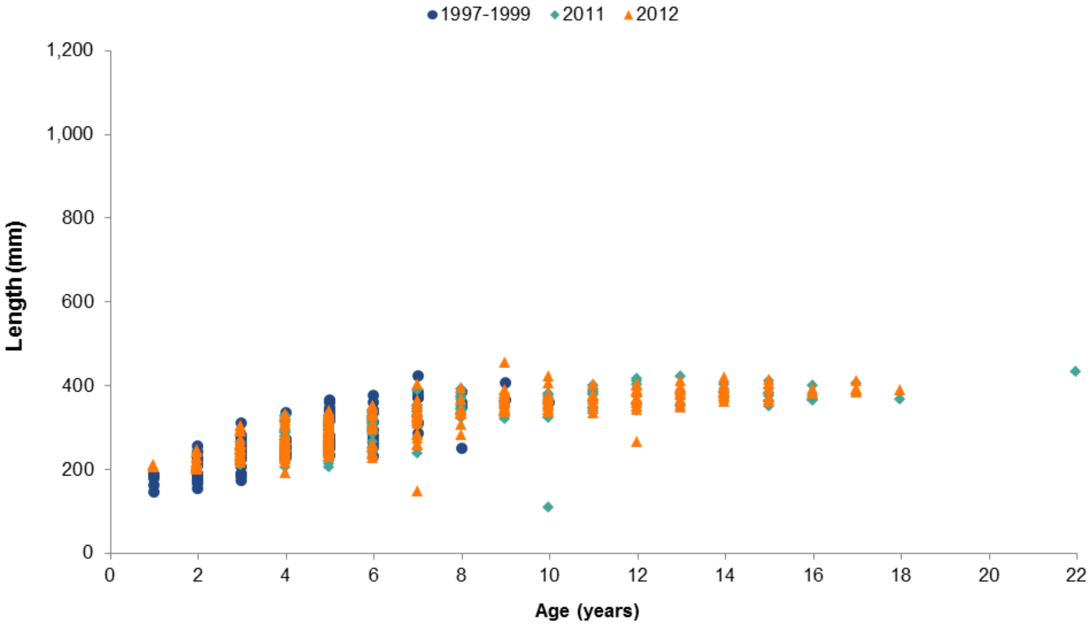
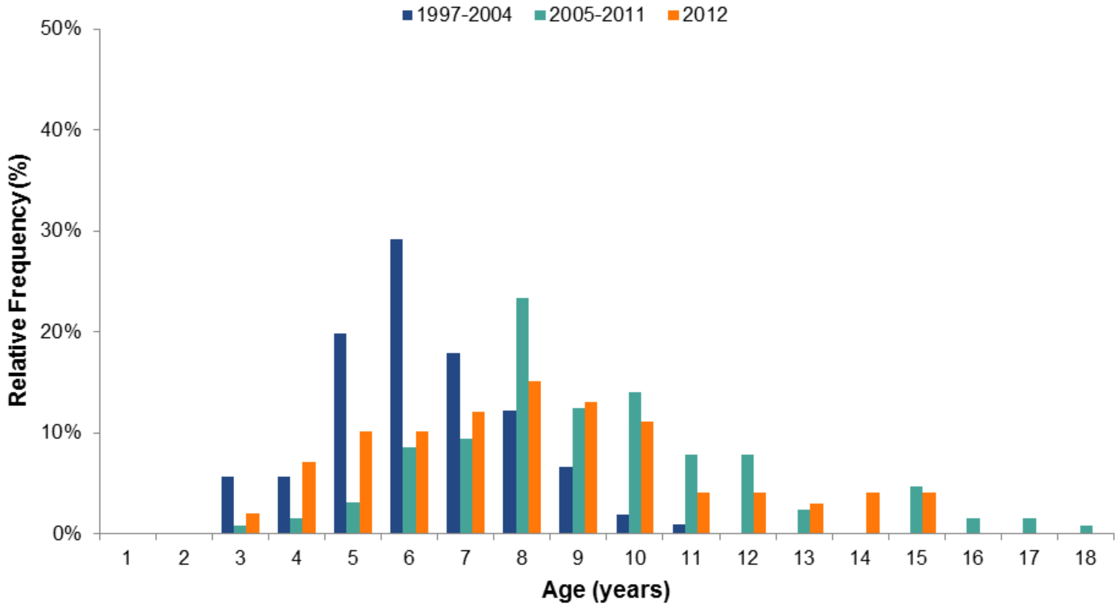


Figure 5.1-30 Relative age-frequency distributions and size-at-age relationship for lake whitefish captured in the Athabasca River from 1987 to 2012.



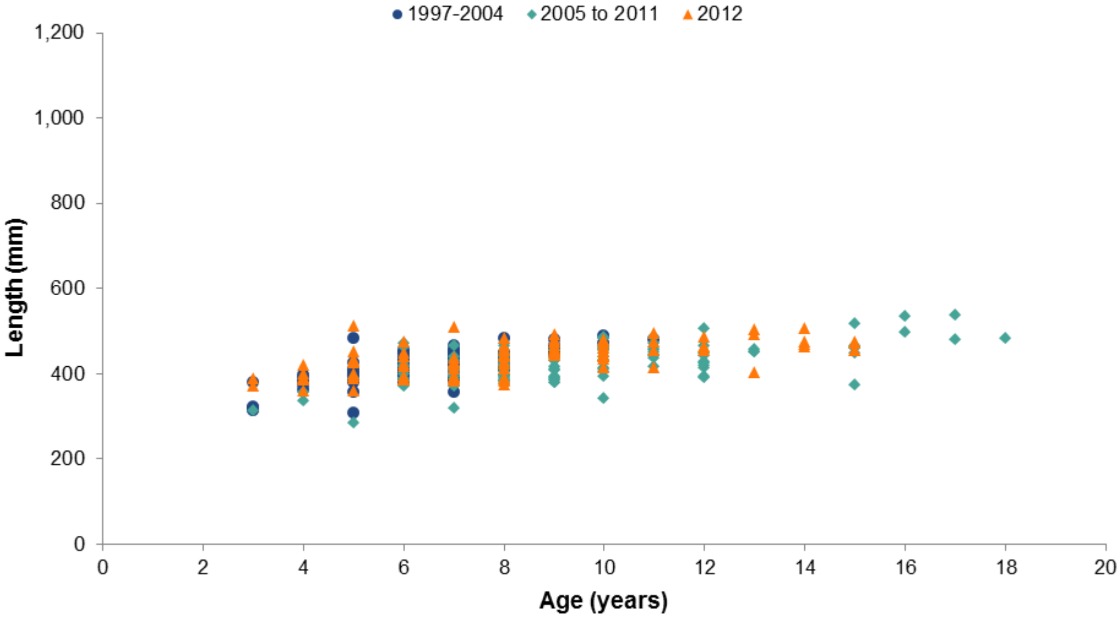
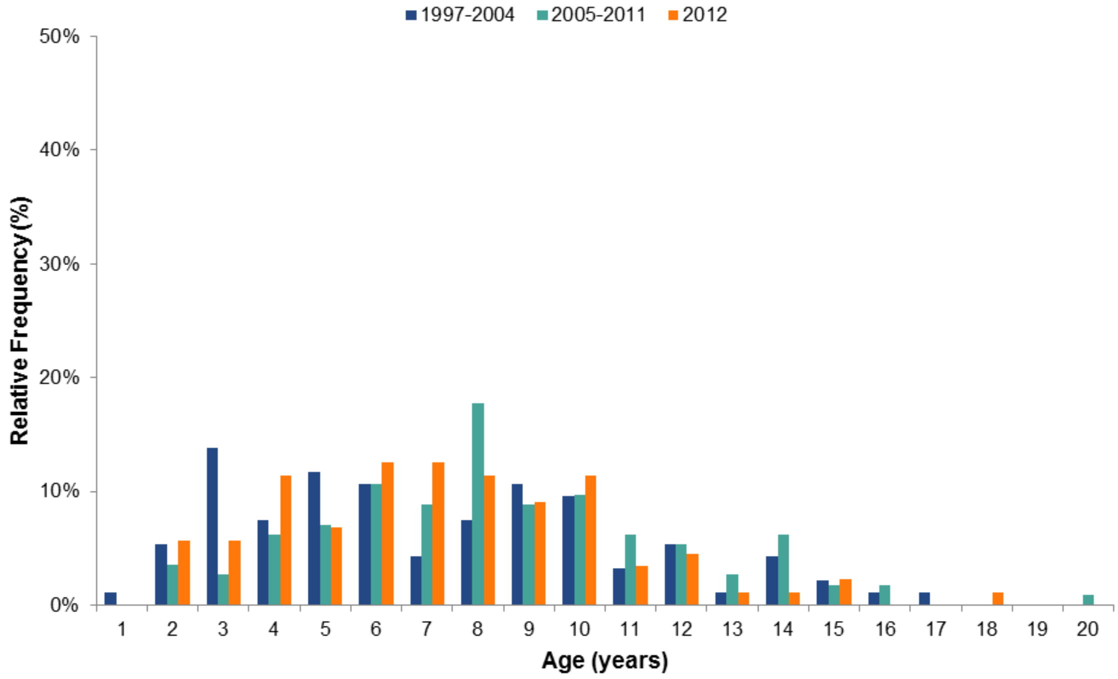


Figure 5.1-31 Relative age-frequency distributions and size-at-age relationship for longnose sucker captured in the Athabasca River from 1987 to 2012.



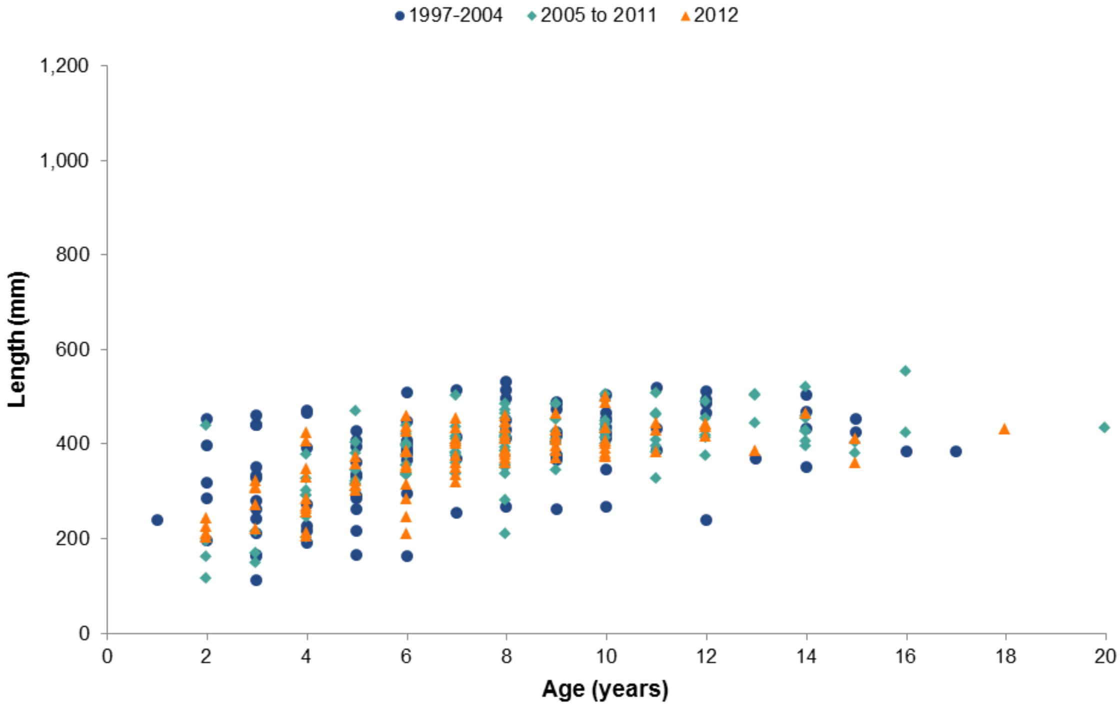
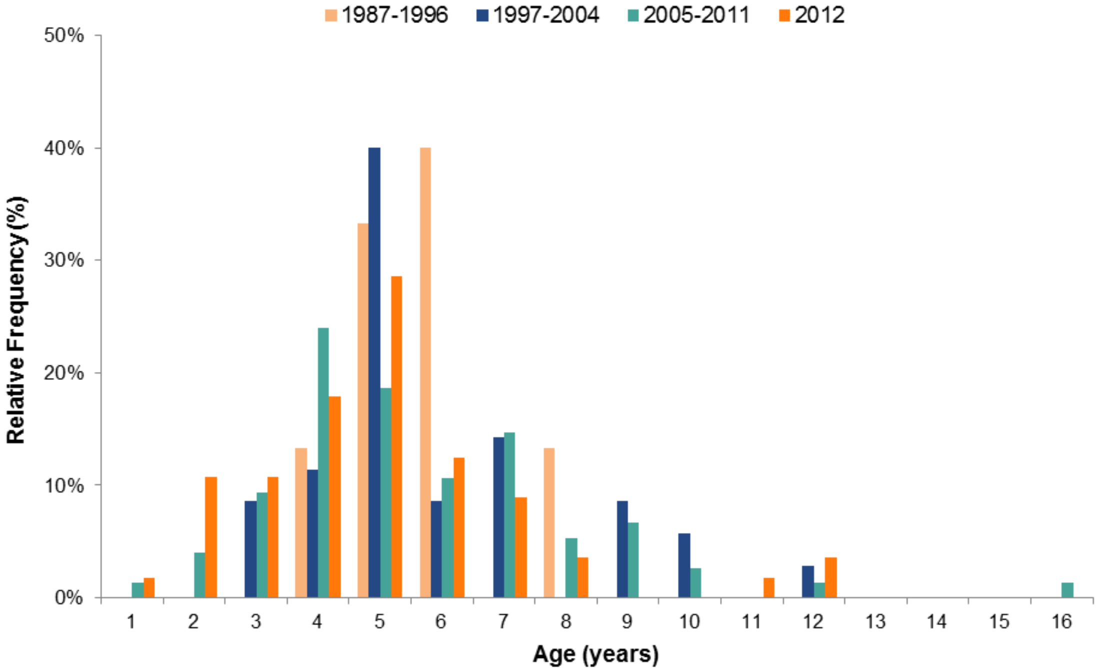


Figure 5.1-32 Relative age-frequency distributions and size-at-age relationship for northern pike captured in the Athabasca River from 1987 to 2012.



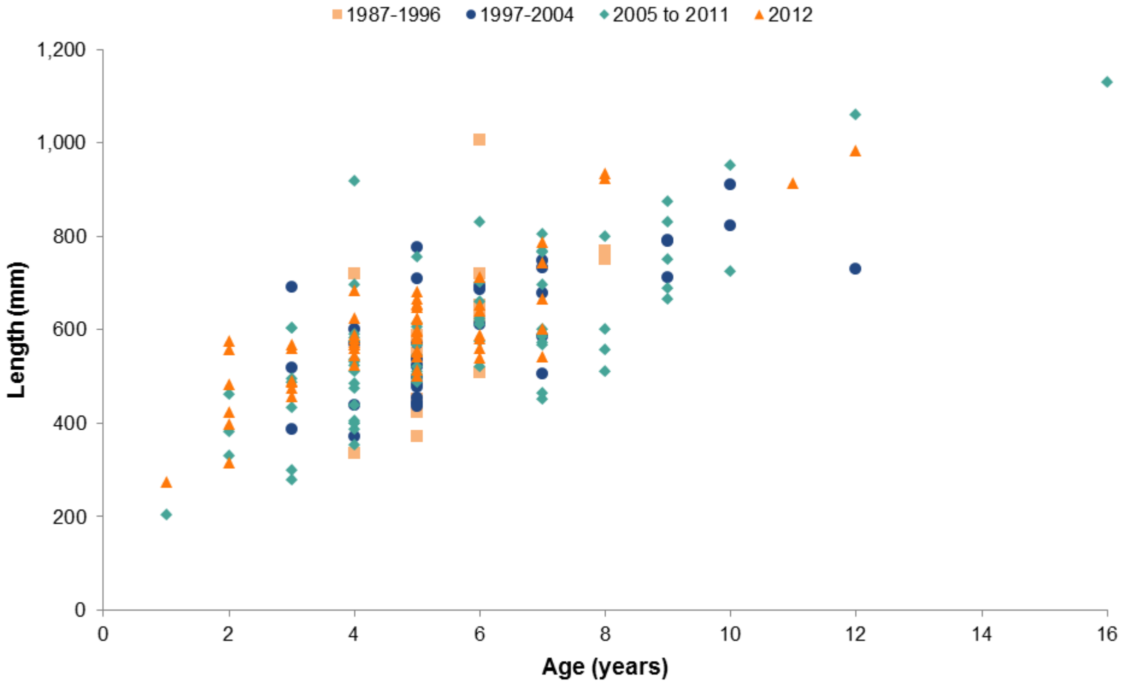
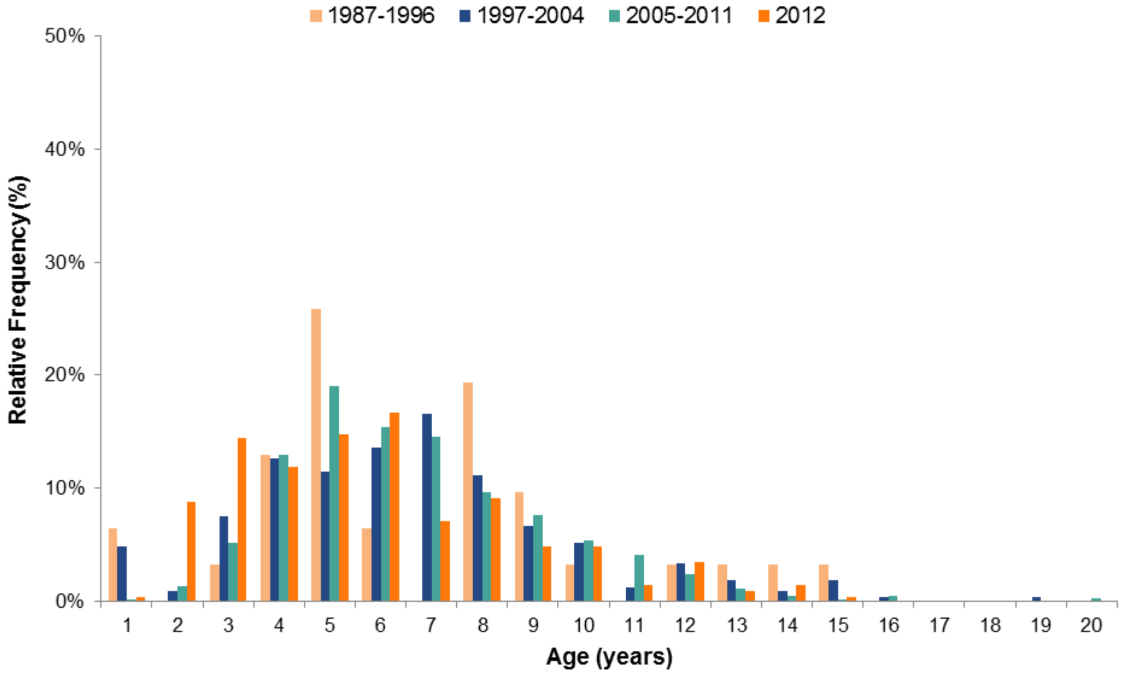


Figure 5.1-33 Relative age-frequency distributions and size-at-age relationship for walleye captured in the Athabasca River from 1987 to 2012.



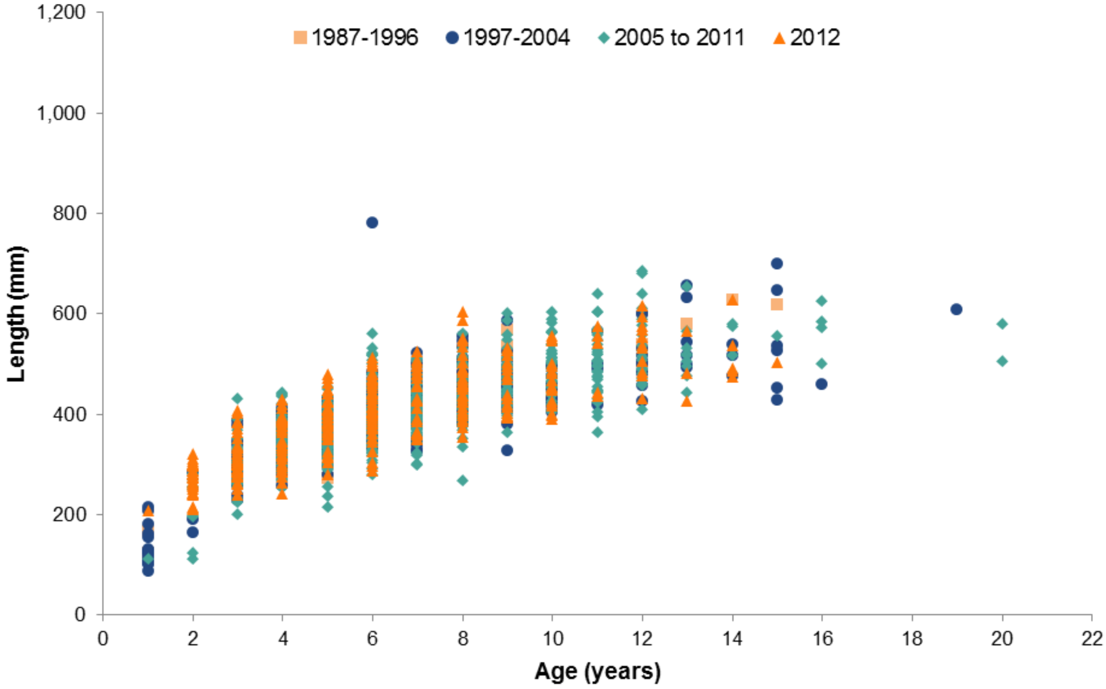
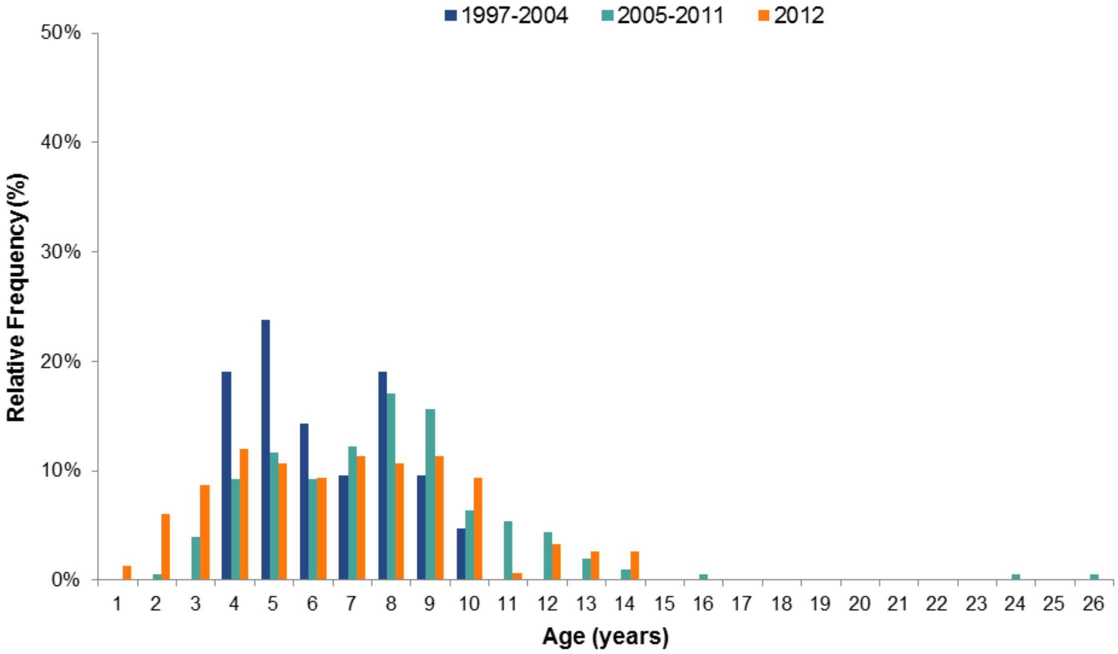


Figure 5.1-34 **Relative age-frequency distributions and size-at-age relationship for white sucker captured in the Athabasca River from 1987 to 2012.**



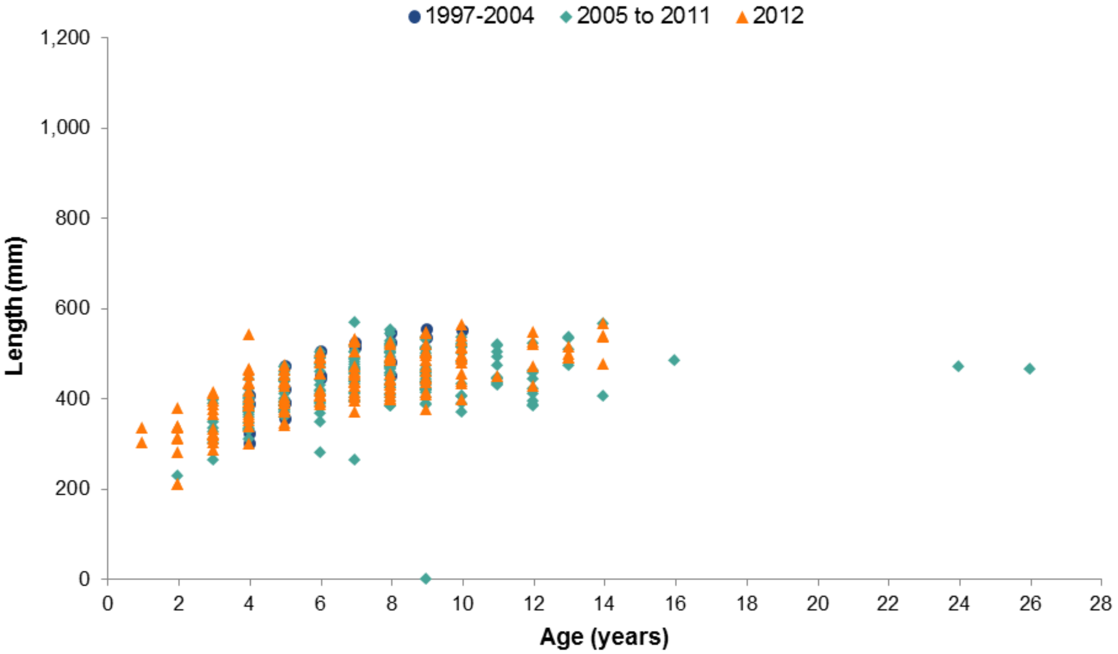


Figure 5.1-35 **Mean condition (±2SD) of goldeye captured in summer and fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

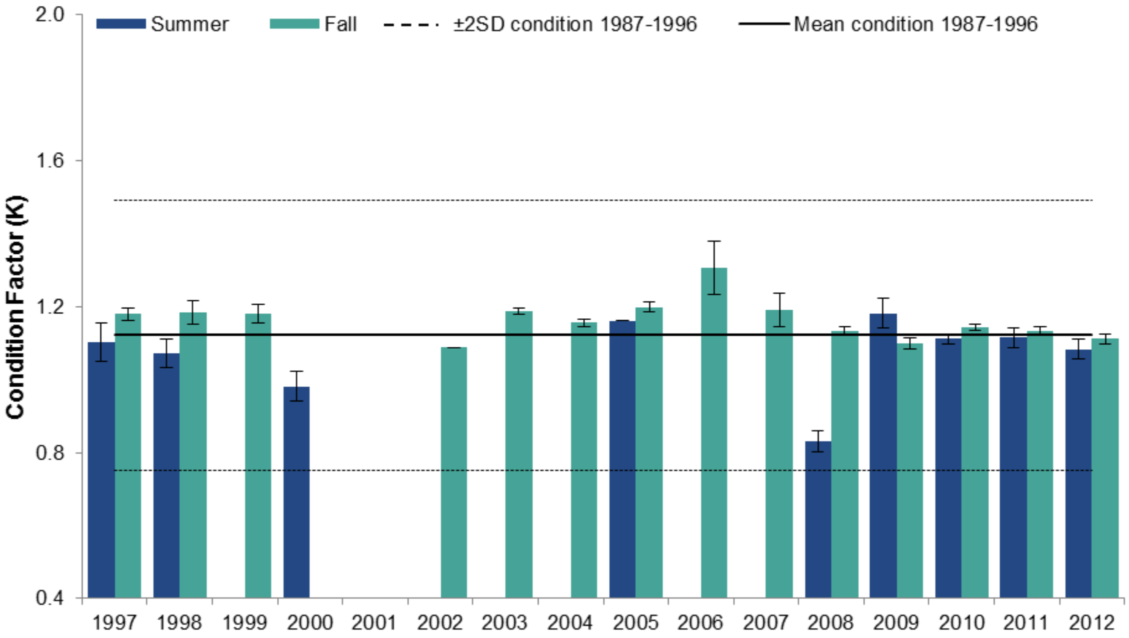


Figure 5.1-36 **Mean condition (±2SD) of lake whitefish captured in fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

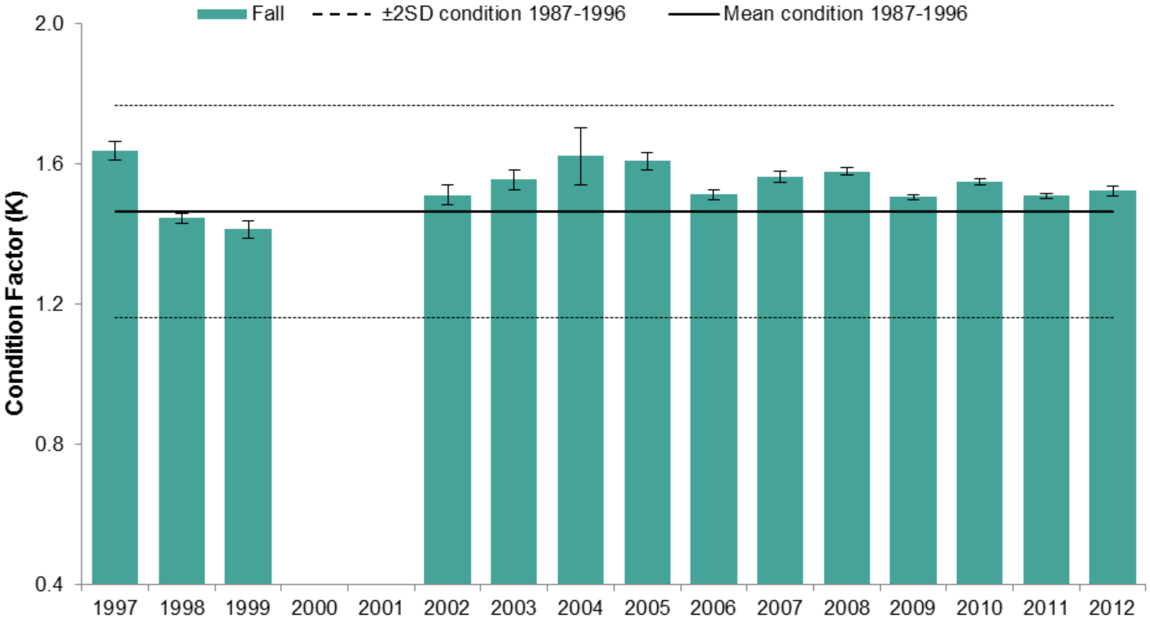


Figure 5.1-37 **Mean condition (±2SD) of longnose sucker captured in summer and fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

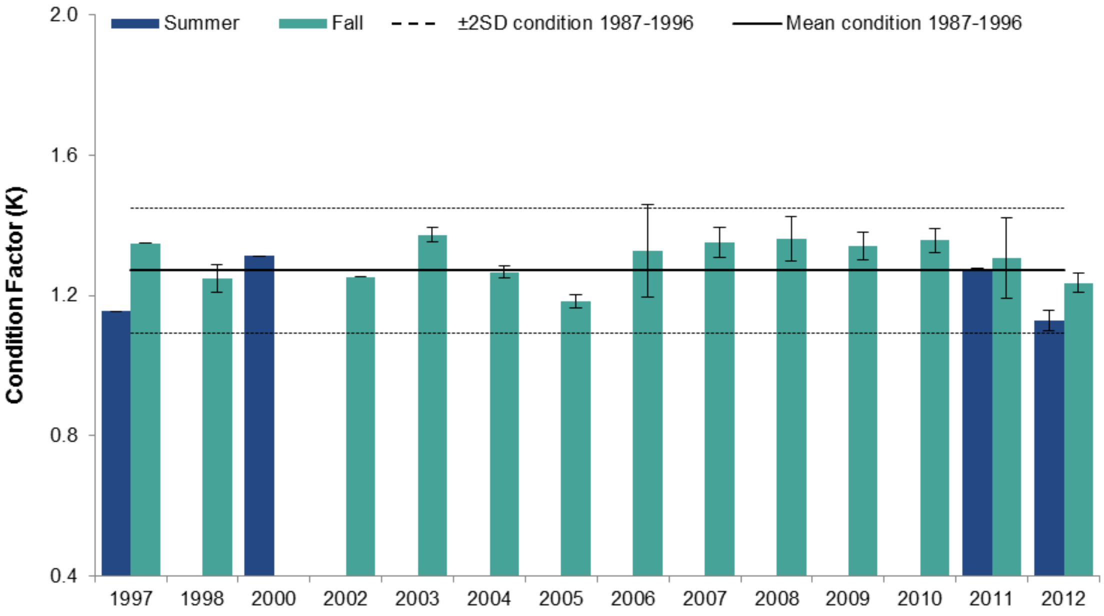


Figure 5.1-38 **Mean condition (±2SD) of northern pike captured in summer and fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

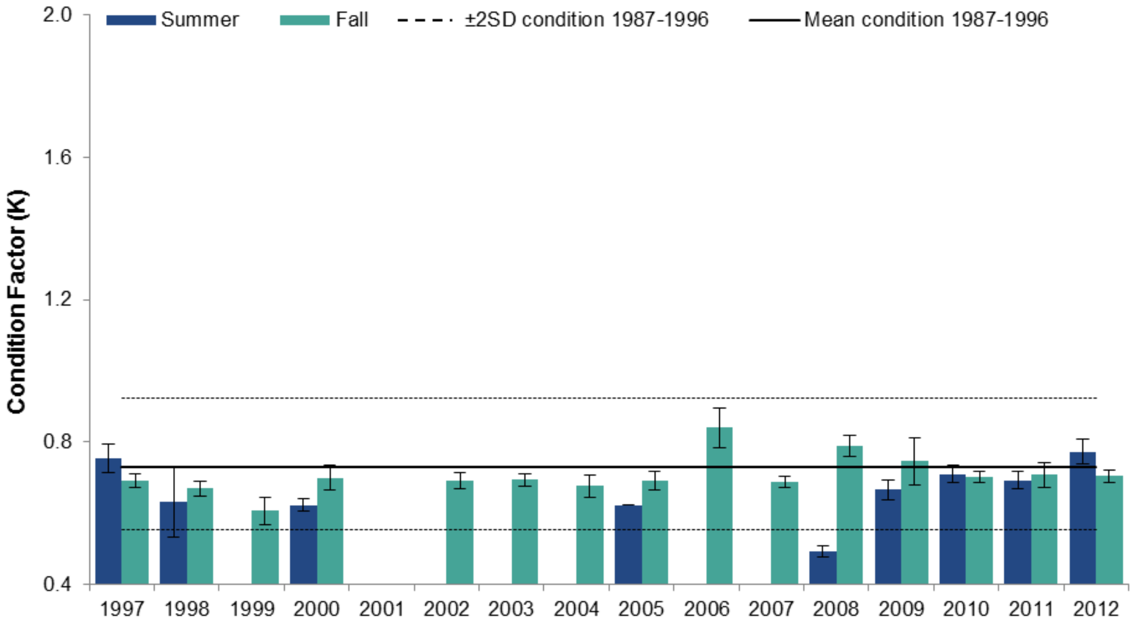


Figure 5.1-39 **Mean condition (±2SD) of trout-perch captured in summer and fall from 1997 to 2012 in the Athabasca River.**

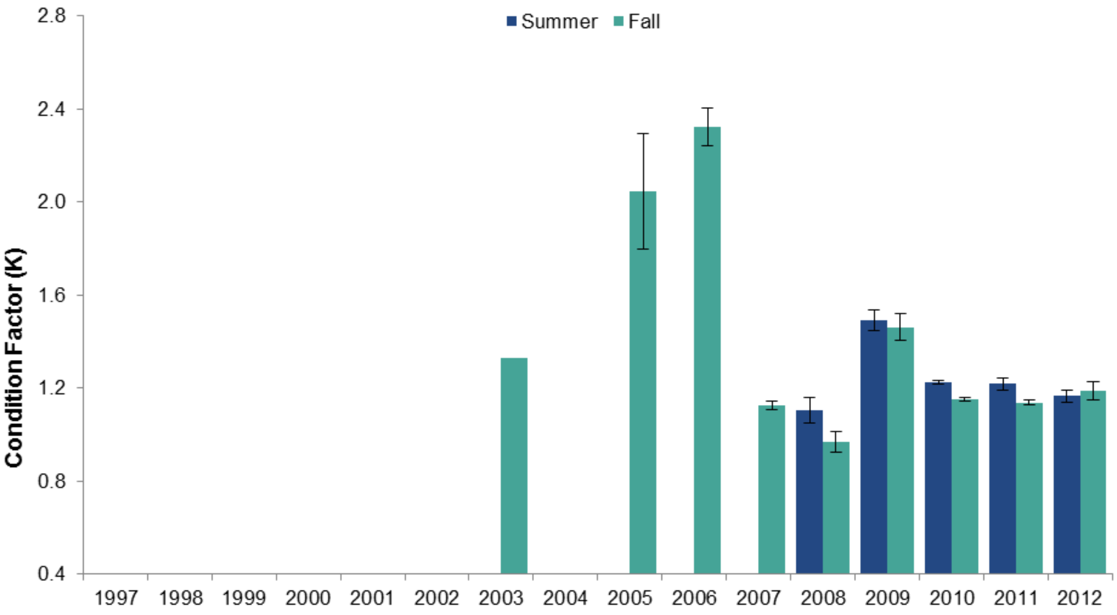


Figure 5.1-40 **Mean condition (±2SD) of walleye captured in summer and fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

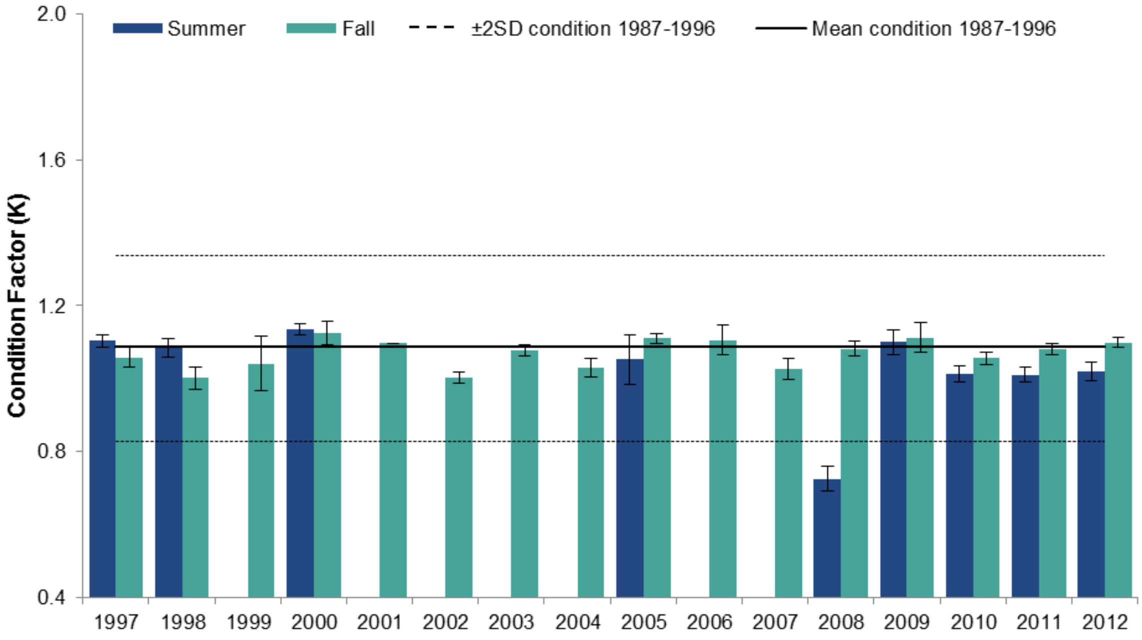


Figure 5.1-41 Mean condition (±2SD) of white sucker captured in summer and fall from 1997 to 2012 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

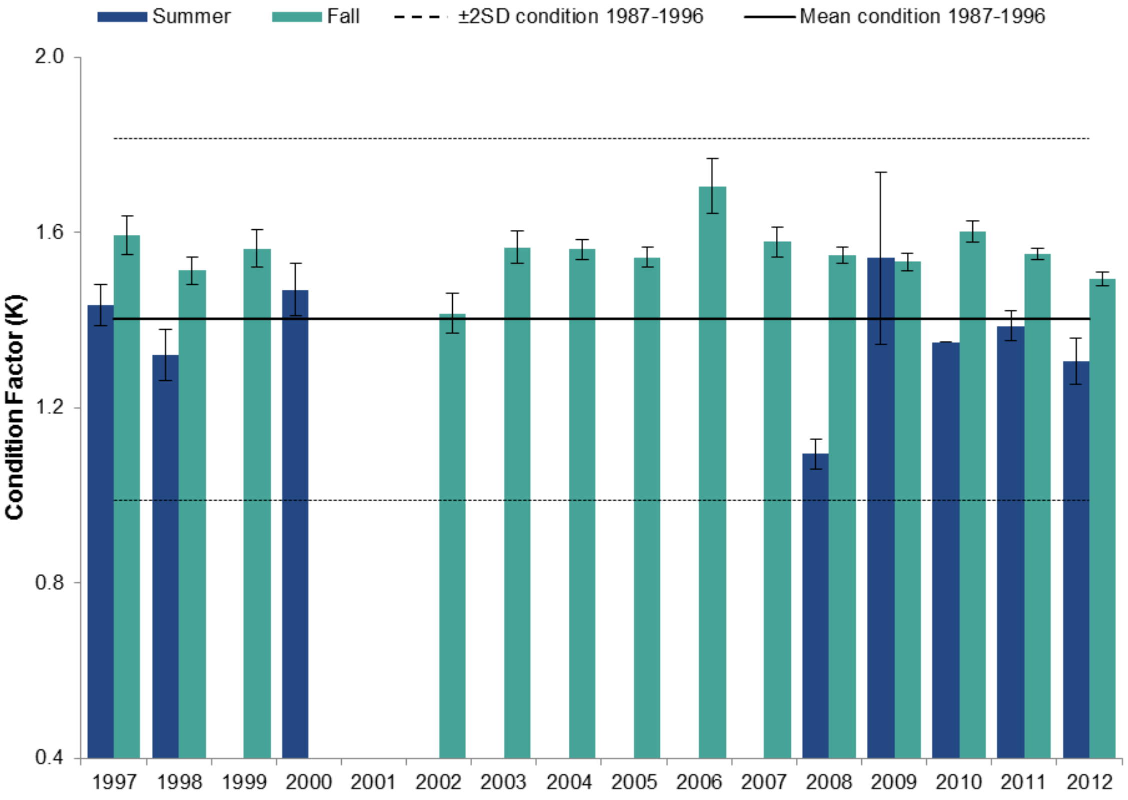


Table 5.1-23 Percent of total fish captured in the Athabasca River with external pathology (growth/lesion, deformity, parasites), 1987 to 2012.

Year	% Growth/Lesion	% Deformity (Body/Fins)	% Parasites	% Total	Total # Fish
1987	0.33	0.00	0	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

Figure 5.1-42 Percent of total fish captured in the Athabasca River with some type of external pathology, 1987 to 2012.

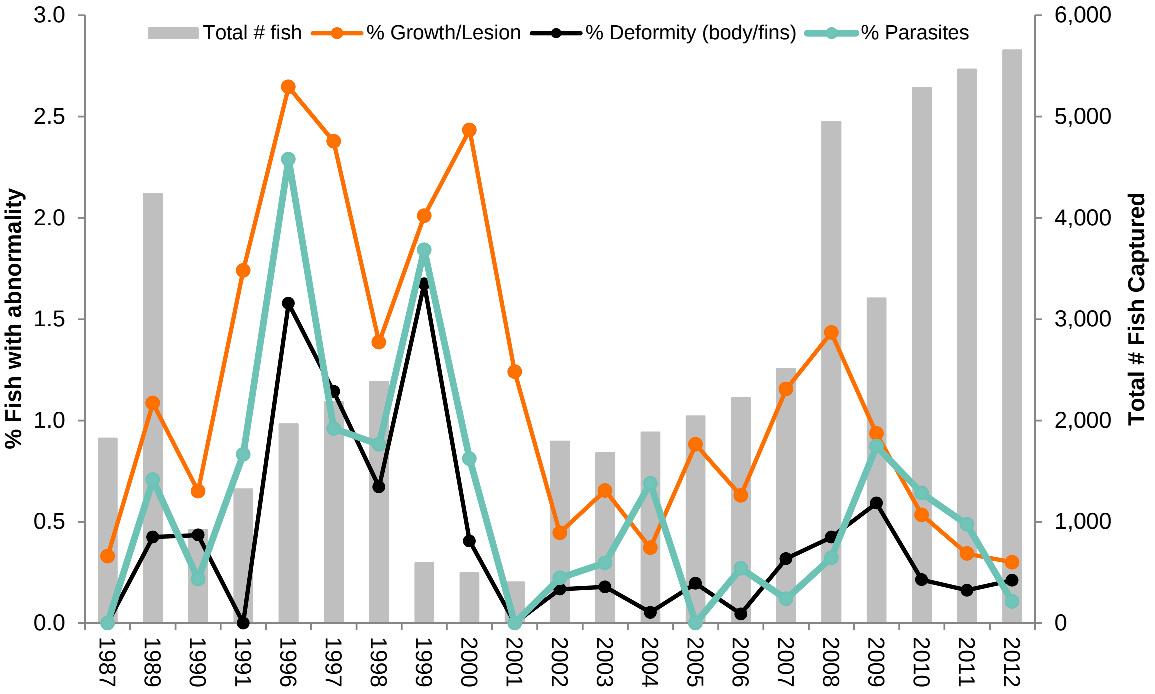


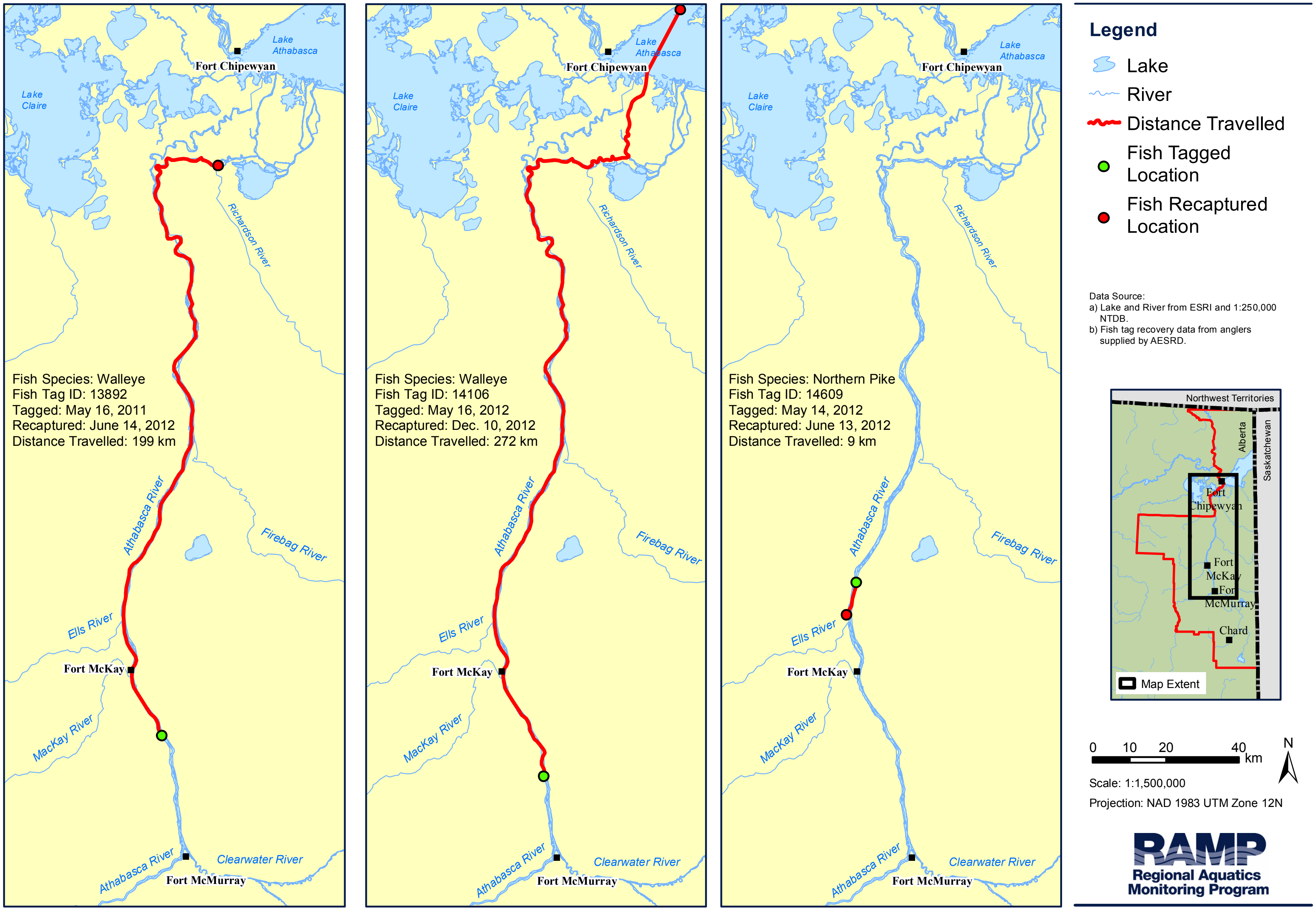
Table 5.1-24 Results of RAMP fish tag returns by anglers and during the Athabasca River and Clearwater River fish inventories, 2012.

Variable	Walleye	Northern Pike
No. of Fish Captured	12	12
Minimum Distance Travelled (km)	≥1	≥1
Maximum Distance Travelled (km)	272	9

Table 5.1-25 Results of RAMP fish tag returns by anglers, Athabasca and Clearwater rivers (1999 to 2012).

Variable	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Captured	1	2	45	96	4
Minimum Distance Travelled (km)	271	5.3	≥1	≥1	≥1
Maximum Distance Travelled (km)	271	236	57	715	241

Figure 5.1-42 Location where tagged fish were recaptured by anglers in 2012.



Fish Species: Walleye
Fish Tag ID: 13892
Tagged: May 16, 2011
Recaptured: June 14, 2012
Distance Travelled: 199 km

Fish Species: Walleye
Fish Tag ID: 14106
Tagged: May 16, 2012
Recaptured: Dec. 10, 2012
Distance Travelled: 272 km

Fish Species: Northern Pike
Fish Tag ID: 14609
Tagged: May 14, 2012
Recaptured: June 13, 2012
Distance Travelled: 9 km

Data Source:
a) Lake and River from ESRI and 1:250,000 NTDB.
b) Fish tag recovery data from anglers supplied by AESRD.

Scale: 1:1,500,000

Projection: NAD 1983 UTM Zone 12N

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5.2 MUSKEG RIVER WATERSHED

Table 5.2-1 Summary of results for the Muskeg River watershed.

Muskeg River Watershed	**Summary of 2012 Conditions**										
	Muskeg River			***Jackpine Creek***		***Other Creeks***				***Lakes***	
Climate and Hydrology											
Criteria	**07DA008/S7** near Fort McKay		**S20** Upland	**S2** at Canterra Road		**S22** Muskeg Creek near the mouth		**S10** Wapasu Creek at Canterra Road	**S03** 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
Mean winter discharge	🟤		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
Minimum open-water season discharge	🟤		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-6** 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 sampled
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 sampled	no reach sampled	no reach sampled	no reach sampled	**KEL-1** Kearl Lake	no reach sampled
Benthic Invertebrate Communities	🟠	🟡	🟡	🟡	n/a					🟠	
Sediment Quality Index	n/a	🟡	🟡	🟡	🟡					n/a	
Fish Populations											
Criteria	**MUR-E1/MR-E** lower reach	**MUR-D2** middle reach	**MUR-D3** upper reach	**JAC-D1** lower reach	**JAC-D2** upper reach	no reach sampled	no reach sampled	no reach sampled	no reach sampled	no reach sampled	no reach sampled
Sentinel Species	-[1]	ns	ns	ns	ns						
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 *baseline* reaches.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other 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.

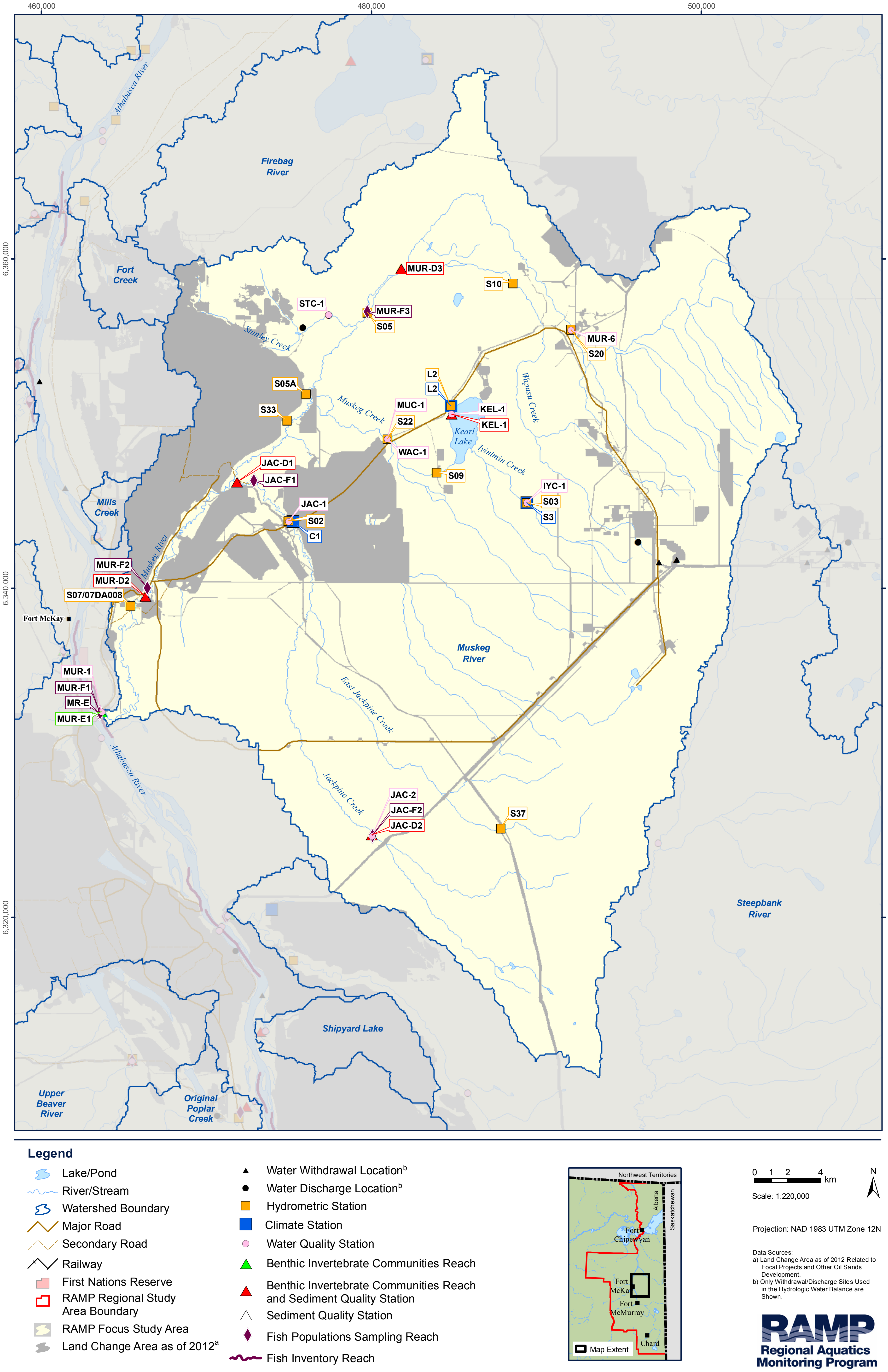
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baselines*; see Section 3.3.1.10 for a detailed description of the classification methodology.

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.

[1] A classification of results could not be completed given the low sample size of slimy sculpin captured at *test* site MR-E for the sentinel species program.

Figure 5.2-1 Muskeg River watershed.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

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Figure 5.2-2 Representative monitoring stations of the Muskeg River watershed, 2012.

Benthic Invertebrate Reach MUR-E1 (Muskeg River): facing upstream

Water Quality Station IYC-1 (Iyinimin Creek): facing downstream

Benthic and Sediment Quality Reach MUR-D3 (Muskeg River): facing upstream

Benthic and Sediment Quality Reach JAC-D2 (Jackpine Creek): facing downstream

Benthic and Sediment Quality Reach JAC-D1 (Jackpine Creek): facing upstream

Water Quality Station STC-1 (Stanley Creek)

Hydrology Station S10 (Wapasu Creek)

Water Quality Station KEL-1: Kearl Lake

5.2.1 Summary of 2012 Conditions

As of 2012, approximately 15% (21,473 ha) of the Muskeg River watershed had undergone land change from focal projects (Table 2.5-2). 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 Shell Jackpine Mine 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 of RAMP in the Muskeg River watershed in 2012. Table 5.2-1 is a summary of the 2012 assessment of the Muskeg River watershed, and Figure 5.2-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations, and the area of land change for 2012 in the Muskeg River watershed. Figure 5.2-2 contains fall 2012 photos of representative monitoring stations in the watershed.

Hydrology The calculated mean open-water discharge and the annual maximum daily discharge were 5.2% and 6.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **Moderate.** The calculated mean winter discharge and the open-water period minimum daily discharge were 140.3% and 34.8% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **High.**

Water Quality Concentrations of many water quality measurement endpoints at upper Jackpine Creek (*baseline* station JAC-2) were outside previously-measured concentrations and exceeded the 95th percentile of regional *baseline* conditions. Concentrations of water quality measurement endpoints at other locations of the Muskeg River watershed in fall 2012 were frequently within the range of previously-measured concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2012 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were **Negligible-Low,** with the exception of *baseline* station JAC-2 and *test* station IYC-1, which had **Moderate** differences from regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-E1 were classified as **Moderate** because there was a significant increase in total abundance and CA Axis 1 and 2 scores over time and significant differences in abundance, EPT taxa, and CA Axis 1 and 2 scores in 2012 relative to previous sampling years. The benthic invertebrate community at *test* reach MUR-E1; however, appeared to be in good condition, with high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies. The percentage of the fauna as worms (tubificids and naidids) was relatively similar to previous years indicating no significant change in the quality of the habitat.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches and there was no evidence of a negative change over time in any measurement endpoints.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches. In addition, there was little evidence of any negative changes and the relative abundance of tubificids were lower than 2011.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach JAC-D1 were classified as **Negligible-Low** because although there were significant differences from *baseline* reach JAC-D2 (i.e., higher CA Axis 1 scores, abundance, and richness), the differences were not indicative of degraded habitat quality at *test* reach JAC-D1. The strong statistical signal in CA Axis 1 scores was due to a lower abundance of tubificids in 2012 at *test* reach JAC-D1, suggesting good habitat quality. The presence of sensitive taxa including mayflies, caddisflies, clams, and snails, also suggested that *test* reach JAC-D1 had a benthic fauna indicative of good depositional habitat conditions.

Differences in values of measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Moderate** because of the significant decrease in percent EPT (i.e., particularly mayflies and caddisflies) and the increase in multivariate CA Axis scores compared to the period when Kearl Lake was designated as *baseline*. However, the benthic invertebrate community contained a diverse fauna and included several taxa that were typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and caddisflies). The relative abundance of ostracods, which has decreased since 2011, was still high compared to *baseline* lakes in the RAMP FSA and all measurement endpoints were within the range of values reported during the *baseline* period for Kearl Lake, with the exception of diversity. Simpson's Diversity was higher in 2012 than in the *baseline* period, indicating good or better habitat quality.

Sediment quality at all Muskeg River watershed stations sampled in fall 2012 was generally consistent with that of previous years and regional *baseline* conditions. Concentrations of total PAHs at these stations were within previously-measured concentrations, with a few exceptions where PAH concentrations were below previously-measured concentrations. Differences in sediment quality in fall 2012 at all applicable stations in the Muskeg River watershed were assessed as **Negligible-Low** compared to regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in values of measurement endpoints for fish assemblages between *test* reach MUR-F1 and regional *baseline* conditions were classified as **Negligible-Low** given that most measurement endpoints were within the regional range of variation of *baseline* reaches. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and *test* reach MUR-F3 and regional *baseline* conditions were classified as **Moderate** given all measurement endpoints were outside the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between *test* reach JAC-F1 and regional *baseline* conditions were classified as **Moderate** given that all measurement endpoints were below the regional range of variation of *baseline* reaches, likely related to the high flows observed in fall 2012.

Fish Populations (sentinel species) Given the small sample size of slimy sculpin captured at *test* site MR-E, it was not possible to make statistical comparisons or compare the results to the effects criteria to provide a classification of results. A complete description of the results is provided in Section 5.3.

5.2.2 Hydrologic Conditions: 2011 Water Year

Muskeg River

Hydrometric monitoring for the Muskeg River watershed was conducted at the WSC Station 07DA008 (RAMP Station S7), Muskeg River near Fort McKay, which was used for the water balance analysis. Additional hydrometric data for the Muskeg River watershed were available from stations L2 Kearl Lake, S2 Jackpine Creek at Canterra Road, S3 Iyinimin Creek above Kearl Lake, S5 Muskeg River above Stanley Creek, S5A Muskeg River above Muskeg Creek, S9 Kearl Lake Outlet, S10 Wapasu Creek near the mouth, S20 Muskeg River Upland, S22 Muskeg Creek near the mouth, S33 Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary, and S37 East Jackpine Creek near the 1,300 ft. contour. Details for each of these stations can be found in Appendix C.

Continuous annual hydrometric data have been collected at the WSC Station 07DA008 (RAMP Station S7) from 1974 to 1986 and from 1999 to 2012. Seasonal data from March to October have been collected every year since 1974. The 2012 WY annual and open-water runoff volumes were 110.0 million m^3 and 102.3 million m^3, respectively. The annual runoff volume was 1.5% higher than the historical mean annual runoff and the open-water runoff volume was 0.60% higher than the historical mean open-water runoff. Flows decreased steadily from November 2011 to March 2012, with flows from December to March similar to historical lower quartile flows recorded during this period (Figure 5.2-3). Flows increased in April and May during freshet to a peak of 3.87 m^3/s on May 5. Following the freshet, flows generally decreased until mid-June following the historical lower quartile values. In response to rainfall in late June and early July, flows increased to above historical median values for the month of July. Flows decreased through August until the lowest open-water flow of 0.45 m^3/s on September 1, which was 58% lower than the historical mean open-water minimum daily flow. Large rainfall events in September resulted in the annual maximum flow of 29.4 m^3/s on September 20, which was 35% higher than the historical mean maximum daily flow. The reminder of the 2012 WY was characterized by flows above the historical upper quartile.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at WSC Station 07DA008 (RAMP Station S7) for the 2012 WY is presented in Table 5.2-2 and described below:

1. The closed-circuited land area from focal projects in the Muskeg River watershed as of 2012 was estimated to be 126.2 km^2 (Table 2.5-1). The loss of flow to the Muskeg River that would have otherwise occurred from this land area was estimated at approximately 9.79 million m^3.

2. As of 2012, the area of land change in the Muskeg River watershed from focal projects that was not closed-circuited was estimated to be 88.5 km^2 (Table 2.5-1). The increase in flow to the Muskeg River that would not have otherwise occurred from this land area was estimated at 1.37 million m^3.

3. Syncrude discharged 5.50 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), the assumption was made in this analysis that none of the water released from the CWD would have reached the Muskeg River through other means. Given that some of the CWD flows are diverted surface water, some proportion of this water likely would have contributed to the Muskeg River naturally; however, this is currently undefined.

4. Suncor withdrew 0.07 million m^3 of water to support dust suppression activities associated with the Firebag project.
5. Husky released 0.01 million m^3 of water from its Sunshine project treatment plant.

The estimated cumulative effect of land change, water withdrawals, and water releases was a decrease in flow of 2.97 million m^3 to the Muskeg River. The observed and estimated *baseline* hydrographs for WSC Station 07DA008 (RAMP Station S7) are presented in Figure 5.2-3. The calculated mean open-water discharge and the annual maximum daily discharge were 5.2% and 6.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **Moderate.** The calculated mean winter discharge and the open-water period minimum daily discharge were 140.3% and 34.8% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively (Table 5.2-3). These differences were classified as **High** (Table 5.2-1).

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 2012 WY, lake levels showed little variation from November to June, with levels remaining below historical minimum values for this period (Figure 5.2-4). The minimum lake level in the 2012 WY was 331.51 masl, recorded on June 15. Lake levels increased from July through September in response to rainfall events. A large and rapid increase in lake level of 43 cm was recorded from September 12 to 17 due to sustained rainfall events from late August to mid-September. The peak lake level of 332.11 m on September 22 was the maximum recorded lake level for the 2012 WY. Following this peak, lake levels declined slightly to near upper quartile levels by the end of the 2012 WY.

5.2.3 Water Quality

In fall 2012, water quality samples were taken from:

- the Muskeg River near its mouth (*test* station MUR-1, sampled from 1997 to 2012);
- the Muskeg River upstream of Wapasu Creek (*test* station MUR-6, designated as *baseline* from 1998 to 2007 and *test* from 2008 to 2012);
- Jackpine Creek near its mouth (*test* station JAC-1, designated as *baseline* from 1998 to 2005 and *test* from 2006 to 2012);
- upper Jackpine Creek (*baseline* station JAC-2, sampled from 2008 to 2012);
- Muskeg Creek near its mouth (*test* station MUC-1, sampled intermittently from 1998 to 2012, designated as *baseline* from 1998 to 2007 and *test* from 2008 to 2012);
- Stanley Creek near its mouth (*test* station STC-1, designated as *baseline* from 2001 to 2002 and *test* from 2003 to 2012);
- Iyinimin Creek near its mouth (*test* station IYC-1, sampled in 2007, 2008, 2010, 2011 and 2012, designated as *baseline* from 2007 to 2008 and *test* from 2010 to 2012);

- Wapasu Creek near its mouth (*test* station WAC-1, sampled intermittently from 1998 to 2012, designated as *baseline* from 1998 to 2006 and *test* from 2007 to 2012); and
- Kearl Lake (*test* station KEL-1, designated as *baseline* from 1998 to 2008 and *test* from 2009 to 2012).

Temporal Trends The following statistically significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- an increasing concentration of total arsenic at *test* station MUR-1;
- an increasing concentration of total boron and a decreasing concentration of chloride at *test* station MUR-6;
- an increasing concentration of total arsenic at *test* station JAC-1;
- increasing concentrations of total boron and total dissolved phosphorus at *test* station STC-1;
- decreasing concentrations of calcium and sulphate and increasing concentrations of total nitrogen and total arsenic at *test* station WAC-1; and
- decreasing concentrations of potassium, sulphate, and total dissolved phosphorus at *test* station KEL-1.

Trend analyses could not be completed for *baseline* station JAC-2 or *test* station IYC-1 due to an insufficient number of sampling years.

2012 Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2012 were within previously-measured concentrations, with the exception of the following (Table 5.2-4 to Table 5.2-12):

- total boron, with a concentration that exceeded the previously-measured maximum concentration and conductivity, sodium, calcium, magnesium, and total alkalinity, with concentrations that were below previously-measured minimum concentrations at *test* station MUR-6;
- total mercury (ultra-trace), with a concentration that exceeded the previously-measured maximum concentration and dissolved organic carbon, with a concentration that was below the previously-measured minimum concentration at *test* station MUC-1;
- total suspended solids, dissolved organic carbon, total aluminum, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations, and magnesium, alkalinity, and total strontium, with concentrations that were below previously-measured minimum concentrations at *test* station JAC-1;
- total suspended solids, sulphate, total and dissolved aluminum, total arsenic, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations, and total dissolved phosphorus and total strontium, with concentrations that were below previously-measured minimum concentrations at *baseline* station JAC-2;
- total dissolved phosphorus, with a concentration that exceeded the previously-measured maximum concentration at *test* station STC-1;

- chloride, with a concentration that exceeded the previously-measured maximum concentration at *test* station WAC-1;
- total suspended solids, chloride, total and dissolved aluminum, total arsenic, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations at *test* station IYC-1; and
- conductivity and total alkalinity, with concentrations that exceeded previously-measured maximum concentrations, and sulphate, with a concentration that was below the previously-measured minimum concentration at *test* station KEL-1.

All water quality measurement endpoints for *test* station MUR-1 were within previously-measured concentrations.

Ion balance The ionic composition of water in the Muskeg River watershed in fall 2012 was similar to that measured in previous years (Figure 5.2-5, Figure 5.2-6). The ionic composition of water in Stanley Creek (*test* station STC-1) has historically shown the greatest variability of all stations (Figure 5.2-6), indicating influence of site-drainage water from Syncrude's Aurora North project ("Clean Water Discharge"). In the last four 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 Water Quality Measurement Endpoints to Published Guidelines In fall 2012, concentrations of water quality measurement endpoints at stations in the Muskeg River watershed were below water quality guidelines, with the exception of:

- total aluminum and total nitrogen at *test* stations MUR-6 and JAC-1 (Table 5.2-5, Table 5.2-7);
- total nitrogen at *test* stations MUC-1, WAC-1, and KEL-1 (Table 5.2-6, Table 5.2-10, Table 5.2-12); and
- total nitrogen, total aluminum, and total mercury (ultra-trace) at *baseline* station JAC-2 and *test* station IYC-1 (Table 5.2-8, Table 5.2-11).

Other Water Quality Guideline Exceedances The following other water quality measurement endpoints exceeded water quality guidelines in the Muskeg River watershed in fall 2012 (Table 5.2-13):

- sulphide at *test* stations MUR-1, WAC-1, JAC-1, IYC-1, STC-1, and MUC-1, and *baseline* station JAC-2;
- total iron at *test* stations MUR-1, MUR-6, 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 MUR-1, MUR-6, WAC-1, JAC-1, IYC-1, STC-1, KEL-1, and MUC-1, and *baseline* station JAC-2;
- total phosphorus at *test* stations JAC-1, IYC-1, and STC-1, and *baseline* station JAC-2;
- total chromium at *test* station IYC-1 and *baseline* station JAC-2; and
- total copper at *baseline* station JAC-2.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints in fall 2012 at *test* stations MUR-1, MUR-6, JAC-1, STC-1, IYC-1, and WAC-1, and *baseline* station JAC-2 were within regional *baseline* concentrations, with the exception of (Figure 5.2-7 to Figure 5.2-8):

- dissolved phosphorous, with concentrations that were below the 5th percentile of regional *baseline* concentrations at *test* station JAC-1 and *baseline* station JAC-2;
- sulphate, with a concentration that was below the 5th percentile of regional *baseline* concentrations at *test* station WAC-1;
- total suspended solids, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations IYC-1 and JAC-1 and *baseline* station JAC-2;
- total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station JAC-2 and *test* station IYC-1 and was below the 5th percentile of regional *baseline* concentrations at *test* station STC-1; and
- total mercury, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations JAC-1 and IYC-1 and *baseline* station JAC-2.

Concentrations of water quality measurement endpoints in Kearl Lake (Figure 5.2-9) 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 that are sampled by RAMP due to the limited *baseline* data available.

Water Quality Index The WQI values for *test* stations MUR-1, MUR-6, MUC-1, JAC-1, STC-1, and WAC-1 in fall 2012 indicated **Negligible-Low** differences from regional *baseline* water quality conditions (Table 5.2-14). The WQI values from *baseline* station JAC-2 and *test* station IYC-1 indicated **Moderate** differences from the regional *baseline* water quality (Table 5.2-14). These lower values appeared to be driven by very high concentrations of total suspended solids (TSS), dissolved titanium, dissolved vanadium, and various total metals associated with particulates (e.g., Al, As, Cr, Co, Fe, Pb, Hg, Ti, U, V). The fall 2012 WQI at *baseline* station JAC-2 was 73.7 (versus 92.4 in 2011 and 93.6 in 2010) and 75.7 (versus 81.2 in 2011 and 88.5 in 2010) at *test* station IYC-1 (Table 5.2-14).

Classification of Results Concentrations of many water quality measurement endpoints at upper Jackpine Creek (*baseline* station JAC-2) were outside previously-measured concentrations and exceeded the 95th percentile of regional *baseline* conditions. Concentrations of water quality measurement endpoints at other locations of the Muskeg River watershed in fall 2012 were frequently within the range of previously-measured concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2012 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were **Negligible-Low,** with the exception of *baseline* station JAC-2 and *test* station IYC-1, which had **Moderate** differences from regional *baseline* conditions.

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 2012 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 2012.

2012 Habitat Conditions Water at *test* reach MUR-E1 in fall 2012 was shallow (0.2 m), fast flowing (1.46 m/s), alkaline (pH: 8.2), with high conductivity (304 µS/cm) (Table 5.2-15). The substrate was dominated by gravel (~35%) and cobble (between 10 and 20%). Periphyton biomass averaged 36 mg/m^2, which was within but below the median, for regional *baseline* erosional reaches (Figure 5.2-10).

Water at *test* reach MUR-D2 in fall 2012 was deep (3.4 m), weakly alkaline (pH: 7.3), with high conductivity (363 µS/cm), and high dissolved oxygen (Table 5.2-15). The substrate was dominated by sand (88%) with smaller amounts of silt (10%) and clay (2%).

Water at *test* reach MUR-D3 in fall 2011 was deep (1.3 m), slow moving (0.27 m/s), alkaline (pH: 7.5), with high conductivity (334 µS/cm) (Table 5.2-15). The substrate was dominated by sand (80%) with smaller amounts of silt (17%) and clay (2%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach MUR-E1 in fall 2012 was dominated by chironomids (36%), Ephemeroptera (11%), and Hydracarina (11%), with subdominant taxa consisting of tubificid worms (9%) and bivalves (9%) (Table 5.2-16). Chironomids were diverse, consisting of many common forms (Wiederholm 1983) including many taxa from the Tanytarsini tribe (i.e., *Micropsectra/Tanytarsus, Stempellina, and Stempellinella)*, but were primarily comprised of the genus *Lopescladius.* Mayfly relative abundance had decreased from 2011 but were still represented by the genera *Acerpenna pygmaea, Baetis, and Leptophlebia*. Stonefiles (*Chloroperlidae, Isoperla,* and *Taeniopteryx*) and damselfies (*Ophiogomphus*) were found in low relative abundances. Caddisflies were better represented in 2012 than in 2011 and consisted primarily of the genera *Protoptila, Hydropsyche,* and *Lepidostoma*. Fingernail and pea clams (*Pisidium* and *Sphaerium*) and the Gastropod limpet (*Ferrissia rivularis*) were also present.

The benthic invertebrate community of *test* reach MUR-D2 in fall 2012 was dominated by chironomids (77%), with subdominant taxa consisting of ceratopogonids (4%), nematodes (4%), bivalves (3%), and Ephemeroptera (3%) (Table 5.2-17). Chironomids were diverse, including *Cladotanytarsus*, *Pagastiella*, *Micropsectra/Tanytarsus*, *Stempellinella*, and *Polypedilum.* Ephemeroptera (*Caenis)* and bivalves *(Pisidium / Sphaerium)* were present along with caddisflies (Trichoptera; *Oecetis)* and *Dubiraphia* beetles (Table 5.2-17).

The benthic invertebrate community of *test* reach MUR-D3 in fall 2012 was dominated by chironomids (31%), ostracods (24%), and Hydracarina (11%) (Table 5.2-18). Dominant chironomids included the common forms *Procladius*, *Paratanytarsus,* and *Micropsectra / Tanytarsus* (Wiederholm 1983). Mayflies (Ephemeroptera; *Leptophlebiidae)* and fingernail clams *(Pisidium / Sphaerium)* were present 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 Muskeg River.

Temporal comparisons for *test* reach MUR-E1 included testing for:

- changes over time (Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling.

Temporal comparisons for *test* reach MUR-D2 included testing for:

- changes over time (Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling.

Temporal comparisons 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 2, Section 3.2.3.1);
- changes over time during the *test* period (Hypothesis 1, Section 3.2.3.1);
- changes between 2012 values and the mean of all *baseline* years; and
- changes between 2012 values and the mean of all previous years of sampling.

CA Axis 2 scores were lower in 2012 than the mean of previous years at *test* reach MUR-E1, accounting for 34% of the variance in annual means (Table 5.2-19). This difference was likely due to a decrease in naidid worms and Ostracods (Table 5.2-11).

CA Axis 2 scores increased significantly over time at *test* reach MUR-D2, accounting for 20% of the variance in annual means (Table 5.2-20). This was reflected by a shift in taxa composition over time, with fewer tubificids observed in recent years and an increase in the abundance of mayflies (Ephemeroptera) and water mites (Hydracarina) over time (Figure 5.2-12).

Total abundance at *test* reach MUR-D3 was significantly higher in 2012 than the mean of previous sampling years, accounting for nearly 30% of the variance in annual means (Table 5.2-21). The percentage of the fauna as EPT taxa has decreased during the period that reach MUR-D3 has been designated as *test* (since 2008) (Table 5.2-21). CA Axis 2 scores were higher in 2012 than the mean of *baseline* years (2002 to 2007) and higher in 2012 than the mean of all previous years of sampling (Table 5.2-21).

Comparison to Published Literature The benthic invertebrate community at *test* reach MUR-E1 was diverse with a mean of 37 taxa per sample and contained a number of taxa that are considered sensitive including the mayfly *Acerpenna pygmaea*, caddisflies *Protoptila* and *Psychomyia*, and the stonefly *Isoperla* (Hynes 1960, Mandaville 2001, Griffiths 1998). Tubificidae (generally considered a group of tolerant worms, Mandaville 2001) were not present in 2012.

The benthic invertebrate community at *test* reach MUR-D2 was diverse with a mean of 22 taxa per sample and included a number of taxa that are considered relatively sensitive including mayflies such as *Caenis* and *Acerpenna* and fingernail clams (*Pisidium/ Sphaerium*). The percentage of the fauna as worms was less than 5% (Table 5.2-17), indicating good habitat quality (Hynes 1960, Griffiths 1998).

The benthic invertebrate community at *test* reach MUR-D3 reflected typical depositional habitat conditions. The community was dominated by chironomids (30%) and naidid worms (17%) but also contained a high relative abundance of fingernail clams (*Pisidium/Sphaerium*, 11%), and other sensitive forms such as the mayfly Leptophlebiidae (Mandaville 2001) (Table 5.2-18, Figure 5.2-13).

2012 Results Relative to Regional *Baseline* Conditions Values of all measurement endpoints for benthic invertebrate communities in fall 2012 at *test* reach MUR-E1 were within the range of regional *baseline* erosional reaches, with the exception of abundance, which was slightly above the 95th percentile of regional *baseline* values but lower than 2011 (Figure 5.2-14).

Values of all measurement endpoints for benthic invertebrate communities at *test* reaches MUR-D2 and MUR-D3 were within the range of variation for regional *baseline* depositional reaches (Figure 5.2-15).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-E1 were classified as **Moderate** because there was a significant increase in total abundance and CA Axis 1 and 2 scores over time and significant differences in abundance, EPT taxa, and CA Axis 1 and 2 scores in 2012 relative to previous sampling years. The benthic invertebrate community at *test* reach MUR-E1; however, appeared to be in good condition, with high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies. The percentage of the fauna as worms (tubificids and naidids) was relatively similar to previous years indicating no significant change in the quality of the habitat.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches and there was no evidence of negative change over time in any measurement endpoints.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches. In addition, there was little evidence of any negative changes and the relative abundance of tubificids were lower than 2011.

Jackpine Creek

Benthic invertebrate communities were sampled in fall 2012 at:

- depositional *test* reach JAC-D1, near the mouth of Jackpine Creek (designated as *baseline* from 2002 to 2005 and *test* from 2006 to 2012); and
- depositional *baseline* reach JAC-D2 (designated as *baseline* from 2006 to 2012).

2012 Habitat Conditions Water at *test* reach JAC-D1 in fall 2012 was deep (1.3 m), relatively fast flowing (0.72 m/s), weakly basic (pH: 7.5), with high dissolved oxygen, and low conductivity (162 µS/cm) (Table 5.2-22). The substrate was dominated by sand (79%), with low total organic carbon content (3 %) (Table 5.2-22).

Water at *baseline* reach JAC-D2 was deep (1.3 m), fast flowing (0.81 m/s), with high dissolved oxygen and low conductivity (100 µS/cm) (Table 5.2-22). The substrate was dominated by sand (89%), with low total organic carbon content (<1%) (Table 5.2-22).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach JAC-D1 was consistent to 2011 and dominated by chironomids (38%), with subdominant taxa consisting of enchytaeid worms (18%) and ceratopogonids (16%) (Table 5.2-23). Ephemeroptera (*Caenis, Acerpenna*), Trichoptera (Limnephilidae), and Anisoptera (Gomphidae) were found in low relative abundances (Table 5.2-23). Gastropods (*Gyraulus* and *Physa*) and a few bivalves (*Pisidium/Spaerium*) were also found. Chironomids were diverse and dominated by *Paralauterborniella, Larsia, Procladius,* and *Stempellinella*.

The benthic invertebrate community at *baseline* reach JAC-D2 was dominated by chironomids (28%), with subdominant taxa consisting of naidid worms (13%), bivalves (13%), and Ceratopogonidae (13%) (Table 5.2-24). Ephemeroptera (*Caenis*) and Trichoptera were present in low relative abundances. Bivalves were principally from the genera *Pisidium / Sphaerium*. Chironomids were dominated by only a few taxa (*Polypedilum* and *Tanytarsus)* with several others in small relative abundances (Table 5.2-24).

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 for *test* reach JAC-D1 included testing for:

- changes over time during the *test* period (i.e., since 2002, Hypothesis 4, Section 3.2.3.1);
- changes between 2012 values and the mean of all available *baseline* data for Jackpine Creek; and
- changes between 2012 values and the mean of all previous years of sampling (2002 to 2011).

Spatial comparisons 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 2, Section 3.2.3.1);
- differences from *baseline* reach JAC-D2 from before to after (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 reaches during the *test* period (2006 to 2012) of the lower reach, explaining >20% of the variance in annual means (Table 5.2-25).

CA Axis 1 scores at *test* reach JAC-D1 were higher in 2012 than the mean of all available *baseline* data, explaining 28% of the variance in annual means (Table 5.2-25). CA Axis 1 scores at *test* reach JAC-D1 were also higher in 2012 than the mean of previous years of sampling at this reach, explaining 39% of the variance in annual means (Table 5.2-25), reflecting a decrease in Tubificidae over time at this reach (Table 5.2-23 and Table 5.2-25).

Comparison to Published Literature The benthic invertebrate community at *test* reach JAC-D1 had a composition typical of depositional riverine fauna, with a dominance of chironomids (Griffiths 1998, Barton and Smith 1984). Mayflies and caddisflies, snails, clams, and various other flies were present. Worms were present in relatively low abundance indicating good habitat quality (Hynes 1960, Griffiths 1998).

The benthic invertebrate community at *baseline* reach JAC-D2 was, similar to the lower reach and comprised of a relatively typical depositional-river fauna. Chironomids were dominant, including those genera (e.g., *Tanytarsus*) that have a general preference for depositional habitats. The fauna were; however, diverse with mayflies, caddisflies, and gastropods, and a relatively high abundance of fingernail clams (Bivalvia). Worms (Naididae, Tubificidae, and Enchytraeidae) accounted for a relatively small proportion (18% combined) of the total numbers of organisms observed. These observations were consistent with a community reflective of good habitat conditions (Hynes 1960, Griffiths 1998).

2012 Results Comparison to Regional *Baseline* Conditions Values of all measurement endpoints for benthic invertebrate communities in fall 2012 at *test* reach JAC-D1 were within the range of variation for depositional *baseline* reaches, with the exception of the CA Axis 1 and 2 scores, which was due to a lower abundance of Tubificidae worms (Figure 5.2-16, Figure 5.2-17). That absence of tubificids was not considered indicative of degraded habitat quality. Values of all measurement endpoints for benthic invertebrate communities in fall 2012 at *baseline* reach JAC-D2 were within the range of variation for *baseline* depositional reaches (Figure 5.2-16).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities at lower *test* reach JAC-D1 were classified as **Negligible-Low** because although there were significant differences between the *baseline* and *test* reaches (i.e., higher CA Axis 1 scores, increased in abundance and richness at the *test* reach), the differences were not indicative of degraded habitat quality at *test* reach JAC-D1. The strong statistical signal in CA Axis 1 scores was due to a lower abundance of tubificids in 2012 at *test* reach JAC-D1, suggesting good habitat quality. The presence of sensitive taxa including mayflies, caddisflies, clams, and snails, also suggested that *test* reach JAC-D1 had a benthic fauna indicative of good depositional habitat conditions.

Kearl Lake

2012 Habitat Conditions Water in Kearl Lake in fall 2012 was alkaline (pH: 10.5) with moderate conductivity (171 µS/cm) (Table 5.2-26). The substrate of Kearl Lake was dominated by silt (70%) with smaller amounts of sand (17%) and clay (13%), with organic materials being a major component of the substrate of Kearl Lake (31% TOC) (Table 5.2-26).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Kearl Lake in fall 2012 was dominated by chironomidae (36%), with subdominant taxa consisting of Copepoda (26%), Ostracoda (14%), and Amphipoda (10%) (Table 5.2-27). Trichoptera (*Molannodes* and *Polycentropus*) and Ephemeroptera (*Caenis*) were present in low relative abundances (~1% each). Dominant chironomids included *Procladius, Cladotanytarsus,* and *Dicrotendipes*, which are commonly distributed in holarctic lakes (Widerholm 1983). Gastropods (*Gyraulus*) were present and sparse, whereas bivalves (*Pisidium/Sphaerium*) were well represented (7%) in Kearl Lake. Amphipods were principally of the genera *Hyalella azteca* and *Gammarus lacustris*.

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 Kearl Lake.

Temporal comparisons for *test* reach KEL-1 included testing for:

- changes between *baseline* (2001 to 2008) and *test* (2009 to present) periods;
- changes over time in the *test* period (i.e., since 2009);
- changes between 2012 values and the mean of all *baseline* years; and
- changes between 2012 values and the mean of all previous sampling years.

There was a significant increase in Simpson's Diversity over time during the *test* period (2009 to 2012) explaining 21% of the variance in annual means (Table 5.2-28). The percentage of fauna as EPT taxa was higher during the *baseline* period in Kearl Lake, explaining 25% of the variance in annual means (Table 5.2-28); however, there has been an increase in some of the individual EPT taxa including mayflies and caddisflies during the *test* period resulting in the percent EPT to be within the range of values observed during the *baseline* period.

There was a significant increase in CA Axis 2 scores over time during the *test* period in Kearl Lake, explaining 26% of the variance in annual means (Table 5.2-28). The increase was reflected by a decrease in the relative abundance of amphipods and an increase in the relative abundance of Ephemeroptera, Gastropoda, and Ostracods (Figure 5.2-18).

Comparison to Published Literature The benthic invertebrate community of Kearl Lake was considered relatively typical of a shallow lake. The percent of the fauna as worms was low (2%) generally indicating good water and sediment quality (O'Toole et al. 2008). Chironomids accounted for 36% of the total benthic fauna, with a mixture of sensitive and tolerant taxa (Broderson and Lindegaard 1999). The benthic invertebrate community also contained a mixture of permanent aquatic forms including amphipods, bivalves, and gastropods, as well as flying insects (i.e., chironomids, Ephemeroptera, Trichoptera), which indicate favourable long-term water quality (Resh and Unzicker 1975, Niemi et al. 1990). The most unusual aspect of the benthic invertebrate community of Kearl Lake was the higher relative abundance of ostracods, which similarly to last year, made up a relatively large percentage of the overall abundance. Other lakes in *baseline* condition (i.e., Johnson Lake) in the RAMP FSA generally do not have ostracods and mites in relative abundances observed in Kearl Lake in 2012 (e.g., Parsons et al. 2010).

Comparison to *Baseline* Conditions in Kearl Lake Values of all measurement endpoints for benthic invertebrate communities in fall 2012 were within the range of variation for Kearl Lake during the *baseline* period, with the exception of Simpson's Diversity, which was just slightly higher (0.77) than the previously-measured maximum value during the *baseline* period (0.76), but not indicative of a negative change (Figure 5.2-19).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Moderate** because of the significant decrease in percent EPT (i.e., particularly mayflies and caddisflies) and the increase in multivariate CA Axis scores compared to the period when Kearl Lake was designated as *baseline*. However, the benthic invertebrate community contained a diverse fauna and included several taxa that were typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and caddisflies). The relative abundance of ostracods, which has decreased since 2011, was still high compared to *baseline* lakes in the RAMP FSA and all measurement endpoints were within the range of values reported during the *baseline* period for Kearl Lake, with the exception of diversity. Simpson's Diversity was higher in 2012 than in the *baseline* period, indicating good or better habitat quality.

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 communities were sampled in fall 2012:

- *test* station MUR-D2 on the Muskeg River (sampled in 2000, and 2003 to 2012);
- *test* station MUR-D3 on the Muskeg River (designated as *baseline* from 2002 to 2007 and *test* from 2008 to 2012);
- *test* station JAC-D1 on Jackpine Creek near its mouth (designated as *baseline* in 1997 and *test* from 2006 to 2012);
- *baseline* station JAC-D2 on Jackpine Creek (sampled from 2008 to 2012); and
- *test* station KEL-1 in Kearl Lake (designated as *baseline* from 2001 to 2008 and as *test* from 2009 to 2012).

Temporal Trends The following significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected:

- a decreasing concentration of total arsenic at *test* station KEL-1; however, when results from 1998 to 2001 (when detection limits for total arsenic were significantly higher than presently measured) were removed, no significant trend in arsenic concentrations was detected; and
- decreasing concentrations of C1 hydrocarbons at *test* stations MUR-D2 and KEL-1.

Trend analysis was not completed for *baseline* station JAC-D2 because insufficient data exists (n=5).

2012 Results Relative to Historical Concentrations Sediments sampled in 2012 from all stations in the Muskeg River watershed were taken from the same locations as those reaches sampled from 2006 to 2011. Prior to the integration of the Sediment Quality component with the Benthic Invertebrate Communities component in 2006, benthic invertebrate community *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 2008 (see Table 5.2-29 to Table 5.2-33).

Concentrations of sediment quality measurement endpoints were similar to previously-measured concentrations at each station (Table 5.2-29 to Table 5.2-33). All stations were dominated by sand, with the exception of KEL-1, which was dominated by silt in fall 2012. Proportions of silt exceeded previously-measured maximum values at *test* stations JAC-D1 and KEL-1. The increase in silt contributed to a higher percentage of fines at *test* station JAC-D1, causing the concentration of total metals normalized to percent fines to be lower than previously-measured minimum concentrations. Sediments exhibited a higher total organic carbon content than previously measured at *test* station JAC-D1 (Table 5.2-31).

Concentrations of volatile, low-molecular-weight hydrocarbons (i.e., CCME fraction 1 and BTEX – benzene, toluene, ethylene, and xylene) were undetectable at all stations in fall 2012. Concentrations of heavier hydrocarbon fractions in fall 2012 were within previously-measured concentrations. The concentration of total PAHs (carbon-normalized) was below the previous-measured minimum concentration at *test* station JAC-D1. Similar to previous years, concentrations of total PAHs in sediments generally increased from upstream to downstream in tributaries, with lowest concentrations observed at *baseline* station JAC-D2 (Table 5.2-32) and *test* station MUR-D3 (Table 5.2-30) and highest concentrations observed at *test* station MUR-D2 (Table 5.2-29).

In fall 2012, potential PAH toxicity in sediments was higher than previously-calculated maximum values at *baseline* station JAC-D2. Survival of the midge, *Chironomus* at *test* station JAC-D1, and 10-day growth of *Chironomus* and survival of the amphipod, *Hyalella*, at *test* station KEL-1 were higher than previously-measured maximum values. Growth of *Hyalella* at *test* station JAC-D1 was lower than previously-measured minimum values. No toxicity testing was performed on sediments from *test* stations MUR-D2 and MUR-D3 in 2012.

Spatial comparisons The following comparisons of sediment quality measurement endpoints among stations in the Muskeg River watershed in fall 2012 were noted:

- percent sand was lower at *test* station MUR-D3 (67.1%) than *test* station MUR-D2 82%) and lower at *test* station JAC-D1 (74.5%) than *baseline* station JAC-D2 (87.2%), which was opposite to 2011;
- total organic carbon was higher at *test* station MUR-D3 (24.5%) than *test* station MUR-D2 (2.19%);
- concentrations of hydrocarbons (including PAHs) were higher at *test* station MUR-D2 than all other stations in the Muskeg River watershed; *baseline* station JAC-D2 exhibited the lowest hydrocarbon concentrations; and
- survival and growth of *Chironomus*, and survival of *Hyalella* were similar between *test* station JAC-D1 and *baseline* station JAC-D2; *Hyalella* growth was higher at *baseline* station JAC-D2 (0.25 mg/organism) than *test* station JAC-D1 (0.15 mg/organism).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of Fraction-3 hydrocarbons exceeded relevant CCME soil-quality guidelines at *test* stations JAC-D1, MUR-D2, MUR-D3, and KEL-1. The concentration of Fraction-1 and Fraction-2 hydrocarbons at *test* station KEL-1, and the concentration of Fraction-1 hydrocarbons at *test* station MUR-D3 were below detection limits but the detection limits exceeded the CCME guidelines.

2012 Results Relative to Regional *Baseline* Conditions Concentrations of all sediment quality measurement endpoints at *test* stations MUR-D2 and MUR-D3 in fall 2012 were within regional *baseline* concentrations, with the exception of total PAHs normalized to %TOC at *test* station MUR-D3, which was below the 95th percentile of regional *baseline* concentrations (Figure 5.2-20 to Figure 5.2-21). Concentrations of all sediment quality measurement endpoints at *test* station JAC-D1 and *baseline* station JAC-D2 in fall 2012 were within regional *baseline* concentrations, with the exception of total metals normalized to percent fine sediments at *test* station JAC-D1 and total PAHS normalized to %TOC at *baseline* station JAC-D2, which were below the 95th percentile of regional *baseline* concentrations (Figure 5.2-22 to Figure 5.2-23).

Concentrations of sediment quality measurement endpoints in Kearl Lake (Figure 5.2-24) 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 that are sampled by RAMP due to the limited *baseline* data available.

Sediment Quality Index The SQI values for all stations in the Muskeg River watershed in fall 2012 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 Sediment quality at all Muskeg River watershed stations sampled in fall 2012 was generally consistent with that of previous years and regional *baseline* conditions. Concentrations of total PAHs at these stations were within previously-measured concentrations with a few exceptions where PAH concentrations were below previously-measured concentrations and regional *baseline* concentrations. Differences in sediment quality in fall 2012 at all applicable stations in the Muskeg River watershed were assessed as **Negligible-Low** compared to regional *baseline* conditions.

5.2.5 Fish Populations

Muskeg River Mainstem

Fish assemblages were sampled in fall 2012 at:

- erosional *test* reach MUR-F1, near the mouth of the Muskeg River, previously sampled from 2009 to 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-E1);
- depositional *test* reach MUR-F2, sampled for the first time in 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D2); and
- depositional *test* reach MUR-F3, sampled for the first time in 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D2).

2012 Habitat Conditions *Test* reach MUR-F1 was comprised of run and shallow riffle habitat with a wetted width of 14.5 m and a bankfull width of 17.5 m (Table 5.2-35). The substrate was dominated by coarse gravel with smaller amounts of cobble and silt/clay. Water at *test* reach MUR-F1 in fall 2012 was shallow (average depth: 0.5 m), moderately flowing (average: 0.39 m/s), alkaline (pH: 8.23), with high conductivity (305 µS/cm), and a temperature of 12.5˚C. Instream cover was comprised primarily of boulders with small amounts of small woody debris, undercut banks, and overhanging vegetation (Table 5.2-35).

Test reach MUR-F2 was comprised entirely of run habitat with wetted and bankfull widths of 12.5 m (Table 5.2-35). The substrate was dominated by sand and organic material. Water at *test* reach MUR-F2 was deep (average and maximum depth: 1.5 m) and slow flowing (average flow: 0.27 m/s), slightly alkaline (pH: 7.97), with moderate conductivity (294 µS/cm), high dissolved oxygen (8.85 mg/L) and a temperature of 14.1˚C. Instream cover was comprised primarily of macrophytes, with smaller amounts of filamentous algae, overhanging vegetation, and protruding roots.

Test reach MUR-F3 was also comprised entirely of run habitat with wetted and bankfull widths of 11 m (Table 5.2-35). Water at *test* reach MUR-F3 was very deep (average depth: 1.5 m), which prevented an assessment of substrate, slow flowing (0.3 m/s), slightly acidic (pH: 6.7), with moderate conductivity (214 µs/cm), low dissolved oxygen (4.6 mg/L), and a temperature of 10.4˚C. Instream cover was comprised primarily of macrophytes.

Temporal and Spatial Comparisons Sampling was initiated at *test* reach MUR-F1 in 2009 during the RAMP Fish Assemblage Pilot Study; therefore, temporal comparisons were conducted from 2009 to 2012. *Test* reaches MUR-F2 and MUR-F3 were first sampled in 2011; therefore, temporal comparisons were conducted between 2011 and 2012. Spatial comparisons were not conducted for *test* reach MUR-F1 because there is no upstream *baseline* erosional reach on the Muskeg River. Spatial comparisons for *test* reaches MUR-F2 and MUR-F3 were not conducted because there is no upstream *baseline* depositional reach on the Muskeg River.

There was a decrease in abundance and CPUE at all three reaches in 2012 compared to previous years (Table 5.2-36). Species richness and diversity at *test* reach MUR-F1 were lower in 2012 compared to all other years (Table 5.2-37). The ATI value at *test* reach MUR-F1 in 2012 was lower than in 2010 and 2011, but higher than 2009. This difference was likely related to the presence of more sensitive fish species (e.g., spoonhead sculpin and slimy sculpin) and the low number of fish captured in fall 2012 (n=6). With only six fish captured, there was no dominant species in the catch at *test* reach MUR-F1; however, yellow perch and northern pike were captured at *test* reach MUR-F1 in 2012, which was the first time either species was documented at this reach during RAMP. There were no fish captured at *test* reach MUR-F2; therefore no comparisons were made with 2011. The absence of fish at *test* reach MUR-F2 was likely due to high water levels and the difficulty in effectively sampling the reach. One brook stickleback was captured at *test* reach MUR-F3 in 2012; therefore, the measurement endpoints values represented the historical minimum values for abundance, diversity, and richness and the historical maximum value for ATI given that brook stickleback is a very tolerant species (Table 5.2-36).

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 RAMP. Based on past studies, 21 species have been documented in the Muskeg River; whereas RAMP has found only fourteen fish species from 2009 to 2012, which included finescale dace and spoonhead sculpin that have not previously been documented. 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 RAMP 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 RAMP versus historical studies. In addition, Golder (2004) documents fish inventory studies throughout the entire Muskeg River, whereas RAMP samples smaller, defined reach lengths.

Golder (2004) has documented similar habitat conditions in the portion of the Muskeg River where *test* reach MUR-F1 is located, consisting of slow riffles, 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 minimum spawning areas and food supply for most fish species (Golder 2004).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reach MUR-F1 were within regional *baseline* conditions for erosional reaches in the region (Figure 5.2-25). No fish were captured at *test* reach MUR-F2 in 2012, so all measurement endpoints were below the 5th percentile of regional *baseline* conditions (Figure 5.2-25). Mean values of all measurement endpoints in fall 2012 at *test* reach MUR-F3 were below the 5th percentile of regional *baseline* conditions for depositional reaches, with the exception of ATI, which exceeded the 95th percentile of regional *baseline* conditions (Figure 5.2-25).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach MUR-F1 and regional *baseline* conditions were classified as **Negligible-Low** given most measurement endpoints were within the regional range of variation of *baseline* reaches. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and *test* reach MUR-F3 and regional *baseline* conditions were classified as **Moderate** given all measurement endpoints were outside the range of variation for *baseline* depositional reaches.

Jackpine Creek

Fish assemblages were sampled in fall 2012 at:

- depositional *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
- depositional *baseline* reach JAC-F2, sampled since 2009 (this reach is at the same location as the benthic invertebrate community *baseline* reach JAC-D2).

2012 Habitat Conditions *Test* reach JAC-F1 was comprised of run habitat with backwater pools and a wetted width of 9.5 m and bankfull width of 9.0 m (Table 5.2-38). The substrate was dominated by sand. Water at *test* reach JAC-F1 in fall 2012 was of moderately deep (average depth: 0.72 m), with moderate flow (average flow: 0.34 m/s), alkaline (pH: 8.03), with moderate conductivity (241 μS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 12.7°C. Instream cover was comprised primarily of small woody debris, with smaller proportions of overhanging vegetation and macrophytes.

Baseline reach JAC-F2 was comprised of run and riffle habitat and a wetted width of 7 m and a bankfull width of 7.5 m. The substrate was dominated by fines. Water at *baseline* reach JAC-F2 in fall 2012 was deep (maximum depth: 1.5 m), slow flowing (flow: 0.26 m/s), slightly alkaline (pH: 7.37), with moderate conductivity (149 μS/cm), high dissolved oxygen (9.4 mg/L), and a temperature of 8.7°C. Instream cover was comprised primarily of overhanging vegetation with some large woody debris and undercut banks.

Temporal and Spatial Comparisons Sampling was initiated in Jackpine Creek in 2009; therefore, temporal comparisons were conducted from 2009 to 2012; spatial comparisons were conducted between *test* reach JAC-F1 and *baseline* reach JAC-F2.

There was a sharp decrease in abundance, diversity, and CPUE of fish from 2009 to 2012 at *test* reach JAC-F1 and *baseline* reach JAC-F2, particularly between 2011 and 2012 (Table 5.2-36, Table 5.2-37, Figure 5.2-26). High flows in early September made fish capture difficult and likely contributed to the overall low numbers at both reaches. Species richness decreased at both reaches since 2010. Although ATI was lower in 2012 compared to previous years, it was only based on two slimy sculpin that were captured, which have a low tolerance value (Whittier et al. 2007) (Table 5.2-36). No single fish species dominated the catch at either *test* reach JAC-F1 or *baseline* reach JAC-F2, with relatively equal proportions of all species captured.

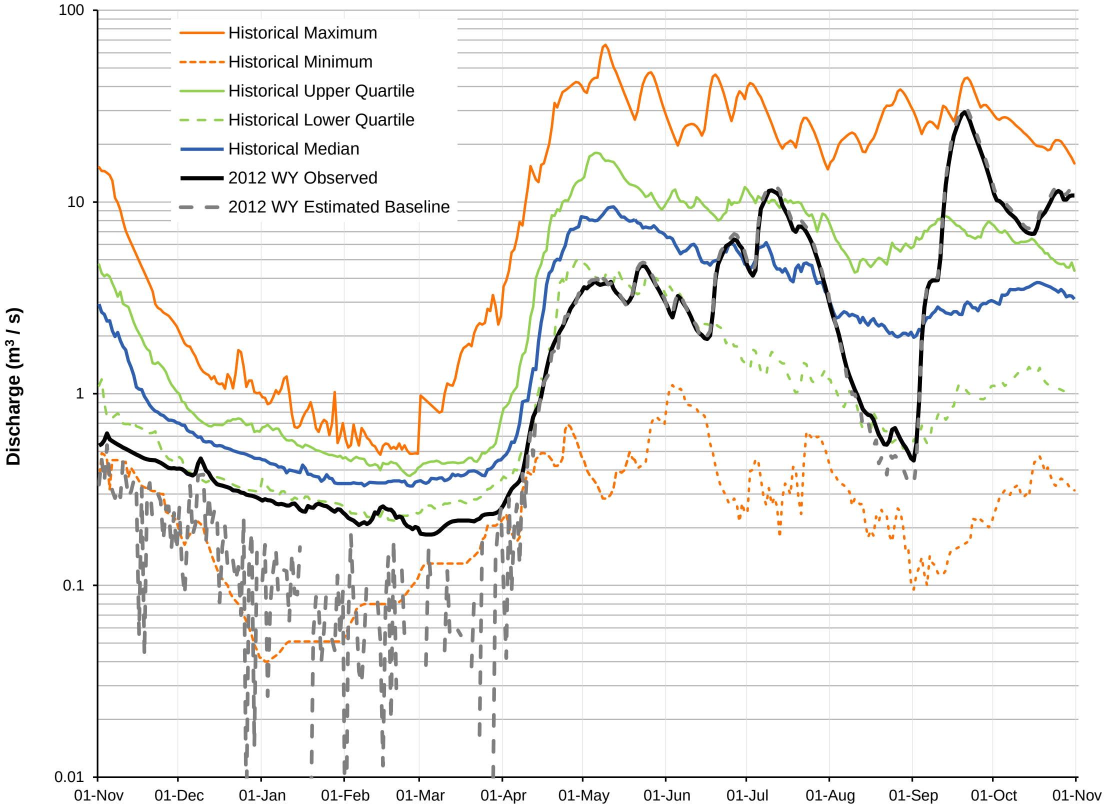
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by RAMP. Based on past studies, a total of 15 fish species were recorded in Jackpine Creek; whereas RAMP found only 11 species from 2009 to 2012, with the exception of Arctic grayling, fathead minnow, flathead chub, and spoonhead sculpin. Two additional fish species were observed by RAMP from 2009 to 2011, including finescale dace and trout-perch (Table 5.2-36). As noted in the Muskeg River section, 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., RAMP 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 RAMP, 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). These conditions, combined with the high flows, were likely the contributing factors to low richness and abundance observed in 2012.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reach JAC-F1 were below the 5th percentile of regional *baseline* conditions (Figure 5.2-26). ATI and richness were below the 5th percentile of regional *baseline* conditions at *baseline* reach JAC-F2 (Figure 5.2-26).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach JAC-F1 and regional *baseline* conditions were classified as **Moderate** given that all measurement endpoints were below the regional range of variation of *baseline* reaches, likely related to the high flows observed in fall 2012.

Figure 5.2-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Muskeg River in the 2012 WY, compared to historical values.



Note: Based on provisional 2012 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7). The upstream drainage area is 1,457 km^2. Historical values from March 1 to October 31 calculated from data collected from 1974 to 2011, and values for other months calculated from data collected from 1974 to 1986 and 1999 to 2011.

Note: In some cases observed flows at WSC Station 07DA008 (RAMP Station S7) minus the net flow releases from focal projects resulted in negative estimated *baseline* values that were set to zero. These values do not appear on the graph due to the logarithmic scale used.

Table 5.2-2 Estimated water balance at WSC Station 07DA008 (RAMP Station S7), Muskeg River near Fort McKay, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**109.96**	**Observed discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7)**
Closed-circuited area water loss from the observed *test* hydrograph	-9.79	Estimated 126.2 km^2 of the Muskeg River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+1.37	Estimated 88.5 km^2 of the Muskeg River watershed with land change from focal projects as of 2011 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Muskeg River watershed from focal projects	-0.07	Water withdrawn by Suncor Firebag (all values provided daily)
Water releases into the Muskeg River watershed from focal projects	0.01	Water released by Husky (all values provided daily)
Diversions into or out of the watershed	5.50	Syncrude Aurora Clean Water Diversion discharges to Stanley Creek
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Muskeg River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**113.02**	**Estimated *baseline* discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7)**
Incremental flow (change in total discharge)	-2.97	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-2.71%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Based on provisional 2012 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7).

Note: *Baseline* values shown in the table are likely underestimated, because they are based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: In some cases observed flows at WSC Station 07DA008 (RAMP Station S7) minus the net flow releases from focal projects resulted in negative estimated *baseline* values that were set to zero.

Table 5.2-3 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	6.79	6.44	-5.2%
Mean winter discharge	0.13	0.31	140.3%
Annual maximum daily discharge	31.55	29.40	-6.8%
Open-water season minimum daily discharge	0.33	0.45	34.8%

Note: Based on provisional the 2012 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7).

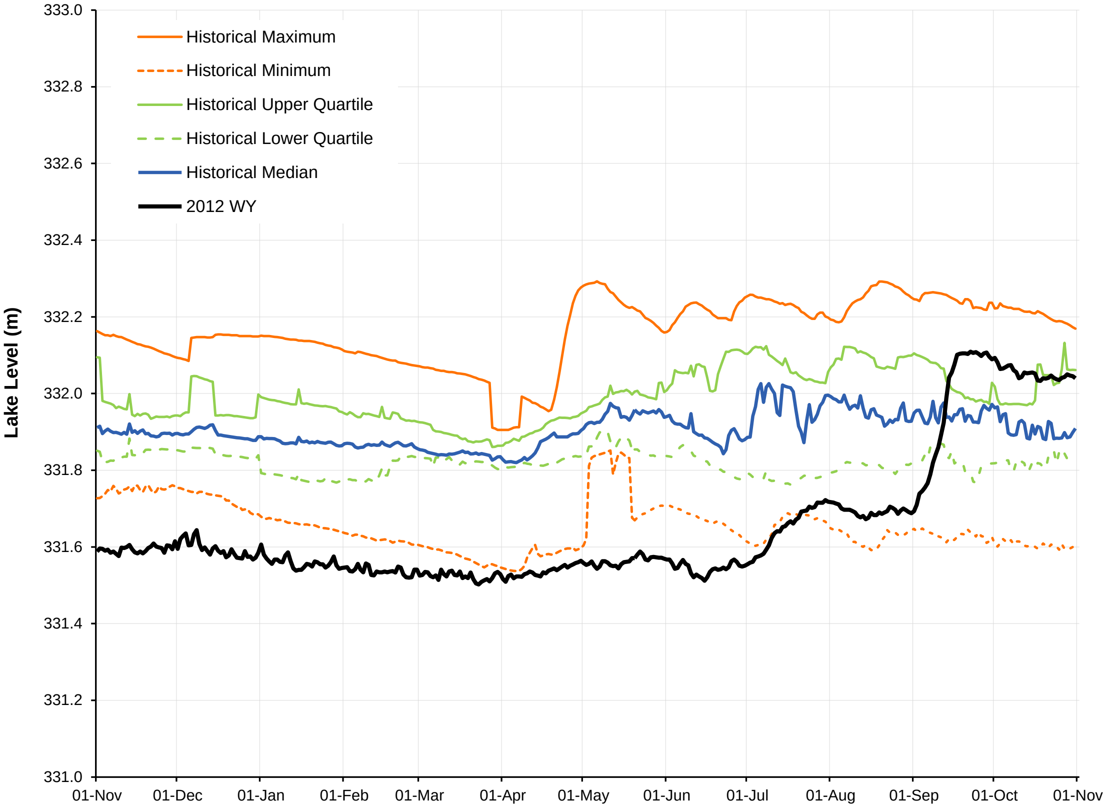
Note: *Baseline* values shown in the table are likely underestimated, because they are based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: In some cases observed flows at WSC Station 07DA008 (RAMP Station S7) minus the net flow releases from focal projects resulted in negative estimated *baseline* values that were set to zero.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to two and one decimal places, respectively.

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 Observed lake levels for Kearl Lake in the 2012 WY, compared to historical values.



Note: Observed 2012 WY lake levels based on the 2012 WY provisional data for Kearl Lake, RAMP Station L2. Historical values calculated from 1999 to October 2011, with periods of missing data present in most years.

Table 5.2-4 Concentrations of selected water quality measurement endpoints, mouth of Muskeg River (*test* station MUR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	15	7.4	8.2	8.6
Total suspended solids	mg/L	-	6	15	<3	3	70
Conductivity	µS/cm	-	365	15	220	330	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.013	15	0.004	0.013	0.030
Total nitrogen	mg/L	1	0.99	15	0.40	0.90	**1.62**
Nitrate+nitrite	mg/L	1.3	<0.071	15	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24.5	15	15.0	22.0	29.0
Ions							
Sodium	mg/L	-	12.1	15	8.0	13.0	64.0
Calcium	mg/L	-	46.2	15	28.8	46.8	108
Magnesium	mg/L	-	11.9	15	7.1	12.3	18.9
Chloride	mg/L	120	3.3	15	1.0	3.0	36.0
Sulphate	mg/L	270	3.2	15	0.6	5.2	91.0
Total dissolved solids	mg/L	-	263	15	170	280	405
Total alkalinity	mg/L	-	191	15	105	167	313
Selected metals							
Total aluminum	mg/L	0.1	0.08	15	0.03	0.08	**1.20**
Dissolved aluminum	mg/L	0.1	0.003	15	0.002	0.004	0.030
Total arsenic	mg/L	0.005	0.0005	15	0.0003	0.0004	0.0010
Total boron	mg/L	1.2	0.051	15	0.032	0.044	0.150
Total molybdenum	mg/L	0.073	0.00010	15	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	1.9	9	<0.6	<1.2	3.0
Total strontium	mg/L	-	0.13	15	0.09	0.12	0.30
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	-	0.21	1	-	0.88	-
Oilsands Extractable	mg/L	-	0.48	1	-	1.99	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.894	1	-	2.15	-
Total dibenzothiophenes	ng/L	-	40.16	1	-	10.17	-
Total PAHs	ng/L	-	239.3	1	-	181.5	-
Total Parent PAHs	ng/L	-	17.18	1	-	20.69	-
Total Alkylated PAHs	ng/L	-	222.2	1	-	160.8	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**0.63**	15	0.29	**0.66**	**1.81**
Total phenols	mg/L	0.004	**0.010**	15	<0.001	0.004	**0.011**
Sulphide	mg/L	0.002	**0.0021**	15	<0.002	**0.0050**	**0.0220**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline;

Table 5.2-5 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (*test* station MUR-6), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.7	14	7.2	8.1	8.4
Total suspended solids	mg/L	-	4	14	<3	3	25
Conductivity	µS/cm	-	225	14	233	311.5	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.017	14	0.011	0.014	0.029
Total nitrogen	mg/L	1	**1.01**	14	0.30	0.85	**1.93**
Nitrate+nitrite	mg/L	1.3	<0.071	14	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	36.3	14	13.0	19.0	36.3
Ions							
Sodium	mg/L	-	2.9	14	3.0	3.5	7.0
Calcium	mg/L	-	28.1	14	31.3	44.3	67.4
Magnesium	mg/L	-	10.0	14	11.6	15.9	24.0
Chloride	mg/L	120	0.7	14	<0.5	1.0	3.0
Sulphate	mg/L	270	5.4	14	1.5	3.0	6.3
Total dissolved solids	mg/L	-	183	14	180	233	320
Total alkalinity	mg/L	-	99	14	120	175	292
Selected metals							
Total aluminum	mg/L	0.1	**0.102**	14	0.003	0.020	**0.110**
Dissolved aluminum	mg/L	0.1	0.0096	14	0.0015	0.0050	<0.0100
Total arsenic	mg/L	0.005	0.0004	14	0.0003	0.0004	<0.001
Total boron	mg/L	1.2	0.025	14	0.006	0.011	0.019
Total molybdenum	mg/L	0.073	0.00013	14	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	1.8	9	0.6	<1.2	<1.2
Total strontium	mg/L	-	0.053	14	0.058	0.085	0.164
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	-	0.42	1	-	0.20	-
Oilsands Extractable	mg/L	-	0.73	1	-	1.50	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.692	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	7.087	-
Total PAHs	ng/L	-	203.7	1	-	154.9	-
Total Parent PAHs	ng/L	-	16.48	1	-	19.84	-
Total Alkylated PAHs	ng/L	-	187.2	1	-	135.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phenols	mg/L	0.004	**0.012**	14	<0.001	**0.005**	**0.031**
Total iron	mg/L	0.3	**0.371**	14	**0.070**	**0.250**	**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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.59.0	8.1	12	7.4	8.0	8.3
Total suspended solids	mg/L	-	<3	12	<3	3.5	9
Conductivity	µS/cm	-	274	12	184	274	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.013	12	0.012	0.016	0.034
Total nitrogen	mg/L	1	**1.1**	12	0.4	1.0	**1.2**
Nitrate+nitrite	mg/L	1.3	<0.071	12	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	6.3	12	12.0	23.5	29.0
Ions							
Sodium	mg/L	-	20.4	12	7.0	17.0	64.0
Calcium	mg/L	-	25.5	12	20.8	32.1	71.1
Magnesium	mg/L	-	8.9	12	6.5	10.1	17.3
Chloride	mg/L	120	1.2	12	<1.0	2.0	36.0
Sulphate	mg/L	270	2.3	12	2.0	3.5	8.0
Total dissolved solids	mg/L	-	212	12	140	215	378
Total alkalinity	mg/L	-	139	12	93	138	313
Selected metals							
Total aluminum	mg/L	0.1	0.082	12	0.021	0.045	**0.142**
Dissolved aluminum	mg/L	0.1	0.009	12	0.003	0.007	0.030
Total arsenic	mg/L	0.005	0.0006	12	0.0002	0.0005	0.0010
Total boron	mg/L	1.2	0.061	12	0.024	0.055	0.150
Total molybdenum	mg/L	0.073	0.00013	12	0.00004	0.00010	0.00640
Total mercury (ultra-trace)	ng/L	5, 13	2.3	7	<0.6	<1.2	1.8
Total strontium	mg/L	-	0.098	12	0.069	0.101	0.296
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	-	0.03	1	-	0.54	-
Oilsands Extractable	mg/L	-	0.24	1	-	1.58	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.789	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	36.93	1	-	9.615	-
Total PAHs	ng/L	-	210.7	1	-	160.3	-
Total Parent PAHs	ng/L	-	16.73	1	-	19.32	-
Total Alkylated PAHs	ng/L	-	194.0	1	-	141.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Sulphide	mg/L	0.002	**0.004**	12	0.002	**0.010**	**0.068**
Total iron	mg/L	0.3	**0.39**	12	0.29	**0.64**	**1.81**
Total phenols	mg/L	0.004	**0.008**	12	<0.001	**0.006**	**0.017**

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	13	7.8	8.1	8.3
Total suspended solids	mg/L	-	50	13	<3	<3	8
Conductivity	µS/cm	-	190	13	183	237	483
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.008	13	0.006	0.014	0.026
Total nitrogen	mg/L	1	**1.32**	13	0.70	0.90	**1.62**
Nitrate+nitrite	mg/L	1.3	<0.071	13	<0.05	<0.10	<0.10
Dissolved organic carbon	mg/L	-	31.8	13	18.6	23.7	30.0
Ions							
Sodium	mg/L	-	11.6	13	10.0	12.0	18.8
Calcium	mg/L	-	20.0	13	22.2	29.2	65.6
Magnesium	mg/L	-	6.1	13	6.6	8.5	16.3
Chloride	mg/L	120	1.7	13	0.9	2.0	5.6
Sulphate	mg/L	270	2.9	13	<0.5	2.7	9.8
Total dissolved solids	mg/L	-	170	13	110	206	322
Total alkalinity	mg/L	-	89	13	93	122	249
Selected metals							
Total aluminum	mg/L	0.1	**0.658**	13	0.016	0.062	**0.197**
Dissolved aluminum	mg/L	0.1	0.012	13	0.002	0.007	**0.170**
Total arsenic	mg/L	0.005	0.0006	13	0.0003	0.0005	<0.0010
Total boron	mg/L	1.2	0.052	13	0.033	0.046	0.071
Total molybdenum	mg/L	0.073	0.00011	13	0.00007	0.00010	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	2.9	9	<0.6	<1.2	1.7
Total strontium	mg/L	-	0.077	13	0.085	0.108	0.212
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	-	0.08	1	-	0.41	-
Oilsands Extractable	mg/L	-	0.38	1	-	2.90	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	13.80	1	-	3.380	-
Total dibenzothiophenes	ng/L	-	136.1	1	-	15.26	-
Total PAHs	ng/L	-	596.2	1	-	180.1	-
Total Parent PAHs	ng/L	-	24.02	1	-	20.37	-
Total Alkylated PAHs	ng/L	-	572.2	1	-	159.8	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**1.35**	13	**0.38**	**0.59**	**1.57**
Total phenols	mg/L	0.004	**0.010**	13	0.001	**0.006**	**0.019**
Dissolved iron	mg/L	0.3	**0.32**	13	0.14	0.28	**0.70**
Sulphide	mg/L	0.002	**0.006**	13	0.002	**0.008**	**0.103**
Total phosphorus	mg/L	0.05	**0.058**	13	0.018	0.022	0.042

[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 5.2-8 Concentrations of selected water quality measurement endpoints, upper Jackpine Creek (*baseline* station JAC-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	4	8.0	8.1	8.3
Total suspended solids	mg/L	-	243	4	3	10	21
Conductivity	µS/cm	-	228	4	202	215	346
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.007	4	0.012	0.016	0.023
Total nitrogen	mg/L	1	**1.5**	4	0.86	0.98	**2.63**
Nitrate+nitrite	mg/L	1.3	<0.071	4	<0.071	<0.071	<0.1
Dissolved organic carbon	mg/L	-	29.1	4	22.6	27.1	29.1
Ions							
Sodium	mg/L	-	12.0	4	10.0	10.7	25.5
Calcium	mg/L	-	25.5	4	22.1	28.7	36.8
Magnesium	mg/L	-	7.8	4	7.2	8.6	11.5
Chloride	mg/L	120	1.4	4	<0.5	0.8	1.6
Sulphate	mg/L	270	4.33	4	0.67	1.44	2.00
Total dissolved solids	mg/L	-	183	4	150	167	264
Total alkalinity	mg/L	-	110	4	103	112	187
Selected metals							
Total aluminum	mg/L	0.1	**2.84**	4	**0.14**	**0.40**	**0.70**
Dissolved aluminum	mg/L	0.1	0.029	4	0.006	0.010	0.014
Total arsenic	mg/L	0.005	0.0016	4	0.0007	0.0007	0.0013
Total boron	mg/L	1.2	0.073	4	0.045	0.059	0.137
Total molybdenum	mg/L	0.073	0.00011	4	0.00011	0.00014	0.00024
Total mercury (ultra-trace)	ng/L	5, 13	**8.80**	4	1	<1.2	2.9
Total strontium	mg/L	-	0.096	4	0.104	0.113	0.201
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	-	0.05	1	-	0.05	-
Oilsands Extractable	mg/L	-	0.42	1	-	1.08	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	11.10	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	45.44	1	-	7.091	-
Total PAHs	ng/L	-	299.1	1	-	154.1	-
Total Parent PAHs	ng/L	-	20.00	1	-	19.55	-
Total Alkylated PAHs	ng/L	-	279.1	1	-	134.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.486**	4	0.238	**0.430**	**0.503**
Sulphide	mg/L	0.002	**0.0052**	4	**0.0047**	**0.0064**	**0.0081**
Total iron	mg/L	0.3	**4.36**	4	**0.69**	**0.76**	**1.21**
Total phenols	mg/L	0.004	**0.009**	4	**0.006**	**0.009**	**0.012**
Total phosphorus	mg/L	0.05	**0.164**	4	0.020	0.027	0.044
Total chromium	mg/L	0.001	**0.0039**	4	<0.0003	0.0005	0.0009
Total copper	mg/L	0.00228	**0.00242**	4	0.00027	0.00045	0.00054

[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 5.2-9 Concentrations of selected water quality measurement endpoints, Stanley Creek (*test* station STC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.59.0	8.0	11	7.6	8.0	8.3
Total suspended solids	mg/L	-	<3	11	<3	<3	6
Conductivity	µS/cm	-	392	11	271	392	760
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.036	12	0.010	0.020	0.033
Total nitrogen	mg/L	1	0.53	12	0.30	0.40	**2.10**
Nitrate+nitrite	mg/L	1.3	<0.071	12	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13.1	11	6.0	9.0	13.1
Ions							
Sodium	mg/L	-	7.0	11	2.0	5.0	26.0
Calcium	mg/L	-	57.0	11	45.4	61.1	112.0
Magnesium	mg/L	-	11.9	11	11.1	12.9	20.5
Chloride	mg/L	120	2.3	11	<0.5	1.4	14.0
Sulphate	mg/L	410	1.5	11	<0.5	5.1	126.0
Total dissolved solids	mg/L	-	224	11	200	264	480
Total alkalinity	mg/L	-	209	11	157	206	260
Selected metals							
Total aluminum	mg/L	0.1	<0.003	12	<0.002	0.007	0.020
Dissolved aluminum	mg/L	0.1	<0.001	12	<0.001	<0.001	0.020
Total arsenic	mg/L	0.005	0.00018	12	<0.00010	0.00014	<0.00100
Total boron	mg/L	1.2	0.052	12	0.018	0.025	0.087
Total molybdenum	mg/L	0.073	<0.0001	12	<0.000008	0.000088	0.000200
Total mercury (ultra-trace)	ng/L	5, 13	1.4000	9	<0.6	<1.2	<1.2
Total strontium	mg/L	-	0.11	12	0.08	0.14	0.25
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	-	0.54	1	-	1.00	-
Oilsands Extractable	mg/L	-	1.29	1	-	1.48	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.554	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.72	1	-	8.250	-
Total PAHs	ng/L	-	206.9	1	-	173.6	-
Total Parent PAHs	ng/L	-	16.52	1	-	19.62	-
Total Alkylated PAHs	ng/L	-	190.3	1	-	154.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phenols	mg/L	0.004	**0.013**	12	<0.001	0.003	**0.052**
Sulphide	mg/L	0.002	**0.004**	12	<0.002	**0.004**	**0.013**
Total phosphorus	mg/L	0.05	**0.054**	12	0.016	0.030	**0.080**

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	10	7.4	8.0	8.2
Total suspended solids	mg/L	-	3	10	<3	<3	23
Conductivity	µS/cm	-	246	10	207	266	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.017	10	0.009	0.014	0.023
Total nitrogen	mg/L	1	**1.11**	10	0.50	1.00	**1.84**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	5.7	10	5.7	17.5	33.2
Ions							
Sodium	mg/L	-	8.7	10	6.0	7.1	9.0
Calcium	mg/L	-	28.0	10	26.7	38.6	71.7
Magnesium	mg/L	-	9.0	10	8.6	13.0	25.1
Chloride	mg/L	120	4.0	10	0.8	2.0	3.0
Sulphate	mg/L	270	0.57	10	0.50	2.33	7.60
Total dissolved solids	mg/L	-	206	10	160	215	312
Total alkalinity	mg/L	-	121	10	99	146	292
Selected metals							
Total aluminum	mg/L	0.1	0.050	10	0.014	0.017	0.074
Dissolved aluminum	mg/L	0.1	0.0048	10	0.0025	0.0063	0.0500
Total arsenic	mg/L	0.005	0.0005	10	0.0002	0.0004	<0.0010
Total boron	mg/L	1.2	0.029	10	0.014	0.022	0.081
Total molybdenum	mg/L	0.073	<0.0001	10	0.00003	0.00005	0.00040
Total mercury (ultra-trace)	ng/L	5, 13	2.50	8	<0.6	<1.2	3.3
Total strontium	mg/L	-	0.082	10	0.063	0.089	0.149
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	-	0.35	-
Oilsands Extractable	mg/L	-	0.13	1	-	1.42	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	<0.509	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.35	1	-	20.36	-
Total PAHs	ng/L	-	207.9	1	-	228.9	-
Total Parent PAHs	ng/L	-	16.64	1	-	20.39	-
Total Alkylated PAHs	ng/L	-	191.2	1	-	208.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**0.686**	10	0.177	**0.420**	**2.070**
Total phenols	mg/L	0.004	**0.012**	10	0.002	**0.007**	**0.016**
Sulphide	mg/L	0.002	**0.004**	10	<0.002	**0.009**	**0.019**

[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 5.2-11 Concentrations of selected water quality measurement endpoints, Iyinimin Creek (*baseline* station IYC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	4	7.9	8.1	8.5
Total suspended solids	mg/L	-	122	4	<3	10	29
Conductivity	µS/cm	-	191	4	134	172.5	535
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.017	4	0.017	0.019	0.031
Total nitrogen	mg/L	1	**1.39**	4	0.58	0.90	**1.93**
Nitrate+nitrite	mg/L	1.3	<0.071	4	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	30.3	4	27.0	31.7	33.9
Ions							
Sodium	mg/L	-	6.4	4	4.9	8.0	40.1
Calcium	mg/L	-	21.8	4	18.0	21.4	51.0
Magnesium	mg/L	-	7.6	4	6.2	7.4	18.0
Chloride	mg/L	120	3.3	4	<0.5	1.3	2.0
Sulphate	mg/L	270	2.4	4	2.2	3.3	12.3
Total dissolved solids	mg/L	-	167	4	134	157	359
Total alkalinity	mg/L	-	89	4	64	88	284
Selected metals							
Total aluminum	mg/L	0.1	**1.930**	4	0.055	**0.502**	**0.902**
Dissolved aluminum	mg/L	0.1	0.051	4	0.008	0.028	0.044
Total arsenic	mg/L	0.005	0.0013	4	0.00072	0.00076	0.00083
Total boron	mg/L	1.2	0.037	4	0.025	0.037	0.228
Total molybdenum	mg/L	0.073	0.00016	4	0.00011	0.00016	0.00047
Total mercury (ultra-trace)	ng/L	5, 13	**8.1**	4	<0.6	1.8	2.8
Total strontium	mg/L	-	0.068	4	0.046	0.062	0.193
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	-	0.37	1	-	<0.02	-
Oilsands Extractable	mg/L	-	1.08	1	-	0.79	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	19.60	1	-	<2.14	-
Total dibenzothiophenes	ng/L	-	35.72	1	-	27.29	-
Total PAHs	ng/L	-	234.7	1	-	221.2	-
Total Parent PAHs	ng/L	-	17.00	1	-	22.87	-
Total Alkylated PAHs	ng/L	-	217.7	1	-	198.3	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.371**	4	0.280	**0.386**	**0.714**
Total iron	mg/L	0.3	**3.06**	4	**0.84**	**1.01**	**1.15**
Total phenols	mg/L	0.004	**0.009**	4	**0.005**	**0.009**	**0.016**
Sulphide	mg/L	0.002	**0.005**	4	<0.002	**0.007**	**0.013**
Total phosphorus	mg/L	0.05	**0.123**	4	0.032	0.041	0.043
Total chromium	mg/L	0.001	**0.0032**	4	<0.0003	0.0007	**0.0013**

[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 5.2-12 Concentrations of selected water quality measurement endpoints, Kearl Lake (*test* station KEL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	13	7.6	8.0	8.3
Total suspended solids	mg/L	-	5	13	<3	4	19
Conductivity	µS/cm	-	207	13	133	174	187
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.0074	13	0.0020	0.0070	0.0130
Total nitrogen	mg/L	1	**1.32**	13	0.45	**1.40**	**1.92**
Nitrate+nitrite	mg/L	1.3	<0.071	13	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	23.4	13	9.8	21.0	24.0
Ions							
Sodium	mg/L	-	10.7	13	8.0	10.0	11.3
Calcium	mg/L	-	19.3	13	16.5	19.6	20.6
Magnesium	mg/L	-	7.0	13	5.7	6.8	7.6
Chloride	mg/L	120	<0.50	13	<0.5	<1.0	3
Sulphate	mg/L	270	1.4	13	2.0	4.7	5.7
Total dissolved solids	mg/L	-	156	13	94	154	220
Total alkalinity	mg/L	-	105	13	72	88	94
Selected metals							
Total aluminum	mg/L	0.1	0.010	13	0.007	0.020	**0.130**
Dissolved aluminum	mg/L	0.1	<0.001	13	<0.001	0.0014	0.0300
Total arsenic	mg/L	0.005	0.00033	13	0.00029	0.00037	<0.0010
Total boron	mg/L	1.2	0.049	13	0.012	0.047	0.052
Total molybdenum	mg/L	0.073	<0.0001	13	0.0000288	0.0001	0.0009
Total mercury (ultra-trace)	ng/L	5, 13	1.0	9	<0.6	<1.2	1.3
Total strontium	mg/L	-	0.068	13	0.056	0.066	0.215
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	-	0.19	1	-	0.49	-
Oilsands Extractable	mg/L	-	0.42	1	-	1.25	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	10.90	1	-	<14.13	-
Retene	ng/L	-	<0.51	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.35	1	-	7.027	-
Total PAHs	ng/L	-	206.9	1	-	161.2	-
Total Parent PAHs	ng/L	-	18.81	1	-	20.73	-
Total Alkylated PAHs	ng/L	-	188.1	1	-	140.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phenols	mg/L	0.004	**0.010**	13	0.001	**0.005**	**0.012**

[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 5.2-5 Piper diagram of fall ion concentrations in the Muskeg River.

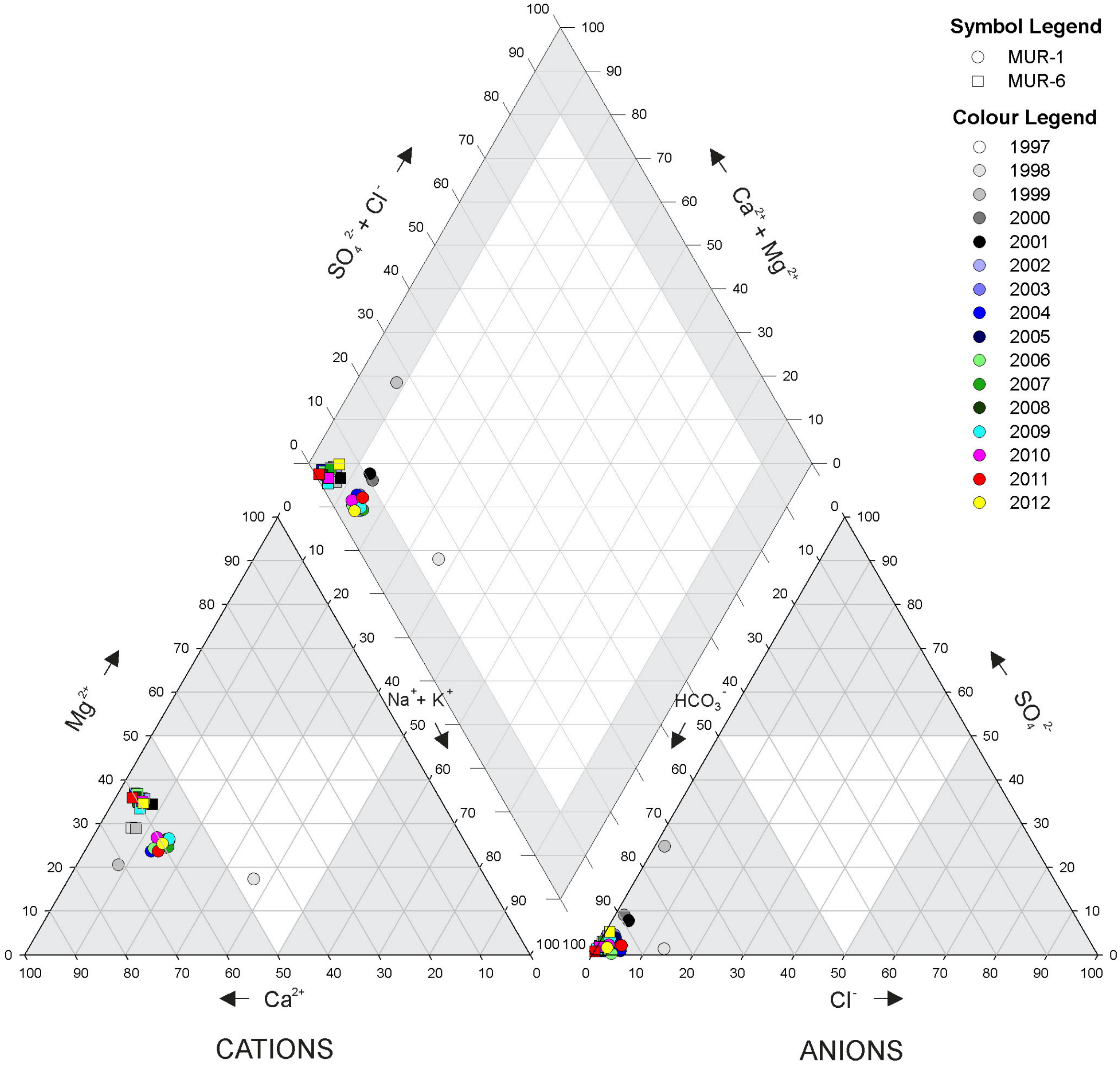


Figure 5.2-6 Piper diagram of fall ion concentrations in tributaries to the Muskeg River and Kearl Lake.

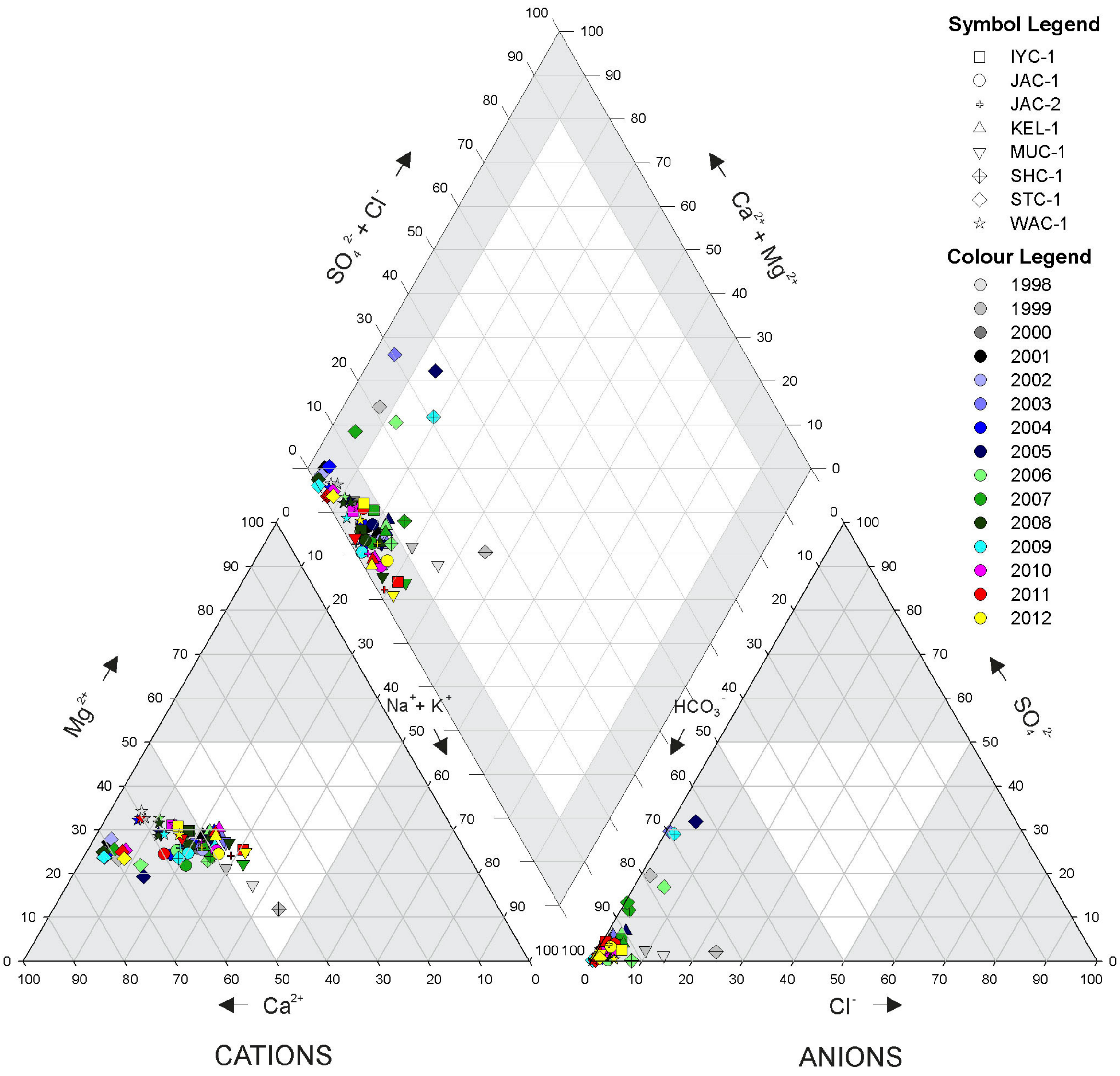


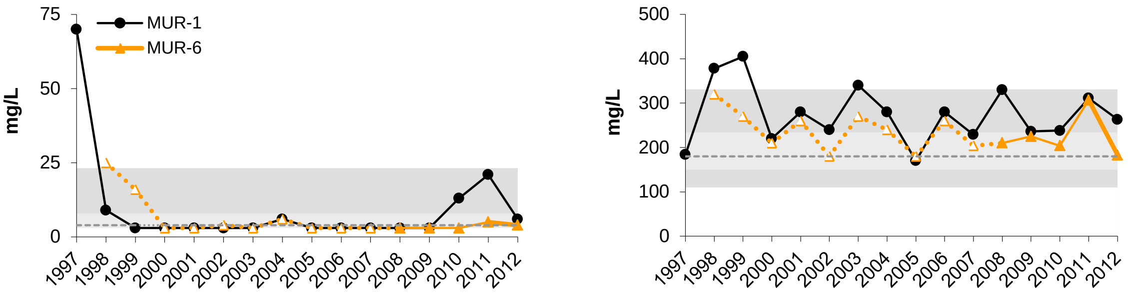
Table 5.2-13 Water quality guideline exceedances, Muskeg River watershed, fall 2012.

Variable	Units	Guideline[a]	MUR-1	MUR-6	MUC-1	JAC-1	JAC-2	STC-1	WAC-1	IYC-1	KEL-1
Dissolved iron	mg/L	0.3	-	-	-	0.32	0.49	-	-	0.37	-
Sulphide	mg/L	0.002	0.0021	-	0.0041	0.0059	0.0052	0.0036	0.0039	0.0053	-
Total aluminum	mg/L	0.1	-	0.102	-	0.658	2.84	-	-	1.93	-
Total chromium	mg/L	0.001	-	-	-	-	0.004	-	-	0.003	-
Total copper	mg/L	0.00228	-	-	-	-	0.0024	-	-	-	-
Total iron	mg/L	0.3	0.632	0.371	0.386	1.35	4.36	-	0.686	3.06	-
Total mercury (ultra-trace)	ng/L	5, 13	-	-	-	-	8.8	-	-	8.1	-
Total nitrogen	mg/L	1	-	1.01	1.08	1.32	1.50	-	1.11	1.39	1.32
Total phenols	mg/L	0.004	0.0096	0.0118	0.0081	0.0100	0.0088	0.0128	0.0120	0.0087	0.0098
Total phosphorus	mg/L	0.05	-	-	-	0.058	0.164	0.054	-	0.123	-

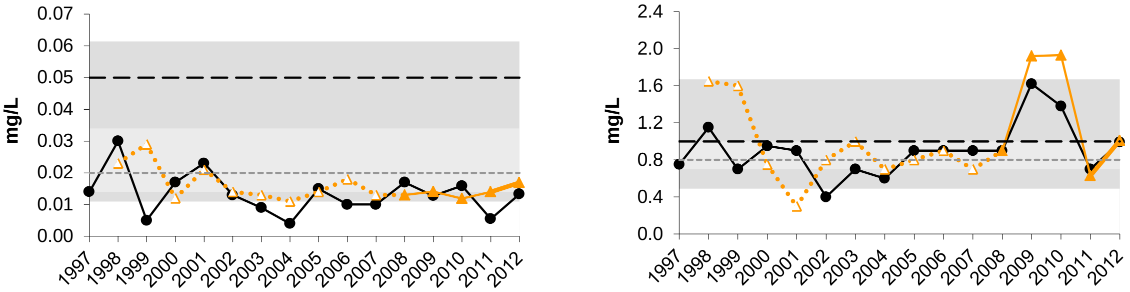
[a] Sources for all guidelines are outlined in Table 3.2-5.

Underline denotes *baseline* station.

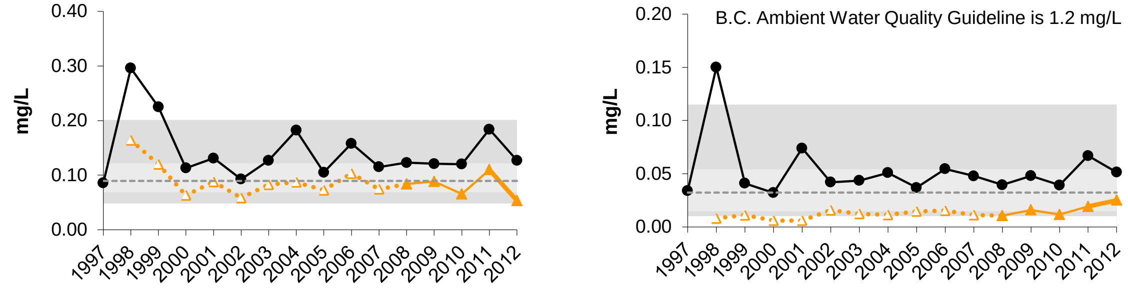
Figure 5.2-7 Selected water quality measurement endpoints in the Muskeg River at the mouth (*test* station MUR-1) and upstream of Wapasu Creek (*test* station MUR-6) (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

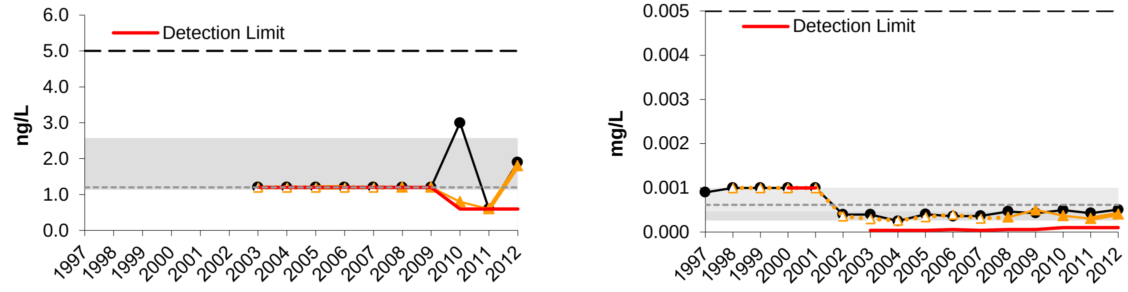
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

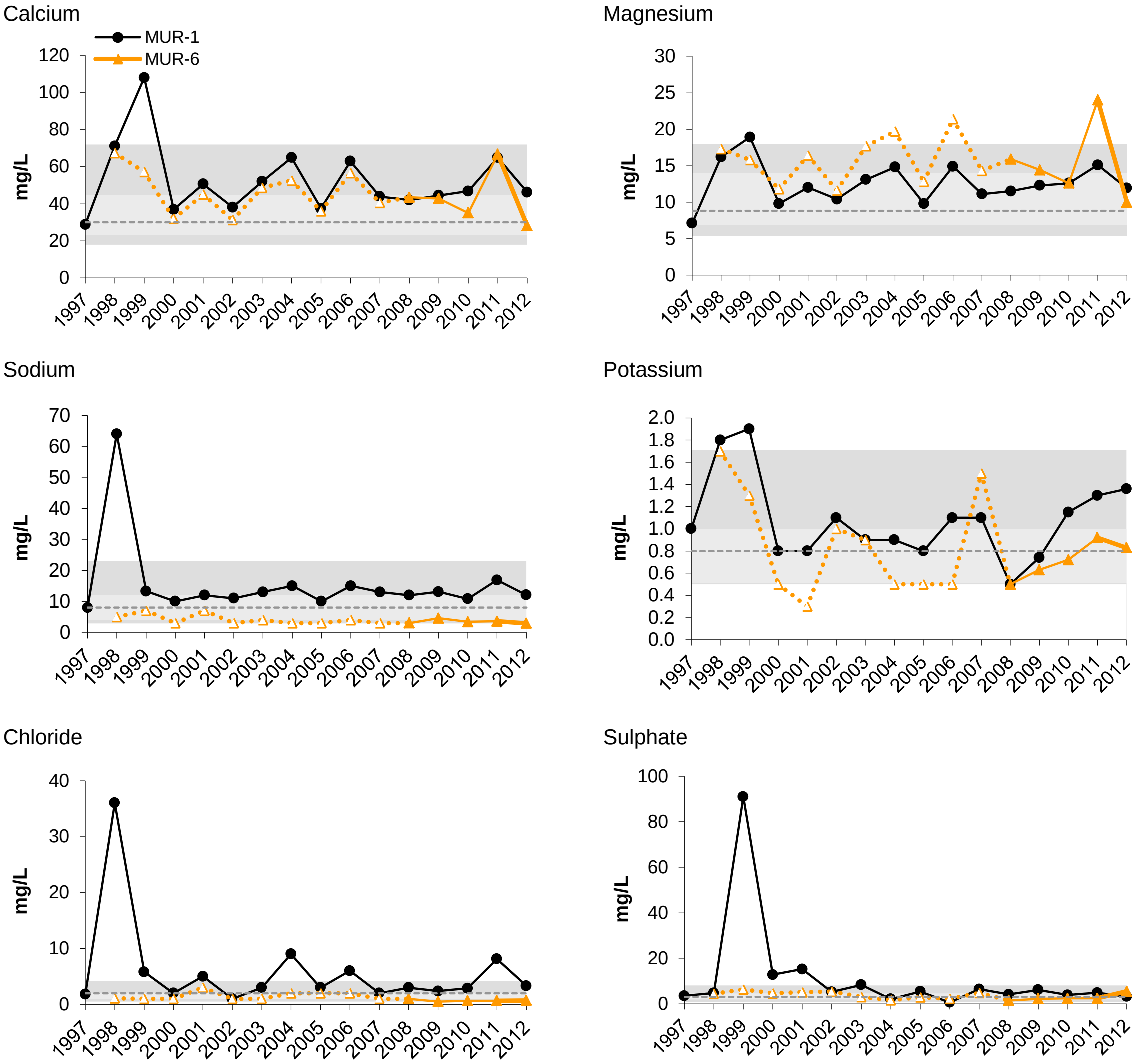
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○……○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.2-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

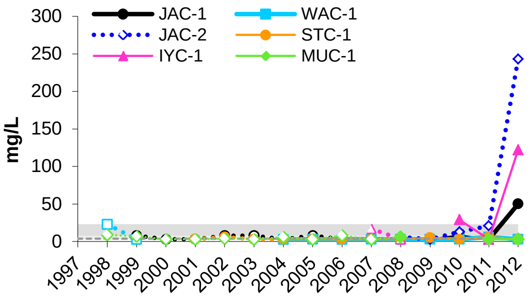
- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

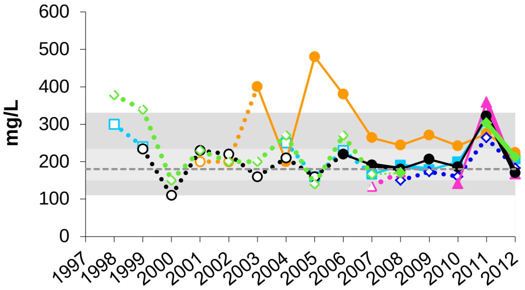
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.2-8 Selected water quality measurement endpoints in Muskeg River tributaries (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

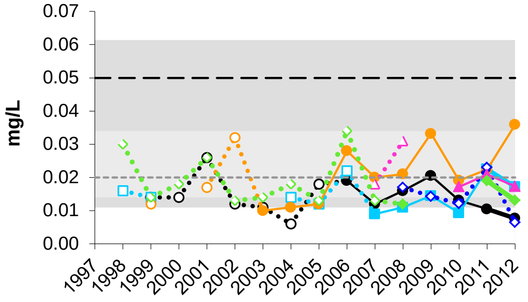
Total Suspended Solids (TSS)



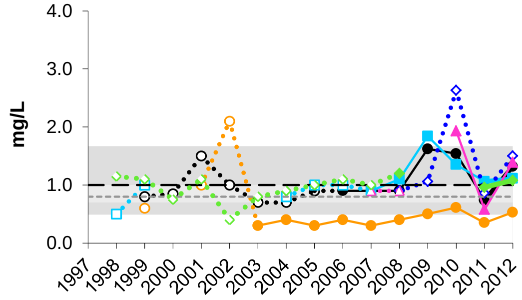
Total Dissolved Solids (TDS)



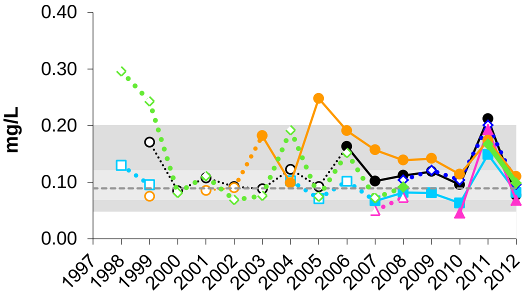
Dissolved Phosphorus



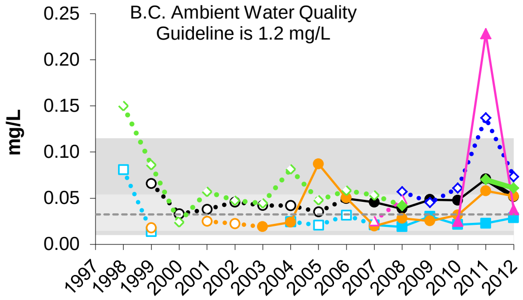
Total Nitrogen



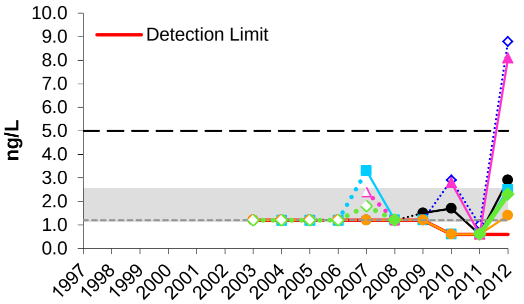
Total Strontium



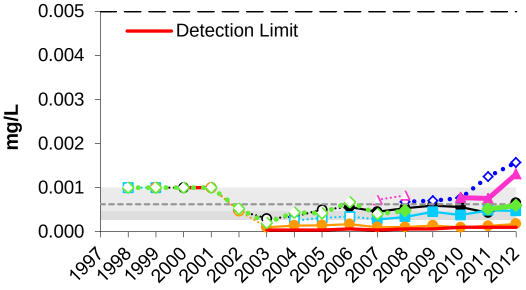
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



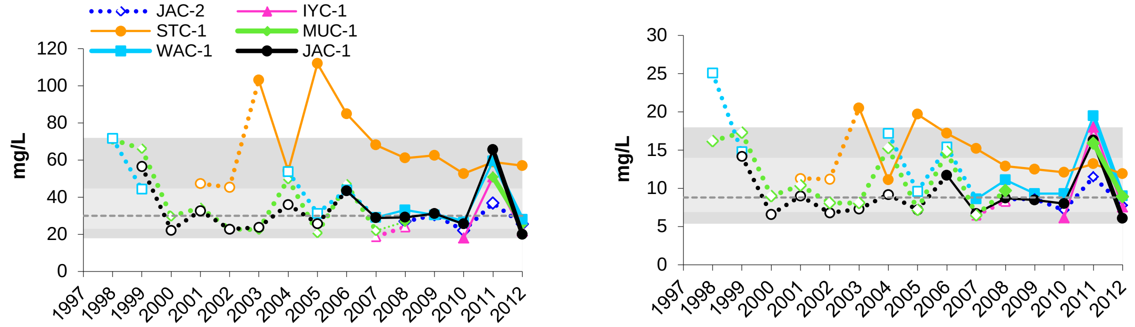
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

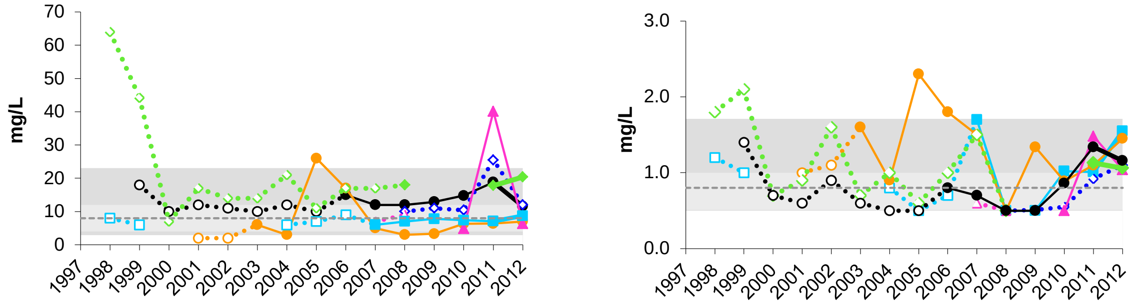
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

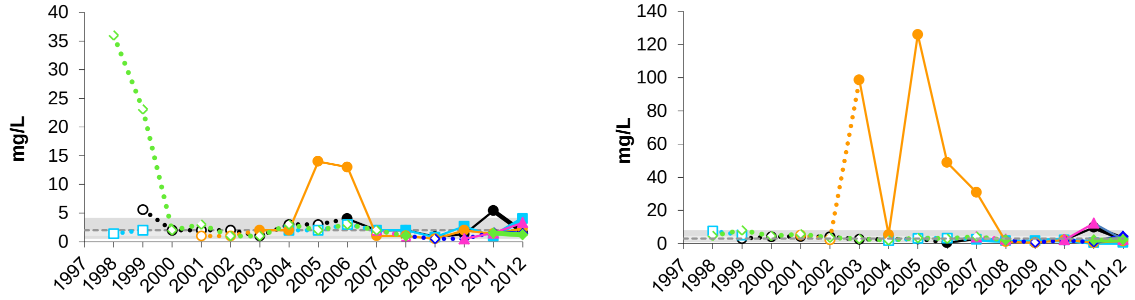
Figure 5.2-8 (Cont'd.)


Calcium

Magnesium


Sodium

Potassium


Chloride

Sulphate

Non-detectable values are shown at the detection limit.

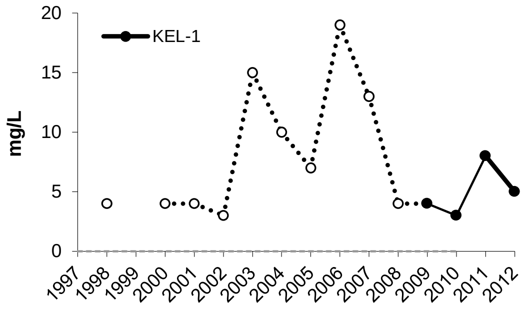
– – – – –   Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○   Sampled as a *baseline* station   ●——●   Sampled as a *test* station

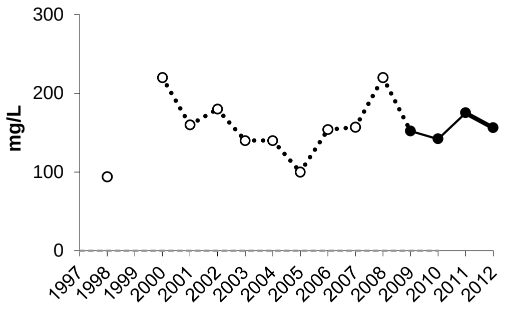
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.2-9 Selected water quality measurement endpoints in Kearl Lake (fall data) relative to historical concentrations.

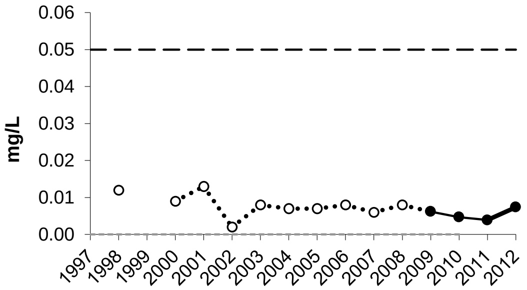
Total Suspended Solids (TSS)



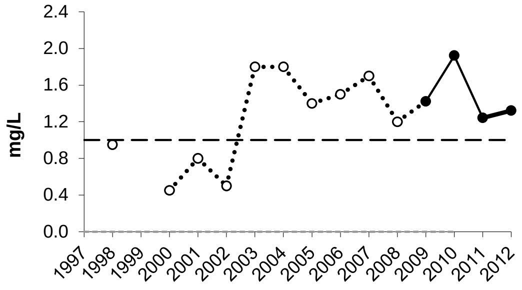
Total Dissolved Solids (TDS)



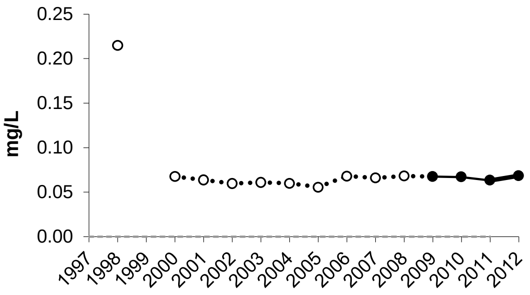
Dissolved Phosphorus



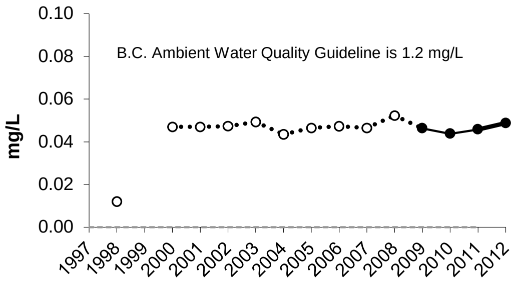
Total Nitrogen



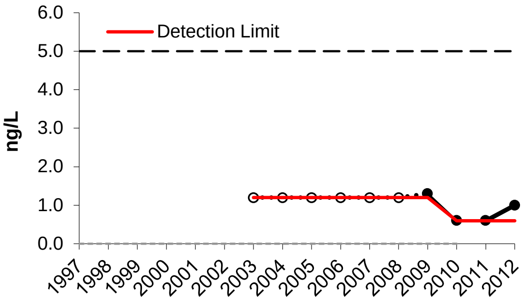
Total Strontium



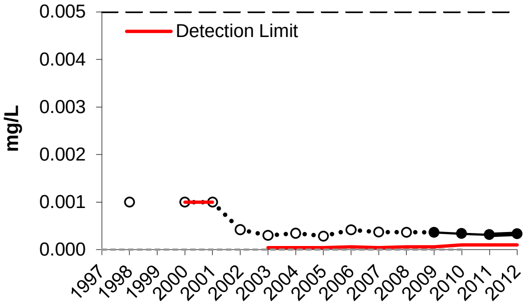
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



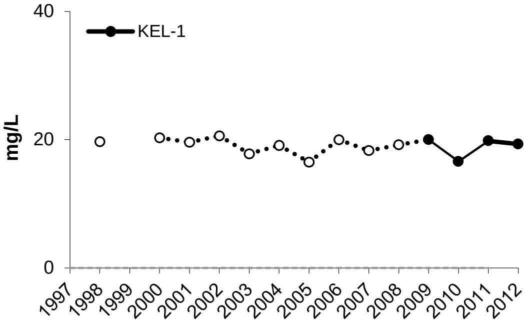
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

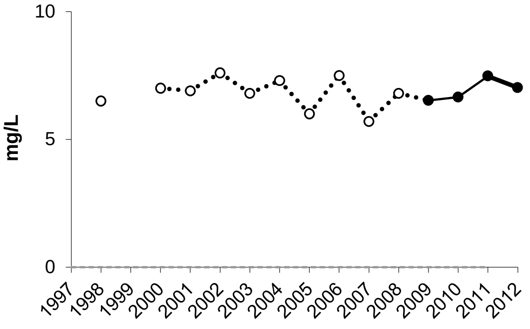
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.2-9 (Cont'd.)

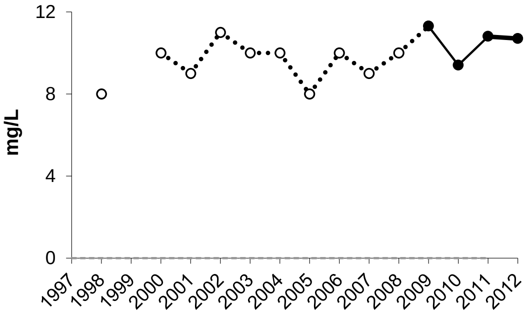
Calcium



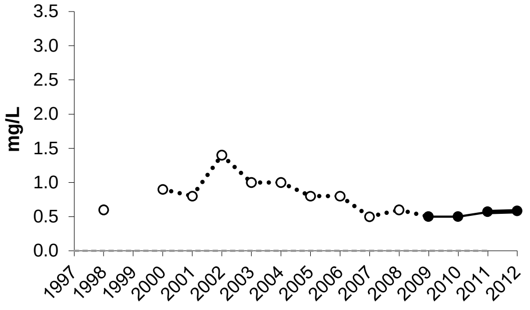
Magnesium



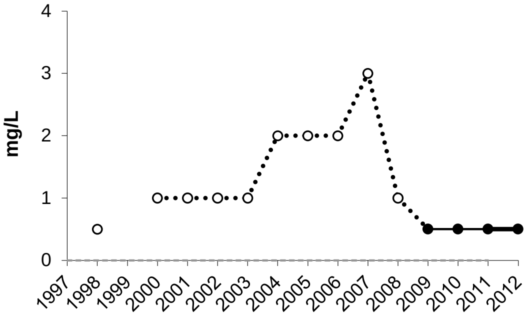
Sodium



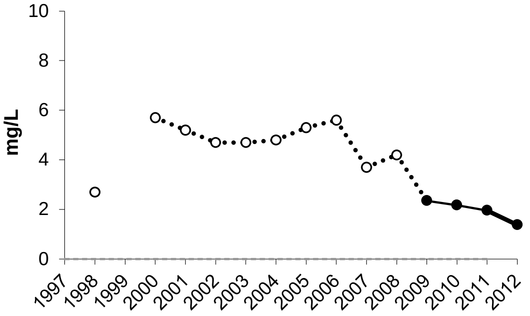
Potassium



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

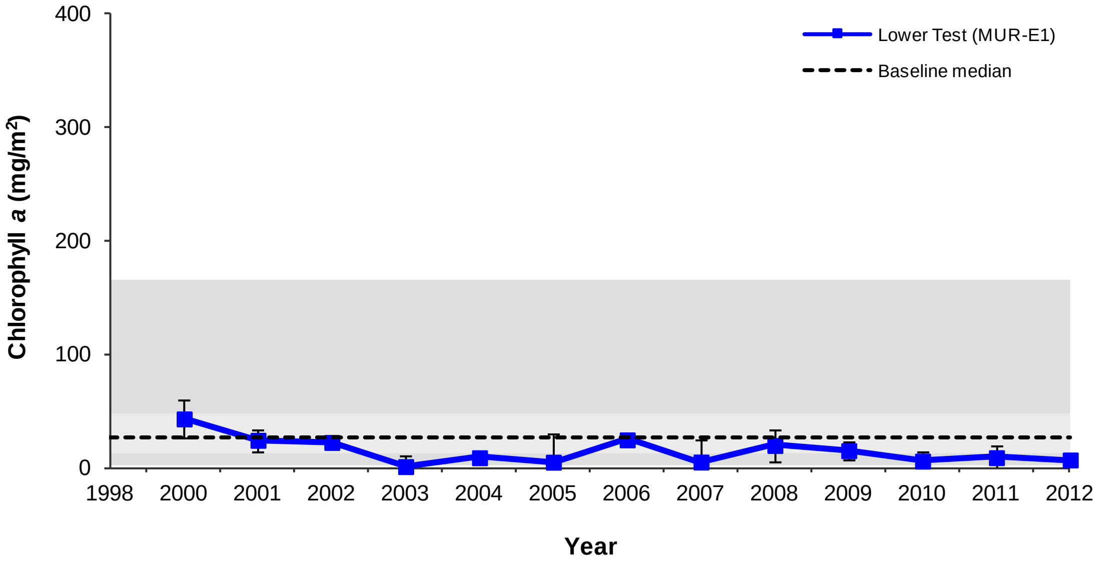
Table 5.2-14 Water quality index (fall 2012) for Muskeg River watershed stations.

Station	**Location**	**2012 Designation**	**Water Quality Index**	**Classification**
MUR-1	lower Muskeg River	*test*	100.0	Negligible-Low
MUR-6	upstream of Wapasu Creek	*test*	97.5	Negligible-Low
MUC-1	near mouth of Muskeg Creek	*test*	100.0	Negligible-Low
JAC-1	near mouth of Jackpine Creek	*test*	91.1	Negligible-Low
JAC-2	upper Jackpine Creek	*baseline*	73.7	Moderate
STC-1	near mouth of Stanley Creek	*test*	100.0	Negligible-Low
IYC-1	near mouth of Iyinimin Creek	*test*	75.7	Moderate
WAC-1	near mouth of Wapasu Creek	*test*	100.0	Negligible-Low

Table 5.2-15 Average habitat characteristics of benthic invertebrate sampling locations of the Muskeg River, fall 2012.

Variable	**Units**	**MUR-E1** **Lower *Test* Reach of Muskeg River**	**MUR-D2** **Middle *Test* Reach of Muskeg River**	**MUR-D3** **Upper *Test* Reach of Muskeg River**
Sample date	-	08-Sept-2012	11-Sept-2012	11-Sept-2012
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	3.5	1.3
Current velocity	m/s	1.46	-	0.27
Field Water Quality				
Dissolved oxygen	mg/L	8.1	7.3	7.5
Conductivity	µS/cm	304	363	334
pH	pH units	8.2	7.7	7.8
Water temperature	°C	14.6	12.0	11.6
Sediment Composition				
sand	%	1	88	80
silt	%		10	17
clay	%		2	2
small gravel	%	33		
large gravel	%	34		
small cobble	%	20		
large cobble	%	10		
boulder	%	2		
Total Organic Carbon	%		2.1	22.6

Figure 5.2-10 Periphyton chlorophyll *a* biomass at *test* reach MUR-E1 of the Muskeg River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.2-16 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the lower Muskeg River (*test* reach MUR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach MUR-E1		
	1998	2000 to 2011	2012
Hydra		0 to <1	
Nematoda	2	<1 to 5	3
Erpobdellidae		0 to <1	
Glossiphoniidae		0 to <1	
Naididae	5	1 to 30	4
Tubificidae	5	0 to 26	9
Enchytraeidae	<1	0 to 1	<1
Lumbriculidae		0 to <1	
Hydracarina	14	0 to 17	11
Amphipoda		0 to <1	
Ostracoda	3	0 to 15	7
Cladocera		0 to <1	<1
Copepoda	<1	0 to 26	<1
Gastropoda	3	0 to 7	1
Bivalvia	6	0 to 5	9
Coleoptera	5	<1 to 10	<1
Ceratopogonidae	1	0 to 26	1
Chironomidae	32	15 to 58	36
Dolichopodidae			<1
Empididae	4	<1 to 22	<1
Ephydridae			<1
Tipulidae	<1	0 to <1	<1
Tabanidae	0	0 to <1	
Simuliidae	<1	0 to <1	
Ephemeroptera	12	5 to 50	11
Anisoptera	<1	<1 to 2	<1
Plecoptera	4	<1 to 8	<1
Trichoptera	2	1 to16	3
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	68,374	2,849 to 151,193	59,089
Richness	60	29 to 43	37
Simpson's Diversity	0.93	0.72 to 0.91	0.89
Equitability	0.25	0.13 to 0.38	0.28
% EPT	18	14 to 57	15

Table 5.2-17 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the middle Muskeg River (*test* reach MUR-D2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach MUR-D2		
	2000	2001 to 2011	2012
Hydra	<1	0 to 4	
Nematoda	2	1 to 6	4
Erpobdellidae	<1	0 to <1	
Glossiphoniidae	<1	0 to 1	<1
Naididae	2	<1 to 11	2
Tubificidae	10	<1 to 31	2
Enchytraeidae	<1	0 to 6	<1
Lumbriculidae	1	0 to 7	<1
Hydracarina	1	<1 to 3	2
Amphipoda		0 to 2	
Ostracoda	1	0 to 10	<1
Cladocera		0 to 8	<1
Copepoda	<1	<1 to 3	<1
Gastropoda	<1	0 to 4	<1
Bivalvia	4	0 to 5	3
Coleoptera	<1	0 to 1	<1
Ceratopogonidae	1	1 to 28	4
Chironomidae	75	32 to 84	77
Empididae	<1	0 to 4	<1
Tipulidae	1	0 to 1	<1
Tabanidae	<1	0 to <1	
Simuliidae		0 to 1	
Ephemeroptera	<1	<1 to 6	3
Anisoptera	<1	0 to <1	<1
Zygoptera		0 to <1	
Plecoptera	<1	0 to <1	<1
Trichoptera	<1	0 to <1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	59,328	6,322 to 66,707	24,405
Richness	26	10 to 32	22
Simpson's Diversity	0.75	0.68 to 0.87	0.78
Equitability	0.2	0.18 to 0.42	0.26
% EPT	<1	<1 to 6	3

Table 5.2-18 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the upper Muskeg River (*test* reach MUR-D3).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach MUR-D3		
	2002	2003 to 2011	2012
Hydra		0 to 1	
Nematoda	1	0 to 6	<1
Erpobdellidae	<1	0 to <1	<1
Glossiphoniidae	<1	0 to 3	<1
Naididae	<1	<1 to 7	<1
Tubificidae	<1	2 to 26	10
Enchytraeidae		0 to 1	
Lumbriculidae		0 to 2	<1
Hydracarina	<1	0 to 15	17
Amphipoda	<1	<1 to 5	<1
Ostracoda	4	0 to 9	24
Cladocera		0 to 2	<1
Copepoda		0 to 5	4
Gastropoda	<1	0 to 2	<1
Bivalvia	28	0 to 18	11
Coleoptera		0 to 1	<1
Ceratopogonidae	<1	0 to 2	<1
Chironomidae	66	27 to 79	31
Tabanidae	<1	0 to 1	
Tipulidae		0 to 2	
Simuliidae		0 to <1	
Ephemeroptera		<1 to 7	<1
Anisoptera		0 to <1	<1
Plecoptera		0 to 1	
Trichoptera	<1	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	9,905	6,087 to 15,887	23,731
Richness	12	9 to 17	17
Simpson's Diversity	0.64	0.68 to 0.84	0.79
Equitability	0.26	0.40 to 0.52	0.39
% EPT	<1	<1 to 5	<1

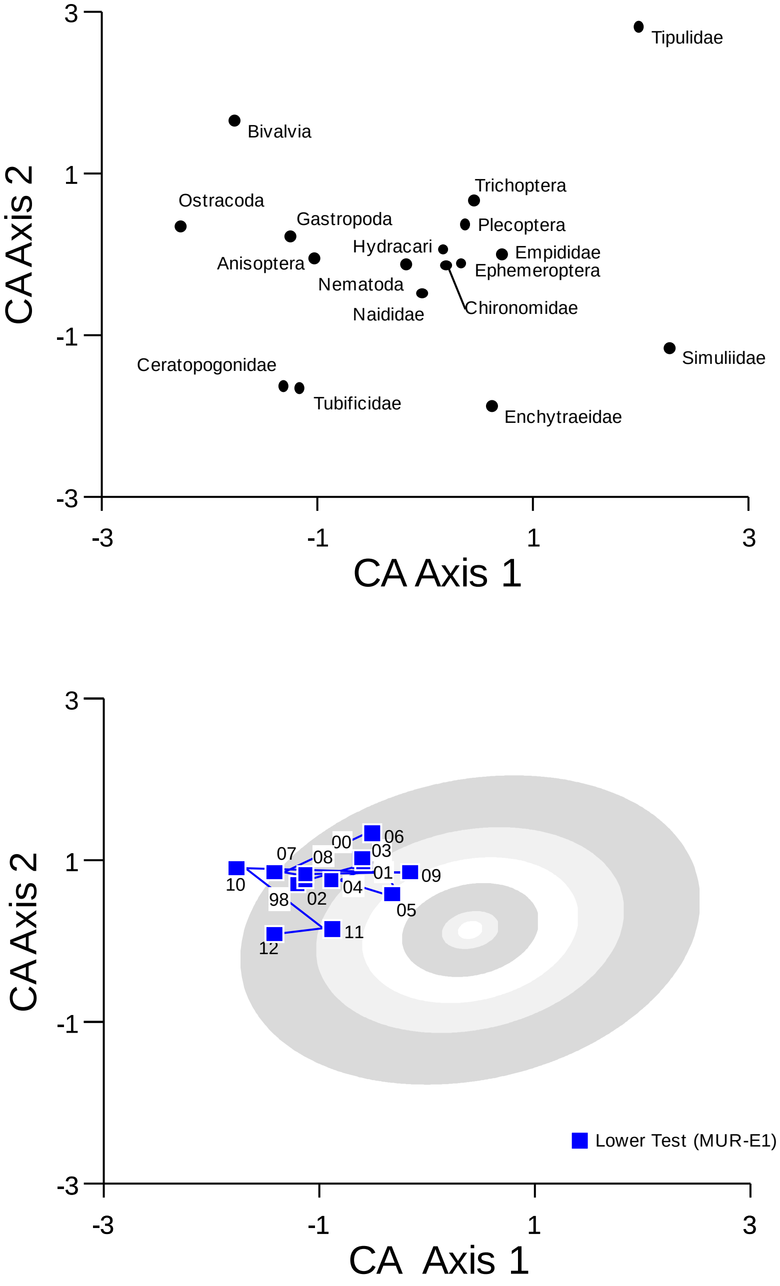
Table 5.2-19 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River, *test* reach MUR-E1.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time trend (*test* period)	2012 vs. Previous Years	Time trend (*test* period)	2012 vs. Previous Years	
Abundance	**<0.001**	**<0.001**	13	14	Increasing over time; higher in 2012 than mean of previous years.
Richness	0.692	0.979	0	0	No change
Simpson's Diversity	0.796	0.207	0	3	No change
Equitability	0.174	0.429	2	1	No change
EPT	0.090	**<0.001**	2	13	Lower in 2012 than mean of previous years.
CA Axis 1	**0.002**	**<0.001**	6	11	Increasing over time; lower in 2012 than mean of previous years.
CA Axis 2	**0.007**	**<0.000**	17	34	Decreasing over time; lower in 2012 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).

Figure 5.2-11 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Muskeg River (*test* reach MUR-E1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* data.

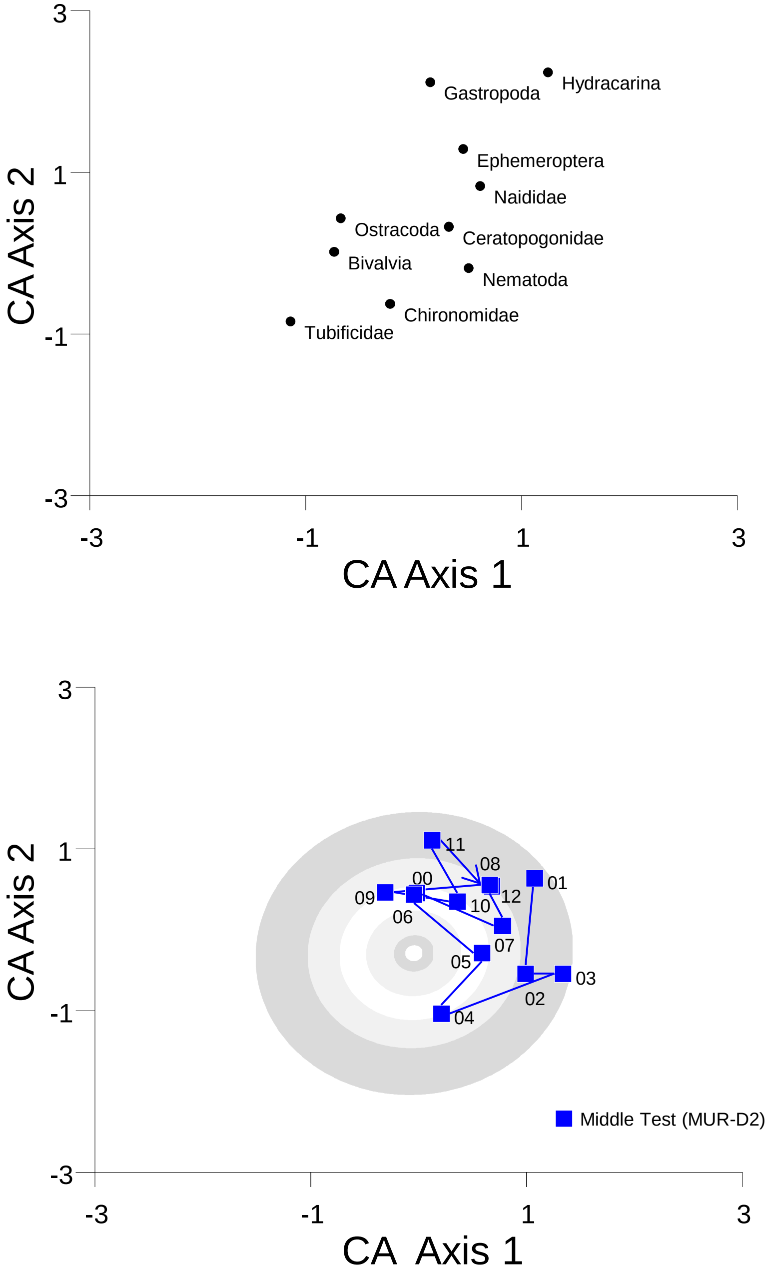
Table 5.2-20 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River, *test* reach MUR-D2.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time trend (*test* period)	**2012 vs. Previous Years**	**Time trend (*test* period)**	**2012 vs. Previous Years**	
Abundance	0.214	0.800	1	0	No change.
Richness	**0.050**	0.842	3	0	Increasing over time.
Simpson's Diversity	0.085	0.790	6	0	No change.
Equitability	0.752	0.208	0	0	No change.
EPT	**0.002**	0.912	16	0	Increasing over time.
CA Axis 1	**0.044**	0.544	9	1	Decreasing over time.
CA Axis 2	**<0.001**	0.134	▨ 20	3	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).

Figure 5.2-12 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Muskeg River, *test* reach MUR-D2.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

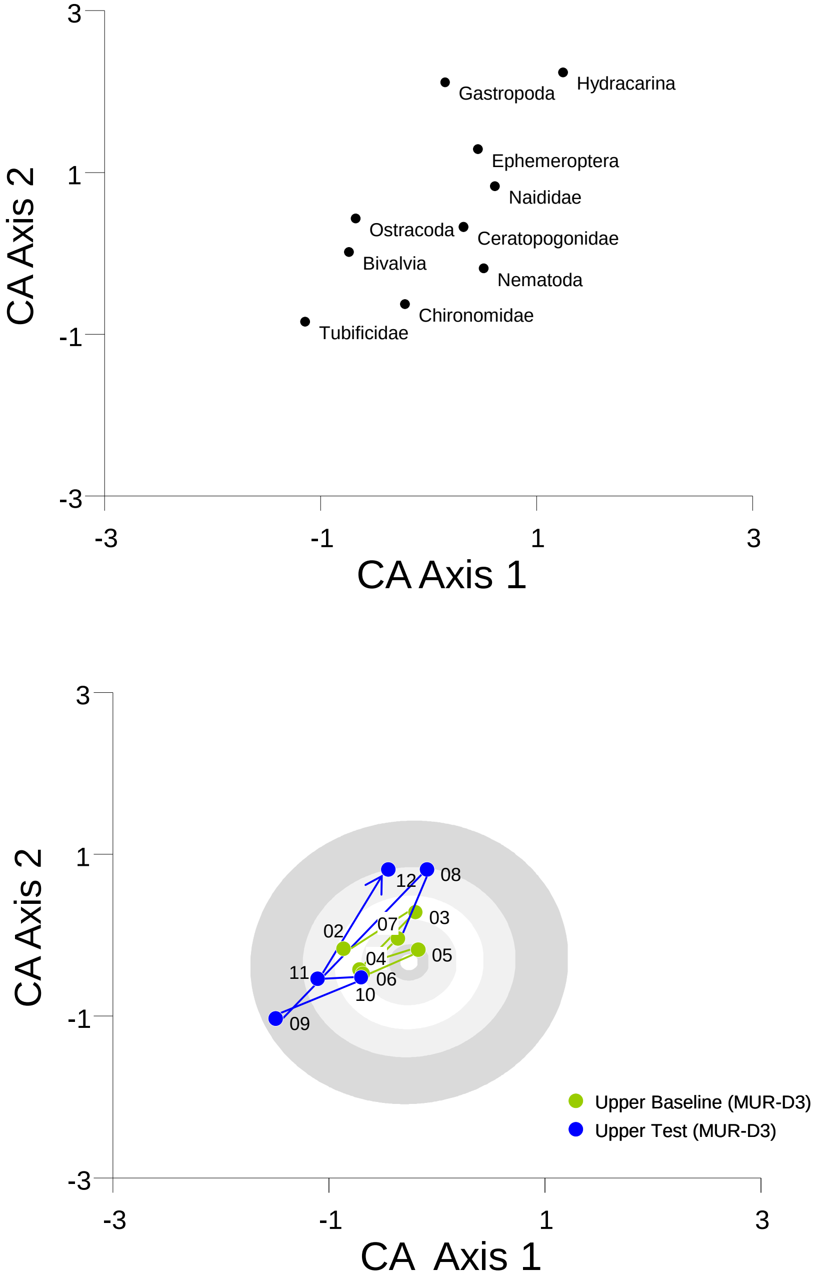
Table 5.2-21 Results of analysis of variance (ANOVA) testing differences in benthic invertebrate community measurement endpoints in the Muskeg River, *test* reach MUR-D3.

Variable	P-value				Variance Explained (%)				Nature of Change(s)
	Baseline Period vs. *Test* Period	Time Trend (*test* period)	2012 vs. *Baseline* Years	2012 vs. Previous Years	*Baseline* Period vs. *Test* Period	Time Trend (*test* period)	2012 vs. *Baseline* Years	2012 vs. Previous Years	
Abundance	0.842	0.072	0.051	**0.033**	0	21	24	29	Higher in 2012 than previous years.
Richness	0.103	0.220	0.373	0.148	11	6	3	9	No change.
Simpson's Diversity	0.282	0.178	0.565	0.340	5	7	1	4	No change.
Equitability	0.447	0.447	0.500	0.319	2	2	1	3	No change.
EPT	**0.027**	**0.012**	**0.022**	**0.035**	17	22	18	15	Decreasing over time during *test* period.
CA Axis 1	**0.046**	0.651	0.834	0.424	11	1	0	2	Lower in *test* period.
CA Axis 2	0.574	0.488	**<0.001**	**<0.001**	1	1	25	30	Higher in 2012 than mean of *baseline* years; higher than mean of previous sampling years.

Bold values indicate significant difference (p<0.05).

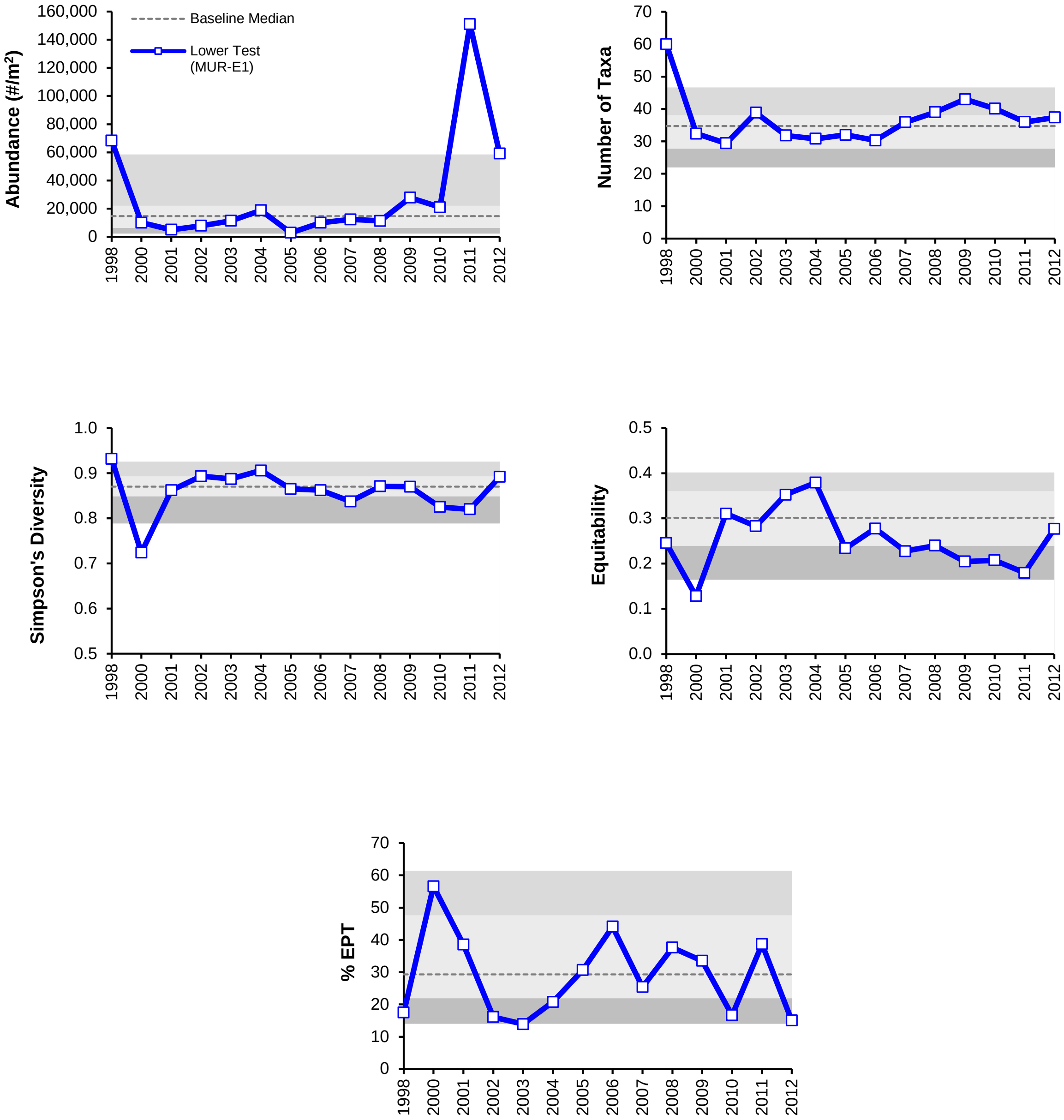
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.2-13 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Muskeg River, *test* reach MUR-D3.



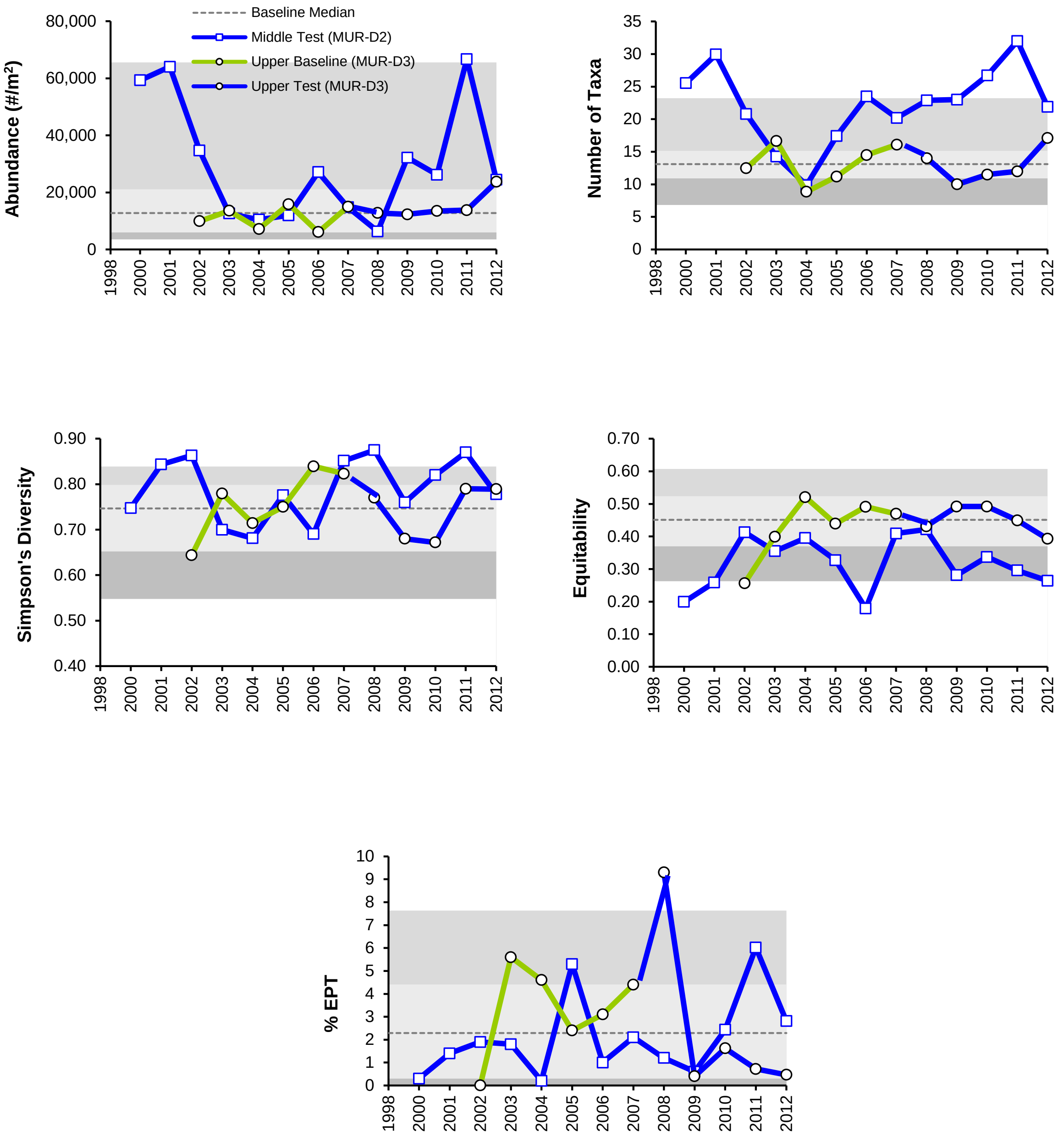
Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Figure 5.2-14 Variation in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-E1).



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.2-15 **Variation in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D2 and test reach MUR-D3).**



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Note: *Test* reach MUR-D3 was designated as *baseline* from 2002 to 2007.

Table 5.2-22 Average habitat characteristics of benthic invertebrate sampling locations in Jackpine Creek, fall 2012.

Variable	Units	JAC-D1 Lower *Test* Reach of Jackpine Creek	JAC-D2 Upper *Baseline* Reach of Jackpine Creek
Sample date	-	13-Sept-2012	11-Sept-2012
Habitat	-	Depositional	Depositional
Water depth	m	1.3	1.3
Current velocity	m/s	0.72	0.81
Field Water Quality			
Dissolved oxygen	mg/L	8.7	8.2
Conductivity	µS/cm	162	100
pH	pH units	7.5	7.5
Water temperature	°C	9.5	10.4
Sediment Composition			
Sand	%	79	89
Silt	%	17	6
Clay	%	4	5
Total Organic Carbon	%	3.00	0.76

Table 5.2-23 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Jackpine Creek (*test* reach JAC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach JAC-D1		
	2002	**2003 to 2011**	**2012**
Hydra		0 to 1	
Nematoda	5	1 to 6	11
Naididae	<1	0 to 8	<1
Tubificidae	<1	<1 to 17	3
Enchytraeidae	<1	0 to 4	18
Lumbriculidae			<1
Glossiphoniidae		0 to <1	
Hydracarina	1	1 to 8	2
Amphipoda		0 to <1	
Ostracoda	<1	0 to 4	2
Cladocera		0 to 15	3
Copepoda	<1	0 to 6	
Gastropoda	<1	0 to 4	1
Bivalvia	1	0 to 3	1
Coleoptera		0 to <1	
Ceratopogonidae	2	0 to 13	16
Chironomidae	88	51 to 86	38
Dolichopodidae			<1
Empididae	<1	1 to 4	<1
Muscidae			<1
Tipulidae	<1	0 to 2	1
Tabanidae	<1	<1 to 1	<1
Ephemeroptera	<1	0 to 7	<1
Anisoptera	<1	0 to <1	<1
Plecoptera		0 to 1	
Trichoptera	<1	<1 to 3	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	28,172	4,017 to 105,500	17,522
Richness	15	7 to 31	21
Simpson's Diversity	0.79	0.58 to 0.87	0.78
Equitability	0.38	0.34 t 0.56	0.40
% EPT	<1	<1 to 3	1

Table 5.2-24 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Jackpine Creek (*baseline* reach JAC-D2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach JAC-D2		
	2003	2004 to 2011	2012
Hydra		0 to <1	
Nematoda	6	<1 to 5	5
Oligochaeta			<1
Naididae	3	0 to 9	<1
Tubificidae	2	1 to 5	13
Enchytraeidae	1	<1 to 2	5
Lumbricidae			<1
Lumbriculidae			<1
Erpobdellidae			<1
Glossiphoniidae		0 to <1	<1
Hydracarina	<1	0 to 18	1
Ostracoda	<1	0 to 3	<1
Cladocera		0 to 7	<1
Copepoda		0 to 3	<1
Amphipoda			<1
Gastropoda		0 to 1	1
Bivalvia	<1	0 to 3	13
Coleoptera	6	1 to 6	7
Ceratopogonidae	1	2 to 31	13
Chironomidae	67	3 to 69	28
Dolichopodidae			<1
Empididae	1	0 to 3	<1
Tipulidae	1	0 to 13	1
Tabanidae	1	<1 to 2	<1
Ephemeroptera	<1	1 to 19	<1
Anisoptera		0 to <1	
Plecoptera	<1	0 to <1	
Trichoptera	<1	1 to 7	4
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	4,787	2,752 to 26,179	5,452
Richness	12	10 to 25	17
Simpson's Diversity	0.8	0.68 to 0.89	0.83
Equitability	0.59	0.46 to 0.61	0.42
% EPT	2	<1 to 21	5

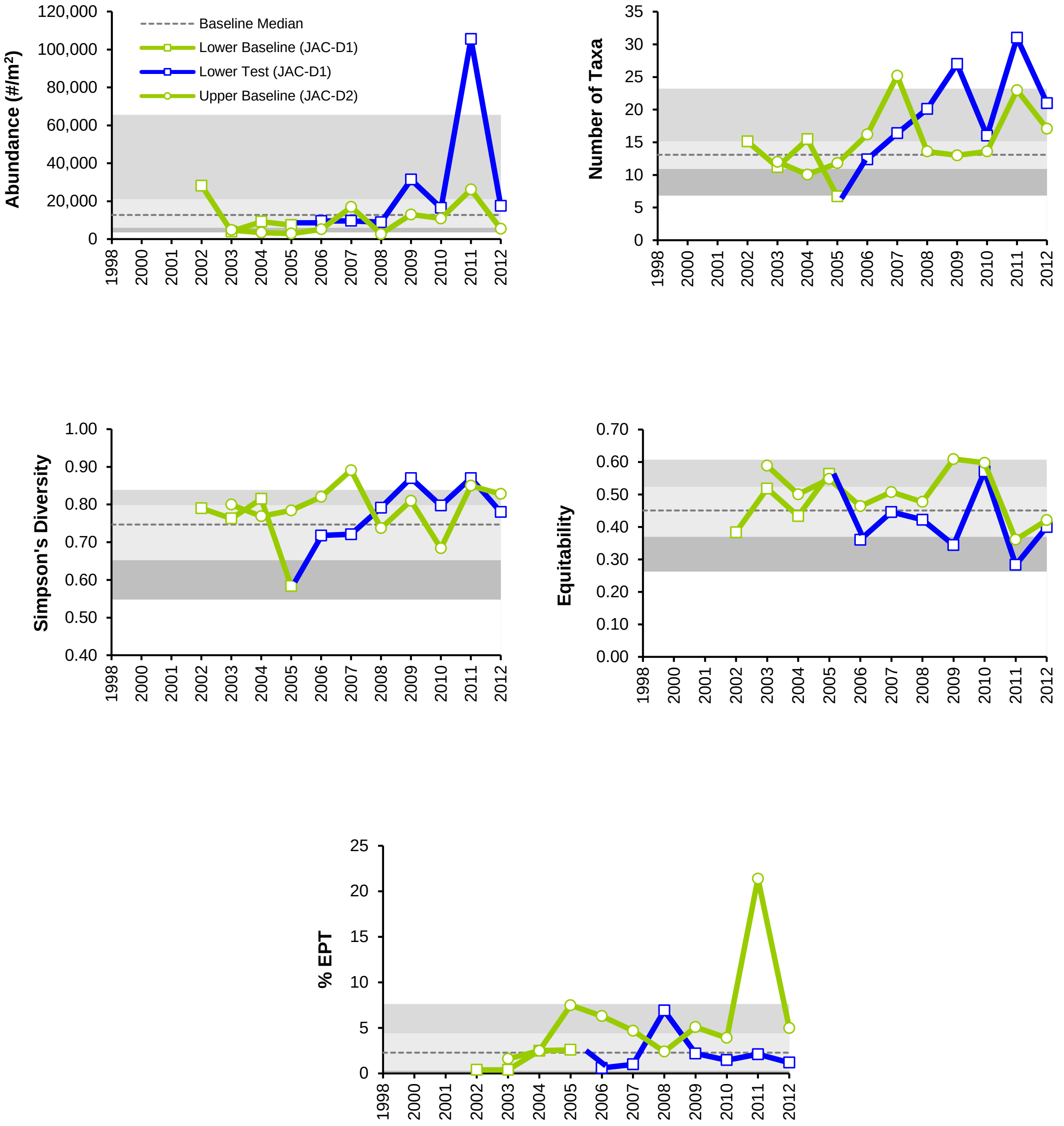
Table 5.2-25 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints between *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.

Variable	P-value							Variance Explained (%)							Nature of Change(s)
	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Differences at *Baseline* and *Test* Reaches from Before to After Lower Reach was Designated as *Test***	**Time Trend (*test* period)**	**Difference in Time Trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Differences at *Baseline* and *Test* Reaches from Before to After Lower Reach was Designated as *Test***	**Time Trend (*test* period)**	**Difference in Time Trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	**0.002**	**<0.001**	0.240	**<0.001**	0.463	**0.001**	0.145	6	36	1	14	0	7	1	Higher at lower reach during *test* period; increasing over time at both reaches; higher in 2012 than mean of all *baseline* years
Richness	0.300	**<0.001**	**0.025**	**0.033**	**0.038**	0.097	0.242	1	28	5	5	5	3	1	Higher during *test* period; increasing over time at both reaches but at a greater rate at *test* reach; difference between reaches from before to after lower reach was designated as *test* (higher at lower reach).
Simpson's Diversity	0.247	0.083	0.171	0.269	0.124	0.722	0.904	3	8	5	3	6	0	0	No change.
Equitability	**0.046**	**0.023**	0.168	0.077	0.119	0.100	0.641	8	10	4	6	5	5	0	Higher at *baseline* reach; higher during period when lower reach was designated as *baseline*.
EPT	**<0.001**	0.595	0.345	0.786	0.761	**<0.001**	0.050	19	0	1	0	0	13	4	Higher at *baseline* reach; lower in 2012 than mean of previous years.
CA Axis 1	0.491	0.586	0.636	**<0.001**	**0.002**	**<0.001**	**<0.001**	1	0	0	23	15	30	46	Increasing over time at *test* reach; decreasing over time at *baseline* reach; higher in 2012 than mean of *baseline* years or mean of all previous years.
CA Axis 2	0.312	**0.001**	0.164	0.122	0.960	0.093	0.052	1	9	2	2	0	2	3	Higher at both reaches during period when lower reach was designated as *baseline*.

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).

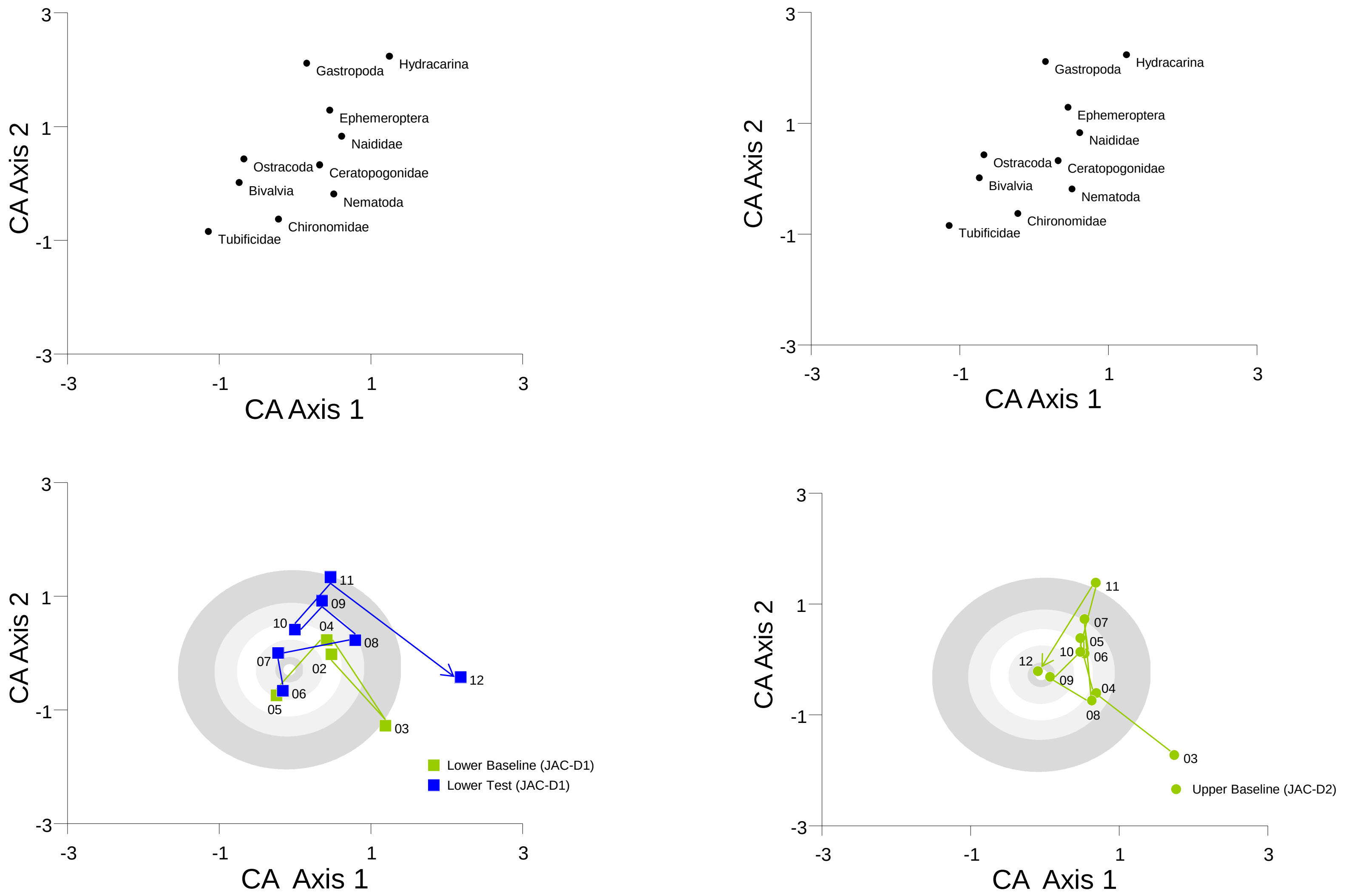
Figure 5.2-16 Variations in benthic invertebrate community measurement endpoints in *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Note: *Test* reach JAC-D1 was designated as *baseline* from 2002 to 2005.

Figure 5.2-17 Ordination (Correspondence Analysis) of benthic invertebrate community composition in *test* reach JAC-D1, and *baseline* reach JAC-D2 of Jackpine Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Table 5.2-26 Average habitat characteristics of benthic invertebrate community sampling locations in Kearl Lake, fall 2012.

Variable	Units	Kearl Lake
Sample date	-	08-Sept-2012
Habitat	-	Depositional
Water depth	m	1.4
Field Water Quality		
Dissolved oxygen	mg/L	8.9
Conductivity	µS/cm	171
pH	pH units	10.47
Water temperature	°C	15.7
Sediment Composition		
Sand	%	17
Silt	%	70
Clay	%	13
Total Organic Carbon	%	31.1

Table 5.2-27 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Kearl Lake (*test* station KEL-1).

Taxon	**Percent Major Taxa Enumerated in Each Year**		
	KEL-1		
	2001	**2002 to 2011**	**2012**
Nematoda		0 to 5	<1
Erpobdellidae		0 to <1	
Glossiphoniidae	<1	0 to <1	<1
Naididae		<1 to 20	2
Tubificidae		0 to 2	
Lumbriculidae		0 to <1	
Hydracarina	<1	0 to 16	<1
Amphipoda	13	2 to 58	10
Ostracoda	7	0 to 25	14
Cladocera	1	0 to 14	1
Copepoda	<1	0 to 56	26
Gastropoda	1	0 to 1	<1
Bivalvia	4	4 to 23	7
Ceratopogonidae		0 to 1	<1
Chaoboridae	1	0 to <1	<1
Chironomidae	6	13 to 46	36
Ephemeroptera	<1	0 to 2	1
Anisoptera		0 to <1	<1
Trichoptera	2	0 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	891	3,209 to 17,405	11,318
Richness	7	7 to 17	15
Simpson's Diversity	0.73	0.49 to 0.76	0.77
Equitability	0.92	0.29 to 0.74	0.45
% EPT	3	<1 to 2	2

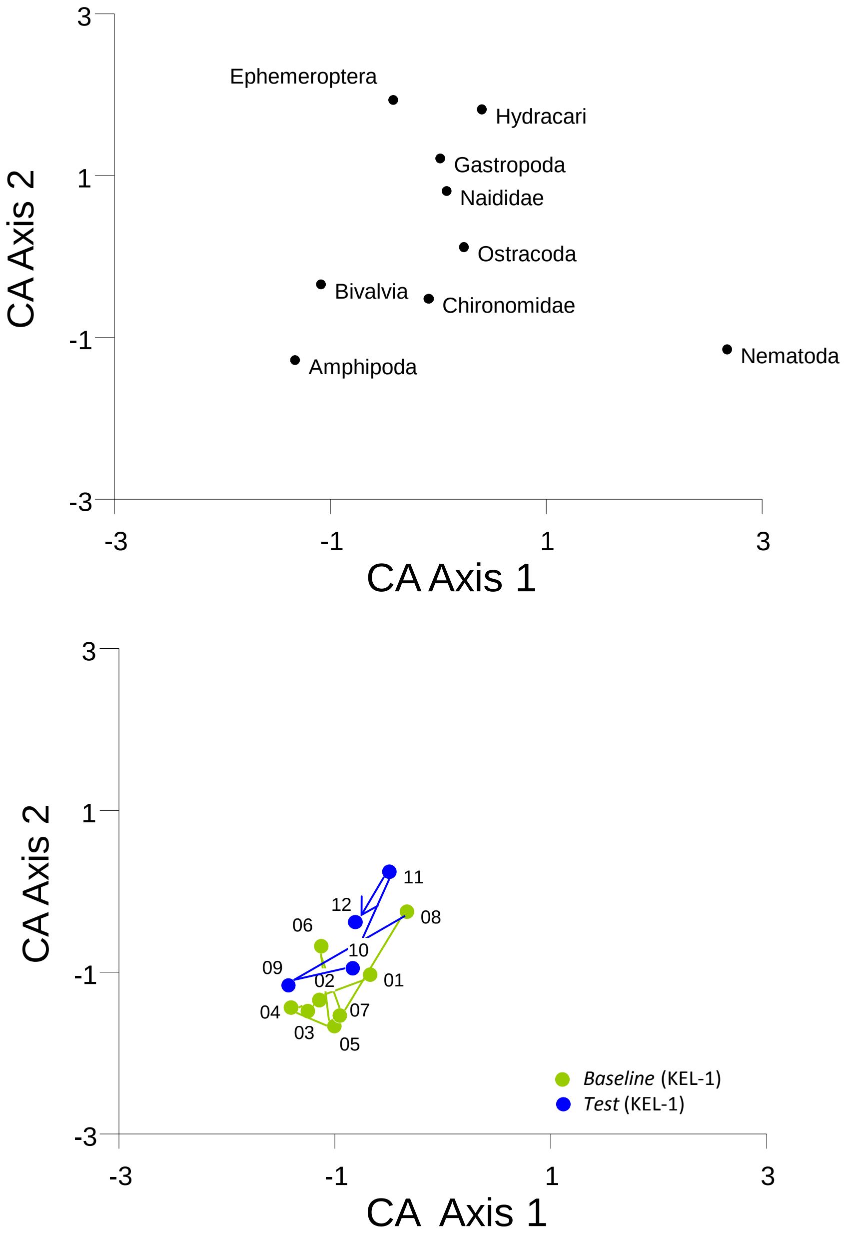
Table 5.2-28 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Kearl Lake.

Variable	P-value				Variance Explained (%)				Nature of Change(s)
	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	0.055	0.257	**0.043**	0.066	6	2	7	5	Higher in 2012 than mean of *baseline* years.
Richness	0.103	0.265	0.056	0.076	8	4	11	9	No change.
Simpson's Diversity	0.298	**0.015**	0.057	0.058	4	21	13	12	Increasing over time in *test* period.
Equitability	0.271	0.343	0.623	0.757	3	2	1	0	No change.
EPT	**0.011**	0.104	0.630	0.985	25	10	1	0	Higher during *baseline* period.
CA Axis 1	0.514	**0.036**	0.480	0.520	2	19	2	2	Increasing over time in *test* period.
CA Axis 2	**0.001**	**0.006**	**0.009**	**0.030**	26	16	15	10	Increasing over time in *test* period; higher during *test* period; higher in 2012 than mean of *baseline* years and mean of previous sampling 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).

Figure 5.2-18 Ordination (Correspondence Analysis) of benthic invertebrate communities in Kearl Lake (KEL-1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Figure 5.2-19 Variations in benthic invertebrate community measurement endpoints in Kearl Lake (KEL-1).

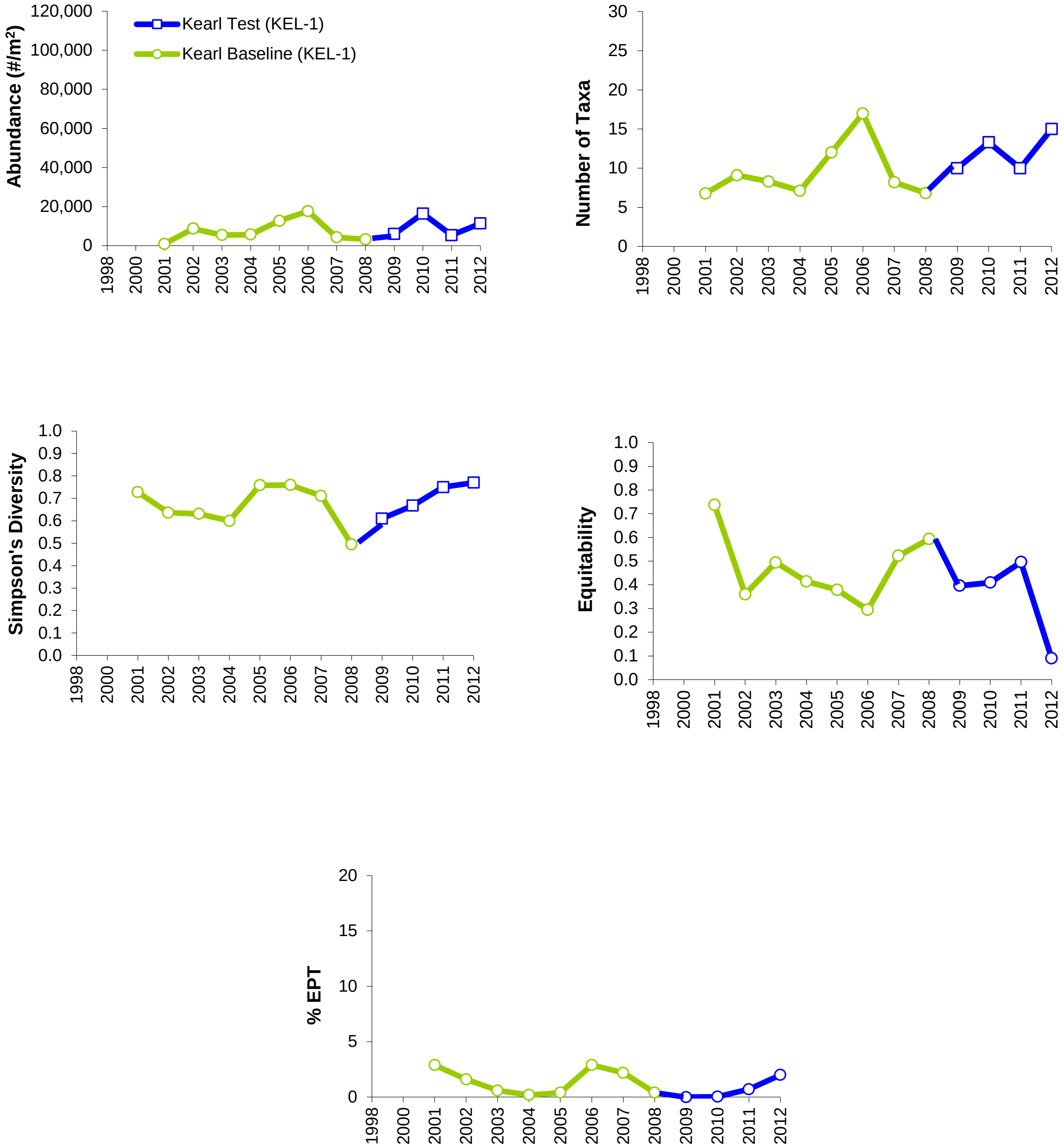


Table 5.2-29 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D2), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	8	1	7	12
Silt	%	-	14	8	8	20	32
Sand	%	-	82	8	60	73	88
Total organic carbon	%	-	2.2	9	1.1	3.3	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<20	8	<5	<8	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	8	<5	<8	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	42	8	<5	69.5	**180**
Fraction 3 (C16-C34)	mg/kg	300[1]	**801**	8	110	**1,140**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	695	8	62	1,135	2,100
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.001	10	0.001	0.002	0.020
Retene	mg/kg	-	0.041	10	0.012	0.165	0.314
Total dibenzothiophenes	mg/kg	-	1.09	10	0.287	4.31	11.0
Total PAHs	mg/kg	-	4.79	10	0.904	14.8	30.4
Total Parent PAHs	mg/kg	-	0.143	10	0.029	0.339	0.676
Total Alkylated PAHs	mg/kg	-	4.64	10	0.875	14.4	29.8
Predicted PAH toxicity[3]	H.I.	1.0	0.917	10	0.731	**1.45**	**4.00**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	7	2.6	7.0	8.6
Chironomus growth - 10d	mg/organism	-	-	7	0.7	2.1	2.5
Hyalella survival - 14d	# surviving	-	-	7	8.0	8.0	9.2
Hyalella growth - 14d	mg/organism	-	-	7	0.1	0.2	0.4

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic 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 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.5	8	5.0	6.8	47.0
Silt	%	-	28	8	6	13	29
Sand	%	-	67	8	26	80	85
Total organic carbon	%	-	24.5	9	1.7	22.2	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<80	8	<5	<5	<73
Fraction 1 (C6-C10)	mg/kg	30[1]	<80	8	<5	<5	<73
Fraction 2 (C10-C16)	mg/kg	150[1]	<83	8	<5	37	130
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,020**	8	52	**726**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	427	8	71	315.5	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0030</u>	9	0.0031	0.0075	0.0145
Retene	mg/kg	-	0.626	9	0.016	0.349	2.33
Total dibenzothiophenes	mg/kg	-	0.141	9	0.048	0.123	0.190
Total PAHs	mg/kg	-	1.54	9	0.379	1.12	3.11
Total Parent PAHs	mg/kg	-	0.056	9	0.030	0.048	0.340
Total Alkylated PAHs	mg/kg	-	1.49	9	0.349	0.968	3.05
Predicted PAH toxicity[3]	H.I.	1.0	0.303	9	0.025	0.284	0.791
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	6	3.0	6.5	8.8
Chironomus growth - 10d	mg/organism	-	-	6	1.3	1.6	2.2
Hyalella survival - 14d	# surviving	-	-	6	7.0	8.2	9.2
Hyalella growth - 14d	mg/organism	-	-	6	0.1	0.2	0.3

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic 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 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.6	8	0.7	3.5	18.7
Silt	%	-	19.9	8	0.3	7.8	13.0
Sand	%	-	74.5	8	81.0	85.5	99.0
Total organic carbon	%	-	3.6	8	0.2	1.1	2.7
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	7	13	20	71
Fraction 3 (C16-C34)	mg/kg	300[1]	**552**	7	101	**450**	**790**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	808	7	137	530	820
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<0.0014	8	0.0003	0.0012	0.0030
Retene	mg/kg	-	0.025	7	0.007	0.037	0.951
Total dibenzothiophenes	mg/kg	-	0.250	8	0.105	0.467	1.64
Total PAHs	mg/kg	-	1.27	8	0.413	1.45	4.49
Total Parent PAHs	mg/kg	-	0.065	8	0.015	0.046	0.136
Total Alkylated PAHs	mg/kg	-	1.20	8	0.391	1.41	4.38
Predicted PAH toxicity[3]	H.I.	1.0	0.248	8	0.214	0.462	**1.33**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.6	6	5.6	7.5	8.8
Chironomus growth - 10d	mg/organism	-	2.14	6	1.15	2.77	3.40
Hyalella survival - 14d	# surviving	-	8.6	6	7.0	9.5	9.8
Hyalella growth - 14d	mg/organism	-	0.15	6	0.14	0.27	0.31

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic 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 2012.

Variables	**Units**	**Guideline**	**September 2012**	**2001-2011 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5	5	1	8	13
Silt	%	-	8	5	<1	21	23
Sand	%	-	87	5	66	70	98
Total organic carbon	%	-	0.8	6	0.1	1.5	2.1
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	<5	14	<27
Fraction 3 (C16-C34)	mg/kg	300[1]	29	6	10	66	190
Fraction 4 (C34-C50)	mg/kg	2,800[1]	26	6	<5	55	160
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<0.0005	5	0.0005	0.0012	0.0041
Retene	mg/kg	-	0.010	5	0.001	0.015	0.033
Total dibenzothiophenes	mg/kg	-	0.014	5	0.002	0.007	0.016
Total PAHs	mg/kg	-	0.096	5	0.014	0.120	0.200
Total Parent PAHs	mg/kg	-	0.009	5	0.004	0.016	0.020
Total Alkylated PAHs	mg/kg	-	0.087	5	0.011	0.100	0.180
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.356</u>	5	0.135	0.226	0.354
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	5	4.6	8.2	9.6
Chironomus growth - 10d	mg/organism	-	1.97	5	0.80	2.26	3.05
Hyalella survival - 14d	# surviving	-	9.2	5	8.0	8.8	9.8
Hyalella growth - 14d	mg/organism	-	<u>0.25</u>	5	0.29	0.33	0.56

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic 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 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	14	6	1	10	58
Silt	%	-	70	6	4	31	62
Sand	%	-	16	6	9	54	93
Total organic carbon	%	-	27.3	8	5.04	34.0	38.1
Total hydrocarbons							
BTEX	mg/kg	-	<170	7	<5	<10	<220
Fraction 1 (C6-C10)	mg/kg	30[1]	<170	7	<5	<10	<220
Fraction 2 (C10-C16)	mg/kg	150[1]	<216	7	<5	30	**530**
Fraction 3 (C16-C34)	mg/kg	300[1]	**714**	7	230	**487**	**3,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	409	7	81	366	2,500
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.008	4	0.012	0.020	**0.036**
Retene	mg/kg	-	0.042	8	0.016	0.049	0.113
Total dibenzothiophenes	mg/kg	-	0.050	8	0.028	0.044	0.084
Total PAHs	mg/kg	-	0.737	8	0.723	0.933	1.46
Total Parent PAHs	mg/kg	-	0.102	8	0.078	0.129	0.345
Total Alkylated PAHs	mg/kg	-	0.634	8	0.642	0.767	1.34
Predicted PAH toxicity[3]	H.I.	1.0	0.141	8	0.031	0.323	0.924
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	4	8.4	8.8	9.0
Chironomus growth - 10d	mg/organism	-	1.50	4	1.16	1.26	1.45
Hyalella survival - 14d	# surviving	-	9.6	4	7.6	9.0	9.2
Hyalella growth - 14d	mg/organism	-	0.15	4	0.12	0.25	0.31

Values in **bold** indicate concentrations exceeding guidelines.

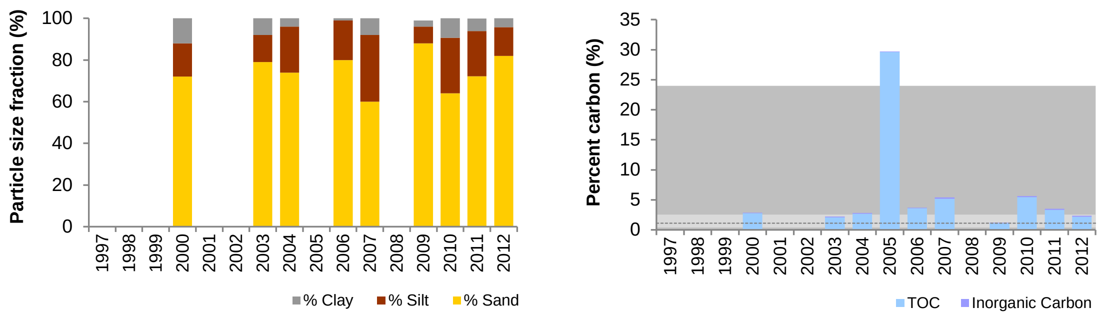
Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

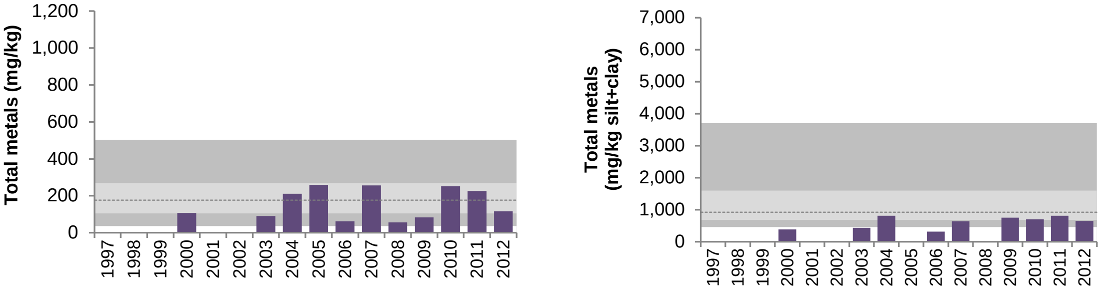
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-20 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D2.



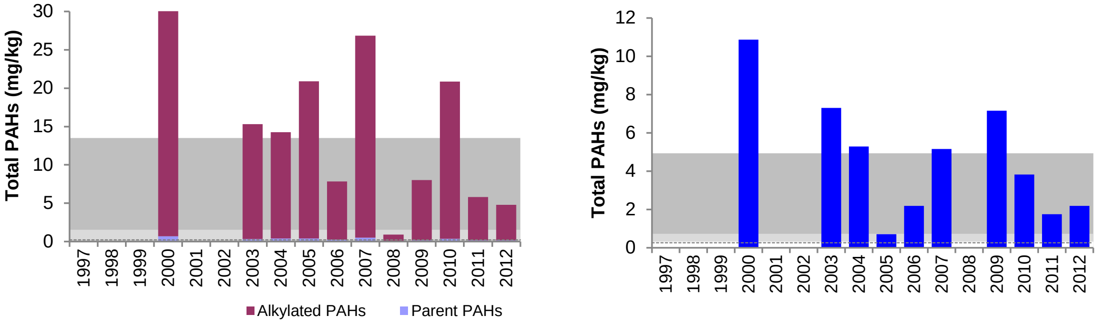
Particle size distribution

Carbon Content[1]



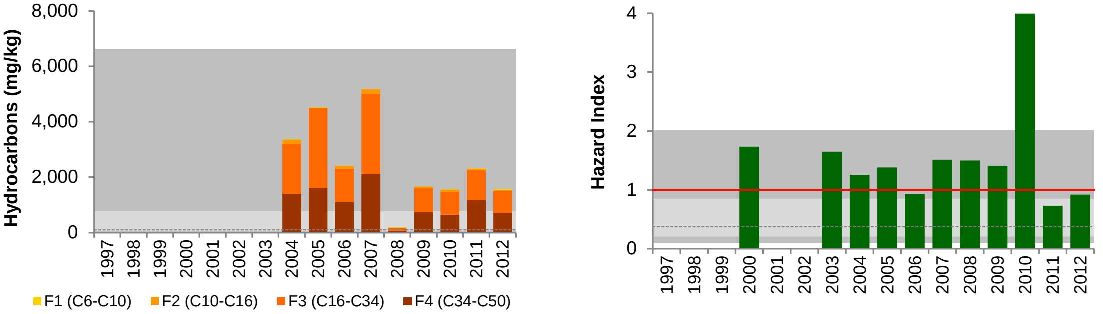
Total Metals[2]

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]

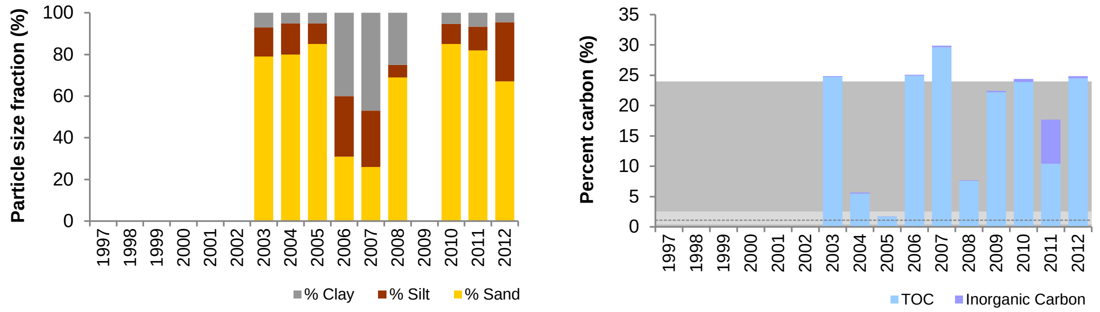
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2012).

[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).

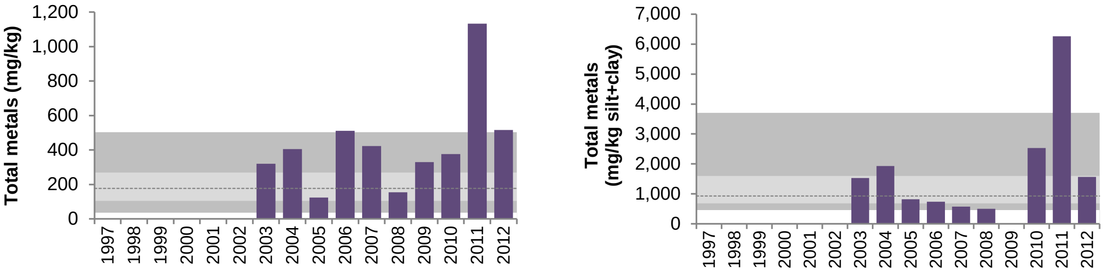
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-21 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D3.



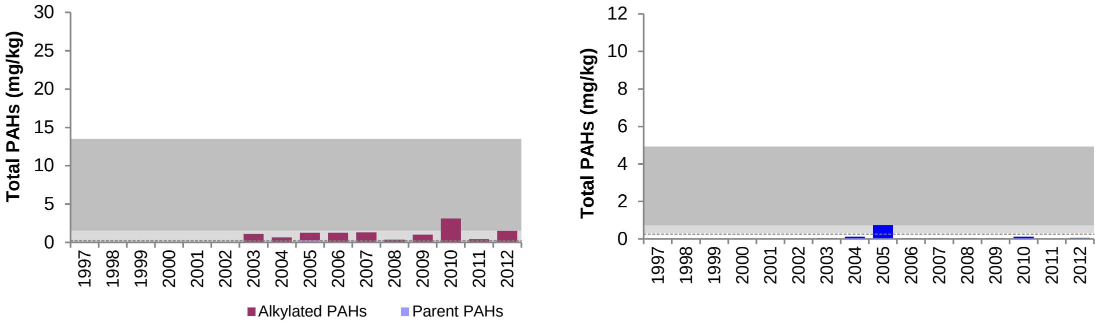
Particle size distribution

Carbon Content[1]



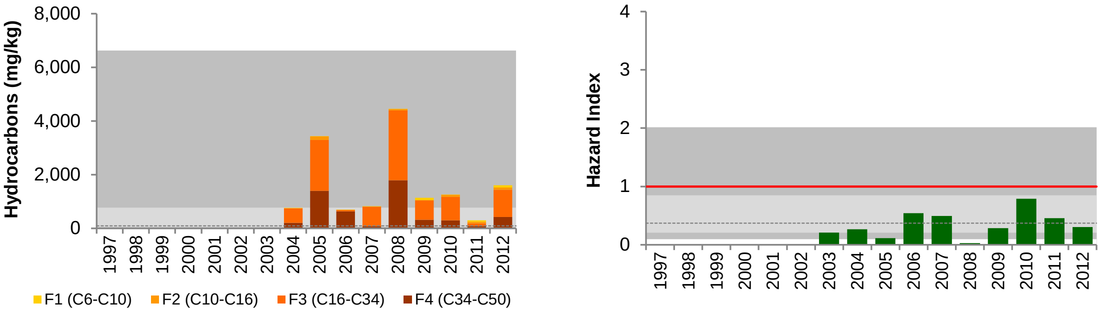
Total Metals[2]

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]

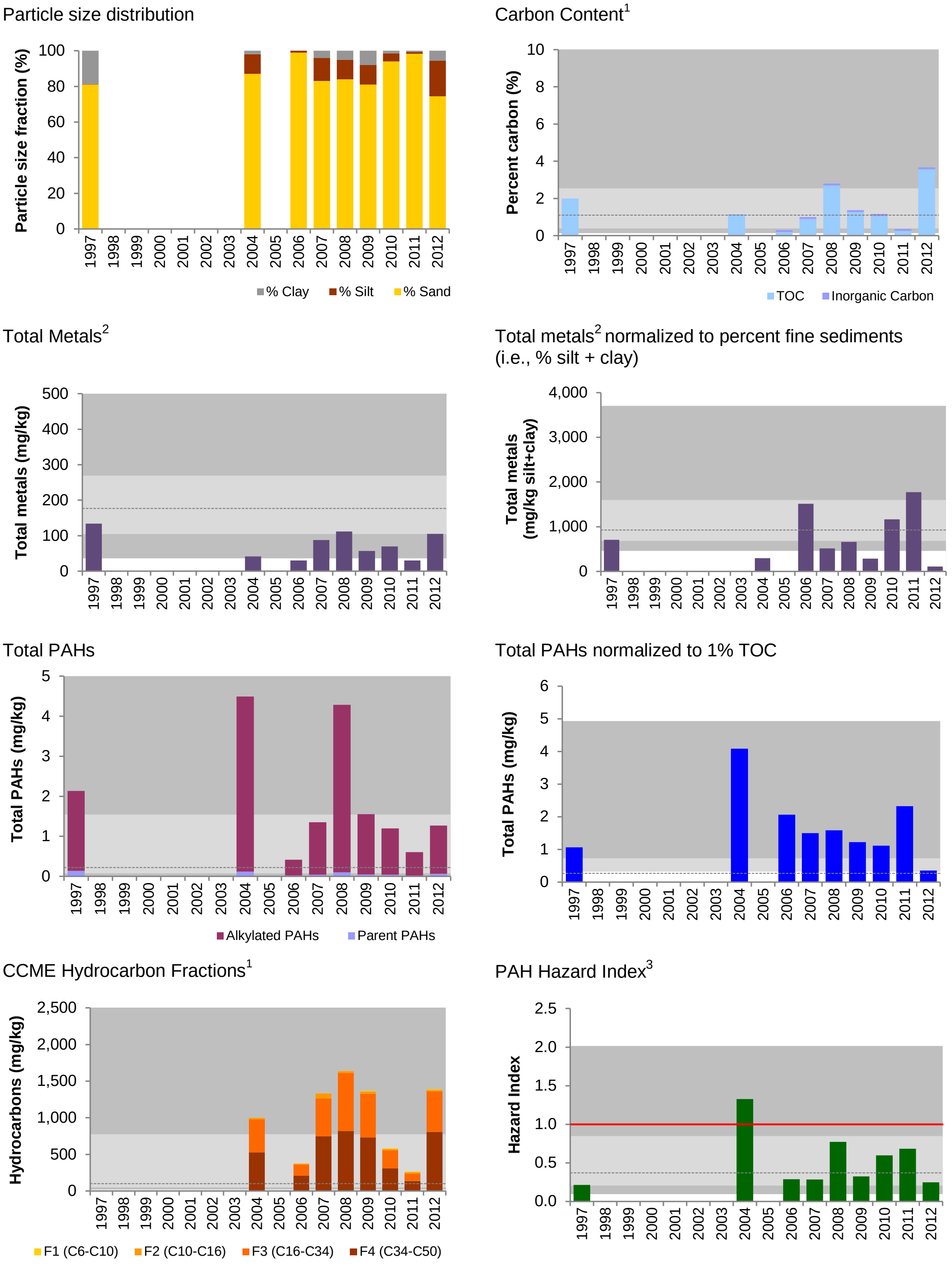
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2012).

[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 5.2-22 Variation in sediment quality measurement endpoints in Jackpine Creek, *test* station JAC-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 (1997-2012).

[1] Regional *baseline* values represent "total" values for multi-variable data.

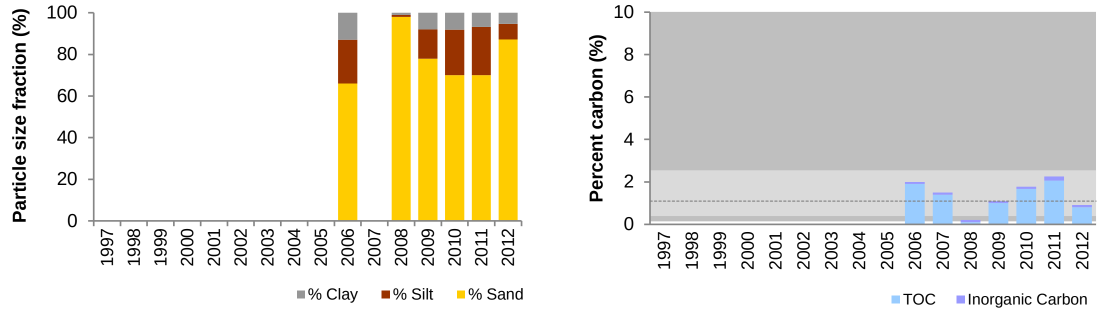
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-23 Variation in sediment quality measurement endpoints in Jackpine Creek, *baseline* station JAC-D2.

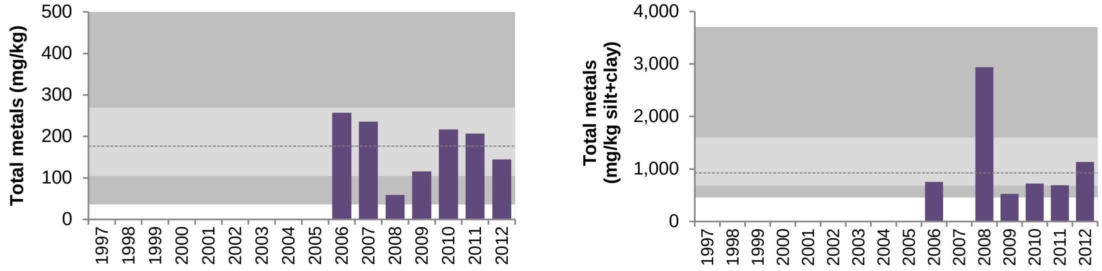
Particle size distribution

Carbon Content[1]



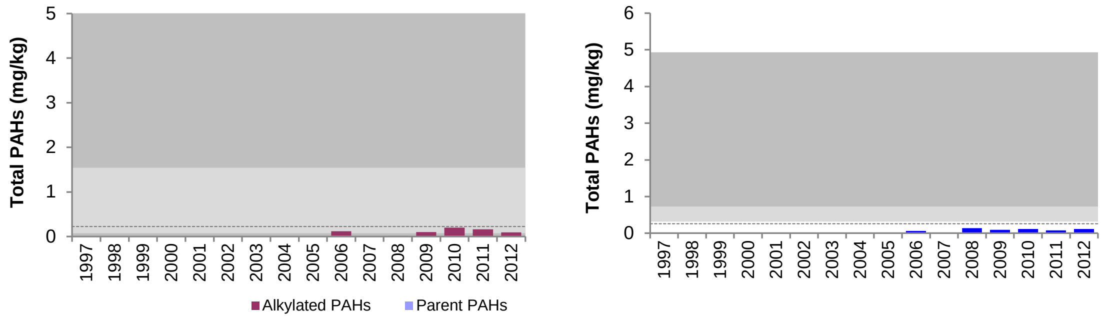
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



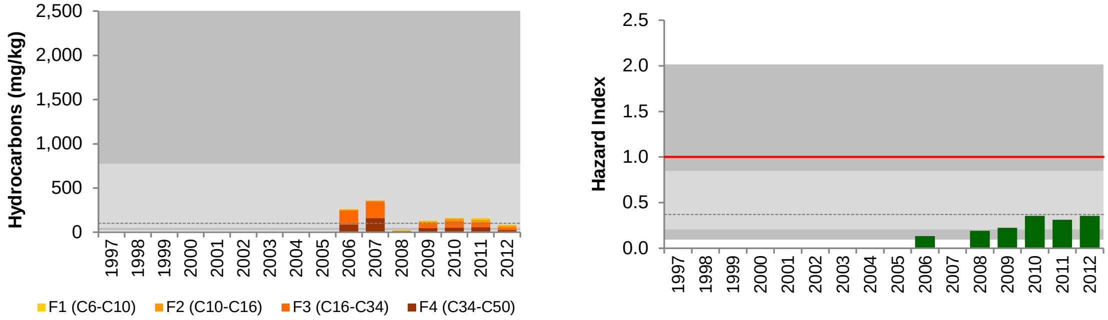
Total PAHs

Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]

PAH Hazard Index[3]



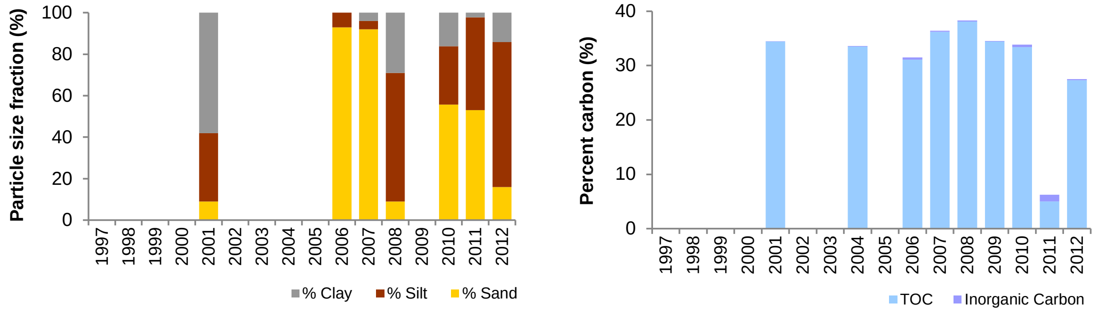
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2012).

[1] Regional *baseline* values represent "total" values for multi-variable data.

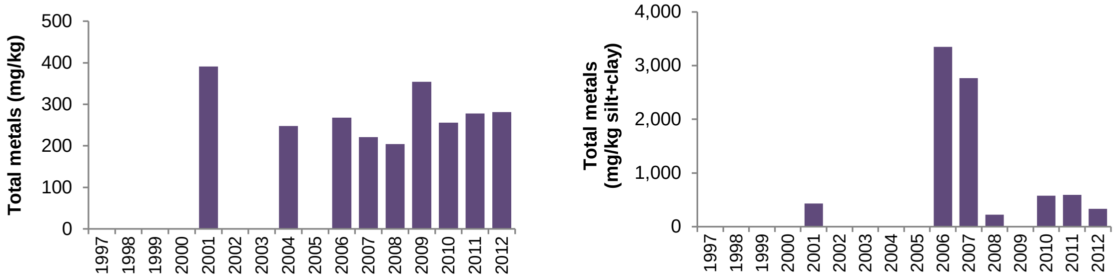
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

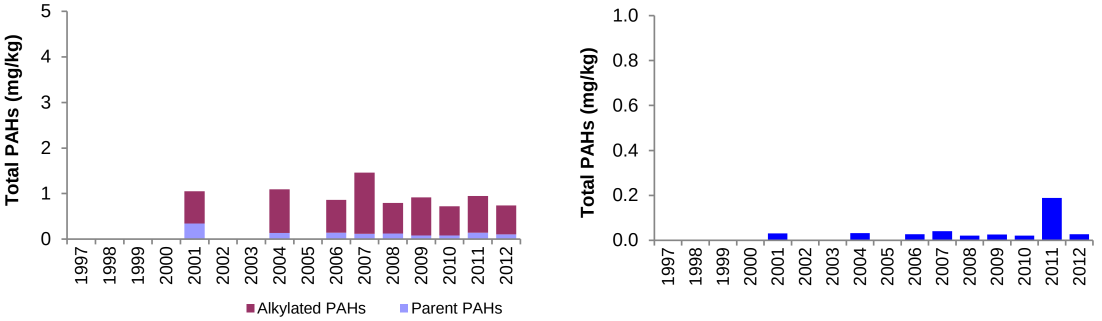
Figure 5.2-24 Variation in sediment quality measurement endpoints in Kearl Lake, *test* station KEL-1.


Particle size distribution

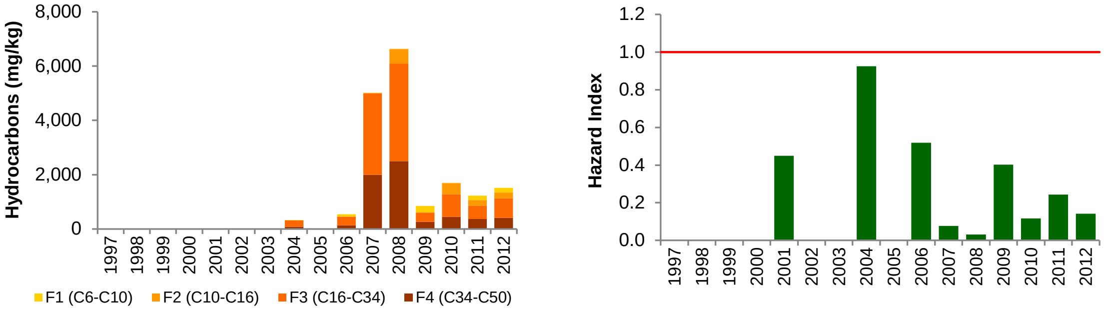
Carbon Content


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]

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[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 2012) for Muskeg River watershed stations.

Station	Location	2012 Designation	Sediment Quality Index	Classification
JAC-D1	mouth of Jackpine Creek	*test*	98.9	Negligible-Low
JAC-D2	upper Jackpine Creek	*baseline*	100.0	Negligible-Low
MUR-D2	Muskeg River at Canterra Road	*test*	97.7	Negligible-Low
MUR-D3	upper Muskeg River	*test*	92.9	Negligible-Low

Table 5.2-35 Average habitat characteristics of fish assemblage monitoring locations of the Muskeg River, fall 2012.

Variable	Units	MUR-F1 Lower *Test* Reach of Muskeg River	MUR-F2 Middle *Test* Reach of Muskeg River	MUR-F3 Upper *Test* Reach of Muskeg River
Sample date		11-Sept-2012	10-Sept-2012	15-Sept-2012
Habitat type	-	run/riffle	run	run
Maximum depth	m	1	1.5	2
Bankfull channel width	m	17.5	12.5	11.0
Wetted channel width	m	14.5	12.5	11.0
Substrate				
Dominant	-	coarse gravel	fines	-
Subdominant	-	cobble/fines	-	-
Instream cover				
Dominant	-	boulders	macrophytes	trees/roots, overhanging vegetation
Subdominant	-	small woody debris, undercut banks, overhanging vegetation	overhanging vegetation, filamentous algae, roots	macrophytes
Field water quality				
Dissolved oxygen	mg/L	8.6	8.85	4.6
Conductivity	µS/cm	305	294	214
pH	pH units	8.23	7.97	6.7
Water temperature	^{0}C	12.5	14.1	10.4
Water velocity				
Left bank velocity	m/s	0.26	0.10	0.30
Left bank water depth	m	0.16	1.45	1.00
Centre of channel velocity	m/s	0.55	0.35	ns
Centre of channel water depth	m	0.36	1.50	ns
Right bank velocity	m/s	0.37	0.35	0.30
Right bank water depth	m	0.98	1.50	2.00
Riparian cover – understory (< 5 m)				
Dominant	-	woody shrubs and samplings	woody shrubs and samplings	woody shrubs and samplings
Subdominant	-	overhanging vegetation	overhanging vegetation	overhanging vegetation

ns = not sampled, too deep to wade across the river to collect measurements.

Table 5.2-36 Percent composition and mean CPUE (catch per unit effort) of fish species in reaches of the Muskeg River and Jackpine Creek, 2009 to 2012.

Common Name	Code	Total Count															
		JAC-F1				JAC-F2				MUR-F1				MUR-F2		MUR-F3	
		2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2011	2012	2011	2012
Arctic grayling	ARGR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
brook stickleback	BRST	-	19	2	-	14	29	36	1	3	5	1	-	-	-	33	1
burbot	BURB	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
fathead minnow	FTMN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
finescale dace	FNDC	-	75	-	-	-	12	-	-	-	15	-	-	-	-	-	-
lake chub	LKCH	1	-	138	-	40	10	-	3	4	8	1	-	-	-	-	-
lake whitefish	LKWH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
longnose dace	LNDC	-	-	-	-	-	-	-	-	-	10	7	1	-	-	-	-
longnose sucker	LNSC	2	3	5	-	-	-	-	-	5	4	49	-	-	-	-	-
northern pike	NRPK	-	1	-	-	-	-	-	-	-	-	-	1	2	-	-	-
northern redbelly dace	NRDC	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
pearl dace	PRDC	-	21	-	-	3	9	50	-	-	35	2	-	-	-	2	-
slimy sculpin	SLSC	-	23	2	2	-	-	-	-	43	11	5	1	-	-	-	-
spoonhead sculpin	SPSC	-	-	-	-	-	-	-	-	1	3	-	1	-	-	-	-
spottail shiner	SPSH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
trout-perch	TRPR	-	9	5	-	-	-	-	-	-	-	-	-	-	-	-	-
walleye	WALL	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
white sucker	WHSC	4	16	2	-	2	1	15	-	-	2	5	-	1	-	-	-
yellow perch	YLPR	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
sucker sp. *		-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
unknown sp. *		-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Total Count		**7**	**167**	**154**	**2**	**59**	**61**	**103**	**4**	**58**	**93**	**71**	**6**	**3**	**0**	**39**	**1**
Total Species Richness		**3**	**8**	**6**	**1**	**4**	**5**	**4**	**2**	**7**	**9**	**8**	**5**	**2**	**0**	**3**	**1**
Electrofishing effort (secs)		**2,221**	**3,863**	**1,052**	**1,590**	**1,352**	**4,183**	**973**	**1,316**	**2,051**	**4,623**	**1,267**	**1,526**	**1,178**	**1,841**	**1,297**	**1,763**
CPUE (#/100 secs)		**0.32**	**4.32**	**14.64**	**0.13**	**4.36**	**1.46**	**10.59**	**0.3**	**2.78**	**2.01**	**5.6**	**0.39**	**0.25**	**0**	**3.01**	**0.06**

* Not included in total species richness.

Table 5.2-36 (Cont'd.)

		Percent of Total Catch															
Common Name	**Code**	**JAC-F1**				**JAC-F2**				**MUR-F1**				**MUR-F2**		**MUR-F3**	
		2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Arctic grayling	ARGR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
brook stickleback	BRST	0	11.4	1.3	0	23.7	47.5	35.0	25.0	5.2	5.4	1.4	0	0	0	84.6	100.0
burbot	BURB	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0
fathead minnow	FTMN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	0	44.9	0	0	0	19.7	0	0	0	16.1	0	0	0	0	0	0
lake chub	LKCH	14.3	0	89.6	0	67.8	16.4	0	75.0	6.9	8.6	1.4	0	0	0	0	0
lake whitefish	LKWH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
longnose dace	LNDC	0	0	0	0	0	0	0	0	0	10.8	9.9	16.7	0	0	0	0
longnose sucker	LNSC	28.6	1.8	3.2	0	0	0	0	0	8.6	4.3	69.0	0	0	0	0	0
northern pike	NRPK	0	0.6	0	0	0	0	0	0	0	0	0	16.7	66.7	0	0	0
northern redbelly dace	NRDC	0	0	0	0	0	0	1.9	0	0	0	0	0	0	0	0	0
pearl dace	PRDC	0	12.6	0	0	5.1	14.8	48.5	0	0	37.6	2.8	0	0	0	5.1	0
slimy sculpin	SLSC	0	13.8	1.3	100.0	0	0	0	0	74.1	11.8	7.0	16.7	0	0	0	0
spoonhead sculpin	SPSC	0	0	0	0	0	0	0	0	1.7	3.2	0	16.7	0	0	0	0
spottail shiner	SPSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
trout-perch	TRPR	0	5.4	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0
walleye	WALL	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0
white sucker	WHSC	57.1	9.6	1.3	0	3.4	1.6	14.6	0	0	2.2	7.0	0	33.3	0	0	0
yellow perch	YLPR	0	0	0	0	0	0	0	0	0	0.0	0	33.3	0	0	0	0
sucker sp. *		0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0
unknown sp. *		0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.3	0
Total Percent		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**-**	**100**	**100**

* Not included in total species richness.

Table 5.2-37 Summary of fish assemblage measurement endpoints in reaches of the Muskeg River and Jackpine Creek, 2009 to 2012.

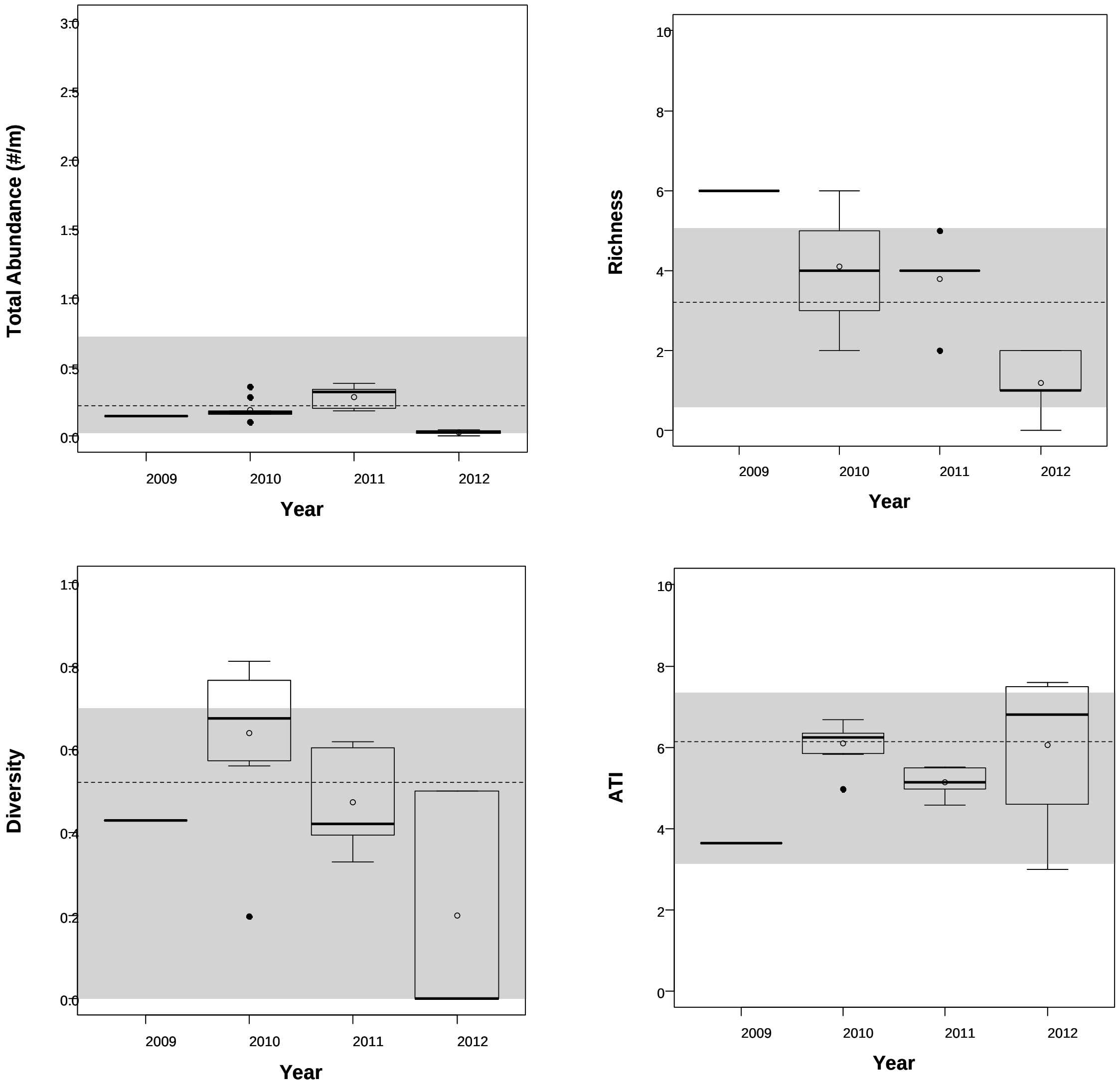
Reach	Year	Abundance (#/m)		Richness*			Diversity*		ATI*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
MUR-F1	2009	0.15		7	-	-	0.43	-	3.65	-
	2010	0.19	0.08	9	4	2.38	0.64	0.29	6.10	0.51
	2011	0.28	0.09		4	1.10	0.47	0.13	5.15	0.39
	2012	0.03	0.02	5	1	0.84	0.20	0.27	6.05	2.13
MUR-F2	2011	0.01	0.02	2	1	0.89	0.10	0.22	7.75	0.07
	2012	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00
MUR-F3	2011	0.14	0.10	3	1	0.55	0.14	0.22	9.06	0.58
	2012	<0.01	0.01	1	<1	0.45	0.00	0.00	9.40	0.00
JAC-F1	2009	0.02		3		-	0.57	-	6.41	-
	2010	0.65	0.59	8	4	2.38	0.53	0.29	7.72	0.51
	2011	1.03	1.04	6	3	0.84	0.20	0.20	5.74	0.35
	2012	0.01	0.01	1	1	0.55	0.00	0.00	3.00	0.00
JAC-F2	2009	0.42		4	-	-	0.48	-	6.56	-
	2010	0.10		5	-	-	0.69	-	7.85	-
	2011	0.69	0.62	4	3	0.84	0.50	0.16	8.18	0.61
	2012	0.02	0.02	2	1	0.55	0.00	0.00	6.80	2.25

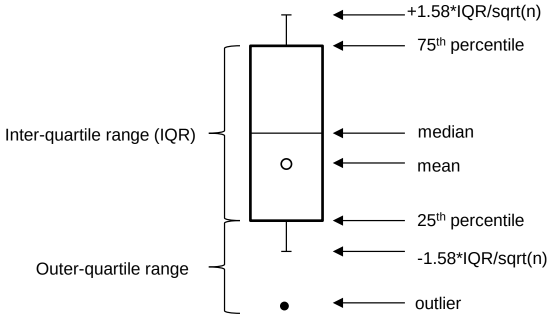
* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

Figure 5.2-25 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the Muskeg River, 2009 to 2011.

Erosional *Test* Reach MUR-F1



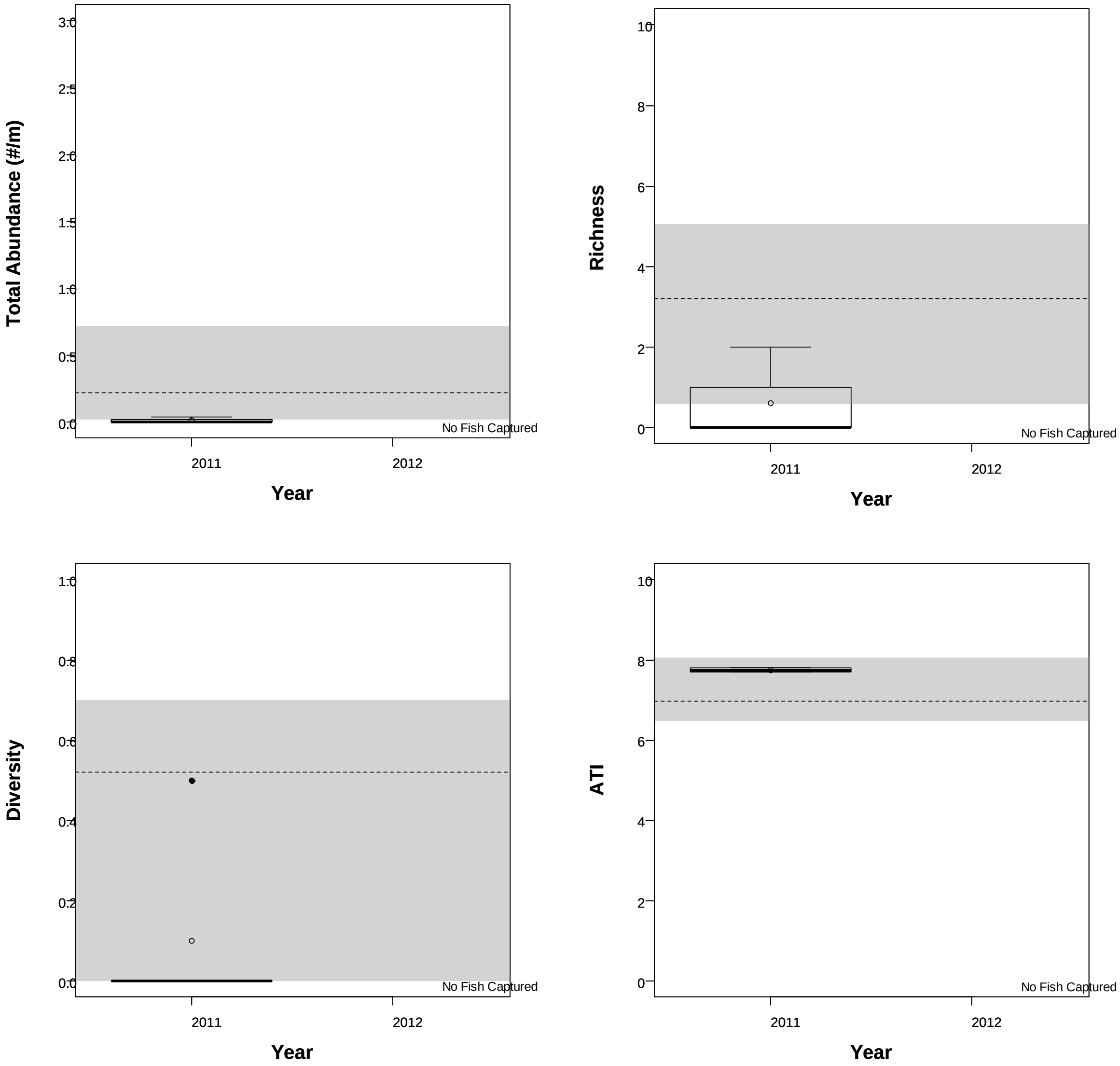


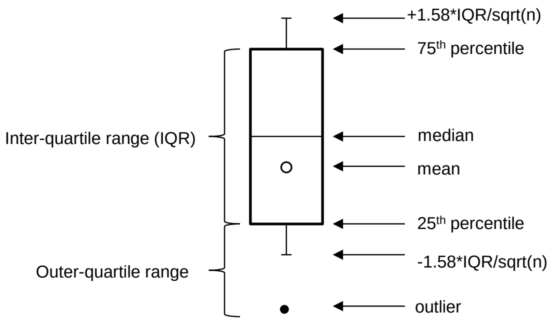
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Figure 5.2-25 (Cont'd.)

Depositional *Test* Reach MUR-F2



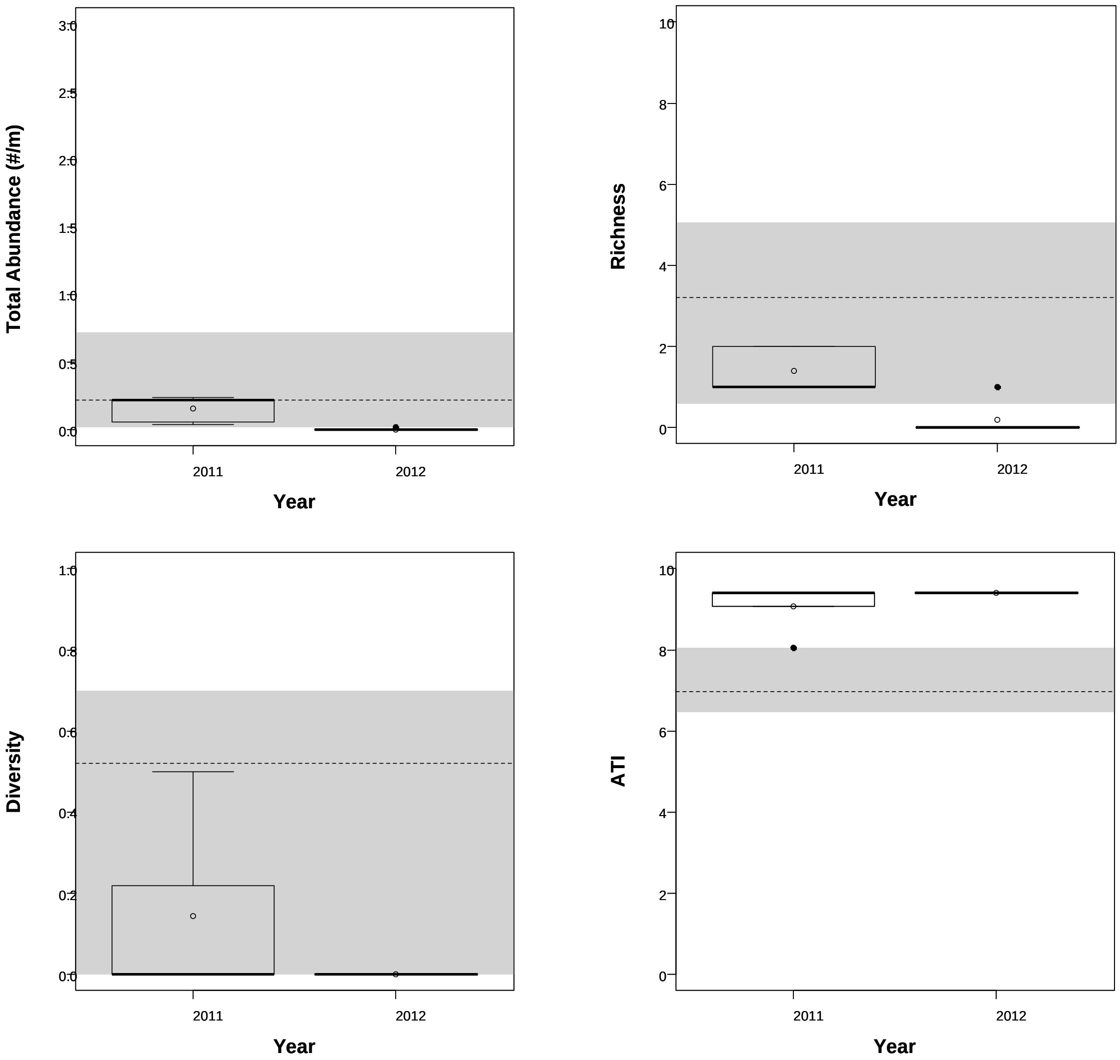


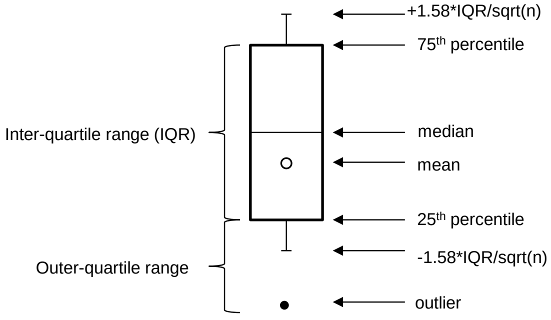
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Figure 5.2-25 (Cont'd.)

Depositional *Test* Reach MUR-F3





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

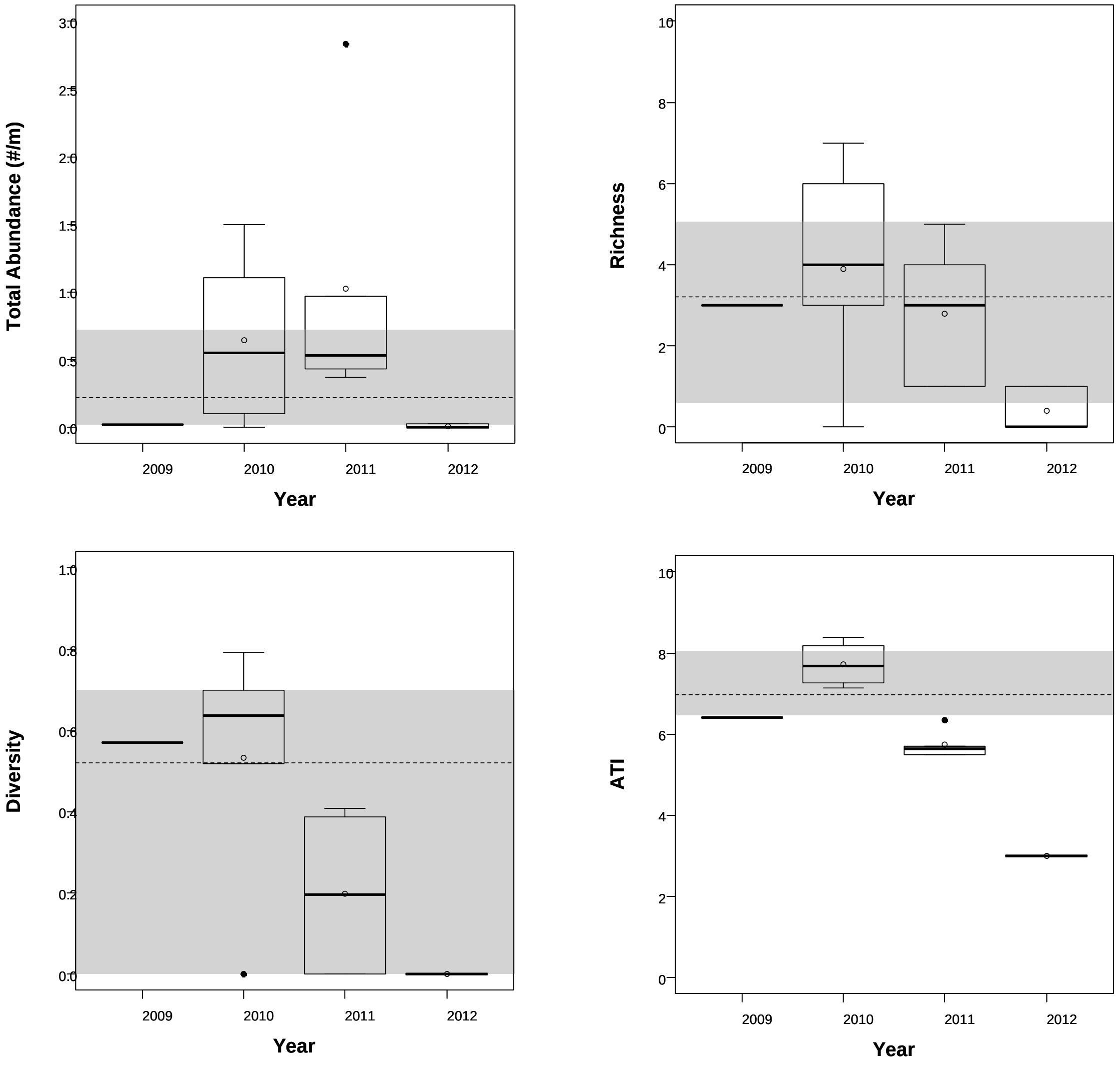
Table 5.2-38 Average habitat characteristics of fish assemblage monitoring locations of Jackpine Creek, fall 2012.

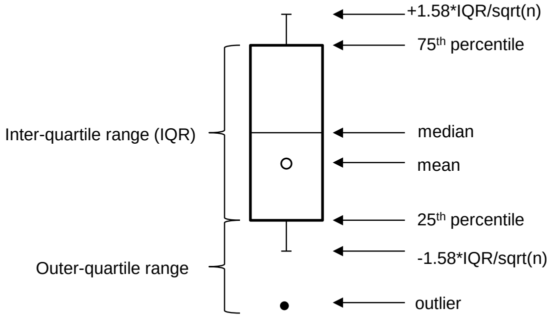
Variable	Units	JAC-F1 Lower *Test* Reach of Jackpine Creek	JAC-F2 Upper *Baseline* Reach of Jackpine Creek
Sample date	-	06-Sept-12	16-Sept-12
Habitat type	-	run/pool	run/riffle
Maximum depth	m	1.18	1.5
Bankfull channel width	m	9.0	7.5
Wetted channel width	m	9.5	7.0
Substrate			
Dominant	-	sand	silt/clay
Subdominant	-	-	-
Instream cover			
Dominant	-	small woody debris	overhanging vegetation
Subdominant	-	overhanging vegetation and macrophytes	large woody debris and undercut banks
Field water quality			
Dissolved oxygen	mg/L	9.2	9.4
Conductivity	µS/cm	241	149
pH	pH units	8.03	7.37
Water temperature	^{0}C	12.7	8.7
Water velocity			
Left bank velocity	m/s	0.48	ns
Left bank water depth	m	0.56	ns
Centre of channel velocity	m/s	0.26	ns
Centre of channel water depth	m	0.91	ns
Right bank velocity	m/s	0.28	0.26
Right bank water depth	m	0.68	1.25
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	overhanging vegetation
Subdominant	-	overhanging vegetation	woody shrubs and saplings

ns = not sampled, too deep to wade across the river to collect measurements.

Figure 5.2-26 Box-plots showing variation in fish assemblage measurement endpoints in reaches of Jackpine Creek, 2009 to 2011.

Depositional *Test* Reach JAC-F1

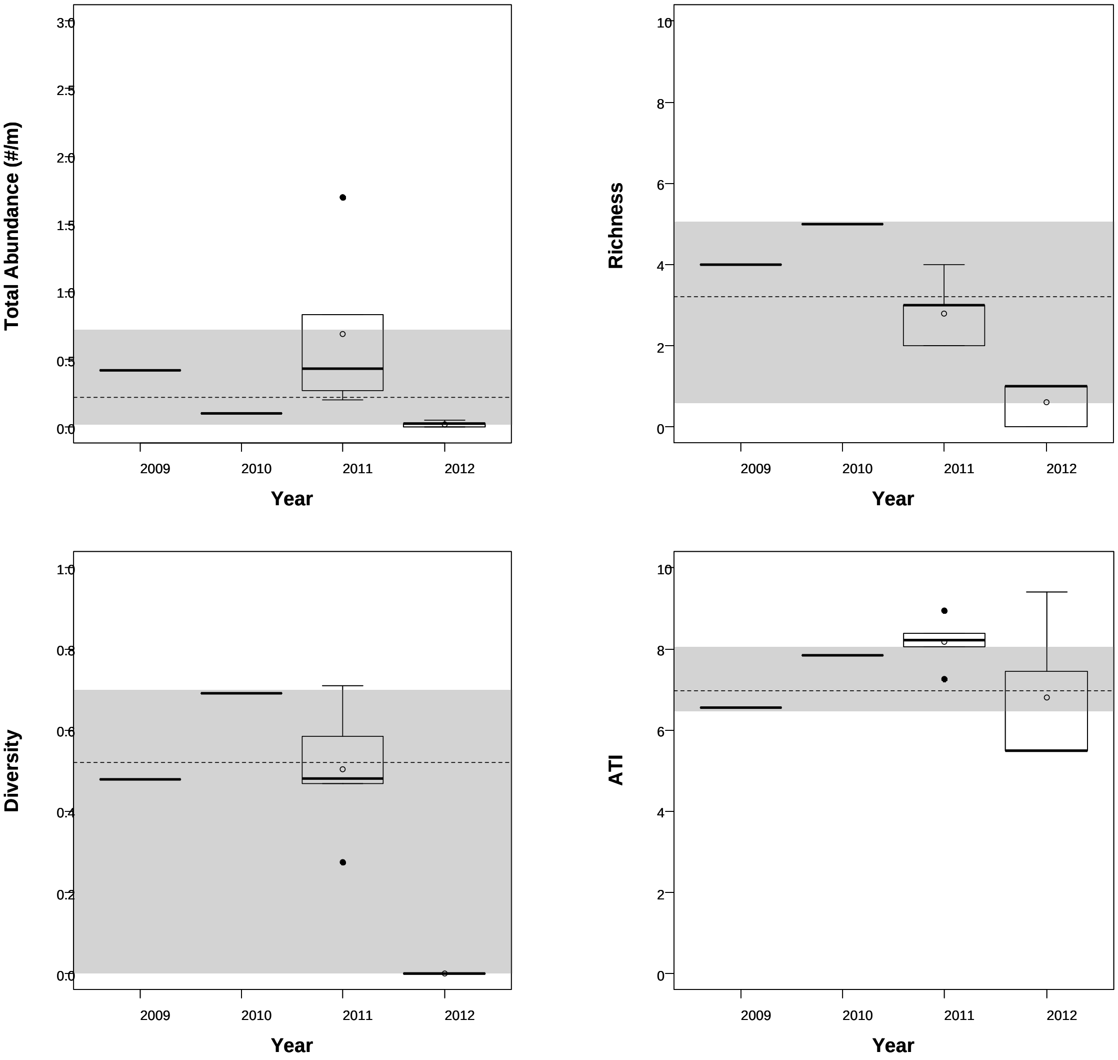


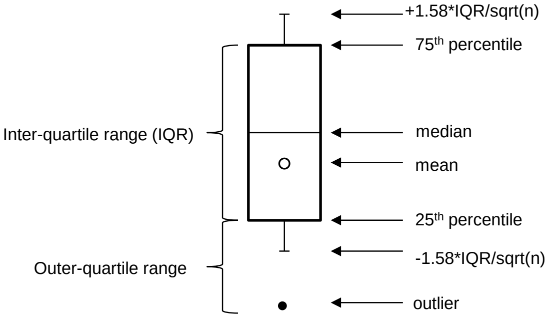


Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Depositional *Baseline* Reach JAC-F2





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

5.3 STEEPBANK RIVER WATERSHED

Table 5.3-1 Summary of results for the Steepbank River watershed.

Steepbank River Watershed	Summary of 2012 Conditions			
	Steepbank River			*North Steepbank River*
Climate and Hydrology				
Criteria	**07DA006/S38** near Fort McMurray	no station sampled	no station sampled	no station sampled
Mean open-water season discharge	🟡			
Mean winter discharge	🟡			
Annual maximum daily discharge	🟡			
Minimum open-water season discharge	🟡			
Water Quality				
Criteria	**STR-1** at the mouth	**STR-2** upstream of Project Millennium	**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 sampled	**STR-E2** upper reach	no reach sampled
Benthic Invertebrate Communities	🟠		n/a	
No Sediment Quality component activities conducted in 2012				
Fish Populations				
Criteria	**SR-E/STR-F1** lower reach	no reach sampled	**SR-R/STR-F2** upper reach	no reach sampled
Sentinel Species	🟡		n/a	
Fish Assemblages	🟡		n/a	

Legend and Notes

🟡	Negligible-Low	*baseline*
🟠	Moderate	*test*
🟤	High	

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 focal projects and other 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.

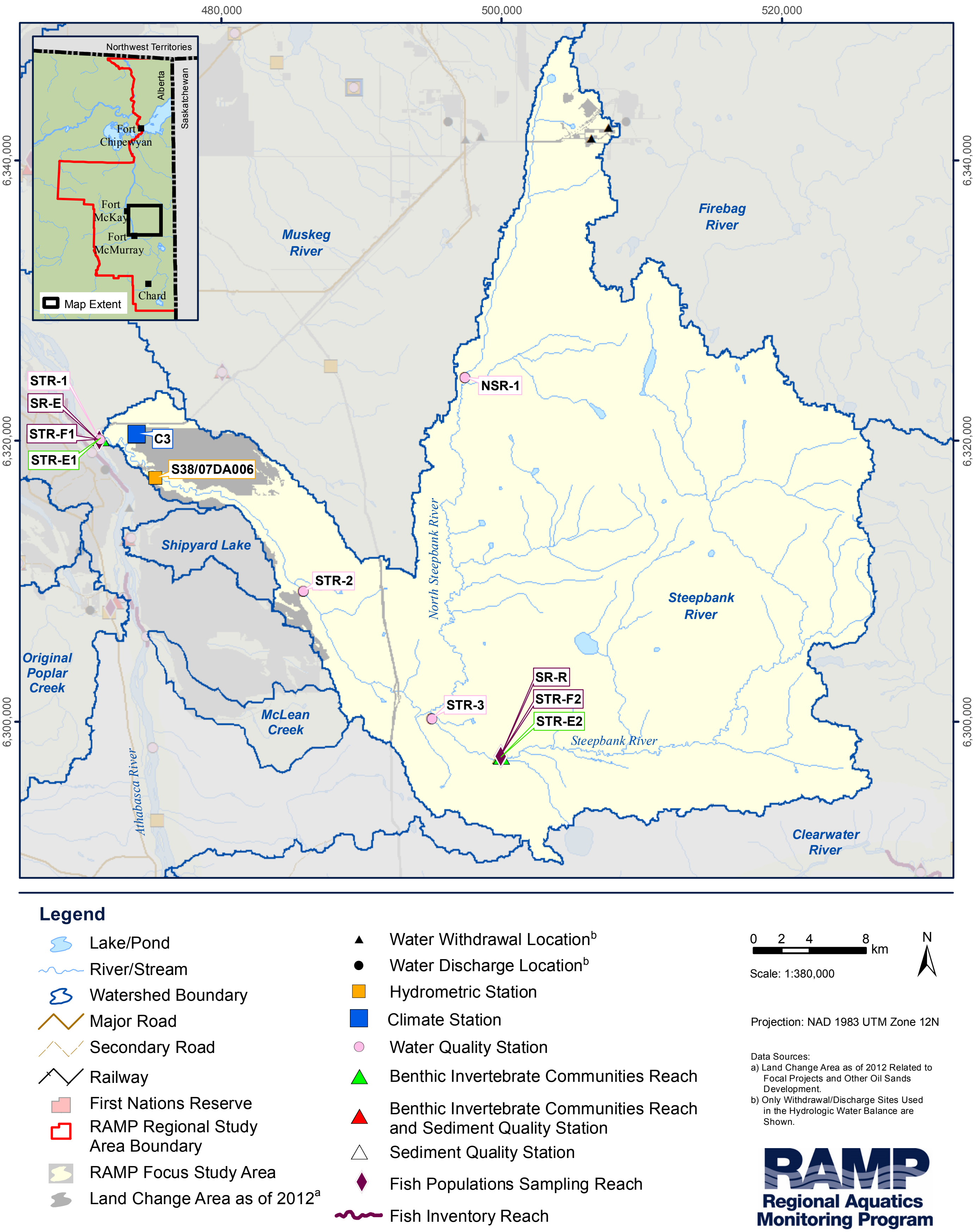
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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 3.2.4.3 for a description of the classification methodology.

Fish Populations (sentinel species): Classification based on effects criteria established for Environment Canada's Environmental Effects Monitoring Program for pulpmills (Environment Canada 2010); see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.3-1 Steepbank River watershed.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

RAMP
Regional Aquatics Monitoring Program

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Figure 5.3-2 Representative monitoring stations of the Steepbank River, fall 2012.

Benthic Invertebrate and Fish Assemblage Reach STR-E1/STR-F1: Left Downstream Bank

Benthic Invertebrate and Fish Assemblage Reach STR-E2/STR-F2: Right Downstream Bank

Water Quality Station STR-2: facing downstream

Water Quality Station NSR-1: North Steepbank River, facing downstream.

5.3.1 Summary of 2012 Conditions

Approximately 3.7% (5,000 ha) of the Steepbank River watershed had undergone land change as of 2012 from focal projects (Table 2.5-1); much of this land change is concentrated in the lower portion of the watershed. The designations of specific areas of the watershed for 2012 are as follows:

1. The Steepbank River watershed downstream of the Suncor oil sands developments (Figure 5.3-1) 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 Fish Populations components of RAMP in the Steepbank River watershed in 2012. Table 5.3-1 is a summary of the 2012 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 RAMP component, reported focal project water withdrawal and discharge locations, and the area of land change for 2012. Figure 5.3-2 contains photos of representative monitoring stations in the watershed taken in fall 2012.

Hydrology The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.31%, 0.32%, 0.32%, and 0.26% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of many water quality measurement endpoints in the Steepbank River watershed in fall 2012 were higher than previously-measured concentrations, particularly at *test* station NSR-1 and *baseline* station STR-3. When compared with regional *baseline* conditions for fall, concentrations of water quality measurement endpoints were generally consistent and within the regional range. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2012 was similar to previous years. Differences in water quality in fall 2012 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed.

Benthic Invertebrate Communities Differences in measurement endpoints for the benthic invertebrate communities at *test* reach STR-E1 were classified as **Moderate** because total abundance, percent EPT, and CA Axis 1 and 2 scores were significantly lower at *test* reach STR-E1 than *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and although it was dominated by somewhat tolerant tubificids, many other taxa were noted that require cool, clean water and not suggesting any degradation of habitat conditions at this reach.

Fish Populations (fish assemblages) Differences in the fish assemblage in fall 2012 between *test* reach STR-F1 and regional *baseline* conditions were classified as **Negligible-Low**, with all values of measurement endpoints within the range of regional *baseline* variability.

Fish Populations (sentinel species) The number of varying exceedances of effects criteria for slimy sculpin at *test* site SR-E compared to each *baseline* site suggested that there was substantial variability in slimy sculpin populations among *baseline* sites, likely related to variability in habitat conditions. Accordingly, to minimize the range of *baseline* variability, the classification of results focused on comparisons between the lower (*test*) and upper (*baseline*) Steepbank River sites given both sites are part of the same river system and; therefore, share similar habitat characteristics. Based on the results of the 2012, which provided inconsistent response patterns in energy use (growth, LSI, and GSI) in female and male slimy sculpin at *test* site SR-E, the differences from the *baseline* site were classified as **Negligible-Low**. Although the lower GSI could be indicative of a negative change, the higher growth of slimy sculpin at the *test* site was not indicative of a negative change and could suggest an increase in food resources at this site.

5.3.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring in the Steepbank River watershed was conducted at WSC Station 07DA006 (RAMP Station S38), Steepbank River near Fort McMurray, which was used for the water balance analysis. There were no additional hydrometric monitoring stations that operated in this watershed during the 2012 WY.

Continuous annual hydrometric data have been collected for WSC Station 07DA006 (RAMP Station S38) from 1974 to 1986 and more recently from 2009 to 2012, with some partial records in 1972 and 1973. Seasonal data from March to October have been collected every year since 1974. The open-water runoff volume in the 2012 WY was 182.7 million m^3, which was 36% higher than the historical mean open-water runoff volume of 134 million m^3. Flows decreased from November 2011 to March 2012, with flows from mid-December to February near historical median values (Figure 5.3-3). Flows increased during spring freshet in April and early May 2012 to a peak of 9.52 m³/s on May 5. Following the freshet peak, flows decreased until mid-May. Rainfall events on May 18 and 19 resulted in a second spring peak on May 21 of similar magnitude to the freshet peak (Figure 5.3-3). Flows increased beyond historical upper quartile values in late June and early July in response to the rainfall events. Late summer flows decreased steadily from July 6 to August 22, and the minimum open-water daily flow of 2.37 m³/s on August 22 was 43% higher than the mean historical minimum open-water daily flow. Rainfall events in early to mid-September increased flows to above historical upper quartile values and exceeding the historical maximum daily flow from September 13 to September 20. The annual maximum daily flow of 51.9 m³/s recorded on September 15 was 59% higher than the historical mean maximum daily flow. Flows in early October decreased to near historical upper quartile values, before increasing in mid- to late October to near historical maximum values.

Differences Between Observed *Test* Hydrograph and Estimated B*aseline* Hydrograph The estimated water balance at the Steepbank River near Fort McMurray is provided in Table 5.3-2 and described below:

1. The closed-circuited land area from focal projects as of 2012 was estimated to be 4.9 km² (Table 2.5-1). The loss of flow to the Steepbank River that would have otherwise occurred from this land area was estimated at 0.73 million m³.
2. As of 2012, the area of land change in the Steepbank watershed that was not closed-circuited was estimated to be 45.3 km² (Table 2.5-1). The increase in flow to the Steepbank River that would not have otherwise occurred from this land area was estimated at 1.35 million m³.
3. In the 2012 WY, Suncor withdrew 0.02 million m³ of water from a source in the northern area of the Steepbank River watershed to support activities including dust suppression.

Classification of Results The estimated cumulative effect of land change and water withdrawals was an increase in flow of 0.60 million m³ in the 2012 WY for WSC Station 07DA006 (RAMP Station S38), Steepbank River near Fort McMurray. The observed and estimated *baseline* hydrographs at WSC Station 07DA006 (RAMP Station S38) are presented in Figure 5.3-3. The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.31%, 0.32%, 0.32% and 0.26% greater, 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).

5.3.3 Water Quality

In fall 2012, water quality samples were taken from:

- the Steepbank River near its mouth (*test* station STR-1, sampled from 1997 to 2012);
- 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 2012);
- the Steepbank River upstream of the confluence with the North Steepbank River (*baseline* station STR-3, sampled from 2004 to 2012); and
- the North Steepbank River (*test* station NSR-1, designated as *baseline* from 2002 to 2008 and *test* from 2009 to 2012).

Winter water quality sampling was also conducted at *test* station STR-1 in 2012.

Temporal Trends The following significant (α=0.05) trends in concentrations of water quality measurement endpoints were detected:

- a decreasing concentration of sulphate at *test* station STR-1 (1997 to 2012);
- decreasing concentrations of chloride and sulphate at *test* station STR-2 (2002 to 2012)
- decreasing concentrations of chloride and sulphate and an increasing concentration of total arsenic at *baseline* station STR-3 (2004 to 2012); and
- an increasing concentration of total nitrogen and total arsenic at *test* station NSR-1 (2002 to 2012).

2012 Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2012 were similar to previously-measured concentrations, with the exception of (Table 5.3-4 to Table 5.3-7):

- total dissolved phosphorus and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations at *test* station STR-1;
- total iron, total phenols, and total phosphorous, with concentrations that exceeded previously-measured maximum concentrations at *test* station STR-2;
- total suspended solids, total aluminum, total arsenic, total mercury (ultra-trace), total iron, and total phosphorous, with concentrations that exceeded previously-measured maximum concentrations and magnesium, with a concentration that was lower than the previously-measured minimum concentration at *baseline* station STR-3; and
- total suspended solids, chloride, sulphate, total aluminum, total mercury (ultra-trace), and total iron, with concentrations that exceeded previously-measured maximum concentrations and total dissolved solids, with a concentration that was lower than the previously-measured minimum concentration at *test* station NSR-1.

Ion Balance In fall 2012, the ionic composition of all stations in the Steepbank River watershed was dominated by calcium and bicarbonate ions. The ion balance was comparable with previous years for all stations, with a slight increase in sulphate and chloride occurring at *test* station NSR-1 (Figure 5.3-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints measured in the Steepbank River in fall 2012 were below water quality guidelines, with the exception of total aluminum and total nitrogen, which exceeded the guidelines at all stations. The concentration of dissolved aluminum, the bioavailable form, did not exceed the guideline and was at least an order of magnitude below the total aluminum concentration at all stations. At *test* station STR-1, the concentration of total mercury (ultra-trace) reached a maximum historical concentration and met the AESRD guideline for chronic effects of 5 ng/L (Table 5.3-4).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Steepbank River watershed in 2012 (Table 5.3-8):

- total iron at *test* station STR-1 in winter 2012;
- total chromium at *test* station STR-1 in fall 2012;
- dissolved iron, sulphide total phenols, total iron, and total phosphorus at *test* stations STR-1, STR-2 and NSR-1, and *baseline* station STR-3 in fall 2012.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints in fall 2012 at *test* stations STR-1, STR-2, and NSR-1, and *baseline* station STR-3 were within regional *baseline* concentrations, with the exception of the following (Figure 5.3-5):

- total mercury (ultra-trace), total arsenic, and total suspended solids, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-1;
- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-2 and *baseline* station STR-3;
- total dissolved solids and sodium, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station NSR-1; and
- total mercury (ultra-trace) and total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station NSR-1.

Water Quality Index WQI values for all stations in the Steepbank River watershed indicated **Negligible-Low** differences from regional *baseline* concentrations in fall 2012. WQI values ranged from 84.7 to 98.7, with *test* station STR-1 having the lowest value and *test* station STR-2 having the highest value (Table 5.3-9).

Classification of Results Concentrations of many water quality measurement endpoints in the Steepbank River watershed in fall 2012 were higher than previously-measured concentrations, particularly at *test* station NSR-1 and *baseline* station STR-3. When compared with regional *baseline* conditions for fall, concentrations of water quality measurement endpoints were generally consistent and within the regional range. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2012 was similar to previous years. Differences in water quality in fall 2012 compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed.

5.3.4 Benthic Invertebrate Communities and Sediment Quality

5.3.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at the upper and lower reaches of the Steepbank River. The lower *test* reach STR-E1 (erosional) has been sampled since 1998. The upper *baseline* reach STR-E2 (erosional) has been sampled since 2004.

2012 Habitat Conditions Water at *test* reach STR-E1 in fall 2012 was shallow (0.4 m), moderately flowing (~0.7 m/s), with low conductivity (165 µS/cm), and moderate dissolved oxygen (7.3 mg/L) (Table 5.3-10). Periphyton biomass averaged 16.8 mg/m^2, which was lower than 2011, but still within the range of regional *baseline* conditions and similar to what was observed at the upstream *baseline* station STR-E2 (Figure 5.3-6).

Water at *baseline* reach STR-E2 was shallow (0.4 m), relatively fast flowing (~1 m/s), basic (pH: 8.2), with moderate conductivity (210 µS/cm), and high dissolved oxygen (8.8 mg/L) (Table 5.3-10). Periphyton biomass averaged 26.3 mg/m^2, which was lower than 2011, but still within the range of regional *baseline* conditions (Figure 5.3-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach STR-E1 was dominated by chironomids (27%) and tubificid worms (23%), with subdominant taxa consisting of Ephemeroptera (mayflies; 19%) (Table 5.3-11). Chironomids were diverse, consisting of many common forms (Wiederholm 1983) including *Cricotopus / Orthocladius, Polypedilum* and *Thienemannimyia*, as well as other forms that are more restricted to clean cold water (Mandaville 2001) such as *Tvetenia*. The mayfly assemblage was also diverse and included the widely distributed *Baetis*, as well as forms restricted to fast flowing waters such as *Ephemerella*. Other sensitive taxa included trichopteran caddisfly *Hydropsyche,* Gastropoda (*Ferrissia rivularis*), and Bivalvia (*Pisidium / Sphaerium*).

The benthic invertebrate community at *baseline* reach STR-E2 was dominated by Chironomidae (31%) and Ephemeroptera (15%), with subdominant taxa consisting of Trichoptera (9%), Hydracarina (9%), and naidid worms (8%) (Table 5.3-12). Similar to the lower reach, the chironomids of the upper reach contained both widely distributed forms (Wiederholm 1983) such as *Micropsectra / Tanytarsus, Cricotopus / Orthocladius,* and *Thienemannimyia gr.*, as well as those more typically associated with clean and cold water such as *Tvetenia*. Mayflies were diverse and abundant and included the ubiquitous *Baetis, Acerpenna pygmaea* and the sensitive *Ephemerella*. Other sensitive taxa included Plecoptera (*Zapada*), and caddisflies (*Lepidostoma, Micrasema*, and *Brachycentrus).* Bivalves (*Pisidium/Sphaerium*) and gastropods (*Ferrissia rivularis*) were also noted but in lower relative abundances.

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 stations in the Steepbank River watershed.

Temporal comparisons for *test* reach STR-E1 included testing for:

- changes over time during the *test* period (1998 to 2012, Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling (1998 to 2011).

Spatial comparisons for *test* reach STR-E1 included testing for:

- differences from *baseline* reach STR-E2 over time (Hypothesis 3, section 3.2.3.1); and
- differences between 2012 values and the mean of all available *baseline* data (2004 to present).

Richness and EPT taxa were significantly higher at *baseline* reach STR-E2 than *test* reach STR-E1, explaining 24% and 34% of the variance in annual means, respectively (Table 5.3-13). CA Axis 1 and 2 scores were significantly higher at *baseline* reach STR-E2 than *test* reach STR-E1, explaining >20% of the variance in annual means (Table 5.3-13). The higher CA Axis scores at *baseline* reach STR-E2, reflected a higher relative abundance of EPT (Ephemeroptera, Plecoptera, Trichoptera) at this reach compared to the lower *test* reach (Figure 5.3-7).

Comparison to Published Literature The benthic invertebrate community at *test* reach STR-E1 was dominated by tubificid worms, which are known to tolerate degraded conditions (Mandaville 2001). The benthic community; however, was diverse with an average of 20 taxa per sample, and contained genera that require colder and cleaner water including the chironomid *Tvetenia* and the mayfly *Ephemerella* (Mandaville 2001). Permanent benthic forms such as fingernail clams (*Pisidium/Sphaerium*) and Gastropods (*Ferrissia rivularis*) were found at *test* reach STR-E1 indicating generally good long-term water quality.

The benthic invertebrate community at *baseline* reach STR-E2 was diverse and contained a benthic fauna that reflected good water and sediment quality. The percentage of the community as worms was low (~10% total), while chironomids accounted for 31% of the fauna. The percentage of the fauna as EPT taxa, as in previous years, was also high (26%), indicating that the benthic invertebrate community was robust and reflected good water and sediment quality (Hynes 1960, Griffiths 1998).

2012 Results Relative to Regional *Baseline* Conditions Values of measurement endpoints for benthic invertebrate communities were within the range of regional *baseline* erosional rivers (Figure 5.3-8). CA Axis 1 and 2 scores were within the range of variation for regional *baseline* erosional rivers, but were generally higher at *test* reach STR-E1 than *baseline* reach STR-E2 (Figure 5.3-7).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* reach STR-E1 were classified as **Moderate** because total abundance, percent EPT, and CA Axis 1 and 2 scores were significantly lower at *test* reach STR-E1 than *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and although it was dominated by somewhat tolerant tubificids, many other taxa were noted that require cool, clean water and not suggesting any degradation of habitat conditions at this reach.

5.3.4.2 Sediment Quality

No sediment quality sampling was conducted in the Steepbank River in 2012. Sediment quality is only sampled in combination with benthic community samples at depositional reaches, but all reaches of the Steepbank River are erosional.

5.3.5 Fish Populations

In 2012, fish assemblage monitoring and sentinel species monitoring were conducted in the Steepbank River.

5.3.5.1 Fish Assemblage Monitoring

Fish assemblages were sampled in fall 2012 at:

- erosional *test* reach STR-F1, near the mouth of the Steepbank River, sampled since 2009 (this reach is in the same location as the benthic invertebrate community *test* reach STR-E1); and
- erosional *baseline* reach STR-F2, sampled since 2011 (this reach is in the same location as the benthic invertebrate community *baseline* reach STR-E2).

2012 Habitat Conditions *Test* reach STR-F1 was comprised of riffle and run habitat. The river was at flood stage at the time of assessment with wetted and bankfull widths of 30 m. The substrate was dominated by coarse gravel with a small amount of fine material. Due to the high flow conditions, only one depth and velocity measurement could be taken. Depth along the right downstream bank was 0.81 m with a flow of

0.52 m/s. Water at *test* reach STR-F1 was slightly alkaline (pH: 7.63), with low conductivity (100 µS/cm), high dissolved oxygen (10.4 mg/L), and a temperature of 9.3°C. Instream cover consisted primarily of overhanging vegetation (Table 5.3-14).

Baseline reach STR-F2 was also at flood stage and comprised of riffle habitat with wetted and bankfull widths of 17.5 m. The water was too fast and deep to make an assessment of substrate. Water at *baseline* reach STR-F2 could only be measured along the right downstream bank, which had a depth of 0.97 m, with a moderate flow of 0.38 m/s. Water at *baseline* reach STR-F2 was slightly alkaline (pH: 7.47), with low conductivity (74 µS/cm), high dissolved oxygen (9 mg/L), and a temperature of 7.9°C. Instream cover consisted primarily of overhanging vegetation with some large woody debris and live tree roots (Table 5.3-14).

Temporal and Spatial Comparisons Sampling was initiated in the Steepbank River in fall 2009 at *test* reach STR-F1 during the RAMP Fish Assemblage Pilot Study; therefore, temporal comparisons were conducted from 2009 to 2012. *Baseline* reach STR-F2 was sampled for the first time in 2011; therefore, spatial comparisons were conducted between lower *test* reach STR-F1 and upper *baseline* reach STR-F2 for 2012.

Abundance and CPUE at *test* reach STR-F1 were the lowest recorded in the past four years, with only 10 fish captured (Table 5.3-15). There was no species that dominated the catch, which consisted of forage fish and juveniles of larger species, including one northern pike. The low capture rate was due to high water levels, which necessitated fishing from the shoreline within a limited range of the river. Deep, fast water also made capturing fish difficult, especially compared to low-water years (e.g., 2011). The ATI at *test* reach STR-F1 was also the lowest recorded, which was likely due to the relatively high percentage of sensitive species (e.g., sculpin sp., longnose dace). Abundance and CPUE at *baseline* reach STR-F2 were much lower than 2011, with only two fish captured in fall 2012 (Table 5.3-15). Due to high and fast flows, fishing could only be conducted from shore at *baseline* reach STR-F2, thereby limiting the capture efficiency.

Mean values of all measurement endpoints were higher at *test* reach STR-F1 in fall 2012 than *baseline* reach STR-F2, but was likely due to the difficulty in effectively sampling in both reaches in high water conditions that were observed in fall 2012 (Table 5.3-16).

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 RAMP. Based on past studies, a total of 24 fish species were recorded in the Steepbank River; whereas RAMP found only 14 species from 2009 to 2012. As noted in Section 5.2, 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., RAMP samples 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 RAMP from 2009 to 2012. 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 2012, RAMP has documented habitat conditions at *test* reach STR-F1 consisting of riffles and runs, with a substrate dominated by coarse gravel and run 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 RAMP in the Steepbank River.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reach STR-F1 were within the range of regional *baseline* conditions (Figure 5.3-9). Mean values of all measurement endpoints for *baseline* reach STR-F2 were primarily at the 95th or 5th percentile of regional *baseline* conditions and represented historical minimum or maximum values for this reach (Figure 5.3-9).

Classification of Results Differences in fish assemblages in fall 2012 between *test* reach STR-F1 and regional *baseline* conditions were classified as **Negligible-Low** with all values of measurement endpoints within the range of regional *baseline* variability.

5.3.5.2 Sentinel Species Monitoring

Sentinel species monitoring, using slimy sculpin, was conducted at six sites on tributaries to the Athabasca River in September 2012. A lethal slimy sculpin sentinel species program was also conducted in 1999 and 2001. *Test* sites located on the Muskeg River (MR-E) and Steepbank River (SR-E) were compared to *baseline* sites located on the upper Steepbank River (SR-R), Horse River (HR-R), High Hills River (HH-R), and Dunkirk River (DR-R), which were located upstream of any influence of oil sands development (Table 5.3-17).

Field Sampling Results Water quality at all sites indicated suitable conditions for slimy sculpin, with dissolved oxygen (DO) ranging from 8.2 to 18.6 mg/L; conductivity ranging from 86 to 218 µS/cm; and pH ranging from 7.65 and 8.55. The mean water velocity across all sites ranged from 0.25 m/s at *baseline* site HH-R to 0.77 m/s at *baseline* site HR-R, with sampling depths ranging from 0.25 m (*baseline* site DR-R) to 0.86 m (*baseline* site SR-R) (Table 5.3-17).

Target numbers of slimy sculpin (20 adult fish of each sex) were collected at all sites for, with the exception of females at *test* site SR-E (n=19), and males at *baseline* sites HR-R (n=16), DR-R (n=18), and HH-R (n=15) (Table 5.3-18). There were very few adult slimy sculpin captured at *test* site MR-E; therefore, *test* site MR-E was excluded from any statistical analyses due to low sample size (Table 5.3-18). A summary of morphometric data for slimy sculpin by site and gender is provided in Table 5.3-18.

Age In 2012, the mean age of adult female slimy sculpin ranged from one year (*baseline* DR-R) to three years (*baseline* HR-R) and the mean age of male adult slimy sculpin ranged from one year (*test* MR-E) to three years (*baseline* HH-R) (Table 5.3-18). The mean age across sampling years (1999, 2001, and 2012) was generally consistent, although a higher mean age of female and male slimy sculpin was observed in 1999 at *test* site SR-MN (*test* site on the Steepbank River, RAMP 2000) (Figure 5.3-10).

The relative age-frequency distributions of slimy sculpin captured in 1999 showed an even distribution across age classes ranging from one to seven years for *test* site MR-E and *baseline* site SR-R and one to eight years for *test* site SR-MN (Figure 5.3-11). Dominant age classes were one and four years at *baseline* site SR-R and *test* site SR-MN, respectively, and one and three years for *test* site MR-E. In 2001 and 2012, the proportion of slimy sculpin in the older age classes was low, with a greater proportion of slimy sculpin between one and three years. The dominant age class in 2001 at *baseline* sites DR-R and HR-R was two years and three years at *baseline* site SR-R. The dominant age class for *test* sites MR-E and SR-E was one year in 2001 (Figure 5.3-11). In 2012, the dominant age class for *baseline* sites HR-R, HH-R and SR-R was two years and one year for site DR-R. The dominant age class at *test* sites MR-E and SR-E was one and two years, respectively, in 2012 (Figure 5.3-11).

An ANOVA was used to compare age of male and female slimy sculpin between *baseline* sites and *test* site SR-E in 2012 (Table 5.3-19). Female slimy sculpin at *test* site SR-E were significantly younger (p=0.002) and older (p=0.049) than female sculpin at *baseline* sites DR-R and HR-R, respectively. Generally, there were no significant differences in mean age between *baseline* and *test* sites in 2012 male slimy sculpin, with the exception of *test* site SR-E, where slimy sculpin were significantly younger than at *baseline* SR-R (p=0.024) (Table 5.3-19). An exceedance of the effects criterion (±25% from the *baseline* mean age) was observed at *test* site SR-E compared to *baseline* site DR-R for males and females (31.9% and 34.9%, respectively) and *baseline* site HR-R for females (-38.8%) (Table 5.3-21). When *baseline* sites were pooled, there was no significant difference and no exceedance of the effects criterion for age of slimy sculpin at *test* site SR-E (Table 5.3-21).

Power analyses were conducted for pair-wise comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, GSI, and LSI and ±10% for condition. Power was relatively high for all comparisons, ranging from 0.60 to 0.99 (Table 5.3-20). There were five comparisons that did not achieve the desired level of Power (>0.9) (Environment Canada 2010) for age, weight-at-age, GSI, and LSI indicating that the sample size was too low to detect a significant difference for an effect size of ±25% (Table 5.3-20). Power was adequate to for all pairwise comparisons for condition.

In 1999, mean age of male and female slimy sculpin at *test* site SR-E exhibited a 54.2 and -51.6% change, respectively, compared to *baseline* site SR-R (Table 5.3-22). In 2001, only male slimy sculpin at *test* site SR-E exhibited an exceedance compared to *baseline* site DR-R (59.9%).

Statistical analyses could not be performed on data from *test* site MR-E due to low sample size; however, the mean age for male and female slimy sculpin at this site was generally lower compared to the *baseline* sites and *test* site SR-E (Figure 5.3-10). This trend was also observed in 2001.

Growth (Weight-at-Age) An ANCOVA was used to compare the relationship between body weight and age of male and female slimy sculpin between *baseline* and *test* sites in tributaries to the Athabasca River in 2012. Both male and female slimy sculpin in 2012 showed a significant difference (p<0.05) at *test* site SR-E compared to all *baseline* sites, with the exception of *baseline* HH-R for male slimy sculpin (Table 5.3-19, Table 5.3-21). Male and female slimy sculpin at *test* site SR-E were heavier at any given age, indicating greater growth compared to slimy sculpin at the *baseline* sites, with the exception of *baseline* site DR-R (Figure 5.3-12). An exceedance of the effects criteria (i.e., ±25% from the *baseline* mean) was observed at *test* site SR-E for male and female slimy sculpin compared to all *baseline* sites, with the exception of males at *baseline* HH-R (Table 5.3-21). When *baseline* sites were pooled, there was no significant difference in weight-at-age and no exceedance of the effects criterion in slimy sculpin at *test* site SR-E (Table 5.3-21).

The effects criterion was not exceeded in slimy sculpin at *test* site SR-E in 1999 when compared to *baseline* site SR-R (Table 5.3-22). Results from 2001 were consistent with observations in 2012. Male and female slimy sculpin at *test* site SR-E exhibited a 112% and 106%, difference from the mean weight-at-age of slimy sculpin at *baseline* site HR-R, respectively; however, male slimy sculpin had a weight-at-age that was 27.5% lower than the mean weight-at-age of slimy sculpin at *baseline* site DR-R (-27.5%) (Table 5.3-22).

Statistical analyses could not be performed on data from *test* site MR-E due to low sample size; however, weight-at-age of male and female slimy sculpin at this site was generally lower than the *baseline* sites (Figure 5.3-12). This trend also was observed in 1999; however, slimy sculpin in 2001 at this site had a higher weight-at-age compared to the *baseline* sites (Figure 5.3-12).

Gonadosomatic Index (GSI) The Gonadosomatic index (GSI) is a measurement endpoint that is calculated for each fish as a ratio of gonad weight to body weight, and provides a measure of gonad development and reproductive success for a fish. In 2012, the mean GSI of adult female slimy sculpin ranged from 1.20 (*test* MR-E) to 2.20 (*baseline* site SR-R) and the mean GSI of male adult slimy sculpin ranged from 1.24 (*test* site MR-E) to 1.93 (*baseline* sites SR-R and DR-R) (Table 5.3-18, Figure 5.3-13).

An ANCOVA was used to compare the relationship between body weight and gonad weight of male and female slimy sculpin between *baseline* and *test* sites in tributaries of the Athabasca River in 2012 (Table 5.3-19). Gonad size was relatively similar in size for both male and female slimy sculpin in 2012, with the exception of female slimy sculpin at *test* site SR-E compared to *baseline* sites SR-R (p=<0.001) and HH-R (p=0.002), where slimy sculpin at *test* site SR-E had a lower gonad weight relative to reference fish (Table 5.3-21, Figure 5.3-14). An exceedance of the effects criterion (±25% of the *baseline* mean) was observed in female slimy sculpin at *test* site SR-E, with 41.4% and 28.2% GSI compared to *baseline* sites SR-R and DR-R, respectively (Table 5.3-22). When *baseline* sites were pooled, GSI was significantly lower in female slimy sculpin at *test* site SR-E compared to all *baseline* sites (p=0.047), but the difference did not exceed the effects criterion (Table 5.3-21).

The effects criterion for GSI was not exceeded in slimy sculpin at *test* site SR-E in 1999 when compared to *baseline* site SR-R (Table 5.3-22). Gonad weights were not measured during the 2001 survey.

Statistical analyses could not be performed on data from *test* site MR-E due to low sample size; however, GSI of male and female slimy sculpin at this site was much lower than the *baseline* sites and *test* site SR-E (Figure 5.3-13). GSI of slimy sculpin in 1999 (gonad weights were not measured in 2001) were generally similar across sites.

Liver Somatic Index (LSI) The liver somatic index (LSI) is a measurement endpoint that is calculated for each fish as a ratio of liver weight to body weight, and provides a measure of energy storage. In 2012, the mean LSI of adult female slimy sculpin ranged from 2.12 (*test* site MR-E) to 2.67 (*test* site SR-E), and from 1.18 (*baseline* site SR-R) to 2.34 (*test* site MR-E) for male slimy sculpin (Table 5.3-18 and Figure 5.3-15).

An ANCOVA was used to compare the relationship between body weight and liver weight of male and female slimy sculpin between *baseline* and *test* sites in the Athabasca River in 2012 (Table 5.3-19, Figure 5.3-16). There was a significant increase (p<0.05) in liver weight relative to body weight in female slimy sculpin at *test* site SR-E compared to *baseline* sites DR-R and HH-R; males also exhibited a larger liver size at *test* site SR-E compared to all *baseline* sites (Table 5.3-19 and Figure 5.3-16). An exceedance of the effects criterion (±25% of the *baseline* mean) was observed in male slimy sculpin at *test* site SR-E compared to all *baseline* sites (SR-R: 38.4%, DR-R: 40.1%, HH-R: 67.4%, HR-R: 51.1%) and females compared to *baseline* site HH-R (54.2%) (Table 5.3-21). When *baseline* sites were pooled, LSI was significantly higher (p=0.032) and exceeded the effects criterion (53.3%) for LSI in male slimy sculpin at *test* site SR-E (Table 5.3-21).

The effects criterion for LSI was not exceeded in slimy sculpin at *test* site SR-E in 1999 when compared to *baseline* site SR-R (Table 5.3-22). Liver weights were not measured during the 2001 survey.

Statistical analyses could not be performed on data from *test* site MR-E due to low sample size; however, LSI of male and female slimy sculpin at this site was generally consistent or higher than the *baseline* sites, but lower than *test* site SR-E (Figure 5.3-15). LSI of slimy sculpin in 1999 (liver weights were not measured in 2001) were generally similar across sites.

Condition Condition factor is a standard measurement endpoint that is calculated for each fish as a ratio of fish length and weight (i.e., how "fat" a fish is), and provides a measure of energy storage. In 2012, the mean condition of female and male slimy sculpin was similar ranging from 0.91 and 0.93 (*baseline* site HR-R) for females and males, respectively, to 1.04 and 1.05 (*baseline* site HH-R) for female and male slimy sculpin, respectively (Table 5.3-18, Figure 5.3-17, Figure 5.3-18).

An ANCOVA was used to compare condition of male and female adult slimy sculpin between *baseline* and *test* sites in tributaries of the Athabasca River in 2012. Condition of male and female slimy sculpin at *test* site SR-E was significantly lower ($p<0.001$ and $p=0.003$) compared to *baseline* site HH-R (Table 5.3-19). An exceedance of the effects criterion for condition (±10% from the *baseline* mean) was observed in male and female slimy sculpin at *test* SR-E compared to *baseline* HH-R Table 5.3-21); in 2001 male and female slimy sculpin exceeded the effects criterion when compared to *baseline* site HR-R (Table 5.3-22). When *baseline* sites were pooled, condition was significantly lower in male and female slimy sculpin ($p=0.015$), but the differences did not exceed the effects criterion for condition of slimy sculpin at *test* site SR-E (Table 5.3-21).

Statistical analyses could not be performed on data from *test* site MR-E due to low sample size; however, condition of male and female slimy sculpin at this site was generally consistent to the *baseline* sites and slightly higher than *test* site SR-E (Figure 5.3-17). Condition of slimy sculpin in previous sampling years, including 2004, 2006, and 2009 when non-lethal sampling was conducted was variable, but relatively consistent across sites (Figure 5.3-17).

Interpretation of 2012 Responses As outlined in RAMP (2009b), the slimy sculpin sentinel species program was developed to evaluate spatial and temporal differences in measurement endpoints between *test* and *baseline* sites. A summary of the response patterns of measurement endpoints for slimy sculpin at *test* site SR-E compared to the *baseline* sites is provided in Table 5.3-21. Similar comparisons were not possible for the *test* site on the Muskeg River given the small sample size of slimy sculpin captured at this location.

There were several significant differences between sculpin from the *test* site on the lower Steepbank River and sculpin from individual *baseline* sites; however, when the *baseline* sites were pooled, there were very few differences observed at the *test* site (i.e., only an increase in LSI in male slimy sculpin). These results suggest there was substantial variability in slimy sculpin populations among *baseline* sites, likely related to variability in habitat conditions. Accordingly, to minimize the range of *baseline* variability, the classification of results focused on comparisons between the lower (*test*) and upper (*baseline*) Steepbank River sites given both sites are part of the same river system and; therefore, share similar habitat characteristics. Results from this comparison, within the context of established effects criteria, indicated that slimy sculpin at the lower *test* site of the Steepbank River exhibited an increase in weight-at-age (growth) in males and females and a decrease in GSI (gonadal development) in males. Growth and GSI typically covary as they both reflect energy use (Gibbons and Munkittrick 1994). As such, it is uncertain as to why this is not the case in this instance; however, slimy sculpin, particularly males, are in a stage of early gonadal development in fall, which could lead to increased variability in this measurement endpoint. Generally, slimy sculpin at the *test* site were larger, heavier and exhibited higher growth compared to slimy sculpin at the *baseline* site, which suggests a response to increased availability of food resources at this site.

Classification of Results The effects criteria for age, weight-at-age, GSI, and LSI defined by Environment Canada (2010) is a ± 25% difference between *test* and *baseline* sites and a ± 10% difference for condition. Differences greater than the effects criteria (identified as "+" and "-" responses in Table 5.3-21) between *baseline* and *test* sites suggest an ecologically relevant change in the slimy sculpin population at the *test* site.

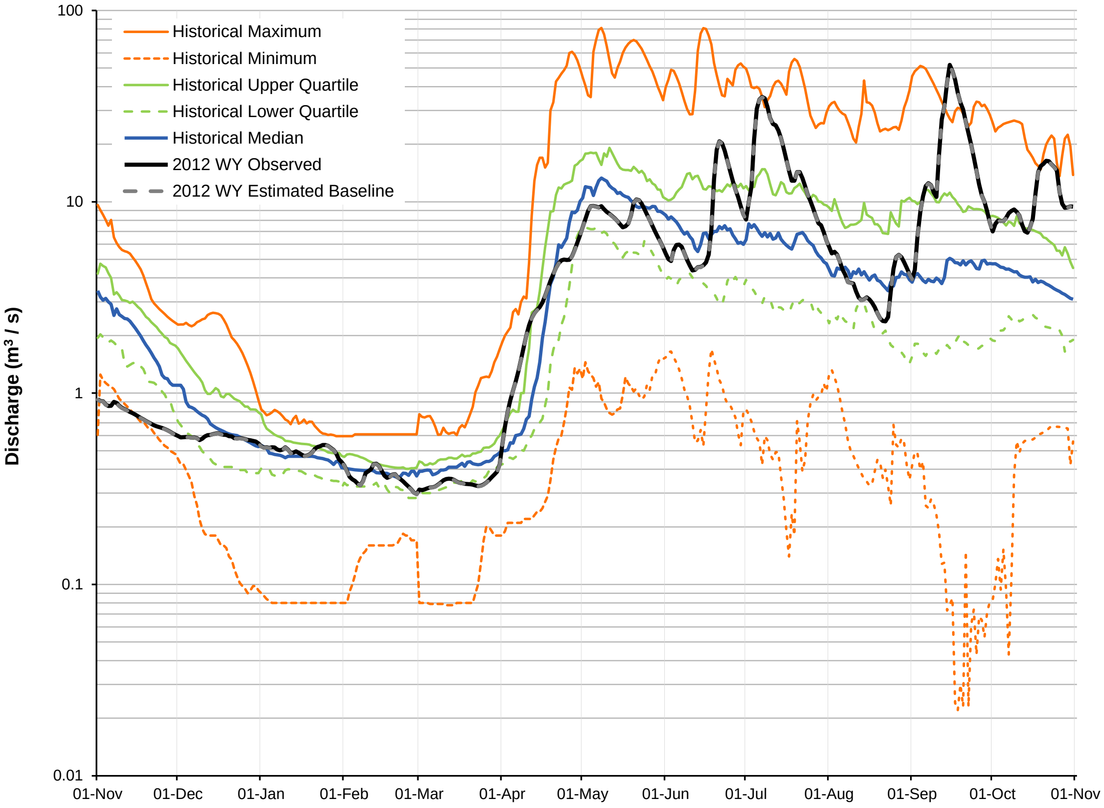
Differences in measurement endpoints that exceeded the Environment Canada effects criteria (Environment Canada 2010) are as follows:

- age of female slimy sculpin at *test* SR-E was 34.9% higher than *baseline site* DR-R and 38.8% lower than *baseline* site HR-R;
- weight-at-age of female slimy sculpin at *test* site SR-E was 54.8, 60.3, and 34.2% higher than *baseline* sites SR-R, HH-R, and HR-R, respectively, and 26.1 % lower compared to *baseline* site DR-R;
- GSI of female slimy sculpin at *test* site SR-E was 41.4 and 28.2 % lower compared to *baseline* sites SR-R and HH-R, respectively;
- LSI of female slimy sculpin at *test* site SR-E was 54.2% higher compared to *baseline* site HH-R;
- condition of female slimy sculpin at *test* site SR-E was 13.1% lower compared to *baseline* site HH-R;
- age of male slimy sculpin at *test* site SR-E was 31.9% lower compared to *baseline* site DR-R;
- weight-at-age of male slimy sculpin at *test* site SR-E was 36.1% and 25.1% higher compared to *baseline* sites SR-R and HR-R, respectively, and 50.7% lower compared to *baseline* site DR-R;
- LSI of male slimy sculpin at *test* site SR-E was 38.4, 40.1, 67.4, and 51.1% higher compared to *baseline* sites SR-R, DR-R, HH-R, and HR-R, respectively; and
- condition of male slimy sculpin at *test* site SR-E was 14.6% lower compared to *baseline* site HH-R.

The number of varying exceedances of effects criteria for slimy sculpin at *test* site SR-E compared to each *baseline* site suggests there was substantial variability in slimy sculpin populations among *baseline* sites, likely related to variability in habitat conditions. Accordingly, to minimize the range of *baseline* variability, the classification of results focused on comparisons between the lower (*test*) and upper (*baseline*) Steepbank River sites given both sites are part of the same river system and; therefore, share similar habitat characteristics.

Based on the results of the 2012, which provided inconsistent response patterns in energy use (growth, LSI, and GSI) in female and male slimy sculpin at *test* site SR-E, the differences from the *baseline* site were classified as **Negligible-Low**. Although the lower GSI could be indicative of a negative change, the higher growth and LSI of slimy sculpin at the *test* site was not indicative of a negative change and could suggest an increase in food resources at this site.

Figure 5.3-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Steepbank River in the 2012 WY, compared to historical values.



Note: Observed 2012 WY hydrograph based on Steepbank River near Fort McMurray, WSC Station 07DA006 (RAMP Station S38) provisional data from March 1 to October 31, 2012 and RAMP Station S38 from November 1, 2011 to February 29, 2012. 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 2011, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1986.

Table 5.3-2 Estimated water balance at WSC Station 07DA006 (RAMP Station S38), Steepbank River near Fort McMurray, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**197.65**	**Observed discharge from Steepbank River near Fort McMurray, WSC Station 07DA006 (RAMP Station S38)**
Closed-circuited area water loss from the observed *test* hydrograph	-0.73	Estimated 4.9 km^2 of the Steepbank River watershed is closed-circuited as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+1.35	Estimated 45.3 km^2 of the Steepbank River watershed with land change as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Steepbank River watershed from focal projects	-0.02	Approximately 0.021 million m^3 of water withdrawn by Suncor from various water sources (daily values provided)
Water releases into the Steepbank River watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Steepbank River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**197.05**	**Estimated *baseline* discharge at Steepbank River near Fort McMurray, WSC Station 07DA006 (RAMP Station S38)**
Incremental flow (change in total discharge)	+0.60	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**+0.31%**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Based on Steepbank River near Fort McMurray, WSC Station 07DA006 provisional data from March 1 to October 31, 2012 and RAMP Station S38 from November 1, 2011 to February 29, 2012. The upstream drainage area of WSC Station 07DA006 is 1,320 km^2, which is slightly smaller than the size of the entire Steepbank River watershed (1,355 km^2, Table 2.5-1).

Table 5.3-3 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	11.458	11.493	+0.31%
Mean winter discharge	0.510	0.512	+0.32%
Annual maximum daily discharge	51.736	51.900	+0.32%
Open-water season minimum daily discharge	2.364	2.370	+0.26%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Based on Steepbank River near Fort McMurray, WSC Station 07DA006 provisional data from March 1 to October 31, 2012 and RAMP Station S38 from November 1, 2011 to February 29, 2012.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to three and two decimal places, respectively.

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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	14	7.7	8.2	8.6
Total suspended solids	mg/L	-	55	14	<3	8	60
Conductivity	µS/cm	-	207	14	141	222	516
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.039	14	0.006	0.019	0.032
Total nitrogen	mg/L	1	**1.07**	14	0.25	0.85	**2.40**
Nitrate+nitrite	mg/L	1.3	<0.07	14	<0.05	<0.10	<0.10
Dissolved organic carbon	mg/L	-	27	14	10	22	30
Ions							
Sodium	mg/L	-	8.8	14	6.0	10.5	38.0
Calcium	mg/L	-	21.5	14	17.2	28.8	50.3
Magnesium	mg/L	-	6.6	14	5.4	8.5	16.2
Chloride	mg/L	120	1.0	14	<1	2.0	8.4
Sulphate	mg/L	270	3.67	14	2.45	4.65	12.3
Total dissolved solids	mg/L	-	160	14	120	181	320
Total alkalinity	mg/L	-	99	14	63	113	263
Selected metals							
Total aluminum	mg/L	0.1	**1.31**	14	0.04	**0.176**	**2.79**
Dissolved aluminum	mg/L	0.1	0.0189	14	<0.004	0.0142	0.0987
Total arsenic	mg/L	0.005	0.0013	14	<0.001	0.0008	0.0013
Total boron	mg/L	1.2	0.052	14	0.025	0.053	0.200
Total molybdenum	mg/L	0.073	0.00024	14	0.00015	0.00020	0.00050
Total mercury (ultra-trace)	ng/L	5, 13	**5.0**	9	<1.2	<1.2	2.9
Total strontium	mg/L	-	0.098	14	0.063	0.108	0.252
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	-	0.19	1	-	0.26	-
Oilsands Extractable	mg/L	-	0.52	1	-	1.08	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	53.70	1	-	9.42	-
Total dibenzothiophenes	ng/L	-	1,678.0	1	-	114.1	-
Total PAHs	ng/L	-	4,774.7	1	-	529.8	-
Total Parent PAHs	ng/L	-	97.42	1	-	32.26	-
Total Alkylated PAHs	ng/L	-	4,677.3	1	-	497.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.48**	14	0.19	**0.37**	**0.60**
Sulphide	mg/L	0.002	**0.013**	14	<0.003	**0.006**	**0.041**
Total chromium	mg/L	0.001	**0.0019**	14	0.0004	0.0007	**0.0083**
Total iron	mg/L	0.3	**2.480**	14	**0.470**	**0.837**	**2.28**
Total phenols	mg/L	0.004	**0.011**	14	<0.001	**0.006**	**0.013**
Total phosphorus	mg/L	0.05	**0.102**	14	0.008	0.040	**0.070**

[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 5.3-5 Concentrations of water quality measurement endpoints in the Steepbank River (*test* station STR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	10	7.8	8.1	8.4
Total suspended solids	mg/L	-	13.0	10	<3.0	4.5	28.0
Conductivity	µS/cm	-	162	10	121	196	329
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.031	10	0.014	0.023	0.048
Total nitrogen	mg/L	1	**1.03**	10	0.60	0.80	**1.99**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.100	0.100
Dissolved organic carbon	mg/L	-	27	10	14	26	30
Ions							
Sodium	mg/L	-	6.4	10	5.0	8.6	18.5
Calcium	mg/L	-	19.4	10	16.8	26.0	35.9
Magnesium	mg/L	-	5.6	10	5.3	7.8	11.4
Chloride	mg/L	120	<0.5	10	<0.5	1.5	3.0
Sulphate	mg/L	270	1.3	10	<0.5	2.8	5.5
Total dissolved solids	mg/L	-	165	10	139	166	249
Total alkalinity	mg/L	-	81	10	61	101	178
Selected metals							
Total aluminum	mg/L	0.1	**0.318**	10	0.018	**0.123**	**0.536**
Dissolved aluminum	mg/L	0.1	0.0205	10	0.0023	0.0137	0.0294
Total arsenic	mg/L	0.005	0.00085	10	0.00050	0.00067	0.00075
Total boron	mg/L	1.2	0.035	10	0.023	0.051	0.157
Total molybdenum	mg/L	0.073	0.00017	10	0.00010	0.00016	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	3.1	9	<0.6	1.2	3.4
Total strontium	mg/L	-	0.075	10	0.053	0.098	0.167
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	-	0.18	1	-	0.15	-
Oilsands Extractable	mg/L	-	0.31	1	-	1.14	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	27.50	1	-	3.99	-
Total dibenzothiophenes	ng/L	-	35.60	1	-	6.37	-
Total PAHs	ng/L	-	221.9	1	-	188.0	-
Total Parent PAHs	ng/L	-	16.61	1	-	20.63	-
Total Alkylated PAHs	ng/L	-	205.3	1	-	167.4	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.48**	10	0.27	**0.45**	**0.60**
Sulphide	mg/L	0.002	**0.005**	10	<0.003	**0.0059**	**0.0120**
Total iron	mg/L	0.3	**1.40**	10	**0.73**	**0.80**	**1.07**
Total phenols	mg/L	0.004	**0.0120**	10	<0.001	**0.0067**	**0.0111**
Total phosphorus	mg/L	0.05	**0.069**	10	0.035	0.038	0.064

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	8	7.9	8.2	8.5
Total suspended solids	mg/L	-	15	8	<3	<3	7
Conductivity	µS/cm	-	151	8	128	253	346
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.039	8	0.024	0.038	0.046
Total nitrogen	mg/L	1	**1.13**	8	0.57	0.75	**1.85**
Nitrate+nitrite	mg/L	1.3	<0.071	8	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	30	8	14	27	32
Ions							
Sodium	mg/L	-	6.8	8	5.4	13.0	22.8
Calcium	mg/L	-	18.0	8	17.1	34.0	40.7
Magnesium	mg/L	-	5.2	8	5.4	10.1	13.2
Chloride	mg/L	120	<0.5	8	<0.5	1.0	2.0
Sulphate	mg/L	270	1.30	8	0.83	2.55	3.40
Total dissolved solids	mg/L	-	151	8	140	193	234
Total alkalinity	mg/L	-	74.5	8	63.6	143.0	186.0
Selected metals							
Total aluminum	mg/L	0.1	**0.240**	8	0.015	0.040	**0.233**
Dissolved aluminum	mg/L	0.1	0.024	8	0.004	0.010	0.030
Total arsenic	mg/L	0.005	0.00083	8	0.00046	0.00066	0.00075
Total boron	mg/L	1.2	0.031	8	0.025	0.065	0.134
Total molybdenum	mg/L	0.073	0.00019	8	0.00014	0.00019	0.00028
Total mercury (ultra-trace)	ng/L	5, 13	3.5	8	<0.6	<1.2	2.1
Total strontium	mg/L	-	0.076	8	0.057	0.108	0.150
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	-	0.03	1	-	0.28	-
Oilsands Extractable	mg/L	-	0.25	1	-	1.12	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	12.20	1	-	2.59	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	5.94	-
Total PAHs	ng/L	-	217.0	1	-	171.7	-
Total Parent PAHs	ng/L	-	16.41	1	-	19.98	-
Total Alkylated PAHs	ng/L	-	200.6	1	-	151.7	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.52**	8	**0.34**	**0.57**	**0.75**
Sulphide	mg/L	0.002	**0.004**	8	**0.004**	**0.006**	**0.011**
Total iron	mg/L	0.3	**1.37**	8	**0.70**	**0.93**	**1.04**
Total phenols	mg/L	0.004	**0.012**	8	0.001	**0.006**	**0.019**
Total phosphorus	mg/L	0.05	**0.08**	8	0.04	**0.05**	**0.06**

[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 5.3-7 Concentrations of water quality measurement endpoints in the North Steepbank River (*test* station NSR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	10	7.5	8.0	8.4
Total suspended solids	mg/L	-	20	10	<3	<3	8
Conductivity	µS/cm	-	164	10	110	154	311
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.024	10	0.015	0.022	0.042
Total nitrogen	mg/L	1	**1.15**	10	0.40	0.70	**1.27**
Nitrate+nitrite	mg/L	1.3	0.40	10	<0.071	<0.10	<0.10
Dissolved organic carbon	mg/L	-	20	10	13	20	23
Ions							
Sodium	mg/L	-	2.8	10	2.0	3.0	6.1
Calcium	mg/L	-	22.7	10	16.5	23.2	42.9
Magnesium	mg/L	-	6.4	10	4.9	6.6	12.5
Chloride	mg/L	120	4.8	10	<0.5	1.0	2.0
Sulphate	mg/L	270	6.5	10	<0.5	1.1	5.2
Total dissolved solids	mg/L	-	102	10	109	145	219
Total alkalinity	mg/L	-	82	10	55	80	169
Selected metals							
Total aluminum	mg/L	0.1	**0.241**	10	0.018	0.052	**0.129**
Dissolved aluminum	mg/L	0.1	0.0115	10	0.0030	0.0106	0.0148
Total arsenic	mg/L	0.005	0.0013	10	0.0005	0.0008	0.0014
Total boron	mg/L	1.2	0.015	10	0.010	0.014	0.050
Total molybdenum	mg/L	0.073	0.00017	10	0.00013	0.00020	0.00080
Total mercury (ultra-trace)	ng/L	5, 13	3.3	9	<0.6	<1.2	1.2
Total strontium	mg/L	-	0.081	10	0.049	0.079	0.245
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	-	0.27	1	-	0.25	-
Oilsands Extractable	mg/L	-	0.89	1	-	1.11	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	6.740	1	-	2.071	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	5.92	-
Total PAHs	ng/L	-	207.1	1	-	178.5	-
Total Parent PAHs	ng/L	-	16.42	1	-	19.51	-
Total Alkylated PAHs	ng/L	-	190.7	1	-	159.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.55**	10	0.23	**0.46**	**0.77**
Total iron	mg/L	0.3	**1.92**	10	**0.51**	**0.84**	**1.29**
Total phenols	mg/L	0.004	**0.007**	10	<0.001	**0.006**	**0.010**
Total phosphorus	mg/L	0.05	**0.076**	10	0.027	**0.035**	**0.059**
Sulphide	mg/L	0.002	**0.004**	10	<0.002	**0.005**	**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.

Figure 5.3-4 Piper diagram of fall ion concentrations in the Steepbank River, fall 2012.

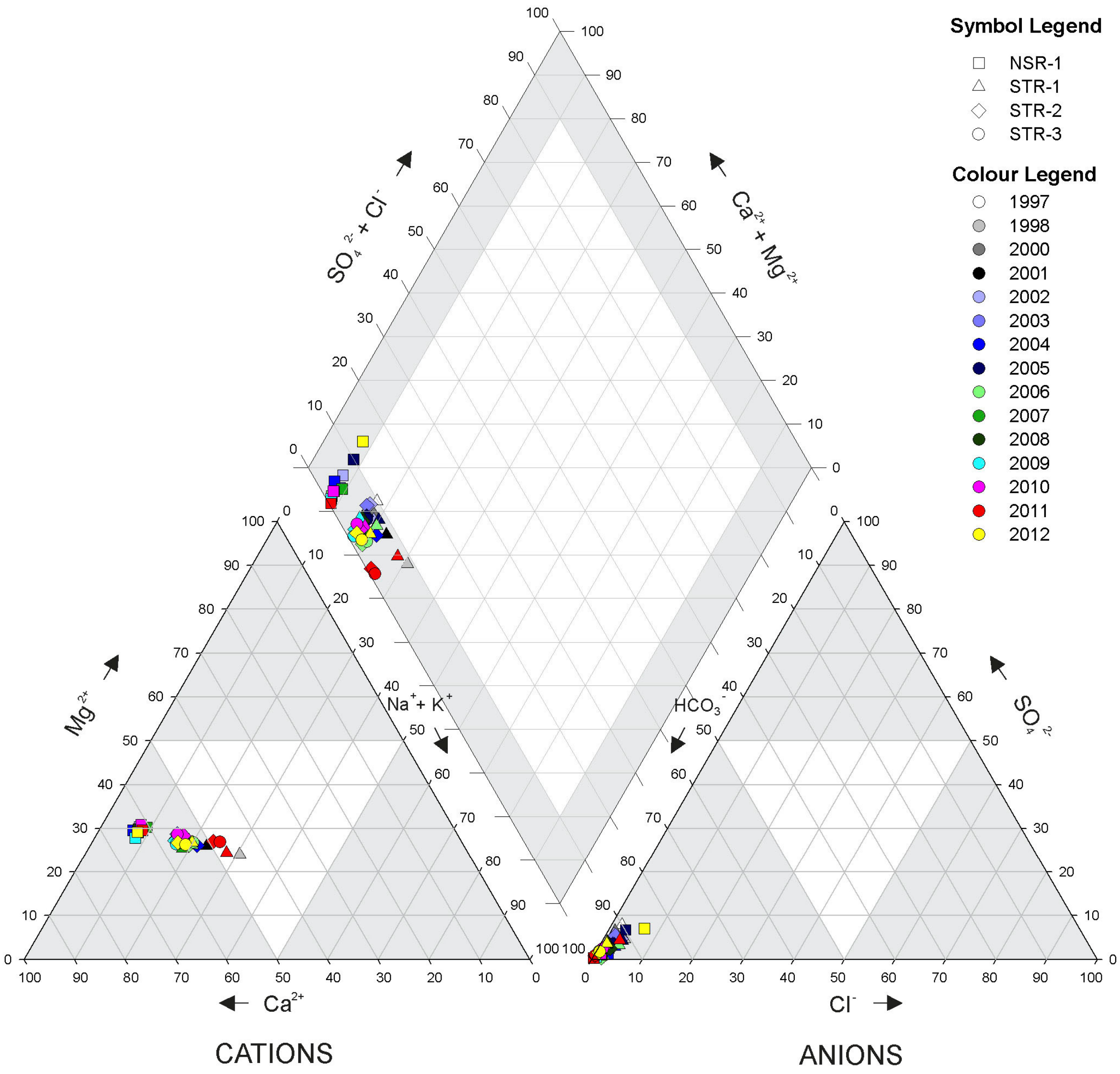


Table 5.3-8 Water quality guideline exceedances, Steepbank River watershed, 2012.

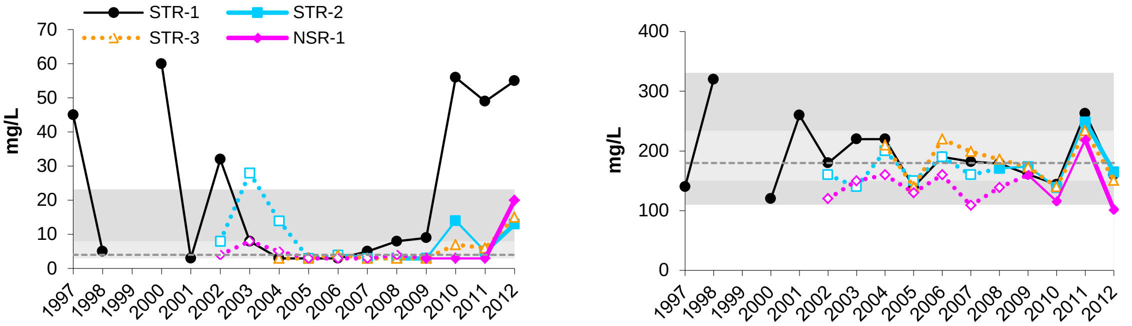
Variable	Units	Guideline[a]	STR-1	STR-2	STR-3	NSR-1
Winter						
Total iron	mg/L	0.3	0.431	ns	ns	ns
Fall						
Dissolved iron	mg/L	0.3	0.48	0.48	0.52	0.55
Sulphide	mg/L	0.0	0.0125	0.0054	0.0044	0.0039
Total aluminum	mg/L	0.1	1.31	0.32	0.24	0.24
Total chromium	mg/L	0.001	0.0019	-	-	-
Total iron	mg/L	0.3	2.48	1.40	1.37	1.92
Total nitrogen	mg/L	1	1.07	1.03	1.13	1.15
Total phenols	mg/L	0.004	0.0108	0.0120	0.0121	0.0066
Total phosphorus	mg/L	0.05	0.102	0.069	0.083	0.076

[a] Sources for all guidelines are outlined in Table 3.2-5.

Underline denotes baseline station.

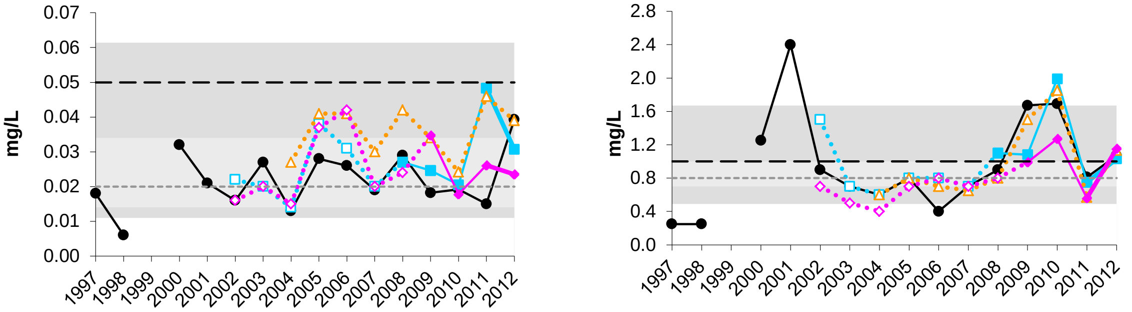
ns = not sampled

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.



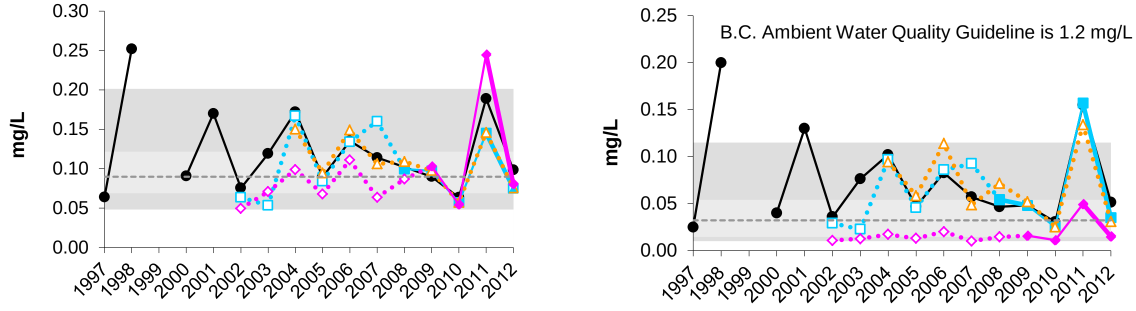
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



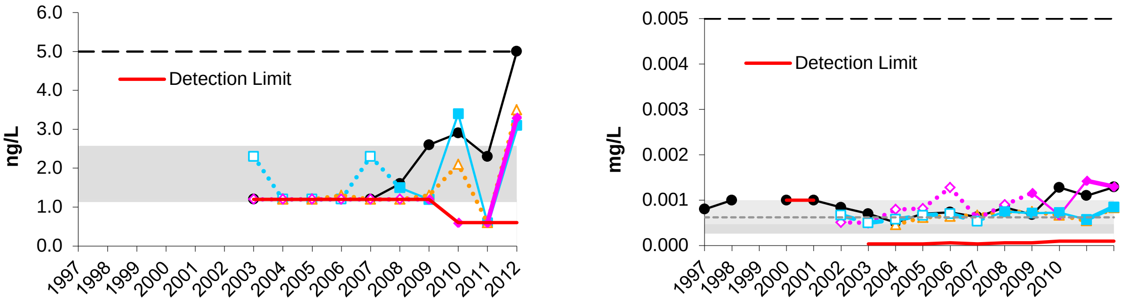
Dissolved Phosphorus

Total Nitrogen



Total Strontium

Total Boron



Total Mercury (Ultra-trace)

Total Arsenic

Non-detectable values are shown at the detection limit.

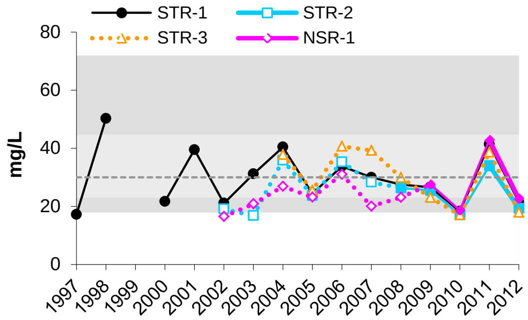
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

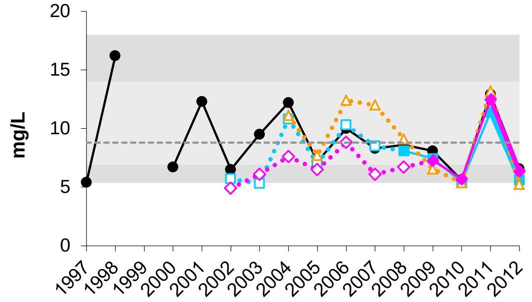
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.3-5 (Cont'd.)

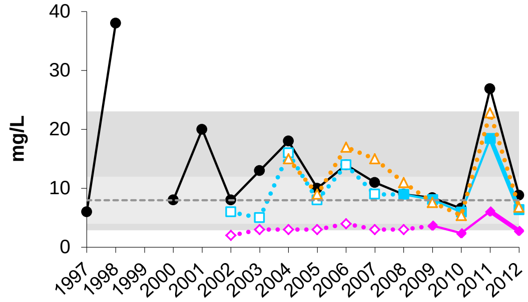
Calcium



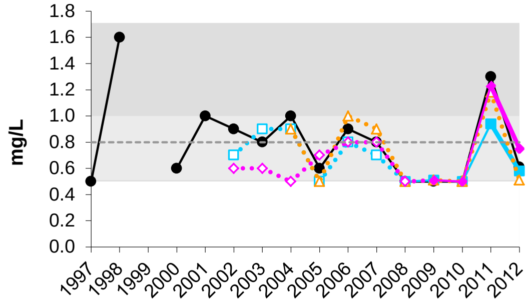
Magnesium



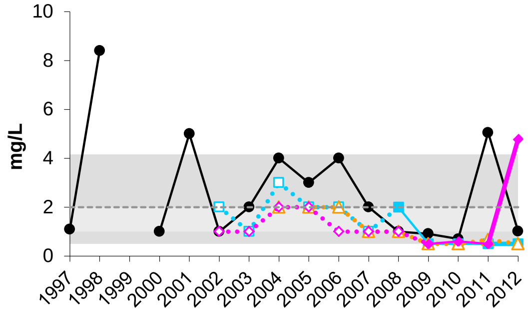
Sodium



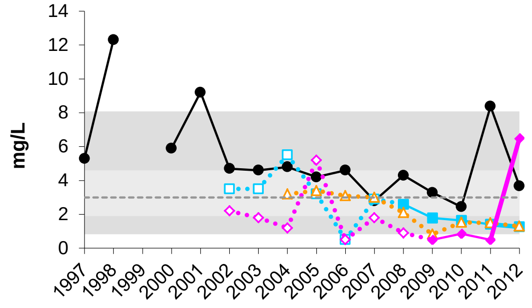
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.3-9 Water quality index (fall 2012) for Steepbank River watershed stations.

Station	Location	2012 Designation	Water Quality Index	Classification
STR-1	Lower Steepbank River	*test*	84.7	Negligible-Low
STR-2	Upstream of Project Millennium	*test*	98.7	Negligible-Low
STR-3	Upstream of North Steepbank River	*baseline*	96.2	Negligible-Low
NSR-1	North Steepbank River	*test*	94.9	Negligible-Low

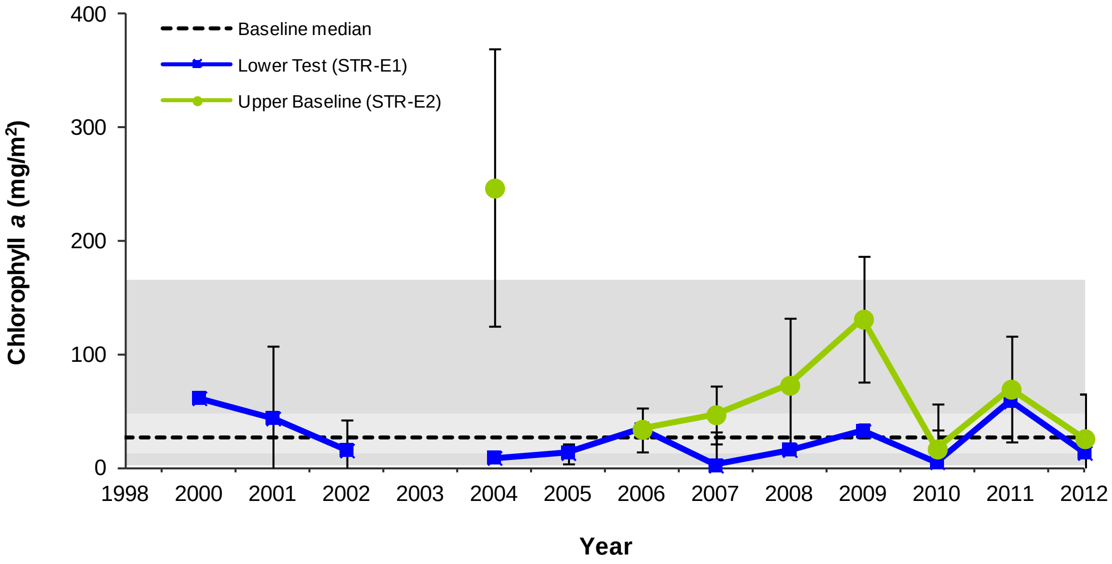
Note: see Figure 5.3-1 for the locations of these water quality stations.

Note: see Section 3.2.2.3 for a description of the Water Quality Index.

Table 5.3-10 Average habitat characteristics of benthic invertebrate sampling locations in the Steepbank River, fall 2012.

Variable	Units	STR-E1 Lower *Test* Reach of Steepbank River	STR-E2 Upper *Baseline* Reach of Steepbank River
Sample date	-	06-Sept-2012	07-Sept-2012
Habitat	-	Erosional	Erosional
Water depth	m	0.4	0.4
Current velocity	m/s	0.68	1.16
Field Water Quality			
Dissolved oxygen	mg/L	7.3	8.8
Conductivity	µS/cm	165	210
pH	pH units	8.3	8.2
Water temperature	°C	11	11.4
Sediment Composition			
Sand/Silt/Clay	%	13	0
Small Gravel	%	10	0
Large Gravel	%	35	3
Small Cobble	%	20	15
Large Cobble	%	20	40
Boulder	%	3	42
Bedrock	%	0	0

Figure 5.3-6 Periphyton chlorophyll *a* biomass in the Steepbank River.



Note: Regional *baseline* values for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.3-11 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the lower Steepbank River (*test* reach STR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach STR-E1		
	1998	2000 to 2011	2012
Nematoda	1	<1 to 2	3
Oligochaeta		0 to <1	
Naididae	2	2 to 41	15
Tubificidae	2	<1 to 19	23
Enchytraeidae	1	1 to 15	3
Hydracarina	6	3 to 20	5
Ostracoda	1	0 to 5	
Cladocera	1	0 to <1	
Copepoda	<1	0 to <1	
Gastropoda	<1	0 to 6	1
Bivalvia		0 to <1	1
Coleoptera		0 to <1	
Ceratopogonidae	<1	0 to 3	<1
Dolichopodidae			<1
Chironomidae	31	15 to 43	27
Athericidae		<1 to 1	
Empididae	2	<1 to 9	<1
Tipulidae	<1	0 to <1	<1
Tabanidae	<1	o to <1	
Simuliidae	3	<1 to 3	2
Ephemeroptera	51	1 to 51	19
Anisoptera	<1	<1 to 1	<1
Plecoptera	<1	<1 to 1	
Trichoptera	1	<1 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	29,87	1,691 to 102, 882	41,697
Richness	41	17 to 41	32
Simpson's Diversity	0.76	0.75 to 0.88	0.88
Equitability	0.11	0.13 to 0.42	0.28
% EPT	47	10 to 47	20

Table 5.3-12 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the upper Steepbank River (*baseline* reach STR-E2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach STR-E2		
	2004	2005 to 2011	2012
Hydra		0 to <1	
Nematoda	3	1 to 3	6
Lumbriculidae			<1
Naididae	2	1 to 24	8
Tubificidae	<1	0 to 1	<1
Enchytraeidae	<1	0 to 1	<1
Hydracarina	7	3 to 12	9
Ostracoda	1	0 to 18	<1
Cladocera	4	0 to 7	5
Copepoda	4	0 to 4	3
Gastropoda		0 to <1	<1
Bivalvia		0 to 4	3
Coleoptera		0 to <1	
Ceratopogonidae		0 to 7	<1
Chironomidae	46	24 to 52	31
Athericidae	<1	1 to 3	<1
Empididae	2	<1 to 8	3
Dolichopodidae			<1
Muscidae			<1
Tipulidae	1	<1 to 2	<1
Tabanidae	<1	0 to <1	<1
Simuliidae	<1	0 to 1	<1
Ephemeroptera	18	6 to 35	15
Anisoptera	<1	0 to <1	<1
Plecoptera	2	1 to 4	3
Trichoptera	9	6 to 34	9
Hemiptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	41,844	12,758 to 196,600	48,628
Richness	34	29 to 46	42
Simpson's Diversity	0.89	0.7 to 0.9	0.92
Equitability	0.28	0.11 to 0.29	0.32
% EPT	29	31 to 56	26

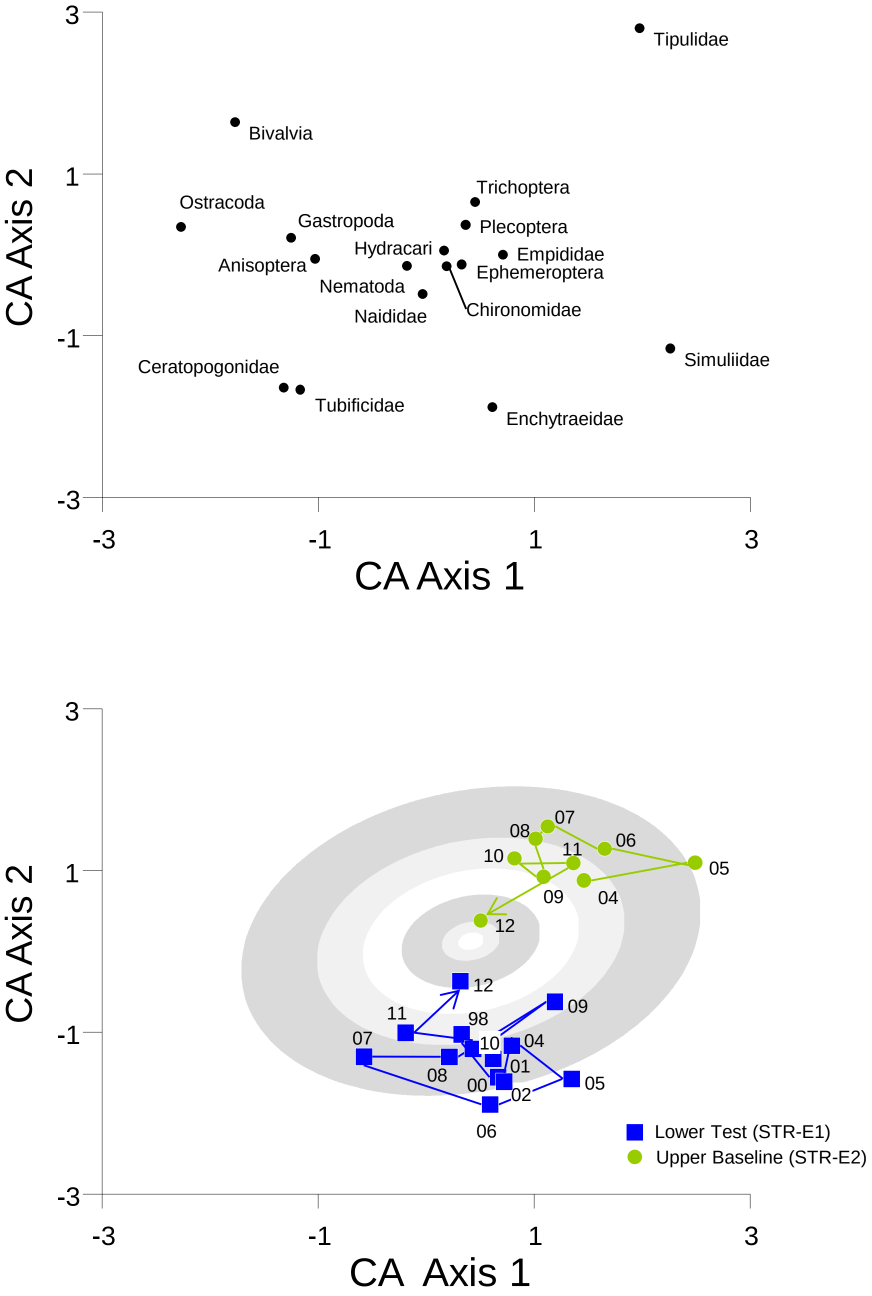
Table 5.3-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Steepbank River.

Variable	**P-value**				**Variance Explained (%)**				**Nature of Change(s)**
	***Baseline* Period vs. *Test* Period**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Data**	**2012 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Data**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**<0.001**	0.495	**<0.001**	19	4	0	2	Higher at *baseline* reach; increased over time; higher in 2012 than the mean of previous years.
Richness	**<0.001**	**0.004**	0.292	0.169	24	2	0	0	Higher at *baseline* reach; increasing over time.
Simpson's Diversity	0.773	0.152	0.448	0.264	0	2	1	1	No change.
Equitability	**<0.001**	0.610	0.417	0.820	16	0	0	0	Higher at *test* reach.
EPT	**<0.001**	**<0.001**	**0.039**	0.557	34	6	2	0	Higher at *baseline* reach; decreasing over time; lower in 2012 than the mean of *baseline* years; lower in 2012 than mean of previous sampling years.
CA Axis 1	**<0.001**	0.060	**0.018**	0.630	28	1	2	0	Higher at *baseline* reach; lower in 2012 than the mean of *baseline* years.
CA Axis 2	**<0.001**	**0.003**	**<0.001**	**0.016**	54	1	1	1	Higher at *baseline* reach; increasing over time; lower in 2012 than mean of *baseline* years, higher in 2012 than mean of previous sampling years.

Bold values indicate significant difference ($p<0.05$).

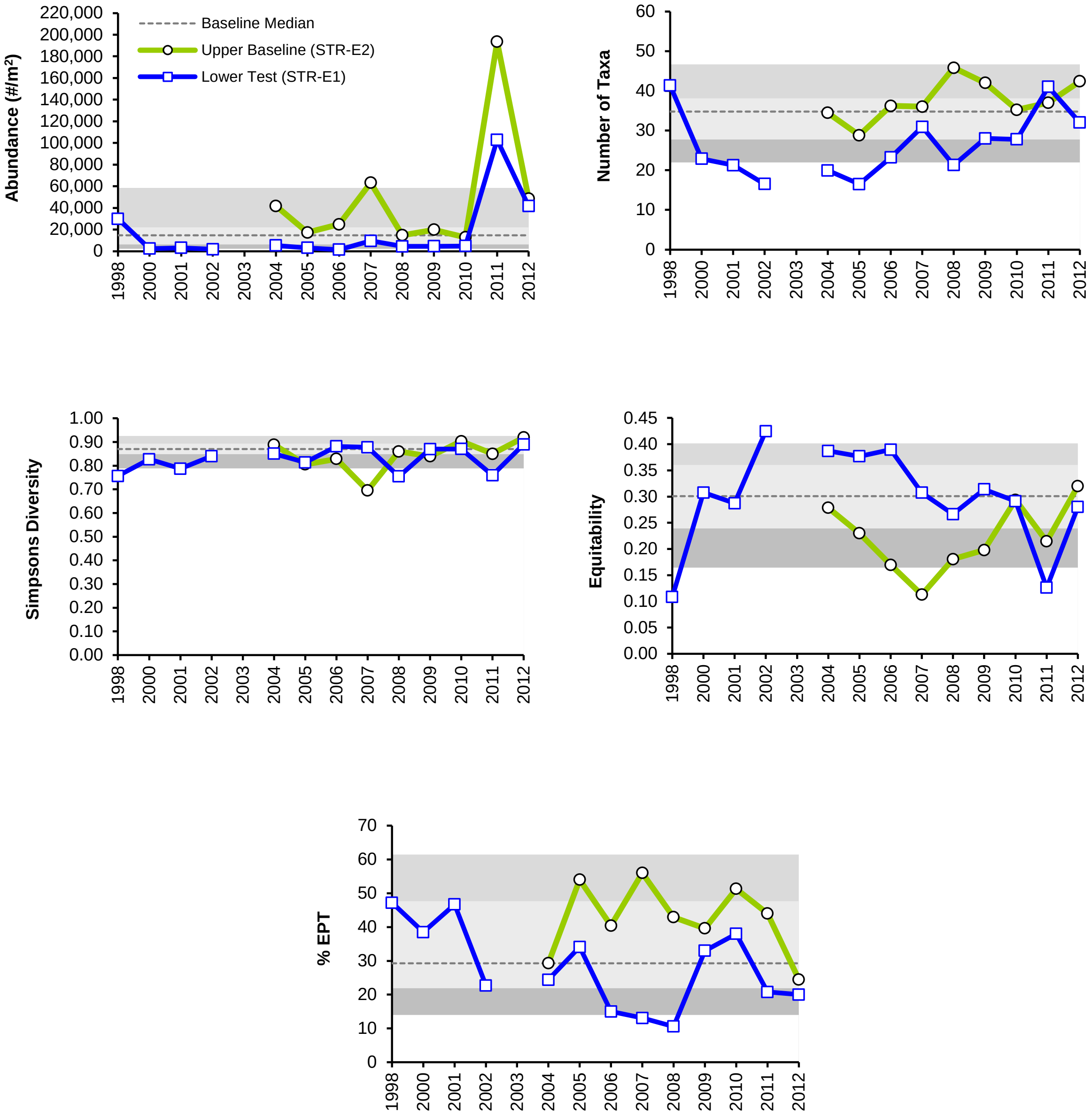
Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.3-7 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Steepbank River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for *baseline* data for erosional reaches in the RAMP FSA.

Figure 5.3-8 Variation in benthic invertebrate community measurement endpoints in the Steepbank River.



Note: Regional *baseline* values for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.3-14 Average habitat characteristics of fish assemblage monitoring locations in the Steepbank River, fall 2012.

Variable	**Units**	**STR-F1 Lower *Test* Reach of Steepbank River**	**STR-F2 Upper *Baseline* Reach of Steepbank River**
Sample date	-	14-Sept-2012	14-Sept-2012
Habitat type	-	run/riffle	riffle
Maximum depth	m	1	1
Bankfull channel width	m	30.0	17.5
Wetted channel width	m	30.0	17.5
Substrate			
Dominant	-	coarse gravel	-
Subdominant	-	fines	-
Instream cover			
Dominant	-	overhanging vegetation	overhanging vegetation
Subdominant	-	-	large woody debris, live trees/roots
Field water quality			
Dissolved oxygen	mg/L	10.4	9
Conductivity	µS/cm	100	74
pH	pH units	7.63	7.47
Water temperature	^{0}C	9.3	7.9
Water velocity			
Left bank velocity	m/s	-	-
Left bank water depth	m	-	-
Centre of channel velocity	m/s	-	-
Centre of channel water depth	m	-	-
Right bank velocity	m/s	0.52	0.38
Right bank water depth	m	0.81	0.97
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.3-15 Percent composition and mean CPUE (catch per unit effort) of fish species at *test* reach STR-F1 and *baseline* reach STR-F2 of Steepbank River, 2009 to 2012.

Common Name	**Code**	**Total Catch**						**Percent of Total Catch**					
		STR-F1				**STR-F2**		**STR-F1**			**STR-F2**		
		2009	**2010**	**2011**	**2012**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2011**	**2012**
Arctic grayling	ARGR	-	-	-	-	-	-	0	0	0	0	0	0
brook stickleback	BRST	-	-	-	-	5	1	0	0	0	0	6.3	50.0
burbot	BURB	-	8	-	-	-	-	0	3.8	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	0	0	0	0	0	0
finescale dace	FNDC	-	-	-	-	-	-	0	0	0	0	0	0
lake chub	LKCH	2	-	-	3	5	1	6.1	0	0	30.0	6.3	50.0
lake whitefish	LKWH	-	-	-	-	1	-	0	0	0	0	1.3	0
longnose dace	LNDC	1	63	2	2	9	-	3.0	30.0	7.7	20.0	11.4	0
longnose sucker	LNSC	2	-	1	1	3	-	6	0	3.8	10.0	3.8	0
northern pike	NRPK	-	-	-	1	-	-	0	0	0	10.0	0	0
northern redbelly dace	NRDC	16	-	-	-	1	-	48.5	0	0	0	1.3	0
pearl dace	PRDC	2	64	-	-	-	-	6.1	30.5	0	0	0	0
slimy sculpin	SLSC	2	60	8	2	35	-	6.1	28.6	30.8	20.0	44.3	0
spoonhead sculpin	SPSC	-	3	3	-	-	-	0	1.4	11.5	0	0	0
spottail shiner	SPSH	-	-	-	-	-	-	0	0	0	0	0	0
trout-perch	TRPR	1	7	-	-	20	-	3.0	3.3	0	0	25.3	0
walleye	WALL	1	-	-	-	-	-	3.0	0	0	0	0	0
white sucker	WHSC	1	4	12	1	-	-	3.0	1.9	46.2	10.0	0	0
yellow perch	YLPR	-	1	-	-	-	-	0	0.5	0	0	0	0
unknown sp. *		5	-	-	-	-	-	15.2	0	0	0	0	0
Total Count		**33**	**210**	**26**	**10**	**79**	**2**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**9**	**8**	**5**	**6**	**8**	**2**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**3,652**	**4,977**	**1,326**	**1,948**	**1,309**	**1,712**	**-**	**-**	**-**	**-**	**-**	**-**
CPUE (#/100 secs)		**0.9**	**4.22**	**1.96**	**0.51**	**6.04**	**0.12**	**-**	**-**	**-**	**-**	**-**	**-**

* not included in total species richness count.

Table 5.3-16 Summary of fish assemblage measurement endpoints in reaches of the Steepbank River watershed, 2009 to 2012.

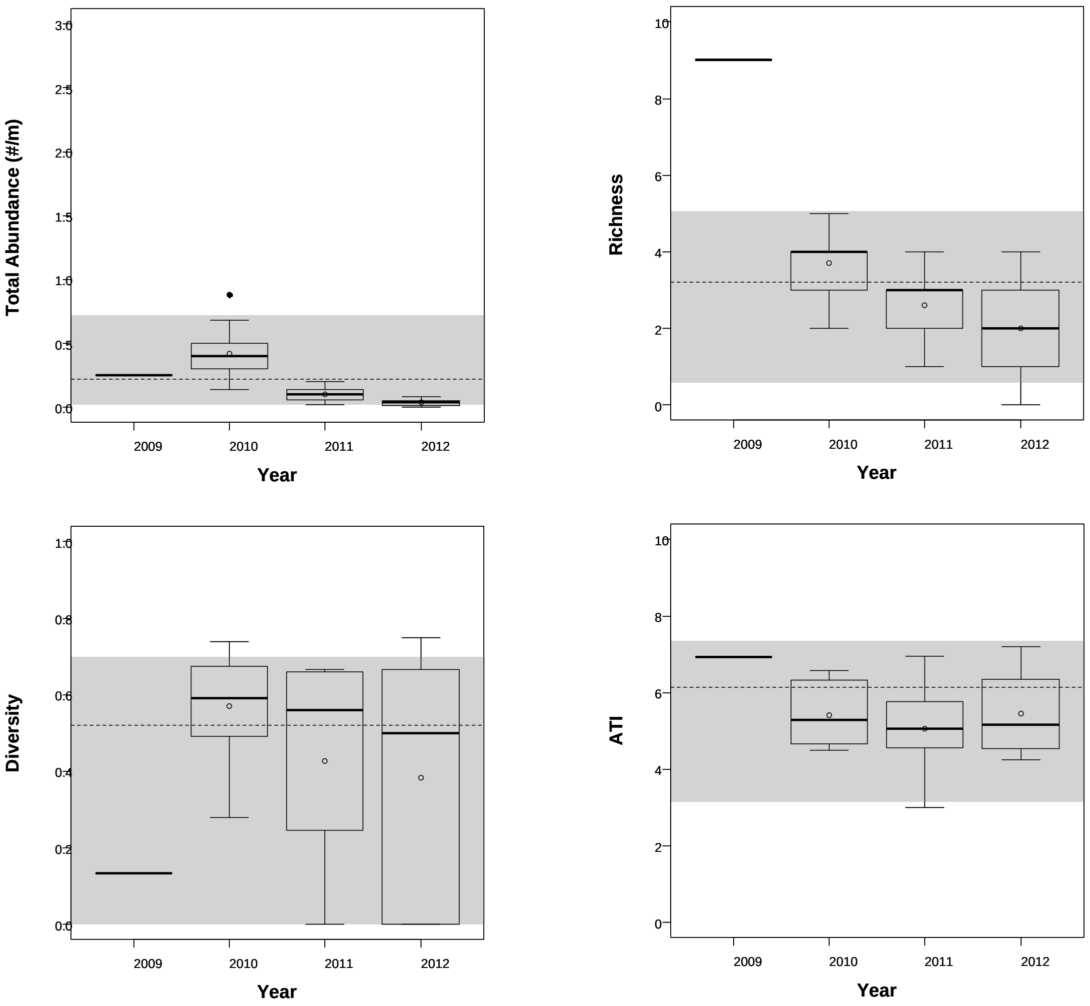
Reach	Year	Abundance (#/m)		Richness*			Diversity*		ATI*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
STR-F1	2009	0.25		10	9	-	0.13	-	6.92	-
	2010	0.42	0.23	8	4	0.95	0.57	0.13	5.42	0.81
	2011	0.10	0.07	5	3	1.14	0.43	0.29	5.07	1.46
	2012	0.04	0.03	6	2	1.58	0.38	0.36	4.36	2.67
STR-F2	2011	0.32	0.18	8	4	1.30	0.59	0.09	6.02	2.08
	2012	0.01	0.01	2	<1	0.55	0.00	0.00	2.98	4.31

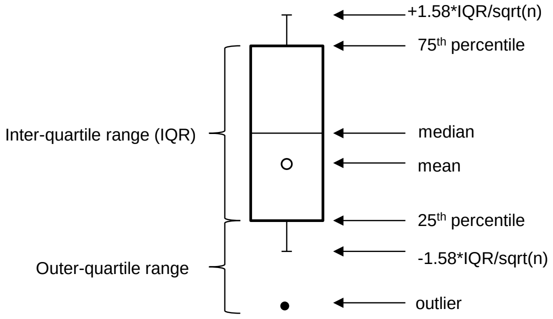
* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

Figure 5.3-9 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the Steepbank River, 2009 to 2012.

Erosional *Test* Reach STR-F1



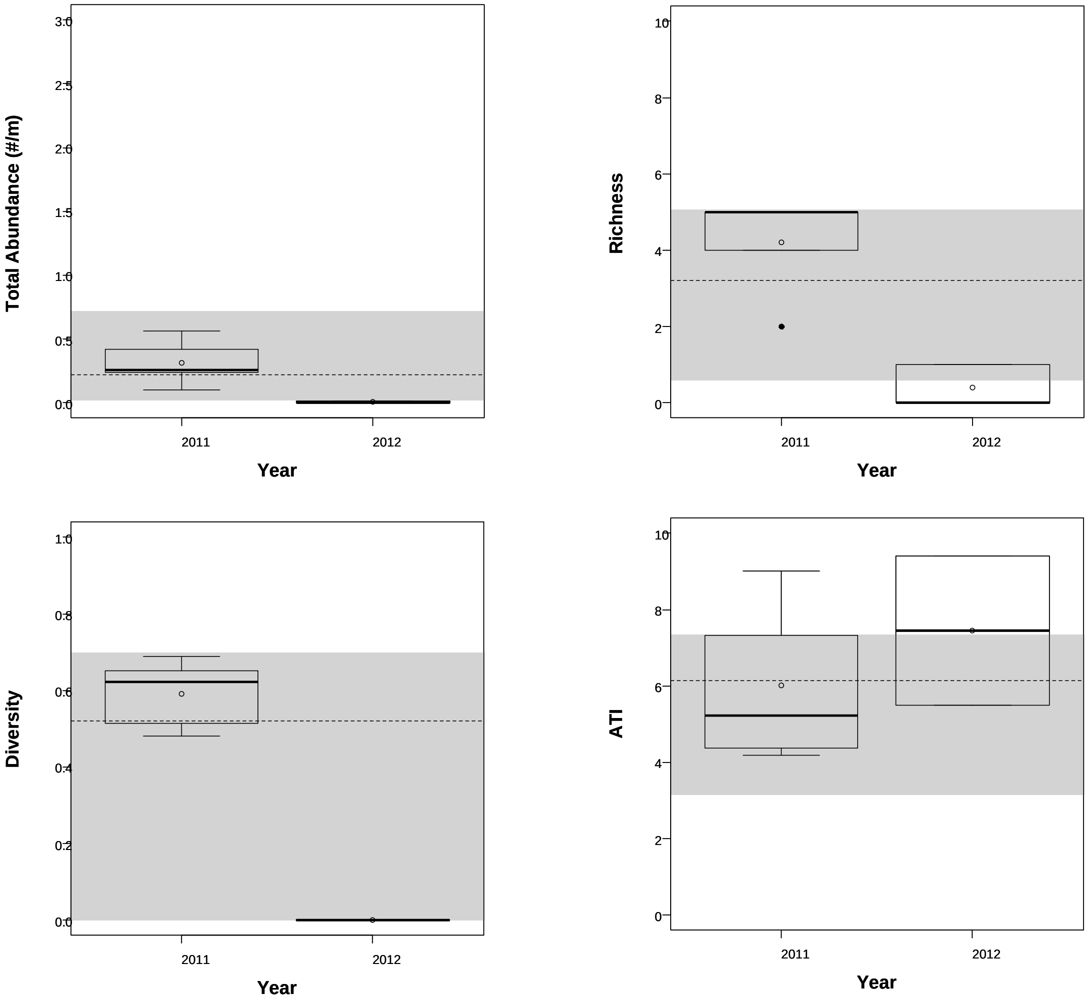


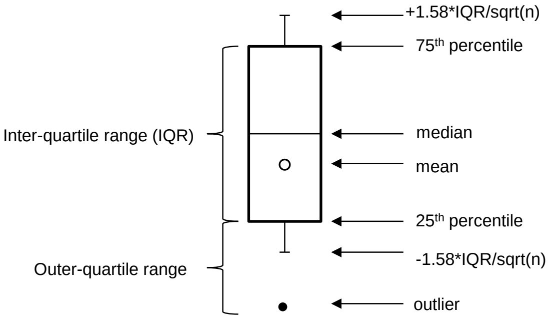
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Figure 5.3-9 (Cont'd.)

Erosional *Baseline* Reach STR-F2





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Table 5.3-17 In situ water quality variables collected during the 2012 Sentinel Species program, September 2012.

Watercourse	Site	Status	Collection Date	Water Temperature (^0C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	Mean Velocity (m/s)	Mean Water Depth (m)
Horse River	HR-R	*Baseline*	22-Sept-12	9.4	86	18.6	8.55	0.77	n/a
Dunkirk River	DR-R	*Baseline*	17-Sept-12	9.5	170	9.2	7.97	0.27	0.25
High Hills River	HH-R	*Baseline*	10-Oct-12	2.7	127	11.6	7.65	0.25	0.49
Upper Steepbank River	SR-R	*Baseline*	22-Sept-12	8.0	105	8.5	7.7	0.46	0.86
Lower Steepbank River	SR-E	*Test*	26-Sept-12	9.6	125	8.9	8.01	0.73	0.27
Lower Muskeg River	MR-E	*Test*	28-Sept-12	10.0	218	8.2	7.94	0.67	0.36

Table 5.3-18 Summary of morphometric data (mean ± 1SD) for slimy sculpin in tributaries to the Athabasca River, 2012.

Site	N	Sex	Age (years)	Length (mm)	Weight (g)	K	GSI	LSI
HR-R	20	Female	3.4±3.3	72.05±11.80	3.42±1.31	0.91±0.13	1.65±0.39	2.46±1.58
	16	Male	2.4±1.8	70.44±14.05	3.37±2.17	0.93±0.15	1.62±0.82	1.20±0.71
DR-R	21	Female	1.4±1.0	77.86±9.86	4.70±1.98	0.98±0.13	1.82±1.02	2.41±1.21
	18	Male	1.7±1.3	89.61±15.43	7.57±4.41	1.03±0.10	1.93±0.52	1.33±0.52
HH-R	24	Female	1.9±1.3	60.21±19.26	2.47±3.13	1.04±0.22	1.90±0.96	1.73±1.26
	15	Male	2.3±1.8	69.13±19.84	3.72±3.60	1.05±0.14	1.57±0.78	1.21±0.82
SR-E	19	Female	1.9±1.4	74.63±12.48	4.00±2.30	0.93±0.17	1.51±0.62	2.67±1.53
	22	Male	2.2±1.2	75.45±12.71	4.20±2.67	0.95±0.22	1.58±0.76	1.91±1.17
SR-R	25	Female	1.9±0.8	64.24±10.84	2.50±1.21	0.93±0.09	2.04±1.38	2.00±1.12
	22	Male	1.8±0.9	64.14±10.53	2.54±1.36	0.94±0.12	1.78±1.48	1.18±0.34
MR-E	5	Female	1.8±2.6	62.00±27.57	2.75±4.83	0.98±0.17	0.68±1.45	2.01±0.84
	6	Male	1.3±1.6	55.17±5.85	1.74±0.65	1.03±0.22	0.62±1.27	1.94±0.93

Figure 5.3-10 **Mean age (± 1SD) of male and female slimy sculpin at *baseline* (SR-R, DR-R, HR-R, and HH-R) and *test* (sites MR-E and SR-E) sites on tributaries to the Athabasca River, 1999, 2001 and 2012.**

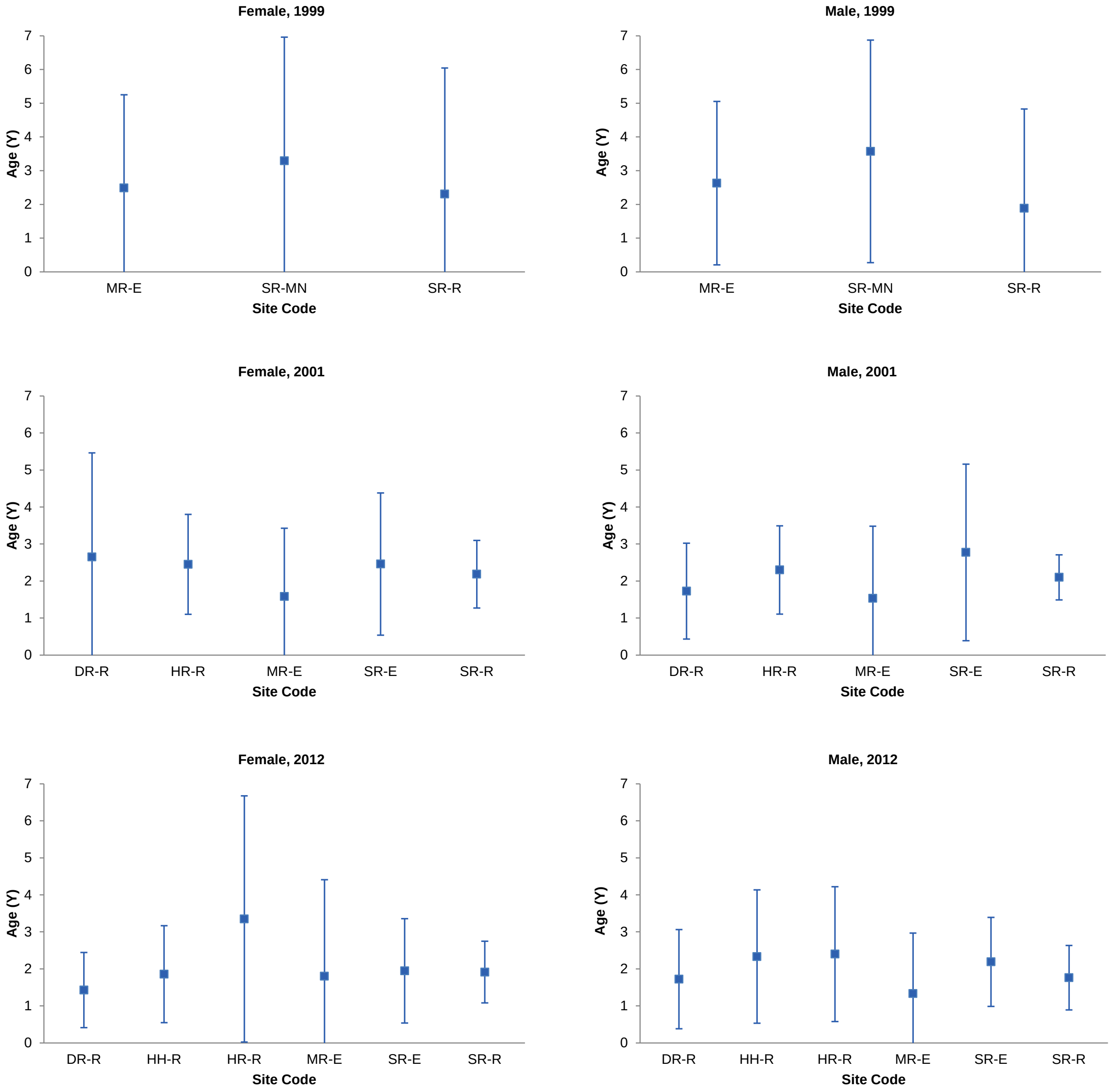


Figure 5.3-11 Relative age-frequency distribution for slimy sculpin across sites, 1999, 2001, and 2012.

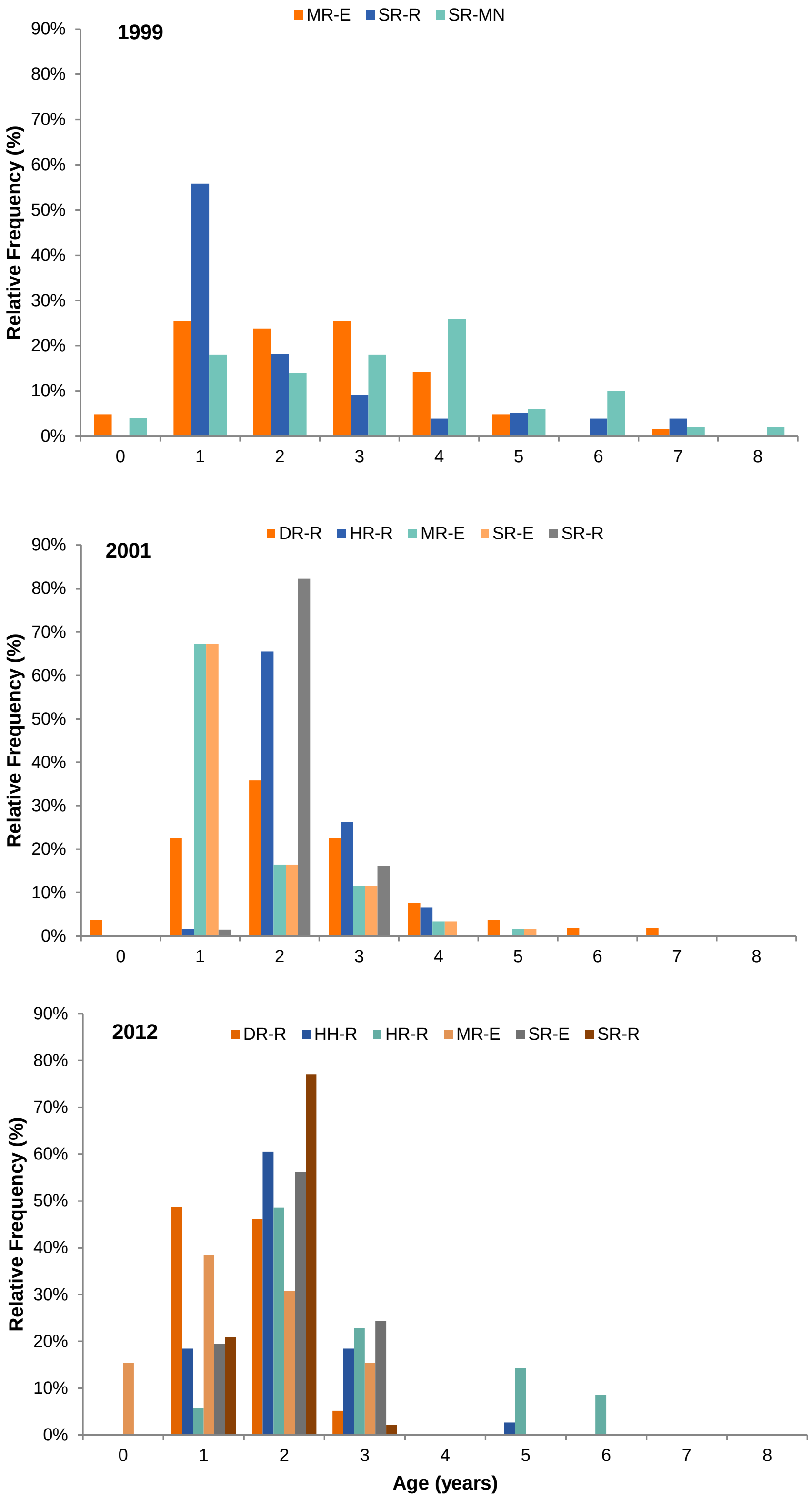


Table 5.3-19 Summary of ANOVA results for each measurement endpoint of slimy sculpin from *test* site SR-E compared to *baseline* sites HR-R, HH-R, and HR-R, September 2012.

Sex	Comparison	WAA	LSI	GSI	K	Age
Female	SR-E vs. SR-R	**<0.001**	0.954	**<0.001**	0.381	0.872
	SR-E vs. DR-R	**<0.001**	**0.038**	0.067	0.134	**0.016**
	SR-E vs. HH-R	**<0.001**	**0.003**	**0.002**	**0.003**	**0.002**
	SR-E vs. HR-R	**<0.001**	0.452	0.086	0.289	**0.049**
	Baseline sites combined	0.997	0.412	**0.047**	**0.015**	0.709
Male	SR-E vs. SR-R	**<0.001**	**<0.001**	0.137	0.083	**0.024**
	SR-E vs. DR-R	**<0.001**	**0.011**	0.084	0.833	0.311
	SR-E vs. HH-R	0.329	**<0.001**	0.744	**<0.001**	0.538
	SR-E vs. HR-R	**0.030**	**0.001**	0.952	0.356	0.902
	Baseline sites combined	0.807	**0.032**	0.734	**0.015**	0.299

Bolded values denote a significant difference (p<0.05).

Statistical analyses were mot performed on *test* site MR-E due to low sample size.

WAA = weight at age; LSI = liversomatic Index; GSI = gonadosomatic Index; K = condition.

Table 5.3-20 Post-hoc power analyses for pairwise comparisons of *test* site SR-E to each *baseline* site, that were not statistically significant, September 2012.

Variable/Sex	Effect Size	Comparison	Effect Size (log)	MSE (ANCOVA)	Actual Sample Size	Post Hoc Power (calculated)
Age						
female	±25%	SR-E vs. SR-R	0.0969	0.022	42	**0.68**
Weight-At-Age						
Male	±25%	SR-E vs. HH-R	0.02142	0.223	34	**0.60**
Gonad Weight vs. Body Weight						
female	±25%	SR-E vs. DR-R	0.0969	0.012	40	**0.86**
	±25%	SR-E vs. HR-R	0.0969	0.009	39	0.94
male	±25%	SR-E vs. SR-R	0.0969	0.021	41	**0.67**
	±25%	SR-E vs. DR-R	0.0969	0.005	39	0.99
	±25%	SR-E vs. HH-R	0.0969	0.005	34	0.99
	±25%	SR-E vs. HR-R	0.0969	0.012	37	**0.83**
Liver Weight vs. Body Weight						
female	±25%	SR-E vs. SR-R	0.0969	0.011	42	0.90
	±25%	SR-E vs. HR-R	0.0969	0.020	39	**0.68**
Condition						
female	±10%	SR-E vs. SR-R	0.0414	0.001	42	0.99
	±10%	SR-E vs. DR-R	0.0414	0.001	40	0.99
	±10%	SR-E vs. HR-R	0.0414	0.001	39	0.97
male	±10%	SR-E vs. SR-R	0.0414	0.002	41	0.95
	±10%	SR-E vs. DR-R	0.0414	0.001	39	0.97
	±10%	SR-E vs. HR-R	0.0414	0.002	37	0.93

Bolded values denote comparisons where power was inadequate and sample size was too low.

Table 5.3-21 Summary of effects criterion for each measurement endpoint from *test* site SR-E compared to each *baseline* site (SR-R HR-R, HH-R, and HR-R) and all *baseline* sites combined, September 2012.

Sex	Site	Age	Energy Use		Energy Storage		Significant Difference from *Baseline*					Response Pattern Based on Effects Criteria				
			Weight-at-age	GSI	LSI	K	Age	Energy Use		Energy Storage		Age	Energy Use		Energy Storage	
								WAA	GSI	LSI	K		WAA	GSI	LSI	K
Female	SR-R	-1.7	**54.8**	**-41.4**	0.6	-2.5	0	+	-	0	0	0	+	-	0	0
	DR-R	**34.9**	**-26.1**	-14.9	20.8	-3.8	+	-	0	+	0	+	-	0	0	0
	HH-R	1.6	**60.3**	**-28.2**	**54.2**	**-13.1**	+	+	-	+	-	0	+	-	+	-
	HR-R	**-38.8**	**34.2**	-11.7	8.5	3	-	+	0	0	0	-	+	0	0	0
	Baseline sites combined	-4.3	**25.7**	-23.9	12.6	-7.0	0	0	-	0	-	0	+	0	0	0
Male	SR-R	18	**36.1**	-23.0	**38.4**	-7.3	+	+	0	+	0	0	+	0	+	0
	DR-R	**31.9**	**-50.7**	-12.7	**40.1**	-0.8	0	-	0	-	0	+	-	0	+	0
	HH-R	-10.6	12.9	-1.9	**67.4**	**-14.6**	0	0	0	+	-	0	0	0	+	-
	HR-R	-6.8	**25.1**	-0.5	**51.1**	-3	0	+	0	+	0	0	+	0	+	0
	Baseline sites combined	10.1	0.9	-7.3	**53.3**	-7.0	0	0	0	+	-	0	0	0	+	0

Bolded values indicate when effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

WAA refers to weight-at-age.

Statistical analyses were not performed on *test* site MR-E due to low sample size.

Table 5.3-22 Summary of effects criterion for measurements endpoints for male and female slimy sculpin from *test* site SR-E compared to *baseline* sites, 1999, 2001, and 2012.

Sex	Comparison	Age			Body Weight at Age			GSI			LSI			Body Weight at Length		
		% Change			% Change			% Change			% Change			% Change		
		1999	2001	2012	1999	2001	2012	1999	2001	2012	1999	2001	2012	1999	2001	2012
Female	SR-E vs. SR-R	**54.2**	8.0	-1.7	3.6	14.5	**54.8**	-3.6		**-41.4**	-6.1		0.6	-5.0	-5.2	-2.5
	SR-E vs. DR-R		-0.3	**34.9**		-19.5	**-26.1**			-14.9			20.8		0.8	-3.8
	SR-E vs. HH-R			1.6			**60.3**			**-28.2**			**54.2**			**-13.1**
	SR-E vs. HR-R		-2.2	**-38.8**		**106.2**	**34.2**			-11.7			8.5		24.7	3.0
Male	SR-E vs. SR-R	**-51.6**	19.2	18.0	15.6	15.6	**36.1**	-6.2		-23.0	-18.3		**38.4**	7.1	-1.8	-7.3
	SR-E vs. DR-R		**59.9**	**31.9**		**-27.5**	**-50.7**			-12.7			**40.1**		-4.6	-0.8
	SR-E vs. HH-R			-10.6			12.9			-1.9			**67.4**			**-14.6**
	SR-E vs. HR-R		15.1	-6.8		**112.1**	**25.1**			-0.5			**51.1**		**13.9**	-3.0

Bolded values indicate when effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI and 10% for condition.

Underlined values were statistically significant at $p<0.05$.

Sites HH-R, HR-R, and DR-R were not sampled in 1999; site HH-R was first sampled in 2012.

Statistical analyses were not performed on *test* site MR-E due to low sample size.

Figure 5.3-12 **Relationship between body weight (g) and age (years) of male and female slimy sculpin at *baseline* (SR-R, DR-R, HR-R, and HH-R) and *test* (sites MR-E and SR-E) sites on tributaries to the Athabasca River, 1999, 2001 and 2012.**

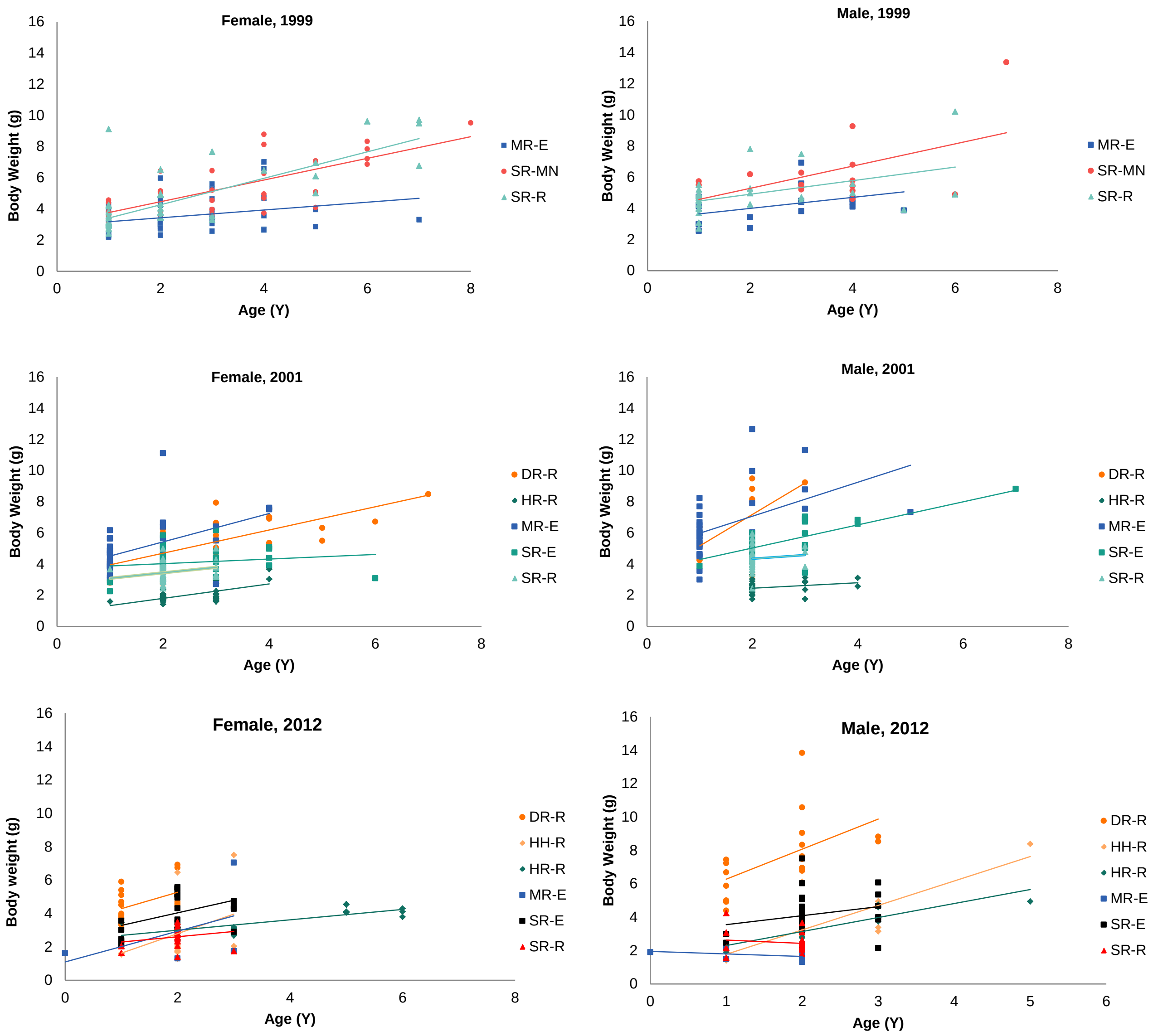


Figure 5.3-13 **Mean gonadosomatic index (GSI) (± 1SD) of female and male slimy sculpin at *baseline* (SR-R, DR-R, HR-R, and HH-R) and *test* (sites MR-E and SR-E) sites on tributaries of the Athabasca River, 1999 and 2012.**

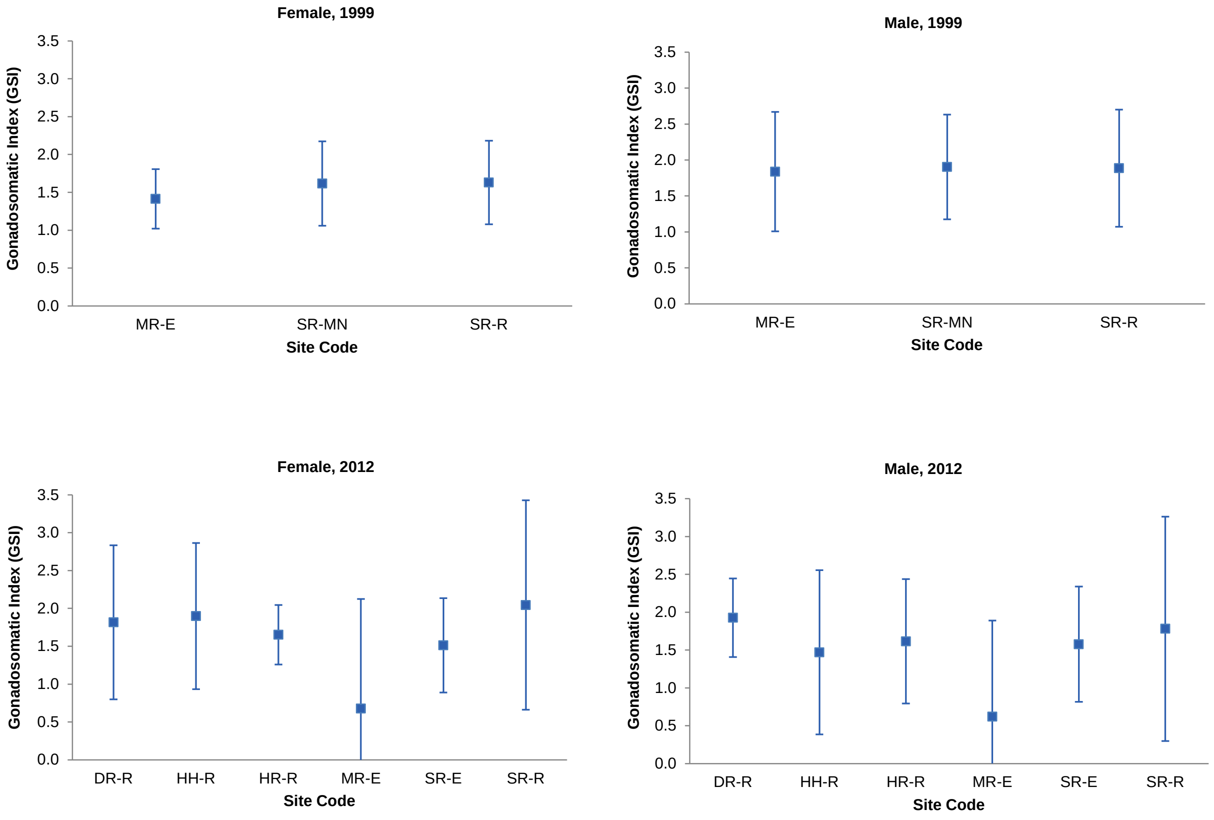


Figure 5.3-14 Relationship between body weight (g) and gonad weight (g) of male and female slimy sculpin at *baseline* (SR-R, DR-R, HR-R, HH-R) and *test* (MR-E and SR-E) sites on tributaries of the Athabasca River, 1999 and 2012.

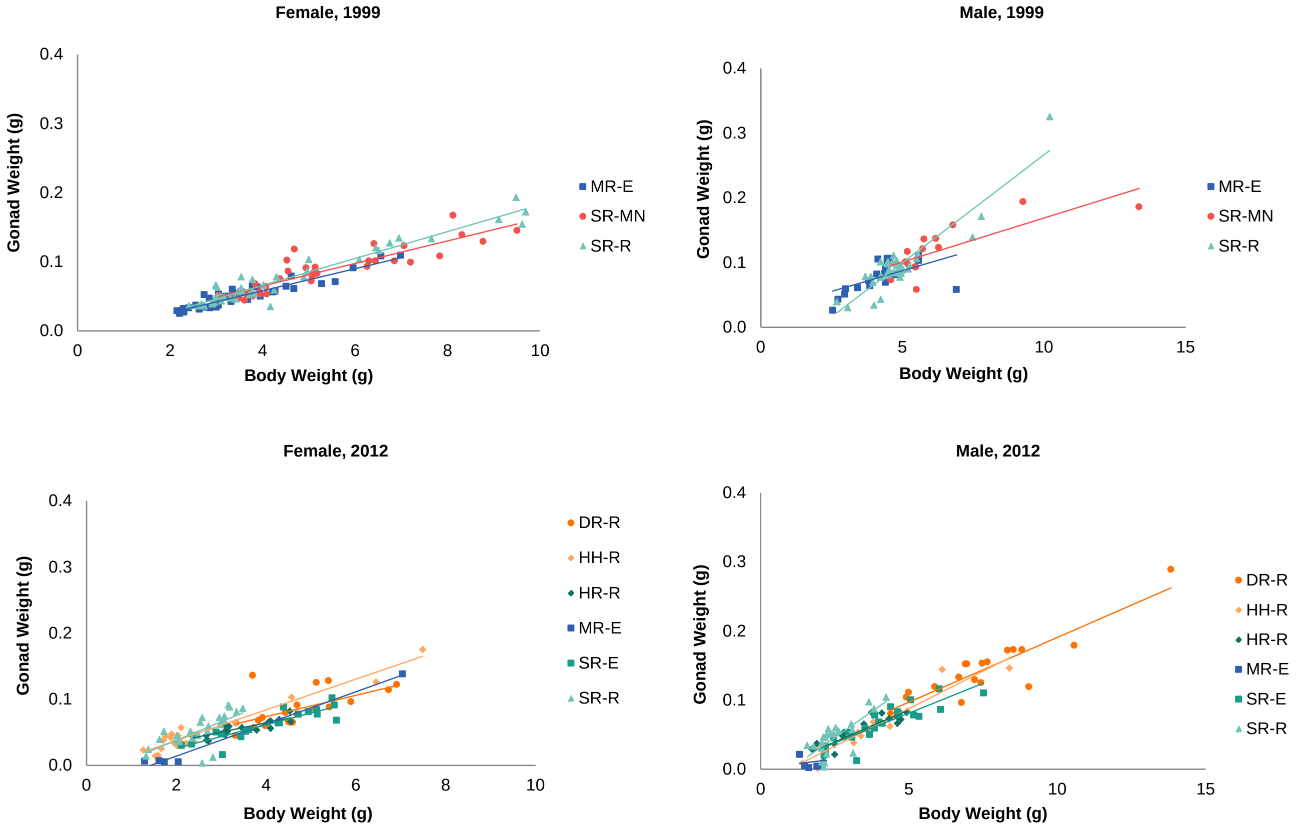


Figure 5.3-15 **Mean liver somatic index (LSI) (± 1SD) of female and male slimy sculpin at *baseline* (SR-R, DR-R, HR-R, HH-R) and *test* (MR-E and SR-E) sites on tributaries of the Athabasca River, 1999 and 2012.**

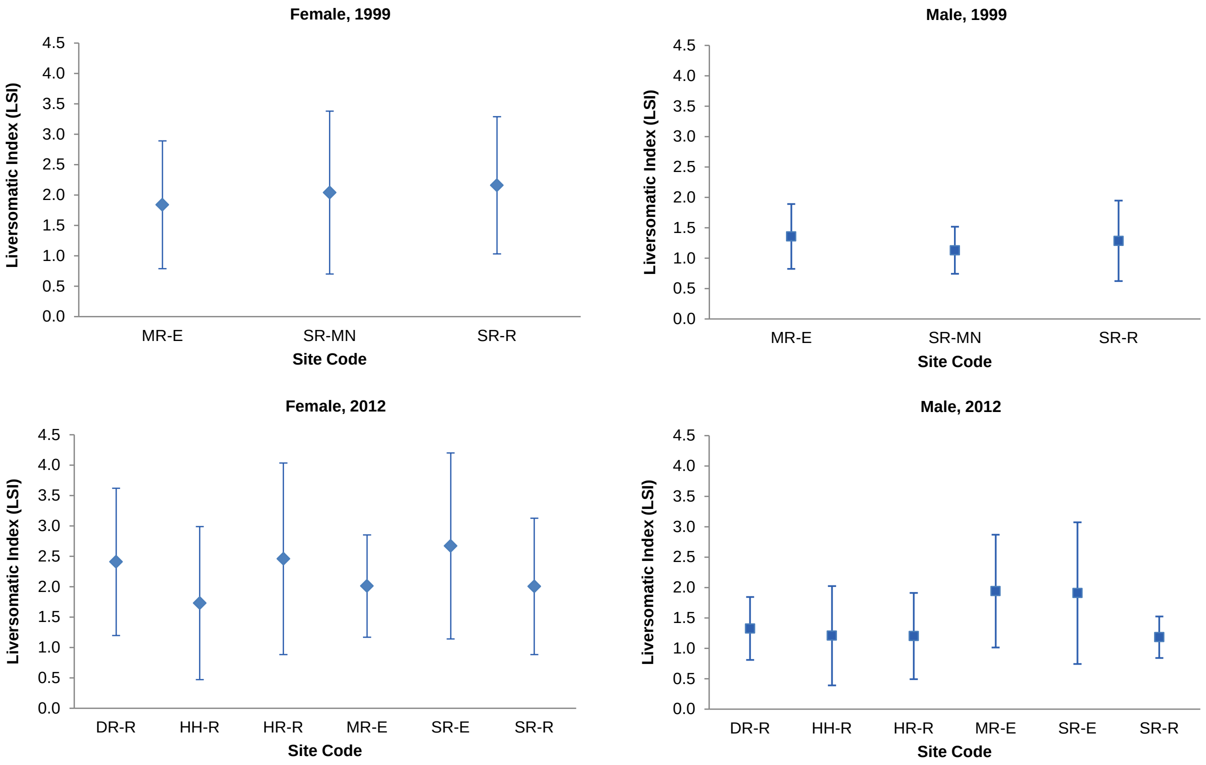


Figure 5.3-16 Relationship between body weight (g) and liver weight (g) of male and female slimy sculpin at *baseline* (SR-R, DR-R, HR-R, HH-R) and *test* (MR-E and STR-E) sites on tributaries of the Athabasca River, 1999 and 2012.

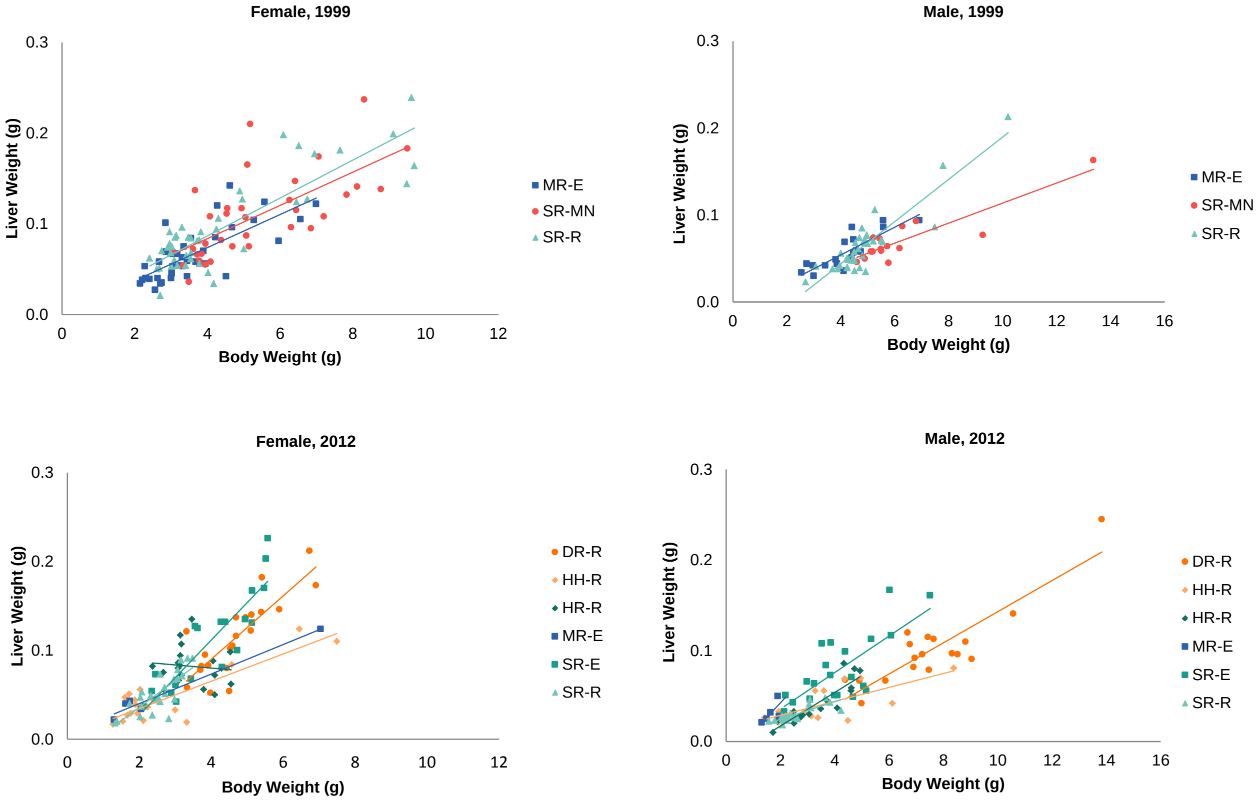


Figure 5.3-17 Mean condition factor of female and male slimy sculpin at *baseline* (SR-R, DR-R, HR-R, and HH-R) and *test* (MR-E and SR-E) sites on tributaries of the Athabasca River, 1999, 2001, 2004, 2006, 2009, 2012.

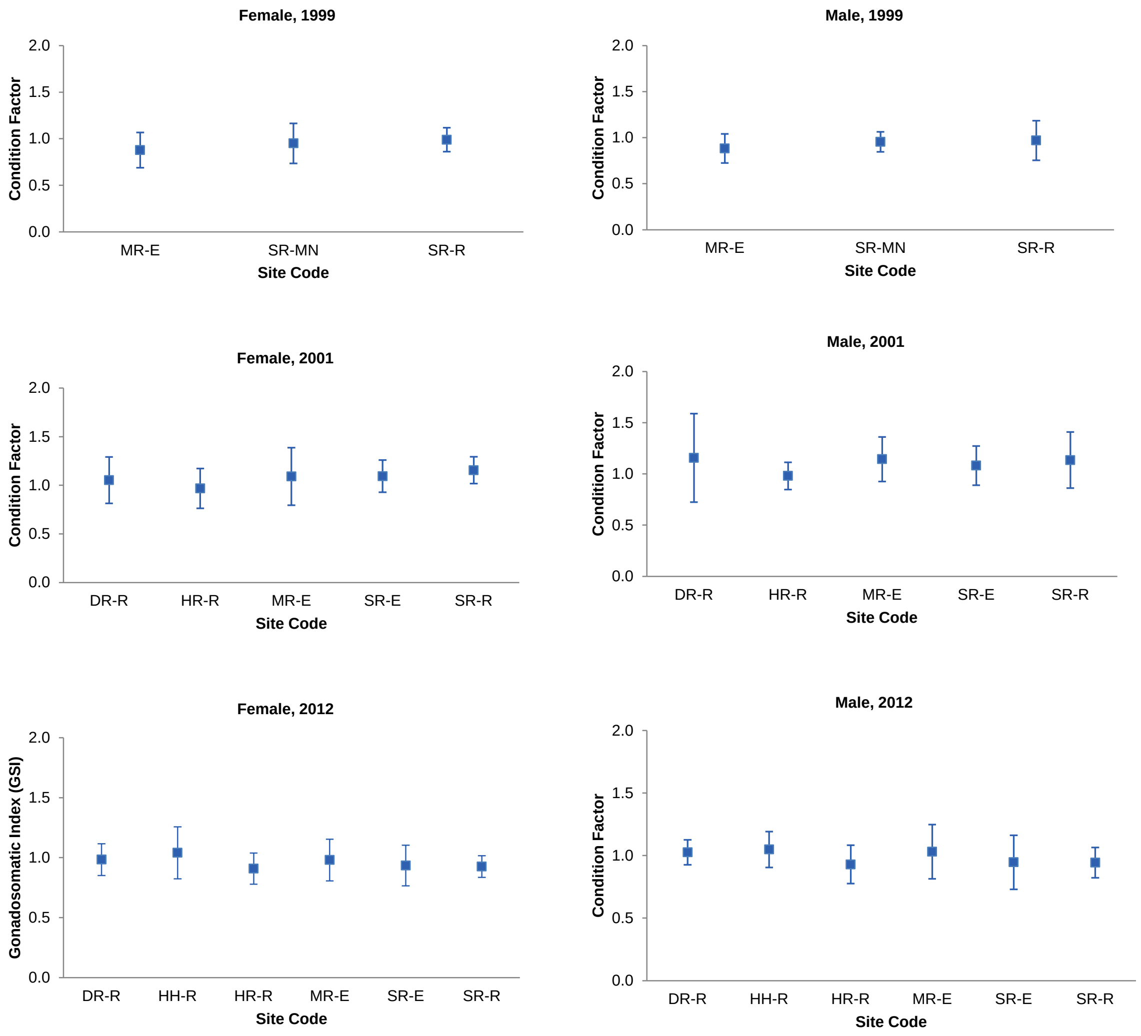
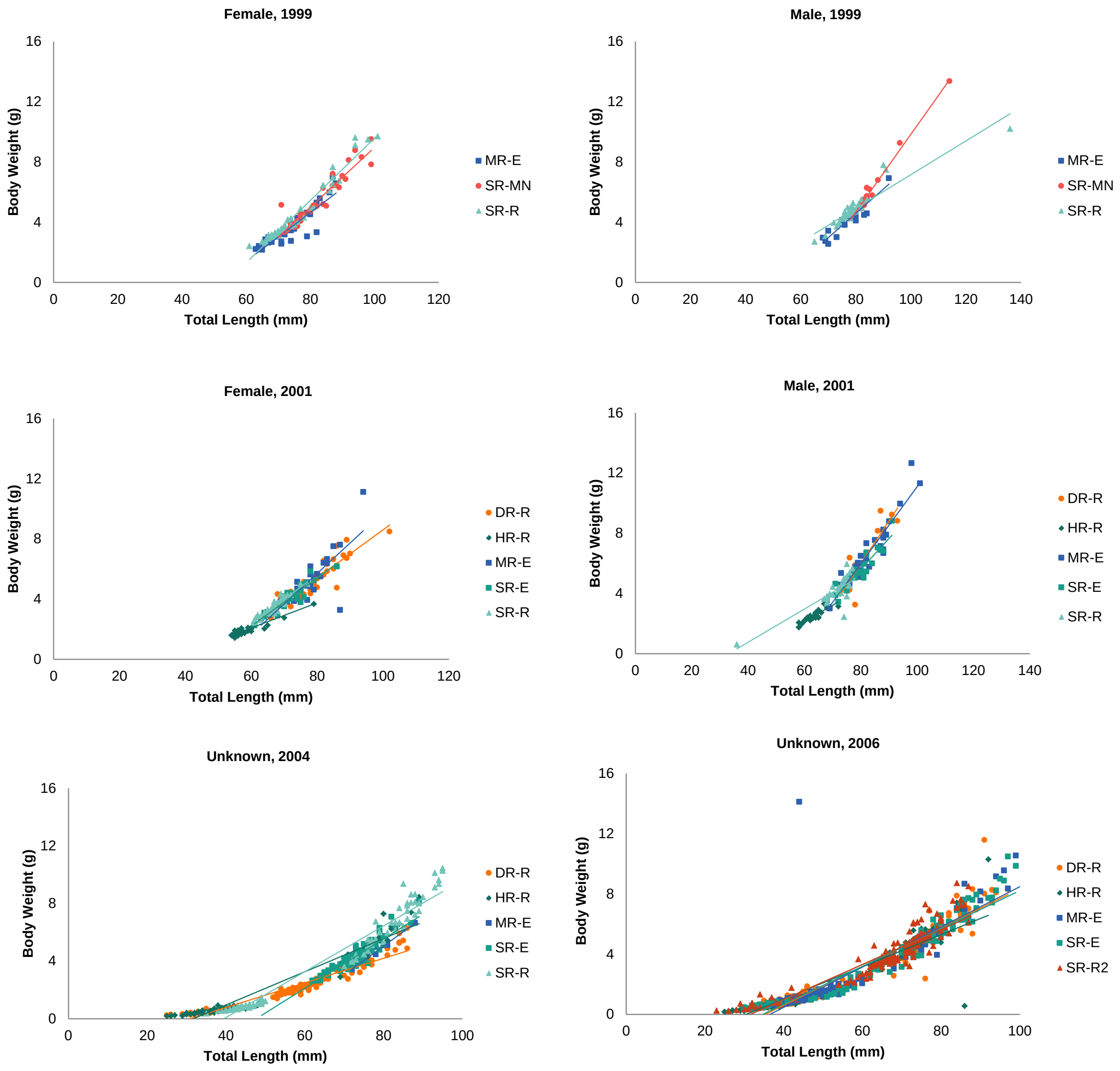
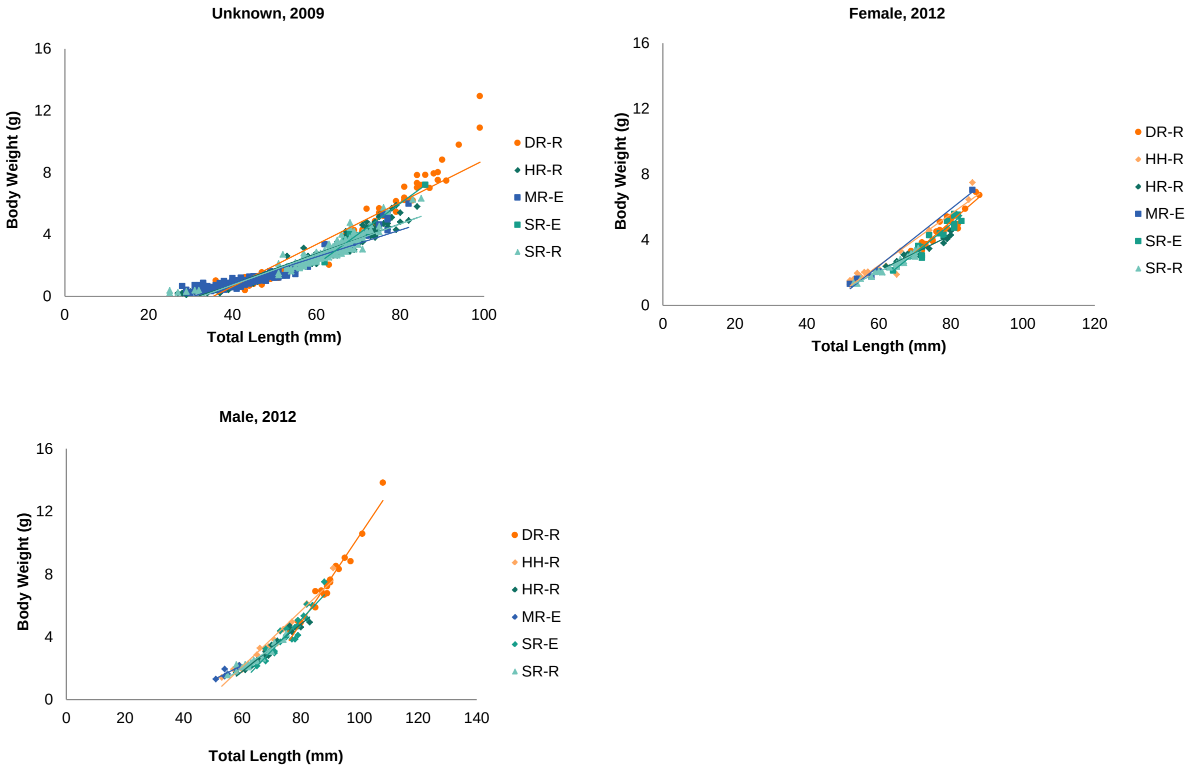


Figure 5.3-18 Relationship between body weight (g) and total length (mm) of slimy sculpin at *baseline* and *test* sites on tributaries of the Athabasca River, 1999, 2001, 2004, 2006, 2009, 2012.



Note: 2004, 2006, 2009 surveys were non-lethal; therefore, sex was not determined in slimy sculpin.

Figure 5.3-18 (Cont'd.)



Note: 2004, 2006, 2009 surveys were non-lethal; therefore sex was not determined in slimy sculpin.

5.4 TAR RIVER WATERSHED

Table 5.4-1 Summary of results for the Tar River watershed.

Tar River Watershed	**Summary of 2012 Conditions**	
Climate and Hydrology		
Criteria	**S15A** near the mouth	**S34** above CNRL 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	🟡	not sampled
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 focal projects and other 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.

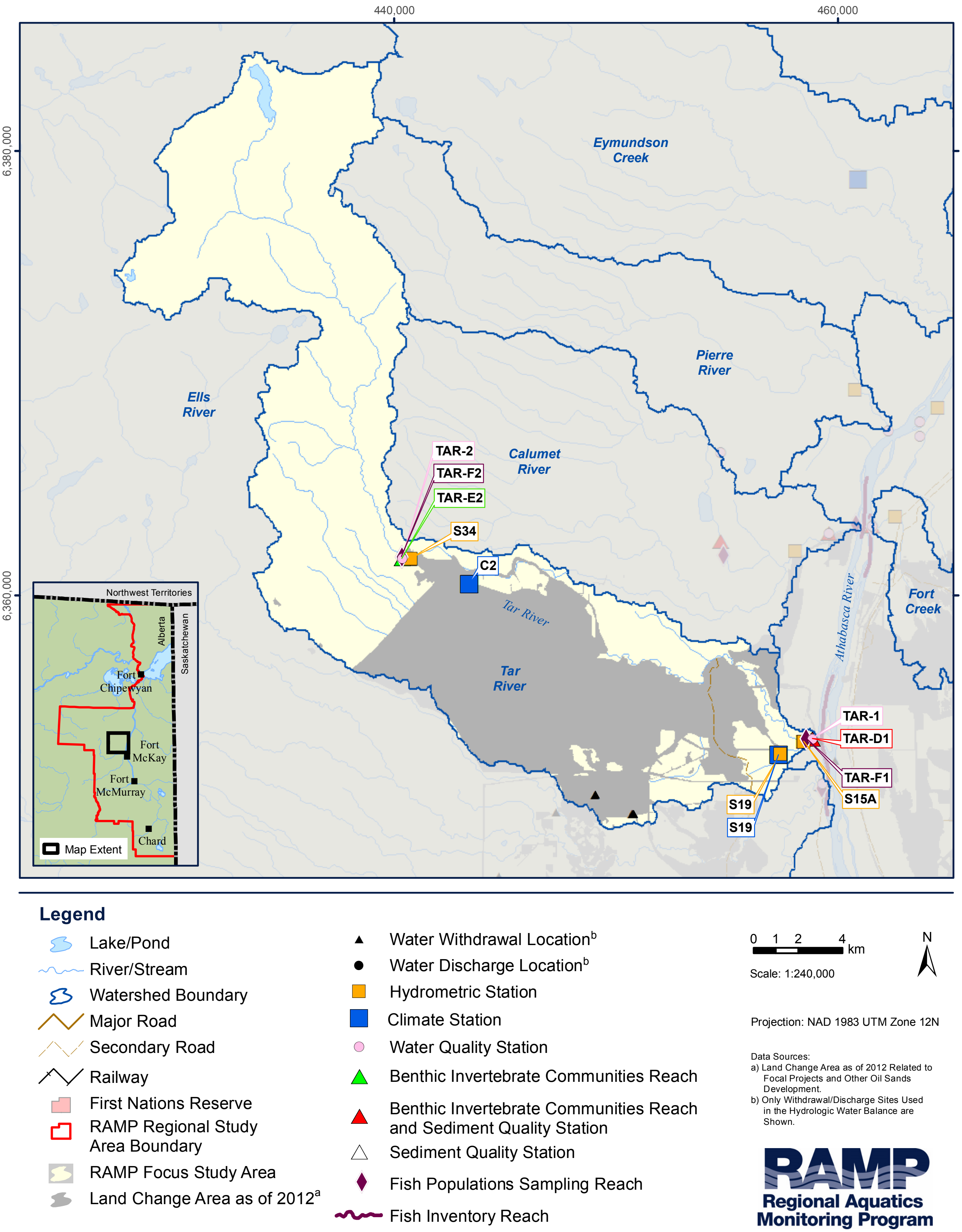
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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: Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.3 for a detailed description of the classification methodology.

Figure 5.4-1 Tar River watershed.



Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K04_Tar_20130418.mxd

Figure 5.4-2 Representative monitoring stations of the Tar River, fall 2012.

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 upstream

5.4.1 Summary of 2012 Conditions

As of 2012, approximately 33% (10,825 ha) of the Tar River watershed had undergone land change from focal projects (Table 2.5-2). 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 of RAMP in the Tar River watershed in 2012. Table 5.4-1 is a summary of the 2012 assessment for the Tar River watershed, while Figure 5.4-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations, and the areas of land change for 2012. Figure 5.4-2 contains fall 2012 photos of representative monitoring stations in the watershed.

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 28.0% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Water Quality Differences in water quality observed in fall 2012 between the Tar River and regional *baseline* fall conditions were classified as **Negligible-Low**. Most water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2 in fall 2012 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations. Higher concentrations of several ions (e.g., Ca, Ng, Na, P, Cl, SO_4) shifted the ionic composition of *test* station TAR-1 to conditions with a greater anion contribution by chloride and sulphate.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate communities at *test* reach TAR-D1 were classified as **Negligible-Low** because although there were significant differences in measurement endpoints over time, the differences were not in a direction consistent with a negative change but rather suggested improvements in habitat quality and species diversity compared to previous years. Values of measurement endpoints for benthic invertebrate communities at both reaches of the Tar River were within the range of regional *baseline* conditions. Differences in sediment quality observed in fall 2012 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low.** Concentrations of sediment quality measurement endpoints were within previously-measured concentrations in fall 2012, including total PAHs and predicted PAH toxicity; however, concentrations of benz[a]anthracene and benzo[a]pyrene represented maximum concentrations for *test* station TAR-D1 and also exceeded CCME guidelines.

Fish Populations Differences in values of measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI value exceeded the regional range of variation for *baseline* reaches, the exceedance was not in a direction consistent with a negative change. The ATI value was lower indicating that sensitive species in greater abundance were present at this reach compared to the range of regional *baseline* conditions.

5.4.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Tar River watershed was conducted at the RAMP Station S15A, Tar River near the mouth, which was used for the water balance analysis. Additional hydrometric data for the Tar River watershed were available from stations S19A, Tar River Lowland Tributary near the mouth and S34, Tar River above CNRL Lake. Details for each of these stations can be found in Appendix C.

Continuous hydrometric data have been collected during the open-water period (May to October) for S15A since 2007. Data were also collected during the open-water period at Station S15 (2001 to 2006) and WSC Station 07DA015 (1975 to 1977), which provided historical context for Station S15A. In the 2012 WY, flows were near historical median values when monitoring began on May 14, but decreased below historical lower quartile values recorded from June 1 to June 12 (Figure 5.4-3). Flows were generally variable for the remainder of the 2012 WY year with multiple peaks occurring in response to rainfall events. The 2012 WY open-water maximum daily flow of 2.70 m^3/s was recorded on July 29 and was 59% lower than the historical mean open-water maximum daily flow. Daily flows then decreased until late August and reached the historical lower quartile range and the minimum open-water daily flow of 0.16 m^3/s on August 31. This open-water minimum was 15% lower than the historical open-water mean minimum daily flow of 0.19 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at RAMP Station S15A is presented in Table 5.4-2 and described as follows:

1. The closed-circuited land area from focal projects as of 2012 was estimated to be 95.8 km^2 (Table 2.5-1). The loss of flow to the Tar River that would have otherwise occurred from this land area was estimated at 3.907 million m^3.
2. As of 2012, the area of land change in the Tar River watershed from focal projects that was not closed-circuited was estimated to be 12.5 km^2 (Table 2.5-1). The increase in flow to the Tar River that would not have otherwise occurred from this land area was estimated at 0.102 million m^3.
3. In 2012 WY, Total E&P withdrew approximately 0.001 million m^3 of water from three locations within the Tar River watershed to support winter drilling and construction activities.

The estimated cumulative effect of this land change was a decrease in flow of 3.806 million m^3 to the Tar River. The resulting observed and estimated *baseline* hydrographs are presented in Figure 5.4-3. The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 28.0% 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).

5.4.3 Water Quality

In fall 2012, 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 2012); and
- the upper Tar River (*baseline* station TAR-2, sampled since 2004).

Temporal Trends There was a significant increasing trend in the concentration of sulphate at *test* station TAR-1 (1998, 2002 to 2012) ($\alpha<0.05$). There was a significant decreasing trend in the concentration of chloride ($\alpha<0.05$) at *baseline* station TAR-2 (2004 to 2012).

2012 Results Relative to Historical Concentrations The concentration of total suspended solids exceeded the previously-measured maximum concentration at *baseline* station TAR-2 and concentrations of total dissolved phosphorus were at or below previously-measured minimum concentrations at *test* station TAR-1 and *baseline* station TAR-2 in fall 2012 (Table 5.4-4, Table 5.4-5). Following three years of steady declines of concentrations of several ions (e.g., Ca, Ng, Na, P, Cl, SO_4), concentrations of these ions increased at *test* station TAR-1 in fall 2012 (Figure 5.4-4).

Ion Balance In fall 2012, the ionic composition of water at *baseline* station TAR-2 and *test* station TAR-1 was generally consistent with previous years. *Test* station TAR-1 has shown much greater variability since sampling was initiated in 1998. Ionic composition of water at *test* station TAR-1 in fall 2012 was more similar to 2005 than to more recent years, with greater anion contribution by chloride and sulphate (Figure 5.4-5).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum exceeded the water quality guideline at *test* station TAR-1 and *baseline* station TAR-2 in fall 2012 (Table 5.4-4, Table 5.4-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Tar River in fall 2012 (Table 5.4-6).

- Concentrations of total iron and total phenols at *test* station TAR-1; and
- Concentrations of dissolved iron, total iron, and total phosphorous at *baseline* station TAR-2.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2 in fall 2012 were within regional *baseline* concentrations, with the exception of (Figure 5.4-4):

- sulphate, with a concentration that exceeded the 95th percentile of the regional *baseline* concentrations at *test* station TAR-1; and
- dissolved phosphorus, with a concentration that was below the 5th percentile of the regional *baseline* concentrations at *baseline* station TAR-2.

Water Quality Index The WQI values for both stations of the Tar River (*test* station TAR-1: 98.5, *baseline* station TAR-2: 100) indicated **Negligible-Low** differences from regional *baseline* fall conditions. The calculated WQI value for *test* station TAR-1 has remained high over the last four years, despite having a low WQI value of 59.8 in 2008.

Classification of Results Differences in water quality observed in fall 2012 between the Tar River and regional *baseline* fall conditions were classified as **Negligible-Low**. Most water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2 in fall 2012 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations. Higher concentrations of several ions (e.g., Ca, Ng, Na, P, Cl, SO_4) shifted the ionic composition of *test* station TAR-1 to conditions with a greater anion contribution by chloride and sulphate.

5.4.4 Benthic Invertebrate Communities and Sediment Quality

5.4.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were samples in fall 2012 at:

- depositional *test* reach TAR-D1, designated as *baseline* from 2002 to 2003 and as *test* from 2004 to 2012 (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 reach was "moved" further upstream due to increased focal project development in the watershed.

2012 Habitat Conditions Water at *test* reach TAR-D1 in fall 2012 was moderately deep (0.6 m), slow flowing (0.34 m/s), alkaline (pH: 8.2), with high conductivity (438 µS/cm) (Table 5.4-7). The substrate was dominated by sand (65%) with smaller amounts of silt and clay and low TOC content.

Water at *baseline* reach TAR-E2 was shallow (0.3 m), slow flowing (0.34 m/s), alkaline (pH: 8.4), with high conductivity (543 µS/cm) (Table 5.4-7). The substrate was dominated by small cobble and gravel. Periphyton biomass at *baseline* reach TAR-E2 averaged 11.1 mg/m^2, which was within the range of previously-measured concentrations (Figure 5.4-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach TAR-D1 was dominated by tubificid worms (38%) and chironomids (34%), with sub-dominant taxa consisting of ceratopogonids, ostracods and hydracarina (Table 5.4-8). Mayflies (*Caenis*), caddisflies, and damselflies were present, but in very low relative abundances. Dominant chironomids included the *Procladius*, *Stempellina* and *Microscpectra/Tanytarsus*, all of which are ubiquitous (Wiederholm 1983).

The benthic invertebrate community at *baseline* reach TAR-E2 was dominated by chironomids (50%), mayflies (Ephemeroptera, 21%), and Trichoptera (9%), with sub-dominant taxa consisting of watermites (Hydracarina), stoneflies (Plecoptera), and Empididae (Table 5.4-9). A variety of worms including enchytraeids, naidids, nematodes, and lumbriculids were present in low relative abundances (<1% each). *Cricotopus* (a common chironomid in north-temperate climates [Wiederholm 1983]) was the most dominant chironomid. Dominant caddisflies included the net spinner *Hydropsyche* and the scraper *Glossosoma*, both of which are common in north-temperate climates (Wiggins 1977). Mayflies included members of the Heptageneiidae and Baetidae, while stoneflies included members of the Capniidae, Chloroperlidae, and *Pteronarcys*, which are all commonly distributed in Alberta (Clifford 1991).

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 because *test* reach TAR-D1 is depositional and *baseline* reach TAR-E2 is erosional.

Temporal comparisons 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 2, Section 3.2.3.1);
- changes over time for the period that the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- changes between 2012 values and the mean of all previous sampling years; and
- changes between 2012 values and the mean of all *baseline* years (2002 and 2003).

Abundance, richness, and Simpson's Diversity were significantly higher at *test* reach TAR-D1 during the *baseline* period (2002 to 2003), explaining >20% of the variance in annual means (Table 5.4-10, Figure 5.4-7). There was also a significant increase in abundance and decrease in equitability over time during the period when the reach was designated as *test* (2004 to present), explaining 21% and 34% of the variance in annual means, respectively (Table 5.4-10, Figure 5.4-7).

The percentage of the fauna as EPT taxa and the CA Axis 1 and 2 scores were significantly higher in 2012 than previous years (Table 5.4-10), reflecting a shift in taxa composition towards fewer tubificids and chironomids and more gastropods, water mites (Hydracari), and Ephemeroptera (Figure 5.4-8). CA Axis 1 scores significantly increased over time during the *test* period of the lower reach accounting for 42% of the variance in annual means (Table 5.4-10). There was a significant increase in CA Axis 2 scores over time, explaining approximately 60% of the variance in annual means and Axis scores in 2012 were higher than the mean of previous sampling years (Table 5.4-10).

Comparison to Published Literature The percent of the benthic invertebrate community as tubificid worms at *test* reach TAR-D1 decreased from previous years suggesting a potential decrease in nutrient enrichment (Hynes 1960, Griffiths 1998), which has been previously observed at this reach. *Test* reach TAR-D1 in fall 2012 contained a high diversity of benthic invertebrate fauna including sphaeriid bivalves, gastropods, Ephemeroptera, and some stoneflies (Plecoptera), all of which indicated a relatively robust benthic invertebrate community.

The benthic invertebrate community at *baseline* reach TAR-E2 was indicative of a diverse and healthy system, with a low abundance of worms and a relatively high percent of fauna as EPT taxa, with Ephemeroptera having the highest relative abundance.

2012 Results Relative to Regional *Baseline* Conditions The mean values of measurement endpoints for the benthic invertebrate community at *test* reach TAR-D1 in fall 2012 were within the range of variation for regional depositional *baseline* reaches (Figure 5.4-7). Values of benthic invertebrate community measurement endpoints were within the range of variation for regional erosional *baseline* reaches at *baseline* reach TAR-E2 (Figure 5.4-9).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* reach TAR-D1 were classified as **Negligible-Low** because although there were significant differences in measurement endpoints over time, the differences were not in a direction consistent with a negative change but rather suggested improvements in habitat quality and species diversity compared to previous years. Values of measurement endpoints for benthic invertebrate communities at both reaches of the Tar River were within the range of regional *baseline* conditions.

5.4.4.2 Sediment Quality

Sediment quality was sampled in fall 2012 in the Tar River, near its mouth (*test* station TAR-D1) in the same location as the benthic invertebrate community *test* reach TAR-D1. This station was designated as *baseline* from 1998 to 2003 and as *test* from 2004 to 2012.

Temporal Trends No statistically significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station TAR-D1 in fall 2012.

2012 Results Relative to Historical Conditions 2012 sediment quality data from *test* reach TAR-D1 were compared directly to data collected from this reach in 2006 and 2009 to 2011. Prior to integration of the Sediment Quality component with the Benthic Invertebrate Communities component of RAMP in 2006, *test* reach TAR-D1 corresponds to pre-2006 sediment quality station TAR-1.

Sediments at *test* station TAR-D1 were dominated by silt in 2012 and exhibited a similar composition to previous sampling years, where proportions of silt, clay, and sand were all within previously-measured values (Table 5.4-11). In fall 2012, concentrations of all other sediment quality measurement endpoints were within previously-measured concentrations at *test* station TAR-D1, with the exception of benz[a]anthracene and benzo[a]pyrene, which were above previously-measured maximum concentrations. Low-molecular-weight Fraction 1 and Fraction 2 hydrocarbons and BTEX (benzene, toluene, ethylene and xylene) were not detectable in fall 2012 (Table 5.4-11). Similar to previous years, concentrations of hydrocarbons in sediments at *test* station TAR-D1 were dominated by Fraction 3 and Fraction 4, which likely indicated the presence of bitumen in the sediment. The concentration of total PAHs in sediment (both absolute and carbon-normalized) were within previously-measured concentrations and similar to concentrations observed in 2011. The predicted PAH toxicity in fall 2012 was within the range of previously-measured values, but continues to exceed the potential chronic toxicity threshold of 1.0, which has been observed during most of the sampling record for this station (Table 5.4-11, Figure 5.4-10). Concentrations of total metals and total metals normalized to percent fine sediments were within the range of previously-measured concentrations (Figure 5.4-10).

Direct tests of sediment toxicity to invertebrates at *test* station TAR-D1 showed ≥95% survival in test organisms of both the amphipod *Hyalella* and the midge *Chironomus,* with *Chironomus* having the highest survival rate observed at this station in fall 2012. Ten-day growth of *Chironomus* and 14-day growth of *Hyalella* were within the range of previously-measured values (Table 5.4-11).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines In fall 2012, concentrations of total arsenic, benz[a]anthracene, benzo[a]pyrene, and chrysene exceeded the relevant CCME sediment quality guidelines at *test* station TAR-D1 (Table 5.4-11).

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints at *test* station TAR-D1 in fall 2012 were within regional *baseline* concentrations, with the exception of the predicted PAH toxicity, which exceeded the 95th percentile of regional *baseline* concentrations (Figure 5.4-10).

Sediment Quality Index A SQI of 81.1 was calculated for *test* station TAR-D1 for fall 2012, indicating a **Negligible-Low** difference from regional *baseline* conditions. Since 1998, this station has had an SQI value that has shown **Negligible-Low** differences from regional *baseline* conditions, with the exception of 2004 and 2011 when sediment quality at this station indicated a **Moderate** difference from regional *baseline* conditions.

Classification of Results Differences in sediment quality observed in fall 2012 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low.** Concentrations of sediment quality measurement endpoints were within previously-measured concentrations in fall 2012, including total PAHs and predicted PAH toxicity; however, concentrations of benz[a]anthracene and benzo[a]pyrene represented maximum concentrations for *test* station TAR-D1 and also exceeded CCME guidelines.

5.4.5 Fish Populations

Fish assemblages were sampled in fall 2012 at:

- depositional *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
- erosional *baseline* reach TAR-F2, sampled since 2011 (this reach is in the same location as the benthic invertebrate community *baseline* reach TAR-E2).

2012 Habitat Conditions *Test* reach TAR-F1 was at a flood stage at the time of sampling, with wetted and bankfull widths of 10.5 m and comprised of run and riffle habitat (Table 5.4-12). The substrate was comprised entirely of sand. Water at *test* reach TAR-F1 in fall 2012 was moderately deep 0.57 m deep, slow flowing (average flow: 0.22 m/s). alkaline (pH: 7.97), with high conductivity (458 µS/cm), high dissolved oxygen (10 mg/L), and a temperature of 11.7°C. Instream cover was comprised primarily of small and large woody debris with some overhanging vegetation and areas with undercut banks (Table 5.4-12).

Baseline reach TAR-F2 was comprised of riffle and run habitat and a wetted width of 5 m and a bankfull width of 7.5 m (Table 5.4-12). The substrate was comprised primarily of cobble with small amounts of coarse gravel and fine material. Water at *baseline* reach TAR-F2 had a maximum depth of 0.8 m, with average depth of only 0.16 m, was slow flowing (average flow: 0.19 m/s), alkaline (pH: 8.27), with moderate conductivity

(294 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 11.5°C. Instream cover was comprised primarily of small woody debris and overhanging vegetation with smaller amounts of large woody debris, undercut banks, and boulders (Table 5.4-12).

Temporal and Spatial Comparisons Temporal comparisons were conducted at *test* reach TAR-F1 between 2009 and 2012 and between 2011 and 2012 at *baseline* reach TAR-F2. Spatial comparisons were not conducted because *test* reach TAR-F1 is depositional and *baseline* reach TAR-F2 is erosional, providing different habitat conditions for fish assemblages.

There was a decrease in abundance, taxa richness, and total CPUE from 2011 to 2012 at *test* reach TAR-F1, with values in 2012 comparable to 2009 (Table 5.4-13, Table 5.4-14, Figure 5.4-11). There was also a decrease in diversity over time at *test* reach TAR-F1; however, the ATI value also decreased compared to previous years given the relatively greater percentage of more sensitive species (e.g., slimy sculpin) in the total catch. The total catch at *test* reach TAR-F1 was low (n=14), with white sucker as the dominant species. Mean values of measurement endpoints were relatively similar between 2011 and 2012 at *baseline* reach TAR-F2, with a slight increase in total species richness in 2012. Consistent to 2011, *baseline* reach TAR-F2 was dominated by slimy sculpin with very few other fish species captured, which explained the low diversity at this reach across sampling years (Table 5.4-13 and Figure 5.4-11).

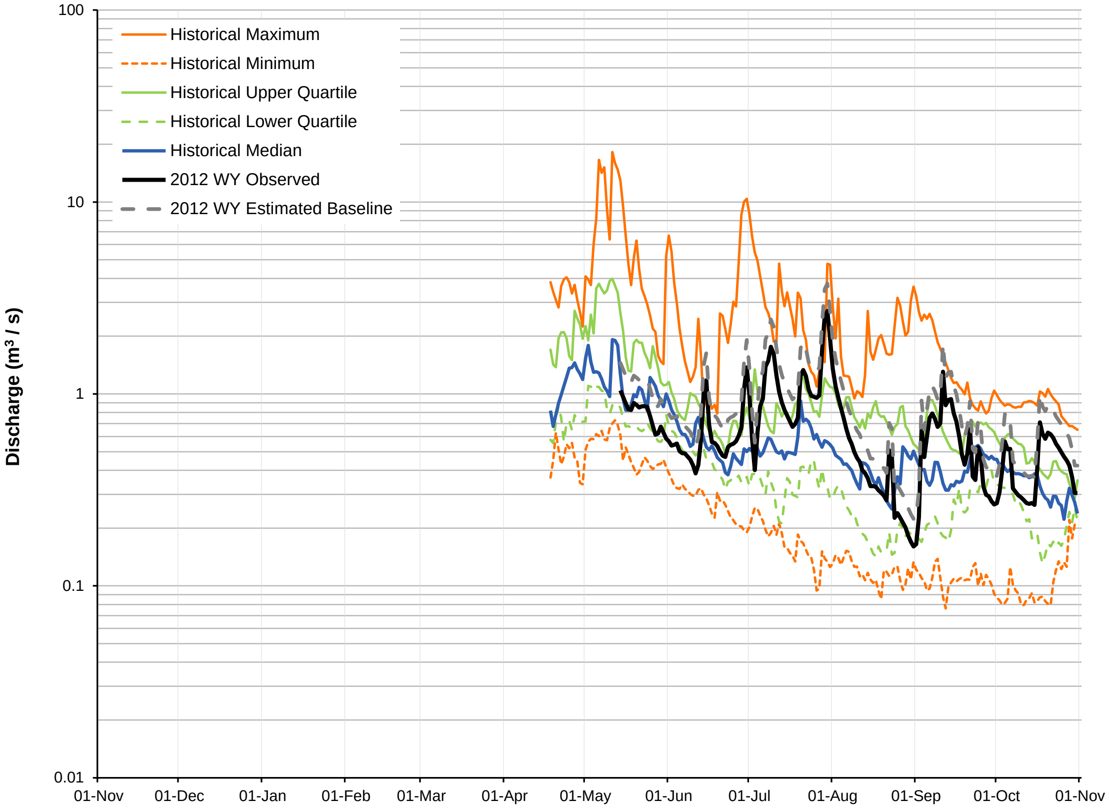
Comparison to Published Literature A summary of fish sampling activities within watersheds in the oil sands region was prepared in Golder (2004). This document provides a thorough assessment of fish species presence in watersheds prior to major oil sands development to capture historical *baseline* fish assemblages for comparison to results reported by RAMP. Historically, 11 fish species have been documented along the entire length of the Tar River (Golder 2004). RAMP has observed seven of these fish species at *test* reach TAR-F1 from 2009 to 2012, as well as three additional species that were not previously documented including finescale dace, longnose dace, and northern pike (Table 5.4-14). The number of species previously-documented is from various methods of sampling (i.e., fish fence, trapping, and electrofishing), which target all life-stages of fish while backpack electrofishing used for the RAMP fish assemblage monitoring targets only small-bodied fish or juvenile large-bodied fish, which likely explains the difference in documented species between historical results and results reported by RAMP.

Habitat conditions documented by Golder (2004) were similar to conditions observed by RAMP from 2009 to 2012 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.

2012 Results Relative to Regional *Baseline* Conditions Similar to 2011, the mean value of ATI at *test* reach TAR-F1 was below the range of regional *baseline* conditions for depositional reaches (Figure 5.4-11). Mean values of all measurement endpoints at *baseline* reach TAR-F2 in fall 2012 were within the range of variation for regional *baseline* conditions (Figure 5.4-11).

Classification of Results Differences in values of measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI value exceeded the regional range of variation for *baseline* reaches, the exceedance was not in a direction consistent with a negative change. The ATI value was lower indicating that sensitive species in greater abundance were present at this reach compared to the range of regional *baseline* conditions.

Figure 5.4-3 **The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Tar River in the 2012 WY, compared to historical values.**



Note: Observed 2012 WY hydrograph based on Tar River near the mouth, Station S15A, provisional data for May 14 to October 31. The upstream drainage area is 333 km^2. Historic values from 1975 to 1977 calculated for the open-water period at WSC Station 07DA015 (1975 to 1977), RAMP Station S15 (2001 to 2006) and RAMP Station S15A (2007 to 2011).

Table 5.4-2 Estimated water balance at RAMP Station S15A, Tar River near the mouth, 2012 WY.

Component	Volume (million m³)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**9.764**	**Observed discharge, obtained from Tar River near the mouth, Station S15A**
Closed-circuited area water loss from the observed *test* hydrograph	-3.907	Estimated 95.8 km² of the Tar River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.102	Estimated 12.5 km² of the Tar River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Tar River watershed from focal projects	-0.001	895 m³ withdrawn from sources in the Tar River watershed for construction activities
Water releases into the Tar River watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Tar River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**13.571**	**Estimated *baseline* discharge at Tar River near the mouth, RAMP Station S15A**
Incremental flow (change in total discharge)	-3.806	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-28.0%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for May 14 to October 31, 2012 for Tar River near the mouth, RAMP Station S15A.

Note: Volumes presented to three decimal places.

Table 5.4-3 Calculated change in hydrologic measurement endpoints for the Tar River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m³/s)	Value from *Test* Hydrograph (m³/s)	Relative Change
Mean open-water season discharge	0.919	0.661	-28.0%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	3.756	2.703	-28.0%
Open-water season minimum daily discharge	0.223	0.161	-28.0%

Note: Values are calculated from provisional data for May 14 to October 31, 2012 for Tar River near the mouth, RAMP Station S15A.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to three and one decimal places, respectively.

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 5.4-4 Concentrations of water quality measurement endpoints, mouth of the Tar River (*test* station TAR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	11	8.1	8.2	8.5
Total suspended solids	mg/L	-	14	11	6	15	214
Conductivity	µS/cm	-	553	11	302	427	875
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.012	11	0.012	0.017	**0.125**
Total nitrogen	mg/L	1	0.60	11	0.50	**1.00**	**4.30**
Nitrate+nitrite	mg/L	1.3	<0.071	11	<0.050	<0.100	**3.5**
Dissolved organic carbon	mg/L	-	19	11	12	17	23
Ions							
Sodium	mg/L	-	24.7	11	14.6	27.0	50.0
Calcium	mg/L	-	62.5	11	38.0	49.2	88.5
Magnesium	mg/L	-	18.2	11	11.3	15.4	24.3
Chloride	mg/L	120	13.5	11	1.7	4.0	50.0
Sulphate	mg/L	410	116	11	20.4	42	173
Total dissolved solids	mg/L	-	339	11	170	300	590
Total alkalinity	mg/L	-	143	11	121	171	221
Selected metals							
Total aluminum	mg/L	0.1	**0.67**	11	**0.17**	**0.53**	**3.95**
Dissolved aluminum	mg/L	0.1	0.015	11	0.005	0.010	0.026
Total arsenic	mg/L	0.005	0.0012	11	0.0009	0.0017	0.0022
Total boron	mg/L	1.2	0.091	11	0.053	0.076	0.145
Total molybdenum	mg/L	0.073	0.0009	11	0.0004	0.0011	0.0020
Total mercury (ultra-trace)	ng/L	5, 13	3.0	9	<1.2	<1.2	**5.6**
Total strontium	mg/L	-	0.19	11	0.14	0.20	0.44
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	-	0.06	1	-	0.63	-
Oilsands Extractable	mg/L	-	0.47	1	-	1.33	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	2.47	1	-	3.66	-
Total dibenzothiophenes	ng/L	-	98.00	1	-	68.28	-
Total PAHs	ng/L	-	599.5	1	-	440.4	-
Total Parent PAHs	ng/L	-	43.79	1	-	36.77	-
Total Alkylated PAHs	ng/L	-	555.8	1	-	403.6	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**1.38**	11	**1.40**	**1.70**	**7.03**
Total phenols	mg/L	0.004	**0.0063**	11	<0.001	**0.0060**	**0.0196**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

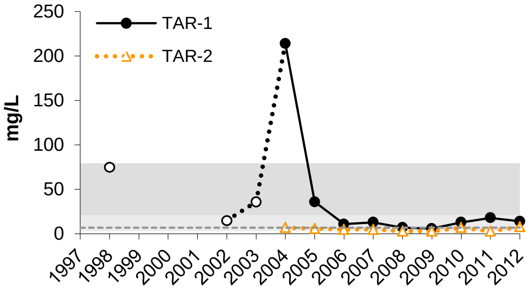
Table 5.4-5 Concentrations of water quality measurement endpoints, upper Tar River (*baseline* station TAR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	8	8.0	8.3	8.4
Total suspended solids	mg/L	-	8	8	<3	5	7
Conductivity	µS/cm	-	332	8	233	336	393
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.005	8	0.022	0.037	**0.058**
Total nitrogen	mg/L	1	0.50	8	0.40	0.50	**1.43**
Nitrate+nitrite	mg/L	1.3	<0.071	8	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15.8	8	8.0	13.0	15.8
Ions							
Sodium	mg/L	-	8.0	8	6.0	12.0	16.0
Calcium	mg/L	-	41.7	8	31.4	44.8	53.0
Magnesium	mg/L	-	11.2	8	8.8	13.4	14.3
Chloride	mg/L	120	<0.5	8	<0.5	1	2
Sulphate	mg/L	270	20.6	8	20.0	37.4	49.0
Total dissolved solids	mg/L	-	206	8	160	234	280
Total alkalinity	mg/L	-	158	8	100	147	162
Selected metals							
Total aluminum	mg/L	0.1	**0.21**	8	0.07	**0.16**	**0.71**
Dissolved aluminum	mg/L	0.1	0.018	8	0.008	0.025	0.052
Total arsenic	mg/L	0.005	0.0013	8	0.0008	0.0012	0.0014
Total boron	mg/L	1.2	0.057	8	0.035	0.061	0.074
Total molybdenum	mg/L	0.073	0.0013	8	0.0008	0.0014	0.0015
Total mercury (ultra-trace)	ng/L	5, 13	1.8	8	<0.8	<1.2	3.4
Total strontium	mg/L	-	0.14	8	0.10	0.16	0.19
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	-	0.04	1	-	<0.02	-
Oilsands Extractable	mg/L	-	0.34	1	-	0.83	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.61	1	-	2.07	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	5.84	-
Total PAHs	ng/L	-	203.4	1	-	157.0	-
Total Parent PAHs	ng/L	-	16.51	1	-	19.23	-
Total Alkylated PAHs	ng/L	-	186.9	1	-	137.8	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.55**	8	0.11	**0.42**	**0.82**
Total iron	mg/L	0.3	**1.24**	8	**0.72**	**1.00**	**1.59**
Total phosphorus	mg/L	0.05	**0.08**	8	0.045	**0.066**	**0.100**

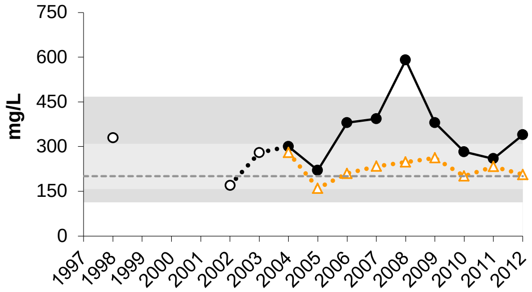
[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.4-4 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

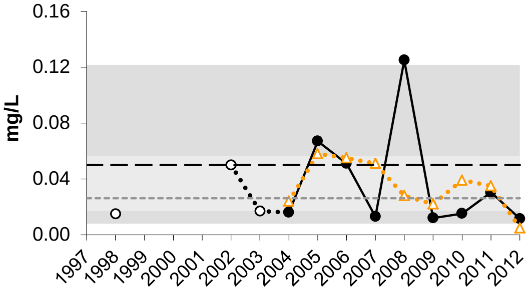
Total Suspended Solids (TSS)



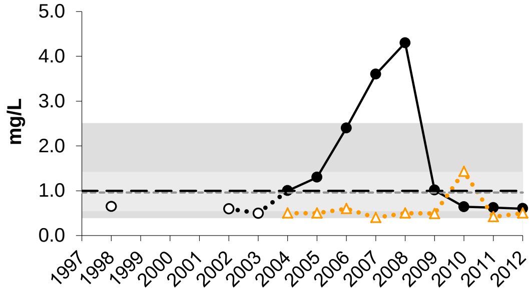
Total Dissolved Solids (TDS)



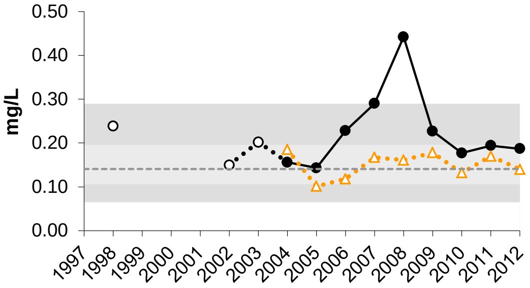
Dissolved Phosphorus



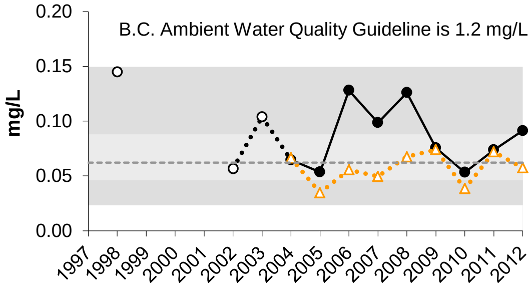
Total Nitrogen



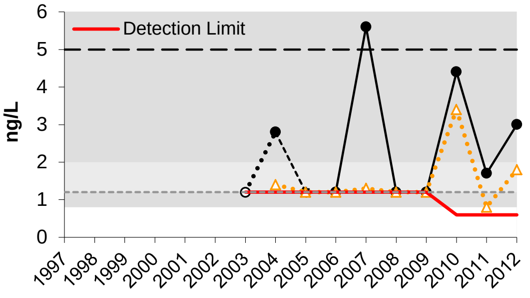
Total Strontium



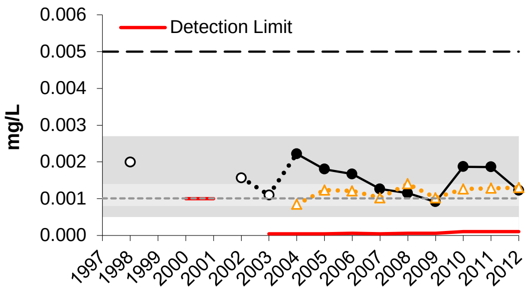
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



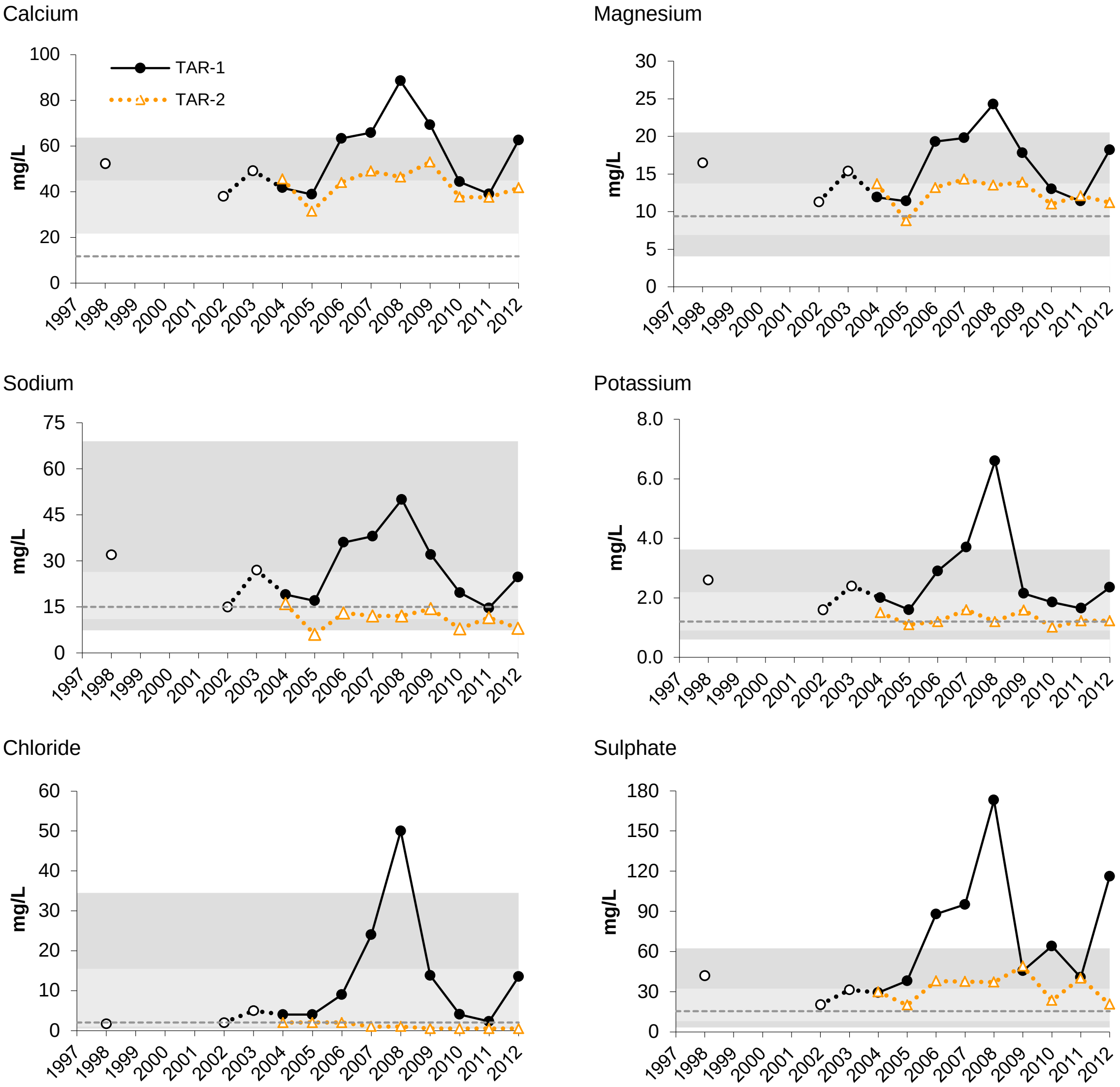
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.4-4 (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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.4-5 Piper diagram of fall ion concentrations, Tar River.

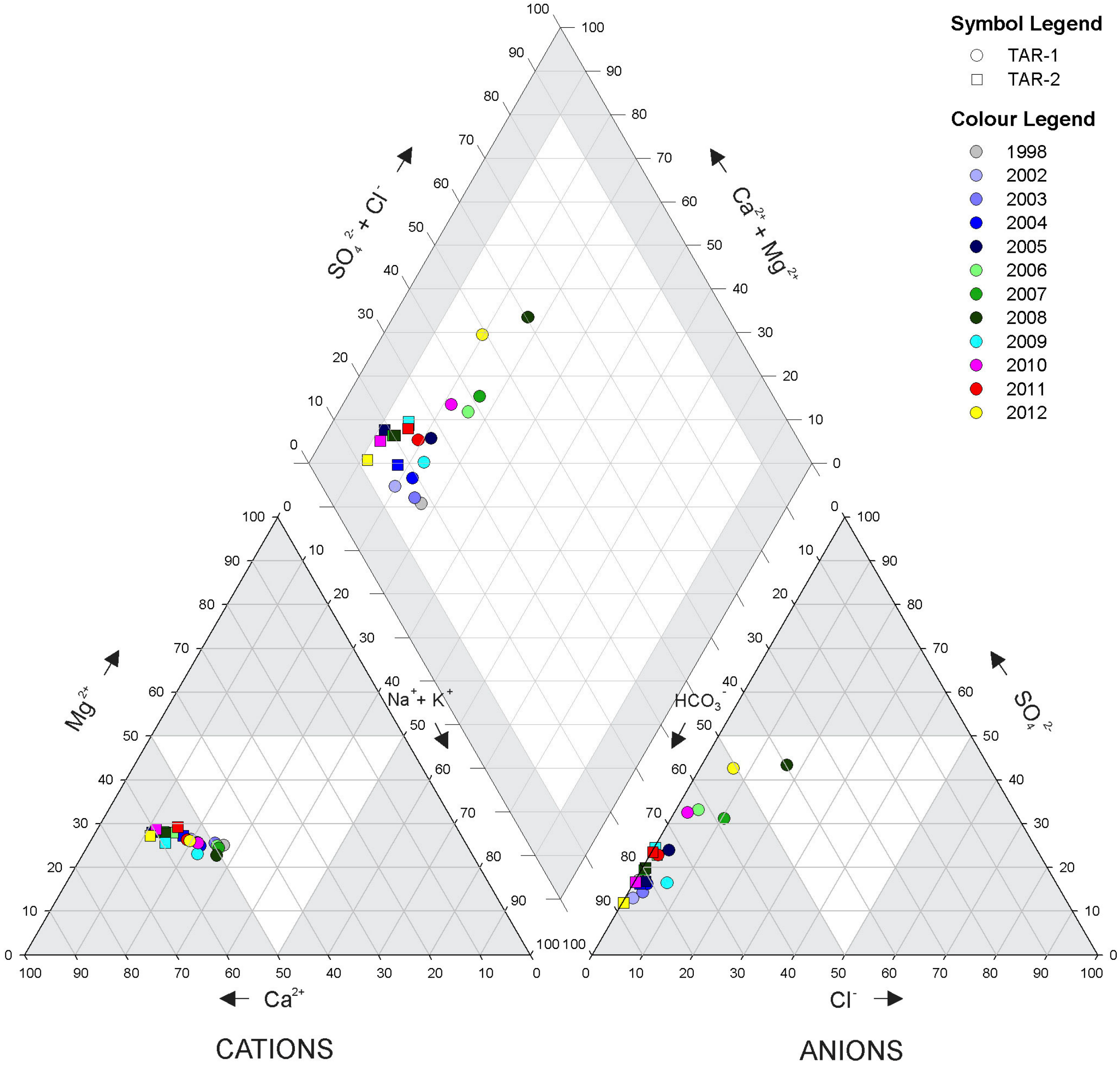


Table 5.4-6 Water quality guideline exceedances, Tar River, fall 2012.

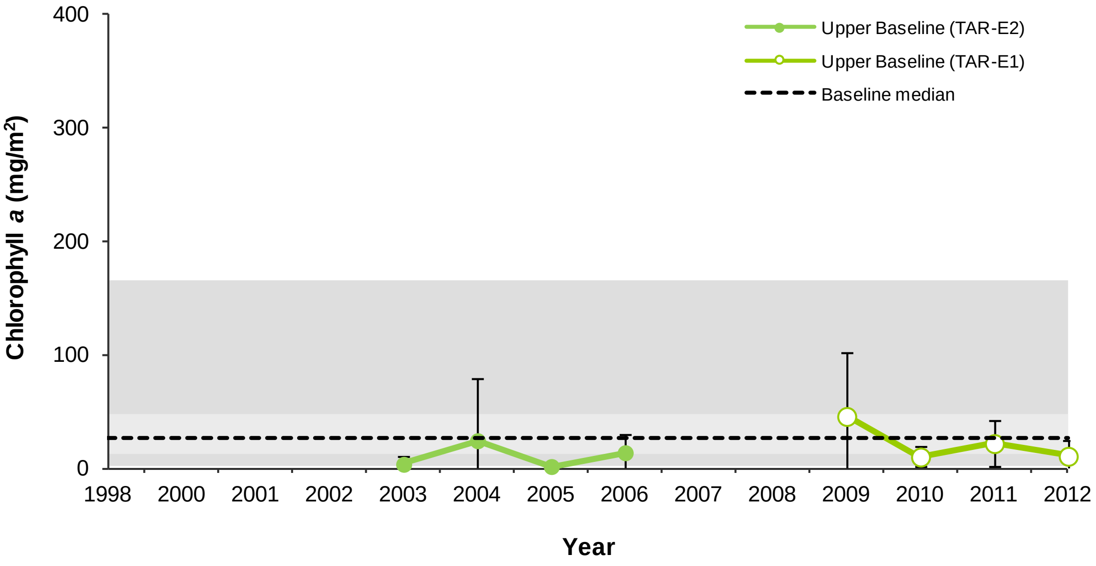
Variable	Units	Guideline[a]	TAR-1	TAR-2
Dissolved iron	mg/L	0.3	-	0.55
Total aluminum	mg/L	0.1	0.67	0.21
Total iron	mg/L	0.3	1.38	1.24
Total phenols	mg/L	0.004	0.0063	-
Total phosphorus	mg/L	0.05	-	0.077

[a] Sources for all guidelines are outlined in Table 3.2-5.

Table 5.4-7 Average habitat characteristics of benthic invertebrate community sampling locations in the Tar River, fall 2012.

Variable	Units	TAR-D1 Lower *Test* Reach of Tar River	TAR-E2 Upper *Baseline* Reach of Tar River
Sample date	-	09-Sept-2012	12-Sept-2012
Habitat	-	Depositional	Erosional
Water depth	m	0.6	0.3
Current velocity	m/s	0.34	0.34
Field Water Quality			
Dissolved oxygen	mg/L	7.2	9.9
Conductivity	µS/cm	438	543
pH	pH units	8.2	8.4
Water temperature	°C	16.0	8.1
Sediment Composition			
Sand	%	65	-
Silt	%	22	-
Clay	%	13	-
Total Organic Carbon	%	1.68	-
Sand/Silt/Clay	%	-	6
Small Gravel	%	-	10
Large Gravel	%	-	14
Small Cobble	%	-	65
Large Cobble	%	-	5
Boulder	%	-	1
Bedrock	%	-	0

Figure 5.4-6 Periphyton chlorophyll *a* biomass in *baseline* reach TAR-E2 of the Tar River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.4-8 Summary of major taxa abundances and benthic invertebrate community measurement endpoints in the lower Tar River (*test* reach TAR-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach TAR-D1		
	2002	2003 to 2011	2012
Nematoda	2	0 to 4	1
Erpobdellidae	<1	0 to <1	
Naididae	<1	0 to 4	<1
Tubificidae	7	1 to 55	38
Enchytraeidae		0 to 5	
Hydracarina	<1	0 to 2	2
Amphipoda	<1		
Ostracoda	2	0 to 37	9
Cladocera			<1
Chydoridae	<1	0 to <1	
Copepoda	<1	0 to 11	<1
Gastropoda	<1	0 to 2	<1
Bivalvia	1	0 to 2	1
Coleoptera	<1	0 to <1	<1
Ceratopogonidae	1	0 to 16	9
Chaoboridae			<1
Chironomidae	86	<1 to 90	34
Dolichopodidae		0 to 1	
Empididae	1	0 to 1	1
Ephydridae			<1
Tipulidae	<1	0 to 37	<1
Tabanidae	<1	0 to 1	<1
Simuliidae		0 to <1	<1
Ephemeroptera	<1	0 to 1	1
Anisoptera	<1	0 to <1	<1
Plecoptera	<1	0 to <1	
Trichoptera	<1	0 to <1	<1
Collembola		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	69,759	657 to 20,805	27,961
Richness	22	4 to 18	18
Simpson's Diversity	0.80	0.33 to 0.74	0.68
Equitability	0.27	0.30 to 0.73	0.27
% EPT	<1	0 to 2	1

Table 5.4-9 Summary of major taxa abundances and benthic invertebrate community measurement endpoints in the upper Tar River (*baseline* reaches TAR-E1 and TAR-E2).

Taxon	Percent Major Taxa Enumerated in Each Year				
	Reach TAR-E1		TAR-E2		
	2003	2004 to 2006	2009	2010 to 2011	2012
Nematoda	2	<1	<1	<1 to 2	<1
Erpobdellidae		0 to <1			
Oligochaeta					<1
Naididae	6	<1 to 1	<1	<1 to 2	<1
Tubificidae	1	<1 to 1	<1	1 to 2	<1
Enchytraeidae	2	<1 to 2	6	1 to 4	1
Lumbricidae					<1
Lumbriculidae				0 to <1	<1
Hydracarina	1	<1 to 2	4	9 to 13	8
Ostracoda			<1	<1 to 1	<1
Cladocera					<1
Copepoda	1	0 to <1	<1	<1	<1
Coleoptera		0 to <1			<1
Ceratopogonidae	<1	0 to <1		0 to <1	<1
Chironomidae	67	8 to 33	28	26 to 32	50
Dolichopodidae		0 to <1			
Empididae	2	1 to 8		1 to 5	2
Ephydridae	<1		26		
Tipulidae	1	<1 to 1	1	<1 to 1	1
Tabanidae				0 to <1	
Simuliidae		1 to 13	<1	<1 to 2	<1
Ephemeroptera	5	38 to 48	1	18 to 26	21
Plecoptera	8	8 to 13	15	3 to 21	4
Trichoptera	2	3 to 19	16	8 to 17	9
Lepidoptera					<1
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	7,166	2,154 to 5,781	2,037	4512 to 20,470	33,658
Richness	25	17 to 24	25	23 to 28	32
Simpson's Diversity	0.85	0.80 to 0.85	0.86	0.86 to 0.89	0.88
Equitability	0.30	0.26 to 0.39	0.33	0.36 to 0.37	0.29
% EPT	18	7 to 61	56	5 to 37	35

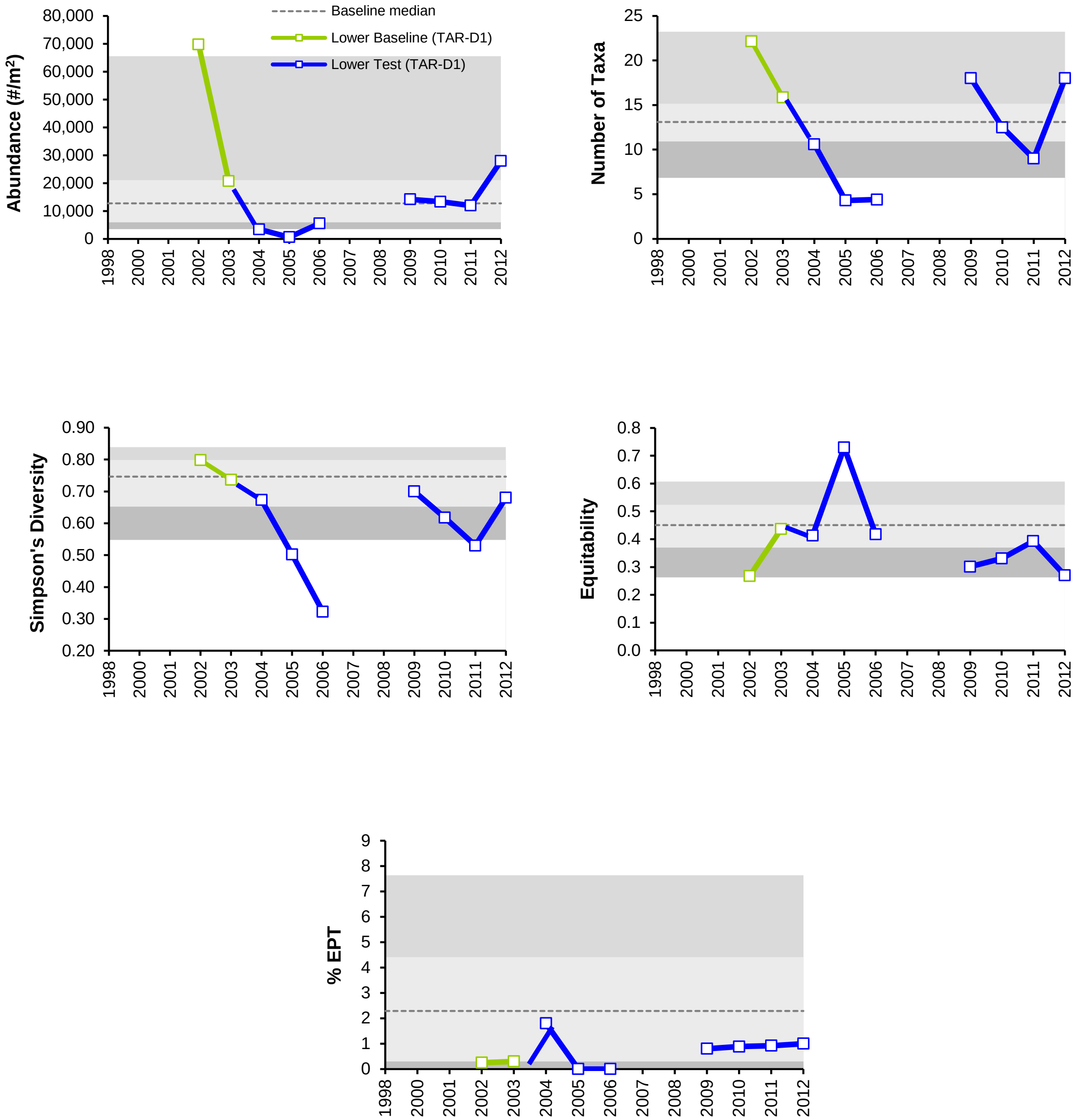
Table 5.4-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach TAR-D1.

Variable	P-value				Variance Explained (%)				Nature of Change(s)
	Baseline **Period vs.** ***Test*** **Period**	**Time Trend (*test* period)**	**2012 vs.** ***Baseline*** **Years**	**2012 vs. Previous Years**	***Baseline*** **Period vs.** ***Test*** **Period**	**Time Trend (*test* period)**	**2012 vs.** ***Baseline*** **Years**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**<0.001**	0.277	**0.040**	37	21	1	4	Higher during *baseline* period; increasing over time in *test* period.
Richness	**<0.001**	**0.002**	0.510	**0.011**	36	10	0	7	Higher during *baseline* period.
Simpson's Diversity	**<0.001**	0.266	0.258	0.314	42	3	3	2	Higher during *baseline* period.
Equitability	0.188	**<0.001**	0.218	**0.025**	4	34	3	11	Decreasing in *test* period.
EPT	0.259	0.432	0.109	**0.014**	6	3	13	30	Higher in 2012 than mean of previous years.
CA Axis 1	0.997	**0.011**	0.823	0.781	0	42	0	0	Decreasing over time.
CA Axis 2	0.115	**<0.001**	0.082	**0.003**	7	40	9	28	Increasing over time in *test* period; higher in 2012 than mean of previous years.

Bold values indicate significant difference (p<0.05).

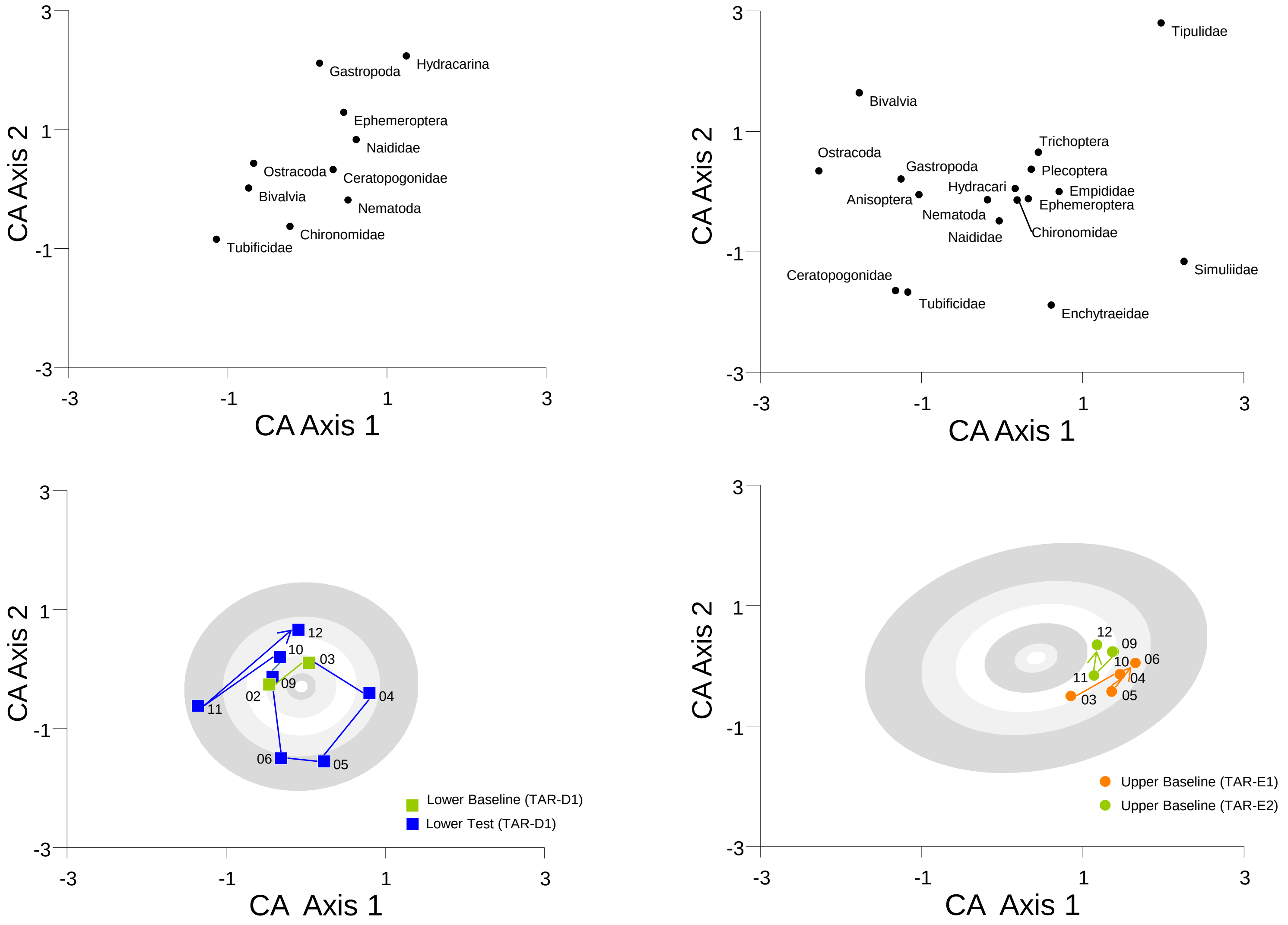
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.4-7 Variation in benthic invertebrate community measurement endpoints in the Tar River (*test* reach TAR-D1).



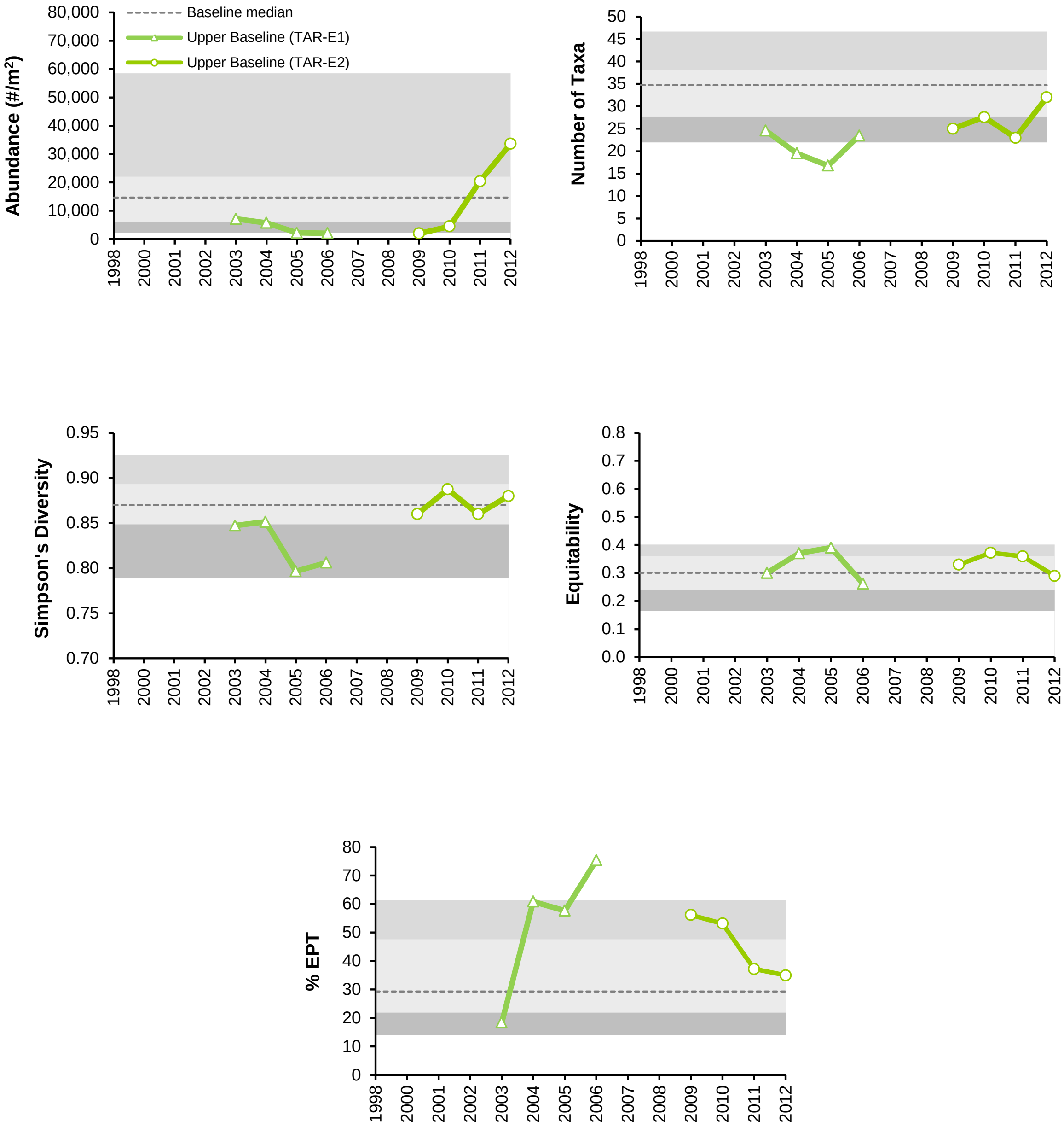
Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.4-8 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Tar River (*test* reach TAR-D1 and *baseline* reach TAR-E2).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Figure 5.4-9 Variation in benthic invertebrate community measurement endpoints in the Tar River (*baseline* reach TAR-E2).



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Note: The upper *baseline* reach of the Tar River was moved further upstream in 2009 due to increasing development. Prior to 2009, the reach was named TAR-E1.

Table 5.4-11 Concentrations of selected sediment measurement endpoints, Tar River (*test* station TAR-D1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	21	9	3	12	29
Silt	%	-	41	9	3	13	50
Sand	%	-	39	9	21	75	94
Total organic carbon	%	-	1.9	9	0.3	1.1	6.3
Total hydrocarbons							
BTEX	mg/kg	-	<20	6	<5	<8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	6	<5	<8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	13	36	100
Fraction 3 (C16-C34)	mg/kg	300[1]	255	6	220	**467**	**860**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	183	6	119	288	460
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.012	9	0.001	0.004	0.015
Retene	mg/kg	-	0.074	8	0.012	0.056	2.19
Total dibenzothiophenes	mg/kg	-	1.34	9	0.152	0.723	6.26
Total PAHs	mg/kg	-	5.51	9	0.624	2.76	19.1
Total Parent PAHs	mg/kg	-	0.373	9	0.047	0.102	0.449
Total Alkylated PAHs	mg/kg	-	5.14	9	0.522	2.67	18.7
Predicted PAH toxicity[3]	H.I.	1.0	**3.42**	9	0.206	**2.03**	**4.40**
Metals that exceed CCME guidelines in 2012							
Total arsenic	mg/kg	5.9	**8.9**	9	3.2	**6.1**	**9.5**
Other analytes that exceeded CCME guidelines in 2012							
Benz[a]anthracene	mg/kg	0.0317	**0.038**	9	0.0005	0.0027	0.0302
Benzo[a]pyrene	mg/kg	0.0319	**0.037**	9	0.002	0.006	0.023
Chrysene	mg/kg	0.0571	**0.079**	9	0.016	0.021	**0.093**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.8	6	5.0	6.8	8.8
Chironomus growth - 10d	mg/organism	-	1.92	6	0.90	1.94	4.00
Hyalella survival - 14d	# surviving	-	9.6	6	6.6	8.8	10.0
Hyalella growth - 14d	mg/organism	-	0.19	6	0.10	0.20	0.56

Values in **bold** indicate concentrations exceeding guidelines.

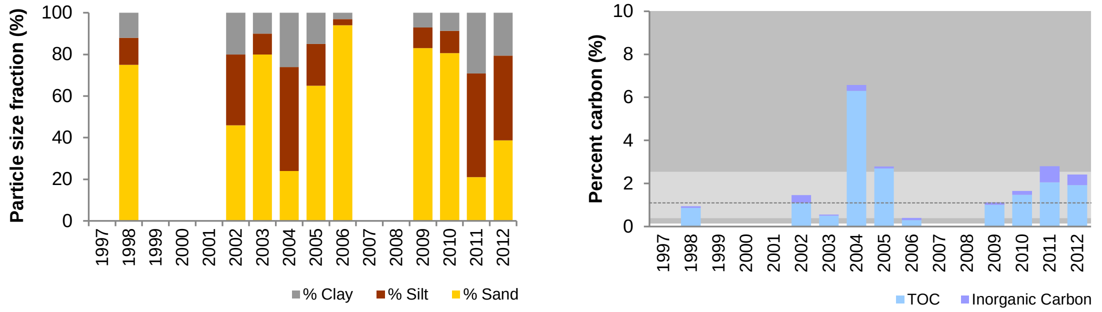
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

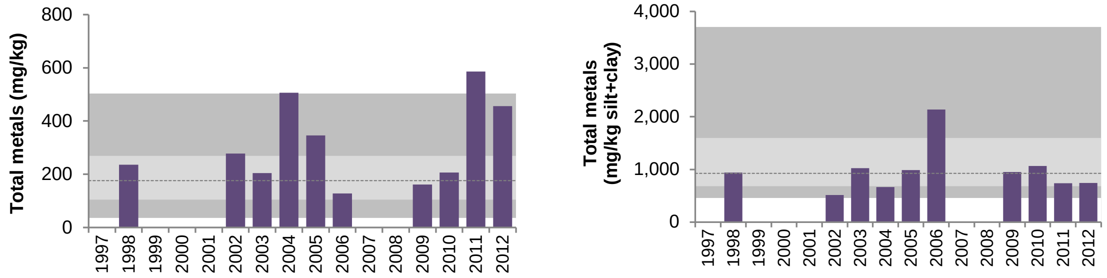
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

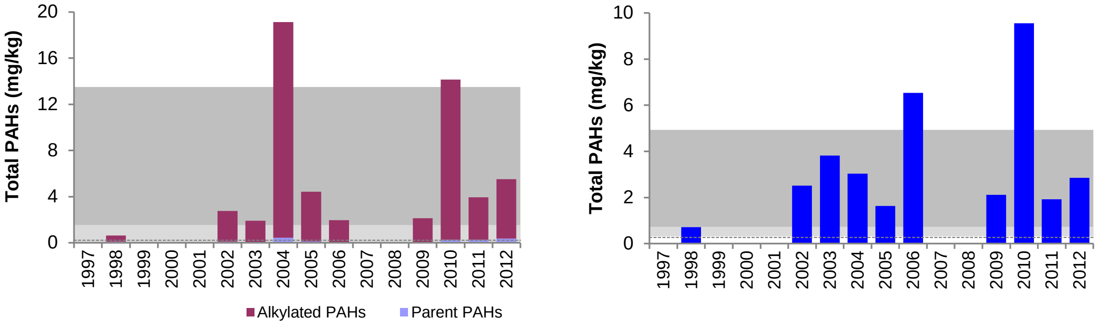
Figure 5.4-10 Variation in sediment quality measurement endpoints in the Tar River, *test* station TAR-D1.


Particle size distribution

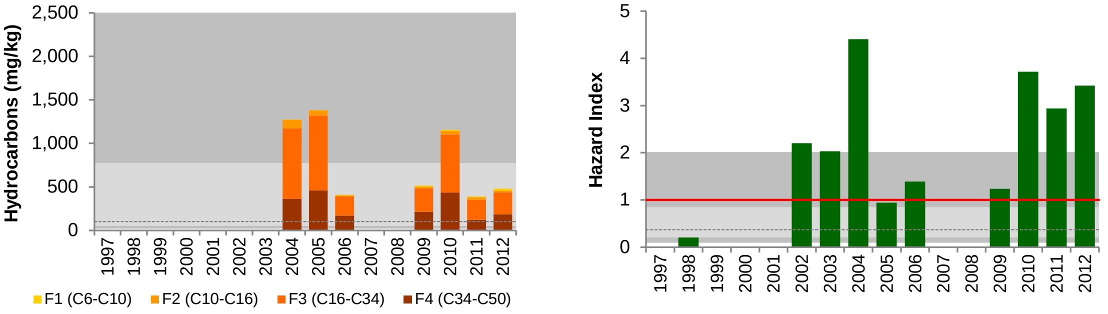
Carbon Content[1]


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 2012).

[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 5.4-12 Average habitat characteristics of fish assemblage monitoring locations at *test* reach TAR-F1 and *baseline* reach TAR-F2 of the Tar River, fall 2012.

Variable	Units	TAR-F1 Lower *Test* Reach of Tar River	TAR-F2 Upper *Baseline* Reach of Tar River
Sample date	-	11-Sept-2012	09-Sept-2012
Habitat type	-	riffle/run	riffle/run
Maximum depth	m	0.98	0.80
Bankfull channel width	m	10.5	7.5
Wetted channel width	m	10.5	5.0
Substrate			
Dominant	-	sand	cobble
Subdominant	-	-	coarse gravel and silt/clay/fines
Instream cover			
Dominant	-	small and large woody debris	overhanging vegetation and small woody debris
Subdominant	-	overhanging vegetation and undercut banks	large woody debris, undercut banks and boulders
Field water quality			
Dissolved oxygen	mg/L	10	9.6
Conductivity	µS/cm	458	294
pH	pH units	7.97	8.27
Water temperature	^{0}C	11.7	11.5
Water velocity			
Left bank velocity	m/s	0.15	0.04
Left bank water depth	m	0.43	0.08
Centre of channel velocity	m/s	0.40	0.33
Centre of channel water depth	m	0.93	0.20
Right bank velocity	m/s	0.10	0.20
Right bank water depth	m	0.35	0.20
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.4-13 Percent composition and mean CPUE (catch per unit effort) of fish species at *test* reach TAR-F1 and *baseline* reach TAR-F2 of the Tar River, 2009 to 2012.

Common Name	Code	Total Species					Percent of Total Catch				
		TAR-F1			TAR-F2		TAR-F1			TAR-F2	
		2009	2011	2012	2011	2012	2009	2011	2012	2011	2012
Arctic grayling	ARGR	-	-	-	1	2	0	0	0	0.9	1.6
brook stickleback	BRST	2	2	-	-	-	18.2	3.9	0	0	0
brassy minnow	BRMN	-	-	-	-	1	0	0	0	0	0.8
burbot	BURB	-	-	-	-	-	0	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	0	0	0	0	0
finescale dace	FNDC	-	5	1	-	-	0	9.8	7.1	0	0
lake chub	LKCH	4	26	-	5	-	36.4	51.0	0	4.7	0
lake whitefish	LKWH	-	-	-	-	-	0	0	0	0	0
longnose dace	LNDC	-	1	-	-	-	0	2.0	0	0	0
longnose sucker	LNSC	-	4	3	-	7	0	7.8	21.4	0	5.7
northern pike	NRPK	1	1	-	-	-	9.1	2.0	0	0	0
northern redbelly dace	NRDC	-	-	-	-	-	0	0	0	0	0
pearl dace	PRDC	-	-	-	-	-	0	0	0	0	0
slimy sculpin	SLSC	-	-	2	101	113	0	0	14.3	94.4	92.6
spoonhead sculpin	SPSC	-	-	-	-	-	0	0	0	0	0
spottail shiner	SPSH	-	-	-	-	-	0	0	0	0	0
trout-perch	TRPR	-	8	1	-	-	0	15.7	7.1	0	0
walleye	WALL	-	-	-	-	-	0	0	0	0	0
white sucker	WHSC	4	4	7	-	-	36.4	7.8	50.0	0	0
yellow perch	YLPR	-	-	-	-	-	0	0	0	0	0
Total Count		**11**	**51**	**14**	**107**	**122**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**4**	**8**	**5**	**3**	**4**	**-**	**-**	**-**	**-**	-
Electrofishing effort (secs)		**1,552**	**743**	**1905**	**1,043**	**1,526**	**-**	**-**		**-**	
CPUE (#/100 secs)		**0.71**	**6.86**	**0.73**	**10.26**	**7.99**	**-**	**-**		**-**	

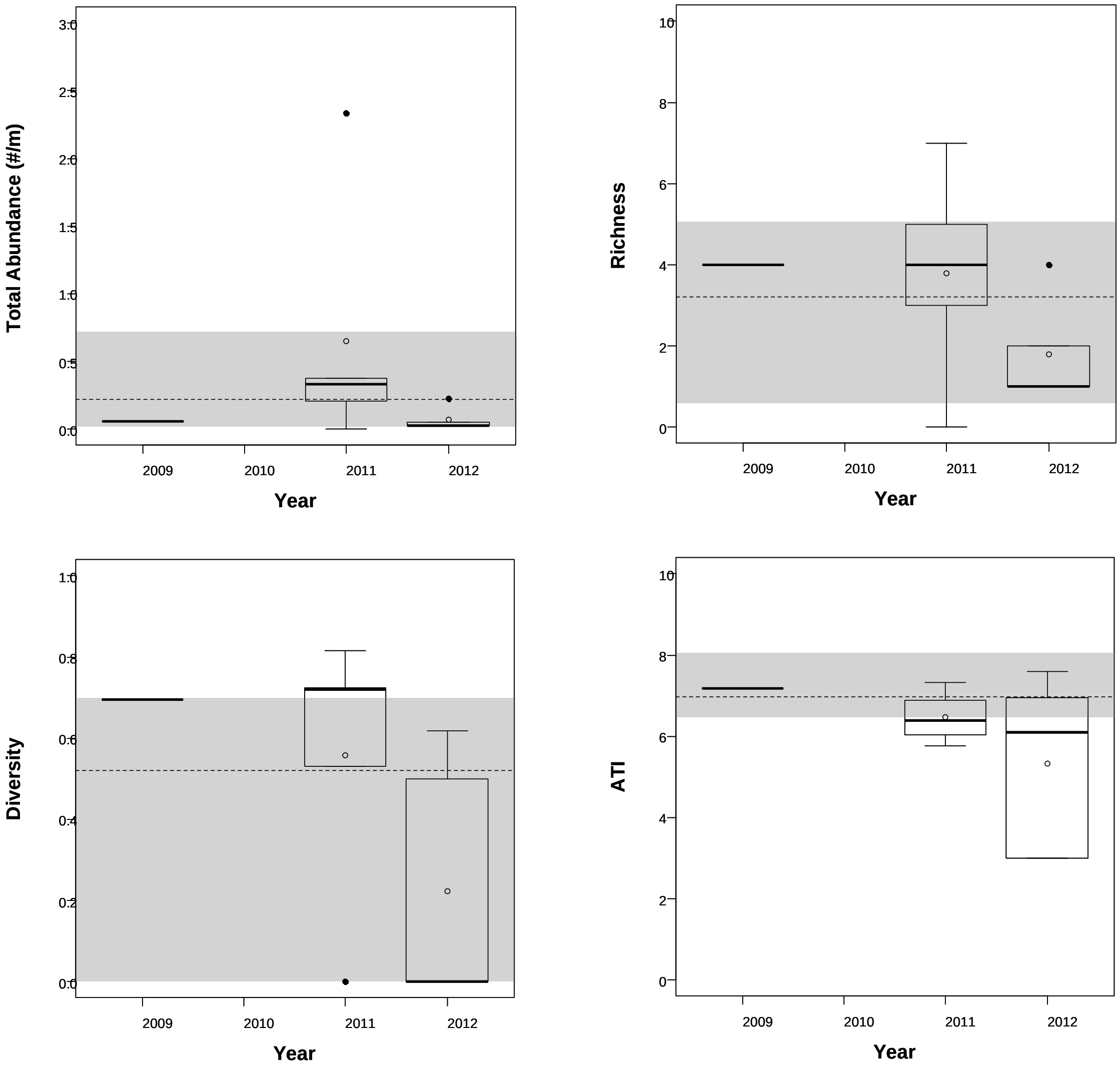
Table 5.4-14 Summary of fish assemblage measurement endpoints (±1SD) in reaches of the Tar River, 2009 to 2012.

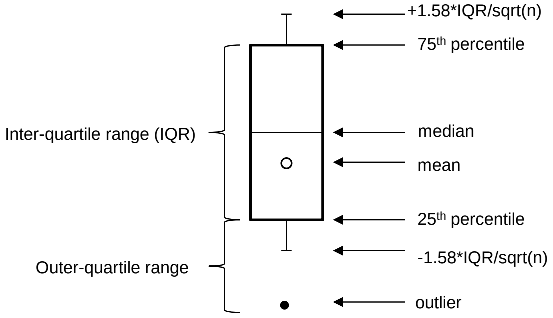
Reach	Year	Abundance		Richness			Diversity		ATI	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
TAR-F1	2009	0.06	-	4	4	-	0.69	-	7.18	-
	2011	0.65	0.95	8	4	2.59	0.56	0.33	6.46	0.65
	2012	0.07	0.09	5	2	1.30	0.22	0.31	5.33	2.19
TAR-F2	2011	0.71	0.24	3	2	0.55	0.10	0.13	3.13	0.22
	2012	0.65	0.16	5	2	0.84	0.15	0.11	3.16	0.20

SD = standard deviation across sub-reaches within a reach.

Figure 5.4-11 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the Tar River, 2009 to 2012.

Depositional *Test* Reach TAR-F1



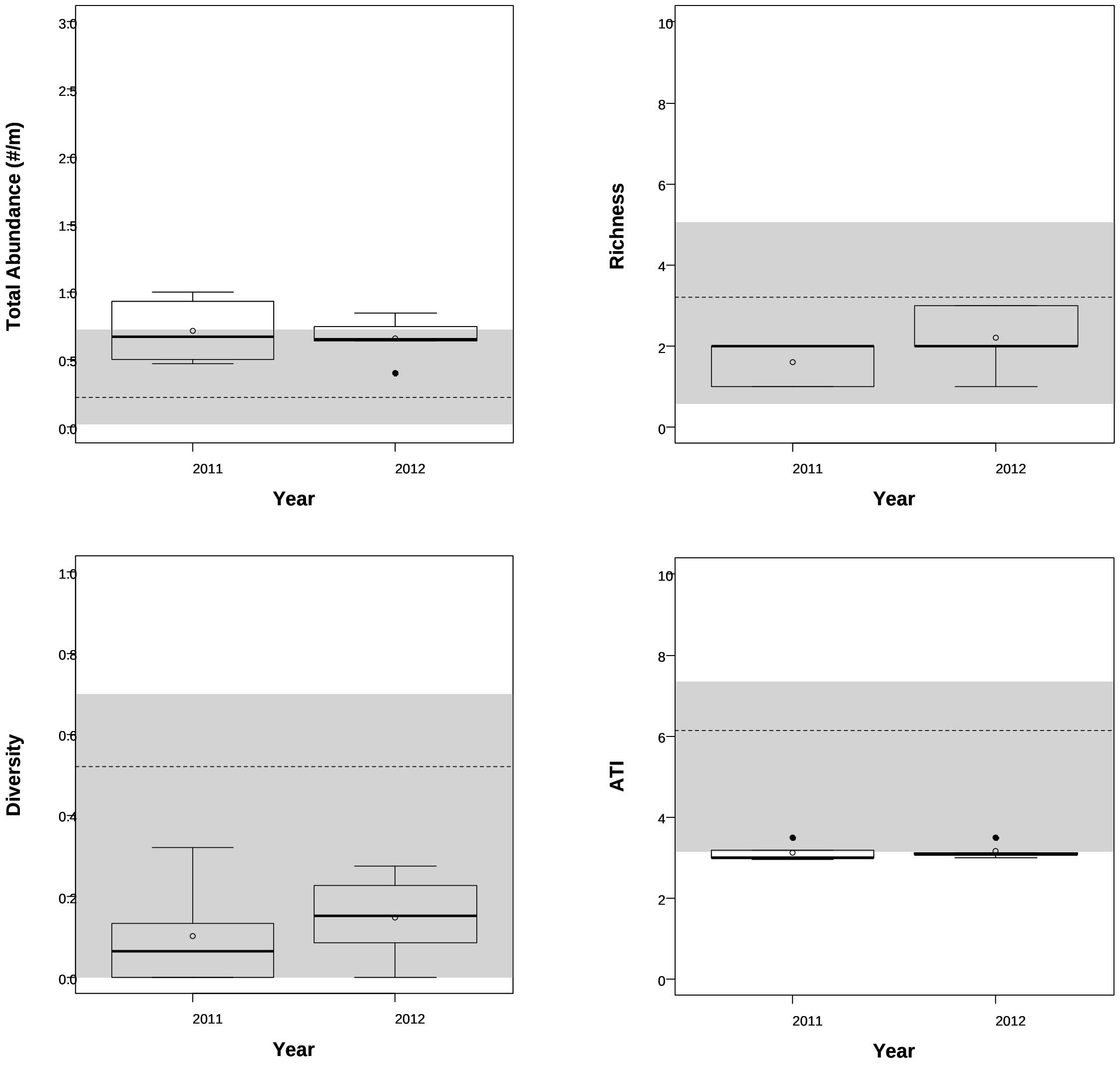


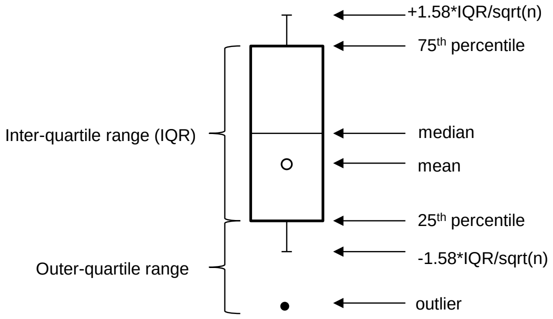
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Figure 5.4-11 (Cont'd.)

Erosional *Baseline* Reach TAR-F2





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

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5.5 MACKAY RIVER WATERSHED

Table 5.5-1 Summary of results for the MacKay River watershed.

MacKay River Watershed	**Summary of 2012 Conditions**		
Climate and Hydrology			
Criteria	**S26** near Fort McKay	no stations sampled	
Mean open-water season discharge	🟡		
Mean winter discharge	🟡		
Annual maximum daily discharge	🟡		
Minimum open-water season discharge	🟡		
Water Quality			
Criteria	**MAR-1** at the mouth	**MAR-2A** upstream of Suncor MacKay	**MAR-2** upstream of Suncor Dover
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
Benthic Invertebrate Communities	🟠	🟠	n/a
No Sediment Quality component activities conducted in 2012			
Fish Populations			
Criteria	**MAR-F1** at the mouth	**MAR-F2** upstream of Suncor MacKay	**MAR-F3** upstream of Suncor Dover
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.

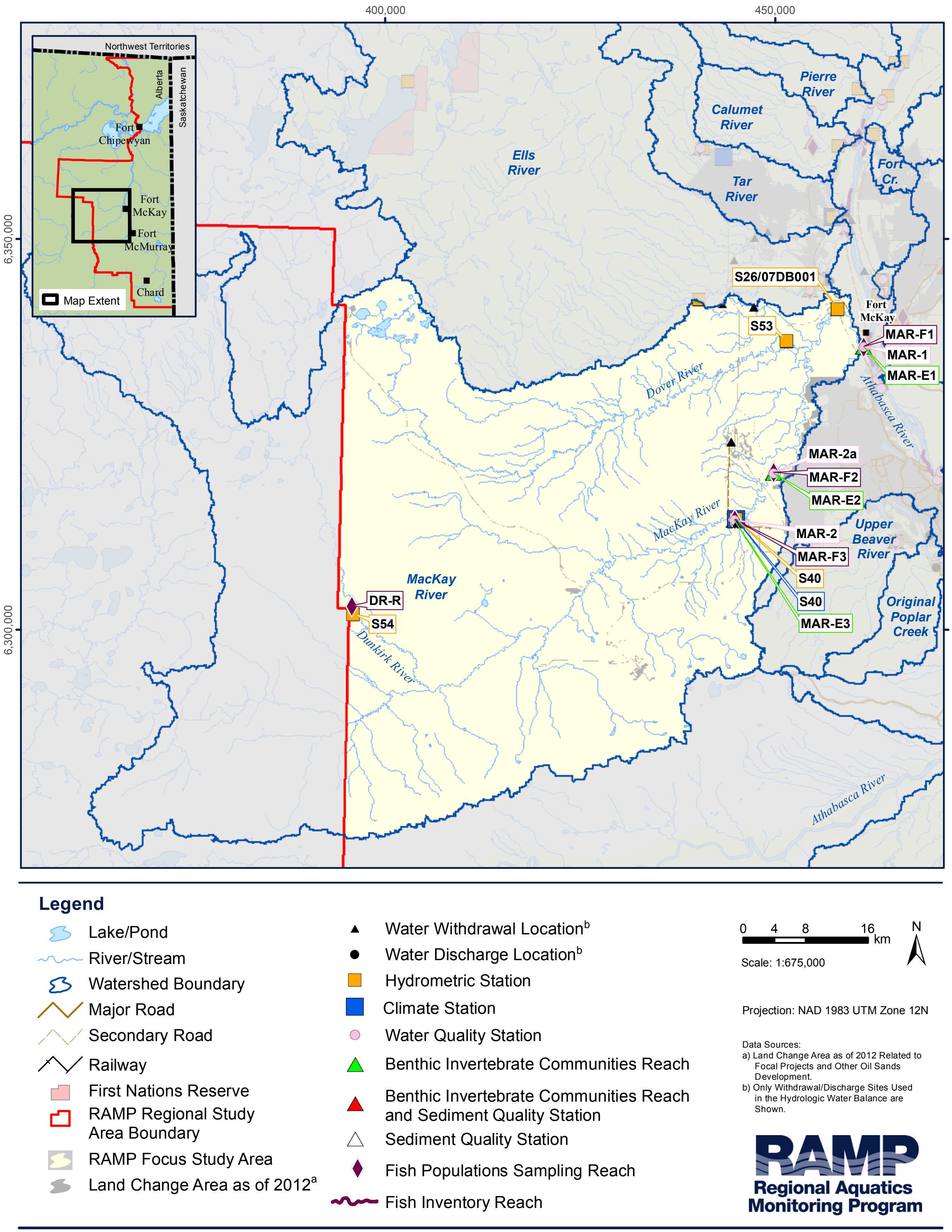
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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: Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.3 for a detailed description of the classification methodology.

Figure 5.5-1 MacKay River watershed.



Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K05_MacKay_20130314.mxd

Figure 5.5-2 Representative monitoring stations of the MacKay River watershed, fall 2012.

Benthic Invertebrate Reach MAR-E1: Left Downstream Bank

Benthic Invertebrate Reach MAR-E2: Left Downstream Bank

Hydrology Station S40: at the Petro-Canada Bridge

Benthic Invertebrate Reach MAR-E3: Left Downstream Bank

5.5.1 Summary of 2012 Conditions

As of 2012, approximately 1% (3,806 ha) of the MacKay River watershed had undergone land change as a result of focal projects (Table 2.5-2). 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*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Populations components of RAMP in the MacKay River watershed in 2012. Table 5.5-1 is a summary of the 2012 assessment of the MacKay River watershed, while Figure 5.5-1 denotes the location of the monitoring stations for each RAMP component, locations of reported focal project water withdrawal and discharge locations, and the area of land change for 2012. Figure 5.5-2 contains fall 2012 photos of monitoring stations in the watershed.

Hydrology The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated from the observed *test* hydrograph were 0.004% lower from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2012 at *test* station MAR-1 and *baseline* station MAR-2 relative to regional *baseline* water quality conditions were classified as **Negligible-Low**, while water quality at *test* station MAR-2A was classified as **Moderate**, likely due to very high flow conditions at the time of sampling, which resulted in high total suspended solids and total metals that are associated with particulates.

Benthic Invertebrate Communities Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MAR-E1 were classified as **Moderate** because there was a decrease in EPT taxa below regional *baseline* conditions and significantly lower abundance of EPT taxa at *test* reach MAR-E1 compared to *baseline* reach MAR-E3, accounting for greater than 20% of the variance in annual means. In addition, CA Axis 1 scores were significantly lower at *test* reach MAR-E1 in 2012 compared to *baseline* reach MAR-E3 reflecting a difference in taxa composition, with fewer water mites. Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MAR-E2 were classified as **Moderate** because the CA Axis 1 scores were significantly lower compared to *baseline* reach MAR-E3, which accounted for greater than 20% of the variance in annual means.

Fish Populations Differences in measurement endpoints for fish assemblages between *test* reaches MAR-F1 and MAR-F2 and the regional *baseline* conditions were classified as **Negligible-Low** given there was only one measurement endpoint at *test* reach MAR-F1 that exceeded the regional range of variation of *baseline* reaches. The increase in ATI at *test* reach MAR-F1 was due to the dominance of trout-perch captured at this reach, which has a high tolerance value.

5.5.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the MacKay River watershed was conducted at the WSC Station 07DB001, MacKay River near Fort McKay, which was used for the water balance analysis. Additional hydrometric data for the MacKay River watershed were available from stations S40, MacKay River at the Petro-Canada Bridge; S53, Dover River near the mouth; and S54, Dunkirk River near Fort McKay. Details for each of these stations can be found in Appendix C.

Continuous annual hydrometric data have been collected for the WSC Station 07DB001 (RAMP Station S26) from 1973 to 1986 and more recently from 2002 to 2012, with some partial records in 1972. Seasonal data from March to October have been collected every year since 1973. The annual runoff volume in the 2012 water year (WY) was 239 million m^3. This value was 40% below the mean historical annual runoff volume based on the period of record. Flows steadily decreased from November 2011 to mid-February 2012, with flows from November 2011 to January 2012 near the historical lower quartile values (Figure 5.5-3). Flows increased from March to early May to a freshet peak of 22.8 m^3/s on May 7, 2012. Flows decreased until mid-June before increasing due to rainfall events in late June and July. The maximum daily flow of 33.3 m^3/s occurred on July 8, which was 69% lower than the historical mean annual maximum daily flow. Flows from mid-June to late October fluctuated between historical lower and upper quartile values. The minimum open-water daily flow of 4.17 m^3/s on August 24 was 14% higher than the historical mean open-water minimum daily flow of 3.65 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at WSC Station 07DB001 (RAMP Station S26) is presented in Table 5.5-2 and described below:

1. The closed-circuited land area from focal projects as of 2012 was estimated to be 6.2 km^2 (Table 2.5-1). The loss of flow to the MacKay River that would have otherwise occurred from this land area was estimated at 265,909 m^3.
2. As of 2012, the area of land change in the MacKay River watershed that was not closed-circuited was estimated to be 31.9 km^2 (Table 2.5-1). The increase in flow to the MacKay River that would not have otherwise occurred from this land area was estimated at 273,531 m^3.
3. In the 2012 WY, Suncor withdrew approximately 11,442 m^3 of water for dust suppression.
4. In the 2012 WY, Total E&P withdrew 64 m^3 of water to support winter drilling and construction activities.

The estimated cumulative effect of land change and water withdrawals was a loss of flow of 3,884 m^3 in the 2012 WY at WSC Station 07DB001 (RAMP Station S26). The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.5-3. The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated from the observed *test* hydrograph were 0.004% lower from the estimated *baseline* hydrograph (Table 5.5-3); these differences were classified as **Negligible-Low** (Table 5.5-1).

5.5.3 Water Quality

In fall 2012, water quality samples were collected from:

- the MacKay River near its mouth (*test* station MAR-1, first sampled in 1998, fall sampling every year from 2000 to 2012);
- the MacKay River upstream of the Suncor Dover development *(test* station MAR-2A, initiated as a new RAMP station in 2009); and
- the MacKay River upstream of the Suncor MacKay River Dover in situ developments (*baseline* station MAR-2, sampled from 2002 to 2012, excluded from the 2012 regional *baseline* calculations because of upstream, non-RAMP oil-sands activities).

Winter, spring, and summer water quality sampling was also conducted at *test* station MAR-2A in 2012.

Temporal Trends Significant (α=0.05) decreasing trends in concentrations of sulphate were observed in fall over time at *test* station MAR-1 (1998 to 2012) and *baseline* station MAR-2 (2002 to 2012). Trend analysis was not conducted for *test* station MAR-2A given that there were only three years of data.

2012 Results Relative to Historical Concentrations In fall 2012, concentrations of water quality measurement endpoints were within previously-measured concentrations (Table 5.5-4 to Table 5.5-6), with the exception of magnesium and sulphate, with concentrations lower than previously-measured minimum concentrations at *baseline* station MAR-2 (Table 5.5-6). Many historical high and low concentrations of measurement endpoints were observed at *test* station MAR-2A in fall 2012 because of very high water levels (Table 5.5-5).

Ion Balance In fall 2012, the ionic composition of water at all stations in the MacKay River was dominated by bicarbonate and calcium, and was similar to the ionic composition measured in this watershed since 1998 (Figure 5.5-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of water quality variables exceeded the guidelines for total nitrogen and total aluminum at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2 (Table 5.5-4 to Table 5.5-6). The guidelines for total mercury (ultra-trace) and dissolved aluminum were also exceeded at *test* station MAR-2A.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the MacKay River in 2012 (Table 5.5-7):

- **Winter** – dissolved iron, sulphide, total aluminum, total chromium, total iron, total nitrogen, total phenols, and total phosphorous at *test* station MAR-2A;
- **Spring** – dissolved iron, sulphide, total aluminum, total iron, total nitrogen, total phenols, and total phosphorous at *test* station MAR-2A;
- **Summer** – dissolved iron, sulphide, total aluminum, total iron, total nitrogen, total phenols, and total phosphorus at *test* station MAR-2A; and
- **Fall** – total iron, dissolved iron, sulphide, total phenols, and total phosphorus at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2. Total copper, total chromium, and total lead at *test* station MAR-2A.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, all water quality measurement endpoints were within the range of regional *baseline* concentrations, with the exception of total suspended solids and total mercury (ultra-trace), which exceeded the 95th percentile or regional *baseline* concentrations at *test* station MAR-2A (Figure 5.5-5).

Water Quality Index The WQI for *test* station MAR-1 and *baseline* station MAR-2 were 98.7 and 100, respectively, indicating **Negligible-Low** differences from regional *baseline* water quality conditions. The WQI of 74.5 for *test* station MAR-2A indicated a **Moderate** difference from the regional *baseline* water quality conditions. This difference was driven by very high concentrations of total suspended solids and total metals often associated with particulates (e.g., Al, Ba, Cr, Co, Fe, Pb, V), likely related to very high flows at *test* station MAR-2A during the fall sampling event.

Classification of Results Concentrations of all water quality measurement endpoints in the MacKay River watershed were within the range of previously-measured concentrations, with the exception of magnesium and sulphate, which were lower in fall 2012 than previously-measured concentrations at *baseline* station MAR-2, as well as many variables at *test* station MAR-2A. Water quality measurement endpoints in the MacKay River watershed in fall 2012 were within the range of regional *baseline* concentrations with the exception of total mercury (ultra-trace) and total suspended solids, which exceeded the 95th percentile of regional *baseline* concentrations at *test* station MAR-2A. Differences in water quality in fall 2012 at *test* station MAR-1 and *baseline* station MAR-2 relative to regional *baseline* water quality conditions were classified as **Negligible-Low**, while water quality at *test* station MAR-2A was classified as **Moderate**, likely due to very high flow conditions at the time of sampling, which resulted in high total suspended solids and total metals that are associated with particulates.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- erosional *test* reach MAR-E1 near the mouth of the river, sampled since 1998;
- 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.

2012 Habitat Conditions Water at *test* reach MAR-E1 in fall 2012 was shallow (0.4 m), slowly flowing (0.3 m/s), alkaline (pH = 8.5), with moderate conductivity (226 µS/cm), and high dissolved oxygen (Table 5.5-8). The substrate was dominated by gravel (81%) with a small proportion of sand/silt/clay (15%) (Table 5.5-8). Periphyton biomass averaged 39 mg/m^2, which was within the range of variation of *baseline* erosional reaches (Figure 5.5-6).

Water at *test* reach MAR-E2 in fall 2012 was shallow (0.2 m), fast flowing (0.7 m/s), alkaline (pH = 8.5), with low conductivity (95 µS/cm), and high dissolved oxygen (Table 5.5-8). The substrate was dominated by small and large cobble (50% and 38%, respectively) (Table 5.5-8). Periphyton biomass averaged 216 mg/m^2, which was within the range of variation of *baseline* erosional reaches (Figure 5.5-6).

Water at *baseline* reach MAR-E3 was shallow (0.3 m), fast flowing (0.7 m/s), alkaline (pH = 8.0), with moderate conductivity (167 µS/cm), and high dissolved oxygen (Table 5.5-8). The substrate was dominated by small cobble (31%) and large gravel (24%) with smaller amounts of large cobble (10%) and small gravel (5%) (Table 5.5-8). Periphyton biomass averaged 216 mg/m^2, which was within the range of variation of *baseline* erosional reaches (Figure 5.5-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of the *test* reach MAR-E1 in fall 2012 was dominated by chironomids (42%) and naidids (16%), with subdominant taxa consisting of Ephemeroptera (6%) and Ostracoda (6%) (Table 5.5-9). Chironomid taxa at *test* reach MAR-E1 were numerous and included the common genera *Polypedilum*, *Stempellina*, *Larsia,* and *Micropsectra / Tanytarsus* (Wiederholm 1983). Mayflies (Ephemeroptera) included *Acerpenna pygmaea* and other *Baetids*, *Caensis*, and *Leptophlebia*. Stoneflies (Plecoptera) were present, reflecting that the lower reach of the MacKay River was a cool/cold water environment. Common stoneflies included *Isoperla* and Chloroperlidae. Caddisflies were represented by *Hydroptila* and *Oecetis* and damnselflies from the genus *Opigomphus* were also observed.

The benthic invertebrate community at *test* reach MAR-E2 in fall 2012 was dominated by chironomids (29%), naidids (16%), and Ephemeroptera (16%), with subdominant taxa consisting of Hydracarina (8%) and Ostracoda (6%) (Table 5.5-10). Chironomid taxa were diverse and dominated by *Micropsectra / Tanytarsus*, *Rheotanytarsus,* and *Thienemannimyia gr.* Similarly to the lower reach, mayflies (Ephemeroptera) present at *test* reach MAR-E2 were primarily *Acerpenna pygmaea* and other *Baetids.* Stoneflies (Plecoptera) were represented primarily by the genera *Isoperla* and caddisflies included *Protoptila, Lepidostoma*, and *Hydropsyche* (Table 5.5-10). Fingernail clams were present in low relative abundances (Table 5.5-10).

The benthic invertebrate community at *baseline* reach MAR-E3 in fall 2012 was dominated by chironomids (38%), Naididae worms (15%), Ephemeroptra (14%), and Hydracarina (13%) (Table 5.5-10). Dominant chironomids included *Polypedilum, Micropsectra / Tanytarsus,* and *Thienemannimyia gr.* Mayflies were abundant and diverse, represented primarily by the genera *Baetis, Acerpenna, Tricorythodes*, and *Ephemerella*. Plecoptera (Chloroperlidae and *Isoperla*) and Trichoptera (*Protoptila, Chimara, Oecetis*, and *Lepidostoma*) were also present. Both Gastropoda (*Ferrissia rivularis)* and Bivalvia (*Pisidium / Sphaerium*) were present but in low relative abundances at *baseline* reach MAR-E3.

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 MacKay River watershed.

Temporal comparisons 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 2, 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 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling (1998 to 2011).

Temporal comparisons for *test* reach MAR-E2 included testing for:

- changes over time (Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling (2002 to 2011).

Spatial comparisons for *test* reaches MAR-E1 and MAR-E2 included testing for:

- differences from *baseline* reach MAR-E3 over the last three years (2010 to 2012) (Hypothesis 3, Section 3.2.3.1);
- differences between 2012 values at *test* reach MAR-E1 and all *baseline* data available for the MacKay River watershed (MAR-E1 – 1998, 2000, and 2001; MAR-E3 – 2010 to 2012); and
- differences in 2012 values at *test* reach MAR-E2 compared to *baseline* reach MAR-E3.

CA Axis 2 scores were higher in the *baseline* years (1998, 2000, and 2001) compared to the *test* years (2002 to 2012) at *test* reach MAR-E1, explaining 49% of the variance in annual means (Table 5.5-11), with a higher abundance of worms (naidids and enchytraeids) present during the *baseline* years (Figure 5.5-8).

The percentage of EPT taxa in 2012 was significantly higher at *baseline* reach MAR-E3 than *test* reach MAR-E1, explaining 29% of the variance in annual means. EPT taxa accounted for only 7% of the total benthic invertebrate community at *test* reach MAR-E1 and 26% at *baseline* reach MAR-E3.

CA Axis 1 scores were significantly higher in 2012 at *baseline* reach MAR-E3 than either of the *test* reaches (MAR-E1 and MAR-E2), accounting for >20% of the variance in annual means in both cases (Table 5.5-11). The higher scores at *baseline* reach MAR-E3 were indicative of a benthic invertebrate community consisting of a higher abundance of Hydracarina (Figure 5.5-8).

Comparison to Published Literature The benthic invertebrate community at *test* reach MAR-E1 was challenging because there were conflicting indications of conditions based on the taxa that were present and dominant. The percent of the community as naidid worms was relatively high (25%), while the percent of the community as Ephemeroptera was relatively low, potentially indicating a degradation of habitat quality (Hynes 1960, Griffiths 1998). The community did; however, include members of the Plecoptera, which indicated a stable, cold-water habitat (Hynes 1960, Griffiths 1998).

Test reach MAR-E2 supported a benthic invertebrate community reflecting somewhat favourable conditions, with high relative abundances of chironomids and Ephemeroptera (Hynes 1960, Griffiths 1998).

Baseline reach MAR-E3 contained a benthic invertebrate community similar to *test* reach MAR-E2, which reflected good water quality conditions based on high relative abundances of chironomids and Ephemeroptera (Griffiths 1998).

2012 Results Comparison to Regional *Baseline* Conditions Mean values of all measurement endpoints for benthic invertebrate communities at *test* reach MAR-E1, *test* reach MAR-E2, and *baseline* reach MAR-E3 were within the range of variation of *baseline* erosional reaches, with the exception of %EPT at *test* reach MAR-E1, which was below the 5th percentile of *baseline* variability (Figure 5.5-7).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MAR-E1 were classified as **Moderate** because there was a decrease in EPT taxa below regional *baseline* conditions and significantly lower abundance of EPT taxa at *test* reach MAR-E1 compared to *baseline* reach MAR-E3, accounting for greater than 20% of the variance in annual means. In addition, CA Axis 1 scores were significantly lower at *test* reach MAR-E1 in 2012 compared to *baseline* reach MAR-E3 reflecting a difference in taxa composition, with fewer water mites.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MAR-E2 were classified as **Moderate** because the CA Axis 1 scores were significantly lower compared to *baseline* reach MAR-E3, which accounted for greater than 20% of the variance in annual means.

5.5.4.2 Sediment Quality

No sediment quality sampling was conducted in the MacKay River in 2012 because sediment quality is only sampled in the depositional reaches in which benthic invertebrate communities were sampled and the reaches of the MacKay River where benthic invertebrate communities were sampled are erosional.

5.5.5 Fish Populations

Fish assemblages were sampled in fall 2012 at:

- erosional *test* reach MAR-F1, first sampled in 2009 as part of the Fish Assemblage Pilot Study and since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MAR-E1);
- erosional *test* reach MAR-F2, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach MAR-E2); and
- erosional *baseline* reach MAR-F3, sampled since 2011 (this reach is at the same location as the benthic invertebrate community *baseline* reach MAR-E3).

2012 Habitat Conditions *Test* reach MAR-F1 was comprised entirely of run habitat with a wetted width of 47.0 m and a bankfull width of 50.0 m (Table 5.5-13). The substrate was primarily coarse gravel with fines along the margins. Water at *test* reach MAR-F1 in fall 2012 had a mean depth of 0.47 m, with a moderate flow (0.30 m/s). Water at *test* reach MAR-F1 was alkaline (pH: 7.88), with moderate conductivity (260 µS/cm), high dissolved oxygen (8.8 mg/L), and a temperature of 12.2°C. Instream cover consisted primarily of macrophytes with smaller amounts of boulders (Table 5.5-13).

Test reach MAR-F2 was comprised of riffle habitat with a wetted width of 41.5 m and a bankfull width of 46.0 m (Table 5.5-13). The substrate was primarily coarse gravel with some cobble. Water at *test* reach MAR-F2 in fall 2012 was shallow (0.29 m), fast flowing (0.79 m/s), alkaline (pH: 8.3), with moderate conductivity (158 µS/cm), high dissolved oxygen (10.8 mg/L), and a temperature of 8.3°C. Instream cover consisted primarily of boulders with some macrophytes (Table 5.5-13).

Baseline reach MAR-F3 was comprised entirely of run habitat with a wetted width of 30.0 m and a bankfull width of 30.0 m (Table 5.5-13). The substrate was primarily gravel with smaller amounts of cobble and fine material. Water at *baseline* reach MAR-F3 in fall 2012 was moderately deep (0.47 m), slow flowing (0.29 m/s), alkaline (pH: 8.12), with moderate conductivity (196 µS/cm), moderate dissolved oxygen (9 mg/L), and a temperature of 11.2°C. Instream cover consisted primarily of boulders with small amounts of overhanging vegetation (Table 5.5-13).

Temporal and Spatial Comparisons Sampling was conducted at *test* reach MAR-F1 in 2009 and 2011; therefore, temporal comparisons were conducted between 2009 and 2012. *Test* reach MAR-F2 and *baseline* reach MAR-F3 were first sampled in 2011 and temporal comparisons were conducted between 2011 and 2012 for these reaches. Spatial comparisons between the three reaches were conducted for fall 2012.

There was an increase in mean abundance and mean CPUE of fish from 2009 to 2012 at *test* reach MAR-F1 (Table 5.5-14, Table 5.5-15, Figure 5.5-9). Total species richness was consistent to 2011 but higher than 2009. Diversity was lower in 2012 compared to previous years, which was likely due to the dominance of trout-perch in 2012. The ATI increased from 2011 to 2012, reflected by a large increase in abundance of trout-perch, which is a tolerant species (Table 5.5-14). There was a slight decrease in the mean of all measurement endpoints at *test* reach MAR-F2 from 2011 to 2012, with the exception of species richness. Species composition was similar between years; however, the decrease in diversity was likely due to the dominance of lake chub captured at this reach compared to other species (Table 5.5-14).

All measurement endpoints at *baseline* reach MAR-F3 were similar between 2011 and 2012, with the exception of ATI, which increased in 2012 due to the dominance of trout-perch (a more tolerant species) at this reach in 2012.

All measurement endpoints for fish assemblages were relatively consistent between *test* reach MAR-F2 and *baseline* reach MAR-F3 of the MacKay River (Table 5.5-15). Abundance and species richness was higher at *test* reach MAR-F1 compared to the other reaches; however, the large percentage of trout-perch resulted in a lower diversity and a higher ATI compared to the other MacKay River reaches (Table 5.5-15 and Figure 5.5-9).

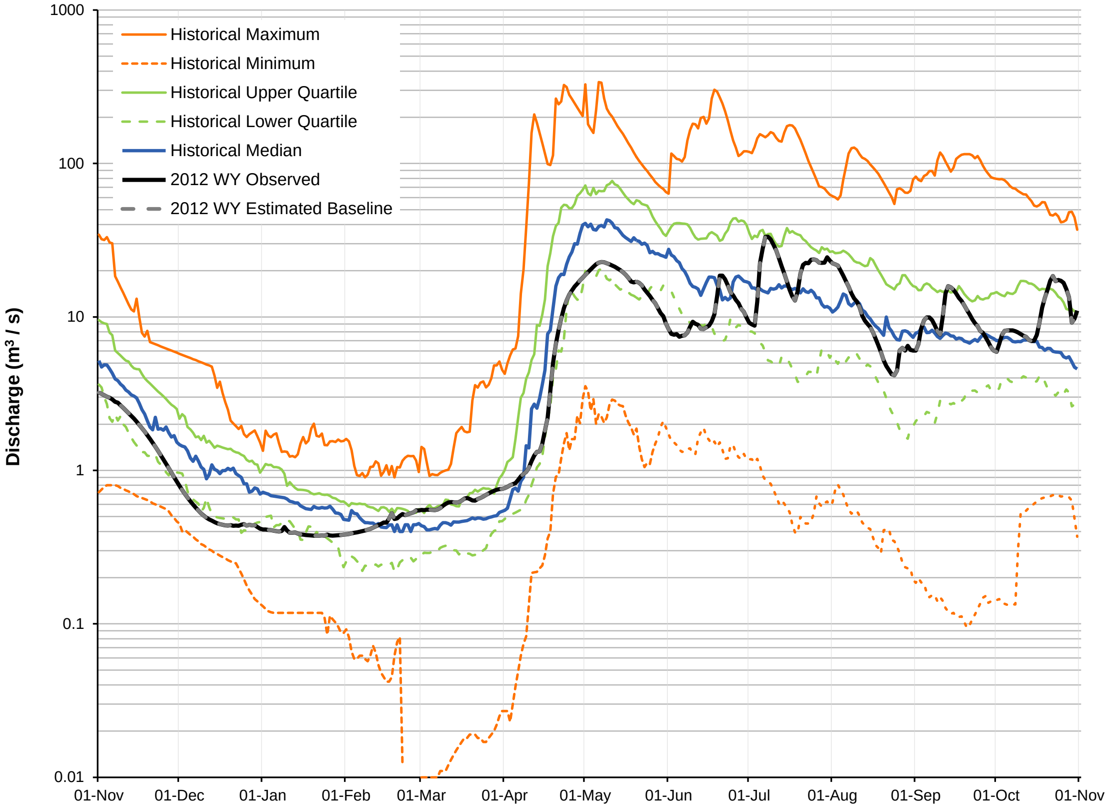
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by RAMP. Based on past studies, a total of 23 fish species were recorded in the MacKay River watershed; whereas RAMP found only 15 species from 2009 to 2012. As noted in Section 5.2, 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., RAMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder [2004]).

Golder (2004) documented similar riffle habitat with substrate consisting of 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 2012 (Table 5.5-13). This section of the river provides moderate to high fisheries potential (Golder 2004).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reaches MAR-F1 and MAR-F2 and *baseline* reach MAR-F3 were within the range of regional *baseline* conditions, with the exception of ATI at *test* reach MAR-F1, which was higher than the range of regional *baseline* conditions (Figure 5.5-9).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reaches MAR-F1 and MAR-F2 and the regional *baseline* conditions were classified as **Negligible-Low** given there were was only one measurement endpoint at *test* reach MAR-F1 that exceeded the regional range of variation of *baseline* reaches. The increase in ATI at *test* reach MAR-F1 was due to the dominance of trout-perch captured at this reach, which has a high tolerance value.

Figure 5.5-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the MacKay River in the 2012 WY, compared to historical values.



Note: Observed 2012 WY hydrograph are based on provisional data for MacKay River near Fort McKay, WSC Station 07DB001, from March 1 to October 31, 2012, and RAMP Station S26 for other months in 2012. The upstream drainage area is 5,569.3 km^2. Historical values from March 1 to October 31 calculated for the period from 1972 to 2011, and historical values for other months calculated for the period from 1972 to 1987 and from 2002 onwards.

Table 5.5-2 Estimated water balance at WSC Station 07DB001 (RAMP Station S26), MacKay River near Fort McKay, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**239.175**	**Observed discharge, obtained from MacKay River near Fort McKay, WSC Station 07DB001 (RAMP Station S26)**
Closed-circuited area water loss from the observed *test* hydrograph	-0.266	Estimated 6.2 km^2 of the MacKay River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.274	Estimated 31.9 km^2 of the MacKay River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the MacKay River watershed from focal projects	-0.012	Water withdrawals by Suncor and Total E&P (daily values provided)
Water releases into the MacKay River watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of MacKay River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**239.179**	**Estimated *baseline* discharge at MacKay River near Fort McKay, WSC Station 07DB001 (RAMP Station S26)**
Incremental flow (change in total annual discharge)	-0.004	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-0.002%**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for March 1 to October 31, 2012 for WSC Station 07DB001 and on RAMP Station S26 for other months in the 2012 WY.

Table 5.5-3 Calculated change in hydrologic measurement endpoints for the MacKay River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	13.443	13.443	-0.002%
Mean winter discharge	0.801	0.801	0.003%
Annual maximum daily discharge	33.300	33.300	0.000%
Open-water season minimum daily discharge	4.170	4.170	-0.004%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for March 1 to October 31, 2012 for WSC Station 07DB001 and on RAMP Station S26 for other months in the 2012 WY.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are 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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	13	7.6	8.2	8.6
Total suspended solids	mg/L	-	10	13	<2	7	41
Conductivity	µS/cm	-	288	13	183	265	576
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.032	13	0.004	0.024	0.047
Total nitrogen	mg/L	1	**1.06**	13	0.40	**1.20**	**3.20**
Nitrate+nitrite	mg/L	1.3	<0.071	13	<0.05	<0.10	<0.10
Dissolved organic carbon	mg/L	-	28.3	13	20.0	28.0	40.0
Ions							
Sodium	mg/L	-	19.1	13	15.0	20.0	60.0
Calcium	mg/L	-	24.2	13	20.8	27.3	44.7
Magnesium	mg/L	-	8.1	13	7.3	9.0	15.9
Chloride	mg/L	120	3.8	13	1.2	4.0	41.2
Sulphate	mg/L	270	16.1	13	9.3	17.9	35.5
Total dissolved solids	mg/L	-	185	13	170	213	342
Total alkalinity	mg/L		127	13	80.2	118	202
Selected metals							
Total aluminum	mg/L	0.1	**0.37**	13	0.05	**0.24**	**1.74**
Dissolved aluminum	mg/L	0.1	0.046	13	0.007	0.020	0.046
Total arsenic	mg/L	0.005	0.0012	13	0.0007	0.0010	0.0013
Total boron	mg/L	1.2	0.091	13	0.051	0.080	0.140
Total molybdenum	mg/L	0.073	0.00030	13	0.00015	0.00036	0.00060
Total mercury (ultra-trace)	ng/L	5, 13	3.7	9	<1.2	<1.2	**6.3**
Total strontium	mg/L	-	0.13	13	0.11	0.16	0.29
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	-	0.06	1	-	0.17	-
Oilsands Extractable	mg/L	-	0.56	1	-	1.18	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	5.55	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	289.1	1	-	49.94	-
Total PAHs	ng/L	-	1028	1	-	271.9	-
Total Parent PAHs	ng/L	-	30.37	1	-	21.87	-
Total Alkylated PAHs	ng/L	-	997.8	1	-	250.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.692**	13	0.230	**0.469**	**0.787**
Sulphide	mg/L	0.002	**0.010**	13	0.003	**0.012**	**0.032**
Total iron	mg/L	0.3	**1.44**	13	**0.31**	**0.95**	**23.3**
Total phenols	mg/L	0.004	**0.012**	13	0.001	**0.004**	**0.020**
Total phosphorus	mg/L	0.05	**0.059**	13	0.011	0.039	**0.072**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.5-5 Concentrations of water quality measurement endpoints, middle MacKay River (*test* station MAR-2A), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	2009, 2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	2	8.3	8.3	8.4
Total suspended solids	mg/L	-	376	2	3.0	4.0	5.0
Conductivity	µS/cm	-	196	2	223	246	268
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.027	2	0.034	0.036	0.038
Total nitrogen	mg/L	1	**1.7**	2	**1.1**	**1.4**	**1.8**
Nitrate+nitrite	mg/L	1.3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	35.8	2	24.7	30.3	35.8
Ions							
Sodium	mg/L	-	14.1	2	12.9	14.0	15.1
Calcium	mg/L	-	19.4	2	24.7	28.0	31.3
Magnesium	mg/L	-	6.8	2	7.8	8.4	9.1
Chloride	mg/L	120	0.69	2	0.53	0.56	0.58
Sulphate	mg/L	270	7.6	2	10.8	14.6	18.4
Total dissolved solids	mg/L	-	218	2	198	221	244
Total alkalinity	mg/L		92	2	102	112	122
Selected metals							
Total aluminum	mg/L	0.1	**9.65**	2	0.12	**0.13**	**0.14**
Dissolved aluminum	mg/L	0.1	**0.147**	2	0.017	0.019	0.022
Total arsenic	mg/L	0.005	0.0023	2	0.0011	0.0011	0.0011
Total boron	mg/L	1.2	0.080	2	0.056	0.064	0.072
Total molybdenum	mg/L	0.073	<0.0001	2	0.00031	0.00043	0.00056
Total mercury (ultra-trace)	ng/L	5, 13	**10.60**	2	0.60	1.60	2.60
Total strontium	mg/L	-	0.11	2	0.13	0.15	0.17
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	-	0.06	1	-	0.39	-
Oilsands Extractable	mg/L	-	0.42	1	-	1.12	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	28.60	1	-	4.15	-
Total dibenzothiophenes	ng/L	-	75.43	1	-	8.45	-
Total PAHs	ng/L	-	717.3	1	-	171.4	-
Total Parent PAHs	ng/L	-	56.72	1	-	19.82	-
Total Alkylated PAHs	ng/L	-	660.6	1	-	151.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.521**	2	**0.737**	**0.792**	**0.847**
Sulphide	mg/L	0.002	**0.012**	2	**0.013**	**0.015**	**0.018**
Total iron	mg/L	0.3	**6.44**	2	**1.05**	**1.16**	**1.26**
Total phenols	mg/L	0.004	**0.008**	2	**0.009**	**0.010**	**0.010**
Total phosphorus	mg/L	0.05	**0.265**	2	0.043	0.049	**0.054**
Total copper	mg/L	0.002	**0.00743**	2	0.00076	**0.00079**	**0.00083**
Total chromium	mg/L	0.001	**0.01170**	2	0.00031	0.00036	0.00042
Total lead	mg/L	0.0023	**0.00530**	2	0.00014	0.00015	0.00016

[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 5.5-6 Concentrations of water quality measurement endpoints, upper MacKay River (*baseline* station MAR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	10	7.8	8.2	8.3
Total suspended solids	mg/L	-	4	10	<3	<3	23
Conductivity	µS/cm	-	194	10	164	224	264
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.041	10	0.008	0.033	0.043
Total nitrogen	mg/L	1	**1.30**	10	0.80	**1.25**	**3.10**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.1	0.10
Dissolved organic carbon	mg/L	-	30.7	10	22.0	31.5	41.0
Ions							
Sodium	mg/L	-	11.6	10	11.0	15.5	19.0
Calcium	mg/L	-	20.6	10	17.8	25.0	34.5
Magnesium	mg/L	-	6.3	10	6.6	8.5	11.0
Chloride	mg/L	120	0.6	10	<0.5	2.0	3.0
Sulphate	mg/L	270	6.6	10	6.8	12.1	23.7
Total dissolved solids	mg/L	-	190	10	160	195	240
Total alkalinity	mg/L		91.6	10	74.6	104	128
Selected metals							
Total aluminum	mg/L	0.1	**0.20**	10	0.02	**0.15**	**1.08**
Dissolved aluminum	mg/L	0.1	0.044	10	<0.001	0.024	0.044
Total arsenic	mg/L	0.005	0.0010	10	0.0006	0.0009	0.0011
Total boron	mg/L	1.2	0.06	10	0.04	0.06	0.11
Total molybdenum	mg/L	0.073	0.00019	10	0.00013	0.00032	0.00055
Total mercury (ultra-trace)	ng/L	5, 13	3.0	9	<0.6	1.2	**5.0**
Total strontium	mg/L	-	0.12	10	0.11	0.13	0.20
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	-	0.15	1	-	0.25	-
Oilsands Extractable	mg/L	-	0.18	1	-	0.79	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	1.19	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.33	1	-	16.11	-
Total PAHs	ng/L	-	205.1	1	-	193.4	-
Total Parent PAHs	ng/L	-	16.73	1	-	20.01	-
Total Alkylated PAHs	ng/L	-	188.3	1	-	173.4	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.723**	10	0.289	**0.564**	**0.841**
Sulphide	mg/L	0.002	**0.010**	10	**0.008**	**0.020**	**0.030**
Total iron	mg/L	0.3	**1.13**	10	**0.39**	**0.98**	**1.34**
Total phenols	mg/L	0.004	**0.012**	10	<0.001	**0.009**	**0.020**
Total phosphorus	mg/L	0.05	**0.061**	10	0.014	0.048	**0.074**

[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 5.5-4 Piper diagram of fall ion concentrations in the MacKay River watershed.

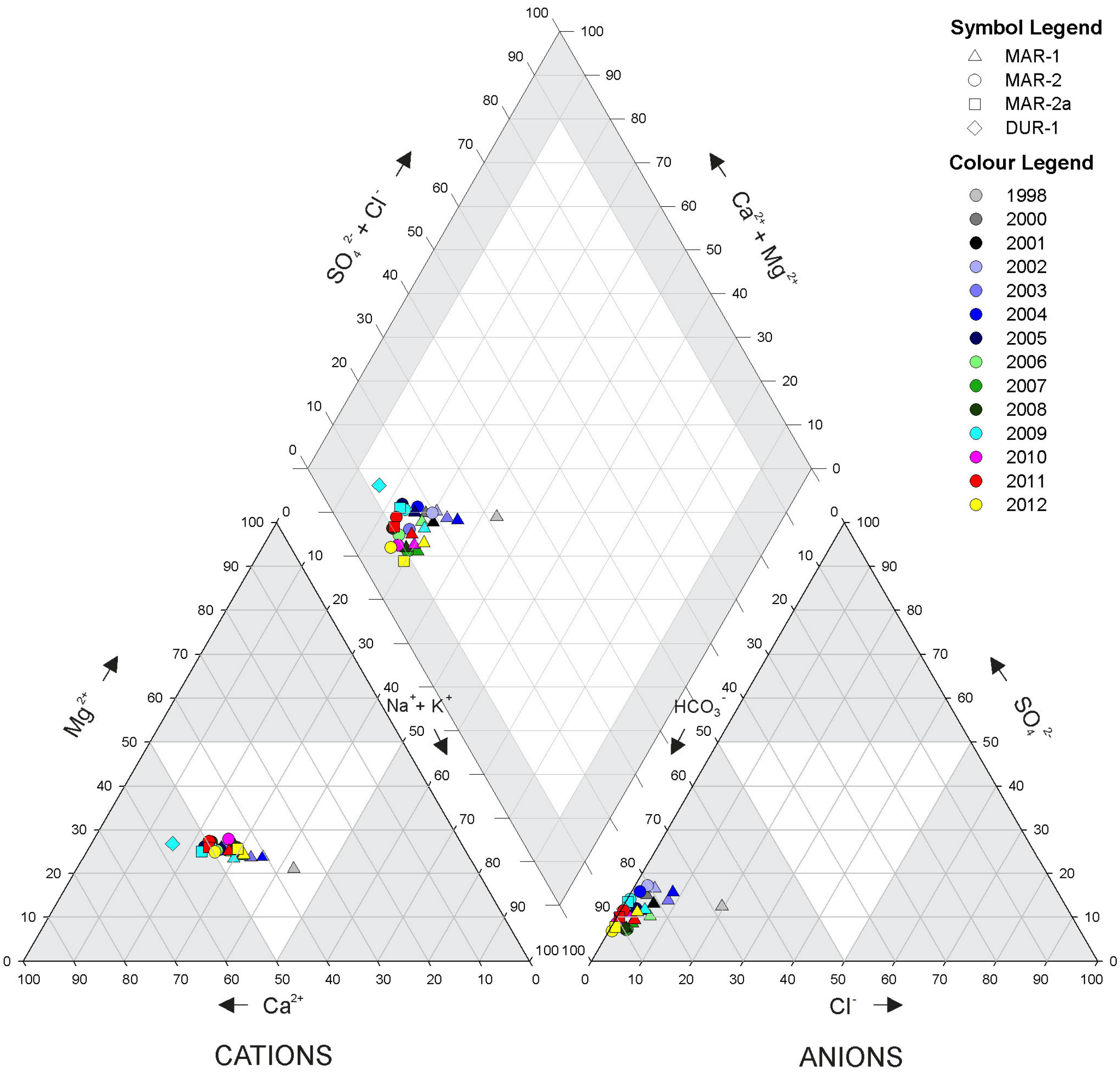


Table 5.5-7 Water quality guideline exceedances, MacKay River watershed, 2012.

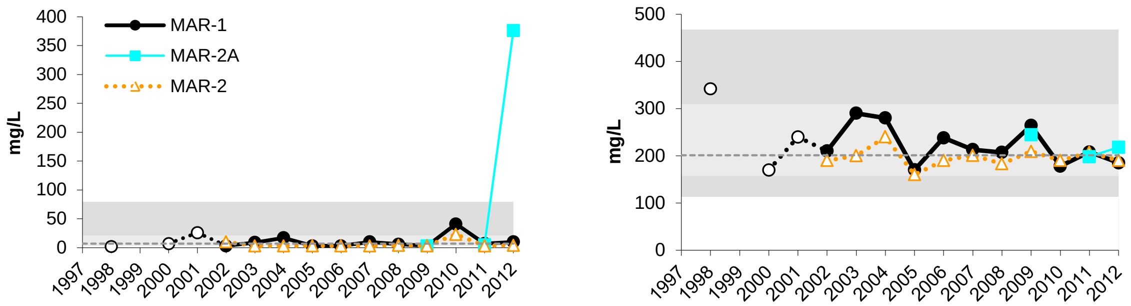
Variable	Units	Guideline[a]	MAR-1	MAR-2A	MAR-2
Winter					
Dissolved iron	mg/L	0.3	ns	0.40	ns
Sulphide	mg/L	0.002	ns	0.0079	ns
Total aluminum	mg/L	0.1	ns	0.30	ns
Total chromium	mg/L	0.001	ns	0.004	ns
Total iron	mg/L	0.3	ns	1.79	ns
Total nitrogen	mg/L	1	ns	1.70	ns
Total phenols	mg/L	0.004	ns	0.009	ns
Total phosphorus	mg/L	0.5	ns	0.106	ns
Spring					
Dissolved iron	mg/L	0.3	ns	0.50	ns
Sulphide	mg/L	0.002	ns	0.0114	ns
Total aluminum	mg/L	0.1	ns	0.17	ns
Total iron	mg/L	0.3	ns	0.984	ns
Total nitrogen	mg/L	1	ns	1.01	ns
Total phenols	mg/L	0.004	ns	0.010	ns
Total phosphorus	mg/L	0.5	ns	0.052	ns
Summer					
Dissolved iron	mg/L	0.3	ns	0.49	ns
Sulphide	mg/L	0.002	ns	0.0133	ns
Total aluminum	mg/L	0.1	ns	0.17	ns
Total iron	mg/L	0.3	ns	0.866	ns
Total nitrogen	mg/L	1	ns	1.26	ns
Total phenols	mg/L	0.004	ns	0.012	ns
Total phosphorus	mg/L	0.5	ns	0.057	ns
Fall					
Dissolved aluminum	mg/L	0.1	-	0.147	-
Dissolved iron	mg/L	0.3	0.69	0.52	0.72
Mercury (ultra-trace)	ng/L	5, 13	-	10.6	-
Sulphide	mg/L	0.002	0.010	0.012	0.010
Total aluminum	mg/L	0.1	0.37	9.65	0.20
Total chromium	mg/L	0.001	-	0.012	-
Total copper	mg/L	0.002	-	0.007	-
Total iron	mg/L	0.3	1.44	6.44	1.13
Total lead	mg/L	0.0023	-	0.0053	-
Total nitrogen	mg/L	1	1.06	1.67	1.30
Total phenols	mg/L	0.004	0.012	0.008	0.012
Total phosphorus	mg/L	0.5	0.059	0.265	0.061

[a] Sources for all guidelines are outlined in Table 3.2-5.

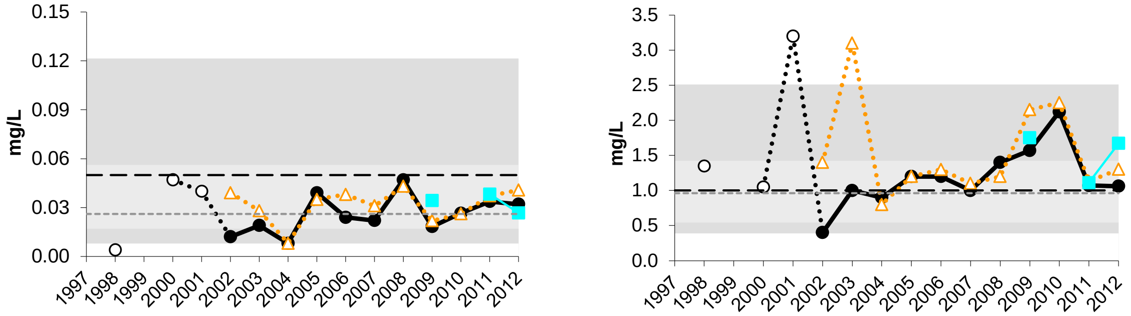
ns = not sampled

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.

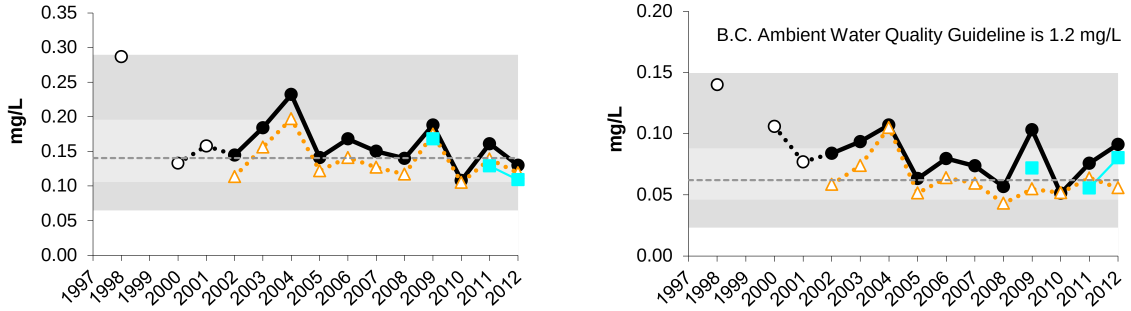
Total Suspended Solids (TSS) Total Dissolved Solids (TDS)



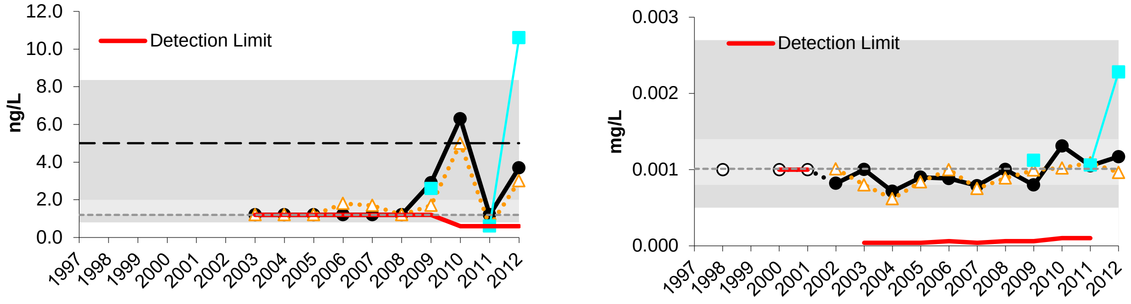
Dissolved Phosphorus Total Nitrogen



Total Strontium Total Boron



Total Mercury (Ultra-trace) Total Arsenic



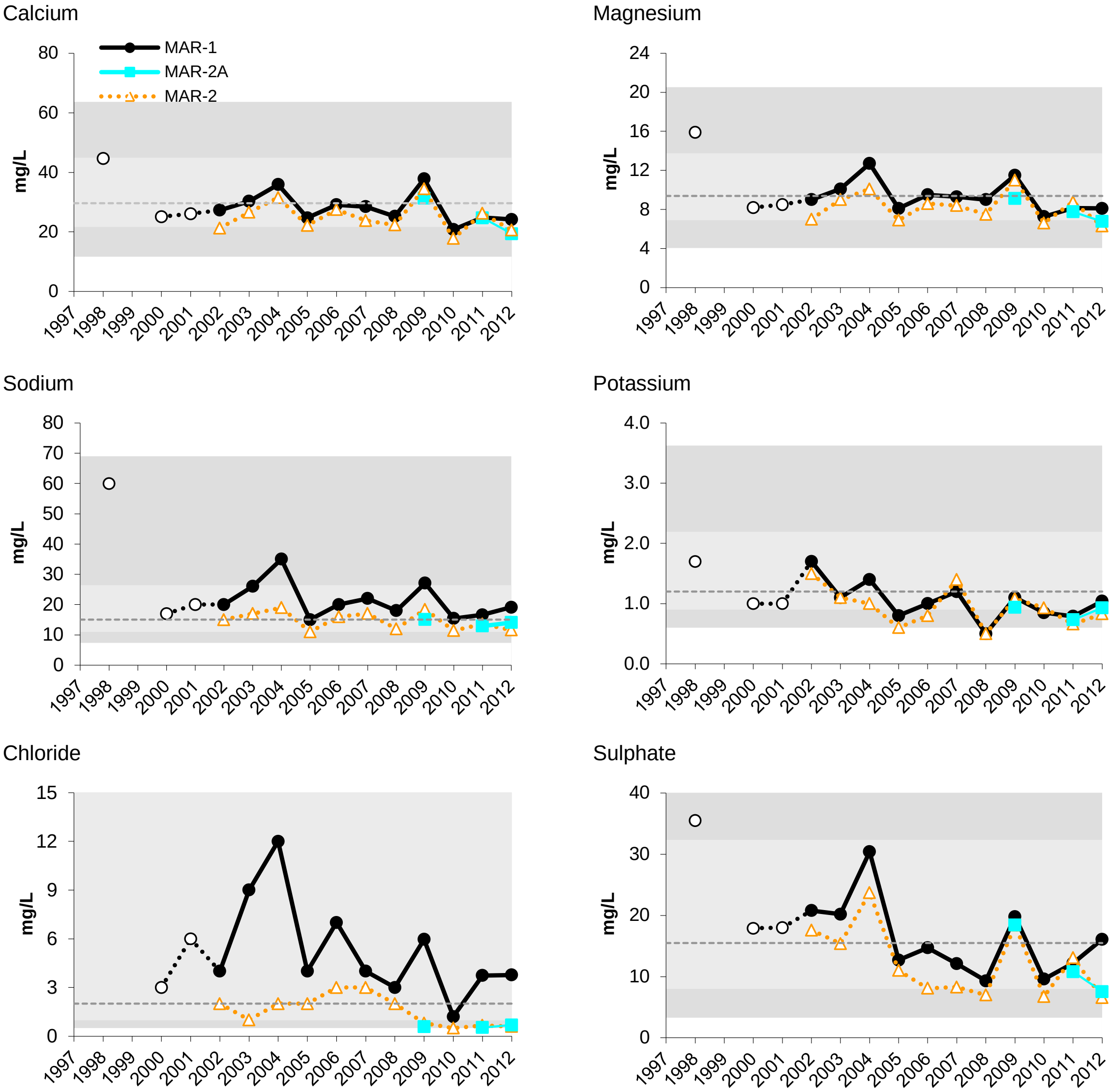
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.5-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

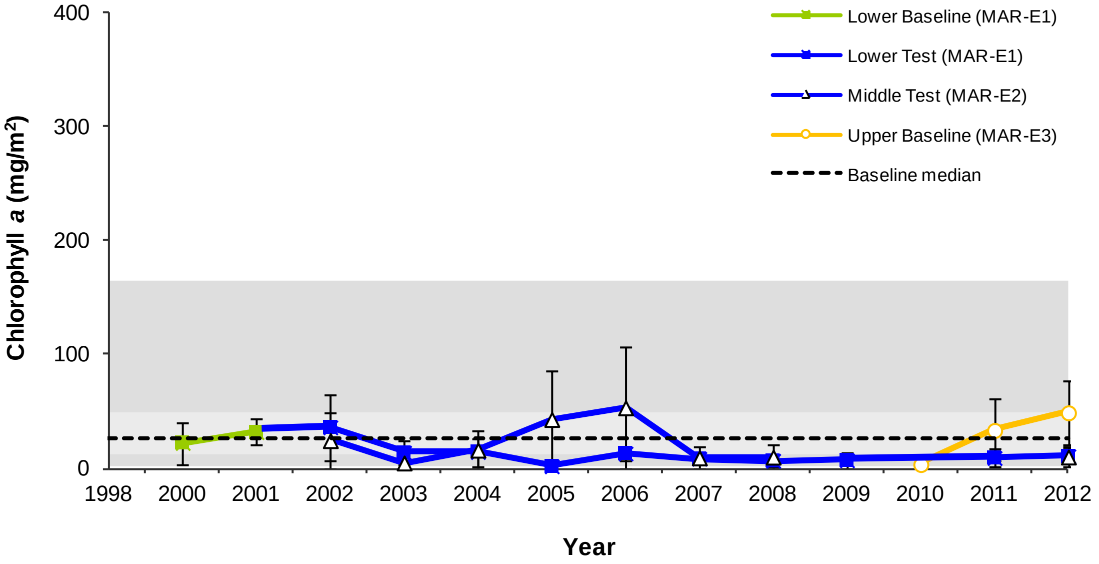
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.5-8 Average habitat characteristics of benthic invertebrate sampling locations in the MacKay River, fall 2012.

Variable	Units	MAR-E1 Lower *Test* Reach of MacKay River	MAR-E2 Middle *Test* Reach of MacKay River	MAR-E3 Upper *Baseline* Reach of MacKay River
Sample date	-	05-Sept-2012	14-Sept-2012	07-Sept-2012
Habitat	-	Erosional	Erosional	Erosional
Water depth	m	0.4	0.2	0.2
Current velocity	m/s	0.30	0.71	0.69
Field Water Quality				
Dissolved oxygen	mg/L	8.5	8.5	8.0
Conductivity	µS/cm	226	95	167
pH	pH units	8.4	8.1	8.1
Water temperature	°C	16.3	11.5	13.1
Sediment Composition				
Sand/Silt/Clay	%	15	0	1
Small Gravel	%	55	2	5
Large Gravel	%	26	9	24
Small Cobble	%	4	50	31
Large Cobble	%	0	38	10
Boulder	%	0	1	3
Bedrock	%	0	0	0

Figure 5.5-6 Periphyton chlorophyll *a* biomass in the *test* (MAR-E1 and MAR-E2) and *baseline* (MAR-E3) reaches of the MacKay River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.5-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the MacKay River (*test* reach MAR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach MAR-E1		
	1998	2000 to 2011	2012
Hydra	<1	0 to <1	
Nematoda	2	1 to 8	2
Erpobdellidae		0 to <1	
Naididae	2	2 to 30	16
Tubificidae	2	<1 to 23	9
Enchytraeidae	4	1 to 12	
Lumbriculidae		0 to <1	
Hydracarina	1	<1 to 18	4
Ostracoda	<1	0 to 6	6
Cladocera			2
Macrothricidae		0 to 1	
Copepoda	<1	0 to 1	<1
Gastropoda	<1	0 to 3	<1
Bivalvia		0 to 2	4
Coleoptera	<1	0 to <1	<1
Ceratopogonidae	1	<1 to 5	3
Chironomidae	57	2 to 69	42
Dolichopodidae			<1
Empididae	1	0 to 12	2
Tipulidae	<1	0 to 1	
Tabanidae		0 to 1	
Simuliidae	1	0 to 2	<1
Ephemeroptera	26	11 to 29	6
Anisoptera	1	<1 to 5	2
Plecoptera	2	<1 to 8	<1
Trichoptera	<1	<1 to 5	<1
Heteroptera	<1	0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	56,434	2,055 to 28,597	29,058
Richness	49	23 to 38	29
Simpson's Diversity	0.87	0.83 to 0.90	0.88
Equitability	0.16	0.23 to 0.34	0.38
% EPT	26	13 to 42	7

Table 5.5-10 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the MacKay River (*test* reach MAR-E2 and *baseline* reach MAR-E3).

Taxon	**Percent Major Taxa Enumerated in Each Year**					
	Reach MAR-E2			**Reach MAR-E3**		
	2002	**2003 to 2011**	**2012**	**2010**	**2011**	**2012**
Hydra	<1					
Nematoda	3	1 to 4	3	1	1	<1
Erpobdellidae		0 to <1				
Naididae	48	2 to 32	16	41	18	15
Tubificidae	<1	<1 to 8	3	<1	<1	<1
Enchytraeidae	1	<1 to 4	4	2	3	<1
Lumbriculidae		0 to 3	<1			
Hydracarina	7	4 to 21	8	5	8	13
Ostracoda	<1	0 to 2	6	2	<1	<1
Cladocera			5			3
Copepoda	<1	0 to <1	1	<1	<1	<1
Gastropoda	<1	0 to 2	<1	1	<1	<1
Bivalvia	<1	0 to 4	3	1	<1	1
Coleoptera		0 to <1	<1	<1	1	<1
Ceratopogonidae	<1	<1 to 3	<1	1	<1	<1
Chironomidae	31	3 to 63	29	25	35	38
Empididae	1	<1 to 5	2	<1	<1	<1
Tipulidae	<1	0 to 1	<1		<1	<1
Tabanidae		0 to <1	<1	<1		
Simuliidae		0 to 1		<1		<1
Ephemeroptera	2	1 to 20	16	9	18	14
Anisoptera	<1	<1 to 1	<1	<1	1	<1
Plecoptera	<1	1 to 3	<1	3	4	2
Trichoptera	6	1 to 12	3	8	7	10
Neuroptera						<1
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	28,222	2,703 to 74,977	30,640	4,300	23,631	54,715
Richness	40	27 to 41	30	35	31	43
Simpson's Diversity	0.74	0.65 to 0.91	0.88	0.81	0.87	0.9
Equitability	0.11	0.16 to 0.40	0.37	0.24	0.32	0.26
% EPT	8	16 to 32	20	22	29	26

Table 5.5-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E1 of the MacKay River.

Variable	P-value					Variance Explained (%)					Nature of Change(s)
	***Baseline* Reach vs. *Test* Reach**	***Baseline* vs. *Test* Periods**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	***Baseline* vs. *Test* Periods**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**<0.001**	**<0.001**	**0.002**	0.645	12	7	10	3	0	Higher in *baseline* reach; increasing over time in *test* period.
Richness	**0.033**	**0.029**	**0.032**	0.338	0.434	5	6	5	1	1	Higher in *baseline* reach; higher in *baseline* period; increasing over time in *test* period.
Simpson's Diversity	0.159	0.440	1.000	0.440	1.000	7	2	0	2	0	No change.
Evenness	0.670	**0.042**	**0.031**	0.763	0.395	0	8	9	0	1	Higher in *test* period; increasing over time in *test* period.
EPT	**<0.001**	0.261	0.360	1.000	0.115	29	1	1	0	3	Higher at *baseline* reach than *test* reach.
CA Axis 1	**<0.001**	0.609	**0.039**	0.236	0.065	55	0	3	1	2	Higher at *baseline* reach; decreasing over time at *test* reach.
CA Axis 2	0.694	**<0.001**	0.808	**<0.001**	**0.007**	0	49	0	12	6	Higher during *baseline* years; higher in 2012 than mean of *baseline* 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).

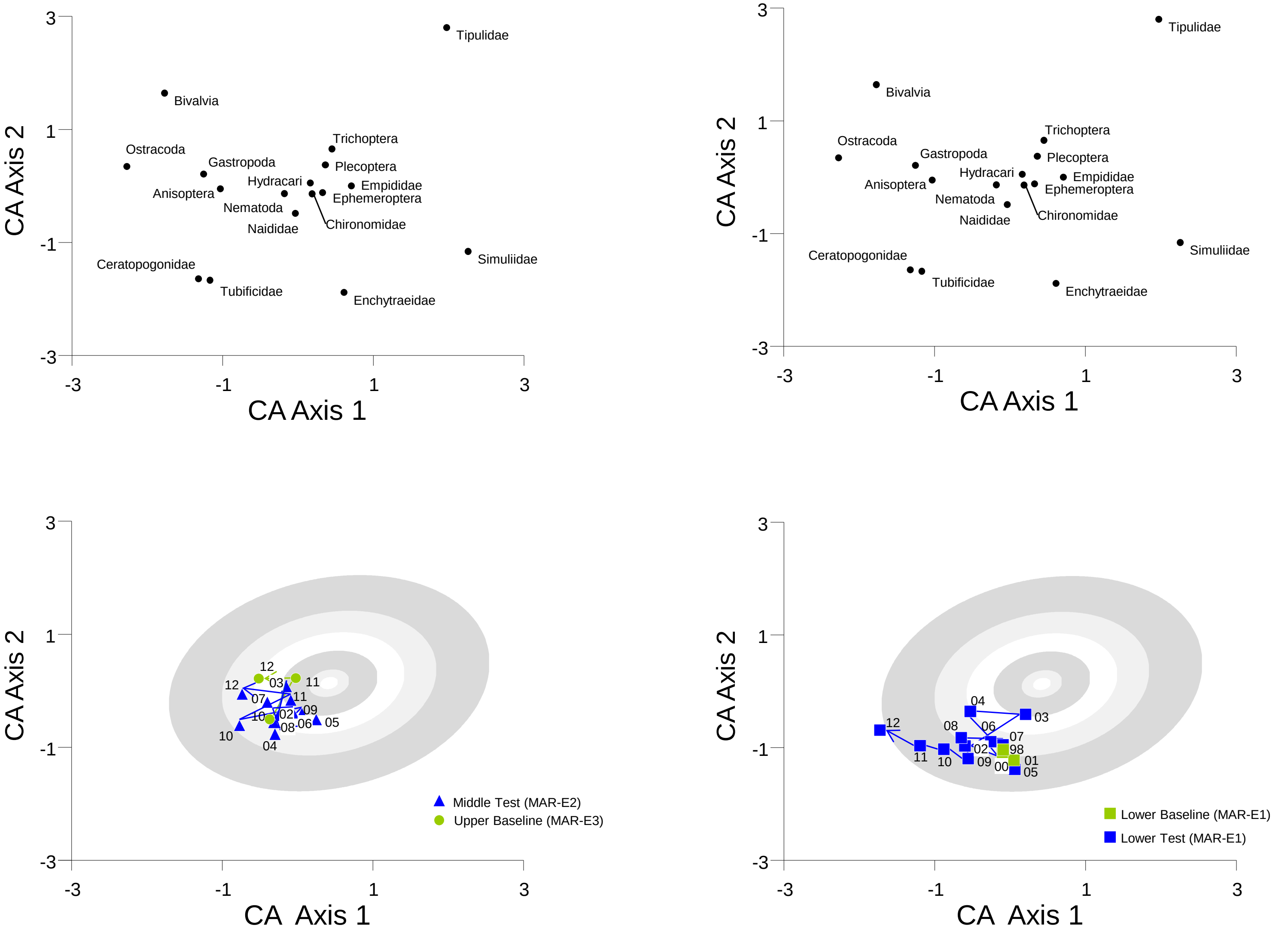
Table 5.5-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E2 of the MacKay River.

Variable	P-value				Variance Explained (%)				Nature of Change(s)
	***Baseline* Reach vs. *Test* Reach**	**Time Trend**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	**Time Trend**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	**0.039**	**0.079**	0.075	0.446	2	1	1	0	Higher in *baseline* reach; increasing over time in *test* reach.
Richness	0.501	0.342	0.180	0.230	1	1	3	2	No change
Simpson's Diversity	**0.041**	1.000	0.431	**0.018**	4	0	1	6	Higher in *baseline* reach; higher in 2012 than previous years.
Equitability	**0.025**	0.724	0.481	**0.017**	4	0	0	5	Lower at *test* reach; higher in 2012 than previous years.
EPT	0.799	0.119	**0.046**	**0.024**	0	4	6	8	Lower in 2012 at *test* reach than *baseline* reach average; lower in 2012 than previous years.
CA Axis 1	**0.001**	0.319	**0.008**	0.383	26	2	15	2	Higher at *baseline* reach; lower in 2012 than mean of *baseline* years.
CA Axis 2	0.889	0.051	0.636	0.630	0	11	1	1	No change.

Bold values indicate significant difference (p<0.05).

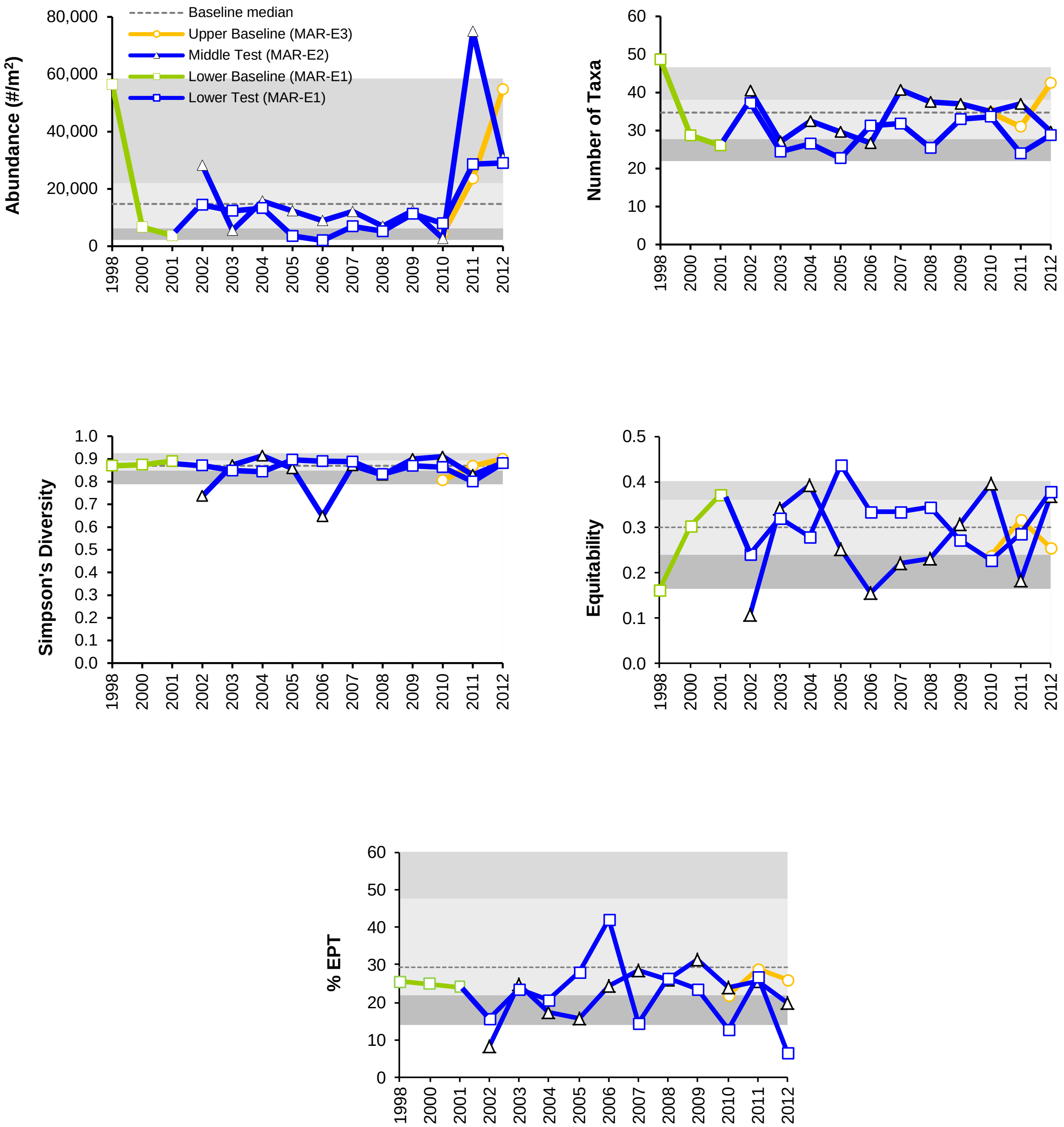
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

Figure 5.5-7 Ordination (Correspondence Analysis) of benthic invertebrate communities in the MacKay River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* erosional reaches in the RAMP FSA.

Figure 5.5-8 Variation in benthic invertebrate community measurement endpoints in the MacKay River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1.

Note: The lower *test* reach was designated as *baseline* prior to 2002.

Table 5.5-13 Average habitat characteristics of fish assemblage monitoring locations in the MacKay River, fall 2012.

Variable	Units	MAR-F1 Lower *Test* Reach of MacKay River	MAR-F2 Middle *Test* Reach of MacKay River	MAR-F3 Upper *Baseline* Reach of MacKay River
Sample date	-	11-Sept-12	16-Sept-12	11-Sept-12
Habitat type	-	run	riffle	run
Maximum depth	m	0.85	0.70	0.80
Bankfull channel width	m	50	46	30.0
Wetted channel width	m	47.0	41.5	30.0
Substrate				
Dominant	-	coarse gravel	coarse gravel	gravel
Subdominant	-	fines	cobble	fines and cobble
Instream cover				
Dominant	-	macrophytes	boulders	boulders
Subdominant	-	boulders	macrophytes	overhanging vegetation
Field water quality				
Dissolved oxygen	mg/L	8.8	10.8	9
Conductivity	µS/cm	260	158	196
pH	pH units	7.88	7.89	8.12
Water temperature	^{0}C	12.2	8.3	11.2
Water velocity				
Left bank velocity	m/s	0.10	0.45	0.26
Left bank water depth	m	0.20	0.145	0.27
Centre of channel velocity	m/s	0.39	1.00	0.52
Centre of channel water depth	m	0.57	0.44	0.83
Right bank velocity	m/s	0.40	ns	0.09
Right bank water depth	m	0.65	ns	0.30
Riparian cover – understory (<5 m)				
Dominant	-	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	-	overhanging vegetation

ns = not sampled, too deep to cross the channel

Table 5.5-14 Percent composition and mean CPUE (catch per unit effort) of fish species at *test* reaches MAR-F1 and MAR-F2 and *baseline* reach MAR-F3 of the MacKay River, 2009 to 2012.

Common Name	Code	Total Catch							Percent of Total Catch						
		MAR-F1			MAR-F2		MAR-F3		MAR-F1			MAR-F2		MAR-F3	
		2009	2011	2012	2011	2012	2011	2012	2009	2011	2012	2011	2012	2011	2012
Arctic grayling	ARGR	-	-	-	-	-	-	-	0	0	0	0	0	0	0
brook stickleback	BRST	1	-	1	-	-	-	-	5.6	0	0.7	0	0	0	0
burbot	BURB	-	-	-	-	-	-	-	0	0	0	0	0	0	0
flathead chub	FLCH	-	-	1	-	-	-	-	0	0	0.7	0	0		0
fathead minnow	FTMN	-	-	-	-	-	-	-	0	0	0	0	0	0	0
finescale dace	FNDC	-	1	-	-	1	-	-	0	3.4	0	0	2.4	0	0
goldeye	GOLD	-	-	1	-	-	-	-	0	0	0.7	0	0		0
lake chub	LKCH	1	3	-	22	30	6	3	5.6	10.3	0	40.7	71.4	15.8	7.3
lake whitefish	LKWH	-	-	-	-	-	-	-	0	0	0	0	0	0	0
longnose dace	LNDC	-	4	-	21	3	1	1	0	13.8	0	38.9	7.1	2.6	2.4
longnose sucker	LNSC	-	1	-	2	1	1	1	0	3.4	0	3.7	2.4	2.6	2.4
northern pike	NRPK	1	-	-	-	-	-	1	5.6	0	0	0	0	0	2.4
northern redbelly dace	NRDC	-	-	-	-	-	-	-	0	0	0	0	0	0	0
pearl dace	PRDC	-	-	7	-	-	-	-	0	0	4.7	0	0	0	0
slimy sculpin	SLSC	-	1	-	1	2	21	12	0	3.4	0	1.9	4.8	55.3	29.3
spoonhead sculpin	SPSC	9	7	-	-	-	-	-	50	24.1	0	0	0	0	0
spottail shiner	SPSH	-	-	2	-	-	-	-	0	0	1.3	0	0	0	0
trout-perch	TRPR	6	10	133	8	5	9	23	33.3	34.5	88.7	14.8	11.9	23.7	56.1
walleye	WALL	-	-	2	-	-	-	-	0	0	1.3	0	0	0	0
white sucker	WHSC	-	2	3	-	-	-	-	0	6.9	2.0	0	0	0	0
Total Count		**18**	**29**	**150**	**54**	**42**	**38**	**41**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**8**	**8**	**5**	**6**	**5**	**6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**2,980**	**1,372**	**2,920**	**1,480**	**2,017**	**1,375**	**1,977**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CPUE (#/100secs)		**0.6**	**2.11**	**5.14**	**3.65**	**2.08**	**2.76**	**2.07**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

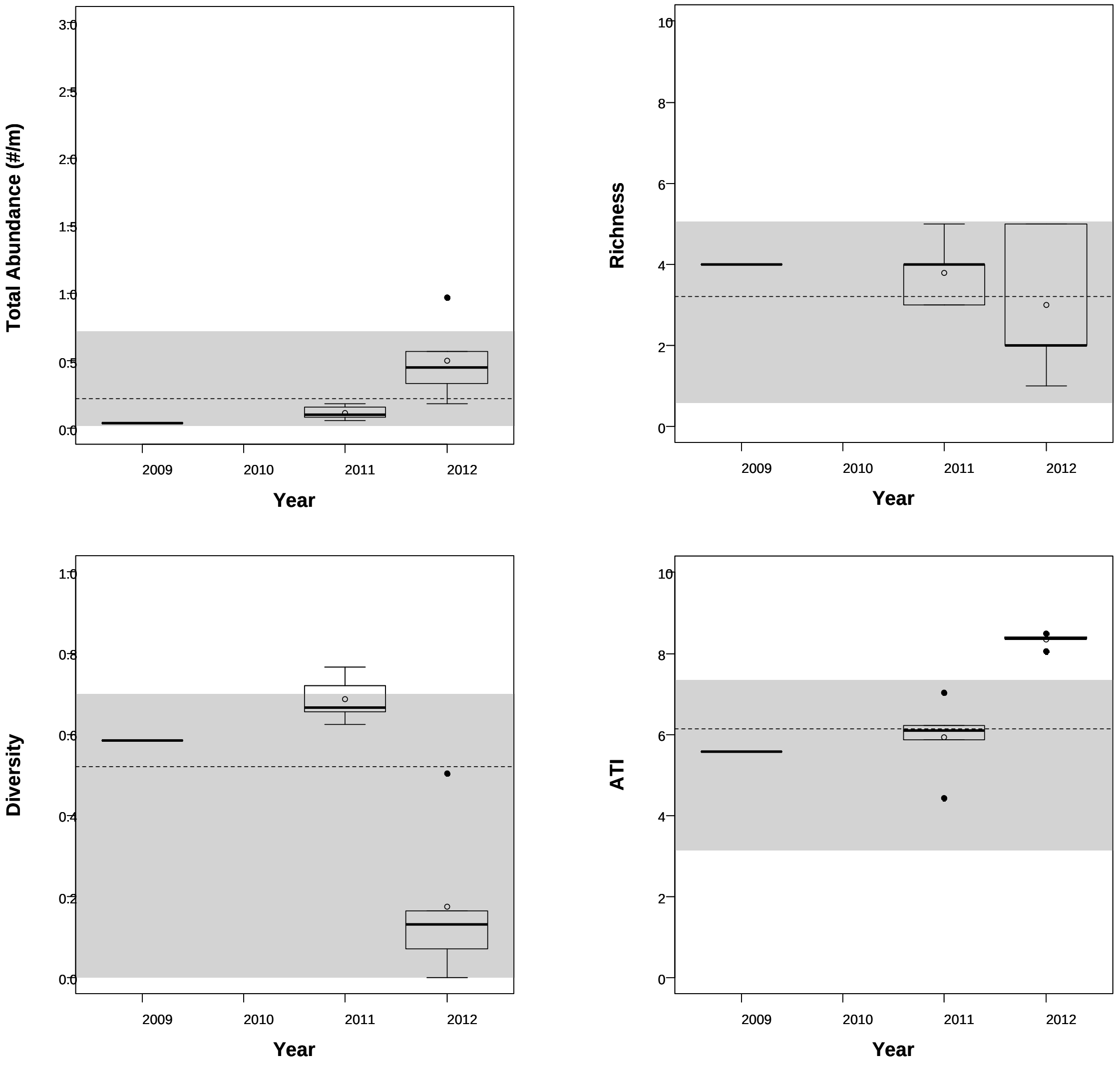
Table 5.5-15 Summary of fish assemblage measurement endpoints (± 1SD) in reaches of the MacKay River, 2009 to 2012.

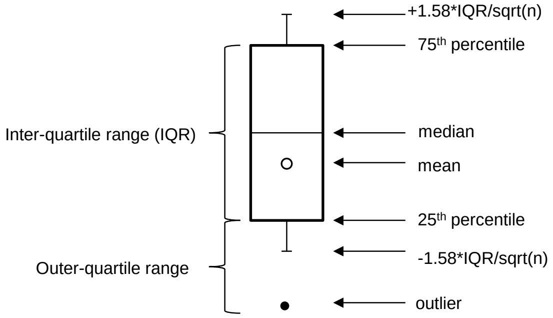
Reach	**Year**	**Abundance**		**Richness**			**Diversity**		**ATI**	
		Mean	**SD**	**Total**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
MAR-F1	2009	0.04	-	4	4	-	0.58	-	5.57	-
	2011	0.12	0.05	8	4	0.84	0.69	0.06	5.93	0.95
	2012	0.50	0.30	8	3	1.87	0.17	0.19	8.34	0.16
MAR-F2	2011	0.22	0.05	5	3	1.10	0.52	0.21	6.17	0.32
	2012	0.14	0.03	6	3	0.84	0.41	0.19	5.77	0.56
MAR-F3	2011	0.15	0.05	5	3	1.30	0.44	0.28	4.66	1.51
	2012	0.11	0.08	6	3	1.34	0.42	0.25	6.25	1.48

SD = standard deviation across sub-reaches within a reach.

Figure 5.5-9 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the MacKay River, 2009 to 2012.

Erosional *Test* Reach MAR-F1



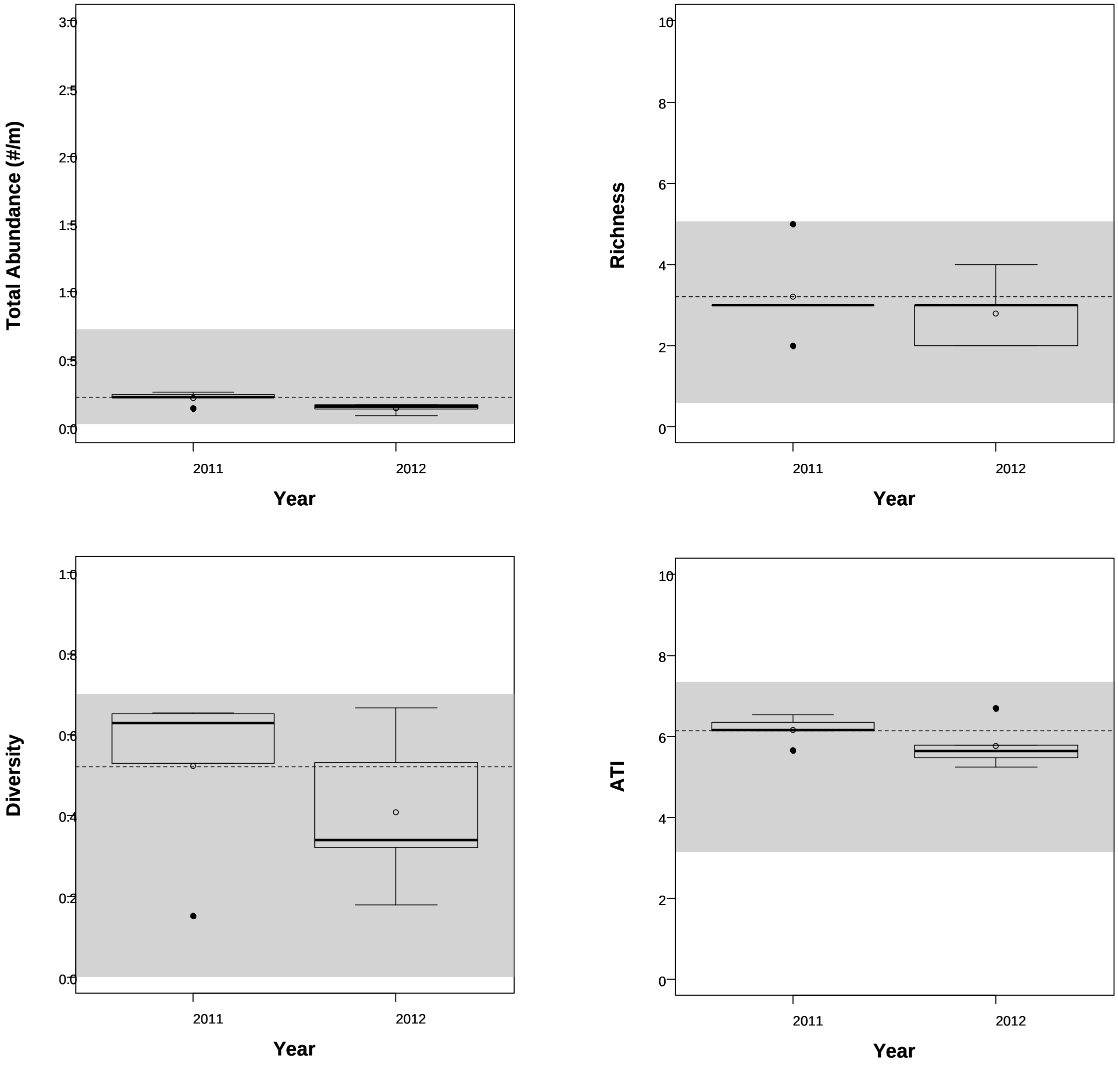


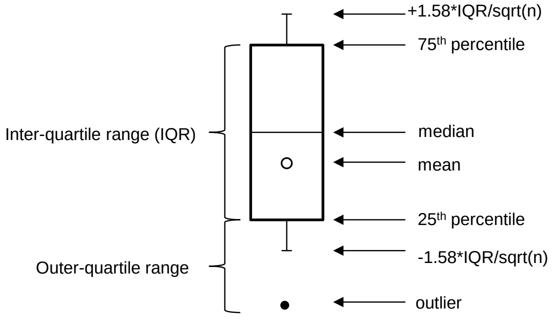
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Figure 5.5-9 (Cont'd.)

Erosional *Test* Reach MAR-F2



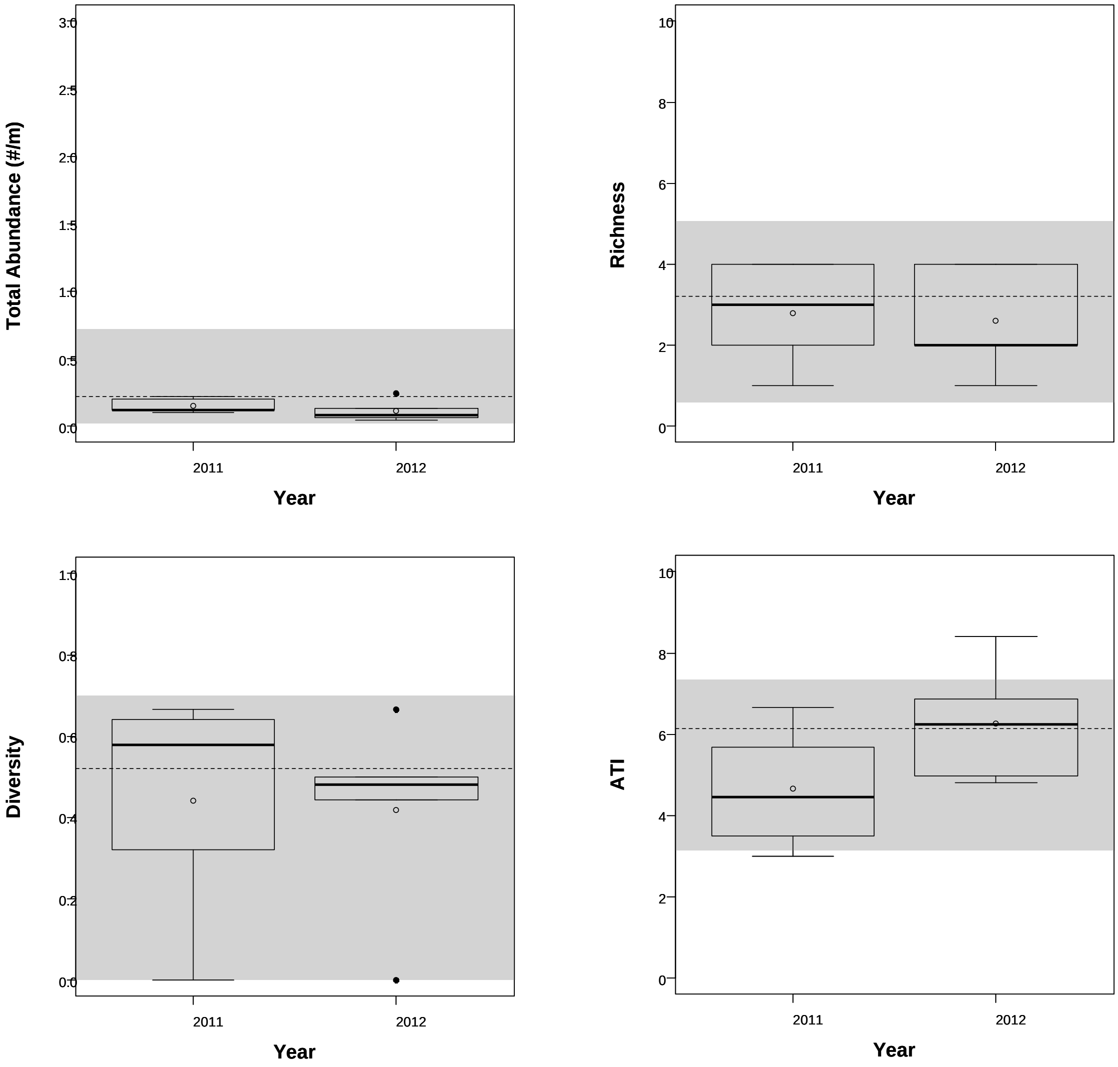


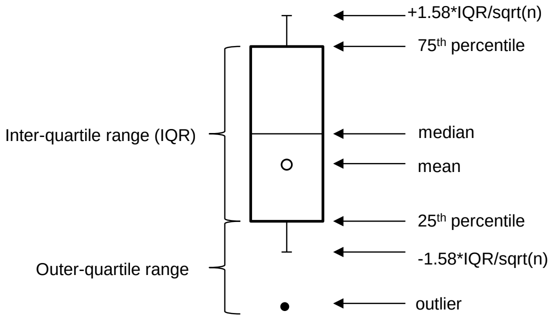
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Figure 5.5-9 (Cont'd.)

Erosional *Baseline* Reach MAR-F3





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

5.6 CALUMET RIVER WATERSHED

Table 5.6-1 Summary of results for the Calumet River watershed.

Calumet River Watershed	**Summary of 2012 Conditions**	
	Climate and Hydrology	
Criteria	**Station S16A** at the mouth	no station sampled
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	
Criteria	**CAR-D1** at the mouth	**CAR-D2** upstream of Canadian Natural Horizon
Benthic Invertebrate Communities	🟡	n/a
Sediment Quality Index	🟠	🟡
	Fish Populations	
Criteria	**CAR-F1** at the mouth	**CAR-F2** upstream of Canadian Natural Horizon
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 focal projects and other 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: Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.3 for a detailed description of the classification methodology.

Figure 5.6-1 Calumet River watershed.

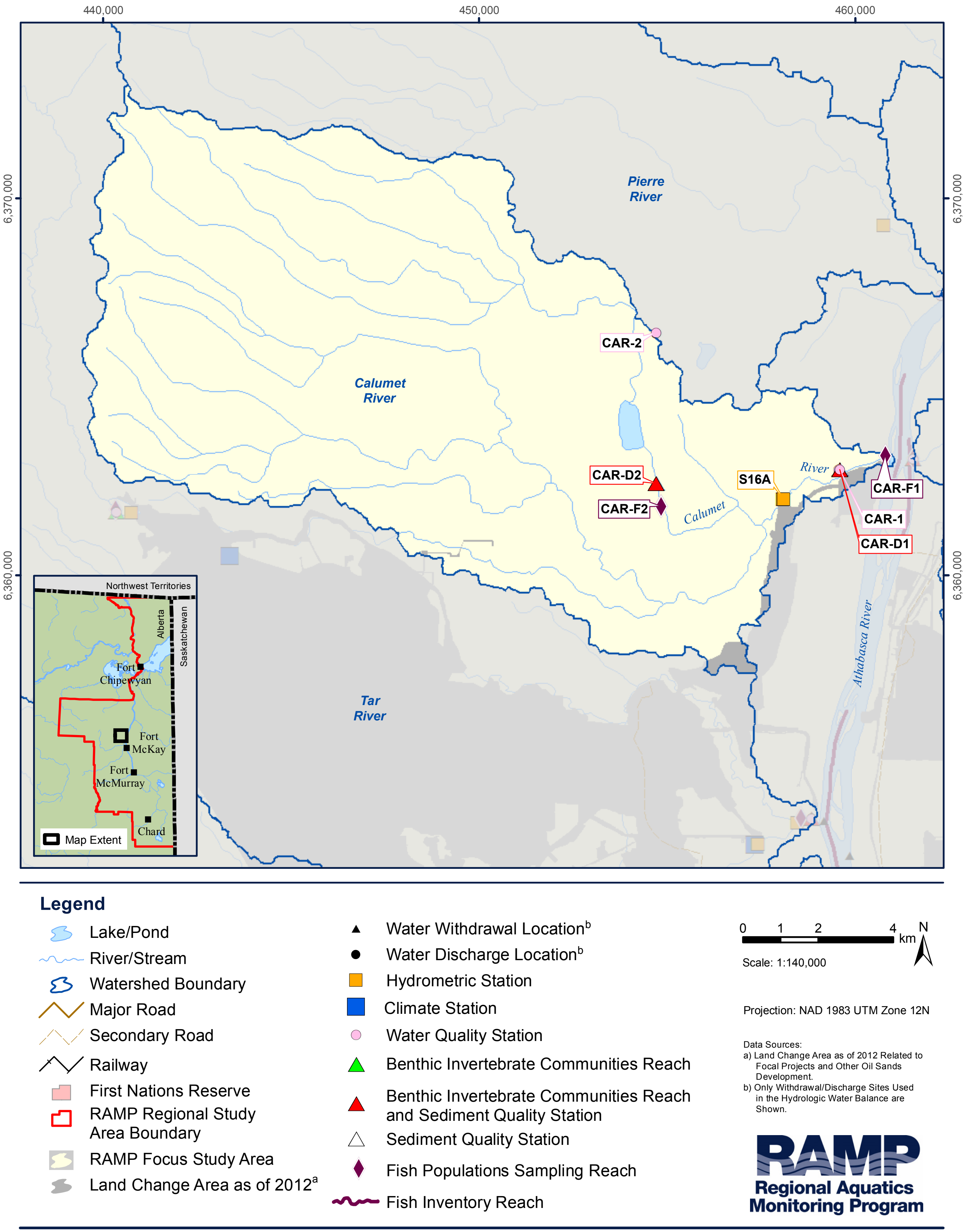


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Figure 5.6-2 Representative monitoring stations of the Calumet River, fall 2012.

Water Quality Station CAR-1:
Right Downstream Bank, facing upstream

Benthic Invertebrate Reach CAR-D1:
Right Downstream Bank

Water Quality Station CAR-2:
Left Downstream Bank, facing upstream

Benthic Invertebrate Reach CAR-D2:
Cross-channel

5.6.1 Summary of 2012 Conditions

As of 2012, 1.14% (198 ha) of the Calumet River watershed had undergone land change from focal projects, with no change from 2011 (Table 2.5-2). 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, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components of RAMP in the Calumet River watershed in 2012. Table 5.6-1 is a summary of the 2012 assessment for the Calumet River watershed, while Figure 5.6-1 denotes the location of the monitoring stations for each RAMP component and the areas with land change as of 2012. Figure 5.6-2 contains fall 2012 photos of the water quality monitoring stations in the watershed.

Hydrology For the 2012 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge were estimated to be 0.2% lower than from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality In fall 2012, water quality at *test* station CAR-1 and *baseline* station CAR-2 showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of all water quality measurement endpoints at *test* station CAR-1 and *baseline* station CAR-2 were within the range of regional *baseline* concentrations in fall 2012. The ionic composition of water at *test* station CAR-1 was consistent with previous years, and the ionic composition of *baseline* station CAR-2 appeared to have returned to its historical range following a deviation in fall 2010.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at *test* reach CAR-D1 were classified as **Negligible-Low** because although there were significant differences in measurement endpoints compared to *baseline* reach CAR-D2 (e.g., higher diversity, EPT taxa, and lower equitability at *test* reach CAR-D1), these differences were not in a direction consistent with a negative change or degraded habitat quality. In addition, mean values of measurement endpoints were within the range of variation for *baseline* depositional reaches and the benthic invertebrate community at *test* reach CAR-D1 was considered diverse and supported by good water quality. The benthic invertebrate community at *baseline* reach CAR-D2 was somewhat unusual relative to previous sampling years. The benthic invertebrate community was heavily dominated by nematodes and copepods, while several groups typically observed were not found in 2012 (e.g., Chaoboridae, Bivalvia, Ceratopogonidae). Concentrations of sediment quality measurement endpoints at both stations of the Calumet River in fall 2012 were generally within the range of previously-measured concentrations, with both stations comprised almost exclusively of sand substrate, with low concentrations of total organic carbon. Direct measurements of sediment toxicity indicated a survival ≥70% at both stations. Differences in sediment quality observed in fall 2012 between *baseline* station CAR-D2 and regional *baseline* conditions were classified as **Negligible-Low**. Differences between *test* station CAR-D1 and regional *baseline* conditions were classified as **Moderate**.

Fish Populations Differences in measurement endpoints for fish assemblages between *test* reach CAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** given that all measurement endpoints were within the regional range of variation of *baseline* reaches.

5.6.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Calumet River watershed was conducted at Station S16A, Calumet River near the mouth, which was used for the water balance analysis. There were no additional hydrometric monitoring stations that were operated in this watershed during the 2012 WY.

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 Station CR-1 from 2005 to 2009. Only partial records exist for each historical year; therefore, calculated statistics of historical runoff volumes and daily flows for comparison against the 2012 water year (WY) data were not as robust.

The annual runoff volume in the 2012 WY was 2.52 million m^3 measured from May 17 to October 31, 2012. Flows increased rapidly for four days once monitoring began on May 17 and then decreased until June 24 with values near the historical lower quartile (Figure 5.6-3). Flows increased in late June and early July due to rainfall events that generally exceeded historical upper quartile values from July 4 to July 27. Flows then decreased in late July and reached lower quartile flows by the end of August. Flows increased sharply in response to rainfall events in late August and early September, reaching a maximum daily value of 1.28 m^3/s on September 11, 2012, which was 67% higher than the historical mean annual maximum daily flow. Flows remained above the historical mean for the remainder of the 2012 WY and exceeded the historical maximum value for the last 16 days of October. The minimum open-water daily flow of 0.02 m^3/s recorded on June 24 was 20% higher than the historical mean open-water mean minimum daily flow of 0.012 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the 2012 WY at Station S16A is presented in Table 5.6-2 and described below:

1. The closed-circuited land area from focal projects as of 2012 was estimated to be 0.68 km^2 (Table 2.5-1). The loss of flow to the Calumet River that would have otherwise occurred from this land area was estimated at approximately 10,000 m^3.
2. As of 2012, the area of land change in the Calumet River watershed from focal projects that was not closed-circuited was estimated to be 1.30 km^2 (Table 2.5-1). The increase in flow to the Calumet River that would not have otherwise occurred from this land area was estimated at approximately 4,000 m^3.

The estimated cumulative effect of land change in the 2012 WY was a loss of flow of 6,000 m^3 at Station S16A (Table 5.6-2). The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.6-3. For the 2012 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge for Station S16A were estimated to be 0.2% lower than from the estimated *baseline* hydrograph (Table 5.6-3); these differences were classified as **Negligible-Low** (Table 5.6-4).

5.6.3 Water Quality

In fall 2012, 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 2012); 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 or *baseline* station CAR-2.

2012 Results Relative to Historical Concentrations Concentrations of total dissolved phosphorus and total strontium in fall 2012 were above and below the range of previously-measured concentrations, respectively at *test* station CAR-1. Concentrations of many measurement endpoints were below previously-measured minimum concentrations at *baseline* station CAR-2, including dissolved phosphorus, dissolved organic carbon, calcium, magnesium, sulphate, total dissolved solids, total arsenic, total boron, and total strontium. The concentration of chloride increased above the previously-measured maximum concentration at *baseline* station CAR-2 (Table 5.6-4, Table 5.6-5).

Ion Balance The ionic composition of water at *test* station CAR-1 in fall 2012 was similar to previous years (Figure 5.6-4). The ionic composition of water at this station has remained consistent since water quality monitoring first began in 2002, with the exception of fall 2007 when cation composition was more calcium-dominated than in other years. In fall 2012, the ionic composition of water at *baseline* station CAR-2 was generally similar to previous sampling years although greater relative concentrations of sodium and chloride were present than in most other years. Historically, water at *baseline* station CAR-2 has had a lower relative concentration of bicarbonate composition 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 2012 were below water quality guidelines (Table 5.6-4 and Table 5.6-5), with the exception of:

- total dissolved phosphorous at *test* station CAR-1 and *baseline* station CAR-2;
- total aluminum at *test* station CAR-1; and
- total nitrogen at *test* station CAR-1 and *baseline* station CAR-2.

Other Water Quality Guideline Exceedances *Test* station CAR-1 and *baseline* station CAR-2 had additional exceedances in fall 2012 of sulphide, total phenols, and total phosphorous (Table 5.6-6). Concentrations of dissolved iron and total iron also exceeded water quality guidelines at *test* station CAR-1.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, concentrations of all water quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station CAR-1 and *baseline* station CAR-2 (Figure 5.6-5).

Water Quality Index The WQI values for *test* station CAR-1 and *baseline* station CAR-2 indicated **Negligible-Low** differences from regional *baseline* conditions in fall 2012. The WQI values were higher in 2012 than 2011 at both stations, with an increase from 89.9 to 97.5 at *test* station CAR-1 and an increase from of 80.9 to 100.0 at *baseline* station CAR-2.

Classification of Results In fall 2012, water quality at *test* station CAR-1 and *baseline* station CAR-2 showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of all water quality measurement endpoints at *test* station CAR-1 and *baseline* station CAR-2 were within the range of regional *baseline* concentrations in fall 2012. The ionic composition of water at *test* station CAR-1 was consistent with previous years, and the ionic composition of *baseline* station CAR-2 appeared to have returned to its historical range following a deviation in fall 2010.

5.6.4 Benthic Invertebrate Communities and Sediment Quality

5.6.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- depositional *test* reach CAR-D1, designated as *baseline* from 2002 to 2004 and sampled as a *test* reach in 2005, 2009, and 2012; and
- depositional *baseline* reach CAR-D2, sampled from 2003 to 2006, 2009, and 2012.

2012 Habitat Conditions Water at *test* reach CAR-D1 in fall 2012 was deep (1 m), slow flowing (0.24 m/s), alkaline (pH: 8.2), with high dissolved oxygen (9.2 mg/L), and high conductivity (395 µS/cm). The substrate was dominated by sand (75%) with some silt (17%) and clay (8%) and low total organic carbon content (3.46 %) (Table 5.6-7).

Water at *baseline* reach CAR-D2 in fall 2012 was deep (1.1 m), neutral (pH: 7.1), with high conductivity (454 µS/cm), low dissolved oxygen (2.8 mg/L), and negligible flow (Table 5.6-7). The substrate was nearly equally comprised of sand (45%) and silt (41%) with some clay (14%) and moderately high total organic carbon content (Table 5.6-7).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach CAR-Dl in fall 2012 was dominated by chironomids (46%), with subdominant taxa consisting of tubificid worms (16%), ostracods (15%), and bivalves (14%) (Table 5.6-8). Gastropoda (*Gyraulus*), Ephemeroptera (*Caenis*), and Trichoptera (*Lepidostoma*) were present in low relative abundances (Table 5.6-8). Chironomids were diverse and primarily included the common forms *Micropsectra / Tanytarsus, Stictochironomus*, and *Polypedilum* (Wiederholm 1983).

The benthic invertebrate community at *baseline* reach CAR-D2 in fall 2012 was dominated by nematodes (49%) and copepods (36%), with subdominant taxa consisting of chironomids (*chironomus* and *parachironomus*) and tubificid worms (6%). One individual gastropod (*Menetus cooperi*) and damselfly (Libellulidae) were present at this reach (Table 5.6-8).

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 the Calumet River watershed.

Temporal comparisons for *test* reach CAR-D1 included testing for:

- changes over time for the period that the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- changes from before (2002 to 2004) to after (2005, 2009, and 2012) the reach was designated as *test* (Hypothesis 2, Section 3.2.3.1);
- changes between 2012 values and the mean of all available *baseline* data for the Calumet River watershed; and
- changes between 2012 values and the mean of all previous years of sampling.

Spatial comparisons for *test* reach CAR-D1 included testing for:

- differences from *baseline* reach CAR-D2 (Hypothesis 3, Section 3.2.3.1);
- differences from *baseline* reach CAR-D2 from before to after the reach was designated as *test*;
- differences from *baseline* reach CAR-D2 over time during the *test* period; and
- differences from *baseline* reach CAR-D2 over time.

Richness was significantly higher at *test* reach CAR-D1 than *baseline* reach CAR-D2 and higher in 2012 at *test* reach CAR-D1 than the mean of all *baseline* data or all previous sampling years at this reach (Table 5.6-9). All of these changes accounted for >20% of the variance in annual means (Table 5.6-9).

Simpson's Diversity was higher at *test* reach CAR-D1 than *baseline* reach CAR-D2 during the *test* period of reach CAR-D1 (i.e., after 2004) (Table 5.6-9). There was a difference in time trends in Simpson's Diversity between the upper and lower reaches, with an increasing trend over time at *test* reach CAR-D1 and a decreasing trend over time at *baseline* reach CAR-D2 (Table 5.6-9). Simpson's Diversity at *test* reach CAR-D1 in 2012 was higher than the mean of all *baseline* data for the Calumet River watershed and higher than the mean of all previous sampling years at this reach (Table 5.6-9). All of these differences accounted for >20% of variance in annual means.

Equitability was significantly higher at *baseline* reach CAR-D2 than *test* reach CAR-D1, accounting for 30% of the variance in annual means (Table 5.6-9).

The percentage of fauna as EPT taxa from before (2002 to 2004) to after (2005, 2009, 2012) the lower reach was designated as *test* was higher at *test* reach CAR-D1 than *baseline* reach CAR-D2 (Table 5.6-9).

CA Axis 2 scores increased over time at *test* reach CAR-D1 due to a shift in taxonomic composition towards fewer tubificids and more gastropods (Figure 5.6-6). CA Axis 2 scores decreased over time at *baseline* reach CAR-D2 due to an increase in nematodes and a decrease in Ephemeroptera and gastropods (Figure 5.6-6).

Comparison to Published Literature *Test* reach CAR-Dl in fall 2012 remained relatively similar in terms of taxa composition and measurement endpoints to previous sampling years. Diversity was high with many chironomids, bivalves, and gastropods as well as low relative abundances of Ephemeroptera and Trichoptera. The presence of these taxa was indicative of high quality benthic habitat (Hynes 1960, Griffiths 1998, Mandaville 2001).

Baseline reach CAR-D2 in fall 2012 had a less diverse benthic invertebrate community than previously observed, with a decrease in diversity, richness, and the percentage of fauna as EPT taxa over time. The benthic fauna in fall 2012 consisted primarily of tolerant taxa including nematodes and tubificid worms, and copepods. In previous years, chironomids were dominant but were rare in 2012 (9%).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for benthic invertebrate communities at *test* reach CAR-D1 and *baseline* reach CAR-D2 were within the range of regional variation for depositional reaches, with the exception of Simpson's Diversity at *baseline* reach CAR-D2 (Figure 5.6-7). Diversity at *baseline* reach CAR-D2 in fall 2012 was below the 5th percentile for regional *baseline* conditions and lower than in all previous sampling years at this reach.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities for *test* reach CAR-D1 were classified as **Negligible-Low** because although there were significant differences in measurement endpoints compared to *baseline* reach CAR-D2 (e.g., higher Diversity, EPT taxa, and lower equitability at *test* reach CAR-D1), these differences were not in a direction consistent with a negative change or degraded habitat quality. In addition, values of measurement endpoints were within the range of variation for *baseline* depositional reaches and the benthic invertebrate community at *test* reach CAR-D1 was considered diverse and supported by good water quality.

The benthic invertebrate community at *baseline* reach CAR-D2 was somewhat unusual relative to previous sampling years. The benthic invertebrate community was heavily dominated numerically by nematodes and copepods, while several groups typically observed were not found in 2012 (e.g., Chaoboridae, Bivalvia, Ceratopogonidae), perhaps related to the low dissolved oxygen observed in 2012.

5.6.4.2 Sediment Quality

Sediment quality was sampled in the same locations as benthic invertebrate communities were sampled in fall 2012:

- *test* station CAR-D1, designated as *baseline* from 2002 to 2004 and *test* from 2005 to 2012; and
- *baseline* station CAR-D2, sampled since 2005.

Temporal Trends Insufficient data existed to conduct trend analysis for stations on the Calumet River. At least seven years of data are required to complete a trend analysis and only five and four years of sediment quality data exist for *test* station CAR-D1 and *baseline* station CAR-D2, respectively.

2012 Results Relative to Historical Concentrations Concentrations of sediment quality variables were all within the range of previously-measured concentrations, with the following exceptions:

- Sediment at both stations were dominated by sand in 2012 and similar to substrate composition observed in 2009, when the station was last sampled (Table 5.6-10 and Table 5.6-11). However, the percentage of sand in 2012 exceeded the previously measured maximum value at *baseline* station CAR-D2 (Table 5.6-11). Concentrations of total metals were within previously measured concentrations at both stations in fall 2012; however, total metals normalized to percent fine sediments exceeded previously measured maximum concentrations at both stations, likely due to the small percentage of silt and clay observed;
- The concentration of total hydrocarbons at *test* station CAR-D1 was below the previously measured minimum concentration in 2012 (Figure 5.6-8). Individually all CCME fractions were lower than previously measured concentrations, with Fraction 1 hydrocarbons (containing 6 to 10 carbon atoms), continuing to remain below the detection limit. Concentrations of total PAHs normalized to total organic carbon, chrysene, and pyrene all had higher concentrations in 2012 than previously measured maximum concentrations at *test* station CAR-D1. The concentration of retene was lower than the previously measured minimum concentration, while the predicted PAH toxicity was higher than previously-measured values at *baseline* station CAR-D2 in fall 2012; and
- Direct tests of sediment toxicity to invertebrates for both the amphipod *Hyalella* and the midge *Chironomus* at *test* station CAR-D1 and *baseline* station CAR-D2 indicated survival of ≥ 70% (Table 5.6-10 and Table 5.6-11). Ten-day growth of *Chironomus* and fourteen-day growth of *Hyalella* were within the range of previously-measured values at both stations. Survival of both *Hyalella* and *Chironomus* exposed to sediment at *baseline* station CAR-D2 were higher than previously-measured values for this station (Table 5.6-11). The survival of *Hyalella* at *test* station CAR-D1 was lower in 2012 than previously measured (Table 5.6-10).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of chrysene, pyrene, and Fraction-3 hydrocarbons (C16-C34) exceeded CCME sediment quality guidelines at *test* station CAR-D1 (Table 5.6-10). The potential chronic toxicity of PAHs in sediment at *test* station CAR-D1 exceeded the potential chronic toxicity threshold value of 1.0. No sediment quality measurement endpoints in fall 2012 had concentrations that exceeded the relevant CCME sediment quality guidelines at *baseline* station CAR-D2 (Table 5.6-11).

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints at *test* station CAR-D1 and *baseline* station CAR-D2 in fall 2012 were within regional *baseline* concentrations, with the exception of total PAHs normalized to %TOC, which was below the 95th percentile of regional *baseline* concentrations at *baseline* station CAR-D2 (Figure 5.6-9).

Sediment Quality Index The SQI value (92.2) at *baseline* station CAR-D2 in fall 2012 indicated a **Negligible-Low** difference from regional *baseline* conditions, while *test* station CAR-D1 indicated a **Moderate** difference in sediment quality conditions with an SQI value of 76.0. Differences from regional *baseline* conditions at *test* station CAR-D1 were due to high concentrations of PAHs, specifically C1- and C2- benzofluoranthenes/pyrenes, C1-, C2- and C3-fluoranthenes/pyrenes, C1-, C2- and C3- fluorenes, C2-benzo[a]anthracenes/chrysenes, C2-benzofluoranthenes/pyrenes, C3-dibenzothiophenes, C4-dibenzothiophenes, C4-phenanthrenes/anthracenes, chrysene dibenz[ah]anthracene, indeno[1,2,3-cd] pyrene, and pyrene.

Classification of Results Concentrations of sediment quality measurement endpoints at both stations of the Calumet River in fall 2012 were generally within the range of previously measured concentrations, with both stations comprised almost exclusively of sand substrate, with low concentrations of total organic carbon. Direct measurements of sediment toxicity indicated a survival ≥70% at both stations. Based on the SQI values, differences in sediment quality observed in fall 2012 between *baseline* station CAR-D2 and regional *baseline* conditions were classified as **Negligible-Low**. Differences between *test* station CAR-D1 and regional *baseline* conditions were classified as **Moderate**.

5.6.5 Fish Populations

Fish assemblages were sampled for the first time in fall 2012 at:

- depositional *test* reach CAR-F1 (this reach is in the same location as the benthic invertebrate community *test* reach CAR-D1); and
- depositional *baseline* reach CAR-F2 (this reach is in the same location as the benthic invertebrate community *test* reach CAR-D2).

2012 Habitat Conditions *Test* reach CAR-F1 was comprised of shallow run habitat with some areas of riffle habitat and a wetted width of 4.5 m and a bankfull width of 5.5 m (Table 5.6-12). The substrate was comprised of sand and silt with smaller amounts of gravel, which were heavily embedded with fine material. Water at *test* reach CAR-F1 in fall 2012 had an average depth of 0.37, was slow flowing (average flow: 0.22 m/s), alkaline (pH: 7.74), with high conductivity (389 µS/cm), high dissolved oxygen (10.5 mg/L), and a temperature of 8.6˚C. Instream cover was comprised primarily of small woody debris with lesser amounts of macrophytes, algae, and live tree roots (Table 5.6-12).

Baseline reach CAR-F2 was comprised of a beaver impoundment with a wetted width of 44 m and a bankfull width of 46 m (Table 5.6-12). The maximum depth at *baseline* reach CAR-F2 in fall 2012 was 1.5 m, with negligible flow. The substrate was comprised of fines and organic material. Water at *baseline* reach CAR-F2 in fall 2012 was neutral (pH: 7.1), with high conductivity (442 µS/cm), low dissolved oxygen (3.2 mg/L), and a temperature of 10˚C. Instream cover was comprised primarily of macrophytes and woody debris typical of a beaver impoundment (Table 5.6-12).

Temporal and Spatial Comparisons Sampling was initiated in Calumet River in fall 2012; therefore, no temporal comparisons could be conducted. Spatial comparisons were not conducted between *test* reach CAR-F1 and *baseline* reach CAR-F2 given that the habitat characteristics between the two reaches were very different, with the *baseline* reach being an impounded area with deep water and unsuitable fish habitat for most species.

Test reach CAR-F1 had a fish assemblage composed of small-bodied fish species and juvenile sucker species, with northern redbelly dace as the dominant species while brook stickleback was the only species captured at *baseline* reach CAR-F2 (Table 5.6-13). *Baseline* reach CAR-F2 was a beaver impoundment with low dissolved oxygen concentration and no flow, which was not suitable fish habitat for many fish species.

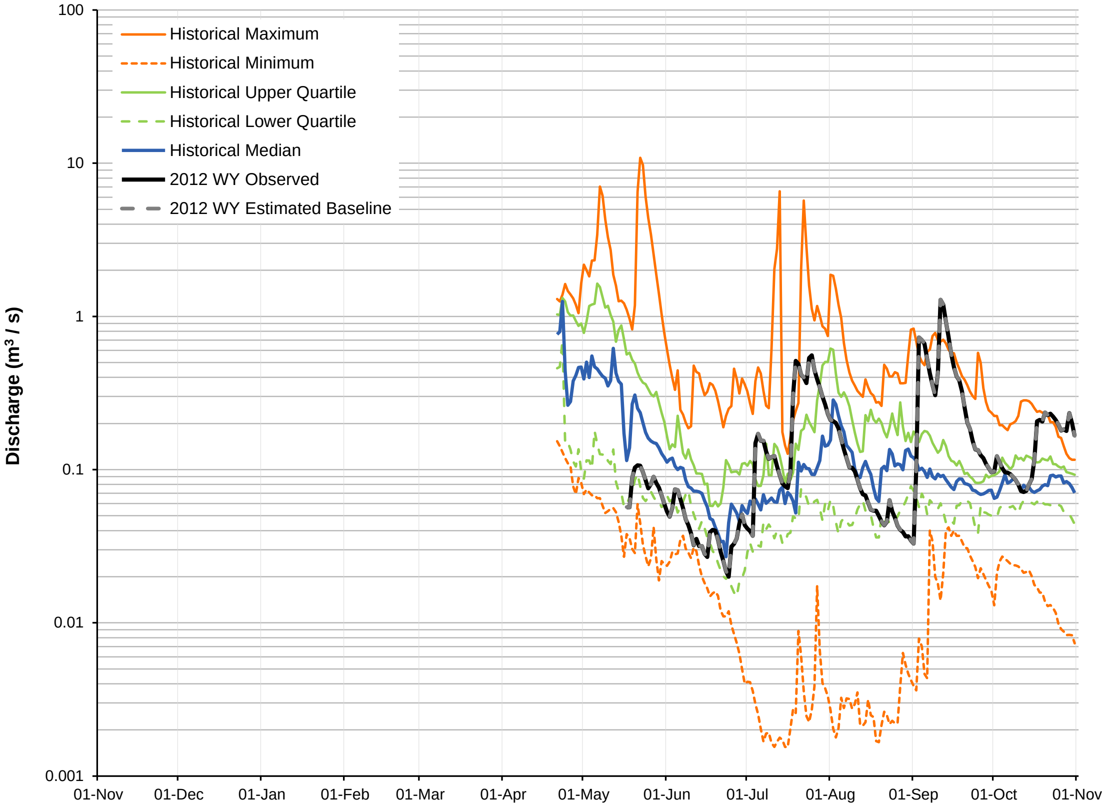
Comparison to Published Literature A summary of fish sampling activities within watersheds in the oil sands region was prepared in Golder (2004). This document provides a thorough assessment of fish species presence in watersheds prior to major oil sands development to capture historical *baseline* fish assemblages for comparison to results reported by RAMP. Historically, 14 fish species have been documented in the Calumet River (Golder 2004). RAMP has observed five of these fish species at *test* reach CAR-F1 in fall 2012, as well as two additional species that were not previously documented (northern redbelly dace and fathead minnow) (Table 5.6-14). The number of species previously-documented was from various methods of sampling (i.e., fish fence, trapping, and electrofishing), which target all life-stages of fish while backpack electrofishing used for the RAMP fish assemblage monitoring targets only small-bodied fish or juvenile large-bodied fish, which likely explains the difference in documented species between historical results and results reported by RAMP.

Habitat conditions documented by Golder (2004) were similar to conditions observed by RAMP in 2012 at both *test* reach CAR-F1 and *baseline* reach CAR-F2. Golder (2004) documented low habitat diversity and predominantly sand substrate within the lower portion of the river (near the mouth) in the vicinity of *test* reach CAR-F1 and extensive beaver activity in upstream areas where *baseline* reach CAR-F2 is located.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reach CAR-F1 were within the range of regional *baseline* conditions (Figure 5.6-10). Given that fishing was not divided into subreaches in the impounded area at *baseline* reach CAR-F2, only one value for each measurement endpoint could be calculated. Brook stickleback was the only species captured at *baseline* reach CAR-F2 and has a high tolerance value, which resulted in a diversity value of zero and an ATI value that exceeded the range of *baseline* conditions at *baseline* reach CAR-F2.

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach CAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** given that all measurement endpoints were within the regional range of variation of *baseline* reaches.

Figure 5.6-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Calumet River in the 2012 WY, compared to historical values.



Note: Observed 2012 WY hydrograph based on Calumet River near the mouth, RAMP Station S16A, provisional data for May 17 to October 31, 2012. The upstream drainage area is 173.5 km^2. Historical values from 2001 to 2011 calculated for the open-water period at Station S16 (2001 to 2004), Station CR-1 (2005 to 2009), and Station S16A (2010 to 2011).

Table 5.6-2 Estimated water balance at Station S16A, Calumet River near the mouth, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**2.518**	**Observed discharge from Calumet River near the mouth, RAMP Station S16A**
Closed-circuited area water loss from the observed *test* hydrograph	-0.010	Estimated 0.68 km^2 of the Calumet River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.004	Estimated 1.30 km^2 of the Calumet River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Calumet River watershed from focal projects	0	None reported
Water releases into the Calumet River watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Calumet River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**2.524**	**Estimated *baseline* discharge from Calumet River near the mouth, RAMP Station S16A.**
Incremental flow (change in total discharge)	-0.006	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-0.25%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for May 17 to October 31, 2012 for RAMP Station S16A, Calumet River near the mouth.

Table 5.6-3 Calculated change in hydrologic measurement endpoints in the Calumet River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.174	0.173	-0.2%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	1.287	1.284	-0.2%
Open-water season minimum daily discharge	0.020	0.020	-0.2%

Note: Values are calculated from provisional data for May 17 to October 31, 2012 for Calumet River near the mouth, RAMP Station S16A.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to three and one decimal places, respectively.

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 5.6-4 Concentrations of water quality measurement endpoints, mouth of Calumet River (*test* station CAR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.59.0	8.4	10	8.1	8.2	8.4
Total suspended solids	mg/L	-	16.0	10	<3.0	10.5	66.0
Conductivity	µS/cm	-	482	10	188	583	702
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.12**	10	0.03	**0.06**	**0.08**
Total nitrogen	mg/L	1.0	**1.4**	10	0.8	**1.4**	**1.5**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	32.5	10	22.0	33.0	40.7
Ions							
Sodium	mg/L	-	40.0	10	7.00	49.4	71.0
Calcium	mg/L	-	42.6	10	25.3	55.5	67.3
Magnesium	mg/L	-	13.6	10	7.80	18.6	22.5
Chloride	mg/L	120	11.2	10	2.00	15.6	34.0
Sulphate	mg/L	270	12.6	10	3.60	12.1	20.5
Total dissolved solids	mg/L	-	330	10	151	397	480
Total alkalinity	mg/L	-	233	10	96	285	337
Selected metals							
Total aluminum	mg/L	0.1	**0.38**	10	0.04	**0.15**	**1.28**
Dissolved aluminum	mg/L	0.1	0.0040	10	0.0013	0.0035	0.0058
Total arsenic	mg/L	0.005	0.0011	10	0.0009	0.0011	0.0016
Total boron	mg/L	1.2	0.093	10	0.074	0.084	0.122
Total molybdenum	mg/L	0.073	0.00015	10	0.00011	0.00015	0.00030
Total mercury (ultratrace)	ng/L	5, 13	2.7	9	<1.2	<1.2	3.8
Total strontium	mg/L	-	0.16	10	0.17	0.25	0.30
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	-	0.26	1	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	<0.25	1	-	<0.25	-
Naphthenic Acids	mg/L	-	0.05	1	-	0.55	-
Oilsands Extractable	mg/L	-	0.55	1	-	2.87	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	3.35	1	-	15.1	-
Total dibenzothiophenes	ng/L	-	67.1	1	-	105.0	-
Total PAHs	ng/L	-	387.1	1	-	493.6	-
Total Parent PAHs	ng/L	-	23.6	1	-	29.1	-
Total Alkylated PAHs	ng/L	-	363.6	1	-	464.5	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.45**	10	0.27	**0.52**	**0.91**
Sulphide	mg/L	0.002	**0.005**	10	**0.005**	**0.016**	**0.028**
Total iron	mg/L	0.3	**1.33**	10	**0.54**	**1.47**	**3.14**
Total phenols	mg/L	0.004	**0.010**	9	<0.001	**0.008**	**0.013**
Total phosphorous	mg/L	0.05	**0.12**	10	**0.07**	**0.09**	**0.21**

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	7	7.7	8.0	8.2
Total suspended solids	mg/L	-	<3.0	7	<3.0	5.0	208
Conductivity	µS/cm	-	494	7	526	610	772
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.08**	7	**0.09**	**0.13**	**0.31**
Total nitrogen	mg/L	1.0	**1.9**	7	**1.8**	**2.0**	**5.5**
Nitrate+nitrite	mg/L	1.3	<0.071	7	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	36.1	7	40.0	48.0	54.4
Ions							
Sodium	mg/L	-	54.7	7	53	69	76
Calcium	mg/L	-	29.6	7	44.0	48.5	68.2
Magnesium	mg/L	-	12.3	7	17.7	20.5	26.6
Chloride	mg/L	120	24.3	7	12.3	15.3	17.0
Sulphate	mg/L	270	23.5	7	45.3	55.8	101.0
Total dissolved solids	mg/L	-	323	7	370	467	547
Total alkalinity	mg/L		195.0	7	188	238	315
Selected metals							
Total aluminum	mg/L	0.1	0.04	7	0.02	0.06	**4.10**
Dissolved aluminum	mg/L	0.1	0.010	7	0.004	0.013	0.024
Total arsenic	mg/L	0.005	0.0009	7	0.0021	0.0026	0.0050
Total boron	mg/L	1.2	0.076	7	0.081	0.094	0.128
Total molybdenum	mg/L	0.073	0.00033	7	0.00009	0.00055	0.00080
Total mercury (ultra-trace)	ng/L	5, 13	1.40	7	<1.2	1.3	4.4
Total strontium	mg/L	-	0.15	7	0.24	0.29	0.36
Total hydrocarbons							
BTEX	mg/L	-	<0.10	1	-	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	<0.10	1	-	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	<0.25	1	-	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	0.65	1	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	0.49	1	-	<0.25	-
Naphthenic Acids	mg/L	-	0.11	1	-	0.45	-
Oilsands Extractable	mg/L	-	0.73	1	-	1.98	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.97	1	-	3.73	-
Total dibenzothiophenes	ng/L	-	35.41	1	-	5.88	-
Total PAHs	ng/L	-	207.1	1	-	151.2	-
Total Parent PAHs	ng/L	-	17.37	1	-	19.26	-
Total Alkylated PAHs	ng/L	-	189.7	1	-	132.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Sulphide	mg/L	0.002	**0.03**	7	**0.02**	**0.04**	**0.59**
Total phenols	mg/L	0.004	**0.018**	7	**0.008**	**0.014**	**0.041**
Total phosphorous	mg/L	0.05	**0.08**	7	**0.10**	**0.31**	**1.48**

[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.

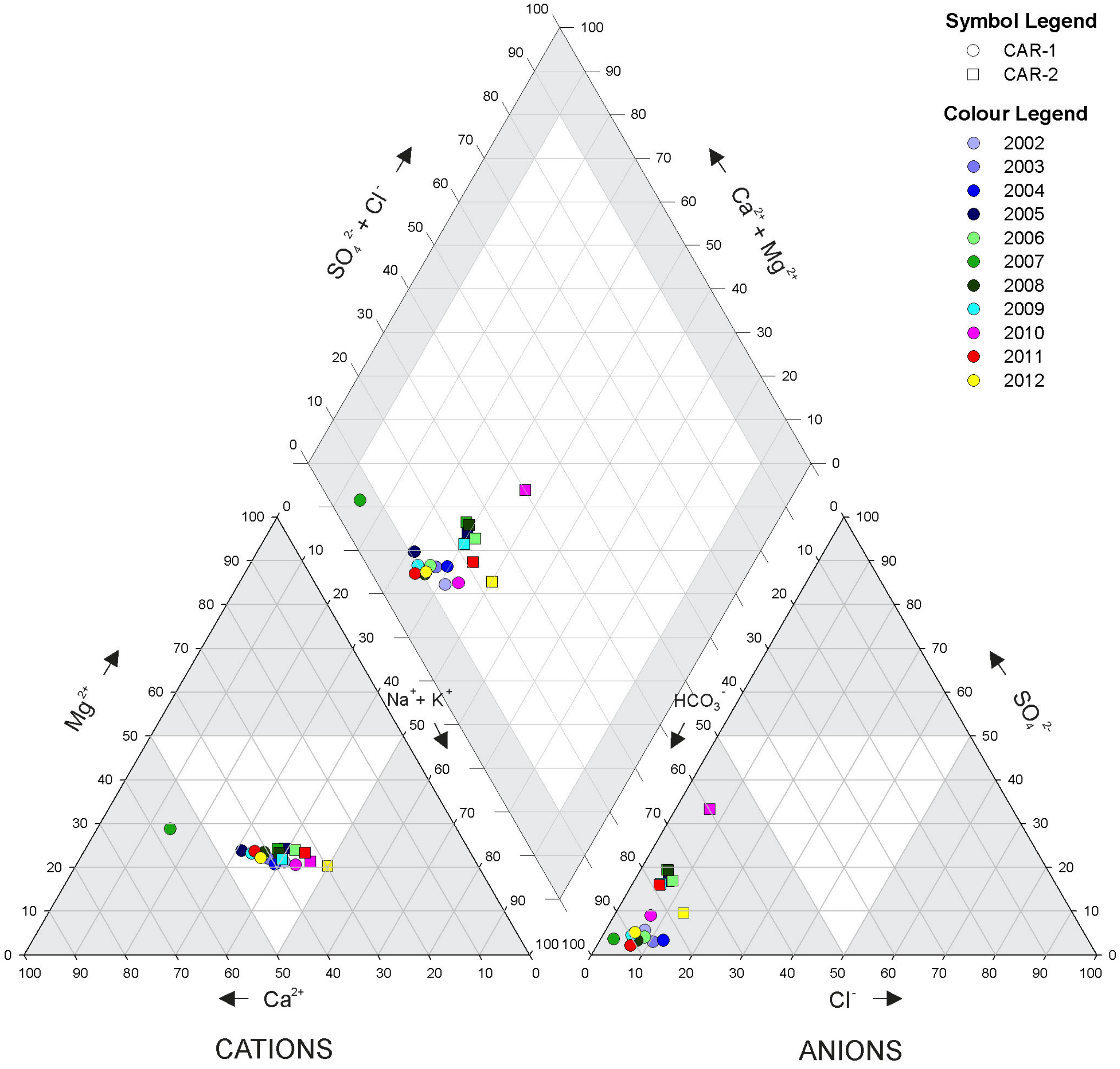


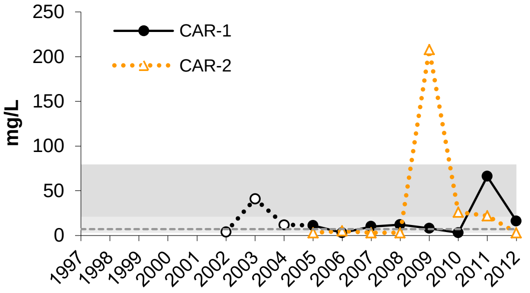
Table 5.6-6 Water quality guideline exceedances, Calumet River watershed, fall 2012.

Variable	Units	Guideline[a]	CAR-1	CAR-2
Dissolved iron	mg/L	0.3	0.45	-
Sulphide	mg/L	0.002	0.005	0.034
Total aluminum	mg/L	0.1	0.38	-
Total dissolved phosphorus	mg/L	0.05	0.12	0.08
Total iron	mg/L	0.3	1.33	-
Total nitrogen	mg/L	1	1.35	1.85
Total phenols	mg/L	0.004	0.010	0.018
Total phosphorous	mg/L	0.05	0.14	0.08

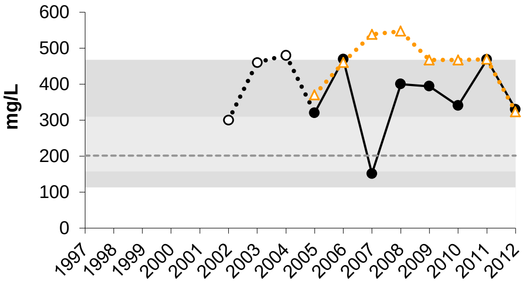
[a] Sources for all guidelines are outlined in Table 3.2-5.

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.

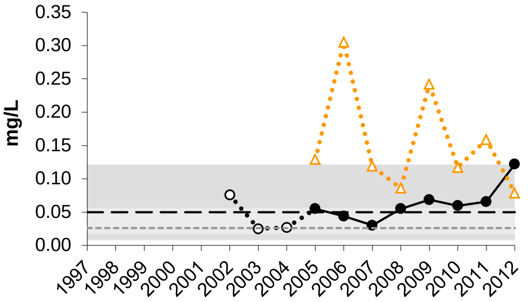
Total Suspended Solids (TSS)



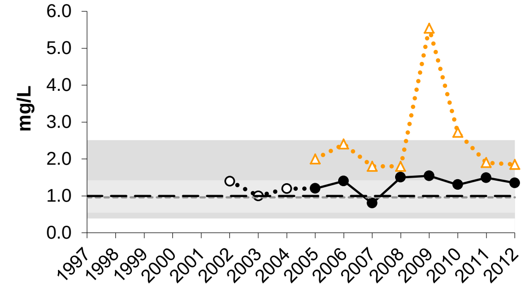
Total Dissolved Solids (TDS)



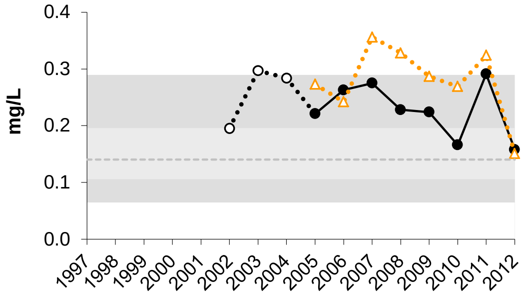
Dissolved Phosphorus



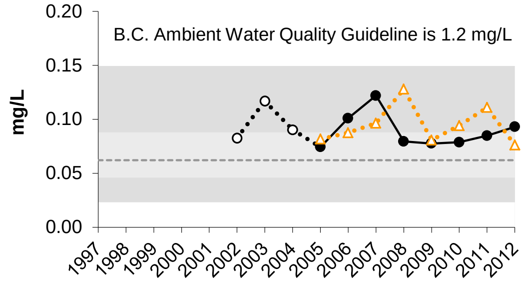
Total Nitrogen



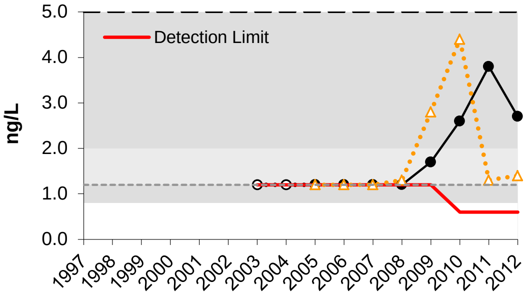
Total Strontium



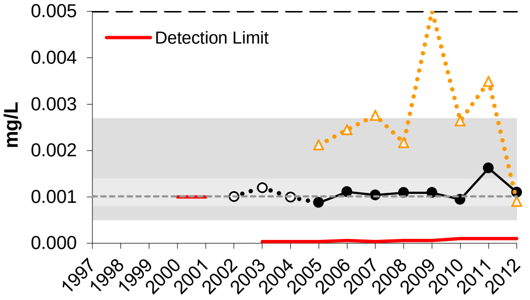
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



Non-detectable values are shown at the detection limit.

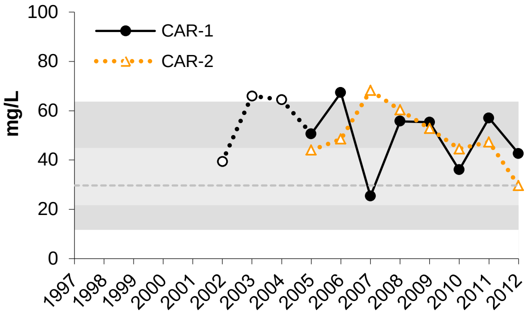
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

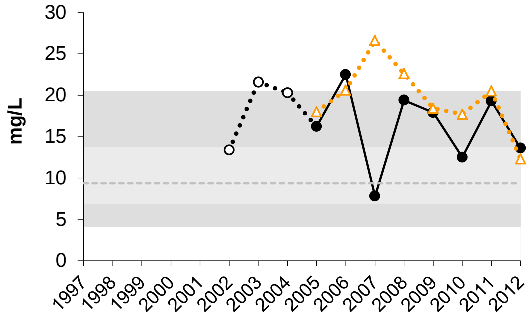
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.6-5 (Cont'd.)

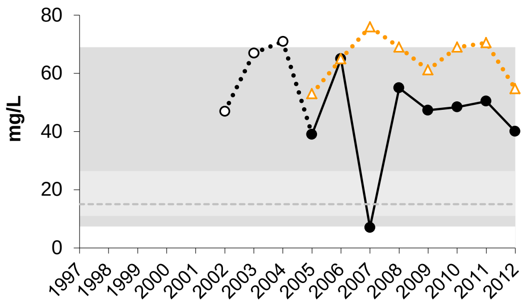
Calcium



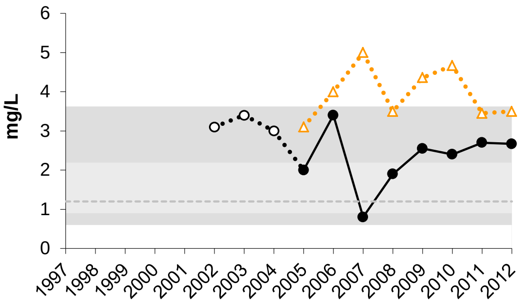
Magnesium



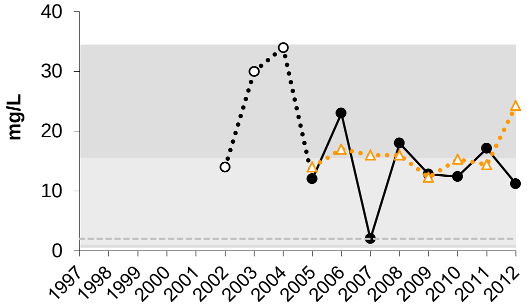
Sodium



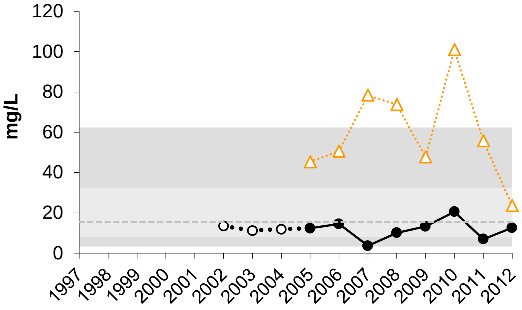
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.6-7 Average habitat characteristics of benthic invertebrate sampling locations in the Calumet River, fall 2012.

Variable	Units	CAR-D1 Lower *Test* Reach of Calumet River	CAR-D2 Upper *Baseline* Reach of Calumet River
Sample date	-	06-Sept-2012	06-Sept-2012
Habitat	-	Depositional	Depositional
Water depth	m	1.0	1.1
Current velocity	m/s	0.24	-
Field Water Quality			
Dissolved oxygen	mg/L	9.2	2.8
Conductivity	µS/cm	395	454
pH	pH units	8.2	7.1
Water temperature	°C	10.3	12.3
Sediment Composition			
Sand	%	75	45
Silt	%	17	41
Clay	%	8	14
Total Organic Carbon	%	3.46	13.96

Table 5.6-8 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at *test* reach CAR-D1 and *baseline* reach CAR-D2.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Reach CAR-D1			Reach CAR-D2		
	2002	2003 to 2009	2012	2003	2004 to 2009	2012
Hydra			<1			
Nematoda	1	<1 to 3	<1	4	2 to 16	49
Naididae	<1	<1 to 4	2	9	1 to 6	
Tubificidae	1	1 to 37	16		0 to 2	6
Enchytraeidae	<1	<1 to 1	<1			
Lumbriculidae			<1			
Erpobdellidae	<1	0 to <1	<1	0	0 to <1	
Glossiphoniidae			<1			<1
Ostracoda	3	1 to 4	15		7 to 14	
Cladocera			1			
Copepoda	1	<1 to 4	<1	4	0 to 4	36
Chydoridae	<1					
Macrothricidae	<1	0 to <1				
Daphniidae	<1	0 to <1		3		
Amphipoda	<1	0 to <1		3	<1 to 2	<1
Hydracarina	<1	0 to <1	<1	3	0 to 2	
Gastropoda	<1	0 to <1	3	13	1 to 5	<1
Bivalvia	1	0 to 2	12	1	<1 to 10	
Ceratopogonidae	1	<1 to 2	1	3	1 to 4	
Chaoboridae				3	1 to 54	
Chironomidae	91	48 to 86	46	54	42 to 67	9
Empididae			<1			
Tabanidae			<1			
Tipulidae			<1			
Coleoptera	<1	0 to 1	<1		0 to 22	
Ephemeroptera	<1	<1 to 2	1	<1	1	
Anisoptera	<1	0 to <1	<1	<1	<1 to 1	<1
Plecoptera	<1	0 to 1				
Trichoptera	<1	0 to <1	<1	<1	0 to <1	
Heteroptera	<1	0 to <1				
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance	73,983	16,954 to 22,301	42,640	10,302	4612 to 38,358	14,600
Richness	23	11 to 21	23	12	8 to 15	6
Simpson's Diversity	0.74	0.61 to 0.79	0.81	0.76	0.64 to 0.80	0.44
Equitability	0.26	0.32 to 0.37	0.33	0.56	0.29 to 0.62	0.41
Percent EPT	<1	<1 to 1	1	<1	<1 to 2	0

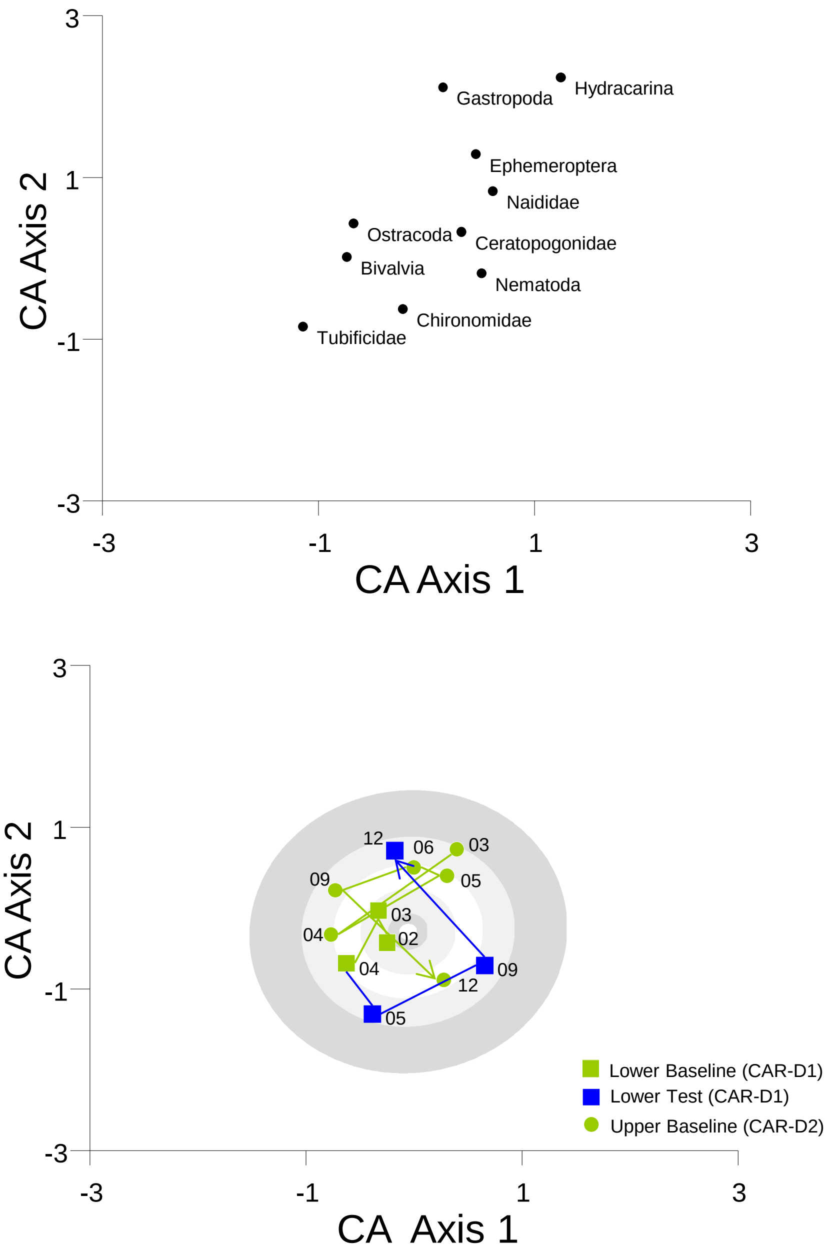
Table 5.6-9 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach CAR-D1 of the Calumet River.

	P-value							Variance Explained (%)							
Variable	*Baseline* Reach vs. *Test* Reach	*Baseline* vs. *Test* Periods	Differences at *Baseline* and *Test* Reaches from Before to After Lower Reach was Designated as *Test*	Time Trend (*test* period)	Difference in Time Trend Between Base*line and Test Reaches*	2012 vs. All *Baseline* Data	2012 vs. Previous Years	*Baseline* Reach vs. *Test* Reach	*Baseline* vs. *Test* Periods	Differences at *Baseline* and *Test* Reaches from Before to After Lower Reach was Designated as *Test*	Time Trend (*test* period)	Difference in Time Trend Between Base*line and Test Reaches*	2012 vs. All *Baseline* Data	2012 vs. Previous Years	Nature of Change(s)
Abundance	**0.022**	0.727	0.109	0.675	0.135	0.059	0.447	18	0	0	0	0	0	0	Higher at *test* reach.
Richness	**<0.001**	0.195	0.536	1.000	**0.003**	**<0.001**	**0.001**	44	3	1	0	14	43	17	Higher at *test* reach; higher in 2012 than mean of *baseline* years or mean of previous years.
Simpson's Diversity	**0.010**	**0.004**	**0.010**	0.544	**0.010**	**<0.001**	**0.002**	20	25	19	1	20	48	29	Higher after the lower reach was designated *test; h*igher at *test* reach.
Equitability	**0.003**	**0.047**	**0.030**	1.000	1.000	0.389	0.452	30	13	16	0	0	2	2	Higher at *baseline* reach.
EPT	0.597	0.333	**0.006**	0.873	0.597	0.193	0.193	1	5	42	0	1	9	9	Higher at *test* reach during *baseline* period than at the *baseline* reach.
CA Axis 1	0.893	0.460	0.713	0.284	0.803	0.349	0.324	0	2	1	5	0	4	4	No change.
CA Axis 2	0.386	0.846	0.839	1.00	**<0.001**	**0.003**	**0.013**	2	0	0	0	35	22	15	Increasing over time at *test* reach and decreasing over time at *baseline* reach; higher at *test* reach in 2012 than mean of all *baseline* data or previous years.

Bold values indicate significant difference (p<0.05).

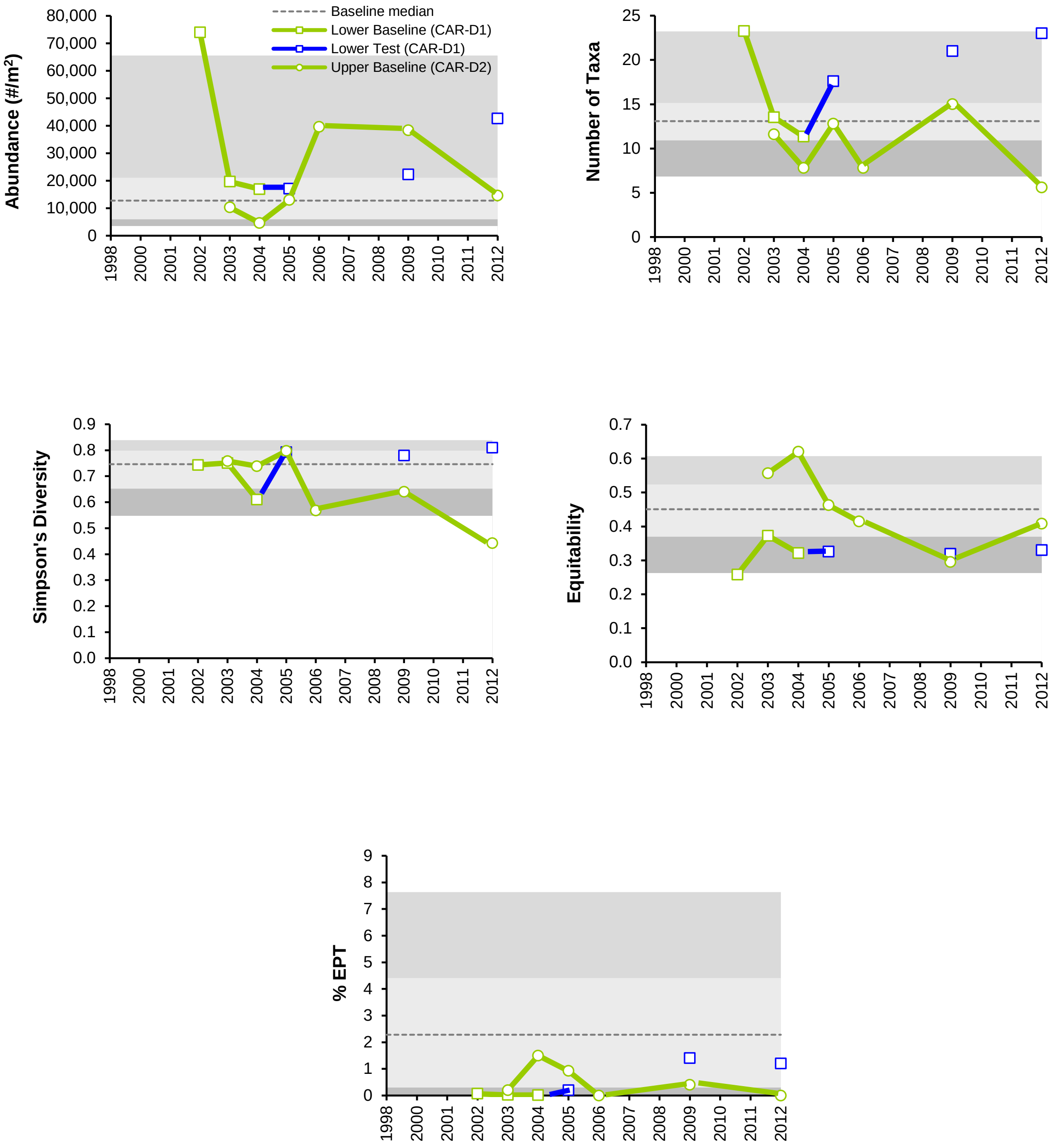
Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.6-6 Ordination (Correspondence Analysis) of benthic invertebrate communities in the Calumet River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Figure 5.6-7 Variation in benthic invertebrate community measurement endpoints in the Calumet River.



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.6-10 Concentrations of selected sediment quality measurement endpoints, Calumet River (*test* station CAR-D1), fall 2012.

Variables	**Units**	**Guideline**	**September 2012**	**2002-2011 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7.3	4	6	14	21
Silt	%	-	12.3	4	7	16	30
Sand	%	-	80.5	4	52	69	87
Total organic carbon	%	-	2.3	4	0.6	3.3	4.1
Total hydrocarbons							
BTEX	mg/kg	-	<10	3	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	3	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	92	3	**200**	**215**	**640**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,730**	3	**2,850**	**3,400**	**7,200**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	1,600	3	2,260	**3,000**	**5,300**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.003	4	0.001	0.004	0.011
Retene	mg/kg	-	0.160	4	0.050	0.133	0.181
Total dibenzothiophenes	mg/kg	-	6.61	4	0.311	5.45	9.68
Total PAHs	mg/kg	-	21.8	4	1.542	16.0	27.0
Total Parent PAHs	mg/kg	-	0.672	4	0.113	0.463	0.628
Total Alkylated PAHs	mg/kg	-	21.2	4	1.43	15.6	26.4
Predicted PAH toxicity[3]	H.I.	1.0	**1.87**	4	0.598	0.786	**1.95**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2012							
Chrysene	mg/kg	0.0571	**0.276**	4	0.019	**0.165**	**0.222**
Pyrene	mg/kg	0.053	**0.077**	4	0.010	0.048	**0.056**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	3	6.8	8.0	9.0
Chironomus growth - 10d	mg/organism	-	1.61	3	1.27	1.80	1.88
Hyalella survival - 14d	# surviving	-	7.0	3	9.0	9.0	9.0
Hyalella growth - 14d	mg/organism	-	0.27	3	0.20	0.28	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.

Table 5.6-11 Concentrations of selected sediment quality measurement endpoints, Calumet River (*baseline* station CAR-D2), fall 2012.

Variables	**Units**	**Guideline**	**September 2012**	**2001-2011 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.3	2	13	28	42
Silt	%	-	21.8	2	31	42	53
Sand	%	-	66.9	2	5	31	56
Total organic carbon	%	-	7.8	3	12	16.5	20.5
Total hydrocarbons							
BTEX	mg/kg	-	<40	3	<5	<30	<80
Fraction 1 (C6-C10)	mg/kg	30[1]	<40	3	<5	<30	<80
Fraction 2 (C10-C16)	mg/kg	150[1]	<43	3	<5	50	**230**
Fraction 3 (C16-C34)	mg/kg	300[1]	235	3	245	**4,100**	**6,100**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	188	3	154	**3,000**	**4,300**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.005	3	0.002	0.015	0.020
Retene	mg/kg	-	0.045	3	0.107	0.353	0.745
Total dibenzothiophenes	mg/kg	-	0.023	3	0.016	0.022	0.041
Total PAHs	mg/kg	-	0.322	3	0.253	1.93	2.68
Total Parent PAHs	mg/kg	-	0.046	3	0.018	0.065	0.096
Total Alkylated PAHs	mg/kg	-	0.276	3	0.235	1.83	2.61
Predicted PAH toxicity[3]	H.I.	1.0	0.187	3	0.056	0.105	0.168
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.6	3	4.6	6.0	8.0
Chironomus growth - 10d	mg/organism	-	1.60	3	1.28	2.24	2.52
Hyalella survival - 14d	# surviving	-	7.8	3	5.8	6.0	6.6
Hyalella growth - 14d	mg/organism	-	0.31	3	0.24	0.42	0.44

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

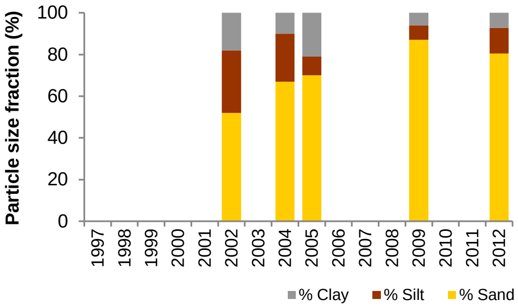
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

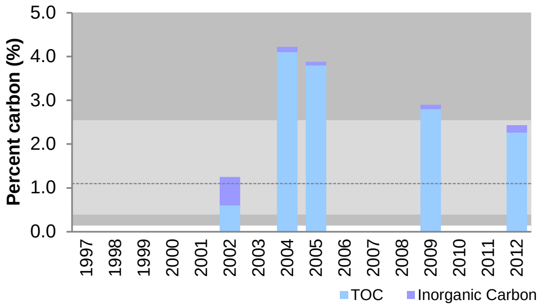
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.6-8 Variation in sediment quality measurement endpoints in the Calumet River, *test* station CAR-D1.

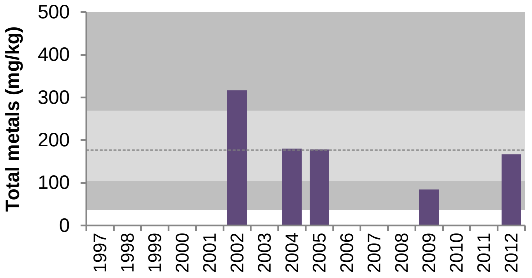
Particle size distribution



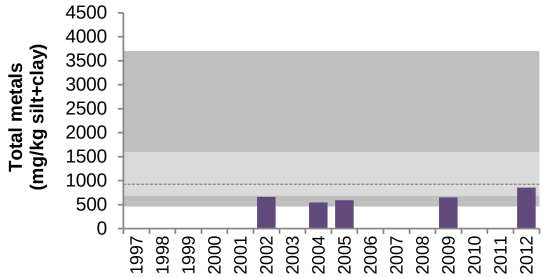
Carbon Content



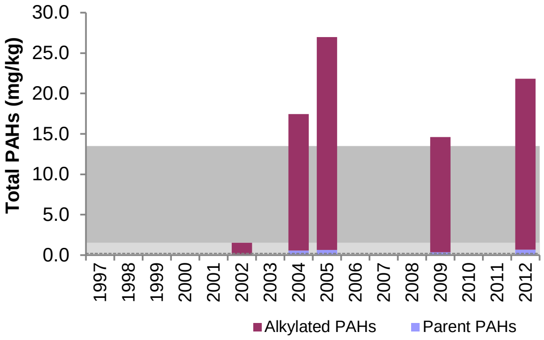
Total Metals[1]



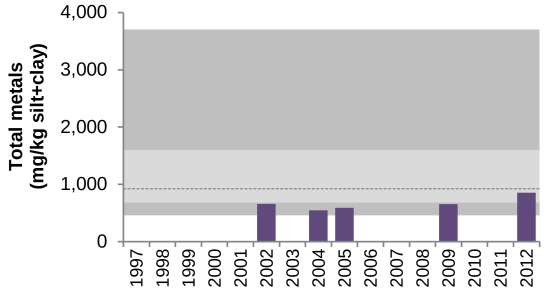
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



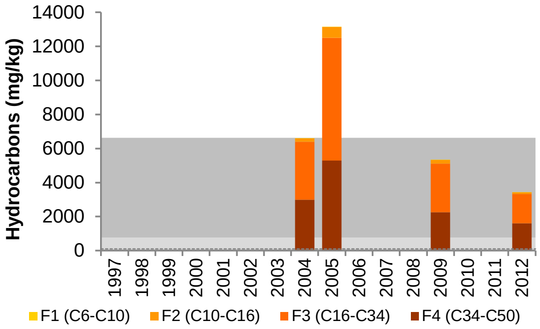
Total PAHs



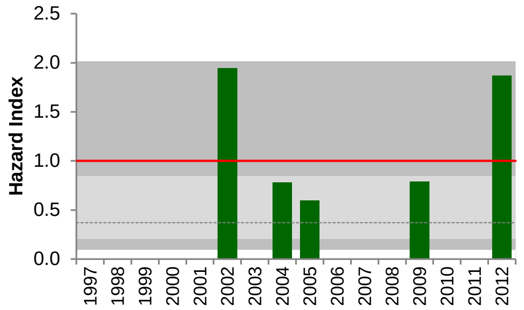
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



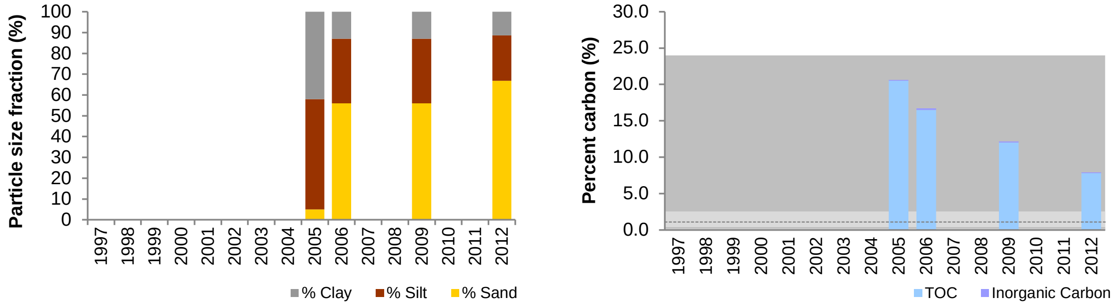
PAH Hazard Index[2]



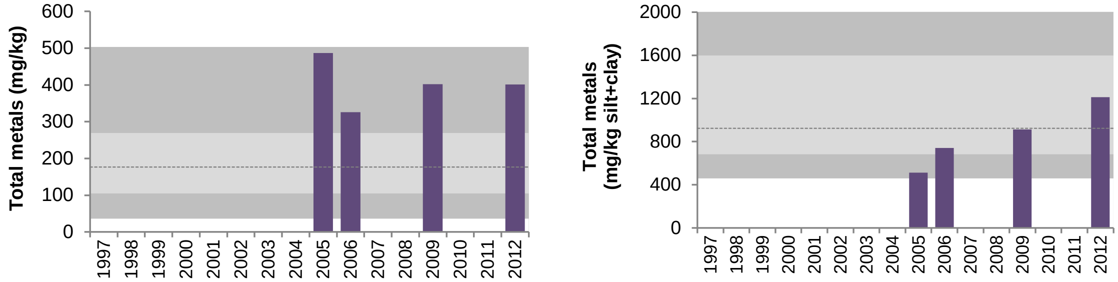
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

** Red line indicates potential chronic effects level (HI = 1.0)

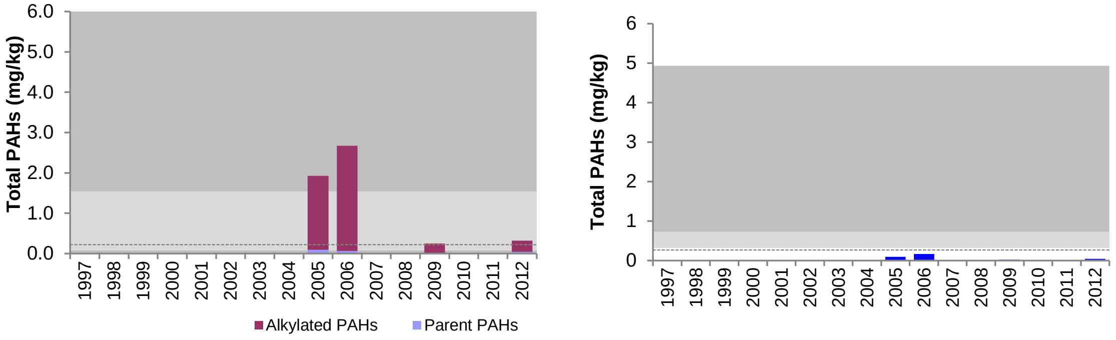
Figure 5.6-9 Variation in sediment quality measurement endpoints in the Calumet River, *baseline* station CAR-D2.


Particle size distribution

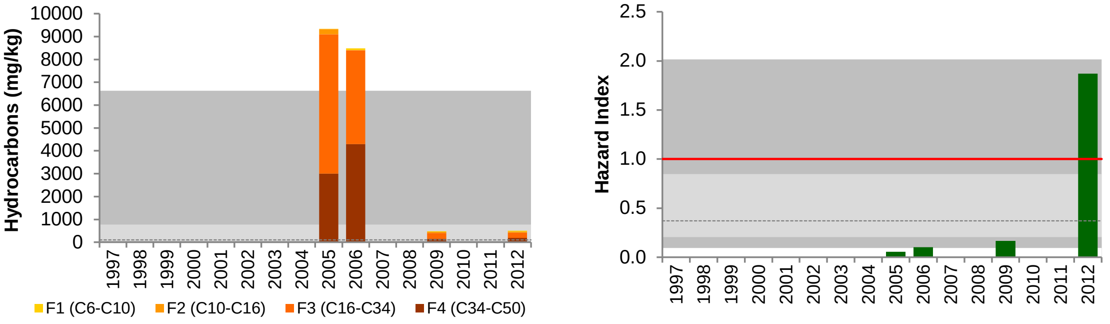
Carbon Content


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]

Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2012).

* 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).

** Red line indicates potential chronic effects level (HI = 1.0)

Table 5.6-12 Average habitat characteristics of fish assemblage monitoring locations at *test* reach CAR-F1 and *baseline* reach CAR-F2 of the Calumet River, fall 2012.

Variable	**Units**	**CAR-F1** Lower *Test* Reach of Calumet River	**CAR-F2** Upper B*aseline* Reach of Calumet River
Sample date	-	13-Sept-2012	15-Sept-2012
Habitat type	-	riffle/run	beaver impoundment
Maximum depth	m	0.80	1.5
Bankfull channel width	m	5.5	46.0
Wetted channel width	m	4.5	44.0
Substrate			
Dominant	-	fines	fines
Subdominant	-	-	-
Instream cover			
Dominant	-	small woody debris	macrophytes
Subdominant	-	filamentous algae, macrophytes, live tree roots	small woody debris, large woody debris
Field water quality			
Dissolved oxygen	mg/L	10.5	3.2
Conductivity	µS/cm	389	442
pH	pH units	7.74	7.10
Water temperature	^{0}C	8.6	10
Water velocity			
Left bank velocity	m/s	0.10	-
Left bank water depth	m	0.24	-
Centre of channel velocity	m/s	0.30	-
Centre of channel water depth	m	0.52	-
Right bank velocity	m/s	0.25	-
Right bank water depth	m	0.35	-
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	-
Subdominant	-	overhanging vegetation	-

Table 5.6-13 Percent composition and mean CPUE (catch per unit effort) of fish species at *test* reach CAR-F1 and *baseline* reach CAR-F2 of the Calumet River, 2012.

Common Name	**Code**	**Total Species**		**Percent of Total Catch**	
		CAR-F1	**CAR-F2**	**CAR-F1**	**CAR-F2**
Arctic grayling	ARGR	-	-	0	0
brook stickleback	BRST	-	14	0	100
burbot	BURB	-	-	0	0
fathead minnow	FTMN	1	-	2.2	0
finescale dace	FNDC	-	-	0	0
lake chub	LKCH	2	-	4.4	0
lake whitefish	LKWH	-	-	0	0
longnose dace	LNDC	-	-	0	0
longnose sucker	LNSC	7	-	15.6	0
northern pike	NRPK	-	-	0	0
northern redbelly dace	NRDC	20	-	44.4	0
pearl dace	PRDC	3	-	6.7	0
slimy sculpin	SLSC	-	-	0	0
spoonhead sculpin	SPSC	-	-	0	0
spottail shiner	SPSH	-	-	0	0
trout-perch	TRPR	4	-	8.9	0
walleye	WALL	-	-	0	0
white sucker	WHSC	8	-	17.8	0
yellow perch	YLPR	-	-	0	0
sucker sp. *		-	-	0	0
unknown sp. *		-	-	0	0
Total Count		45	14	100	100
Total Species Richness		7	1	-	-
Electrofishing effort (secs)		1,282	1,335	-	-
CPUE (#/100 secs)		3.51	1.05	-	-

* not included in total species count

Table 5.6-14 Summary of fish assemblage measurement endpoints (±1SD) in reaches of the Calumet River, 2012.

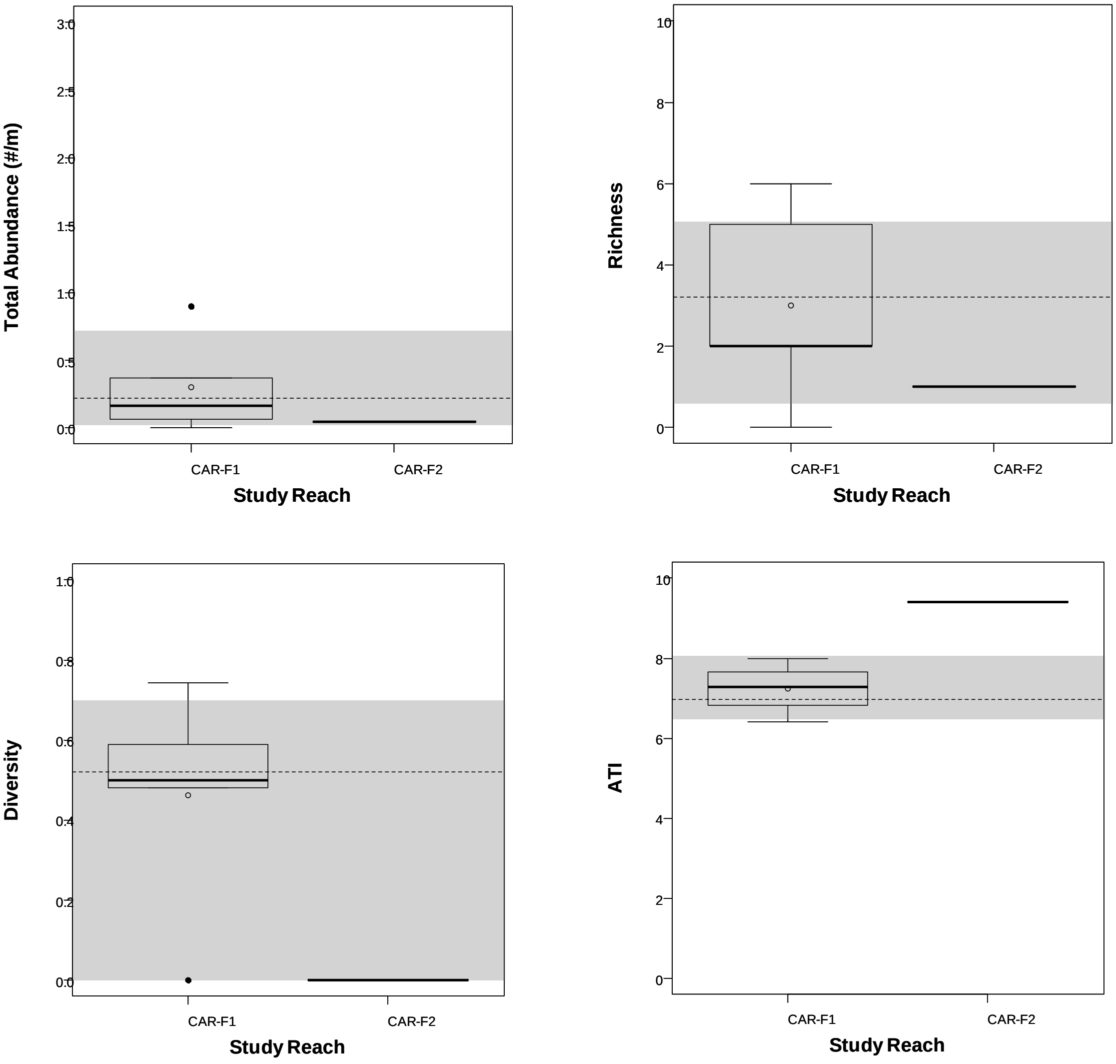
Reach	Abundance		Richness*			Diversity*		ATI*	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
CAR-F1	0.30	0.36	7	3	2.45	0.46	0.28	7.25	0.65
CAR-F2**	14	na	1	1	na	0	na	9.40	na

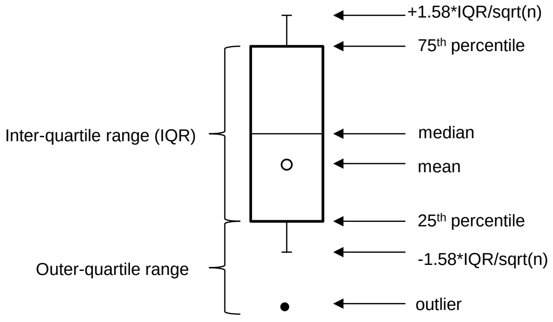
* Unknown species not included in the calculation.

** Only one fish sampling pass was conducted at *baseline* reach CAR-F2 in the beaver pond; therefore, SD could not be calculated.

SD = standard deviation across sub-reaches within a reach.

Figure 5.6-10 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the Calumet River, 2012.





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

2012 was the first year data were collected at these reaches.

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

5.7 FIREBAG RIVER WATERSHED

Table 5.7-1 Summary of results for the Firebag River watershed.

Firebag River Watershed	**Summary of 2012 Conditions**			
	Firebag River		***Lakes***	
Climate and Hydrology				
Criteria	**07DC001/S27** at the mouth	no station sampled	no station sampled	no station sampled
Mean open-water season discharge	🟡			
Mean winter discharge	🟡			
Annual maximum daily discharge	🟡			
Minimum open-water season discharge	🟡			
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	not sampled	🟠	n/a
Sediment Quality Index	not sampled	not sampled	n/a	n/a
Fish Populations				
No Fish Populations component activities conducted in 2012				

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.

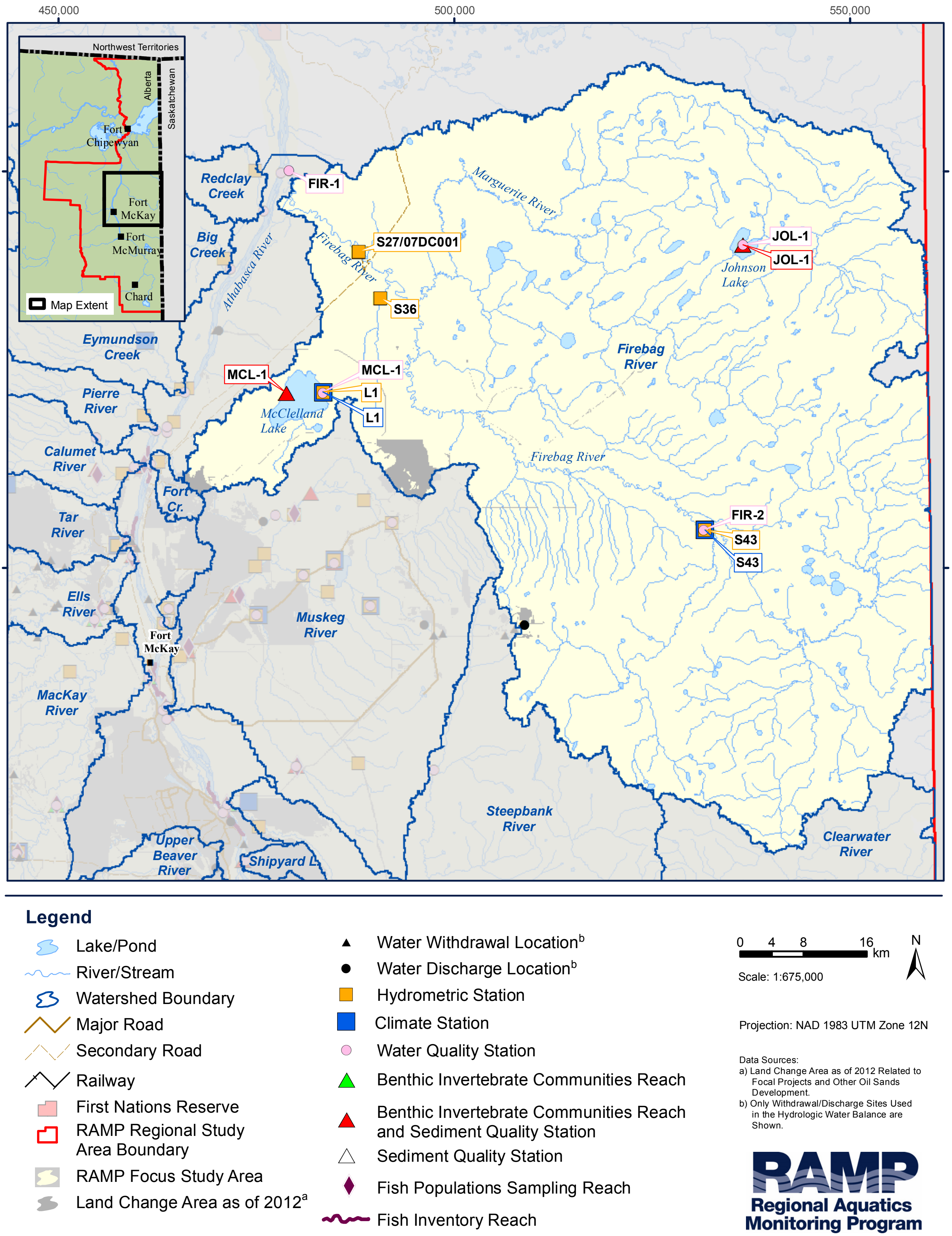
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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.



Scale: 1:675,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

RAMP Regional Aquatics Monitoring Program

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Figure 5.7-2 Representative monitoring stations of the Firebag River watershed, fall 2012.

Water Quality Station FIR-1:
Right Downstream Bank, facing upstream

Water Quality Station FIR-1:
Left Downstream Bank, cross-section

Water Quality Station FIR-2:
Right Downstream Bank, facing upstream

Water Quality Station JOL-1:
Johnston Lake, aerial view

Hydrology Station L1:
McClelland Lake

Water Quality Station MCL-1:
McClelland Lake

5.7.1 Summary of 2012 Conditions

Approximately 0.94% (5,355 ha) of the Firebag River watershed underwent land change as of 2012 from focal projects (Table 2.5-2). 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 of RAMP in the Firebag River watershed in 2012. Table 5.7-1 is a summary of the 2012 assessment of the Firebag River watershed, while Figure 5.7-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations, and the area with land change as of 2012. Figure 5.7-2 contains fall 2012 photos from a number of monitoring stations in the watershed.

Hydrology The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated were 0.1% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. Water levels recorded at Station L1, McClelland Lake, were, with the exception of a short period in November 2011 and May 2012, below the historical minimum for the duration of the 2012 WY.

Water Quality In fall 2012, water quality at *test* station FIR-1 and *baseline* station FIR-2 showed **Negligible-Low** differences from regional *baseline* water quality conditions. The ionic composition of water in fall 2012 at both Firebag River stations and McClelland Lake was consistent with previous sampling years. 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 in fall 2012. 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. Many water quality measurement endpoints, primarily ions and select metals, exceeded previously-measured maximum concentrations at all stations in the Firebag River watershed.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities of McClelland Lake in 2012 were classified as **Negligible-Low** because total abundance was higher in the *test* period than the *baseline* period and although the percentage of fauna as EPT taxa was lower in 2012 than the mean of previous sampling years, it was consistent to 2002, 2003, and 2010. CA Axis 1 scores were significantly different from the *baseline* period and CA Axis 2 scores were different in 2012 than all previous sampling years; however, the composition of the community in terms of relative abundances, included fully aquatic forms and generally sensitive taxa including the mayfly *Caenis* and the caddisfly *Mystacides* suggesting that the community of McClelland Lake was still in good condition and generally similar to *baseline* conditions. The benthic invertebrate community at *baseline* station JOL-1 was indicative of good water and sediment quality conditions due to a the large relative abundance of permanent aquatic forms such as Amphipoda and bivalve clams, the presence of relatively sensitive and large aquatic insect larvae (Ephemeroptera: *Caenis*), and a low relative abundance of worms. Concentrations of sediment quality measurement endpoints at *test* station MCL-1 frequently deviated from historical ranges in fall 2012, generally with lower concentrations of hydrocarbons. The coarser sediment composition and lower total organic carbon content observed in fall 2012 were likely a result of sampling variability and caused concentrations of total metals (normalized to percent fines) and total PAHs (normalized to total organic carbon) to exceed previously measured maximum concentrations at *test* station MCL-1. Sediment toxicity to invertebrates was within previously measured ranges at *test* station MCL-1. Fall 2012 represented the second year of sampling at *baseline* station JOL-1; sediment quality collected at this station was generally similar to sediments collected from *test* station MCL-1, but had higher concentrations of hydrocarbons and total metals than measured at *test* station MCL-1.

5.7.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Firebag River watershed was conducted at the WSC Station 07DC001 (RAMP Station S27), Firebag River near the mouth, which was used for the water balance analysis. Additional hydrometric data for the Firebag River watershed were available from stations L1, McClelland Lake; S43, Firebag River above Suncor Firebag; and S36, McClelland Lake Outlet above the Firebag. Details for each of these stations can be found in Appendix C.

Continuous annual hydrometric data have been collected for the Firebag River near the mouth, WSC Station 07DC001 (RAMP Station S27) from 1972 to 2012. The 2012 WY annual runoff volume was 917 million m^3, which was 16% higher than the historical annual runoff volume of 793 million m^3. The runoff volume in the 2012 open-water period (May to October) was 728 million m^3, which was 23% higher than the historical mean open-water runoff volume of 589 million m^3. Flows from mid-November 2011 to March 2012 generally followed the historical median flows (Figure 5.7-3). Flows increased during freshet in April and early May to a peak flow of 49.5 m^3/s on May 5. Flows remained between the historical lower quartile and historical median values until late May when flows decreased below the historical lower quartile value in early June. Flows exceeded the historical upper quartile in July and exceeded the historical maximum in September due to precipitation in those months. The annual peak flow of 150 m^3/s on September 15 was 28% higher than the annual historical maximum daily flow. Flows decreased following this peak to near upper quartile values until mid-October when flows returned to near historical maximum values for the remainder of the 2012 WY. The minimum open-water daily flow of 19.30 m^3/s recorded on August 12 was 25% higher than the historical open-water mean minimum daily flow of 15.5 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at WSC Station 07DC001 (RAMP Station S27), Firebag River near the mouth, is provided in Table 5.7-2 and described as follows:

1. The closed-circuited land area from focal projects as of 2012 in the Firebag River watershed was estimated to be 13.6 km^2 (Table 2.5-1). The loss of flow to the Firebag River that would have otherwise occurred from this land area was 2.09 million m^3.

2. As of 2012, the area of land change in the Firebag River watershed from focal projects that was not closed-circuited was estimated to be 40.0 km^2 (Table 2.5-1). The increase in flow to the Firebag River that would not have otherwise occurred from this land area was estimated at 1.23 million m^3.

3. Suncor discharged approximately 0.03 million m^3 of water to the Firebag watershed as part of water management activities.

The estimated cumulative effect of land change and water releases was a loss of flow of 0.83 million m^3 to the Firebag River. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.7-3. The 2012 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated were 0.1% 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).

Water levels recorded at Station L1, McClelland Lake, were, with the exception of a short period in November 2011 and May 2012, below the historical minimums for the duration of the 2012 WY (Figure 5.7-4). Following the winter period, lake levels in April increased during freshet to a peak of 294.40 m recorded on April 11, which was the maximum lake level recorded in the 2012 WY. Following the freshet, lake levels steadily decreased from mid-May to early September. The minimum lake level in the 2012 WY was 294.11 m, recorded on September 1, 2012. Lake levels increased during September and October to near historical minimum levels for these months.

5.7.3 Water Quality

In fall 2012, water quality samples were taken from:

- the Firebag River near its mouth (*test* station FIR-1, first sampled in 2002);
- the Firebag River upstream of all focal project development (*baseline* station FIR-2, first sampled in 2003);
- McClelland Lake (*test* station MCL-1, designated as *baseline* from 2000 to 2009 and *test* from 2010 to 2012); 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 2012.

Temporal Trends Significant (α=0.05) decreasing trends in concentrations of total chloride and sulphate were observed in fall over time at *test* station MCL-1 (sampled 2000 to 2003 and 2006 to 2012). A significant increasing trend in the concentration of total nitrogen was observed over time at *baseline* station FIR-2 (2003 to 2012). No significant trends in fall concentrations of water quality measurement endpoints were observed at *test* station FIR-1. Trend analysis could not be conducted on *baseline* station JOL-1 because only two years of data were available.

2012 Results Relative to Historical Concentrations Water quality measurement endpoints that were outside their previously-measured ranges in fall 2012 included (Table 5.7-4 to Table 5.7-7):

- total suspended solids, total arsenic, total boron, and total phosphorus, with concentrations that exceeded previously-measured maximum concentrations at *test* station FIR-1;
- total arsenic, total boron, total mercury (ultra-trace), and total phosphorus, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station FIR-2; and
- conductivity, total suspended solids, and total boron, with concentrations that exceeded previously-measured maximum concentrations at *test* station MCL-1.

Historical comparisons for *baseline* station JOL-1 were not possible given that 2012 was the second year of sampling at this station.

Ion Balance The ionic composition of water sampled in fall 2012 at *test* station FIR-1 and *baseline* station FIR-2 were similar to previous years (Figure 5.7-5). The ionic composition of water at these stations has remained consistent since monitoring began in 2002, with the exception of *baseline* station FIR-2 in 2007, when lower relative concentrations of calcium were measured. The ionic composition of water at *test* station MCL-1 in fall 2012 was consistent with that of previous years and dominated by magnesium and bicarbonate (Figure 5.7-5). Water at *baseline* station JOL-1 has an ionic composition similar to *test* station FIR-1 and *baseline* station FIR-2 (Figure 5.7-5), although absolute concentrations of several ions in Johnson Lake were generally higher than those at the other three stations in the watershed (e.g., calcium and chloride).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in fall 2012 were below water quality guidelines, with the exception of total nitrogen at *baseline* station JOL-1 (Table 5.7-7) and *test* station MCL-1 (Table 5.7-6), dissolved phosphorus at *baseline* station FIR-2, and total aluminum at *test* station FIR-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in fall 2012 (Table 5.7-8):

- total iron, dissolved iron, total phenols, and total phosphorus at *test* station FIR-1;
- total iron, dissolved iron, sulphide, total phosphorous, and total phenols at *baseline* station FIR-2;
- total phenols at *test* station MCL-1; and
- total phenols at *baseline* station JOL-1.

The following water quality guideline exceedances were measured in other seasons at *baseline* station JOL-1 (Table 5.7-8):

- sulphide, total iron, and total nitrogen in winter; and
- sulphide and total nitrogen in summer.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints at *test* station FIR-1 and *baseline* station FIR-2 in fall 2012 were within regional *baseline* concentrations, with the following exceptions (Figure 5.7-6):

- total mercury (ultra-trace), with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station FIR-1; and
- dissolved phosphorus, with a concentration that exceeded the 95th 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* conditions given the ecological differences between lakes and rivers (Figure 5.7-7). A range of regional *baseline* conditions was not calculated for lakes that are sampled by RAMP due to the limited *baseline* data available.

Water Quality Index The WQI values for *test* station FIR-1 (98.7) and *baseline* station FIR-2 (98.7) in the Firebag River watershed in fall 2012 indicated **Negligible-Low** differences from regional *baseline* conditions, and were similar to WQI values from previous years. 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 2012, water quality at *test* station FIR-1 and *baseline* station FIR-2 showed **Negligible-Low** differences from regional *baseline* water quality conditions. The ionic composition of water in fall 2012 at both Firebag River stations and McClelland Lake was consistent with previous sampling years. 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 in fall 2012. Concentrations of water quality measurement endpoints from *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. Several water quality measurement endpoints, primarily ions and select metals, exceeded previously-measured maximum concentrations at all stations in the Firebag River watershed.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2003 and 2006 to 2009 and as *test* from 2010 to 2012; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

McClelland Lake

2012 Habitat Conditions Samples were taken at a depth of 2.0 m in McClelland Lake. The substrate was primarily comprised of sand (91%), with moderate organic carbon content (TOC: 4%). Water in McClelland Lake was alkaline (pH=10.28), with moderate conductivity (233 µS/cm), which was consistent with what was observed in previous years.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* station MCL-1 in fall 2012 was dominated by cladocerans (37%), chironomids (16%), and Ostracoda (15%) (Table 5.7-10). Bivalve clams (*Pisidium/Sphaerium*), gastropod snails (*Gyraulus*), mayflies (*Caenis*), and caddisflies (*Mystacides*) were present in low relative abundances (Table 5.7-10). Dominant chironomids included *Tanytarsus*, *Cladotanytarsus*, *Stempellinella,* and *Procaldius,* all of which are very common in north temperate lakes (Wiederholm 1983).

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.

Temporal comparisons for *test* station MCL-1 included testing for:

- changes from before (2002 to 2009) to after (2010 to present) the reach became *test* (Hypothesis 2, Section 3.2.3.1);
- changes over time in the *test* period (i.e., since 2010);

- changes between 2012 values and the mean of all *baseline* years; and
- changes between 2012 values and the mean of all previous years of sampling.

Abundance was significantly higher during the *test* period at *test* station MCL-1, explaining 21% of the variance in annual means (Table 5.7-11). The percentage of the fauna as EPT taxa was significantly lower in 2012 than the mean of all *baseline* years (2002 to 2009) and the mean of all previous years of sampling at *test* station MCL-1 (Table 5.7-11), explaining 40 and 34% of the variance in annual means, respectively.

CA Axis 1 scores were significantly higher during the *test* period, reflecting a decrease in the relative abundance of gastropods and amphipods, and an increase in the relative abundance of ostracods and water mites (Hydracarina) (Figure 5.7-8).

CA Axis 2 scores were significantly lower in 2012 than the mean of all previous years of sampling, reflecting an increase in the relative abundance of Ostracoda in 2012 (Figure 5.7-9). This difference accounted for 25% of the variance in annual means (Table 5.7-11).

Comparison to Published Literature The benthic invertebrate community at *test* station MCL-1 had a fauna relatively typical of lake environments, with a water depth of 2 m (Parsons et al. 2010, Pennak 1986). McClelland Lake contained several taxa considered to be permanent aquatic forms, including bivalves and gastropods in addition to flying insects (Ephemeroptera and Trichoptera), which indicated good long-term water quality (Niemi et al. 1990).

2012 Results Relative to Historical Conditions Mean values of all measurement endpoints for benthic invertebrate communities in fall 2012 at *test* station MCL-1 were within the range of values from *baseline* years (Figure 5.7-9), with the exception of percent EPT, which was slightly lower in 2012 than previously measured for the lake (Figure 5.7-9). CA Axis 1 scores were slightly higher than the *baseline* range of values observed in McClelland Lake (Figure 5.7-8).

Classification of Results Differences in benthic invertebrate communities of McClelland Lake in 2012 were classified as **Negligible-Low** because total abundance was higher in the *test* period than the *baseline* period and although the percentage of fauna as EPT taxa was lower 2012 than the mean of all previous years of sampling, it was consistent with 2002, 2003, and 2010. CA Axis 1 scores were significantly different from the *baseline* period and CA Axis 2 scores were different in 2012 than all previous years; however, the composition of the community in terms of relative abundances, included fully aquatic forms and generally sensitive taxa including the mayfly *Caenis* and the caddisfly *Mystacides* suggesting that the community of McClelland Lake was still in good condition and generally similar to *baseline* conditions.

Johnson Lake

2012 Habitat Conditions Samples were taken at a depth of 2 m at *baseline* station JOL-1. The substrate at *baseline* station JOL-1 consisted primarily of silt (60%) with smaller amounts of sand (21%) and clay (19%) and high total organic carbon content (23%) (Table 5.7-9). Water in Johnson Lake in fall 2012 was slightly alkaline (pH = 8.1), with moderate conductivity (260 µS/cm) (Table 5.7-9).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *baseline* station JOL-1 in fall 2012 was dominated by chironomids (53%) and amphipods (21%), with subdominant taxa consisting of bivalves (7%) and ostracods

(5%) (Table 5.7-10). Amphipods included *Hyalella azteca* and *Gammarus lacustris*, both of which are commonly distributed in Canada (Väinölä et al. 2008). Bivalves (*Pisidium/Sphaerium*) and gastropods (*Valvata tricarinata*) were also observed in low relative abundances. Chironomids were diverse with 12 genera, with a dominance of common (Wiederholm, 1983) forms including *Microtendipes*, *Procladius,* and *Glyptotendipes.* One individual mayfly (*Caenis*) was found, but contrary to 2011, there were no caddisflies observed (Table 5.7-10).

Comparison to Published Literature The benthic invertebrate community at *baseline* station JOL-1 contained a benthic fauna in 2012 that reflected generally good water quality and lentic (lake-like) conditions. The benthic community contained several permanent aquatic forms including Amphipoda (21%) and fingernail clams (Bivalvia: Sphaeriidae), which were consistent with good long-term water quality (Niemi et al. 1990, Pennak 1989). Ephemeroptera were present and the overall abundance of worms (Enchytaeidae, Naididae, and Lumbriculidae) was low (<7% total).

2012 Results Relative to Historical Conditions Mean values of all measurement endpoints for benthic invertebrate communities in fall 2012 at *baseline* station JOL-1 were similar to what was observed in 2011 (Figure 5.7-10, Figure 5.7-11).

Classification of Results The benthic invertebrate community at *baseline* station JOL-1 was indicative of good water and sediment quality conditions due to the large relative abundance of permanent aquatic forms such as Amphipoda and bivalve clams, the presence of relatively sensitive and large aquatic insect larvae (Ephemeroptera: *Caenis*), and a low relative abundance of worms.

5.7.4.2 Sediment Quality

In fall 2012, sediment quality samples were collected from:

- McClelland Lake (*test* station MCL-1 as *baseline* in 2002, 2003, and 2006 to 2009, and as *test* from 2010 to 2012); and
- Johnson Lake (*baseline* station JOL-1, sampled since 2011).

Temporal Trends Significant decreasing trends (α=0.05) in concentrations of Fraction-1 (C6-C10) hydrocarbons and total arsenic were observed in fall over time at *test* station MCL-1; however, when results from 1998 to 2001 (when detection limits for arsenic were significantly higher than presently measured) were removed, no significant trend in arsenic was detected. Trend analysis could not be completed for *baseline* station JOL-1, given only two years of data exist for this station.

2012 Results Relative to Historical Concentrations Sediments collected at *test* station MCL-1 and *baseline* station JOL-1 in fall 2012 were dominated by sand (Table 5.7-12 and Figure 5.7-12, Table 5.7-13 and Figure 5.7-13). Particle size distribution at *test* station MCL-1 in 2012 was much coarser than in previous years, exceeding the previously measured maximum proportion of sand, while clay and silt made up a lower proportion of the sediment than previously measured. The concentration of total metals measured in absolute terms was lower than the previously-measured minimum concentration at *test* station MCL-1; however, the concentration of total metals normalized to the percentage of silt plus clay was higher than the previously-measured maximum concentration due to the much smaller proportion of silt and clay observed in 2012. The concentration of total organic carbon was below the previously-measured minimum concentration at *test* station MCL-1.

Concentrations of Fraction 1 and Fraction 2 hydrocarbons and BTEX (benzene, toluene, ethylene, and xylene) were not detectable in fall 2012 at either station (Table 5.7-12 and Table 5.7-13). The concentration of total PAHs in sediment was below the previously-measured minimum concentration, while the carbon-normalized total PAHs were higher than the previously-measured maximum concentration at *test* station MCL-1, which was likely related to the observed low TOC content and coarser sediments observed in fall 2012 compared to previous years (Figure 5.7-12). The predicted PAH toxicity in fall 2012 was low at both stations and within the range of historical values at *test* station MCL-1. Concentrations of all other sediment quality measurement endpoints were within previously-measured ranges at *test* station MCL-1, with the exception of naphthalene, retene, total dibenzothiophenes, total parent PAHs, and total alkylated PAHs, which were below previously-measured minimum concentrations.

Direct tests of sediment toxicity to invertebrates at *test* station MCL-1 and *baseline* station JOL-1 indicated high survival of the amphipod *Hyalella* and the midge *Chironomus* (≥88%), consistent with historical results. Ten-day growth of *Chironomus* and 14-day growth of *Hyalella* were within previously observed values at *test* station MCL-1 (Table 5.7-12). Sediment toxicity measurement endpoints of growth and survival were similar between *test* station MCL-1 and *baseline* station JOL-1 (Table 5.7-12 and Table 5.7-13).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of hydrocarbons, PAHs, and metals at *test* station MCL-1 or *baseline* station JOL-1 did not exceed relevant sediment or soil quality guidelines in fall 2012, with the exception of Fraction 1, 2, and 3 hydrocarbons at *baseline* station JOL-1. However, Fraction 1 and Fraction 2 hydrocarbons at *baseline* station JOL-1 were reported as undetectable values with detection limits above relevant sediment quality guidelines.

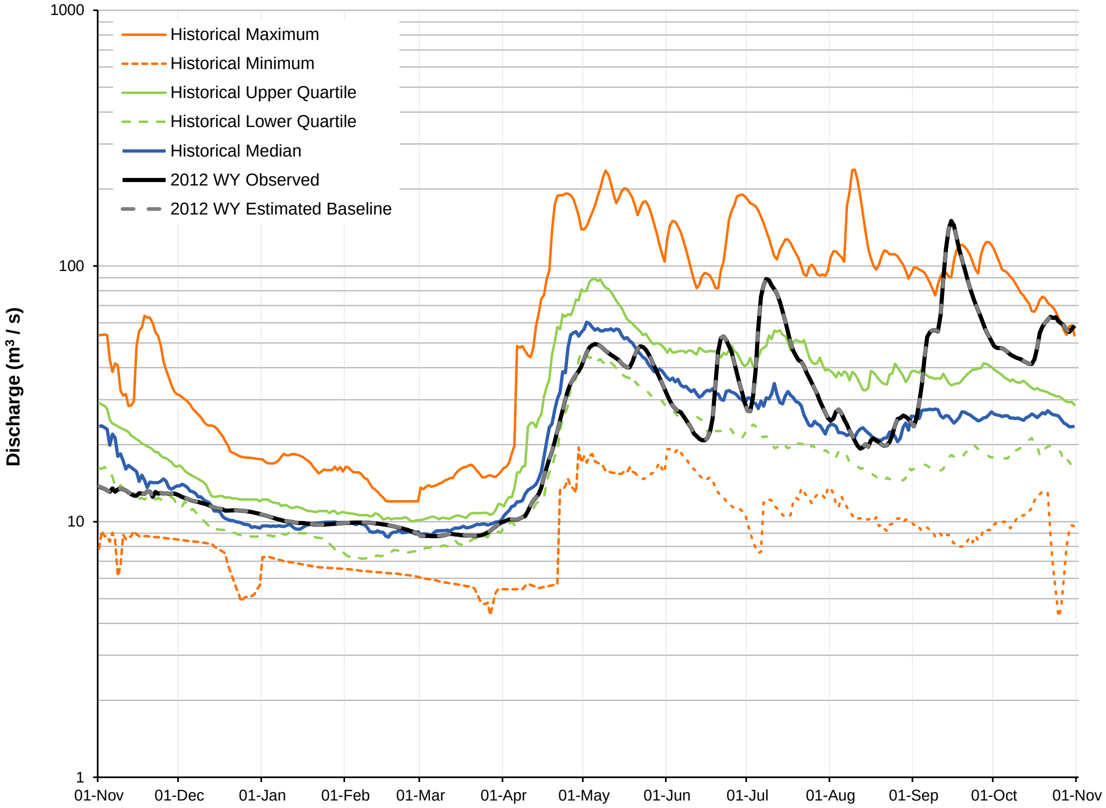
Sediment Quality Index SQI values were not calculated for *test* station MCL-1 or *baseline* station JOL-1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Classification of Results Concentrations of sediment quality measurement endpoints at *test* station MCL-1 frequently deviated from historical ranges in fall 2012, generally with lower concentrations of hydrocarbons. The coarser sediment composition and lower total organic carbon content observed in fall 2012 were likely a result of sampling variability and caused concentrations of total metals (normalized to percent fines) and total PAHs (normalized to total organic carbon) to exceed previously measured maximum concentrations at *test* station MCL-1. Sediment toxicity to invertebrates was within previously-measured ranges at *test* station MCL-1. Fall 2012 represented the second year of sampling at *baseline* station JOL-1; sediment quality collected at this station was generally similar to sediments collected from *test* station MCL-1, but had higher concentrations of hydrocarbons and total metals than measured at *test* station MCL-1.

5.7.5 Fish Populations

There were no Fish Populations component activities conducted in the Firebag River watershed in 2012.

Figure 5.7-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Firebag River in the 2012 WY, compared to historical values.



Note: Observed 2012 WY hydrograph based on provisional data for Firebag River near the mouth, WSC Station 07DC001 (March 1 to October 31, 2012) and on data for RAMP Station S27 for other months in the 2012 WY. The upstream drainage area is 5,988 km^2. Historical values calculated for the period from 1972 to 2011.

Table 5.7-2 Estimated water balance at WSC Station 07DC001 (RAMP Station S27), Firebag River near the mouth, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**917.31**	**Observed discharge, obtained from Firebag River near the mouth, WSC Station 07DC001 (RAMP Station S27)**
Closed-circuited area water loss from the observed hydrograph	-2.09	Estimated 13.6 km^2 of the Firebag River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+1.23	Estimated 40.0 km^2 of the Firebag River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Firebag River watershed from focal projects	0.00	None reported
Water releases into the Firebag River watershed from focal projects	+0.034	Approximately 0.034 million m^3 of water released by Suncor Firebag for water management activities (daily values provided)
Diversions into or out of the watershed	0.00	None reported
The difference between observed and estimated hydrographs on tributary streams	0.00	No focal projects on tributaries of Firebag River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**918.14**	**Estimated *baseline* discharge at Firebag River near the mouth, WSC Station 07DC001 (RAMP Station S27)**
Incremental flow (change in total discharge)	-0.83	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-0.09%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for March 1 to October 31, 2012 for Firebag River near the mouth, WSC Station 07DC001, and on RAMP Station S27 for other months in the 2012 WY.

Table 5.7-3 Calculated change in hydrologic measurement endpoints for the Firebag River near the mouth, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	45.83	45.79	-0.01%
Mean winter discharge	10.62	10.61	-0.01%
Annual maximum daily discharge	150.14	150.00	-0.01%
Open-water season minimum daily discharge	19.32	19.30	-0.01%

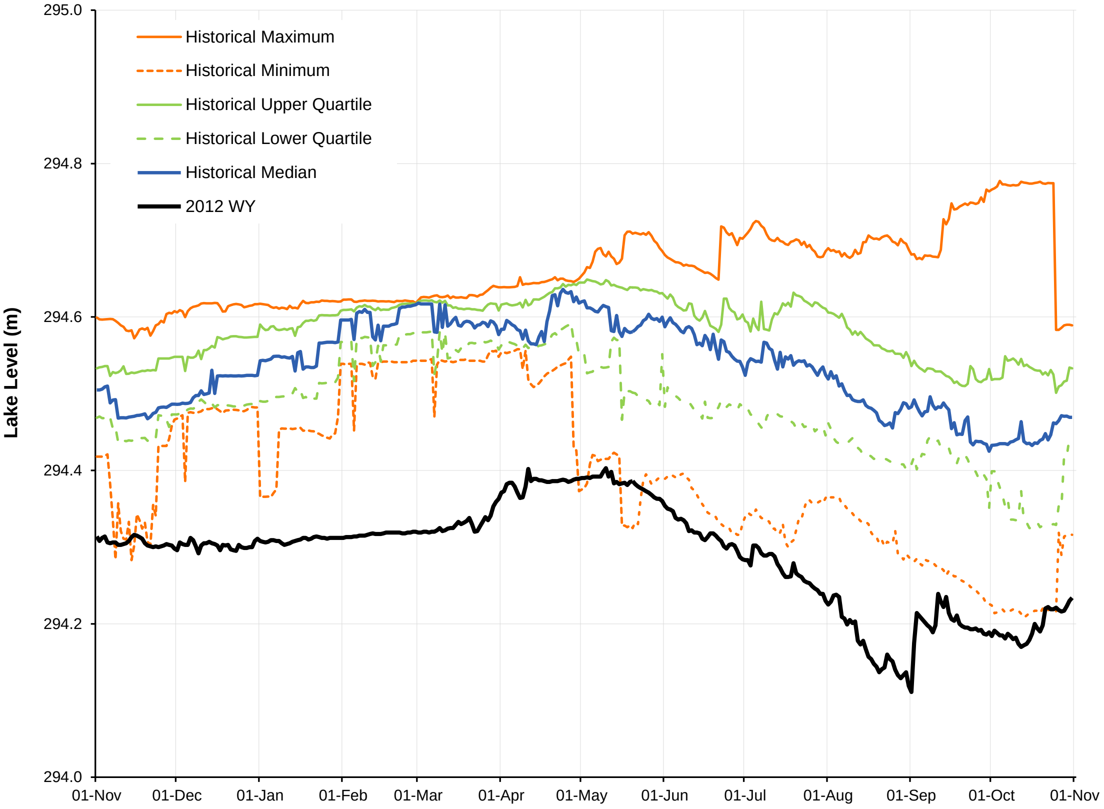
Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for March 1 to October 31, 2012 for Firebag River near the mouth, WSC Station 07DC001, and on RAMP Station S27 for other months in the 2012 WY.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to two 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 McClelland Lake water level data for the 2012 WY, compared to historical values.



Note: Observed 2012 WY record based on McClelland Lake, RAMP Station L1 2012 provisional data. Historical values calculated for the period from 1997 to 2011 with numerous periods of missing data over the data record.

Note: Maximum and minimum data values are calculated based on the data record which includes numerous data gaps.

Table 5.7-4 Concentrations of water quality measurement endpoints, mouth of the Firebag River (*test* station FIR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	10	7.9	8.2	8.5
Total suspended solids	mg/L	-	23	10	<3	6	21
Conductivity	µS/cm	-	230	10	171	207	248
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.028	10	0.012	0.031	0.057
Total nitrogen	mg/L	1	0.701	10	0.361	0.600	**1.700**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	12.4	10	8.0	13.4	16.2
Ions							
Sodium	mg/L	-	3.5	10	2.0	4.0	4.6
Calcium	mg/L	-	30.8	10	22.6	30.2	33.2
Magnesium	mg/L	-	8.5	10	6.8	8.9	9.7
Chloride	mg/L	120	1.4	10	1.0	2.0	3.1
Sulphate	mg/L	270	1.8	10	1.7	3.0	10.3
Total dissolved solids	mg/L	-	108	10	60	145	170
Total alkalinity	mg/L		117	10	85	109	124
Selected metals							
Total aluminum	mg/L	0.1	**0.23**	10	0.03	0.08	**0.43**
Dissolved aluminum	mg/L	0.1	0.003	10	0.002	0.005	0.009
Total arsenic	mg/L	0.005	0.00062	10	0.00028	0.00044	0.00056
Total boron	mg/L	1.2	0.022	10	0.014	0.017	0.021
Total molybdenum	mg/L	0.073	0.00015	9	0.00011	0.00014	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	2.70	9	0.60	<1.20	<4.40
Total strontium	mg/L	-	0.078	9	0.051	0.069	0.083
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	-	0.34	1	-	0.44	-
Oilsands Extractable	mg/L	-	0.86	1	-	0.89	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	3.43	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	58.15	1	-	9.11	-
Total PAHs	ng/L	-	344.1	1	-	176.8	-
Total Parent PAHs	ng/L	-	22.27	1	-	23.48	-
Total Alkylated PAHs	ng/L	-	321.8	1	-	153.3	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**1.40**	10	0.39	0.79	1.40
Total phosphorus	mg/L	0.05	**0.094**	10	0.027	0.053	0.093
Dissolved iron	mg/L	0.3	**0.301**	10	0.056	0.337	0.540
Total phenols	mg/L	0.004	**0.005**	9	0.001	0.004	0.007

[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 5.7-5 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (*baseline* station FIR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	10	7.4	8.1	8.3
Total suspended solids	mg/L	-	<3	10	<3	4	8
Conductivity	µS/cm	-	194	10	113	170	261
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.069**	10	0.009	**0.057**	**0.096**
Total nitrogen	mg/L	1	0.80	9	0.50	0.70	**1.28**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	15.4	10	8.0	13.6	17.4
Ions							
Sodium	mg/L	-	3.2	10	2.0	4.0	16.0
Calcium	mg/L	-	22.8	10	16.4	24.7	28.4
Magnesium	mg/L	-	6.3	10	5.1	6.8	8.7
Chloride	mg/L	120	0.6	10	0.5	1.0	2.0
Sulphate	mg/L	270	0.9	10	0.8	1.8	22.6
Total dissolved solids	mg/L	-	117	10	110	137	158
Total alkalinity	mg/L		98.8	10	57.0	90.2	114.0
Selected metals							
Total aluminum	mg/L	0.1	0.064	10	0.015	0.035	0.082
Dissolved aluminum	mg/L	0.1	0.007	10	0.001	0.004	0.011
Total arsenic	mg/L	0.005	0.00062	10	0.00010	0.00057	0.00060
Total boron	mg/L	1.2	0.035	10	0.008	0.013	0.024
Total molybdenum	mg/L	0.073	0.00017	10	0.00004	0.00019	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	2.2	9	<0.6	<1.2	1.7
Total strontium	mg/L	-	0.059	10	0.028	0.049	0.068
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	-	0.27	1	-	0.06	-
Oilsands Extractable	mg/L	-	0.99	1	-	0.91	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	1.21	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	5.84	-
Total PAHs	ng/L	-	206.3	1	-	151.2	-
Total Parent PAHs	ng/L	-	16.49	1	-	19.21	-
Total Alkylated PAHs	ng/L	-	189.8	1	-	132.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phosphorus	mg/L	0.05	**0.137**	10	0.047	**0.097**	**0.134**
Dissolved iron	mg/L	0.3	**0.532**	10	0.052	**0.344**	**0.886**
Sulphide	mg/L	0.002	**0.004**	10	<0.002	**0.004**	**0.009**
Total iron	mg/L	0.3	**1.170**	10	0.240	**0.637**	**1.390**
Total phenols	mg/L	0.004	**0.006**	10	<0.001	**0.004**	**0.015**

[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 5.7-6 Concentrations of water quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	10	8.1	8.5	8.7
Total suspended solids	mg/L	-	<u>9.0</u>	10	<3	<3	7
Conductivity	µS/cm	-	<u>267</u>	10	224	239	256
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.013	10	0.002	0.004	0.013
Total nitrogen	mg/L	1	**1.04**	10	0.55	**1.00**	**2.00**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	14.7	10	11.0	13.0	17.0
Ions							
Sodium	mg/L	-	5.0	10	4.0	4.6	6.0
Calcium	mg/L	-	20.3	10	19.3	21.7	25.8
Magnesium	mg/L	-	17.0	10	14.6	16.6	18.0
Chloride	mg/L	120	<0.5	10	<0.5	<1.0	<1.0
Sulphate	mg/L	270	<0.5	10	0.5	0.8	4.3
Total dissolved solids	mg/L	-	143	10	80	158	194
Total alkalinity	mg/L		144	10	122	129	145
Selected metals							
Total aluminum	mg/L	0.1	0.014	10	0.003	0.013	0.026
Dissolved aluminum	mg/L	0.1	0.001	10	<0.001	<0.001	0.010
Total arsenic	mg/L	0.005	0.00023	10	0.00019	0.00021	<0.0010
Total boron	mg/L	1.2	<u>0.089</u>	10	0.051	0.065	0.070
Total molybdenum	mg/L	0.073	<0.0001	10	<0.00001	<0.00003	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	1.0	7	<0.6	<1.2	2.4
Total strontium	mg/L	-	0.11	10	0.11	0.13	0.15
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	-	0.09	1	-	0.38	-
Oilsands Extractable	mg/L	-	0.45	1	-	1.14	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	12.50	1	-	<14.13	-
Retene	ng/L	-	<0.51	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	6.62	-
Total PAHs	ng/L	-	221.5	1	-	165.2	-
Total Parent PAHs	ng/L	-	20.63	1	-	20.47	-
Total Alkylated PAHs	ng/L	-	200.8	1	-	144.8	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phenols	mg/L	0.004	**0.0064**	10	<0.0010	0.0030	**0.0225**

[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 5.7-7 Concentrations of water quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.2	8.4
Total suspended solids	mg/L	-	3	61
Conductivity	µS/cm	-	323	341
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.004	0.013
Total nitrogen	mg/L	1	**1.20**	**2.20**
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	12.2	14.6
Ions				
Sodium	mg/L	-	5.8	6.6
Calcium	mg/L	-	37.8	41.6
Magnesium	mg/L	-	13.5	15.8
Chloride	mg/L	120	4.75	6.07
Sulphate	mg/L	270	1.02	1.49
Total dissolved solids	mg/L	-	199	236
Total alkalinity	mg/L		165	172
Selected metals				
Total aluminum	mg/L	0.1	0.012	**0.132**
Dissolved aluminum	mg/L	0.1	<0.001	0.016
Total arsenic	mg/L	0.005	0.00023	0.00039
Total boron	mg/L	1.2	0.17	0.25
Total molybdenum	mg/L	0.073	0.00010	0.00014
Total mercury (ultra-trace)	ng/L	5, 13	0.9	1.8
Total strontium	mg/L	-	0.11	0.14
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	-	0.11	0.22
Oilsands Extractable	mg/L	-	0.45	1.54
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	9.36	<14.13
Retene	ng/L	-	0.64	17.30
Total dibenzothiophenes	ng/L	-	35.30	6.66
Total PAHs	ng/L	-	212.0	168.5
Total Parent PAHs	ng/L	-	17.55	19.74
Total Alkylated PAHs	ng/L	-	194.4	148.7
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Total phenols	mg/L	0.004	**0.0062**	**0.0063**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Figure 5.7-5 Piper diagram of fall ion concentrations in the Firebag River watershed, fall 2012.

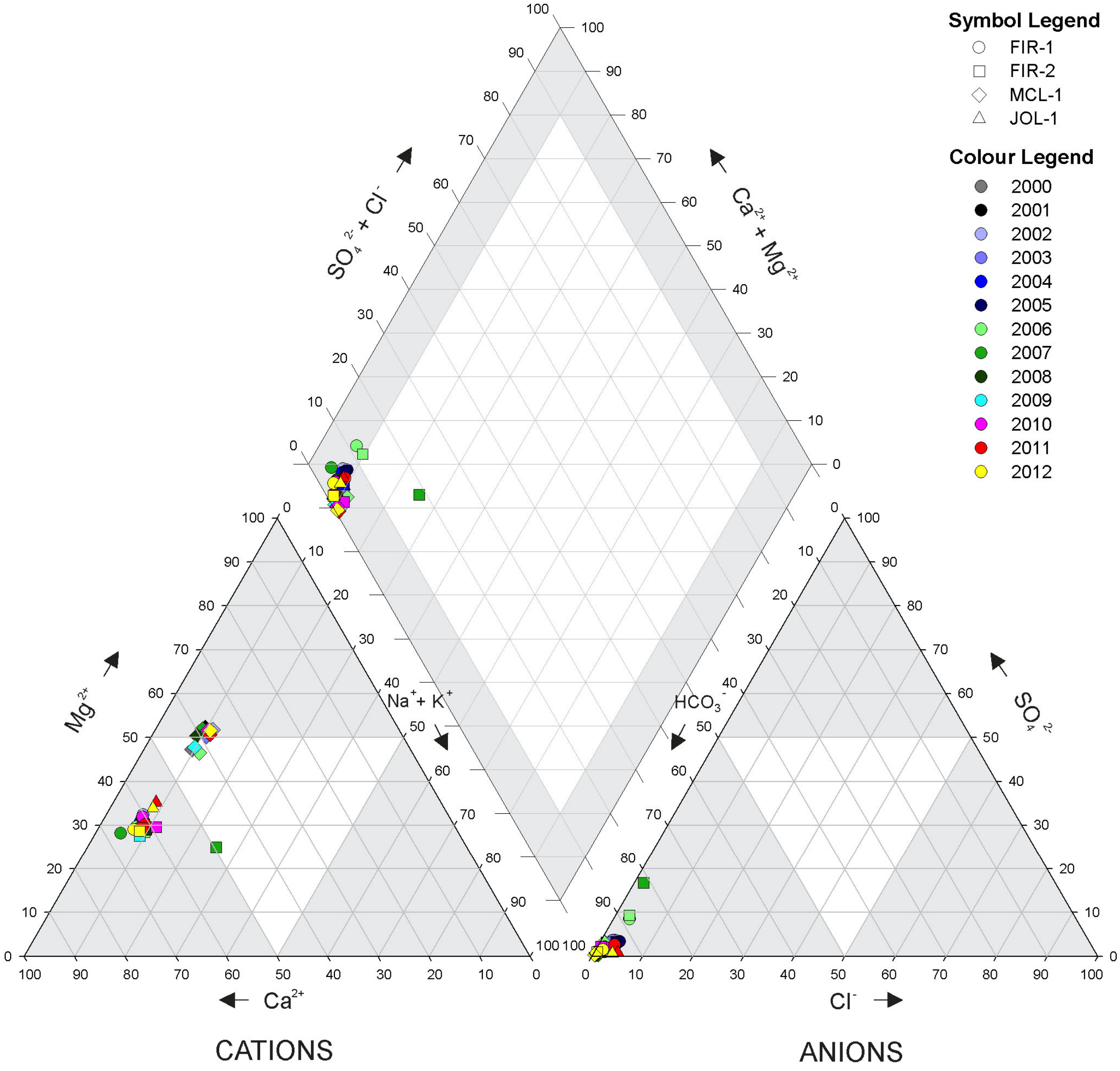


Table 5.7-8 Water quality guideline exceedances, Firebag River watershed, 2012.

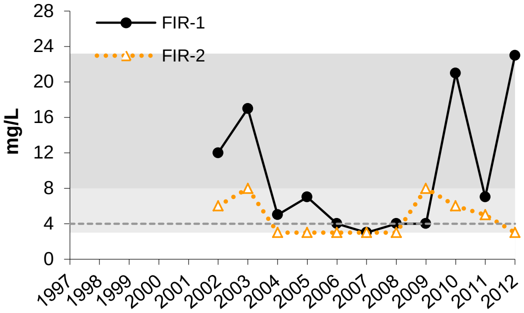
Variable	Units	Guideline[a]	FIR-1	FIR-2	MCL-1	JOL-1
Winter						
Sulphide	mg/L	0.002	ns	ns	ns	0.003
Total iron	mg/L	0.3	ns	ns	ns	1.5
Total nitrogen	mg/L	1	ns	ns	ns	1.64
Summer						
Sulphide	mg/L	0.002	ns	ns	ns	0.007
Total nitrogen	mg/L	1	ns	ns	ns	1.05
Fall						
Dissolved iron	mg/L	0.3	0.301	0.532	-	-
Dissolved phosphorus	mg/L	0.05	-	0.069	-	-
Sulphide	mg/L	0.002	-	0.004	-	-
Total aluminum	mg/L	0.1	0.229	-	-	-
Total iron	mg/L	0.3	1.40	1.17	-	-
Total nitrogen	mg/L	1	-	-	1.04	1.20
Total phenols	mg/L	0.004	0.005	0.006	0.006	0.006
Total phosphorus	mg/L	0.05	0.094	0.137	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

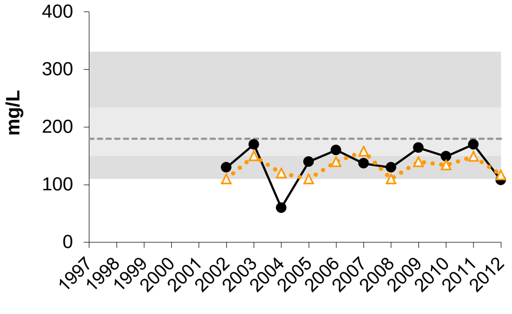
ns = not sampled

Figure 5.7-6 Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2012) relative to historical concentrations and regional *baseline* fall concentrations.

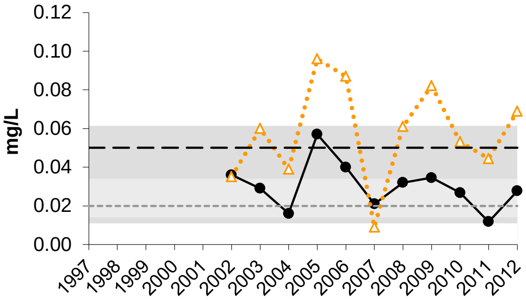
Total Suspended Solids (TSS)



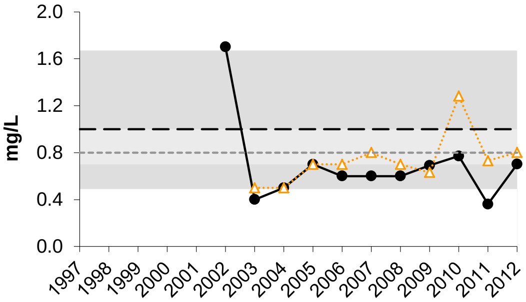
Total Dissolved Solids (TDS)



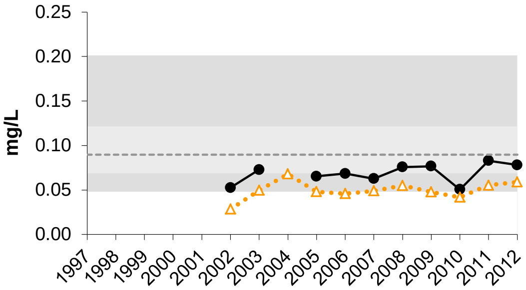
Dissolved Phosphorus



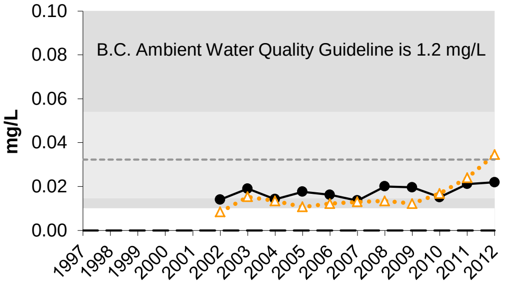
Total Nitrogen



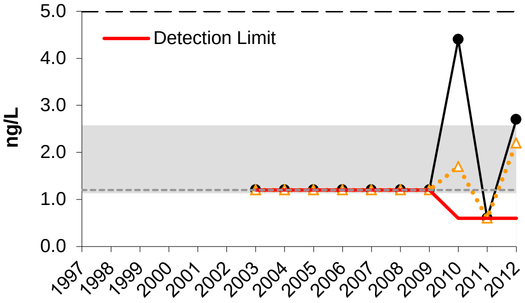
Total Strontium



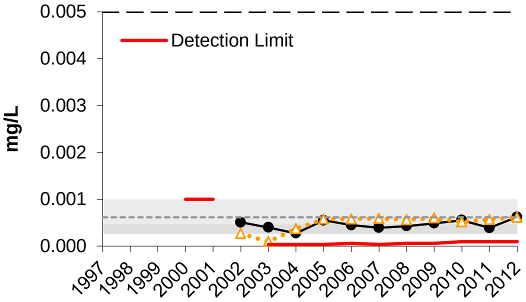
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



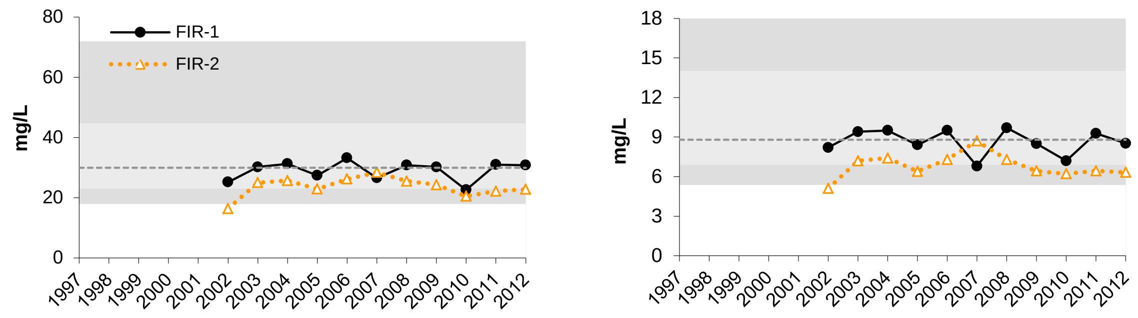
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

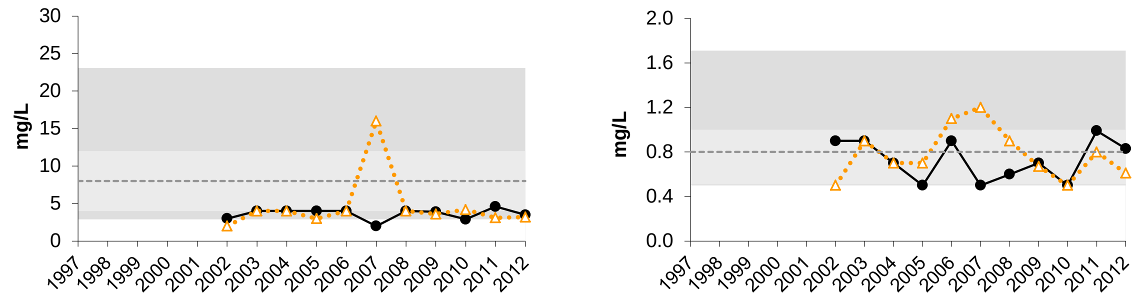
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

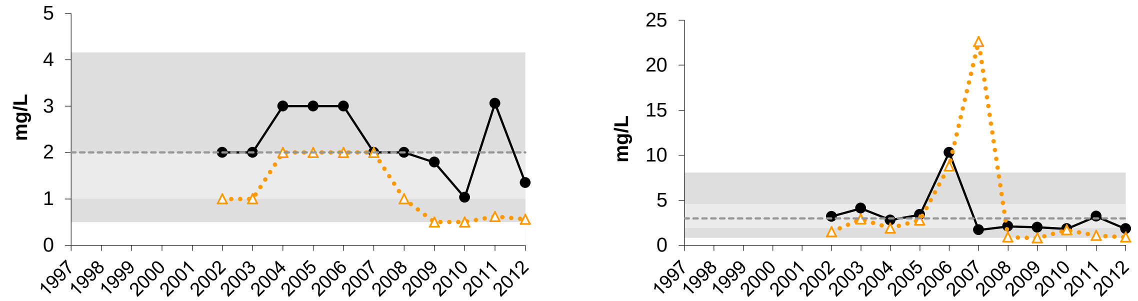
Figure 5.7-6 (Cont'd.)


Calcium

Magnesium


Sodium

Potassium


Chloride

Sulphate

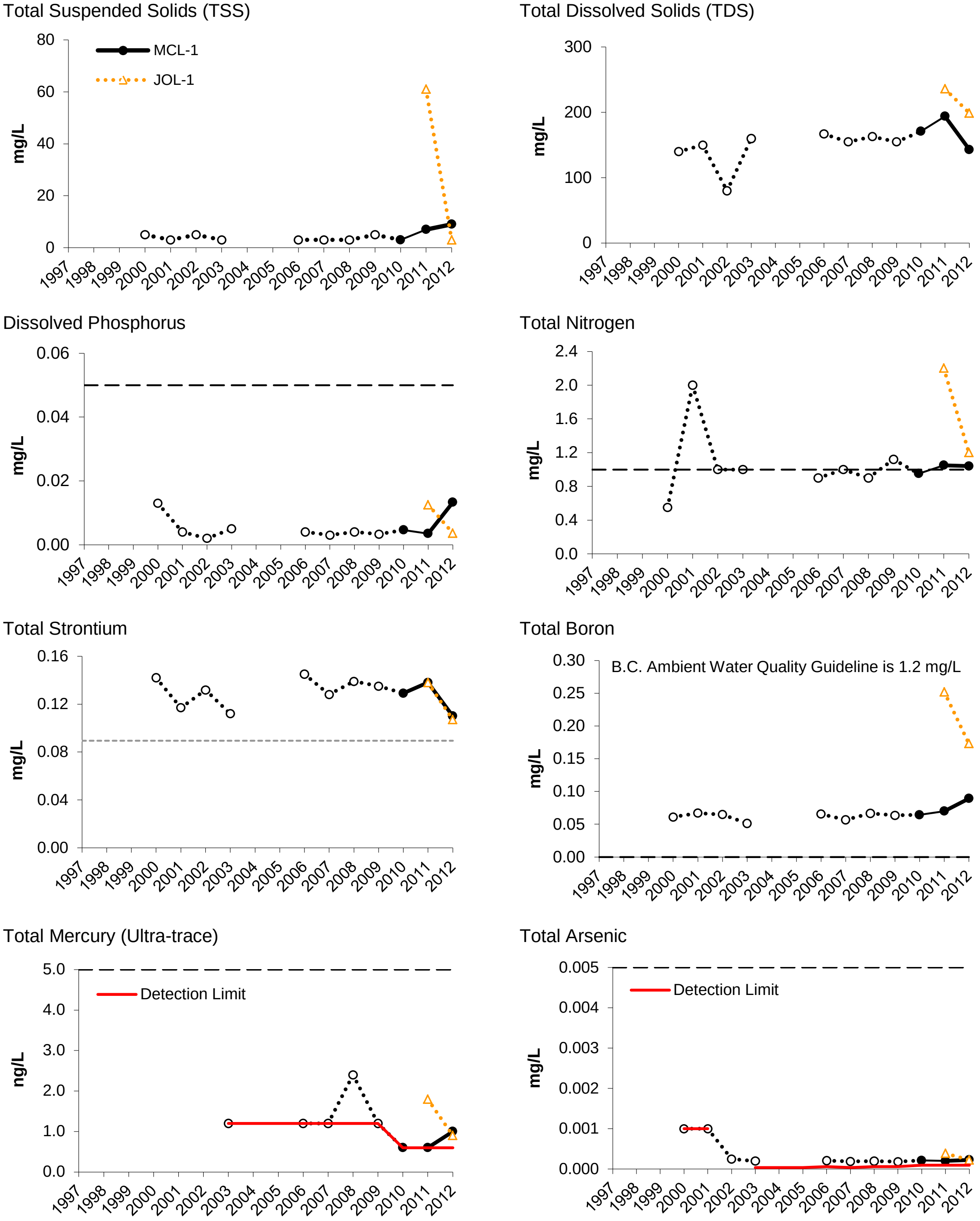
Non-detectable values are shown at the detection limit.

– – – – – 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.7-7 Concentrations of selected water quality measurement endpoints in McClelland Lake and Johnson Lake (fall 2012) relative to historical concentrations.



Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

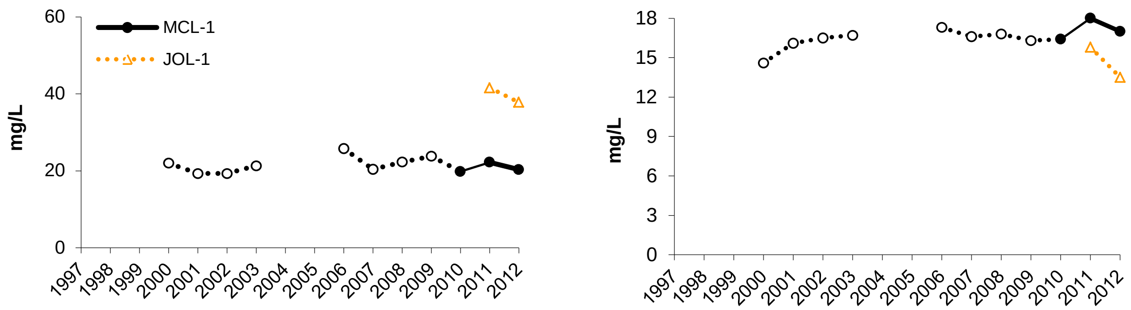
Total Arsenic

Non-detectable values are shown at the detection limit.

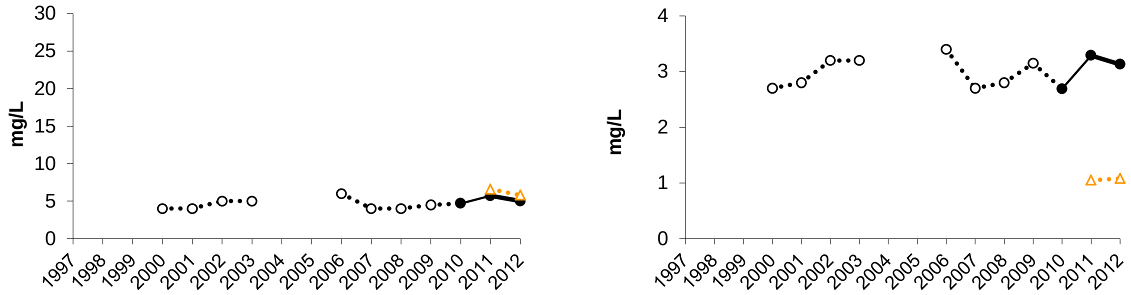
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

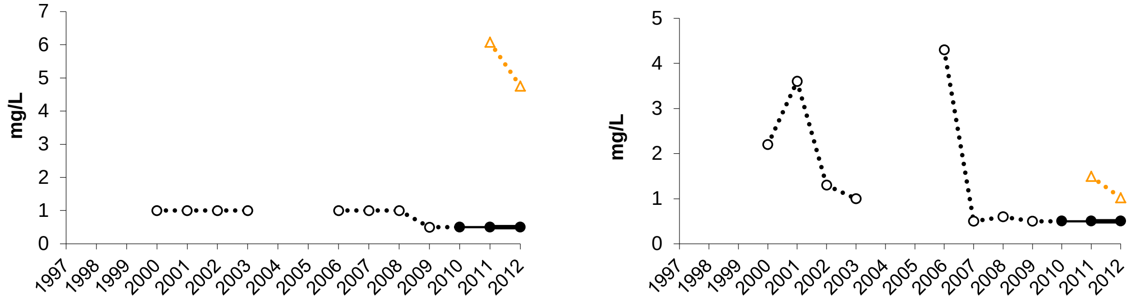
Figure 5.7-7 (Cont'd.)


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

Table 5.7-9 Average habitat characteristics of benthic invertebrate sampling locations in McClelland Lake and Johnson Lake, fall 2012.

Variable	Units	McClelland Lake	Johnson Lake
Sample date	-	09-Sept-2012	13-Sept-2012
Habitat	-	Depositional	Depositional
Water depth	m	2.2	2.0
Field Water Quality			
Dissolved oxygen	mg/L	8.7	8.5
Conductivity	µS/cm	233	260
pH	pH units	10.28	8.05
Water temperature	°C	17.9	10.8
Sediment Composition			
Sand	%	91	21
Silt	%	7	60
Clay	%	2	19
Total Organic Carbon	%	4.13	23.47

Table 5.7-10 Summary of major taxon abundances of benthic invertebrate community measurement endpoints in McClelland Lake and Johnson Lake.

Taxon	Percent Major Taxa Enumerated in Each Year				
	McClelland Lake			Johnson Lake	
	2002	2003 to 2011	2012	2011	2012
Nematoda	1	0 to 4	5	1	<1
Erpobdellidae	1	0 to <1	<1	<1	1
Glossiphoniidae		0 to <1	<1	<1	1
Naididae	14	2 to 17	1	<1	2
Enchytraeidae			<1		<1
Tubificidae		0 to 6	4	3	4
Lumbriculidae		0 to 8	<1		<1
Hydracarina	1	0 to 12	<1	<1	2
Amphipoda	11	0 to 22	3	37	21
Ostracoda	10	1 to 29	15	3	5
Cladocera	<1	0 to 14	37		<1
Copepoda		0 to 13	8	1	1
Gastropoda	<1	0 to 22	3	<1	<1
Bivalvia	2	1 to 9	4	19	7
Ceratopogonidae		0 to 1	1	1	
Chironomidae	58	24 to 91	16	33	53
Ephemeroptera	1	<1 to 12	<1		<1
Anisoptera		0 to 1			
Zygoptera		0 to 1			
Chaoboridae				<1	<1
Trichoptera	1	0 to 3	<1	<1	
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	6,352	3,504 to 107,273	13,918	10,613	18,204
Richness	11	6 to 24	14	11	11
Simpson's Diversity	0.71	0.66 to 0.87	0.72	0.69	0.62
Equitability	0.51	0.22 to 0.73	0.39	0.44	0.46
% EPT	2	1 to 10	<1	<1	<1

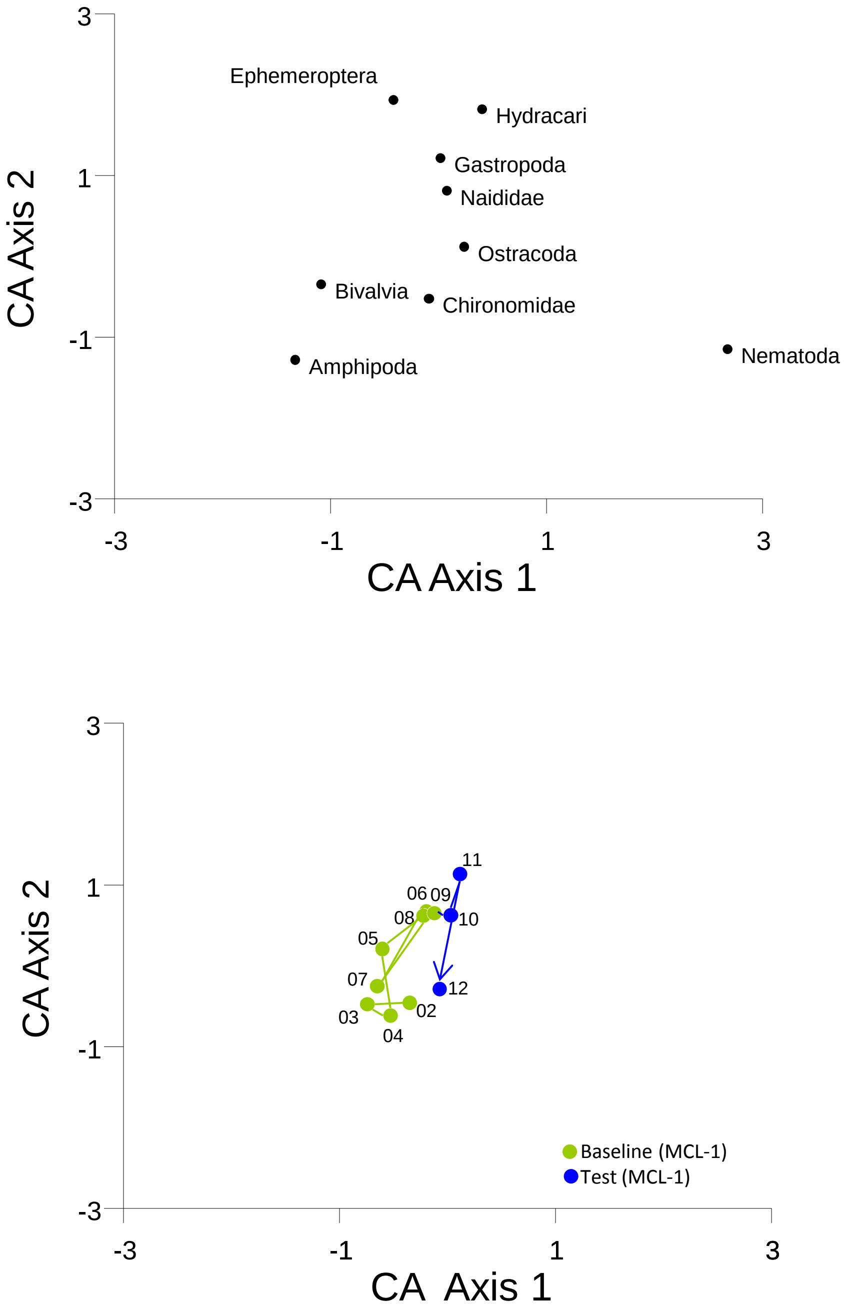
Table 5.7-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in McClelland Lake.

Variable	**P-value**				**Variance Explained (%)**				**Nature of Change(s)**
	***Baseline* Period vs. *Test* Period**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Data**	**2012 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Data**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**0.004**	0.703	**0.001**	21	8	0	11	Higher in *test* period; decreasing over time in *test* period; lower in 2012 than mean of previous years.
Richness	**0.006**	0.126	0.882	**0.014**	10	3	0	8	Higher in *test* period; higher in 2012 than mean of previous years.
Simpson's Diversity	0.070	0.368	0.784	0.064	17	4	0	18	No change.
Equitability	**0.007**	0.246	0.304	0.358	10	2	1	1	Higher in *baseline* period.
EPT	0.237	0.235	**0.008**	**0.014**	8	8	40	34	Lower in 2012 than mean of *baseline* years and previous years.
CA Axis 1	**0.001**	0.706	0.081	0.534	52	1	13	2	Higher in *test* period.
CA Axis 2	0.034	**0.039**	0.313	**0.003**	12	11	3	25	Decreasing over time in *test* period; lower in 2012 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).

Figure 5.7-8 Ordination (Correspondence Analysis) of lake benthic invertebrate communities in McClelland Lake (MCL-1).



Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores.

Figure 5.7-9 **Variation in benthic invertebrate community measurement endpoints in McClelland Lake.**

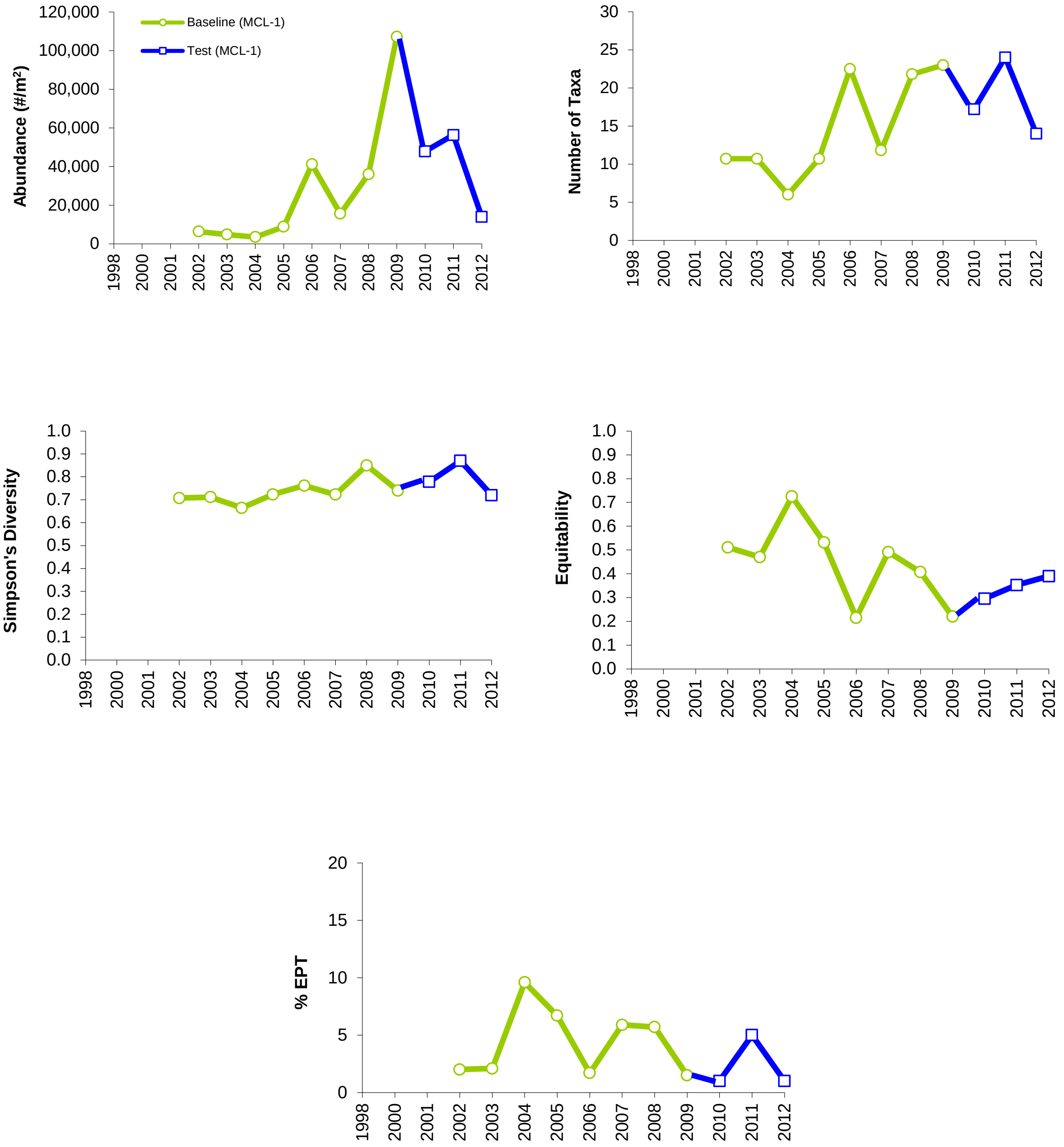


Figure 5.7-10 **Variation in benthic invertebrate community measurement endpoints in Johnson Lake.**

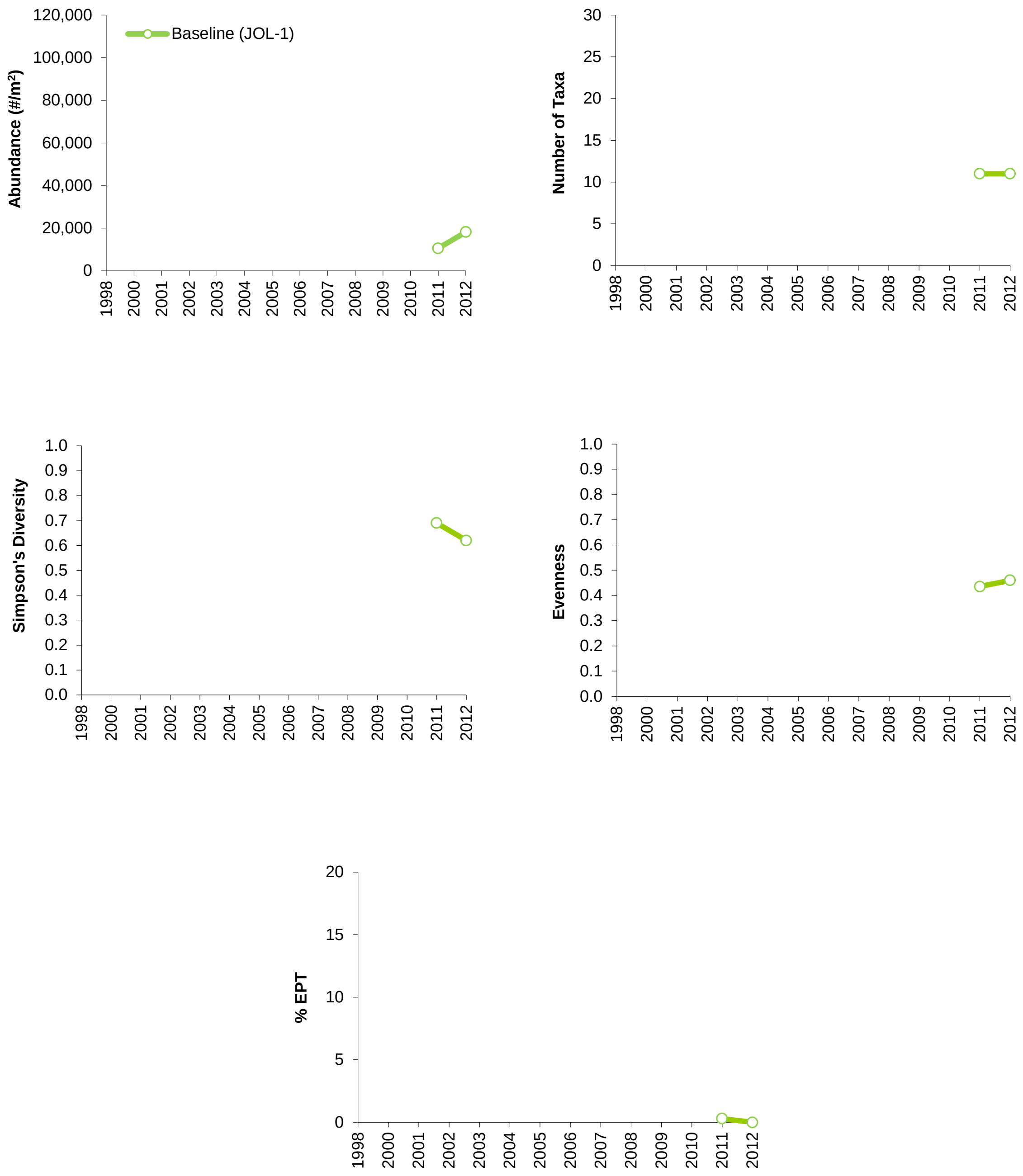
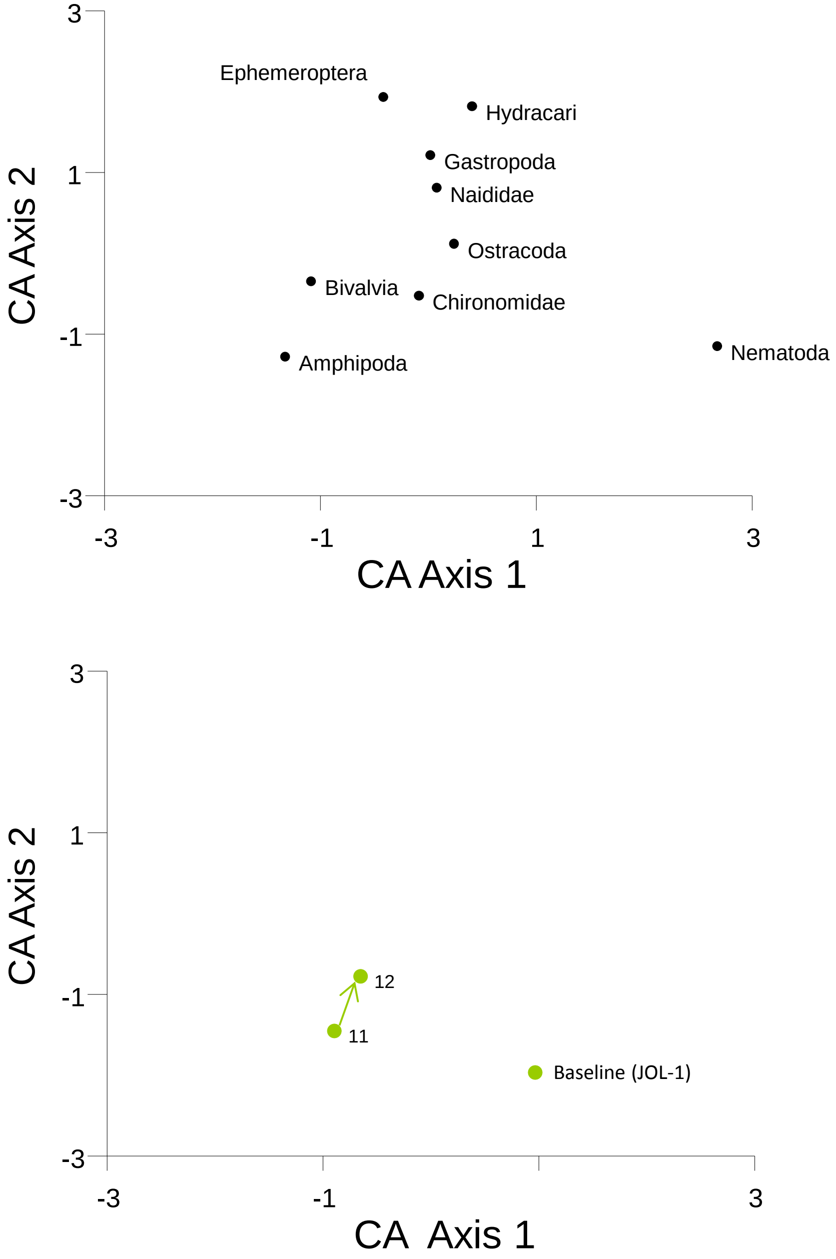


Figure 5.7-11 **Ordination (Correspondence Analysis) of lake benthic invertebrate communities in Johnson Lake (JOL-1).**



Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores.

Table 5.7-12 Concentrations of sediment quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.46	8	2.00	11.05	49.00
Silt	%	-	0.19	8	14.00	28.50	80.10
Sand	%	-	99.40	8	9.76	34.90	83.20
Total organic carbon	%	-	0.4	8	16.7	28.4	33.9
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	<55	<150
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	<55	<150
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	<5	110	**288**
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	6	**360**	**640**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	6	38	434	2,400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	5	0.0051	0.0110	0.0241
Retene	mg/kg	-	0.001	8	0.019	0.085	0.161
Total dibenzothiophenes	mg/kg	-	0.002	8	0.024	0.033	0.083
Total PAHs	mg/kg	-	0.034	8	0.261	0.544	0.753
Total Parent PAHs	mg/kg	-	0.003	8	0.023	0.064	0.107
Total Alkylated PAHs	mg/kg	-	0.031	8	0.239	0.479	0.691
Predicted PAH toxicity[3]	H.I.	1.0	0.150	8	0.039	0.132	0.368
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.6	4	7.8	9.1	9.6
Chironomus growth - 10d	mg/organism	-	1.85	4	1.45	1.52	1.86
Hyalella survival - 14d	# surviving	-	8.8	4	7.4	8.8	9.8
Hyalella growth - 14d	mg/organism	-	0.32	4	0.22	0.30	0.45

Values in **bold** indicate concentrations exceeding guidelines.

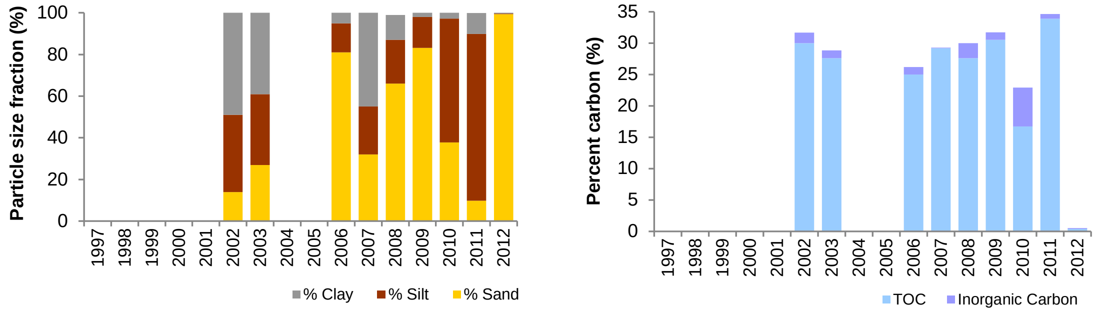
Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

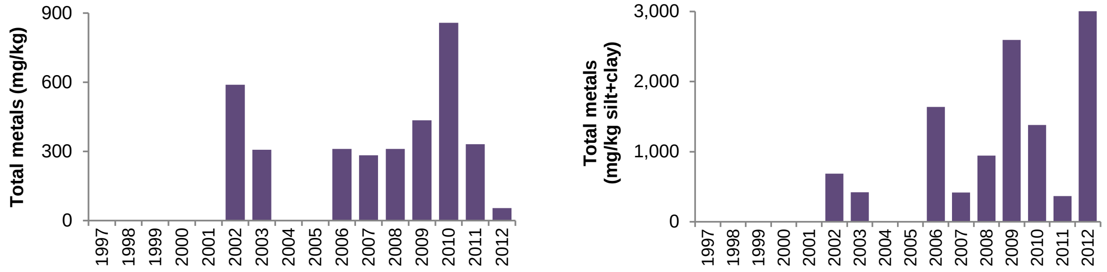
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

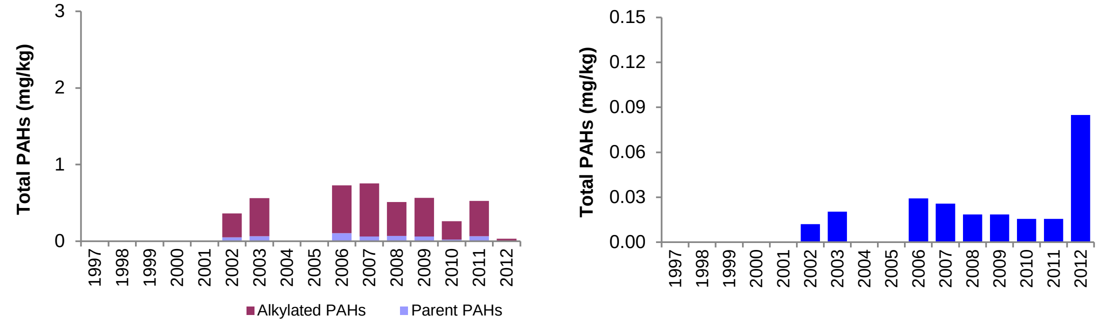
Figure 5.7-12 Variation in sediment quality measurement endpoints in McClelland Lake, *test* station MCL-1.


Particle size distribution

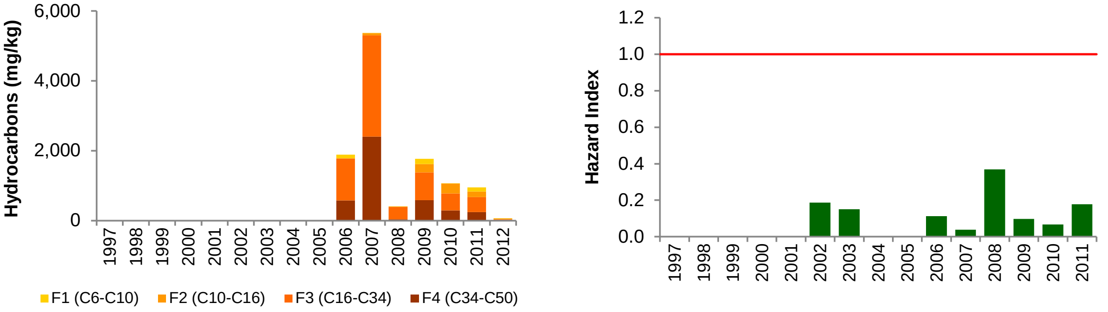
Carbon Content


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 5.7-13 Concentrations of sediment quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2012.

Variables	Units	Guideline	September 2012	September 2011
			Value	Value
Physical variables				
Clay	%	-	18	8
Silt	%	-	34	64
Sand	%	-	48	28
Total organic carbon	%	-	26.2	19.0
Total hydrocarbons				
BTEX	mg/kg	-	<160	<90
Fraction 1 (C6-C10)	mg/kg	30[1]	<160	<90
Fraction 2 (C10-C16)	mg/kg	150[1]	<187	<107
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,300**	281
Fraction 4 (C34-C50)	mg/kg	2,800[1]	760	174
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.006	0.004
Retene	mg/kg	-	0.108	0.219
Total dibenzothiophenes	mg/kg	-	0.037	0.030
Total PAHs	mg/kg	-	1.029	0.547
Total Parent PAHs	mg/kg	-	0.054	0.030
Total Alkylated PAHs	mg/kg	-	0.975	0.517
Predicted PAH toxicity[3]	H.I.	1.0	0.121	0.295
Metals that exceed CCME guidelines in 2012				
none	mg/kg	-	-	-
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	9.0	9.4
Chironomus growth - 10d	mg/organism	-	1.90	1.17
Hyalella survival - 14d	# surviving	-	9.2	8.4
Hyalella growth - 14d	mg/organism	-	0.20	0.37

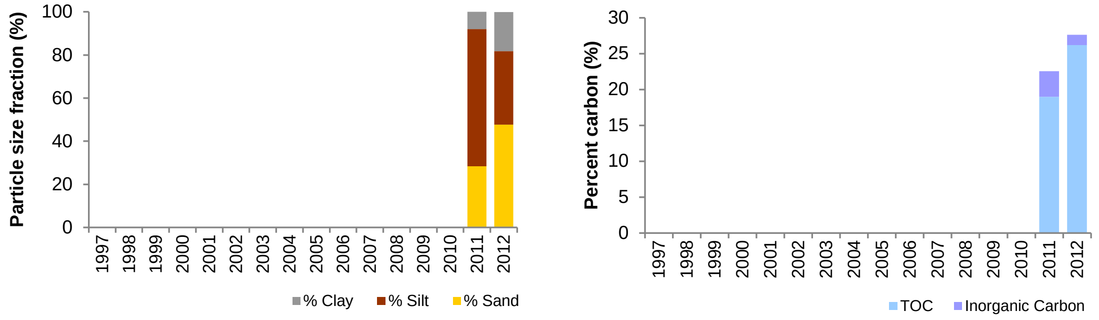
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

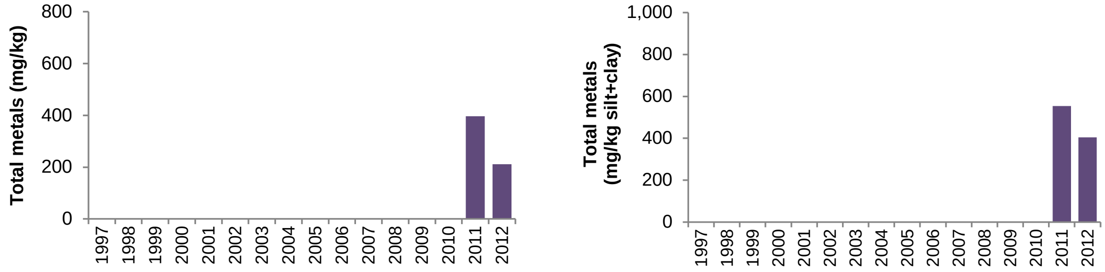
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-13 Variation in sediment quality measurement endpoints in Johnson Lake, *baseline* station JOL-1.



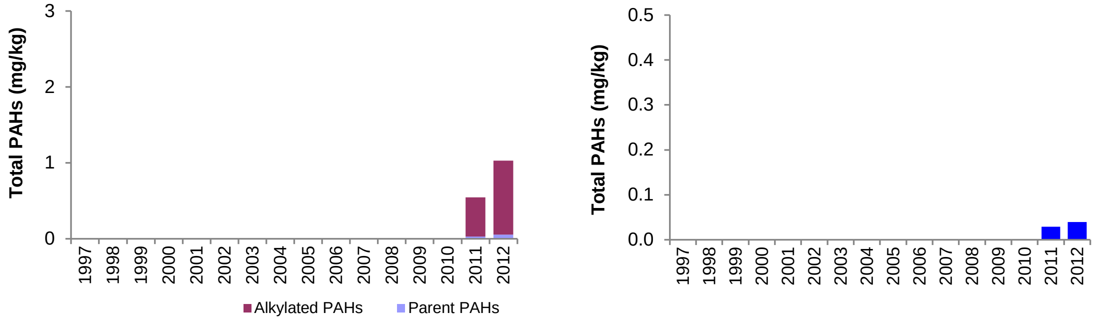
Particle size distribution

Carbon Content



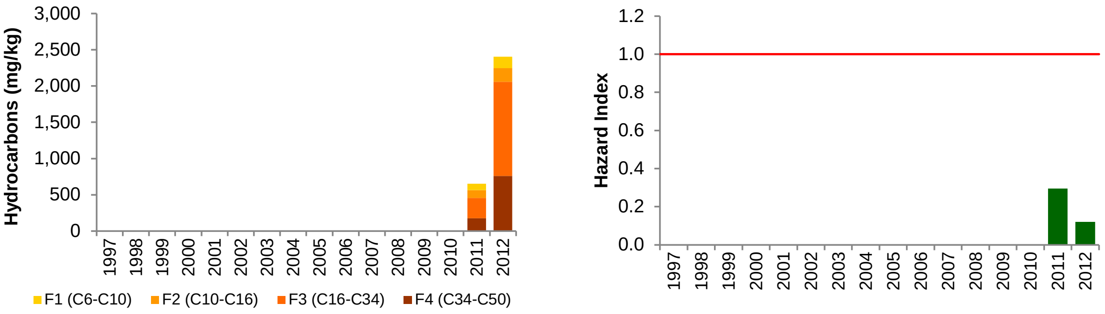
Total Metals[1]

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]

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[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 2012 Conditions**		
Climate and Hydrology			
Criteria	no station sampled	**S14A** at Canadian Natural bridge	no station sampled
Mean open-water season discharge		🟡	
Mean winter discharge		🟡	
Annual maximum daily discharge		🟡	
Minimum open-water season discharge		🟡	
Water Quality			
Criteria	**ELR-1** at the mouth	**ELR-2** at Canadian Natural bridge	**ELR-2A** upstream of Fort McKay water intake
Water Quality Index	🟡	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality			
Criteria	**ELR-D1** lower reach	**ELR-E2** at Canadian Natural bridge	**ELR-E2A** upstream of Fort McKay water intake
Benthic Invertebrate Communities	🟠	🟠	n/a
Sediment Quality Index	🟠	not sampled	not sampled
Fish Populations			
Criteria	**ELR-F1** lower reach	**ELR-F2** at Canadian Natural bridge	**ELR-F2A** upstream of Fort McKay water intake
Fish Assemblages	🟡	🟡	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: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other 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.

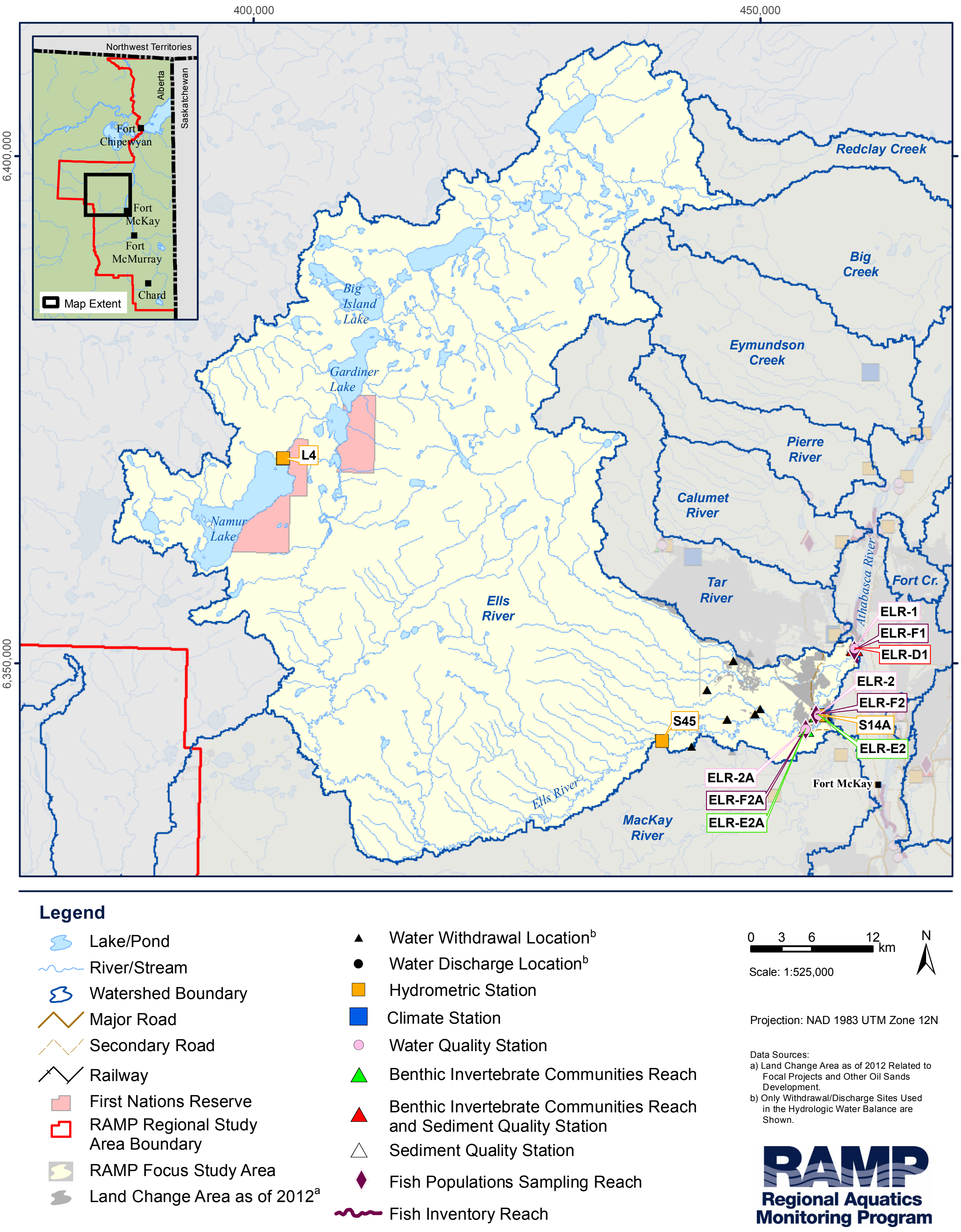
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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: Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.3 for a detailed description of the classification methodology.

Figure 5.8-1 Ells River watershed.



Scale: 1:525,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development.
b) Only Withdrawal/Discharge Sites Used in the Hydrologic Water Balance are Shown.

RAMP
Regional Aquatics Monitoring Program

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Figure 5.8-2 Representative monitoring stations of the Ells River, fall 2012.

Benthic Invertebrate Reach ELR-D1:
Mid-Channel, facing upstream

Water Quality Station ELR-2A:
Right Downstream Bank

Benthic Invertebrate Reach ELR-E2:
Mid-Channel, facing downstream

Hydrology Station S14A:
at the Canadian Natural Bridge

5.8.1 Summary of 2012 Conditions

Approximately 1.1% (2,614 ha) of the Ells River watershed had undergone land change as of 2012 from focal projects (Table 2.5-2); much of this land change is 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 operations 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 of RAMP in the Ells River watershed in 2012. Table 5.8-1 is a summary of the 2012 assessment for the Ells River watershed while Figure 5.8-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations, and the area with land change as of 2012. Figure 5.8-2 contains fall 2012 photos of a number of monitoring stations in the watershed.

Hydrology The mean winter discharge (November to March) was 0.01% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The calculated mean open-water discharge (May to October), the annual maximum daily discharge, and the open-water minimum daily discharge were 0.05% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2012 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* stations ELR-1 and ELR-2, and were within the range of previously measured concentrations and regional *baseline* conditions. Water quality at *baseline* station ELR-2A in fall 2012 was similar to that at the other two stations and consistent with results since it was first sampled in 2010.

Benthic Invertebrate Communities and Sediment Quality Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach ELR-D1 were classified as **Moderate** because of the significant decrease in Simpson's Diversity and %EPT in 2012 compared to the mean of previous sampling years, and a decrease in percentage of fauna as EPT taxa over time. Additionally, Simpson's Diversity was also lower than the range of *baseline* conditions for depositional reaches. Habitat at *test* reach ELR-D1 was of marginal quality for benthic invertebrate communities. The low diversity, high relative abundance of tubificid worms (> 60% in 2012), absence of caddisflies and stoneflies, and low relative abundance of mayflies were indicative of an environment that was somewhat limiting to depositional fauna. Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach ELR-E2 were classified as **Moderate** because there was a significant difference in abundance, richness, equitability, %EPT, and CA Axis 1 and 2 scores between this reach and *baseline* reach ELR-E2A. In addition, abundance, and %EPT were higher and lower, respectively at *test* reach ELR-E2 than the regional *baseline* range. Differences in sediment quality observed in fall 2012 between *test* station ELR-D1 and regional *baseline* conditions were classified as **Moderate**, and likely related to the exceedance of chrysene from previously measured concentrations, and the concentration of total PAHs, which exceeded the regional *baseline* range. In addition, guideline exceedances were observed in concentrations of Fraction 2 and Fraction 3 hydrocarbons, pyrene, chrysene, and the potential chronic toxicity threshold.

Fish Populations Differences in fish assemblages observed in fall 2012 between both *test* reaches ELR-F1 and ELR-F2 and regional *baseline* conditions were classified as **Negligible-Low** with all mean values of measurement endpoints within the range of regional *baseline* variability.

5.8.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Ells River watershed was conducted at the RAMP Station S14A, Ells River at the Canadian Natural Bridge, which was used for the water balance analysis. Additional hydrometric data for the Ells River watershed were available from stations L4, Namur Lake near the outlet, and S45, Ells River above the Joslyn Creek Diversion. Details for each of these stations can be found in Appendix C.

Continuous annual hydrometric data have been collected for Station S14A from 2004 to 2012. Prior to 2004, data were collected during the open-water season at Station S14, Ells River near the mouth, from 2001 to 2004 and WSC station 07DA017, Ells River near the mouth, from 1975 to 1986. The 2012 water year (WY) annual runoff volume measured at

Station S14A was 126 m^3/s, which was 42% lower than the historical mean annual runoff volume. Flows during the winter period decreased from November 2011 to March 2012, with values generally below the historical upper quartile (Figure 5.8-3). Flows increased during the freshet in April 2012 to a peak of 7.85 m^3/s recorded on May 4. Following the freshet peak, flows remained relatively constant through May and June, before increasing again in mid-July. The maximum recorded daily flow of 19.63 m^3/s was recorded on July 21 and was 65% lower than the historical mean annual maximum daily flow of 56.3 m^3/s. Late summer flows decreased to just below historical minimum flow values by September 15, before rising to historical median values in late October. The minimum open-water daily flow of 3.54 m^3/s recorded on September 22 was 51% higher than the historical open-water mean minimum daily flow.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The 2012 WY estimated water balance for the Ells River is based on the recorded flows at RAMP Station S14A, which is upstream of some focal projects located within the Ells River watershed. The station cannot be located downstream of all focal projects because of backwater effects on downstream sections of the Ells River associated with the confluence of the Ells River and the Athabasca River. Consequently, the analysis is conservative with differences between the observed *test* hydrograph and the estimated *baseline* hydrograph expected to be lower at the mouth than currently estimated. The 2012 WY estimated water balance for the Ells River at the Canadian Natural Bridge and above the Joslyn Creek confluence (RAMP Station S14A) is presented in Table 5.8-2 and described below:

1. The closed-circuited land area from focal projects as of 2012 in the Ells watershed was estimated to be 3.4 km^2 (Table 2.5-1). The loss of flow to the Ells River that would have otherwise occurred from this land area was estimated at 0.176 million m^3.

2. As of 2012, the area of land change in the Ells watershed from focal projects that was not closed-circuited was estimated to be 22.7 km^2 (Table 2.5-1). The increase in flow to the Ells River that would not have otherwise occurred from this land area was estimated at 0.234 million m^3.

3. In the 2012 WY, Total E&P withdrew approximately 0.011 million m^3 of water from six locations within the Ells River watershed to support winter drilling and construction activities. Total E&P also withdrew approximately 7,540 m^3 from five locations downstream of S14A that was not included in the *baseline* hydrograph estimation for the Ells River.

The estimated cumulative effect of land change and water withdrawals was an increase of flow of approximately 0.047 million m^3 at RAMP Station S14A in the 2012 WY. The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.8-1. The mean winter discharge (November to March) was 0.01% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.8-3). This difference was classified as **Negligible-Low** (Table 5.8-2). The calculated mean open-water discharge (May to October), the annual maximum daily discharge, and the open-water minimum daily discharge were 0.05% 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).

5.8.3 Water Quality

In fall 2012, water quality samples were taken from:

- the Ells River near its mouth (*test* station ELR-1, established in 1998, sampled annually since 2002);
- the Ells River upstream of Joslyn Creek (*test* station ELR-2, established in 2000, sampled annually since 2004, designated as *baseline* from 2000 to 2010 and *test* from 2011 to 2012); and
- the Ells River upstream of the Fort McKay water intake (*baseline* station ELR-2A, sampled since 2010).

Baseline station ELR-2A was also sampled in winter 2012.

Temporal Trends The following statistically significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- a decreasing concentration of chloride at *test* station ELR-2 (2004 to 2012).

No significant trends existed in the fall concentrations at *test* station ELR-1 (1998, 2002 to 2012). No trend analysis could be conducted for water quality at *baseline* station ELR-2A as this station was first sampled in 2010.

2012 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations in fall 2012 (Table 5.8-4 to Table 5.8-6). Water quality at *baseline* station ELR-2A has been consistent since it was first sampled in 2010 (Table 5.8-6).

Ion Balance The ionic composition of water in fall 2012 at all three water quality stations was similar and dominated by calcium and bicarbonate (Figure 5.8-4). The ionic composition of sampled water at *test* stations ELR-1 and ELR-2 has remained consistent since water quality monitoring first began in 1998 and 2000, respectively. The exception to this trend was at *test* station ELR-2 in 2007 when the anionic composition was more dominated by bicarbonate than in other years.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in the Ells River in fall 2012 were below water quality guidelines (Table 5.8-4 to Table 5.8-6), with the exception of total aluminum at *baseline* station ELR-2A.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Ells River (Table 5.8-7):

- total iron, total aluminum, and sulphide at *baseline* station ELR-2A in winter;
- sulphide, total aluminum, total iron, and total phenols at *baseline* station ELR-2A in fall; and
- total iron at *test* station ELR-1 and *test* station ELR-2, and total phenols at *test* station ELR-2 in fall.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints in fall 2012 were within the range of regional *baseline* concentrations at all stations (Figure 5.8-5).

Water Quality Index The WQI value was 100 for *test* stations ELR-1, ELR-2, and *baseline* station ELR-2A, indicating **Negligible-Low** differences in water quality from regional *baseline* conditions in fall 2012.

Classification of Results Differences in water quality in fall 2012 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* stations ELR-1 and ELR-2, and were within the range of previously-measured concentrations and regional *baseline* conditions. Water quality at *baseline* station ELR-2A in fall 2012 was similar to that at the other two stations and consistent with results since it was first sampled in 2010.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- depositional *test* reach ELR-D1, sampled since 2003;
- erosional *test* reach ELR-E2, designated as *baseline* from 2003 to 2006 and as *test* in 2012; and
- erosional *baseline* reach ELR-E2A, sampled since 2010.

2012 Habitat Conditions Water at *test* reach ELR-D1 in fall 2012 was moderately deep (> 1 m), alkaline (pH: 8.3), with high dissolved oxygen (8.8 mg/L), and moderate conductivity (204 µS/cm). The substrate was dominated by sand (78%) with some silt (15%) and clay (7%) (Table 5.8-8).

Water at *test* reach ELR-E2 in fall 2012 was relatively shallow (0.3 m), fast flowing (0.92 m/s), alkaline (pH: 8.6), with moderate conductivity (181 µS/cm), and high dissolved oxygen (10 mg/L) (Table 5.8-8). The substrate was dominated by large and small cobble (43% and 41%, respectively), with smaller amounts of boulder (17%) and large gravel (10%). Periphyton biomass averaged approximately 221 mg/m^2, which was higher than the previous sampling year (i.e., 2006) and exceeded the range of variation for *baseline* erosional reaches (Figure 5.8-6).

Water at *baseline* reach ELR-E2A in fall 2012 was relatively shallow (0.3 m), fast flowing (0.83 m/s), neutral (pH: 7.5), with moderate conductivity (194 µS/cm), and high dissolved oxygen (7.7 mg/L). The substrate was dominated by small and large cobble (30% and 25% respectively) with smaller amounts of large gravel and boulders s (19% and 16%, respectively) (Table 5.8-1). Periphyton biomass averaged 167 mg/m^2, which exceeded the range of variation for *baseline* erosional reaches (Figure 5.8-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach ELR-Dl in fall 2012 was dominated by tubificid worms (62%) and chironomids (31%) (Table 5.8-9). Bivalves (*Pisidium/Sphaerium*) were present in low relative abundances (Table 5.8-2). Chironomids were not diverse and mostly consisted of the common forms *Procladius* and *Paralauterborniella* (Wiederholm 1983).

The benthic invertebrate community at *test* reach ELR-E2 in fall 2012 was dominated by chironomids (49%), Hydracarina (18%) and naidid worms (16%), with subdominant taxa consisting of Ephemeroptera (6%) and Trichoptera (4%) (Table 5.8-10). Bivalves and gastropods were present in low relative abundances. Chironomid taxa composition was similar to the upper *baseline* reach (ELR-E2A) and consisted primarily of the rheophilic

Rheotanytarsus, and the common forms *Cricotopus/Orthocladius*, *Sublettia, Polypedilum, Tvenia,* and *Thienemannimyia gr*. Ephemeroptera were primarily of the genus *Acerpenna pygmaea* while Trichoptera were represented by the common genus *Hydropsyche*, and *Hydroptila.* Plecoptera (*Taeniopteryx*, *Isoperla*) were present in low relative abundance.

The benthic invertebrate community at *baseline* reach ELR-E2A in fall 2012 was dominated by chironomids (60%) and Hydracarina (13%), with subdominant taxa consisting of Ephemeroptera (9%) and Trichoptera (6%) (Table 5.8-10). Bivalves and gastropods were present in low relative abundances. Chironomids were diverse and included the rheophilic *Rheotanytarsus* and the common forms *Cricotopus/Orthocladius*, *Tvenia,* and *Thienemannimyia gr*. Ephemeroptera were primarily of the family Baetidae while Trichoptera were represented by the common genus *Hydropsyche.* Plecoptera (*Taeniopteryx*, *Isoperla*) were present in low relative abundance.

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 Ells River watershed.

Temporal comparisons for *test* reaches ELR-D1 and ELR-E2 included testing for:

- changes over time (Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling (1998 to 2011).

Spatial comparisons were not conducted because *test* reach ELR-D1 is depositional and *baseline* reach ELR-E2A is erosional. Spatial comparisons for *test* reach ELR-E2 included testing for:

- differences from *baseline* station ELR-E2A in 2012 values; and
- differences between 2012 values and all available *baseline* data for the Ells River watershed.

A significant decrease in Simpson's Diversity was observed between 2012 and the mean of previous sampling years at *test* reach ELR-D1, accounting for only 18% of the variance in annual means (Table 5.8-11). There was a significant decrease in the percentage of fauna as EPT taxa over time at *test* reach ELR-D1 and it was lower in 2012 than the mean of previous sampling years; these differences accounted for >20% of the variance in annual means (Table 5.8-11).

Test reach ELR-E2 had higher abundance, richness, Simpson's Diversity, and equitability in 2012 than the mean of all previous sampling years, accounting for >20% of variance in annual means (Table 5.8-12).

Abundance, richness, and equitability were significantly higher at *test* reach ELR-E2 than *baseline* reach ELR-E2A in 2012, accounting for >20% of the variance in annual means for abundance and richness, but only 16% for equitability (Table 5.8-12). Abundance, richness, and equitability were significantly higher at *test* reach ELR-E2 in 2012 compared to the mean of all available *baseline* data, accounting for >20% of the variance in annual means (Table 5.8-12). The percentage of fauna as EPT taxa was significantly lower in 2012 at *test* reach ELR-E2 than *baseline* reach ELR-E2A, reflecting a taxa composition that was higher in tubificid worms (Figure 5.8-7). The percent of fauna as EPT taxa was lower at *test* reach ELR-E2 in 2012 than the mean of all *baseline* years at this reach and *baseline* reach ELR-E2A (Table 5.8-12).

CA Axis 1 and 2 scores were higher in 2012 at *test* reach ELR-E2 than *baseline* reach ELR-E2A, explaining > 20% of the variance in annual means (Table 5.8-12). This shift in scores was due to a decrease in abundance of water mites and naidid worms at *test* reach ELR-E2 (Figure 5.8-7).

Comparison to Published Literature *Test* reach ELR-Dl in fall 2012 had low diversity and a relatively high percentage of the fauna as tubificid worms (> 60%), potentially indicating some level of degradation (Hynes 1960, Griffiths 1998). The benthic invertebrate community at *test* reach ELR-Dl contained only three individual representative caddisflies (from the family *Hydroptila*) and there were no mayflies or stoneflies indicating that dissolved oxygen may be depleted at certain times of the year.

Test reach ELR-E2 and *baseline* reach ELR-E2A in fall 2012 consisted of benthic invertebrate communities indicative of better health than *test* reach ELR-D1. Abundance at *test* reach ELR-E2 was much higher (~255,000) than previous years, although this reach has not been sampled since 2006. Abundance was also higher at *baseline* reach ELR-E2A than previous years. Both reaches had a diverse species composition including several species of chironomids and sensitive taxa including Ephemeroptera, Trichoptera, and Plectoptera. Clams and snails were observed at both reaches but in low relative abundances. The presence of these taxa was indicative of a long-term, high-quality benthic habitat (Hynes 1960, Griffiths 1998, Mandaville 2001).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all benthic invertebrate community measurement endpoints in fall 2012 were within the range of regional *baseline* depositional reaches at *test* reach ELR-D1, with the exception of Simpson's Diversity, which was slightly lower than the 5th percentile of the *baseline* range (Figure 5.8-8). Abundance in fall 2012 at *test* reach ELR-E2 and *baseline* reach ELR-E2A were higher than the range of regional *baseline* erosional reaches (Figure 5.8-9). The percentage of fauna as EPT taxa was lower than the 5th percentile of regional *baseline* erosional reaches at *test* reach ELR-E2 (Figure 5.8-9).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach ELR-D1 were classified as **Moderate** because of the significant decrease in Simpson's Diversity and percent EPT taxa in 2012 compared to previous years and the decrease in percentage of fauna as EPT taxa over time. Additionally, Simpson's Diversity was also lower than the range of *baseline* conditions for depositional reaches. Habitat at *test* reach ELR-D1 was of marginal quality for benthic invertebrate communities. The low diversity, high relative abundance of tubificid worms (> 60% in 2012), absence of caddisflies and stoneflies, and low relative abundance of mayflies were indicative of an environment that was somewhat limiting to depositional fauna.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach ELR-E2 were classified as **Moderate** because there was a significant difference in abundance, richness, equitability, %EPT, and CA Axis 1 and 2 scores between this reach and *baseline* reach ELR-E2A. In addition, abundance, and %EPT were higher and lower, respectively at *test* reach ELR-E2 than the regional *baseline* range.

5.8.4.2 Sediment Quality

Sediment quality was sampled in fall 2012 in the Ells River near its mouth at *test* station ELR-D1 in the same location as the benthic invertebrates communities *test* reach ELR-D1. This station was designated as *baseline* in 1998 and *test* from 2002 to 2012.

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected at *test* station ELR-D1 in fall 2012, with the exception of C3 hydrocarbons, which showed an increasing trend over time.

2012 Results Relative to Historical Concentrations Prior to the integration of the Sediment Quality component with the Benthic Invertebrate Communities component of RAMP in 2006, *test* reach ELR-D1 corresponded to pre-2006 sediment quality station ELR-1. 2012 sediment quality data from *test* station ELR-D1 was compared to all available data collected at this location (including pre-2006 and 2006 to 2011).

Sediments at *test* station ELR-D1 in fall 2012 were dominated by sand, with proportions of sand and clay similar to those observed during sampling in 2004 (Table 5.8-13, Figure 5.8-10). In fall 2012, concentrations of all sediment quality measurement endpoints were within the range of previously-measured concentrations, with the exception of chrysene, which was higher than the previously-measured maximum concentration. Similar to previous years, concentrations of hydrocarbons were dominated by Fraction 3 and Fraction 4, which likely indicated the presence of bitumen in sediments (Table 5.8-13). All hydrocarbon fractions and total PAHs (absolute and carbon-normalized concentrations) were within the range of previously-measured concentrations. The predicted PAH toxicity of 1.63 exceeded the potential chronic toxicity threshold of 1.0, but was within the range of previously-measured values observed at this station (Table 5.8-13, Figure 5.8-10).

Direct tests of sediment toxicity to invertebrates at *test* station ELR-D1 showed 96% survival in test organisms of the amphipod *Hyalella* and 88% survival in test organisms of the midge *Chironomus.* The survival of the midge *Chironomus* exceeded previously-measured maximum values observed at this station while growth of both test organisms were within the range of previous values for this station (Table 5.8-13).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines There were no sediment quality measurement endpoints that exceeded relevant CCME guidelines at *test* station ELR-D1 in fall 2012, with the exception of Fraction 2 and Fraction 3 hydrocarbons, pyrene, and chrysene (Table 5.8-13).

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints in fall 2012 were within the range of regional *baseline* conditions, with the exception of total PAHs (absolute and normalized to 1% TOC) (Figure 5.8-10).

Sediment Quality Index A SQI value of 69.2 was calculated for *test* station ELR-D1 for fall 2012, indicating a **Moderate** difference from regional *baseline* conditions. Since 1998, this station has frequently had a **Moderate** difference from regional *baseline* conditions, with only four years where the SQI indicated a Negligible-Low difference from regional *baseline* conditions (i.e., 1998, 2002, 2007, and 2010).

Classification of Results Differences in sediment quality observed in fall 2012 between *test* station ELR-D1 and regional *baseline* conditions were classified as **Moderate**, likely related to the exceedance of chrysene from previously-measured concentrations, and the concentration of total PAHs, which exceeded the regional *baseline* range. In addition, guideline exceedances were observed in concentrations of Fraction 2 and Fraction 3 hydrocarbons, pyrene, chrysene, and the potential chronic toxicity threshold.

5.8.5 Fish Populations

Fish assemblages were sampled in fall 2012 at:

- depositional *test* reach ELR-F1, sampled in 2010 as part of the Fish Assemblage Pilot Study and regularly since 2011 (this reach is at the same location as the benthic invertebrate community *test* reach ELR-D1);
- erosional *test* reach ELR-F2, sampled for the first time in 2012 (this reach is at the same location as the benthic invertebrate community *test* reach ELR-E2); and
- erosional *baseline* reach ELR-F2A, sampled in 2010 as part of the Fish Assemblage Pilot Study and regularly since 2011 (this reach is at the same location as the benthic invertebrate community *baseline* reach ELR-E2A).

2012 Habitat Conditions *Test* reach ELR-F1 was comprised entirely of run habitat with a wetted width of 26 m and a bankfull width of 31 m (Table 5.8-14). The substrate was dominated by fine material along the edges, with bitumen and sand in the middle of the channel. Water at *test* reach ELR-F1 in fall 2012 was a mean of 0.36 m in depth, moderately flowing (0.47 m/s), alkaline (pH: 8.19), with moderate conductivity (247 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 9.6˚C. Instream cover was primarily dominated by small woody debris and macrophytes with small amounts of large woody debris and algae (Table 5.8-14).

Test reach ELR-F2 was comprised of run and riffle habitat with a wetted width of 25 m and a bankfull width of 30 m (Table 5.8-14). The substrate was dominated by cobble with smaller amounts of sand. Water at *test* reach ELR-F2 in fall 2012 had a mean depth of 0.41 m, was moderately flowing (0.33 m/s), alkaline (pH: 8.35), with moderate conductivity (191 µ/cm), high dissolved oxygen (10.5 mg/L), and a temperature of 15.3˚C. Instream cover was dominated by large woody debris and macrophytes with small amount of small and large woody debris (Table 5.8-14).

Baseline reach ELR-F2A was comprised of run and riffle habitat with a wetted width of 25.5 m and a bankfull width of 33.5 m (Table 5.8-14). The substrate was dominated by sand with smaller amounts of cobble and exposed bedrock. Water at *baseline* reach ELR-F2A in fall 2012 was a mean of 0.35 m in depth, slow flowing (0.03 m/s), alkaline (pH: 7.7), with moderate conductivity (216 µ/cm), high dissolved oxygen (9 mg/L), and a temperature of 17.5˚C. Instream cover was dominated by filamentous algae, macrophytes and boulders with small amounts of small and live tree roots (Table 5.8-14).

Temporal and Spatial Comparisons Sampling was initiated at *test* reach ELR-F1 and *baseline* reach ELR-F2A in 2010 during the second year of the RAMP Fish Assemblage pilot study; therefore, temporal comparisons were conducted from 2010 to 2012 at these reaches. Sampling was done for the first time in 2012 at *test* reach ELR-F2 to coincide with benthic invertebrate monitoring at this reach.

Abundance and mean CPUE of fish increased from 2011 to 2012 at *test* reach ELR-F1 and *baseline* reach ELR-F2A, but was lower than 2010 at both locations. Diversity increased slightly or remained the same compared to previous years (Table 5.8-15). *Test* reach ELR-F1 was dominated by trout-perch while *baseline* reach ELR-F2A was dominated by lake chub. The assemblage tolerance index (ATI) in 2012 was relatively consistent with previous years at *baseline* reach ELR-F2A and *test* reach ELR-F1 (Table 5.8-16).

All measurement endpoints, with the exception of ATI, were lower at *test* reach ELR-F2 compared to *baseline* reach ELR-F2A (Table 5.8-16). Species composition at both reaches was similar (Table 5.8-15), but longnose sucker were not captured at *test* reach ELR-F2. Given that longnose sucker is a more sensitive species, it is likely the contributing factor to the lower ATI at *baseline* reach ELR-E2A compared to *test* reach ELR-F2.

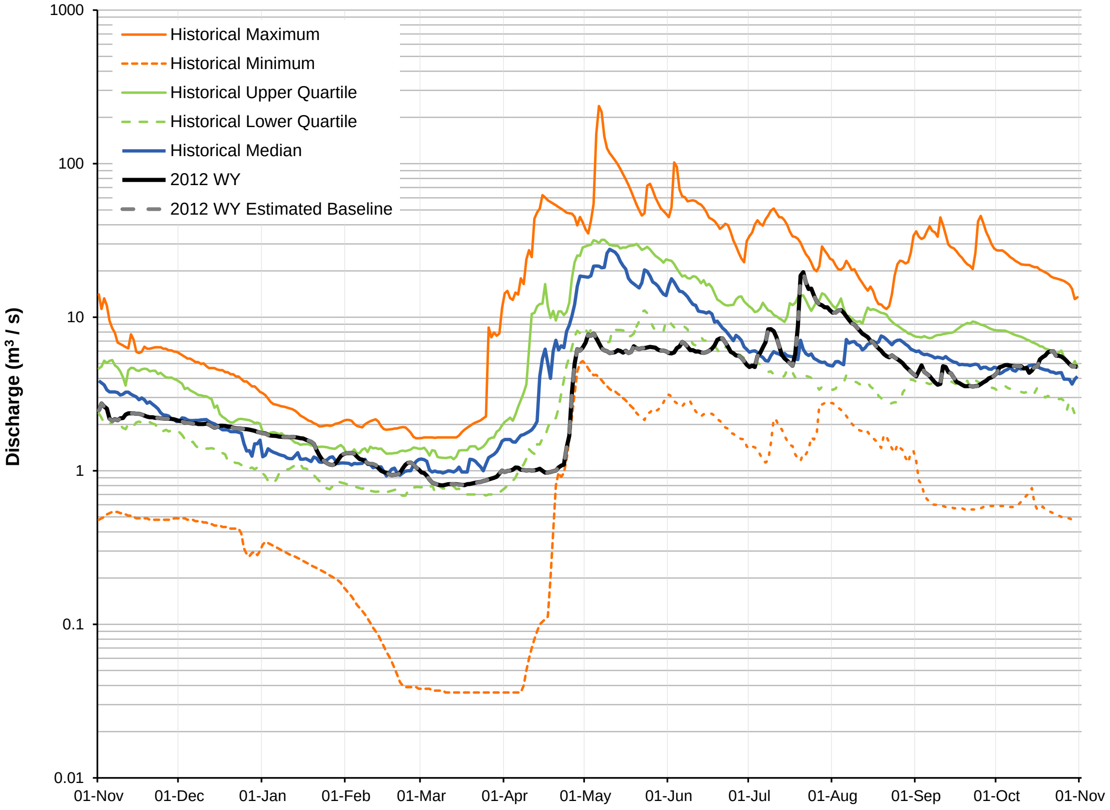
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by RAMP. Based on past studies, a total of 19 fish species were recorded in the Ells River watershed; whereas RAMP found only nine species from 2009 to 2012, as well as finescale dace, which had not been previously documented in the Ells River. As noted in Section 5.2, 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., RAMP 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-F2A is located, which is consistent with observations by RAMP. 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 2012 (Table 5.8-14).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reaches ELR-F1 and ELR-F2 were within the range of regional *baseline* conditions (Figure 5.8-11). Mean values of all measurement endpoints at *baseline* reach ELR-F2A were within the range of regional *baseline* conditions in fall 2012, with the exception of total abundance which was slightly higher than regional *baseline* conditions.

Classification of Results Differences in fish assemblages observed in fall 2012 between *test* reaches ELR-F1 and ELR-F2 and regional *baseline* conditions were classified as **Negligible-Low** with all mean values of measurement endpoints within the range of regional *baseline* variability.

Figure 5.8-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Ells River in the 2012 WY, compared to historical values.



Note: The observed 2012 WY hydrograph is based on Ells River at the Canadian Natural Bridge, Station S14A, 2012 provisional data. The upstream drainage area is 2,450 km^2. Historical values are calculated for the period from 1975 to 1986 and 2001 to 2011 during the open-water period (May to October), and from 1976 to 1986 and 2004 to 2011 for the remaining winter months (November to April), although short periods of missing data exist.

Table 5.8-2 Estimated water balance at Ells River above Joslyn Creek (RAMP Station S14A), 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**126.034**	**Observed discharge at Ells River at CNRL Bridge, RAMP Station S14A**
Closed-circuited area water loss from the observed *test* hydrograph	-0.176	Estimated 3.4 km^2 of the Ells River watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.234	Estimated 22.7 km^2 of the Ells River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Ells River watershed from focal projects	-0.011	10,757 m^3 withdrawn from sources in the Ells River watershed for construction activities
Water releases into the Ells River watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Ells River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**125.987**	**Estimated *baseline* discharge at Ells River at the Canadian Natural Bridge, RAMP Station S14A**
Incremental flow (change in total discharge)	+0.047	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**+0.038%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Based on Ells River at the Canadian Natural Bridge, RAMP Station S14A, 2012 WY provisional data.

Note Flow values in this table presented to three decimal places.

Table 5.8-3 Calculated change in hydrologic measurement endpoints for the Ells River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	6.368	6.371	0.05%
Mean winter discharge	1.535	1.535	0.01%
Annual maximum daily discharge	19.623	19.632	0.05%
Open-water season minimum daily discharge	3.535	3.537	0.05%

Note: Based on Ells River above Joslyn Creek, RAMP Station S14A, 2012 WY provisional data.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to three and two decimal places, respectively.

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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	11	7.8	8.2	8.4
Total suspended solids	mg/L	-	3	11	<3	7	16
Conductivity	µS/cm	-	239	11	175	225	272
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.007	11	0.003	0.011	0.020
Total nitrogen	mg/L	1	0.7	11	0.3	0.6	**1.3**
Nitrate+nitrite	mg/L	1.3	<0.071	11	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	18	11	11	15	20
Ions							
Sodium	mg/L	-	11.3	11	8.0	10.7	18.0
Calcium	mg/L	-	24.6	11	21.6	24.0	30.4
Magnesium	mg/L	-	7.1	11	6.5	7.3	9.1
Chloride	mg/L	120	1.8	11	<0.5	2.0	4.0
Sulphate	mg/L	270	15.8	11	10.5	15.5	27.9
Total dissolved solids	mg/L	-	171	11	110	165	220
Total alkalinity	mg/L		103	11	76	97	117
Selected metals							
Total aluminum	mg/L	0.1	0.09	11	0.06	**0.32**	**0.67**
Dissolved aluminum	mg/L	0.1	0.009	11	0.006	**0.015**	**0.078**
Total arsenic	mg/L	0.005	0.0008	11	<0.001	0.0009	0.0012
Total boron	mg/L	1.2	0.067	11	0.041	0.061	0.083
Total molybdenum	mg/L	0.073	0.0007	11	0.0006	0.0007	0.0008
Total mercury (ultra-trace)	ng/L	5, 13	0.90	9	<1.2	<1.2	1.5
Total strontium	mg/L	-	0.11	11	0.10	0.12	0.14
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	-	0.07	1	-	0.23	-
Oilsands Extractable	mg/L	-	0.43	1	-	1.25	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	3.770	1	-	4.430	-
Total dibenzothiophenes	ng/L	-	134.5	1	-	120.2	-
Total PAHs	ng/L	-	550.9	1	-	448.1	-
Total Parent PAHs	ng/L	-	25.21	1	-	24.92	-
Total Alkylated PAHs	ng/L	-	525.7	1	-	423.1	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**0.45**	11	**0.45**	**0.70**	**1.14**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.8-5 Concentrations of water quality measurement endpoints, upper Ells River (*test* station ELR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	8	7.7	8.1	8.4
Total suspended solids	mg/L	-	<3	8	<3	4	8
Conductivity	µS/cm	-	215	8	164	201	219
Nutrients			-				
Total dissolved phosphorus	mg/L	0.05	0.008	8	0.004	0.011	**0.061**
Total nitrogen	mg/L	1	0.64	8	0.55	0.71	**2.01**
Nitrate+nitrite	mg/L	1.3	<0.071	8	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	17.5	8	10.0	15.3	20.7
Ions			-				
Sodium	mg/L	-	9.4	8	3.0	10.1	13.0
Calcium	mg/L	-	23	8	20.5	23.5	25.6
Magnesium	mg/L	-	6.75	8	6.2	7.1	7.8
Chloride	mg/L	120	0.91	8	0.7	2.0	3.0
Sulphate	mg/L	270	13.2	8	2.2	13.7	18.9
Total dissolved solids	mg/L	-	145	8	110	149	190
Total alkalinity	mg/L		96	8	73	90.75	110
Selected metals							
Total aluminum	mg/L	0.1	0.05	8	0.05	**0.27**	**0.74**
Dissolved aluminum	mg/L	0.1	0.009	8	<0.001	0.014	0.026
Total arsenic	mg/L	0.005	0.0008	8	0.0006	0.0009	0.0011
Total boron	mg/L	1.2	0.05	8	0.04	0.05	0.08
Total molybdenum	mg/L	0.073	0.0006	8	0.0006	0.0007	0.0008
Total mercury (ultra-trace)	ng/L	5, 13	0.90	8	<1.1	<1.2	2
Total strontium	mg/L	-	0.10	8	0.09	0.11	0.14
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	-	0.08	1	-	0.07	-
Oilsands Extractable	mg/L	-	0.27	1	-	1.10	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.97	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	49.81	1	-	44.39	-
Total PAHs	ng/L	-	276.2	1	-	240.5	-
Total Parent PAHs	ng/L	-	17.58	1	-	20.91	-
Total Alkylated PAHs	ng/L	-	258.6	1	-	219.6	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**0.335**	8	0.260	**0.447**	**0.922**
Total phenols	mg/L	0.004	**0.0044**	8	<0.001	**0.005**	**0.025**

[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 5.8-6 Concentrations of water quality measurement endpoints, upper Ells River (*baseline* station ELR-2A), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	2010-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.2	8.3	8.4
Total suspended solids	mg/L	-	<3	2	<3	4	5
Conductivity	µS/cm	-	216	2	206	208	209
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.0181	2	0.0105	0.0114	0.0123
Total nitrogen	mg/L	1	0.611	2	0.561	1.436	2.311
Nitrate+nitrite	mg/L	1.3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	14.0	2	15.3	17.9	20.4
Ions							
Sodium	mg/L	-	10.20	2	9.4	9.8	10.2
Calcium	mg/L	-	21.5	2	21.7	22.2	22.6
Magnesium	mg/L	-	6.46	2	6.88	7.08	7.27
Chloride	mg/L	120	0.90	2	0.65	0.72	0.79
Sulphate	mg/L	270	13.5	2	13.6	15.1	16.6
Total dissolved solids	mg/L	-	119	2	137	148	158
Total alkalinity	mg/L		94.2	2	87.8	90.1	92.3
Selected metals							
Total aluminum	mg/L	0.1	**0.11**	2	0.05	**0.28**	**0.51**
Dissolved aluminum	mg/L	0.1	0.011	2	0.005	0.009	0.013
Total arsenic	mg/L	0.005	0.0008	2	0.0008	0.0009	0.0010
Total boron	mg/L	1.2	0.059	2	0.049	0.052	0.055
Total molybdenum	mg/L	0.073	0.00065	2	0.00054	0.00061	0.00068
Total mercury (ultra-trace)	ng/L	5, 13	1.40	2	0.80	1.40	2.00
Total strontium	mg/L	-	0.108	2	0.117	0.118	0.118
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	-	0.27	1	-	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	0.53	1	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	0.45	1	-	<0.25	-
Naphthenic Acids	mg/L	-	0.17	1	-	0.20	-
Oilsands Extractable	mg/L	-	0.34	1	-	0.80	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.94	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	42.40	1	-	24.89	-
Total PAHs	ng/L	-	229.1	1	-	179.8	-
Total Parent PAHs	ng/L	-	16.53	1	-	19.65	-
Total Alkylated PAHs	ng/L	-	212.6	1	-	160.2	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Sulphide	mg/L	0.002	**0.004**	2	**0.004**	**0.005**	**0.006**
Total phenols	mg/L	0.004	**0.007**	2	**0.006**	**0.008**	**0.011**
Total iron	mg/L	0.3	**0.41**	2	0.28	**0.52**	**0.76**

[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 5.8-4 Piper diagram of fall ion concentrations in the Ells River watershed.

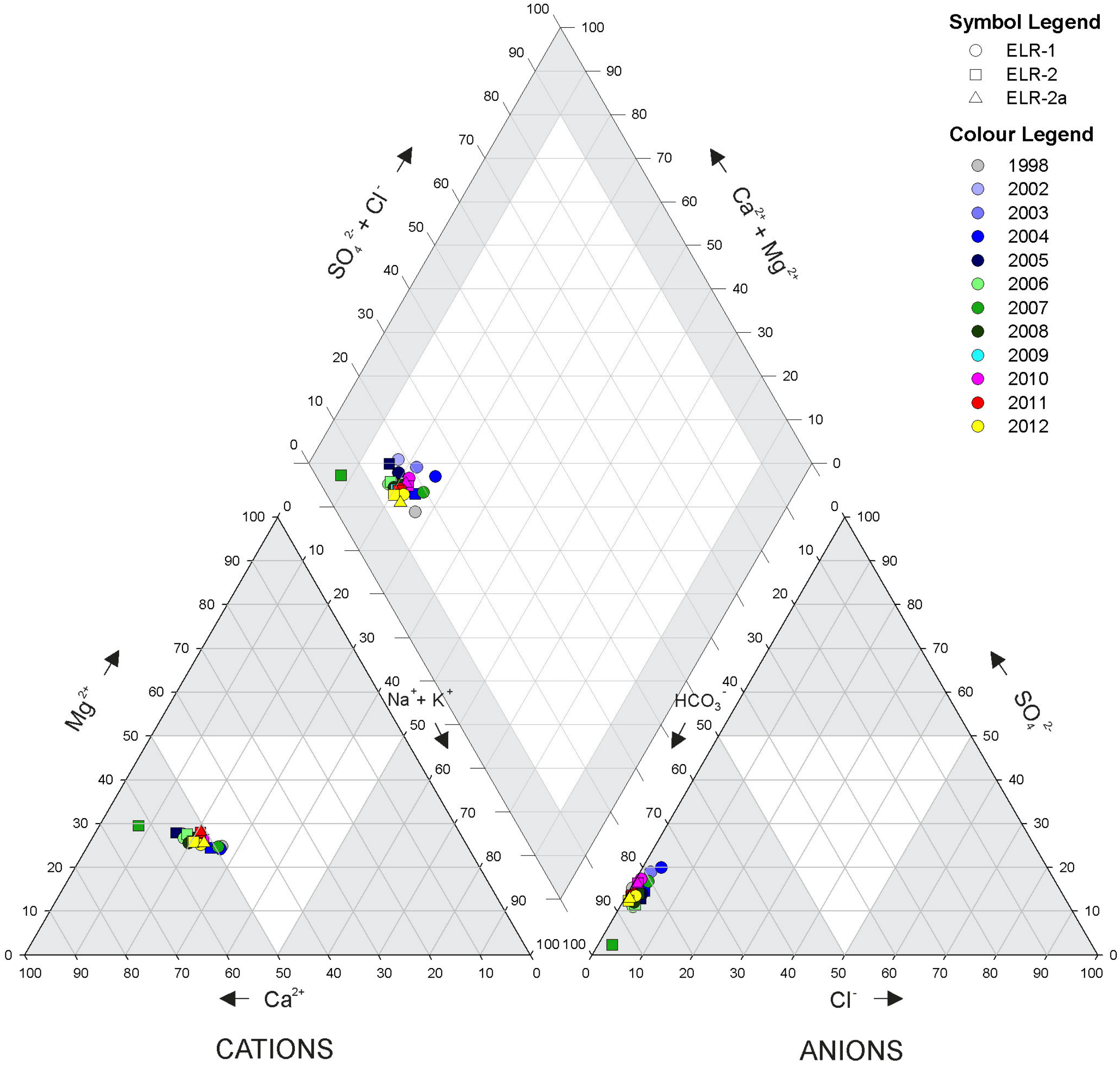


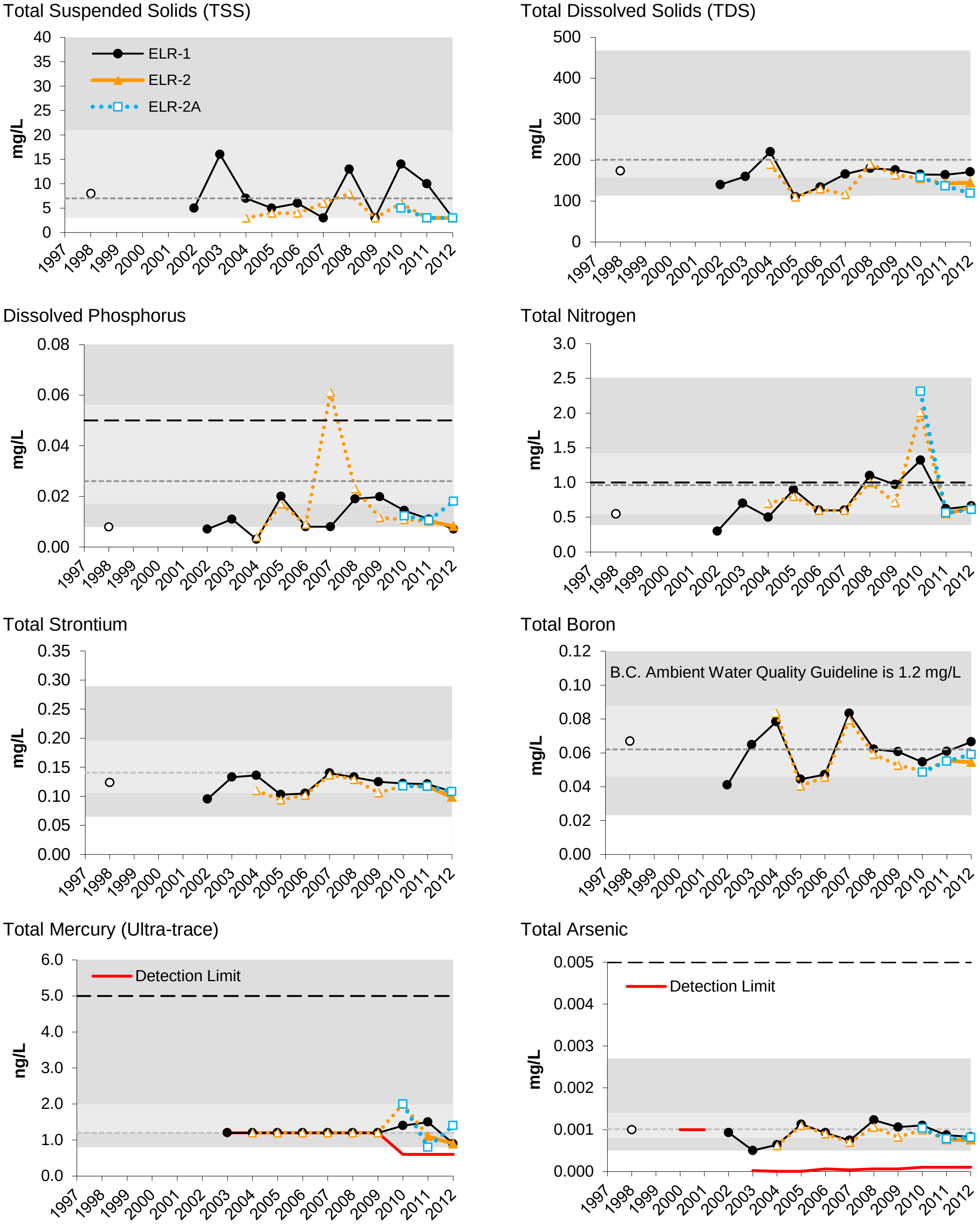
Table 5.8-7 Water quality guideline exceedances, Ells River, 2012.

Variable	Units	Guideline[a]	ELR-1	ELR-2	ELR-2A
Winter					
Total aluminum	mg/L	0.1	ns	ns	0.172
Total iron	mg/L	0.3	ns	ns	0.568
Sulphide	mg/L	0.002	ns	ns	0.0021
Fall					
Total aluminum	mg/L	0.1	-	-	0.108
Total iron	mg/L	0.3	0.450	0.335	0.41
Sulphide	mg/L	0.002	-	-	0.004
Total phenols	mg/L	0.004	-	0.0044	0.007

[a] Sources for all guidelines are outlined in Table 3.2-5.

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.


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.

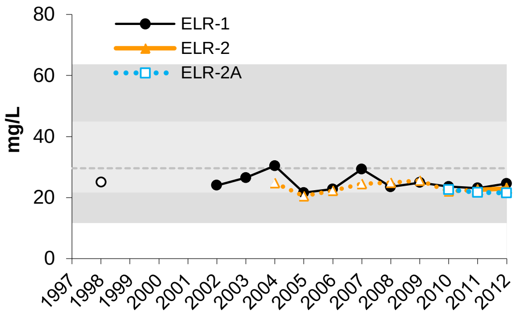
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

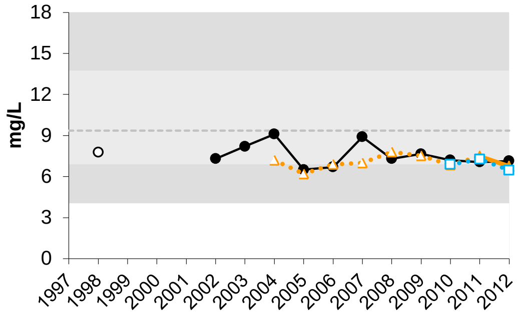
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.8-5 (Cont'd.)

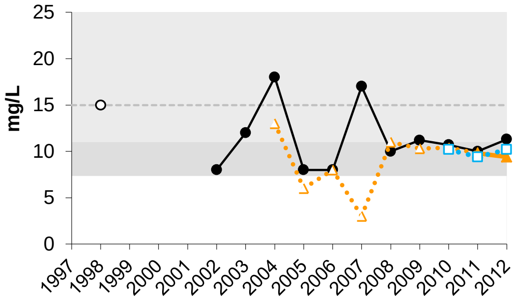
Calcium



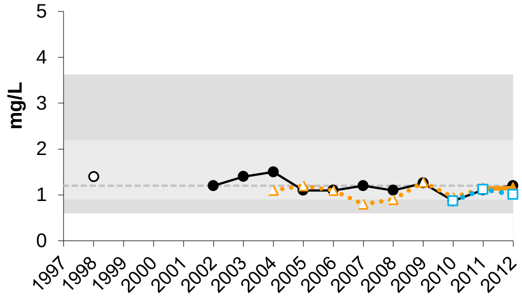
Magnesium



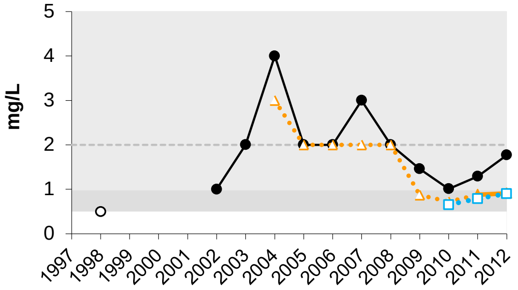
Sodium



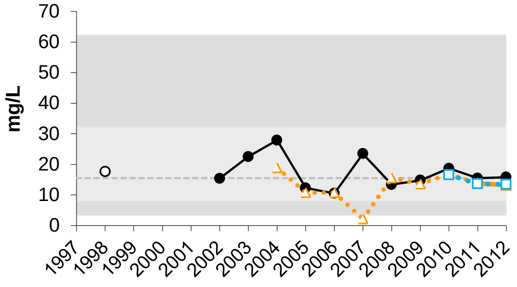
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

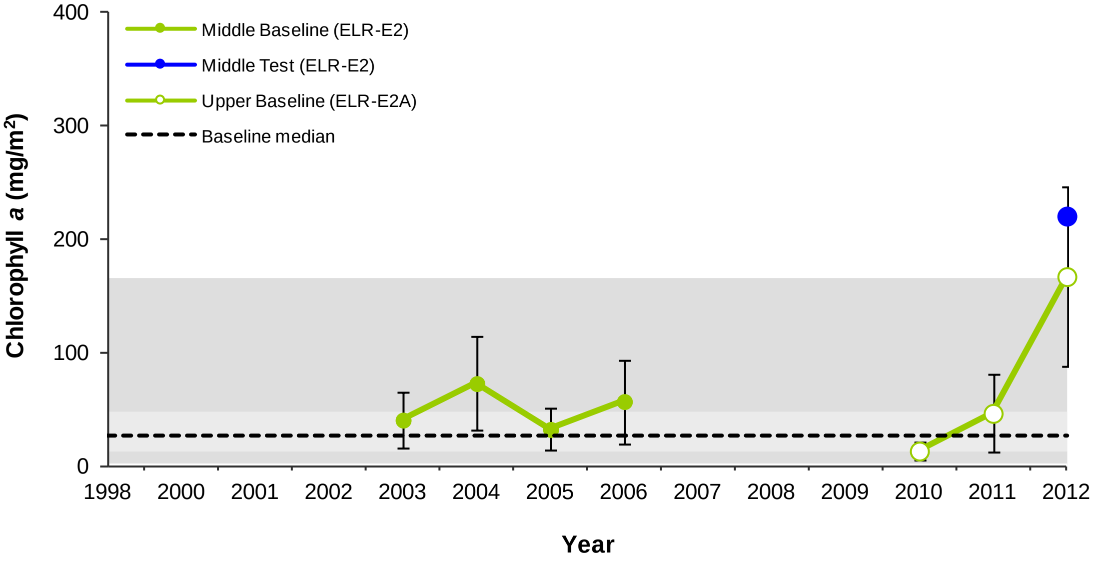
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.8-8 Average habitat characteristics of benthic invertebrate sampling locations in the Ells River, fall 2012.

Variable	**Units**	**ELR-D1** **Lower *Test* Reach of Ells River**	**ELR-E2** **Middle *Test* Reach of Ells River**	**ELR-E2A** **Upper *Baseline* Reach of Ells River**
Sample date	-	10-Sept-2012	12-Sept-2012	06-Sept-2012
Habitat	-	Depositional	Erosional	Erosional
Water depth	m	1.2	0.3	0.3
Current velocity	m/s	-	0.92	0.83
Field Water Quality				
Dissolved oxygen	mg/L	8.8	10.0	7.7
Conductivity	µS/cm	204	181	194
pH	pH units	8.3	8.6	7.5
Water temperature	°C	14.2	15.8	13.6
Sediment Composition				
Sand	%	78	-	-
Silt	%	15	-	-
Clay	%	7	-	-
Total Organic Carbon	%	2.03	-	-
Sand/Silt/Clay	%	-	0	6
Small Gravel	%	-	0	6
Large Gravel	%	-	10	19
Small Cobble	%	-	31	30
Large Cobble	%	-	43	25
Boulder	%	-	17	16
Bedrock	%	-	0	0

Figure 5.8-6 Periphyton chlorophyll *a* biomass in *baseline* reaches ELR-E2 and ELR-E2A of the Ells River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.8-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at *test* reach ELR-D1.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach ELR-D1		
	2003	**2004 to 2011**	**2012**
Nematoda	<1	<1 to 3	<1
Oligochaeta		0 to 1	
Naididae	24	2 to 17	3
Tubificidae	52	18 to 61	62
Enchytraeidae		0 to <1	
Hydracarina	<1	0 to 2	<1
Ostracoda		0 to 18	
Cladocera		0 to <1	
Copepoda	<1	0 to 1	
Gastropoda	<1	0 to 1	<1
Bivalvia	<1	0 to 2	<1
Coleoptera		0 to <1	
Ceratopogonidae	3	1 to 7	1
Chironomidae	19	17 to 56	31
Chaoboridae		0 to <1	
Athericidae		0 to <1	
Empididae	<1	<1 to 2	<1
Tipulidae		0 to <1	
Tabanidae	<1	0 to 1	
Simuliidae		0 to 2	
Ephemeroptera	<1	<1 to 1	
Anisoptera	<1	<1	
Zygoptera		0 to <1	
Plecoptera		0 to <1	
Trichoptera	<1	0 to <1	<1
Heteroptera	<1		
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	30,917	8,731 to 34,606	25,964
Richness	12	9 to 20	9
Simpson's Diversity	0.69	0.47 to 0.79	0.50
Equitability	0.38	0.34 to 0.57	0.27
% EPT	1	0 to 1	<1

Table 5.8-10 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at *test* reach ELR-E2 and *baseline* reach ELR-E2A.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Reach ELR-E2			Reach ELR-E2A		
	2003	2004 to 2006	2012	2010	2011	2012
Nematoda	1	<1 to 4	<1	2	2	<1
Oligochaeta					<1	
Naididae	13	5 to 28	16	10	4	4
Tubificidae	<1	<1 to 1		<1	1	<1
Enchytraeidae	1	<1		1	<1	<1
Hydracarina	11	8 to 19	18	9	9	13
Ostracoda	<1	<1 to 1		1	<1	<1
Cladocera			<1			1
Copepoda		0 to 2		<1	<1	<1
Gastropoda	1	<1	<1	<1	<1	1
Bivalvia	<1	0 to 1	<1	<1	<1	<1
Coleoptera		0 to <1	<1	<1	<1	
Ceratopogonidae	1	<1 to 2	<1	1	<1	<1
Chironomidae	6	35 to 49	49	43	42	60
Athericidae	<1	0 to <1	<1	<1	<1	<1
Empididae	2	1 to 3	1	1	1	<1
Tipulidae	<1	0 to <1		<1	<1	<1
Tabanidae	<1	0 to <1		<1		
Simuliidae	<1	<1 to 1	1	1	<1	1
Ephemeroptera	7	1 to 15	6	18	20	9
Anisoptera	<1	<1 to 2		<1	<1	<1
Zygoptera		0 to <1				
Plecoptera	1	<1 to 6	<1	2	2	2
Trichoptera	2	2 to 4	4	10	15	6
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	17,207	6,779 to 19,659	255,684	12,286	53,976	84,543
Richness	28	26 to 32	34	38	38	42
Simpson's Diversity	0.87	0.85 to 0.91	0.87	0.91	0.88	0.88
Equitability	0.31	0.31 to 0.45	0.25	0.31	0.24	0.22
% EPT	12	14 to 25	12	30	37	17

Table 5.8-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach ELR-D1.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	0.336	0.930	15	0	No change
Richness	0.382	0.110	4	15	No change
Simpson's Diversity	0.338	**0.048**	4	18	Lower in 2012 than previous years.
Equitability	0.084	0.114	18	15	No change
EPT	**<0.001**	**<0.001**	73	88	Decreasing over time; lower in 2012 than mean of previous years.
CA Axis 1	0.692	0.377	1	5	No change
CA Axis 2	0.970	0.537	0	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 comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

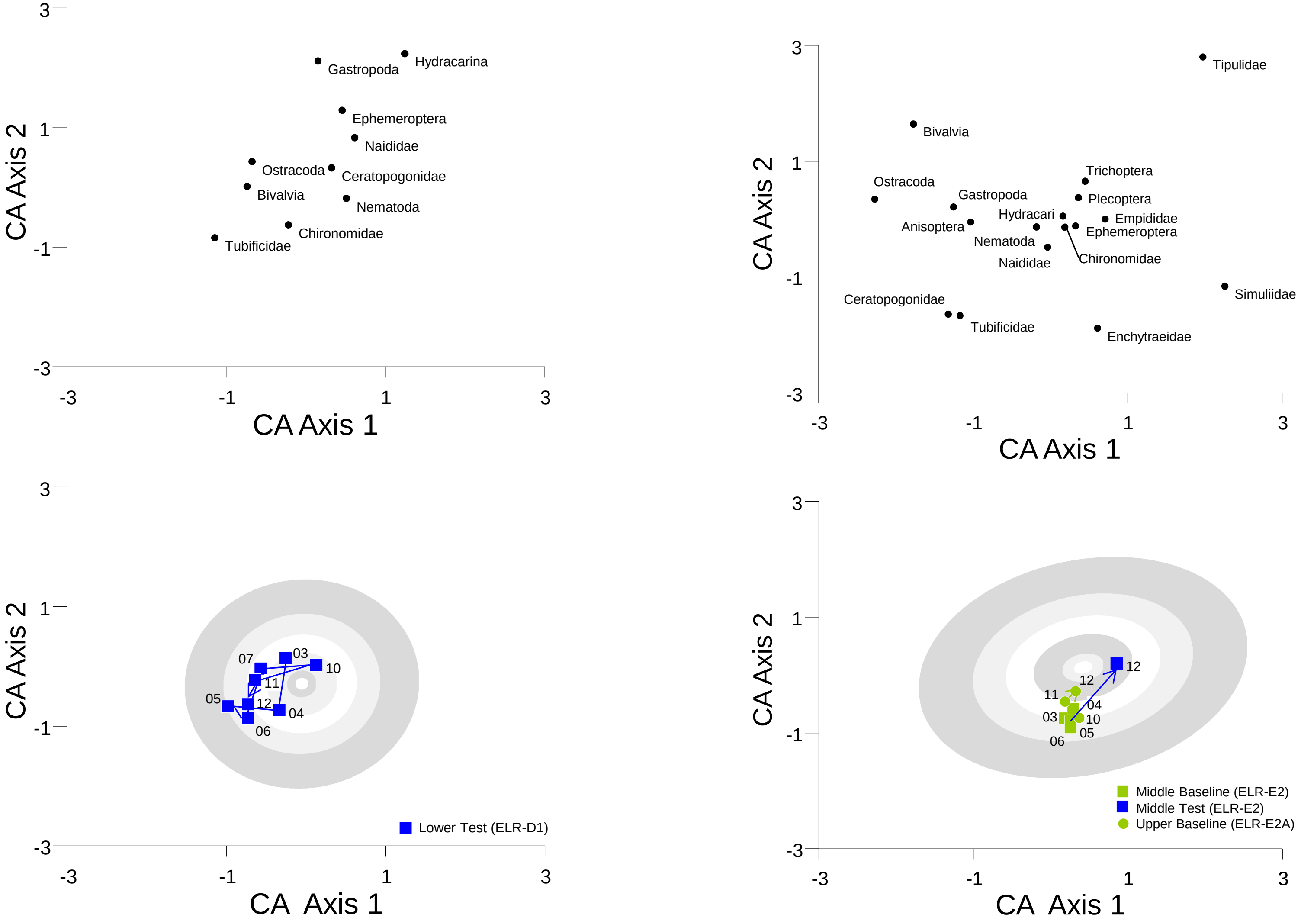
Table 5.8-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach ELR-E2.

Variable	**P-value**			**Variance Explained (%)**			**Nature of Change(s)**
	***Baseline* Reach vs. *Test* Reach**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**<0.001**	**<0.001**	60	24	22	Higher at *test* reach; higher than mean of *baseline* years, and mean of previous years.
Richness	**0.001**	**<0.001**	**<0.001**	16	36	50	Higher in 2012 than mean of *baseline* years; higher than mean of previous years.
Simpson's Diversity	0.065	**0.028**	0.161	25	36	14	Higher in 2012 than mean of *baseline* years.
Equitability	**<0.001**	**<0.001**	**<0.001**	47	81	71	Higher in 2012 than mean of *baseline* years; higher than mean of previous years.
EPT	**<0.001**	**0.010**	0.258	24	9	2	Lower at *test* reach; lower than mean of *baseline* years.
CA Axis 1	**0.028**	0.736	0.916	56	1	0	Higher at *test* reach.
CA Axis 2	**0.006**	0.806	0.928	40	0	0	Higher at *test* reach.

Bold values indicate significant difference ($p<0.05$).

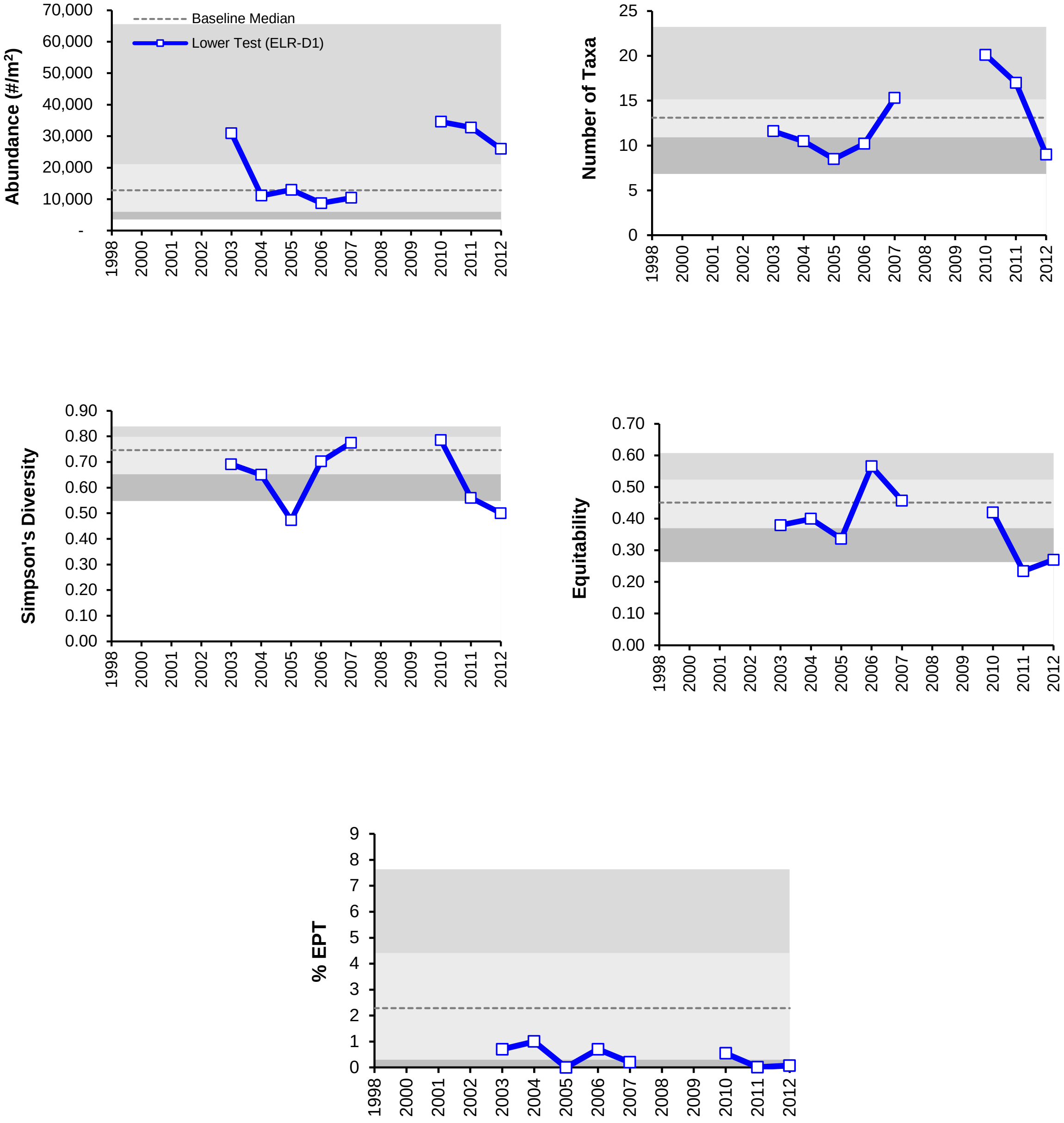
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.8-7 Ordination (Correspondence Analysis) of benthic invertebrate communities at reaches of the Ells River.



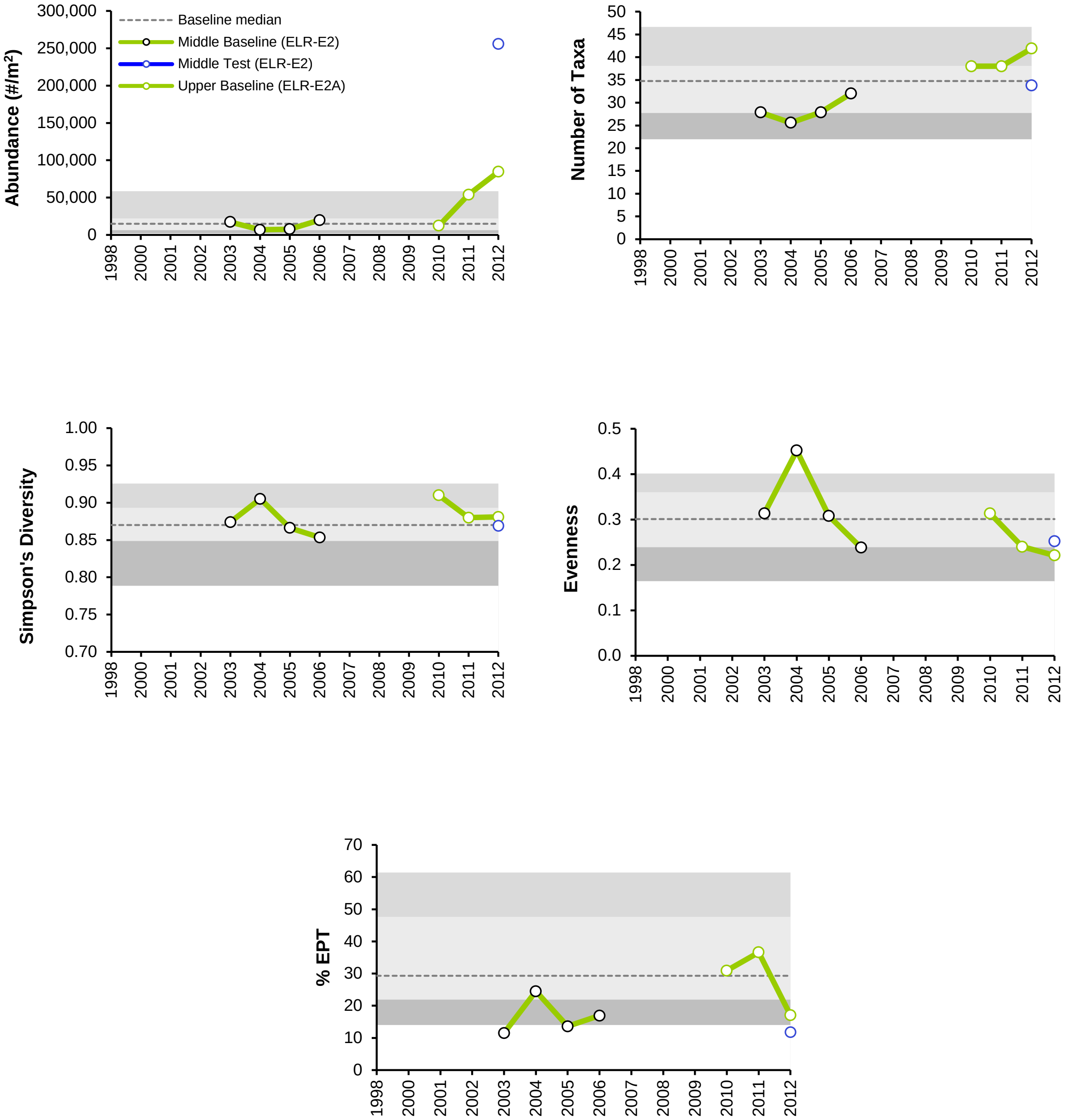
Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipse in the lower panel is for the *baseline* data.

Figure 5.8-8 Variation in benthic invertebrate community measurement endpoints at *test* reach ELR-D1 of the Ells River.



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.8-9 Variation in benthic invertebrate community measurement endpoints at *test* reach ELR-E2 and *baseline* reach ELR-E2A of the Ells River.



Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.8-13 Concentrations of selected sediment quality measurement endpoints, Ells River (*test* station ELR-D1), fall 2012.

Variables	Units	Guideline	September 2012	1998-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	12	9	3	7	26
Silt	%	-	31	9	3	14	51
Sand	%	-	57	9	23	81	94
Total organic carbon	%	-	2.3	9	0.4	1.7	2.8
Total hydrocarbons							
BTEX	mg/kg	-	<20	6	<5	<5	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	6	<5	<5	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	**289**	6	73	**174**	**320**
Fraction 3 (C16-C34)	mg/kg	300[1]	**2,560**	6	**890**	**1,595**	**3,000**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	1,500	6	510	845	1,600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.002	9	0.001	0.004	0.009
Retene	mg/kg	-	0.143	8	0.067	0.204	0.713
Total dibenzothiophenes	mg/kg	-	9.47	9	1.28	5.43	9.88
Total PAHs	mg/kg	-	24.2	9	4.81	16.2	25.1
Total Parent PAHs	mg/kg	-	0.514	9	0.218	0.391	0.571
Total Alkylated PAHs	mg/kg	-	23.7	9	4.46	15.8	24.5
Predicted PAH toxicity[3]	H.I.	1.0	**1.63**	9	**1.18**	**1.95**	**2.51**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	**-**
Other analytes that exceeded CCME guidelines in 2012							
Pyrene	mg/kg	0.053	**0.058**	9	0.024	0.032	**0.071**
Chrysene	mg/kg	0.0571	**0.204**	9	**0.072**	**0.101**	**0.203**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	6	5.0	6.9	7.6
Chironomus growth - 10d	mg/organism	-	1.73	6	0.72	2.04	2.80
Hyalella survival - 14d	# surviving	-	9.6	7	8.0	9.0	10.0
Hyalella growth - 14d	mg/organism	-	0.23	7	0.10	0.13	1.60

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

ns = not sampled

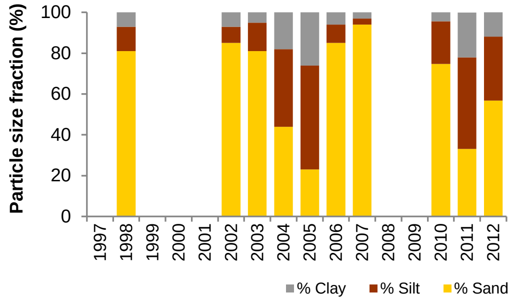
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

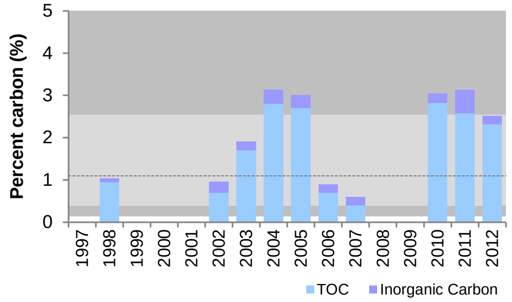
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-10 Variation in sediment quality measurement endpoints in the Ells River, *test* station ELR-D1.

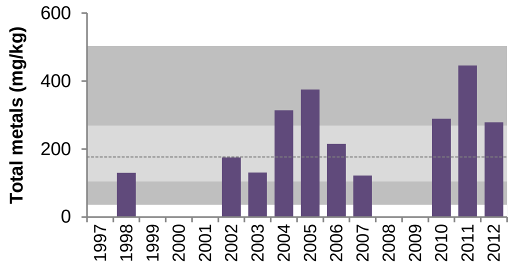
Particle size distribution



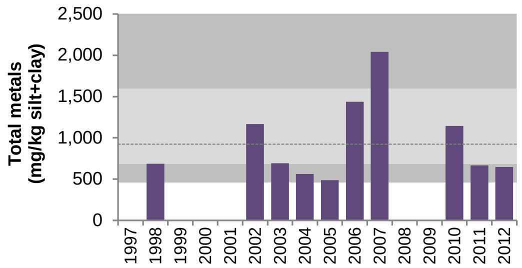
Carbon Content[1]



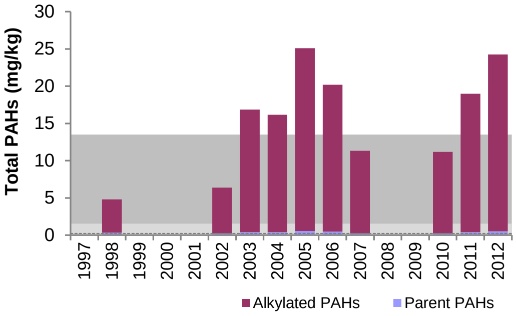
Total Metals[2]



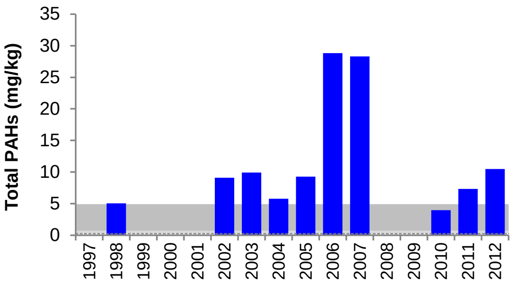
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



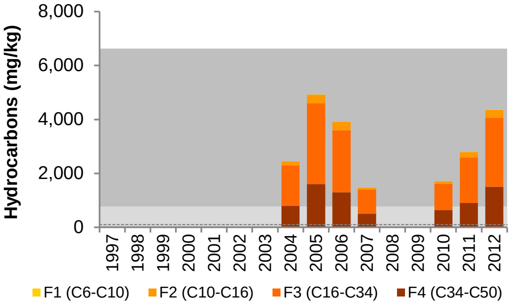
Total PAHs



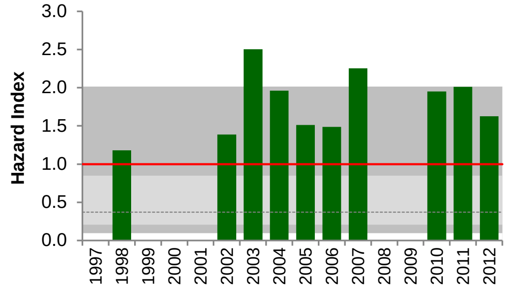
Total PAHs normalized to 1% TOC



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 (1997-2012).

[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 5.8-14 Average habitat characteristics of fish assemblage monitoring locations of the Ells River, fall 2012.

Variable	Units	ELR-F1 Lower *Test* Reach of Ells River	ELR-F2 Middle *Test* Reach of Ells River	ELR-F2A Upper *Baseline* Reach of Ells River
Sample date	-	13-Sept-12	10-Sept-12	09-Sept-12
Habitat type	-	run/riffle	run/riffle	run/riffle
Maximum depth	m	0.65	0.82	1.00
Bankfull channel width	m	31.0	30.0	33.5
Wetted channel width	m	26.0	25.0	25.5
Substrate				
Dominant	-	bitumen/sand	cobble	sand
Subdominant	-	fines	sand	cobble/bedrock
Instream cover				
Dominant	-	small woody debris and macrophytes	large woody debris and macrophytes	filamentous algae, macrophytes and boulders
Subdominant	-	large woody debris and filamentous algae	small woody debris and overhanging vegetation	small woody debris and live tree roots
Field water quality				
Dissolved oxygen	mg/L	10.6	10.5	9
Conductivity	µS/cm	247	191	216
pH	pH units	8.19	8.35	8.45
Water temperature	^{0}C	9.6	15.3	17.5
Water velocity				
Left bank velocity	m/s	0.31	0.30	0.00
Left bank water depth	m	0.32	0.36	0.10
Centre of channel velocity	m/s	0.94	0.35	0.14
Centre of channel water depth	m	0.47	0.46	0.76
Right bank velocity	m/s	0.16	-	0.00
Right bank water depth	m	0.29	-	0.20
Riparian cover – understory (<5 m)				
Dominant	-	woody shrubs and saplings	overhanging vegetation	woody shrubs and saplings
Subdominant	-	overhanging vegetation	woody shrubs and saplings	overhanging vegetation

Table 5.8-15 Percent composition and mean CPUE (catch per unit effort) of fish species at *test* reach ELR-F1 and *baseline* reach ELR-F2A of the Ells River, 2010 to 2012.

Common Name	Code	Total Species							Percent of Total Catch						
		ELR-F1			ELR-F2	ELR-F2A			ELR-F1			ELR-F2	ELR-F2A		
		2010	2011	2012	2012	2010	2011	2012	2010	2011	2012	2012	2010	2011	2012
Arctic grayling	ARGR	-	-	-	-	-	-	-	0	0	0	0	0	0	0
brook stickleback	BRST	-	-	-	-	-	-	-	0	0	0	0	0	0	0
burbot	BURB	-	-	-	-	-	-	-	0	0	0	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	-	0	0	0	0	0	0	0
finescale dace	FNDC	34	-	-	-	160	-	-	30.6	0	0	0	52.5	0	0
lake chub	LKCH	-	4	5	40	-	1	99	0	26.7	11.6	34.8	0	1.4	43.6
lake whitefish	LKWH	-	-	9	-	-	-	-	0	0	20.9	0	0	0	0
longnose dace	LNDC	2	2	-	16	-	19	18	1.8	13.3	0	13.9	0	26.4	7.9
longnose sucker	LNSC	-	-	1	-	13	-	25	0	0	2.3	0	4.3	0	11.0
northern pike	NRPK	-	-	-	1	-	-	1	0	0	0	0.9	0	0	0.4
northern redbelly dace	NRDC	-	-	-	-	-	-	-	0	0	0	0	0	0	0
pearl dace	PRDC	46	-	7	-	82	43	-	41.4	0	16.3	0	26.9	59.7	0
slimy sculpin	SLSC	-	-	-	-	-	1	-	0	0	0	0	0	1.4	0
spoonhead sculpin	SPSC	-	-	-	-	-	-	-	0	0	0	0	0	0	0
spottail shiner	SPSH	-	1	-	-	-	-	-	0	6.7	0	0	0	0	0
trout-perch	TRPR	1	6	18	9	4	6	48	0.9	40	41.9	7.8	1.3	8.3	21.1
walleye	WALL	-	-	-	-	-	-	-	0	0	0	0	0	0	0
white sucker	WHSC	12	-	2	49	46	2	36	10.8	0	4.7	42.6	15.1	2.8	15.9
yellow perch	YLPR	15	2	1	-	-	-	-	13.5	13.3	2.3	0	0	0	0
sucker sp. *		1	-		-	-	-	-	0.9	0	0	0	0	0	0
Total Count		**111**	**15**	**43**	**115**	**305**	**72**	**227**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**5**	**7**	**5**	**5**	**6**	**6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**5,258**	**1,307**	**1,979**	**2,170**	**3,959**	**1,614**	**1,956**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CPUE (#/100 secs)		**2.11**	**1.15**	**2.17**	**5.30**	**7.70**	**4.46**	**11.61**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* not included in total species richness count.

Table 5.8-16 Summary of fish assemblage measurement endpoints (±1SD) in reaches of the Ells River, 2010 to 2012.

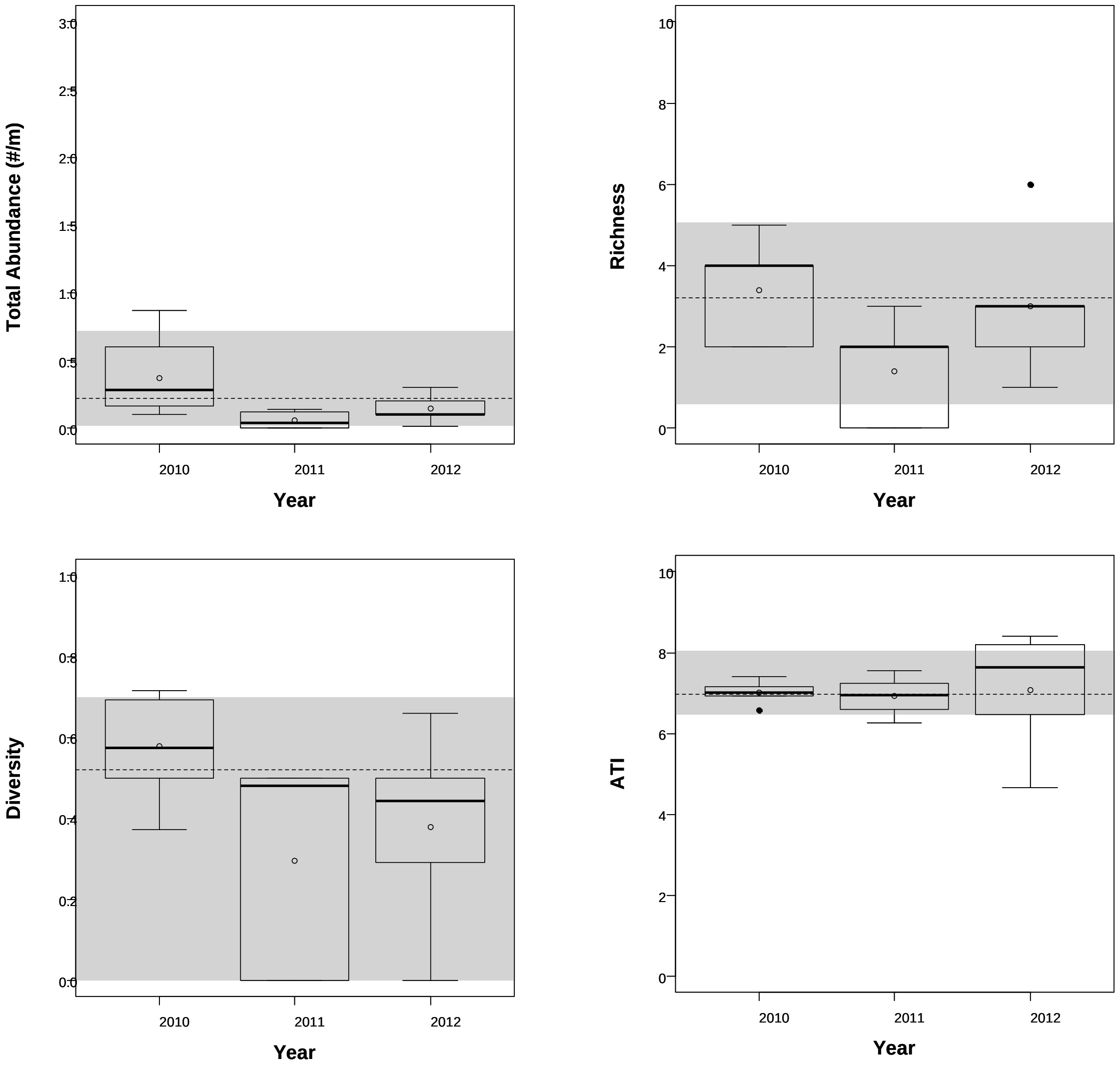
Reach	Year	Abundance		Richness*			Diversity*		ATI*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
ELR-F1	2010	0.37	0.25	7	3	1.07	0.58	0.12	7.02	0.21
	2011	0.06	0.07	6	1	1.34	0.30	0.27	6.92	0.65
	2012	0.14	0.11	7	3	1.87	0.38	0.25	7.07	1.54
ELR-F2	2012	0.38	0.23	5	3	1.10	0.49	0.28	6.80	0.58
ELR-F2A	2010	0.61	0.26	5	4	0.74	0.55	0.11	6.89	0.23
	2011	0.29	0.13	6	3	0.84	0.54	0.28	6.62	0.28
	2012	0.91	0.24	6	5	0.71	0.70	0.06	6.44	0.30

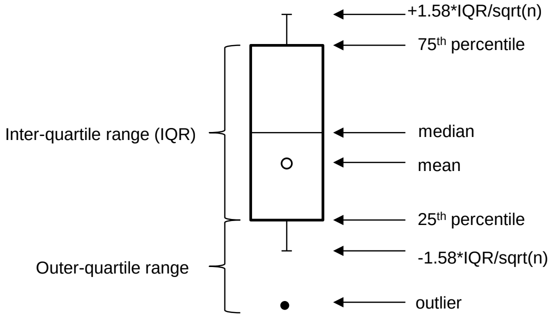
* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

Figure 5.8-11 Box-plots showing variation in fish assemblage measurement endpoints in reaches of the Ells River, 2010 to 2012.

Depositional *Test* Reach ELR-F1



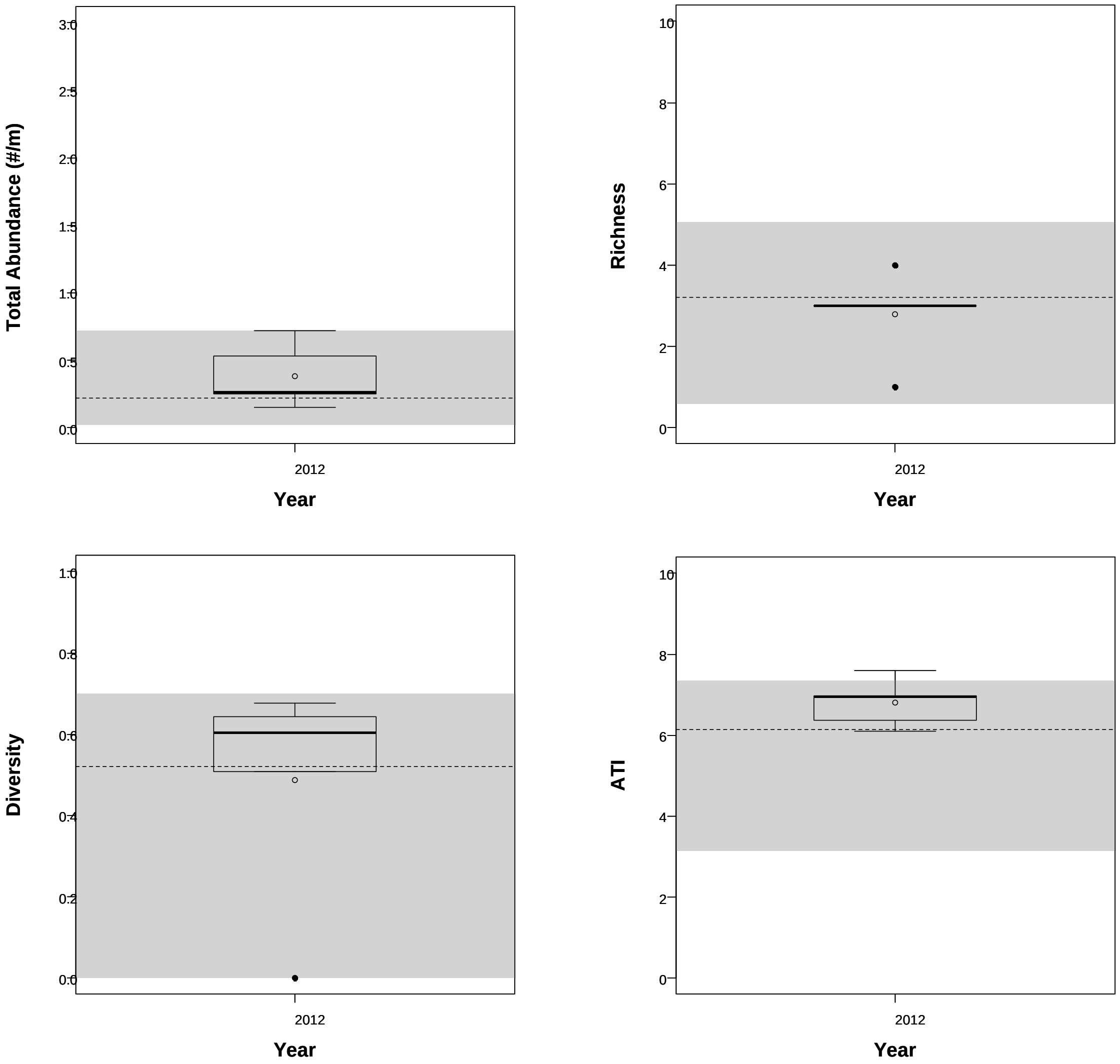


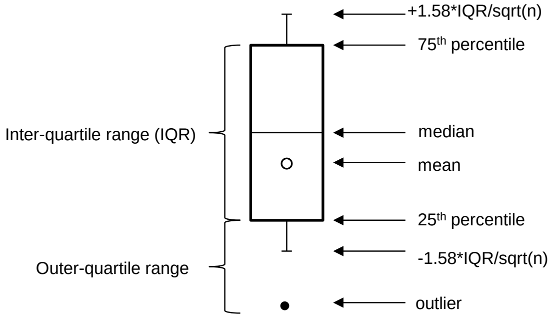
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Figure 5.8-11 (Cont’d.)

Erosional *Test* Reach ELR-F2



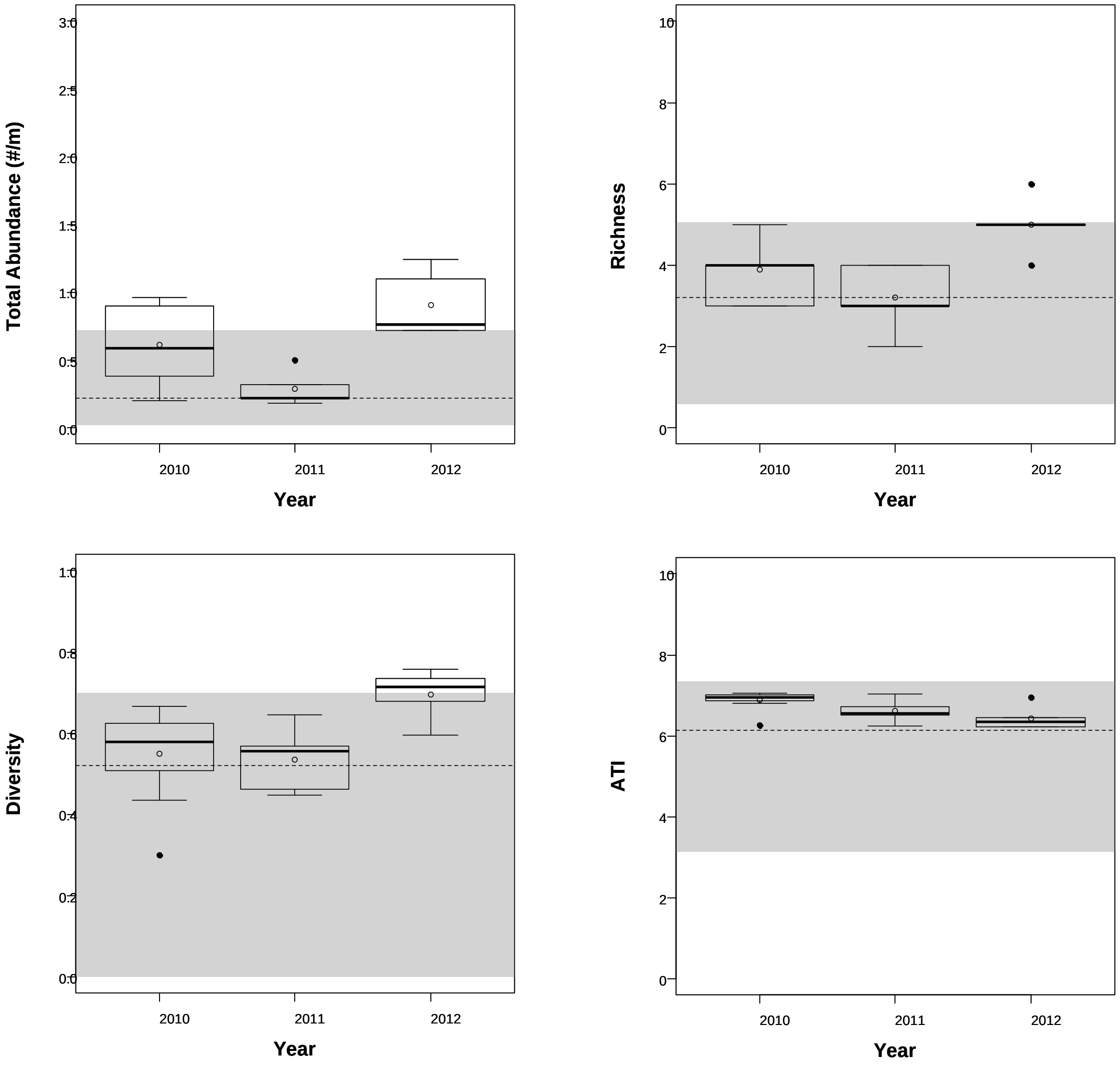


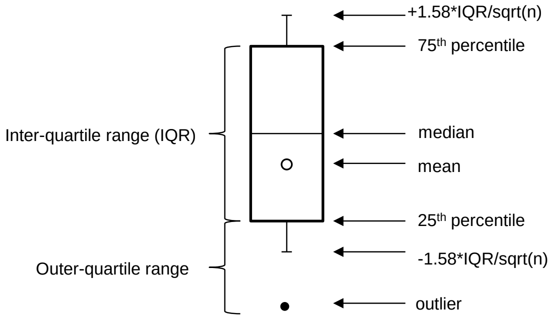
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

Test reach ELR-E2 was sampled for the first time in 2012 to be consistent with benthic sampling at this reach.

Erosional *Baseline* Reach ELR-F2A





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

5.9 CLEARWATER RIVER WATERSHED

Table 5.9-1 Summary of results for the Clearwater River watershed.

Clearwater River Watershed	**Summary of 2012 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 Index	🟠	🟠	🟡
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	not sampled		n/a
No Sediment Quality component activities conducted in 2012			
Fish Populations			
Criteria	**Fish Inventory Reaches (CR1, CR2, CR3)**		**HHR-F1** at the mouth
Human Health	NRPK > 500 mm[1]	Sub[2] 🟤 Gen[2] 🟠	not sampled
Sentinel Species	not sampled	not sampled	n/a
Fish Assemblages	not sampled	not sampled	n/a

Legend and Notes

🟡 Negligible-Low

🟠 Moderate

🟤 High

🟩 *baseline*

🟦 *test*

[1] Species (Sp.): NRPK=northern pike

[2] Sub. refers to subsistence fishers;
Gen. refers to general consumers as defined by Health Canada (see Section 3.4.7.3)

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 focal projects and other 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.

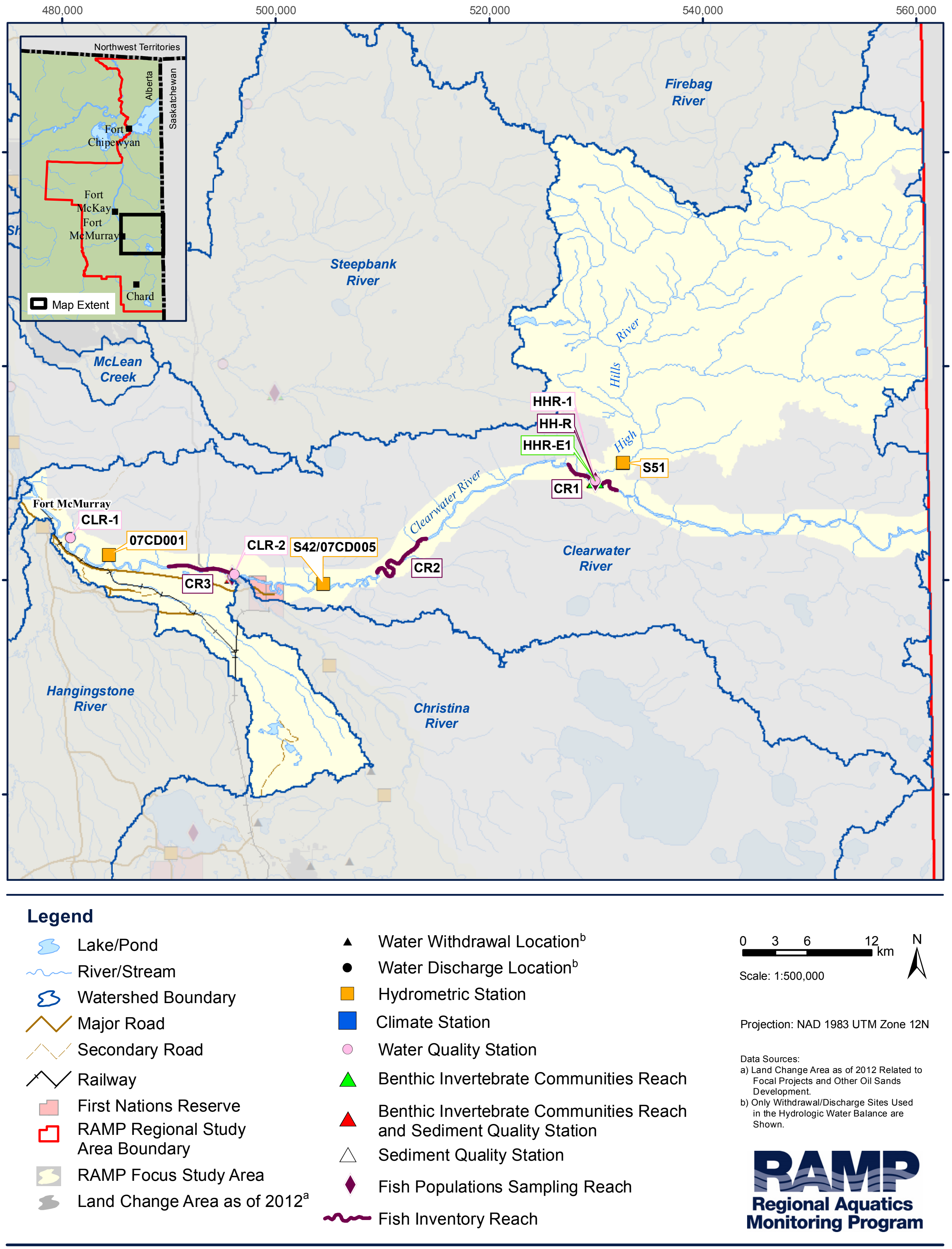
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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 3.3.1.10 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 3.2.4.3 for a 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.

Figure 5.9-1 Clearwater River watershed.



K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K09_Clearwater_20130424.mxd

Figure 5.9-2 Representative monitoring stations of the Clearwater River watershed, fall 2012.

Benthic Invertebrate Reach HHR-E1 (High Hills River): Right Downstream Bank

Fish Assemblage Reach HHR-F1 (High Hills River): Right Downstream Bank, facing upstream

Water Quality Station CLR-1 (Clearwater River): Right Downstream Bank

Water Quality Station CLR-2 (Clearwater River): Left Downstream Bank

5.9.1 Summary of 2012 Conditions

As of 2012, there has been no land change in the Clearwater River watershed from focal projects and other 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, 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 of RAMP in the Clearwater River watershed in 2012. Table 5.9-1 is a summary of the 2012 assessment of the Clearwater River watershed, while Figure 5.9-1 denotes the location of the monitoring stations for each RAMP component. Figure 5.9-2 contains photos of representative monitoring stations in the watersheds.

Water Quality In fall 2012, water quality at *baseline* station HHR-1 indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at stations on the Clearwater River (*test* station CLR-1 and *baseline* station CLR-2) indicated **Moderate** differences from regional *baseline* water quality conditions, with concentrations of several water quality measurement endpoints exceeding the range of previously-measured concentrations and the range of regional *baseline* conditions in 2012.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate community at *baseline* reach HHR-E1 was diverse, including a high percentage of chironomids and EPT taxa that reflected good water quality. High Hills River was used as a regional *baseline* reach for comparisons to *test* reaches in the RAMP FSA. Sediment quality monitoring was not conducted on the High Hills River given it is an erosional river.

Fish Populations (fish inventory) Total fish captured during the fall fish inventory has varied across years, which can be partially attributed to variability in discharge of the Clearwater River. In lower flow years, the amount of available fish habitat and the accessibility of the river is limited.

Species richness across reaches in spring 2012 was higher than previous years, with the exception of 2007 and 2008. Species richness in fall 2012 was also higher than previous sampling years. Species richness at the *test* reach was generally consistent to the *baseline* reaches across years for spring and summer. In fall, species richness was generally higher in the *baseline* reaches than the *test* reach.

The relative abundance of fish species in the Clearwater River was variable without any clear trends observed over time. Similarly, there has been no marked shift in species dominance from year to year. Additionally, there have been no significant differences in condition of large-bodied KIR fish species in the *test* reach of the Clearwater River when compared to *baseline* data. It is important to note; however, that condition cannot necessarily be attributed to the environmental conditions in the capture location, as these fish populations are highly migratory throughout the region.

Fish Populations (fish tissue) Measurement endpoints used in the northern pike Clearwater River fish tissue program included concentrations of metals and tainting compounds in both individual and composite samples. In 2012, the mean concentration of mercury in northern pike was lower than in previous sampling years, with the exception of 2009. The relationship between fork length and concentration of mercury concentration was significant in the northern pike sampled in 2012 but not significant across sampling years. The relationship between age and mercury concentration was significant in northern pike sampled in 2012 and significant across sampling years, demonstrating the influence of size and age on mercury bioaccumulation in fish tissue. The mercury concentration in size classes of northern pike greater than 550 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) The fish assemblage at *baseline* reach HHR-F1 was generally consistent with other *baseline* erosional reaches, with a much higher proportion of slimy sculpin. This species is typical of riffle habitat with faster flowing water and as noted above, is a sensitive species, which likely contributed to the lower ATI observed for *baseline* reach HHR-F1.

5.9.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Clearwater River watershed was conducted at the WSC Station 07CD001, Clearwater River at Draper. The data from this station were used to describe the 2012 WY hydrologic conditions of the Clearwater River. Additional hydrometric data for the Clearwater River watershed were available from WSC Station 07CD005, Clearwater River above the Christina River; details for this station can be found in Appendix C.

Continuous hydrometric data have been collected at Clearwater River at Draper, WSC Station 07CD001, since 1958. The annual runoff and open-water runoff volumes in the 2012 WY were 3,374 million m^3 and 2,518 million m^3, respectively. The annual runoff volume was 10% lower than the historical mean annual runoff, and the open-water runoff volume was 3% lower than the historical mean open-water runoff volume. Flows from December 2011 to March 2012 followed the historical lower quartile values. Flows increased during freshet in April and early May 2012 to a peak of 243 m^3/s on May 5 (Figure 5.9-3). Following the freshet, flows decreased until June and were within the historical inter-quartile range from May to August. Rainfall events in early to mid-September resulted in increased flows to a peak of 254 m^3/s on September 12, which was the maximum daily flow recorded in the 2012 WY and 34% lower than the historical mean annual maximum daily flow of 388 m^3/s. Following the 2012 WY peak, flows decreased until mid-October when rain events caused flows to exceed the upper quartile until the end of the 2012 WY. The minimum open-water daily flow of 97.0 m^3/s was recorded on August 22 and was 9% higher than the historical mean minimum daily flow of 88.8 m^3/s for the open-water period.

There was no land change in the Clearwater River watershed related to focal projects and other oil sands development in 2012. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

5.9.3 Water Quality

In fall 2012, 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 in 2012 to obtain three years of seasonal *baseline* data.

Temporal Trends The only significant ($\alpha=0.05$) trends in fall concentrations of water quality measurement endpoints was an increasing concentration of total nitrogen at *test* station CLR-1 (2002 to 2012). Trend analysis was not conducted for *baseline* station HHR-1 because only two years of data were available.

2012 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 exception of:

- total suspended solids, dissolved organic carbon, total aluminum, dissolved aluminum, total arsenic, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations and total dissolved phosphorus, with a concentration that was below the previously-measured minimum concentration at *test* station CLR-1; and

- total suspended solids, total aluminum, dissolved aluminum, total arsenic, total boron, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations and chloride, with a concentration that was below the previously-measured minimum concentration at *baseline* station CLR-2.

No historical comparisons were possible for *baseline* station HHR-1 on the High Hills River given that only two years of data exist for this station.

Ion Balance The ionic composition of water at all stations in the Clearwater watershed in fall 2012 was similar to previous years (Figure 5.9-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum at all stations exceeded the water quality guideline. Concentrations of dissolved aluminum and total mercury (ultra-trace) exceeded the water quality guidelines at *test* station CLR-1 and *baseline* station CLR-2 on the Clearwater River. Concentrations of total dissolved phosphorus and total nitrogen exceeded the water quality guidelines at *baseline* station HHR-1 and *baseline* station CLR-2, respectively (Table 5.9-2 to Table 5.9-4).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the Clearwater River watershed in fall 2012 (Table 5.9-5):

- dissolved iron, sulphide, total chromium, total copper, total iron, total lead, total phenols, and total phosphorus at *test* station CLR-1;

- dissolved iron, sulphide, total chromium, total copper, total iron, total lead, total phenols, dissolved zinc, total zinc, and total phosphorus at *baseline* station CLR-2; and

- total iron, dissolved iron, total phenols, sulphide, total phosphorus, and total chromium at *baseline* station HHR-1.

In addition, the following water quality guideline exceedances occurred in winter, spring, and summer at *baseline* station HHR-1 (Table 5.9-5):

- total aluminum, total iron, and total phosphorus in winter;

- total aluminum, total iron, total phosphorus, total phenols, sulphide, and dissolved iron in spring; and

- dissolved iron, dissolved phosphorus, sulphide, total aluminum, total chromium, total iron, total phenols, and total phosphorus in summer.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, most of the water quality measurement endpoints were within regional *baseline* concentrations, with the exception of the following (Figure 5.9-5):

- total suspended solids, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CLR-1 and *baseline* station CLR-2;

- total dissolved phosphorus, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station CLR-1 and *baseline* station CLR-2;

- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station CLR-1 and *baseline* station CLR-2; and

- total strontium, sodium, and sulphate, with concentrations below the 5th percentile of regional *baseline* concentrations at *baseline* station HHR-1.

Water Quality Index The WQI value at *baseline* station HHR-1 (97.5) in fall 2012 indicated a **Negligible-Low** difference from regional *baseline* water quality conditions. The WQI values for water quality stations on the Clearwater River (i.e., *test* station CLR-1: 80.0; *baseline* station CLR-2: 77.7) indicated **Moderate** differences from regional *baseline* water quality conditions, likely due to increased total suspended solids (TSS) and total metals associated with particulates.

Classification of Results In fall 2012, water quality at *baseline* station HHR-1 indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at stations on the Clearwater River (*test* station CLR-1 and *baseline* station CLR-2) indicated **Moderate** differences from regional *baseline* water quality conditions, with concentrations of several water quality measurement endpoints exceeding the range of previously-measured concentrations and the range of regional *baseline* conditions in 2012.

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

High Hills River

Benthic invertebrate communities were sampled in fall 2012 at *baseline* reach HHR-E1 (erosional, sampled since 2011).

2012 Habitat Conditions Water at *baseline* reach HHR-E1 in fall 2012 was shallow (0.3 m), fast flowing (1.2 m/s), basic (pH: 8.2), with high dissolved oxygen (7.7 mg/L), and low conductivity (129 µS/cm) (Table 5.9-6). The substrate was comprised of large gravel (32%) and small cobble (26%) with smaller amounts of small gravel and large cobble (15%) (Table 5.9-6). Periphyton biomass averaged 5 mg/m^2, which was much lower than 2011, but still within the range of variation for *baseline* erosional reaches (Figure 5.9-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *baseline* reach HHR-E1 was dominated equally by Naididae worms and Ephemeroptera (26% for each), with subdominant taxa consisting of chironomids (11%) and Trichoptera (9%) (Table 5.9-7). Mayflies were diverse and dominated by Baetis and Ephemerella. Plecoptera (Zapada) and Trichoptera (Lepidostoma, Brachycentrus, Protoptila) were also present in the reach. Dominant chironomids included *Rheotanytarsus*, *Tanytarsus*, and various Orthoclads. Gastropoda (the limpet *Ferrissia rivularis*) and bivalves (Pisidium/Sphaerium) were present indicating good, stable water quality.

Temporal and Spatial Comparisons Sampling was initiated at *baseline* reach HHR-E1 in 2011 to provide more *baseline* data for erosional habitat in the region; therefore, spatial and temporal comparisons were not conducted in 2012.

Comparison to Published Literature The benthic invertebrate community at *baseline* reach HHR-E1 reflected good water and sediment quality, with a decrease in the percentage of the community as worms and an increase in the percentage of EPT taxa compared to 2011. The presence of permanent aquatic organisms including bivalves and gastropods indicated good long-term water quality. The dominant forms of chironomidae found are known to represent fair to good water quality (Mandaville 2002) (e.g., the chironomid *Rheotanytarsus* tends to occur in rocky streams with good flow [Merritt and Cummins 1996]).

2012 Results Relative to Regional *Baseline* Conditions Values of all measurement endpoints in fall 2012 were within the range for regional *baseline* conditions for erosional reaches (Figure 5.9-7). CA Axis scores were within the range of variation for *baseline* erosional reaches (Figure 5.9-8).

Classification of Results The benthic invertebrate community at *baseline* reach HHR-E1 was diverse, including a high percentage of chironomids and EPT taxa that reflected good water quality. High Hills River was used as a regional *baseline* reach for comparisons to *test* reaches in the RAMP FSA.

5.9.4.2 Sediment Quality

No sediment quality sampling was conducted in the High Hills River in 2012 because sediment quality is only sampled in the depositional reaches in which benthic invertebrate communities were sampled and the reach of the High Hills River where benthic invertebrate communities were sampled are erosional.

5.9.5 Fish Populations

In 2012, fish population monitoring in the Clearwater River watershed consisted of a spring, summer, and fall inventory. The *baseline* reaches (CR1 and CR2) have been continually sampled in spring and fall since 2003 with the exception of fall 2011, and in summer since 2009. The *test* reach (CR3) has been sampled in spring and fall since 2003. A fall fish tissue program was also conducted on the Clearwater River in 2012.

In addition to the Clearwater River fish inventory, fish assemblage monitoring and sentinel species monitoring were conducted at the lower High Hills River in fall 2012, which flows into the Clearwater River. The results of the fish inventory, fish tissue program, and fish assemblage monitoring are presented in this section; the results of the sentinel species monitoring are presented in Section 5.3.

5.9.5.1 Clearwater River Fish Inventory

Temporal and Spatial Comparisons

To assess change over time by season, as well as among areas of the river, temporal and spatial comparisons were conducted for the following measurement endpoints: species composition, species richness, catch per unit effort (CPUE), age-frequency distributions, size-at-age, and condition factor.

Total Catch and Species Composition A total of 2,271 fish were captured in the three reaches of the Clearwater River during the spring, summer, and fall inventories in 2012 (Table 5.9-8 and Figure 5.9-9), of which:

- 522 fish representing 17 species were captured in the spring;
- 851 fish representing 16 species were captured in the summer; and
- 898 fish representing 17 species were captured in the fall.

A total of 22 species were captured across all three seasons during the 2012 Clearwater River fish inventory. The dominant large-bodied fish species captured across seasons was white sucker (spring: 35.4%, summer: 32.9%, and fall: 26.1% of the total catch). The sub-dominant large-bodied fish species consisted of longnose sucker in spring and summer (9.39% and 24.32%, respectively), and northern pike (8.13%) in fall. Spottail shiner was the dominant small-bodied fish species in spring, summer, and fall (22.61%, 18.10%, and 27.62%, respectively).

Total Catch versus River Discharge The variability in total catch across years in the fall season was further examined to determine whether river discharge was an influencing factor given that in low flow years, the amount of available habitat in the river and accessibility for fishing is limited. Total catch was compared to discharge of the Clearwater River during the period when the fall fish inventories were conducted (Figure 5.9-10). Prior to 2009, discharge measurements were taken from a hydrology station downstream of *test* reach CR3 (WSC station 07CD001). From 2009 to 2012, discharge measurements were taken from a newly-installed hydrology station within *test* reach CR3 (RAMP hydrology station S42). The relationship between discharge and total catch was low prior to 2009; however, the WSC hydrology station is located in an area with deep, slow moving water, whereas the reaches where fishing is conducted are shallower with typically faster flowing water. From 2010 to 2012, total catch was lower in years when discharge was typically low (Figure 5.9-10). In 2011, flow was measured at a historical low of 48.4 m^3/s for the period when fishing was conducted and it was not possible to sample the *baseline* reaches. In 2012, discharge was higher during the sampling period (103.7 m^3/s) and the total number of fish captured was also higher.

Species Richness Species richness was compared between *baseline* reaches CR1 and CR2 and *test* reach CR3 (Table 5.9-8). In spring and summer 2012, the number of species caught at *test* reach CR3 was generally similar to the number of species caught at *baseline* reaches CR1 and CR2 (Table 5.9-8). There were a higher number of fish species captured at the *test* reach in fall 2012 compared to the *baseline* reaches.

Species richness was higher in spring and summer 2012 than 2011 for both *test* and *baseline* reaches (the *baseline* reaches were not sampled in fall 2011). Species richness in fall 2012 was higher at the *test* reach but lower at the *baseline* reaches than 2011. Species richness across seasons and reaches has been generally consistent across sampling years.

Catch Per Unit Effort Seasonal catch per unit effort (CPUE) for each large-bodied KIR fish species in 2012 between *test* and *baseline* reaches is presented in Figure 5.9-11. In spring 2012, white sucker had the highest CPUE in both the *test* and *baseline* reaches, followed by longnose sucker in the *test* reach and walleye in *baseline* reaches. In summer 2012, longnose sucker had the highest CPUE in the *test* reach and white sucker had the highest CPUE in the *baseline* reaches. In fall 2012, white sucker had the highest CPUE for both *test* and *baseline* reaches (Figure 5.9-12).

Annual CPUE for each season is presented in Figure 5.9-12. Contrary to 2011 when CPUE of walleye was highest in spring, white sucker had the highest CPUE in spring 2012. Walleye had the highest CPUE in summer and fall followed by white sucker.

Age-Frequency Distributions and Size-At-Age The relative age-frequency distributions of large-bodied KIR fish species for years when ageing data were collected are presented in Figure 5.9-13 to Figure 5.9-17. Statistical differences in size-at-age between 2012 and previous years were tested using analysis of covariance (ANCOVA). Only large-bodied

KIR fish species with adequate samples sizes ($n \geq 20$) were included and only significant differences were reported. Species-specific results are as follows:

1. Ageing data for goldeye were only collected in 2011 and 2012 from the Clearwater River. The dominant age class in 2012 was five years with a subdominant age class of four and eight years. In 2011, the dominant age class was ten years. Due to the small sample size over the last two years, it was not possible to determine any trends or shifts in the distribution. Similar to 2011, the regression relationship between length and age was moderate ($R^2=0.71$) (Figure 5.9-13)**.**

2. Ageing data for longnose sucker was collected in 2006, 2011, and 2012 from the Clearwater River. The dominant age class in 2012 was two years with a subdominant age class of three years. A shift to a dominant younger age class was observed between 2006 and 2011 and continues to be evident in 2012. The dominant age classes in 2006 were six and eight years. The regression relationship between length and age in 2012 was moderate ($R^2=0.65$) and similar to 2011 (Figure 5.9-14).

3. The dominant age class of northern pike in 2012 was two years with a subdominant age class of three years. The majority of northern pike caught in 2012 were between one and five years, further supporting the shift to a greater proportion of younger fish, which may be a result of fishing pressure on older, larger fish (RAMP 2012). The regression relationship between length and age of northern pike was strong in 2011 but moderate in 2012 ($R^2=0.67$) (Figure 5.9-15). There was a significant increase in size-at-age in northern pike captured in 2012 compared to individuals captured in all previous years (i.e., 2005 - $p<0.001$, 2006 – $p<0.001$, 2009 – $p<0.001$, 2011 – $p=0.066$), indicating greater growth in northern pike in 2012.

4. The dominant age classes of walleye in 2012 were four and five years with a subdominant age class of two years. Since 2004, when RAMP started collecting ageing data for walleye from the Clearwater River, there has been a dominance of younger walleye. Similar to previous years, the regression relationship between length and age in 2012 was moderate ($R^2=0.73$) (Figure 5.9-16).

5. Ageing data for white sucker were only collected in 2011 and 2012 from the Clearwater River. The dominant age class in both years was four years with a subdominant age class of two years. Similar to 2011, the regression relationship between length and age was moderate ($R^2=0.54$) (Figure 5.9-17). There was a significant increase in size-at-age in white sucker captured in 2012 compared to individuals captured in 2011 ($p=0.022$).

Condition Factor The mean condition factor for each large-bodied KIR fish species captured in summer and fall 2012 in *test* reach CR3, was compared to the mean condition of fish captured in summer 2012 in *baseline* reaches CR1 and CR2 (Figure 5.9-18). The mean condition factor for each large-bodied KIR fish species across all reaches in summer and fall from 2003 to 2012 are presented in Figure 5.9-19. An analysis of covariance (ANCOVA) was performed on condition of large-bodied KIR fish species captured in adequate sample sizes ($n \geq 20$) for summer and fall, to determine if there are any significant differences ($p<0.05$) in condition across years within the *baseline* and *test* reaches; however, due to small sample sizes in summer and fall, the two seasons were grouped together in 2012 and separated by KIR fish species and reach (i.e., *baseline* vs.

test). Fish captured in spring were excluded from the analysis due to the influence of spawning on condition and not necessarily reflective of differences in energy storage (i.e., reproductive vs. somatic tissue). The species-specific results are as follows:

1. Condition of summer-captured goldeye could not be statistically analyzed due to inadequate sample size (n<20) to make comparisons between *baseline* and *test* reaches across years. There were no adult goldeye captured in the *baseline* reaches in fall 2012 to make comparisons.
2. Condition of longnose sucker could not be statistically analyzed for either season due to inadequate sample size (n<20) to make comparisons between *baseline* and *test* reaches across years. Based on the longnose sucker that were captured, condition of longnose sucker in summer was similar across reaches and condition of longnose sucker in fall at the *test* reach was lower than the *baseline* reaches.
3. Condition of northern pike was not significantly different between *test* and *baseline* reaches (p=0.26/0.56) across years (Figure 5.9-19).
4. Condition of walleye could not be statistically analyzed for either season due to inadequate sample size (n<20) to make comparisons between *baseline* and *test* reaches across years. Based on the walleye that were captured, condition of walleye in summer at the *test* reaches was greater than the condition of walleye at the *baseline* reaches and condition of walleye in fall was lower at the *test* reach compared to the *baseline* reaches.
5. Condition of white sucker was not significantly different between *test* and *baseline* reaches across years (p=0.77/0.41) (Figure 5.9-19).

External Health Assessment

Abnormalities present among fish captured in 2012 were primarily associated with minor skin aberrations or wounds, scars and fin erosion. In 2012, 2.5%, 3.3%, and 2.5% of fish captured in spring, summer, and fall, respectively, were found to have some sort of external abnormality. In all seasons in 2012, the percent of external abnormalities was lower than previous years.

A summary from 2003 to 2012 of the percentage of fish of each species exhibiting some form of external pathology is presented in Table 5.9-9. Fifteen of the 2,271 (0.7%) fish exhibited some form of external pathological abnormality such as parasites, growths, lesions or body deformities (Table 5.9-9, Figure 5.9-20). Fish species that were documented with pathological abnormities were lake whitefish, longnose sucker, northern pike, spottail shiner, and white sucker. Similar to 2011, abnormalities in 2012 were primarily observed in white sucker (1.5%).

Summary

The Clearwater fish inventory is a community-driven activity primarily suited for assessing general trends in species composition, abundance, and population variables (i.e., condition of fish and age-frequency distribution) for large-bodied KIR species rather than assessing detailed fish community structures.

Total fish captured during the fall fish inventory has varied across years, which can be partially attributed to the variability in discharge of the Clearwater River. In lower flow years, the amount of available fish habitat and the accessibility of the river is limited.

Species richness across reaches in spring 2012 was higher than previous years, with the exception of 2007 and 2008. Species richness in fall 2012 was also higher than previous sampling years. Species richness at the *test* reach was generally consistent to the *baseline* reaches across years for spring and summer. In fall, species richness was generally higher in the *baseline* reaches than the *test* reach.

The relative abundance of fish species in the Clearwater River was variable without any clear trends observed over time. Similarly, there has been no marked shift in species dominance from year to year. Additionally, there have been no significant differences in condition of large-bodied KIR fish species in the *test* reach of the Clearwater River when compared to *baseline* data. It is important to note; however, that condition cannot necessarily be attributed to the environmental conditions in the capture location, as these fish populations are highly migratory throughout the region.

Similar to 2011, in 2012 a shift towards a younger age class was observed in northern pike and walleye. Although uncertain, this may reflect increasing fishing pressure on adult fish over the years within the Clearwater River causing a shift to a population dominated by younger individuals (Almodóvar and Nicola 2004).

5.9.5.2 Clearwater River Fish Tissue Program

Whole-Organism Metrics

A total of 35 northern pike (9 male, 1 female, and 25 unsexed) were collected from the Clearwater River for fish tissue analysis in conjunction with the 2012 fall fish inventory. The size of northern pike captured ranged from 263 mm to 682 mm (Table 5.9-10). The mean length of northern pike was 476 mm, with an average length of males of 513 mm; the one female captured was 535 mm.

External fish health assessments were conducted on all 24 fish collected for non-lethal mercury analysis and internal fish health assessments were conducted on all 11 northern pike that were sacrificed for metal and organics tissue analyses. There were no abnormalities observed in any of the fish from which tissue was sampled non-lethally. Of the lethal collection of northern pike, parasites were observed internally in one mature male.

Mercury

Total mercury concentrations in muscle tissue of northern pike from the Clearwater River in fall 2012 are presented in Table 5.9-10. Concentrations of mercury in northern pike ranged from 0.07 mg/kg to 0.42 mg/kg, with a mean concentration of 0.15 mg/kg. Temporal comparisons of absolute and length-normalized concentrations of mercury in northern pike from the Clearwater River are presented in Figure 5.9-21. Northern pike captured in 2012 were generally smaller (459 mm) than those caught in previous years (461 mm to 567 mm), with the largest fish captured in 2004 (567 mm) and 2007 (510 mm). To reduce variation in the data due to differences in the length of fish caught in each year of sampling, length-normalized concentrations of mercury (normalized to the mean length of captured northern pike [i.e., 488 mm]) are also presented. Absolute and length-normalized concentrations of mercury in 2012 were within the historical range (2004 to 2009), with 2009 and 2007 exhibiting the lowest and highest concentrations of mercury, respectively (Figure 5.9-21).

Concentrations of mercury relative to fork length and age in 2012 are presented in Figure 5.9-22. Concentrations of mercury show a moderate increasing relationship with fork length and age. Regressions between mercury concentrations ($\log_{10}$-transformed) and fork length and mercury concentrations ($\log_{10}$-transformed) and age of individual northern pike were statistically significant (p<0.001), with a moderate correlation of mercury concentration to length (r=0.58) and a low correlation to age (r=0.45). An analysis of covariance (ANCOVA) on northern pike data from all years of sampling indicated that differences in mercury concentrations relative to length were not statistically significant across sampling years (p=0.88). Differences in mercury concentrations relative to age across sampling years (2004, 2006, 2007, 2009, 2012) was statistically significant (p<0.001) (Figure 5.9-22).

Other Chemicals

Composite samples of northern pike were analysed for concentrations of other chemicals and tainting compounds in fish tissue from the Clearwater River: composite samples were collected for females (500 to 550 mm) and males (450 to 500 mm and 500 to 550 mm) for a total of three composite samples. Fifteen of the 27 metals analysed were below the analytical detection limit for the female composite, while 13 and 14 of the 27 metals analysed were below the analytical detection limit for the 450 to 500 mm and 50 to 550 mm male composite samples, respectively (Table 5.9-11). In 2012, all tainting compounds were below analytical detection limits for all composite tissue samples (Table 5.9-11).

Potential Risk to Human Health

Mercury In 2012, concentrations of mercury in northern pike from the Clearwater River were screened against human health criteria for fish consumption established by Health Canada and the United States Environmental Protection Agency (USEPA) (Table 5.9-10). The mean mercury concentration for northern pike in 2012 was below Health Canada consumption guidelines. Four of the 30 fish captured exceeded the Health Canada consumption guideline for subsistence fishers (0.20 mg/kg), of which none exceeded the Health Canada consumption guideline for general consumers (0.50 mg/kg) (Table 5.9-10). The majority of fish with concentrations of mercury that exceeded Health Canada guidelines were larger (i.e., >550 mm), demonstrating the potential for bioaccumulation of mercury in fish as they grow (Scott and Crossman 1973).

In 2012, 43% of northern pike captured were greater than or equal to 908 g in weight. According to the Government of Alberta (2009), the consumption limits for northern pike from the Clearwater 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 eight servings (75 g per serving) per week; a child of one to four years old should only consume two servings a week; children five to eleven years should only consume four servings a week (300 g); and for adults (includes adults and children over 12 years), there is no limit (Table 3.4-9).

Other Chemicals Concentrations of total arsenic exceeded the USEPA subsistence guideline (0.00327 mg/kg) in the male composite samples (450-500 mm and 500-550 mm) (Table 5.9-11). Exceedances of the subsistence guideline have also been observed in previous sampling years (RAMP 2005, 2007, 2008, 2010). It should be noted that the USEPA guideline was established for inorganic arsenic not total arsenic; therefore, 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). Estimated concentrations of inorganic arsenic are also provided in Table 5.9-11. Concentrations of inorganic arsenic in northern pike did not exceed the USEPA guidelines in 2012. In 2012, concentrations of organic and inorganic arsenic in northern pike from the Clearwater River did not exceed the USEPA recreational guideline.

Potential Risk to Fish and Fish Health

The following are the results of screening for potential risks of chemical concentrations to fish and fish health (Table 5.9-12):

- the concentrations of mercury in northern pike did not exceed any of the effects (or no-effects) thresholds for fish and fish health;
- the concentration of selenium exceeded the lethal no-effects threshold for all composite samples; and
- concentrations of all other analytes were below the lowest no-effects sublethal concentrations (Jarvinen and Ankley 1999).

For the protection of fish and fish health, the sublethal lowest no-effect threshold for selenium (0.08 mg/kg) (Jarvinen and Ankley 1999) was either met or exceeded in all composites in all years of sampling, with the exception of the male composite in 2004. Concentrations of selenium in female composites of northern pike in the Clearwater River have been decreasing since 2007, while both male composites in 2012 had higher selenium concentrations than 2009.

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 Clearwater River and its relationship to toxicity of metals to fish (RAMP 2009a).

Potential Risk to Fish Palatability

Concentrations of all tainting compounds in northern pike from the Clearwater River were present at concentrations below the 1 mg/kg threshold for effects on palatability as outlined in Jardine and Hrudey (1998) (Table 5.9-11).

Regional Comparison

The results from the 2012 Clearwater River northern pike tissue program were compared to results from regional northern pike fish tissue studies conducted in rivers across northern Alberta from 1975 to 2012 to provide a regional context to findings of the 2012 program (Figure 5.9-23) (AOSERP 1977, Grey et al 1995, RAMP 2004, RAMP 2007, RAMP 2008, RAMP 2010). To remove any variability in mean mercury concentrations caused by differences in length of sampled fish across years, concentrations of mercury in northern pike were normalized to the mean fork length of all fish captured (i.e., 496 mm). The mean length of northern pike captured in 2012 (476 mm) was near the historical mean and within the historical range (172 mm to 698 mm). Length-normalized mean concentrations of mercury ranged from 0.067 mg/kg in the Athabasca River (1992) to 0.30 mg/kg in the Slave River (1990), with the mean length-normalized concentration of mercury in northern pike from the Clearwater River in 2012 near the mid-range of historical values (0.16 mg/kg). Across all rivers, 59% of length-normalized concentrations of mercury were below the Health Canada subsistence fisher guideline (0.2 mg/kg) and no mean length-normalized concentrations of mercury were above the general consumer guideline (0.5 mg/kg). The majority of guideline exceedances occurred prior to 1990, with the exception of the Muskeg River in which mercury concentrations in northern pike also exceeded the subsistence guideline in 2004 (Figure 5.9-23).

Summary Assessment for Fish Tissue

Measurement endpoints used in the northern pike Clearwater River fish tissue program included concentrations of metals and tainting compounds in fish tissue of both individual and composite samples., from which potential human and fish health risks were assessed. In 2012, the mean concentration of mercury in northern pike was lower than in previous sampling years, with the exception of 2009. The mercury concentration in size classes of northern pike greater than 550 mm exceeds the subsistence fishers guideline for consumption, indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

5.9.5.3 High Hills River Fish Assemblage Monitoring

Fish assemblages were sampled in fall 2012 at erosional *baseline* reach HHR-F1, which was sampled for the first time in 2011 (this reach is at the same location as the benthic invertebrate community *baseline* reach HHR-E1).

2012 Habitat Conditions *Baseline* reach HHR-F1 was comprised of riffle and run habitat, with a wetted width of 20 m and a bankfull width of 22 m (Table 5.9-13). The substrate was dominated by coarse gravel with smaller amounts of cobble, although high water levels prevented a detailed assessment of substrate composition. Water at *baseline* reach HHR-F1 was an average of 0.41 m in depth, moderately flowing (average flow: 0.46 m/s), slightly alkaline (pH: 7.65), with low conductivity (127 µS/cm), high dissolved oxygen (11.6 mg/L), and a temperature of 2.7˚C (Table 5.9-13). Instream cover was dominated by small and large woody debris (Table 5.9-13).

Temporal and Spatial Comparisons Sampling was initiated in High Hills River in fall 2011; therefore, temporal comparisons were conducted between 2011 and 2012.

There was a decrease in CPUE, abundance, richness, and diversity at *baseline* reach HHR-F1 in 2012 compared to 2011 (Table 5.9-14, Table 5.9-15). There was also a slight decrease in the ATI value, which was related to the dominance of slimy sculpin (low tolerance value) and very low catch of other species. In 2011, the ATI was higher because in addition to the high number of slimy sculpin captured, there were higher numbers of more tolerant species in the catch as well, which was not observed in 2012 (Table 5.9-14).

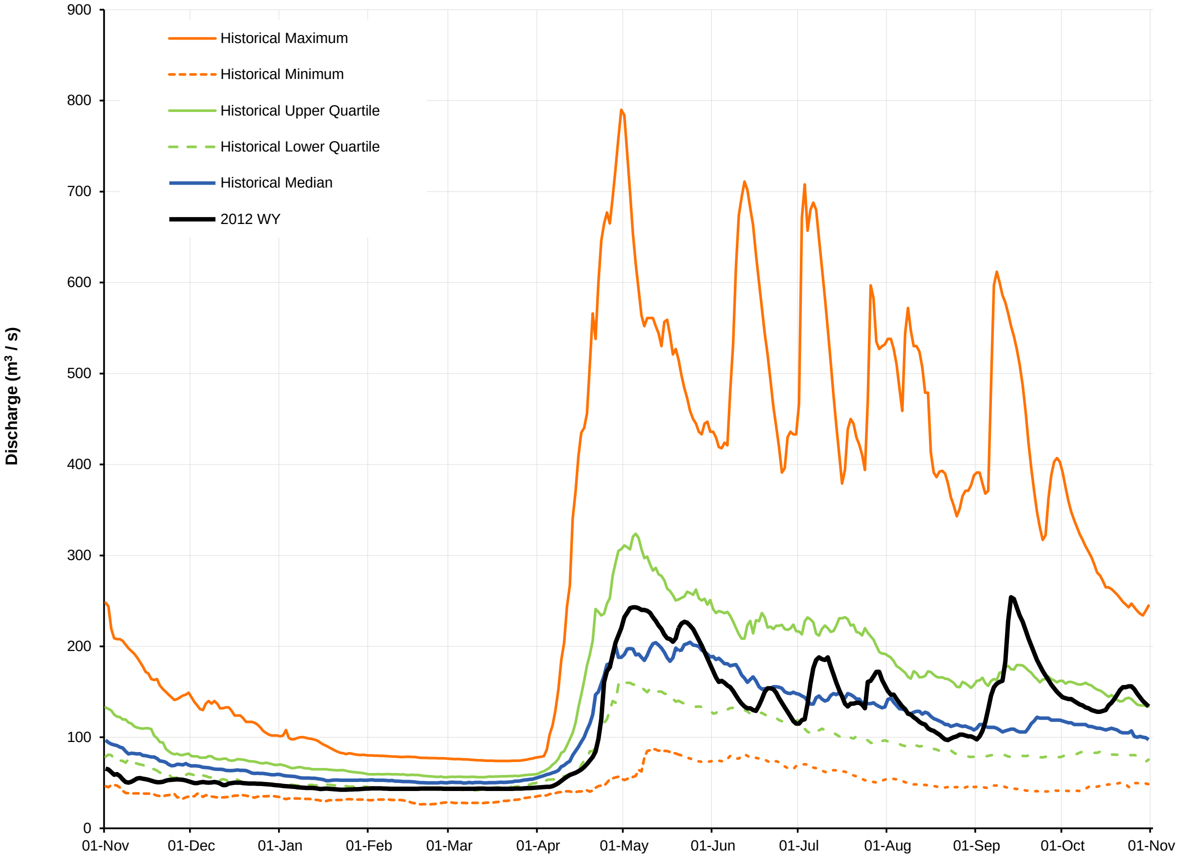
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution for comparison to fish assemblage data reported by RAMP. Based on past studies, a total of nine fish species were recorded in the High Hills River; whereas RAMP found a total of five species in 2011, including slimy sculpin and spoonhead sculpin, which had not been previously reported. Only three species were found in 2012, but two of the three (burbot and finescale dace) have also not previously been reported. The species composition for High Hills River was based on a single report and as noted in Section 5.2, 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., RAMP 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 RAMP in 2012, with the section of the river where *baseline* reach HHR-F1 is located, consisting of pools and riffles with substrate consisting of gravel in the riffles and sand, silt and gravel in the pools. These conditions provide excellent refugia and habitat for sport fish.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *baseline* reach HHR-F1 were within the range of regional *baseline* conditions for erosional reaches (Figure 5.9-24). The mean ATI was near the 5th percentile of regional baseline conditions, which was likely due to the high proportion of slimy sculpin captured, which is a sensitive species with a low tolerance value (Whittier et al. 2007) and the low number of other species captured.

Classification of Results The fish assemblage at *baseline* reach HHR-F1 was generally consistent with other *baseline* erosional reaches, with a much higher proportion of slimy sculpin. This species is typical of riffle habitat with faster flowing water and as noted above, are sensitive species that likely contributed to the lower ATI value observed for *baseline* reach HHR-F1.

Figure 5.9-3 Clearwater River at Draper hydrograph for the 2012 WY, compared to historical values.



Note: 2012 WY hydrograph based on Clearwater River at Draper, WSC Station 07CD001, provisional data for November 1, 2011 to October 31, 2012. Historical values from calculated for the period from 1958 to 2011.

Table 5.9-2 Concentrations of water quality measurement endpoints, mouth of Clearwater River (*test* station CLR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	11	7.5	8.0	8.2
Total suspended solids	mg/L	-	209	11	<3	15	64
Conductivity	µS/cm	-	208	11	177	230	300
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.006	11	0.012	0.021	0.044
Total nitrogen	mg/L	1	0.90	11	0.30	0.60	**1.72**
Nitrate+nitrite	mg/L	1.3	<0.071	11	<0.071	<0.10	<0.10
Dissolved organic carbon	mg/L	-	20.4	11	8.0	10.7	18.8
Ions							
Sodium	mg/L	-	14.8	11	13.1	21.0	31.0
Calcium	mg/L	-	16.3	11	14.7	17.4	20.1
Magnesium	mg/L	-	5.1	11	5.0	5.7	6.5
Chloride	mg/L	120	18.4	11	13.2	25.0	43.0
Sulphate	mg/L	270	7.1	11	1.4	5.7	7.7
Total dissolved solids	mg/L	-	160	11	60	150	200
Total alkalinity	mg/L		68.0	11	55.5	66.0	79.1
Selected metals							
Total aluminum	mg/L	0.1	**4.97**	11	**0.14**	**0.58**	**1.46**
Dissolved aluminum	mg/L	0.1	**0.13**	11	0.006	0.009	0.016
Total arsenic	mg/L	0.005	0.0016	11	0.0005	0.0008	0.0014
Total boron	mg/L	1.2	0.051	11	0.021	0.032	0.055
Total molybdenum	mg/L	0.073	0.00012	11	0.00015	0.00020	0.00036
Total mercury (ultra-trace)	ng/L	5, 13	**13.50**	9	<0.6	<1.2	3.1
Total strontium	mg/L	-	0.0835	11	<0.000005	<0.000005	0.000016
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	-	0.05	1	-	0.15	-
Oilsands Extractable	mg/L	-	0.32	1	-	0.64	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	19.3	-
Retene	ng/L	-	15.40	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	64.2	1	-	6.6	-
Total PAHs	ng/L	-	465.3	1	-	172.6	-
Total Parent PAHs	ng/L	-	36.9	1	-	25.2	-
Total Alkylated PAHs	ng/L	-	428.4	1	-	147.4	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Sulphide	mg/L	0.002	**0.003**	11	**0.003**	**0.004**	**0.009**
Total iron	mg/L	0.3	**5.04**	11	**0.51**	**1.16**	**2.43**
Dissolved iron	mg/L	0.3	**0.454**	11	0.139	0.289	**0.756**
Total phenols	mg/L	0.004	**0.006**	11	<0.001	0.003	**0.009**
Total phosphorus	mg/L	0.05	**0.211**	11	0.033	**0.051**	**0.109**
Total chromium	mg/L	0.001	**0.0062**	11	0.0003	0.0008	**0.0022**
Total copper	mg/L	0.0020	**0.0041**	11	<0.0003	0.0007	0.0014
Total lead	mg/L	0.0017	**0.0028**	11	0.0001	0.0003	0.0007

[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 5.9-3 Concentrations of water quality measurement endpoints, upper Clearwater River (*baseline* station CLR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	11	7.2	7.9	8.1
Total suspended solids	mg/L	-	174	11	3	14	36
Conductivity	µS/cm	-	183	11	138	202	253
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.008	11	0.008	0.019	0.026
Total nitrogen	mg/L	1	**1.0**	11	0.3	0.5	1.2
Nitrate+nitrite	mg/L	1.3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	19.5	11	6	8	24
Ions							
Sodium	mg/L	-	12.4	11	11.0	18.0	29.0
Calcium	mg/L	-	13.8	11	10.0	11.9	21.6
Magnesium	mg/L	-	4.2	11	3.4	4.2	7.0
Chloride	mg/L	120	14.8	11	16	28	43
Sulphate	mg/L	195	6.0	11	<0.5	5.5	7.7
Total dissolved solids	mg/L	-	142	11	40	130	177
Total alkalinity	mg/L		57.6	11	39.0	48.0	52.9
Selected metals							
Total aluminum	mg/L	0.1	**5.0**	11	**0.10**	**0.24**	**2.55**
Dissolved aluminum	mg/L	0.1	**0.2**	11	0.003	0.007	0.040
Total arsenic	mg/L	0.005	0.0014	11	0.0004	0.0005	0.0012
Total boron	mg/L	1.2	0.051	11	0.014	0.024	0.030
Total molybdenum	mg/L	0.073	0.00010	11	0.00009	0.00012	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	**13.7**	9	<0.8	<1.2	2.1
Total strontium	mg/L	-	0.077	11	0.061	0.084	0.103
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	-	0.06	1	-	<0.02	-
Oilsands Extractable	mg/L	-	0.34	1	-	0.72	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	37.9	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	36.2	1	-	5.8	-
Total PAHs	ng/L	-	318.2	1	-	151.2	-
Total Parent PAHs	ng/L	-	29.9	1	-	19.2	-
Total Alkylated PAHs	ng/L	-	288.3	1	-	131.9	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**5.36**	11	**0.545**	**0.835**	**5.36**
Dissolved iron	mg/L	0.3	**0.571**	11	0.096	0.222	**0.672**
Dissolved zinc	mg/L	0.03	**0.0428**	11	0.0005	0.0012	0.0040
Sulphide	mg/L	0.002	**0.005**	11	0.002	**0.004**	**0.013**
Total phosphorus	mg/L	0.05	**0.212**	11	0.025	0.043	**0.074**
Total chromium	mg/L	0.001	**0.0066**	11	**0.0003**	**0.0005**	**0.0029**
Total copper	mg/L	0.002	**0.00391**	11	0.00008	0.00054	0.00200
Total lead	mg/L	0.0013704	**0.0029**	11	0.000083	0.00020	0.00093
Total zinc	mg/L	0.03	**0.0433**	11	0.0007	0.00300	0.01100
Total phenols	mg/L	0.004	**0.0065**	11	<0.0010	0.0026	**0.0070**

[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 5.9-4 Concentrations of water quality measurement endpoints, High Hills River (*baseline* station HHR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.0	8.4
Total suspended solids	mg/L	-	55.0	6.0
Conductivity	µS/cm	-	160.0	249.0
Nutrients				
Total dissolved phosphorus	mg/L	0.05	**0.06**	**0.07**
Total nitrogen	mg/L	1	0.8	0.4
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	26.5	12.8
Ions				
Sodium	mg/L	-	5.8	9.2
Calcium	mg/L	-	20.9	30.8
Magnesium	mg/L	-	6.1	9.7
Chloride	mg/L	120	<0.50	0.6
Sulphate	mg/L	270	2.1	2.6
Total dissolved solids	mg/L	-	114.0	155.0
Total alkalinity	mg/L		81.3	129.0
Selected metals				
Total aluminum	mg/L	0.1	**1.23**	**0.28**
Dissolved aluminum	mg/L	0.1	0.06	0.01
Total arsenic	mg/L	0.005	0.0009	0.0005
Total boron	mg/L	1.2	0.04	0.06
Total molybdenum	mg/L	0.073	0.0002	0.0003
Total mercury (ultra-trace)	ng/L	5, 13	4.80	0.70
Total strontium	mg/L	-	0.06	0.09
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	-	0.03	0.12
Oilsands Extractable	mg/L	-	0.38	0.42
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	10.1	<14.1
Retene	ng/L	-	9.3	<2.1
Total dibenzothiophenes	ng/L	-	5.2	5.8
Total PAHs	ng/L	-	217.6	151.1
Total Parent PAHs	ng/L	-	19.6	19.2
Total Alkylated PAHs	ng/L	-	198.0	131.9
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Total iron	mg/L	0.3	**2.28**	**0.618**
Dissolved Iron	mg/L	0.3	**0.548**	**0.250**
Total phenols	mg/L	0.004	**0.0086**	**0.0050**
Sulphide	mg/L	0.002	**0.0033**	**0.0033**
Total phosphorous	mg/L	0.05	**0.133**	**0.0917**
Total chromium	mg/L	0.001	**0.0018**	<0.0003

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above guideline.

Figure 5.9-4 Piper diagram of fall ion concentrations in the Clearwater River watershed.

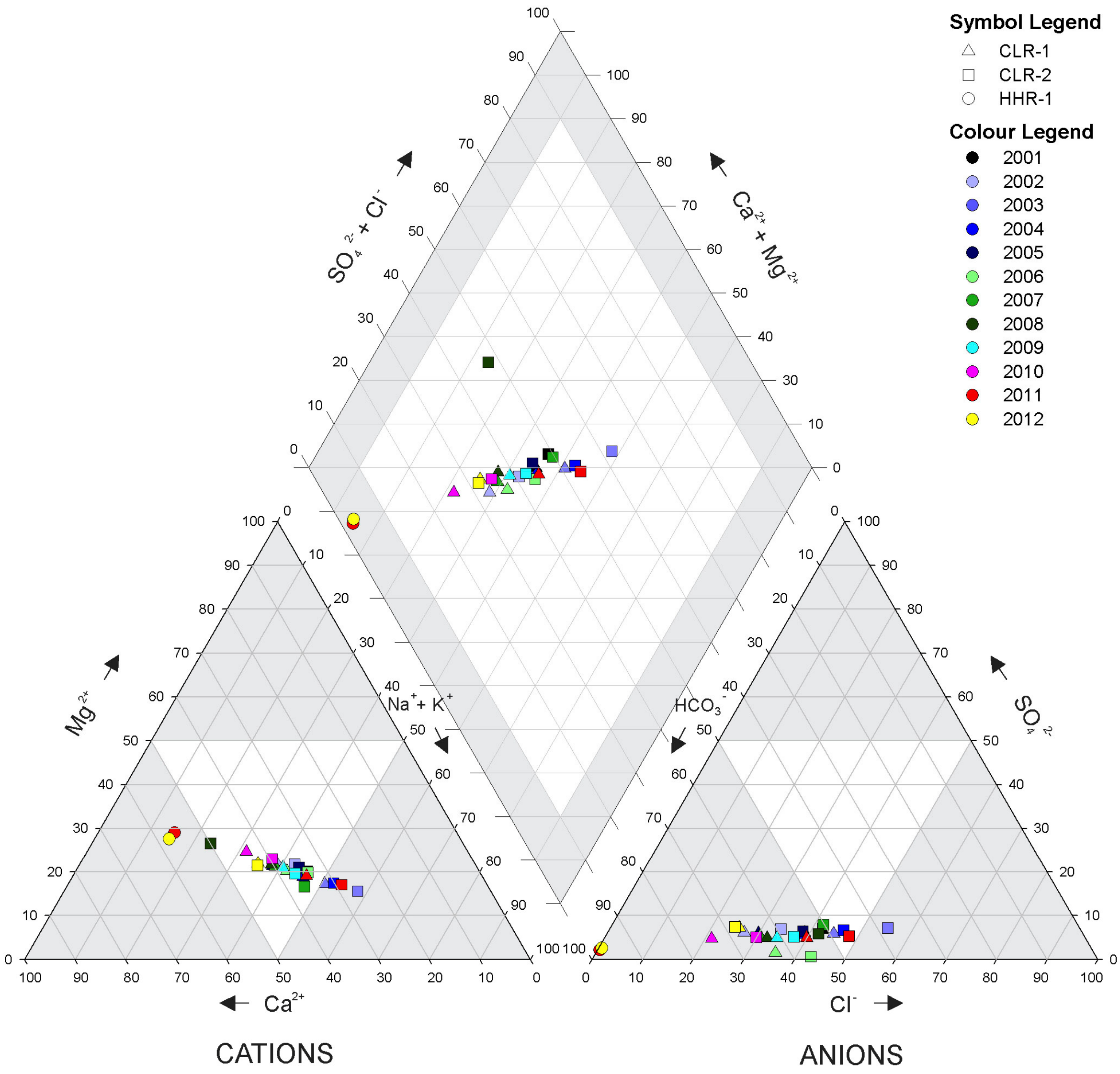


Table 5.9-5 Water quality guideline exceedances, Clearwater River watershed, 2012.

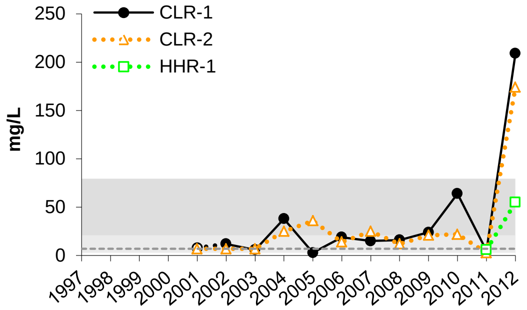
Variable	Units	Guideline[a]	CLR-1	CLR-2	HHR-1
Winter					
Total aluminum	mg/L	0.1	ns	ns	0.20
Total iron	mg/L	0.3	ns	ns	0.97
Total phosphorus	mg/L	0.05	ns	ns	0.093
Spring					
Dissolved iron	mg/L	0.3	ns	ns	0.36
Sulphide	mg/L	0.002	ns	ns	0.0045
Total aluminum	mg/L	0.1	ns	ns	0.61
Total iron	mg/L	0.3	ns	ns	1.25
Total phenols	mg/L	0.004	ns	ns	0.0094
Total phosphorus	mg/L	0.05	ns	ns	0.092
Summer					
Dissolved iron	mg/L	0.3	ns	ns	0.65
Dissolved phosphorous	mg/L	0.05	ns	ns	0.096
Sulphide	mg/L	0.002	ns	ns	0.0063
Total aluminum	mg/L	0.1	ns	ns	0.68
Total chromium	mg/L	0.001	ns	ns	0.0012
Total iron	mg/L	0.3	ns	ns	1.91
Total phenols	mg/L	0.004	ns	ns	0.0109
Total phosphorus	mg/L	0.05	ns	ns	0.16
Fall					
Dissolved aluminum	mg/L	0.1	0.125	0.185	-
Dissolved iron	mg/L	0.3	0.454	0.571	0.548
Dissolved phosphorous	mg/L	0.05	-	-	0.0561
Dissolved thallium	mg/L	0.0008	-	-	-
Dissolved zinc	mg/L	0.03	-	0.0428	-
Mercury (ultra-trace)	mg/L	5	13.5	13.7	-
Sulphide	mg/L	0.002	0.0034	0.0054	0.0033
Total aluminum	mg/L	0.1	4.97	5	1.23
Total cadmium	mg/L	0.00002	-	-	-
Total chromium	mg/L	0.001	0.0062	0.00655	0.00176
Total copper	mg/L	0.002	0.00412	0.00391	-
Total iron	mg/L	0.3	5.04	5.36	2.28
Total lead	mg/L	0.0017	0.00276	0.00292	-
Total phenols	mg/L	0.004	0.0059	0.0065	0.0086
Total phosphorus	mg/L	0.05	0.211	0.212	0.133
Total silver	mg/L	0.0001	-	-	-
Total thallium	mg/L	0.0008	-	-	-
Total zinc	mg/L	0.03	-	0.043	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

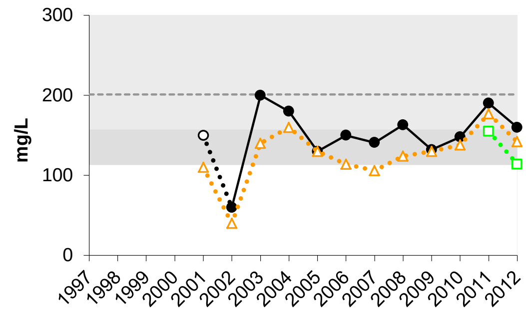
ns = not sampled

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.

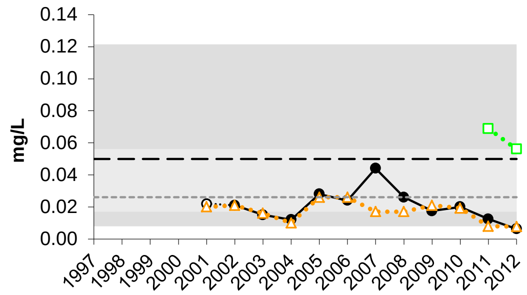
Total Suspended Solids (TSS)



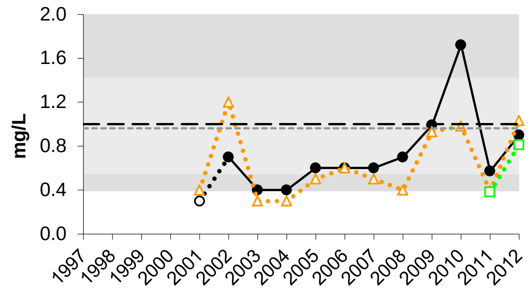
Total Dissolved Solids (TDS)



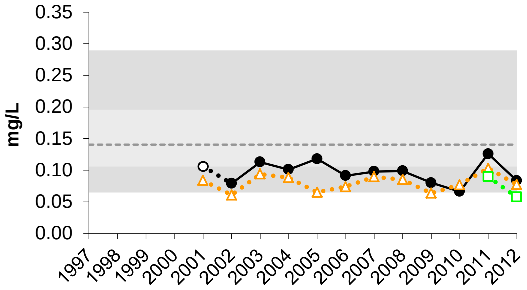
Dissolved Phosphorus



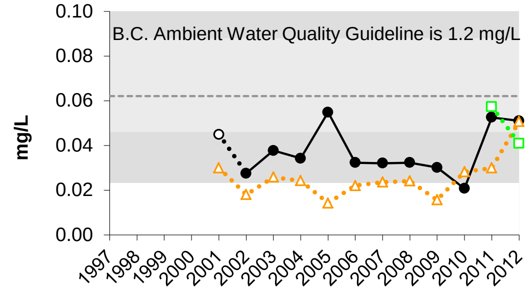
Total Nitrogen



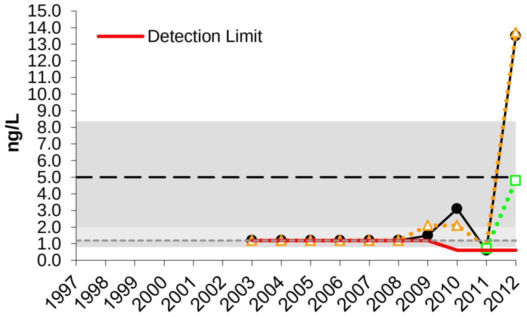
Total Strontium



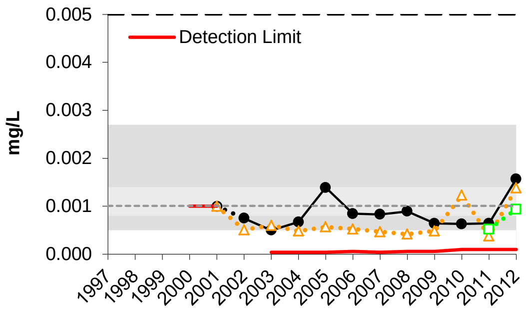
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



Non-detectable values are shown at the detection limit.

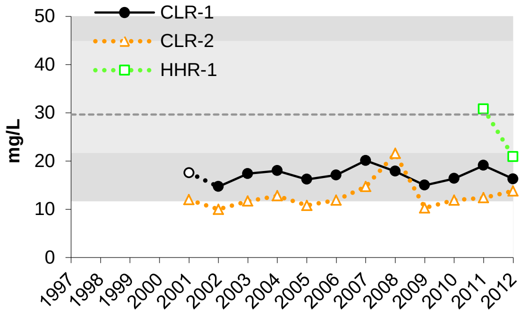
– – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

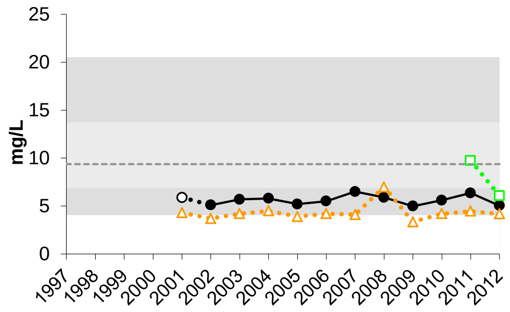
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.9-5 (Cont'd.)

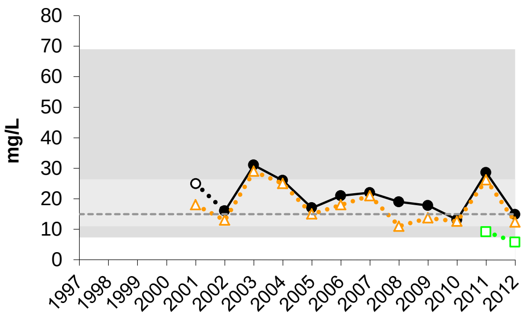
Calcium



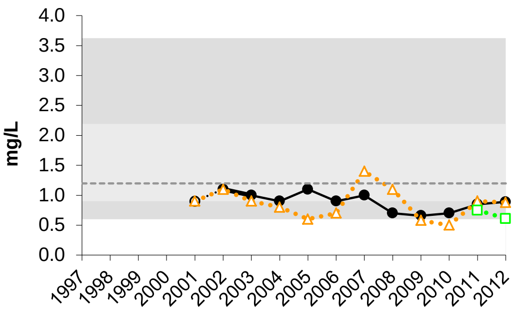
Magnesium



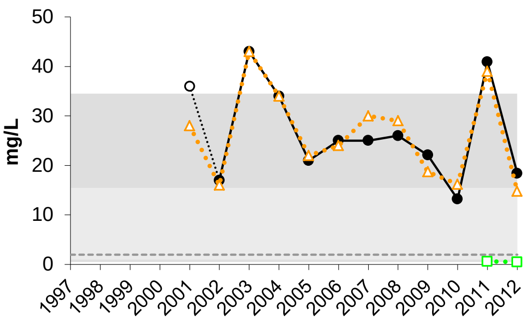
Sodium



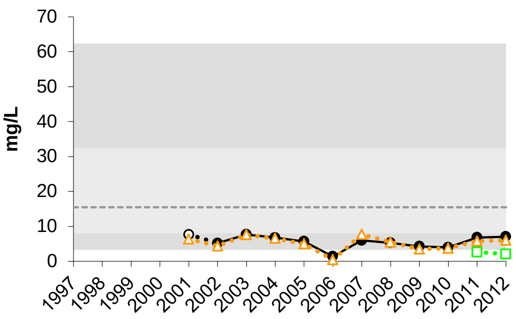
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

- - - - -   Water quality guideline. See Table 3.2-5 for all WQ guidelines.

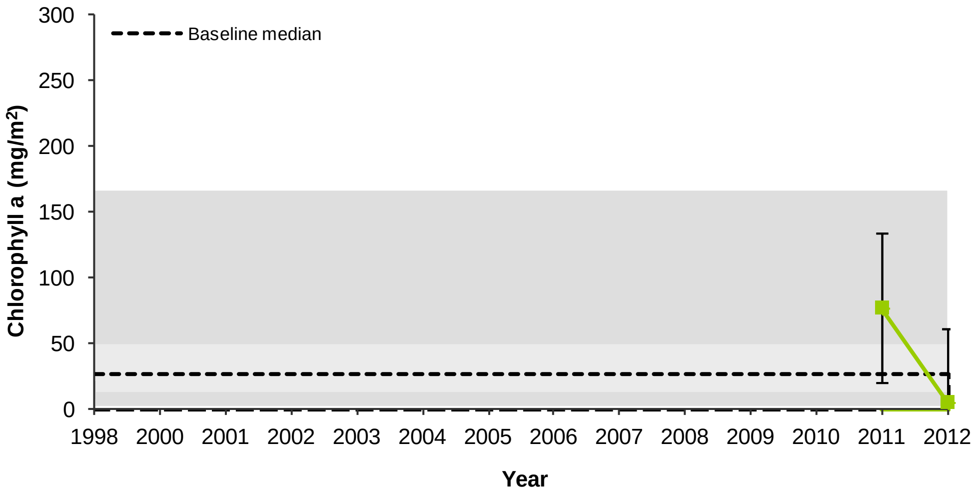
○·······○   Sampled as a *baseline* station   ●——●   Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.9-6 Average habitat characteristics of the benthic invertebrate community sampling location in the High Hills rivers, fall 2012.

Variable	Units	HHR-E1 *Baseline* Reach of High Hills River
Sample date	-	09-Sept-2012
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	1.21
Field Water Quality		
Dissolved oxygen	mg/L	7.7
Conductivity	µS/cm	129
pH	pH units	8.2
Water temperature	°C	11.9
Sediment Composition		
Sand/Silt/Clay	%	1
Small Gravel	%	15
Large Gravel	%	32
Small Cobble	%	26
Large Cobble	%	15
Boulder	%	5
Bedrock	%	0

Figure 5.9-6 Periphyton chlorophyll *a* biomass in the High Hills River.

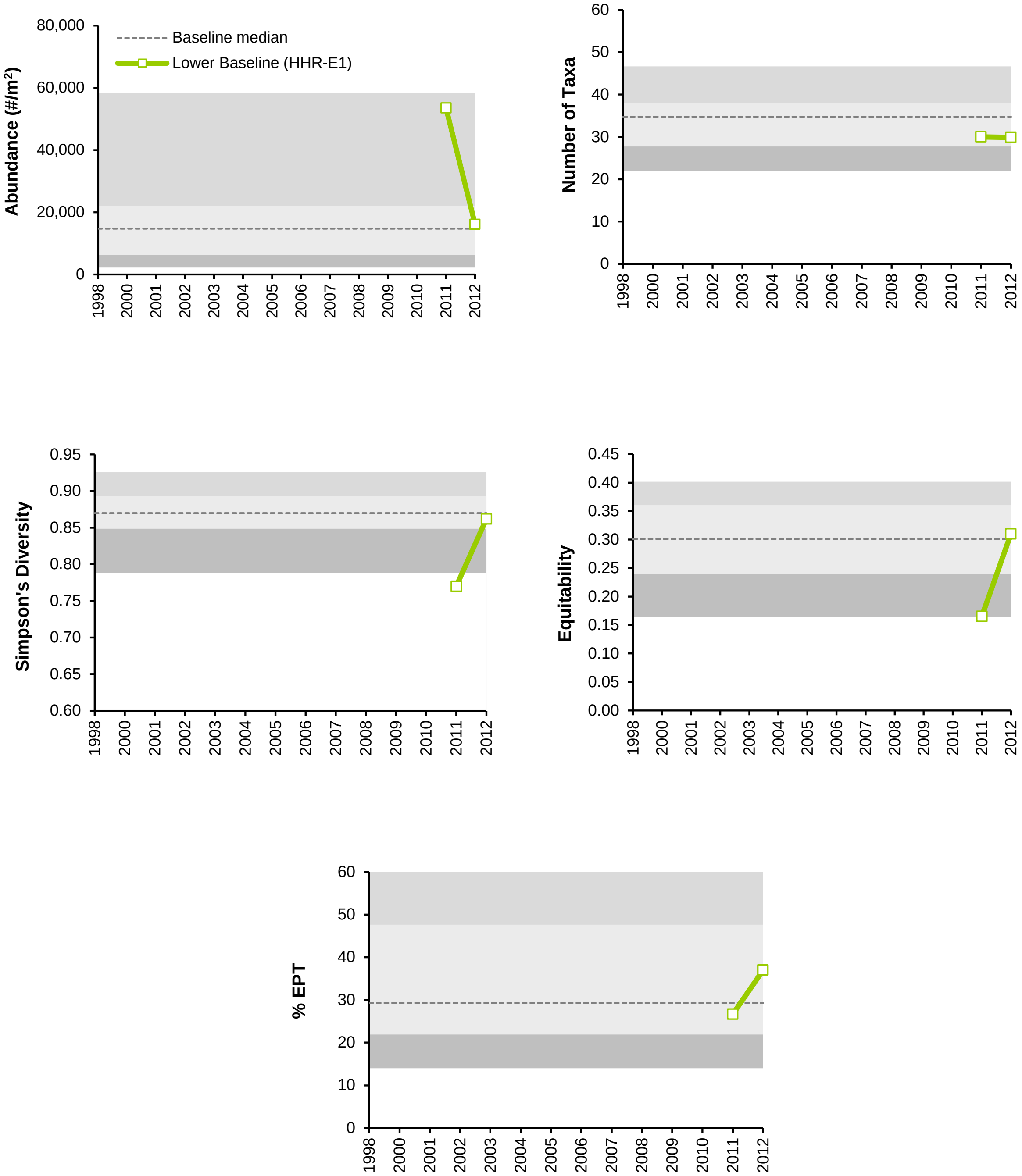


Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.9-7 Summary of major taxon abundances of benthic invertebrate community measurement endpoints at *baseline* reach HHR-E1.

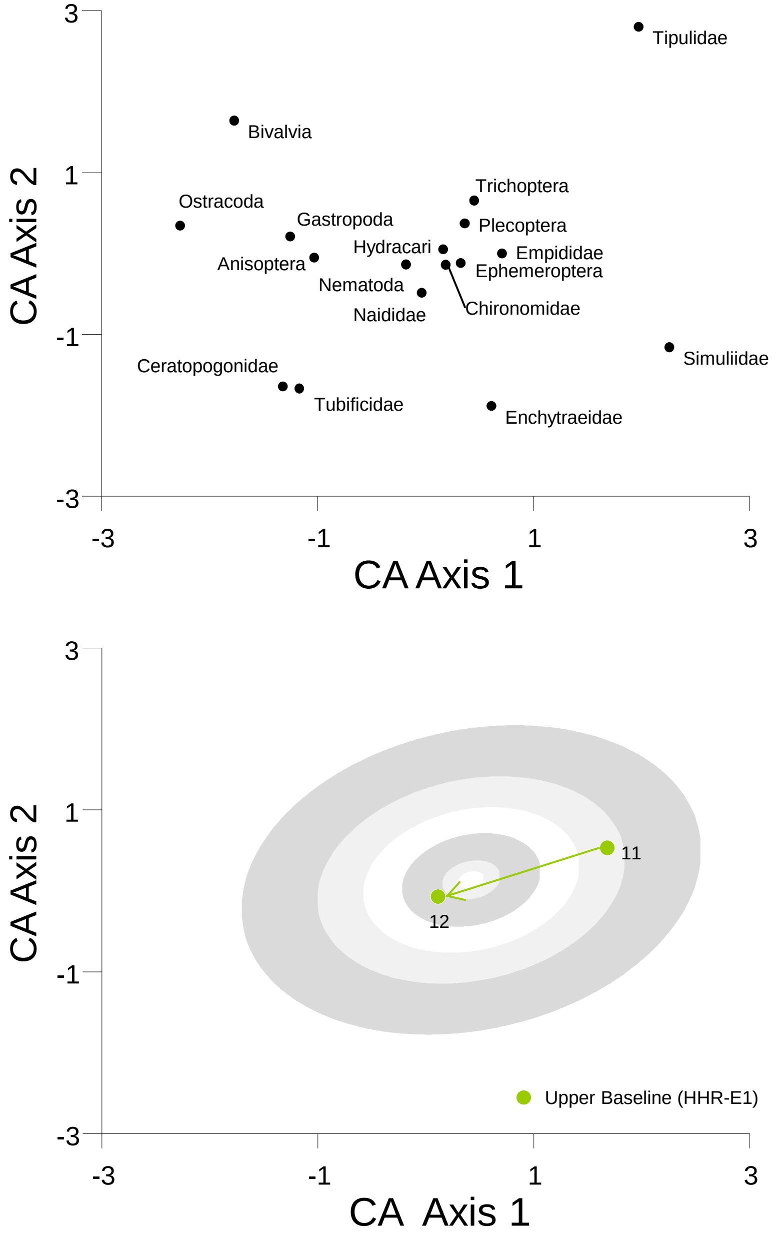
Taxon	Percent Major Taxa Enumerated in Each Year	
	Reach HHR-E1	
	2011	2012
Nematoda	<1	2
Naididae	42	24
Tubificidae		2
Enchytraeidae	7	5
Hydracarina	5	5
Ostracoda		1
Copepoda	<1	<1
Gastropoda	<1	4
Bivalvia		<1
Coleoptera	<1	<1
Ceratopogonidae		3
Chironomidae	13	11
Dolichopodidae		<1
Athericidae	<1	<1
Empididae	3	3
Psychodidae	<1	
Tipulidae	<1	1
Simuliidae	<1	<1
Ephemeroptera	19	26
Anisoptera	<1	<1
Plecoptera	1	2
Trichoptera	6	9
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance (No./m^2)	53,498	16,141
Richness	30	30
Simpson's Diversity	0.77	0.86
Equitability	0.17	0.31
% EPT	27	37

Figure 5.9-7 Variation in benthic invertebrate community measurement endpoints in the High Hills River.



Note: regional *baseline* values for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.9-8 Ordination (Correspondence Analysis) of benthic invertebrate communities at *baseline* reach HHR-E1 of the High Hills River.

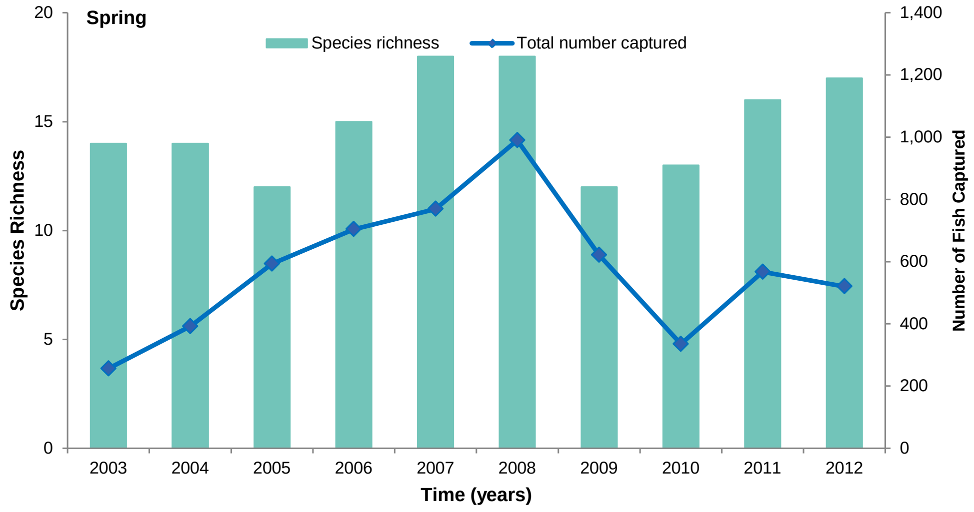


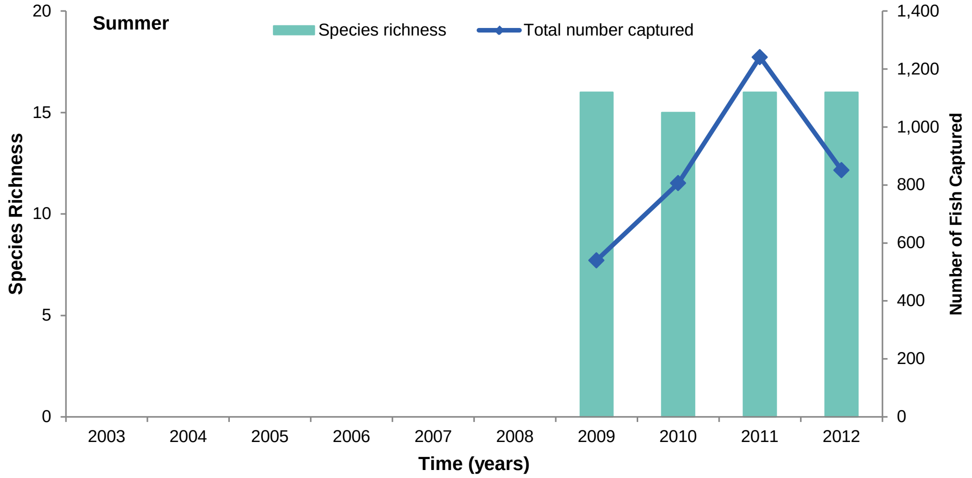
Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipse in the lower panel is for the *baseline* data.

Table 5.9-8 Fish species composition at *baseline* (CR1, CR2) and *test* (CR3) reaches of the Clearwater River during spring, summer, and fall 2012.

Species	Spring				Summer				Fall			
	Baseline	**%**	***Test***	**%**	***Baseline***	**%**	***Test***	**%**	***Baseline***	**%**	***Test***	**%**
Arctic grayling	1	0.3	-	-	1	0.1	-	-	14	2.7	2	0.5
burbot	-	-	-	-	-	-	1	0.2	-	-	-	-
emerald shiner	-	-	-	-	1	0.1	-	-	-	-	-	-
flathead chub	15	4.7	20	10.4	15	2.0	38	6.6	-	-	2	0.5
finescale dace	-	-	-	-	-	-	-	-	-	-	3	0.8
fathead minnow	-	-	-	-	-	-	-	-	-	-	3	0.8
goldeye	2	0.6	21	10.9	6	0.8	31	5.3	-	-	33	8.9
lake chub	1	0.3	-	-	11	1.5	37	6.4	30	5.7	8	2.2
lake whitefish	1	0.3	-	-	9	1.2	-	-	-	-	-	-
lake trout	-	-	1	0.5	-	-	1	0.2	-	-	-	-
longnose dace	2	0.6	1	0.5	2	0.3	2	0.3	1	0.2	-	-
longnose sucker	13	4.1	36	18.8	60	7.9	196	33.8	21	4.0	26	7.0
mountain whitefish	3	0.9	-	-	6	0.8	2	0.3	8	1.5	3	0.8
northern pike	13	4.1	7	3.6	32	4.2	27	4.7	39	7.4	34	9.2
northern redbelly dace	1	0.3	1	0.5	1	0.1	1	0.2	-	-	-	-
pearl dace	-	-	-	-	-	-	-	-	-	-	-	-
slimy sculpin	1	0.3	1	0.5	4	0.5	5	0.9	2	0.4	11	3.0
spoonhead sculpin	-	-	-	-	-	-	-	-	2	0.4	-	-
spottail shiner	113	35.3	5	2.6	247	32.6	25	4.3	244	46.2	4	1.1
trout-perch	20	6.3	19	9.9	33	4.4	36	6.2	39	7.4	101	27.3
walleye	13	4.1	14	7.3	29	3.8	171	29.5	2	0.4	19	5.1
white sucker	120	37.5	65	33.9	294	38.8	7	1.2	124	23.5	110	29.7
yellow perch	1	0.3	1	0.5	6	0.8	-	-	2	0.4	11	3.0
Total # Species	**16**	**-**	**15**	**-**	**17**	-	**16**	-	**13**	-	**15**	-
Total # Fish	**320**	**100**	**192**	**100**	**757**	**100**	**580**	**100**	**528**	**100**	**370**	**100**

Figure 5.9-9 Total catch and number of species captured during the Clearwater River spring, summer, and fall fish inventories, 2003 to 2012.





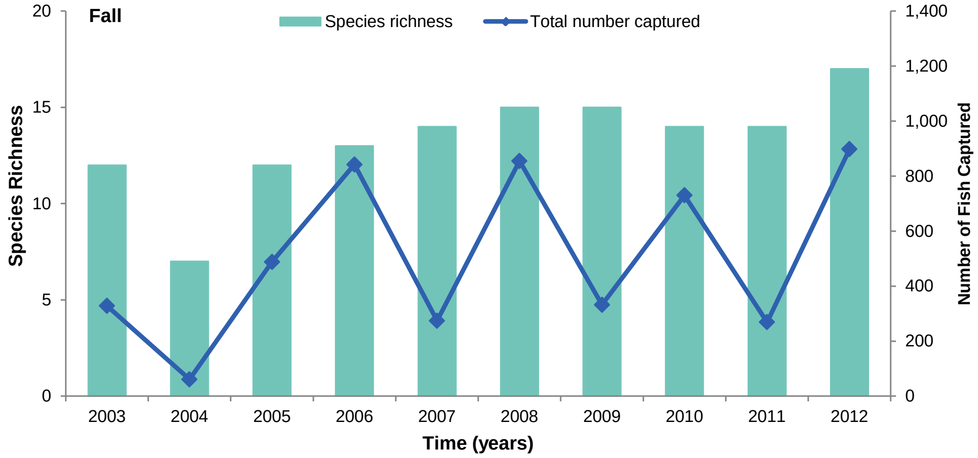
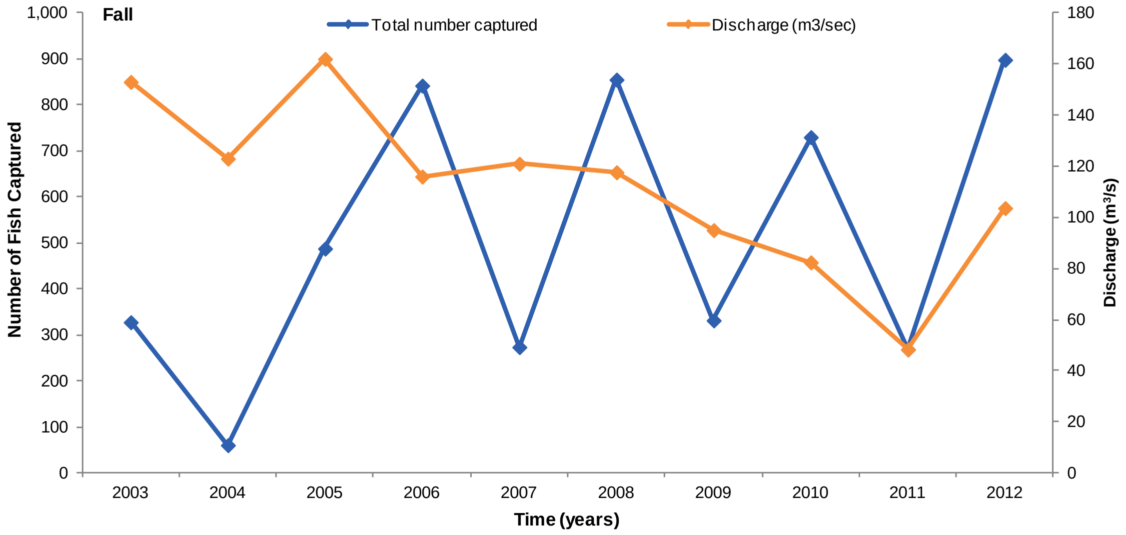


Figure 5.9-10 Relationship between total catch and discharge (m^3/s) of the Clearwater River, Fall 2003 to 2012.



Note: Discharge data was taken from WSC hydrology station 07CD001 from 2003 to 2008; discharge data from 2009 to 2012 was taken from the RAMP hydrology station S42.

Figure 5.9-11 Seasonal catch per unit effort (CPUE ± 1SD) of large-bodied KIR fish species and other species at *test* and *baseline* reaches in the Clearwater River, 2012.

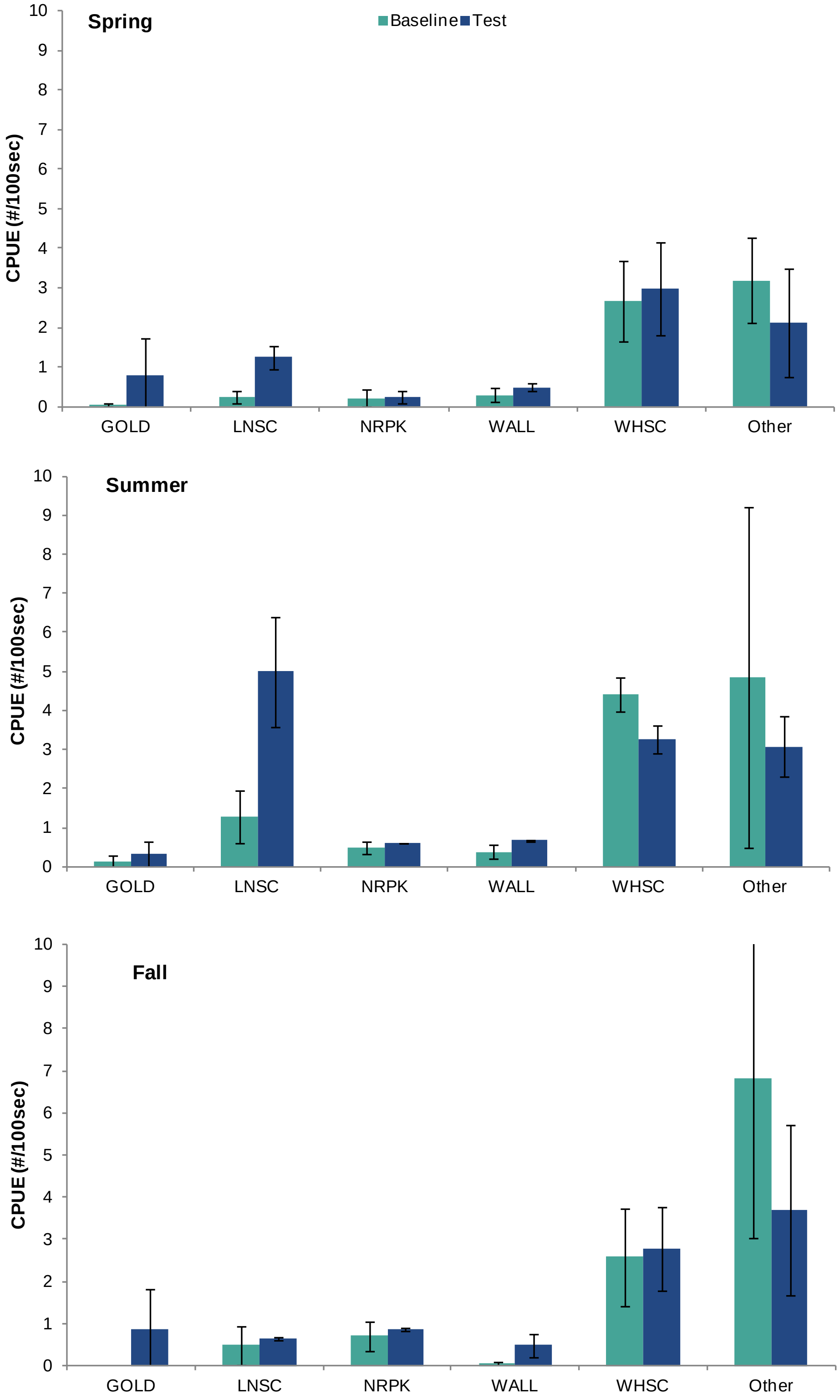


Figure 5.9-12 **Seasonal catch per unit effort (CPUE ± 1SD) of large-bodied KIR fish species and other species in the Clearwater River, 2003 to 2012.**

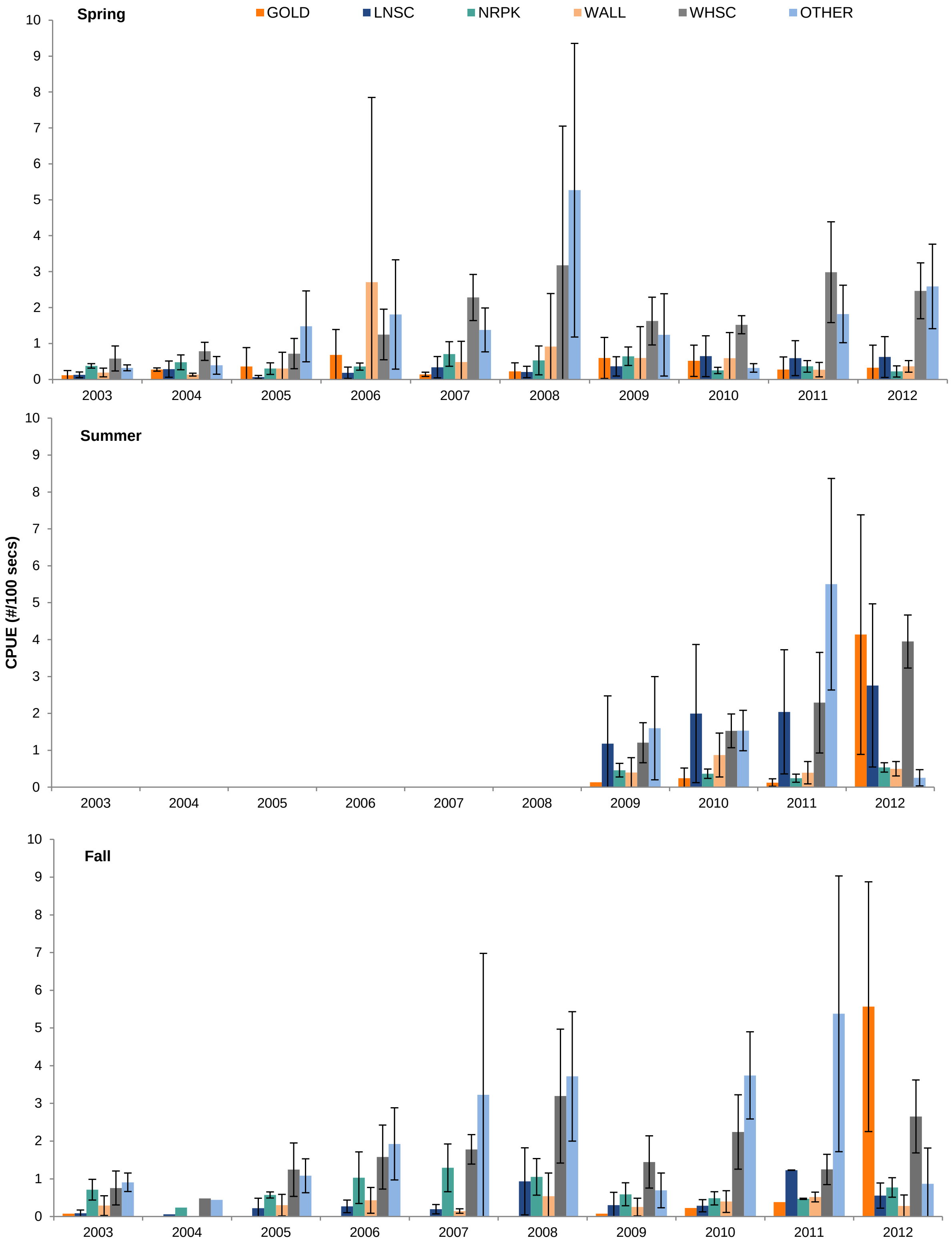
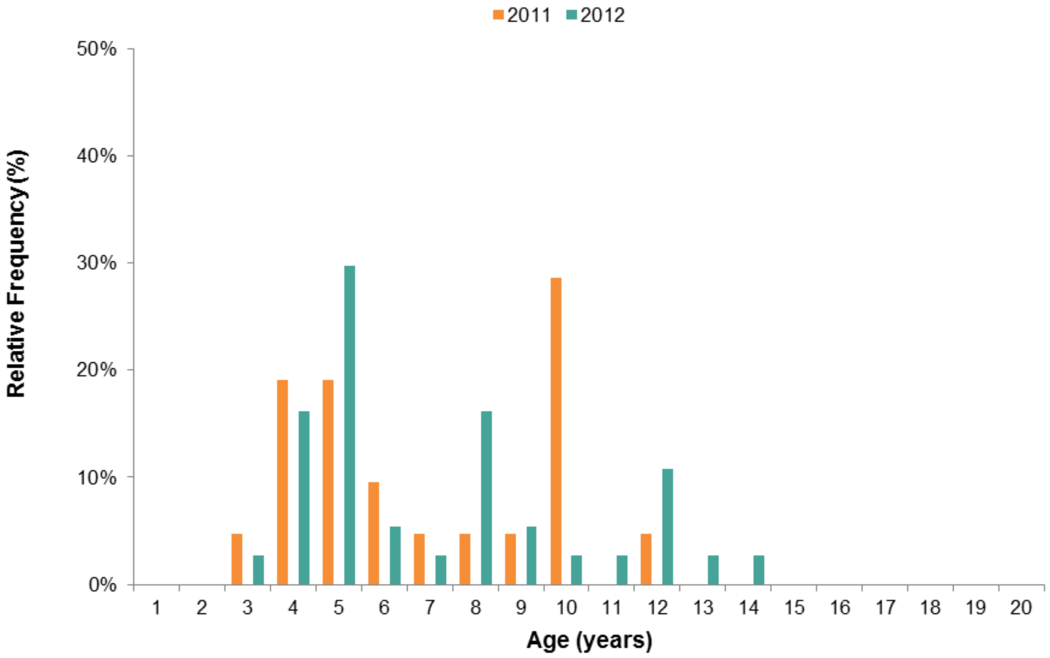


Figure 5.9-13 **Relative age-frequency distributions and size-at-age regression relationships for goldeye in spring, summer, and fall, 2011 to 2012.**



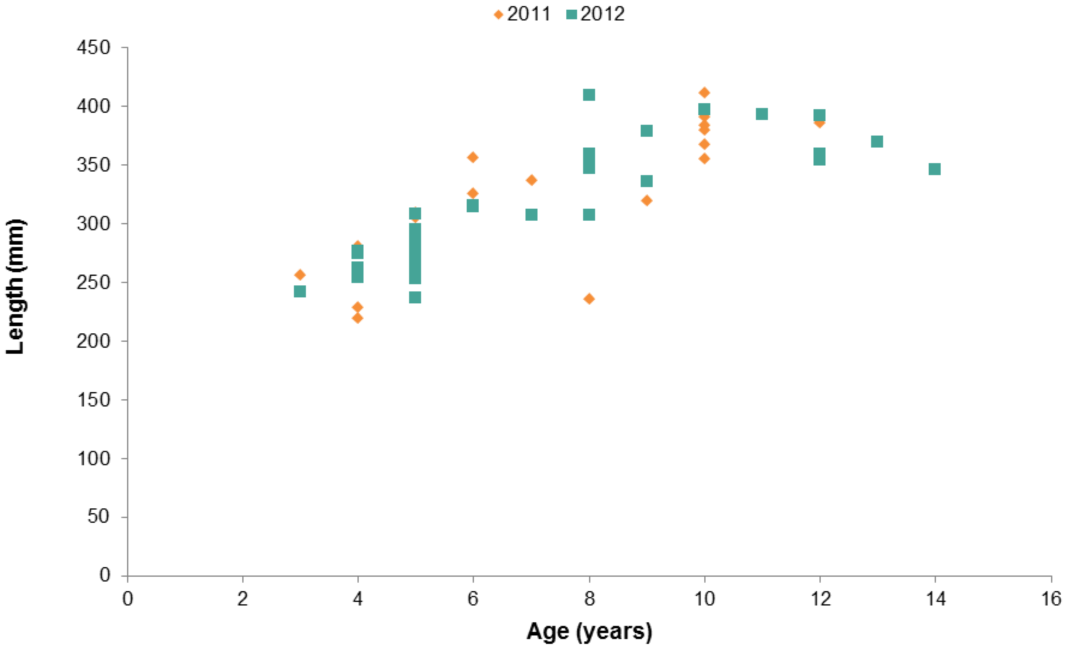
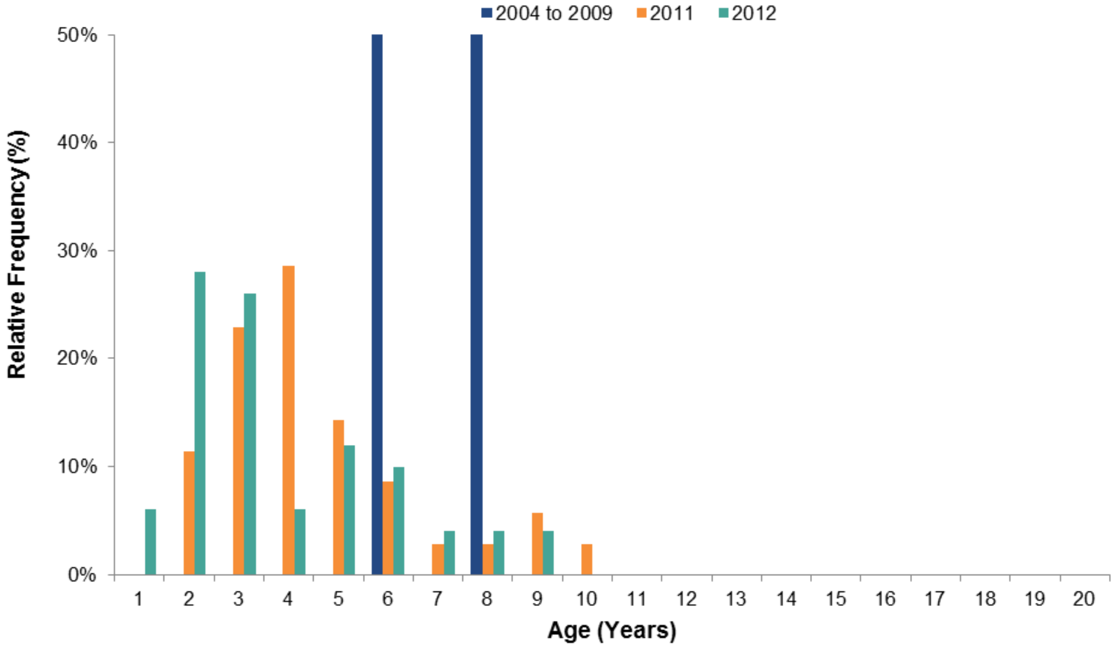


Figure 5.9-14 Relative age-frequency distributions and size-at-age regression relationships for longnose sucker in spring, summer, and fall, 2004 to 2012.



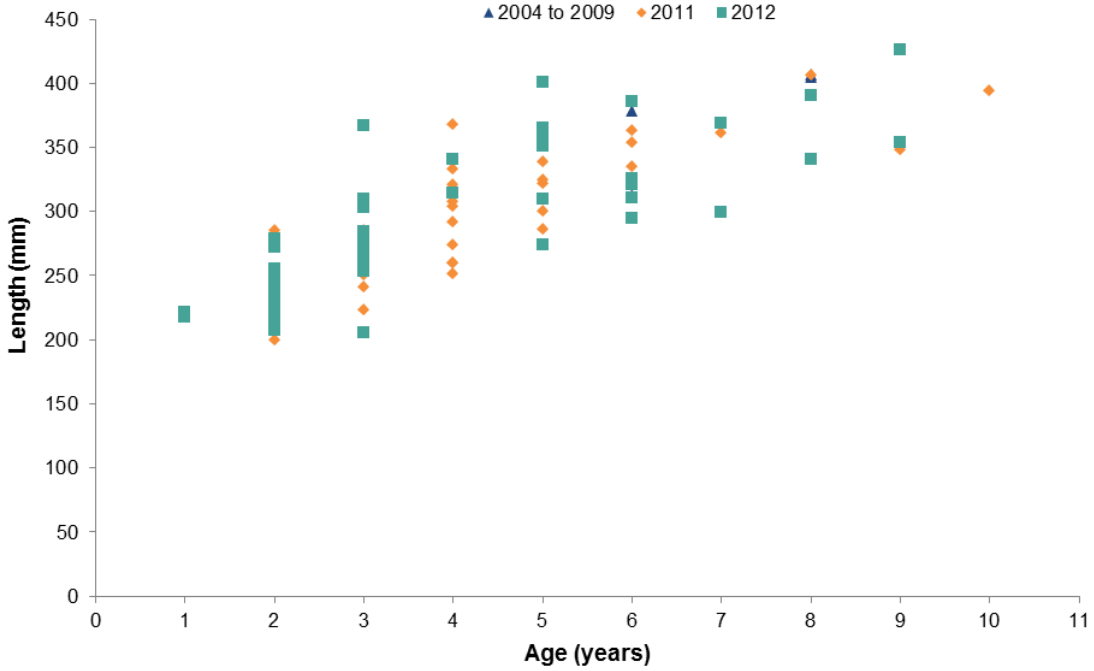
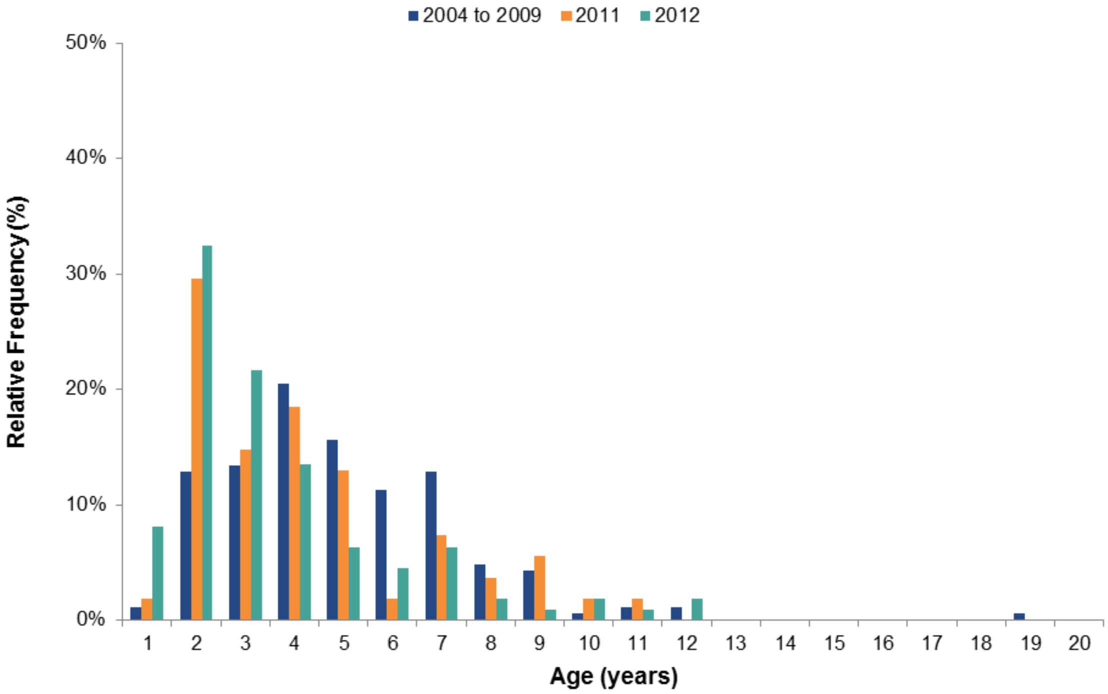


Figure 5.9-15 **Relative age-frequency distributions and size-at-age regression relationships for northern pike in spring, summer, and fall, 2004 to 2012.**



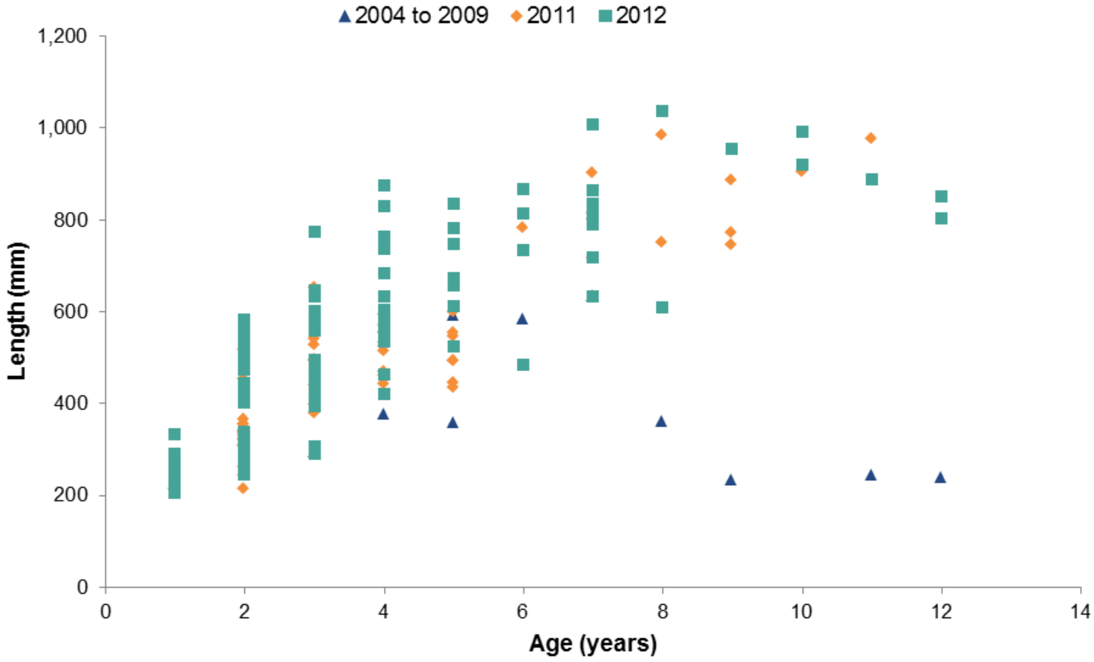
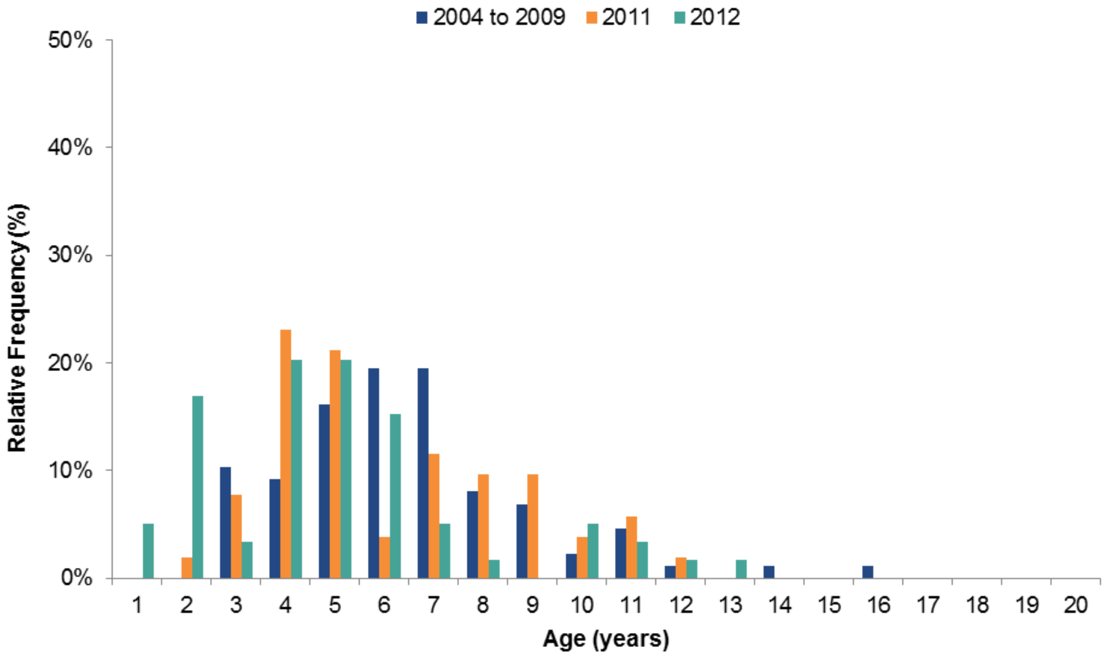


Figure 5.9-16 Relative age-frequency distributions and size-at-age regression relationships for walleye in spring, summer, and fall, 2004 to 2012.



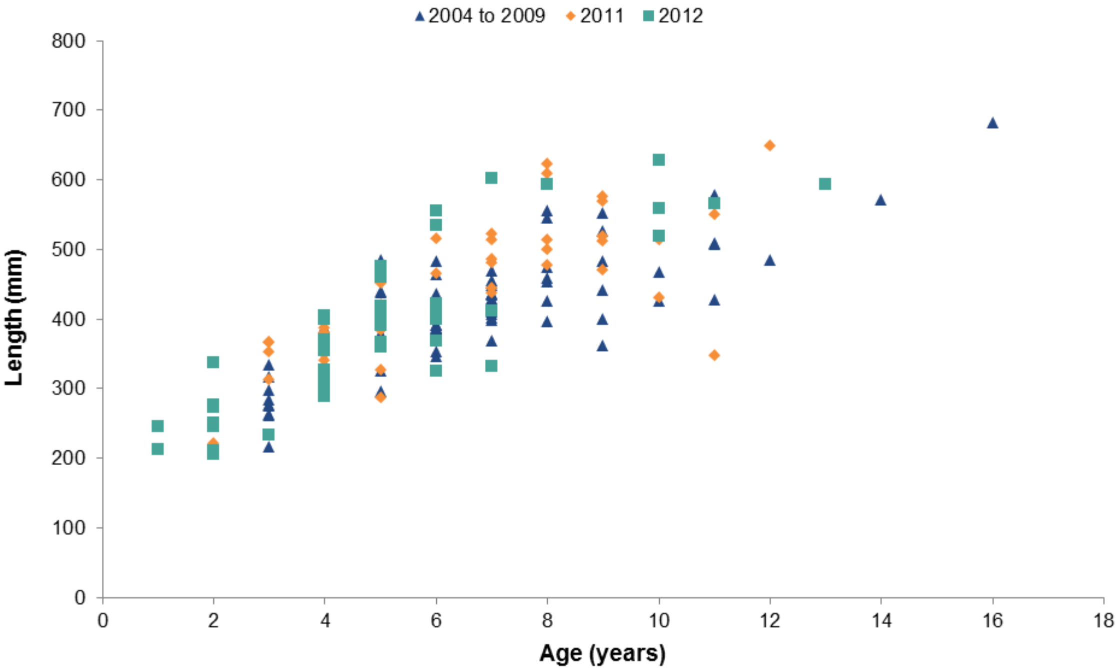
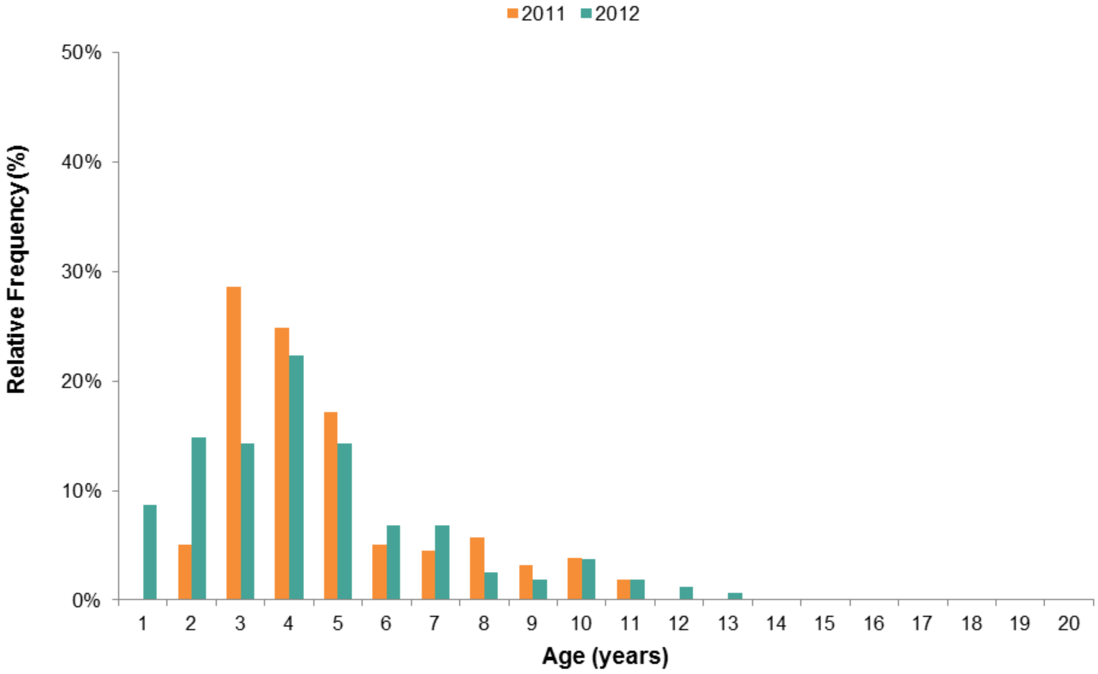


Figure 5.9-17 Relative age-frequency distributions and size-at-age regression relationships for white sucker in spring, summer, and fall, 2011 to 2012.



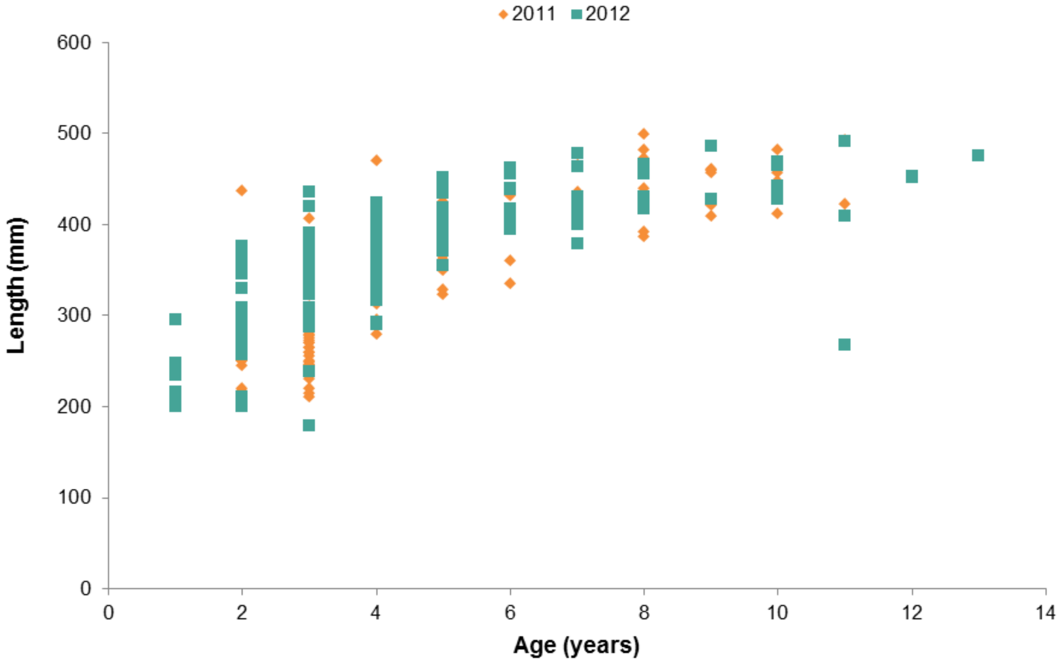


Figure 5.9-18 **Condition factor (±2SD) for large-bodied KIR fish species captured in *test* and *baseline* areas of the Clearwater River during the summer and fall fish inventories, 2012.**

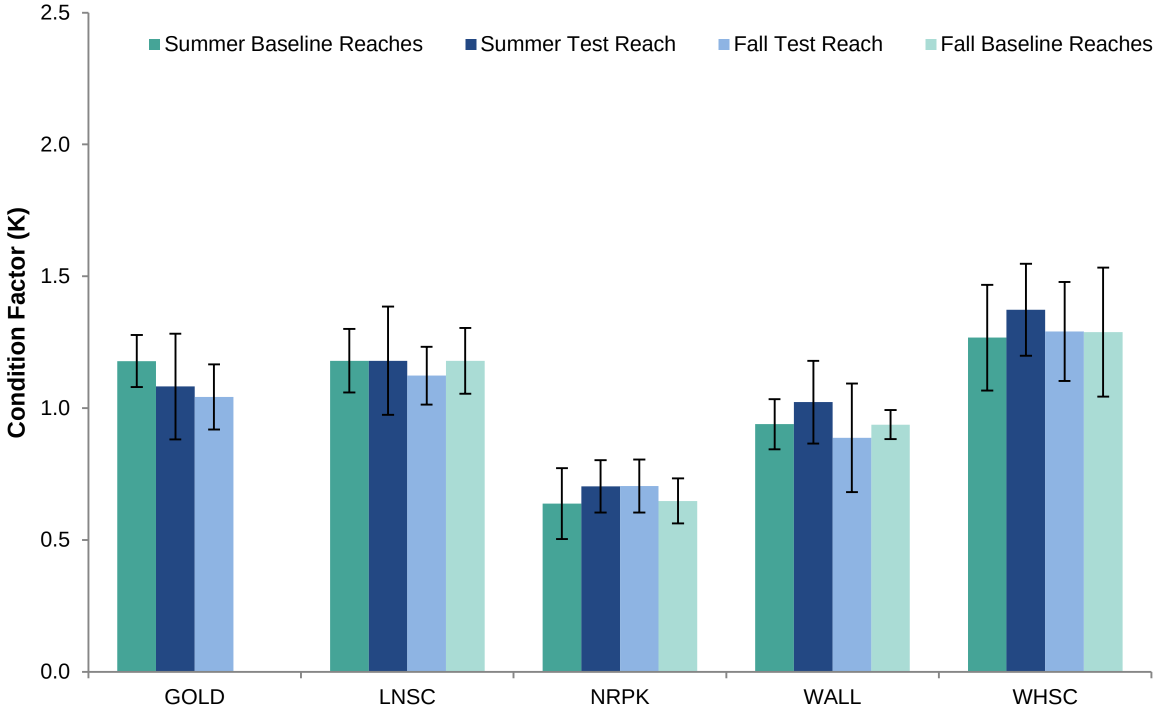


Figure 5.9-19 Condition factor (±2SD) for large-bodied KIR fish species captured in the Clearwater River, summer and fall 2003 to 2012.

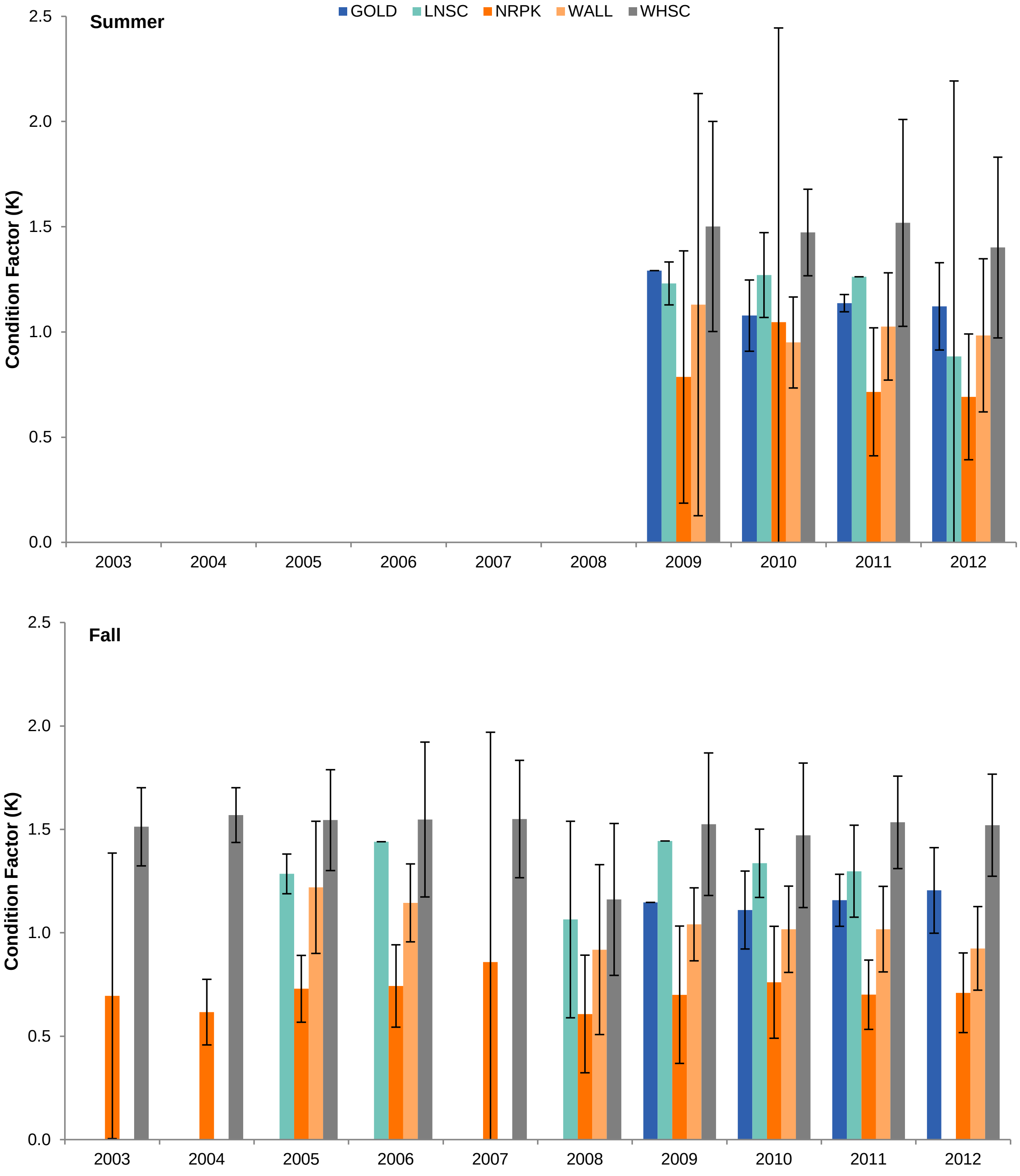


Table 5.9-9 Percent of total fish captured by species with external pathology (i.e., growth/lesion, deformity, and parasite), 2003 to 2012.

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

Figure 5.9-20 Percent of total fish captured in the Clearwater River with external pathology, 2003 to 2012.

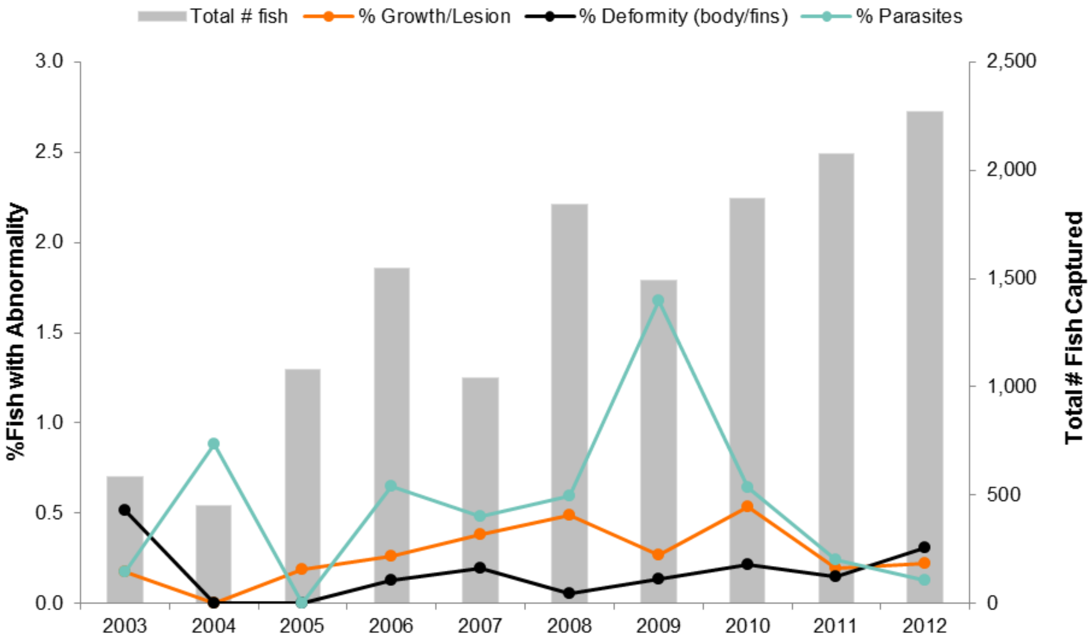


Table 5.9-10 Mercury concentration and whole-organisms metrics of northern pike collected from the Clearwater River in 2012 and screened against criteria for fish consumption for the protection of human health.

Species	Sample ID	Sex	Length (mm)	Weight (g)	Age	Hg (mg/kg)
NRPK	232-01A	U	595	1,692*	3	0.175
NRPK	233-01A	U	406	3,370*	3	0.136
NRPK	234-01A	U	304	107		0.067
NRPK	235-01A	U	394	418	3	0.123
NRPK	236-01A	U	284	119	2	0.138
NRPK	237-01A	U	331	221	2	0.092
NRPK	238-01A	U	289	145	3	0.090
NRPK	239-01A	M	526	994*	2	0.200
NRPK	240-01A	U	580	1,443*	4	0.140
NRPK	241-01A	M	539	1,081*	4	0.188
NRPK	242-01A	U	612	1,773*	5	0.182
NRPK	243-01A	U	557	1,189*	3	0.258
NRPK	245-01A	U	267	127	1	0.083
NRPK	3-01B	U	288	139	2	0.080
NRPK	4-01B	M	474	838	2	0.136
NRPK	2-02A	M	473	751	2	0.105
NRPK	3-02A	U	335	206	2	0.098
NRPK	5-02A	U	337	227	2	0.130
NRPK	2-02B	U	646	1,630*	3	0.246
NRPK	35-02C	U	655	2,159*	5	0.195
NRPK	37-02C	U	682	2,539*	4	0.264
NRPK	40-02C	U	263	122	2	0.089
NRPK	2-03A	U	631	1,728*	7	0.421
NRPK	3-03A	U	600	1,610*	3	0.112
NRPK	6-03A	F	535	1,034*	2	0.082
NRPK	9-03A	U	444	549	2	0.172
NRPK	10-03A	U	403	470	3	0.086
NRPK	11-03A	U	431	521	2	0.121
NRPK	3-03B	U	574	963*	2	0.185
NRPK	37-03B	U	311	173	2	0.081
Mean			**459**	**945**	**3**	**0.149**

M – Male; F – Female; U – Undetermined

* Refer to Table 3.4-9 for fish consumption guidelines for the Clearwater River for northern pike >908 g (GOA 2009).

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.9-21 **Temporal comparison of absolute and length-normalized mercury concentrations in muscle tissue of northern pike from the Clearwater River, fall 2004, 2006, 2007, 2009, and 2012.**

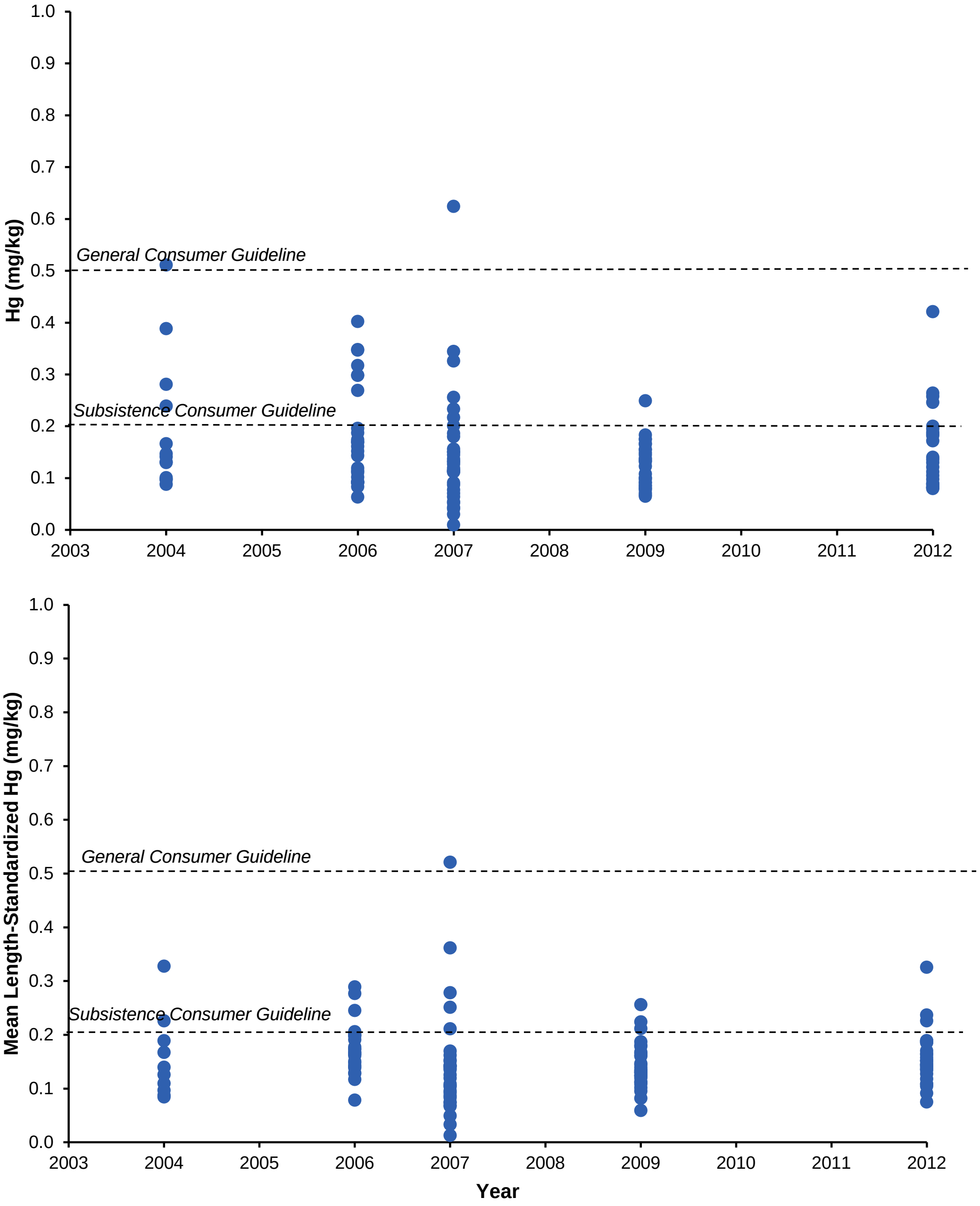
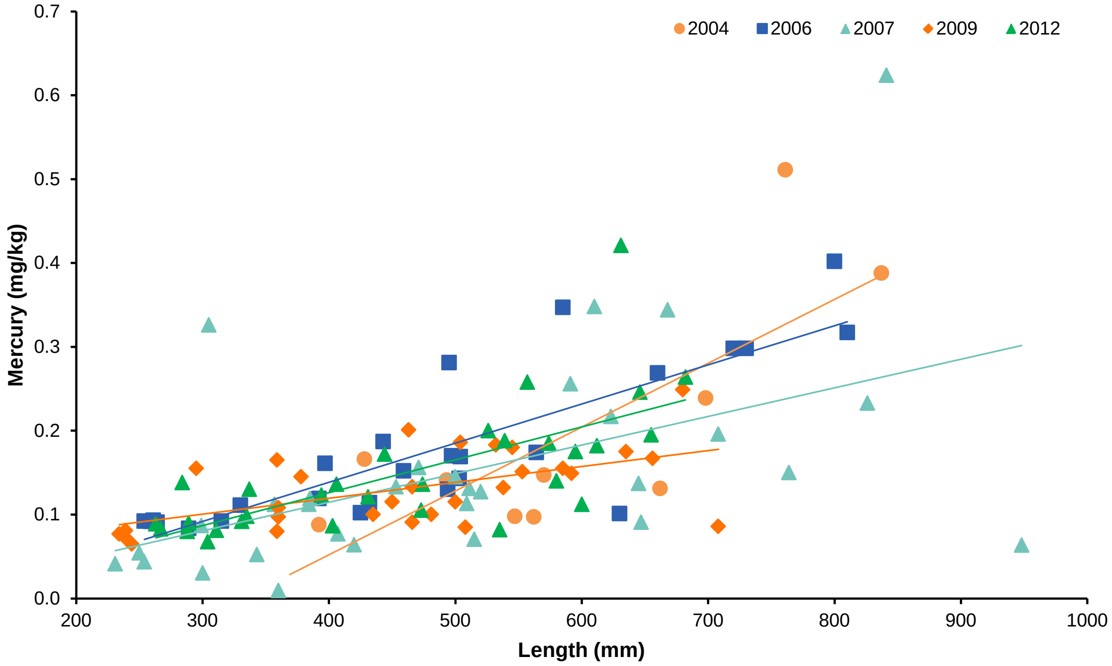


Figure 5.9-22 Relationships between mercury and fork length and mercury and age of northern pike from the Clearwater River, 2004 to 2012.



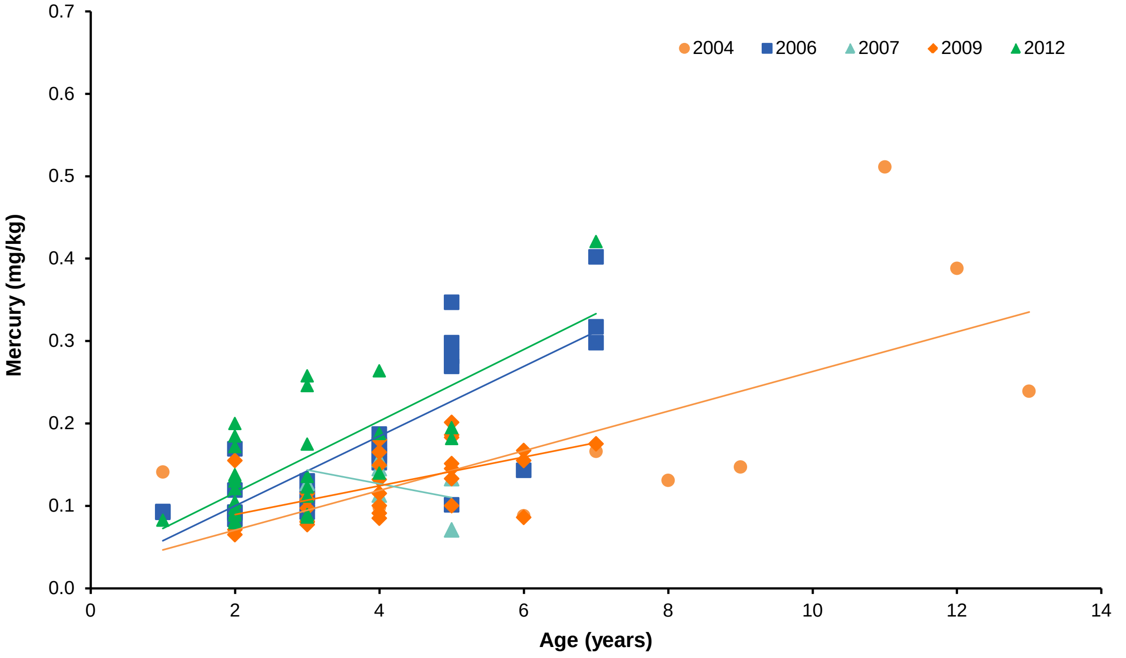


Table 5.9-11 Screening of metals and tainting compounds in northern pike composite samples collected in 2012 from the Clearwater River against fish consumption criteria for the protection of human health.

	Units	DL	Composite NRPK[1]			National USEPA[2]		Region III USEPA[3]
			Male (450-500 mm)	**Male (500-550 mm)**	**Female (500-550 mm)**	**Subsistence**	**Recreational**	**Risk-based Criteria**
Total Metals								
Aluminum (Al)	mg/kg	2	<2.0	<2.0	<2.0	nc	nc	nc
Antimony (Sb)	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	0.54
Arsenic (As)[4]	mg/kg	0.01	**0.015**	**0.013**	<0.010	0.00327	0.026	0.0021
Inorganic Arsenic[5]	mg/kg		0.0015	0.0013	<0.010	0.00327	0.026	0.0021
Barium (Ba)	mg/kg	0.02	0.04	0.028	0.044	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	<0.0060	<0.0060	<0.0060	nc	nc	1.4
Calcium (Ca)	mg/kg	20	222	21.6	195	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	<0.050	<0.050	<0.050	nc	nc	4.1
Cobalt (Co)	mg/kg	0.02	<0.020	<0.020	<0.020	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.223	0.215	0.244	nc	nc	54
Iron (Fe)	mg/kg	5	3	<1.0	3.2	nc	nc	410
Lead (Pb)	mg/kg	0.02	<0.020	<0.020	<0.020	nc	nc	nc
Magnesium (Mg)	mg/kg	5	300	309	269	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	0.247	0.237	0.207	nc	nc	190
Molybdenum (Mo)	mg/kg	0.05	<0.010	<0.010	<0.010	nc	nc	6.8

value = exceeds Region III USEPA Risk-based Criteria

value = exceeds National USEPA Subsistence fishers

shaded value = exceeds National USEPA Recreational fisher guideline; nc = no criterion

[1] Composite sampled taken from northern pike target size class (450-500 mm and 500-550 mm for males; and 500-550 mm for females).

[2] Last updated November 2000: http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

[3] Last updated June 2011: http://www.epa.gov/reg3hwmd/risk/human/pdf/JUNE_2011_FISH.pdf

[4] Guidelines refer to inorganic arsenic not total arsenic.

[5] 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

[6] 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.

Table 5.9-11 (Cont'd.)

	Units	DL	Composite NRPK[1]			National USEPA[2]		Region III USEPA[3]
			Male (450-500 mm)	**Male (500-550 mm)**	**Female (500-550 mm)**	**Subsistence**	**Recreational**	**Risk-based Criteria**
Total Metals (Cont'd.)								
Nickel (Ni)	mg/kg	0.02	0.028	0.06	0.053	nc	nc	27
Phosphorus (P)	mg/kg	20	2130	210	2150	nc	nc	nc
Potassium (K)	mg/kg	20	3770	353	3810	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.134	0.14	0.082	2.457	20	6.8
Silver (Ag)	mg/kg	0.05	<0.050	<0.050	<0.050	nc	nc	6.8
Sodium (Na)	mg/kg	20	475	41	374	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.195	0.191	0.179	nc	nc	810
Thallium (Tl)	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	0.095
Tin (Sn)	mg/kg	0.05	<0.050	<0.050	<0.050	nc	nc	810
Titanium (Ti)	mg/kg	0.1	<0.10	<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	3.6	0.37	4.02	nc	nc	410
Tainting Compounds								
Thiophene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc
Toluene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	110
m+p-Xylenes	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc
Naphthalene[6]	mg/kg	0.05	<0.050	<0.050	<0.050	nc	nc	nc

value = exceeds Region III USEPA Risk-based Criteria

value = exceeds National USEPA Subsistence fishers

shaded value = exceeds National USEPA Recreational fisher guideline; nc = no criterion

[1] Composite sampled taken from northern pike target size class (450-500 mm and 500-550 mm for males; and 500-550 mm for females).

[2] Last updated November 2000: http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/risk/upload/2009_04_23_fish_advice_volume1_v1cover.pdf

[3] Last updated June 2011: http://www.epa.gov/reg3hwmd/risk/human/pdf/JUNE_2011_FISH.pdf

[4] Guidelines refer to inorganic arsenic not total arsenic.

[5] 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

[6] 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.

Table 5.9-12 Screening of metals and tainting compounds in northern pike composite samples collected in 2012 from the Clearwater River against thresholds for the protection of fish health.

			Composite NRPK[1]			Thresholds for the Protection of Fish[2]			
			Male (450-500 mm)	Male (500-550 mm)	Female (500-550 mm)	Lowest No-effects Thresholds		Lowest Effects Thresholds	
	Units	DL				Lethal	Sublethal	Lethal	Sublethal
Total Metals									
Aluminum (Al)	mg/kg	2	<2.0	<2.0	<2.0	1	nc	20	nc
Antimony (Sb)	mg/kg	0.01	<0.010	<0.010	<0.010	5	nc	9	nc
Arsenic (As)[4]	mg/kg	0.01	0.015	0.013	<0.010	2.6	0.9	11.2	3.1
Barium (Ba)	mg/kg	0.02	0.04	0.028	0.044	nc	nc	nc	nc
Beryllium (Be)	mg/kg	0.1	<0.10	<0.10	<0.10	nc	nc	nc	nc
Cadmium (Cd)	mg/kg	0.006	<0.0060	<0.0060	<0.0060	0.02	0.09	0.14	0.12
Calcium (Ca)	mg/kg	20	222	21.6	195	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	<0.050	<0.050	<0.050	nc	nc	nc	nc
Cobalt (Co)	mg/kg	0.02	<0.020	<0.020	<0.020	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.223	0.215	0.244	0.5	3.4	0.5	0.3
Iron (Fe)	mg/kg	5	3	<1.0	3.2	nc	nc	nc	nc
Lead (Pb)	mg/kg	0.02	<0.020	<0.020	<0.020	4	nc	nc	nc
Magnesium (Mg)	mg/kg	5	300	309	269	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	0.247	0.237	0.207	nc	nc	nc	nc
Mercury (Hg)[3,4]	mg/kg	0.002	0.139	0.171	0.0968	1.91	2.28	3.7	8.6
Molybdenum (Mo)	mg/kg	0.05	<0.010	<0.010	<0.010	nc	nc	nc	nc

value = exceeds sublethal lowest no-effects threshold

value = exceeds sublethal lowest effects threshold

value = exceeds lethal lowest no-effects threshold

shaded value = exceeds lethal lowest effects threshold

[1] Composite sampled taken from northern pike target size class (450-500 mm and 500-550 mm for males; and 500-550 mm for females).

[2] Threshold values were derived from effects data for fish muscle tissue presented in Jarvinen and Ankley (1999).

[3] Threshold values were derived from methylated forms of mercury (Jarvinen and Ankley 1999).

[4] Mercury results are average values from individual samples.

[5] Threshold values are presented for carcass and not muscle tissue (Jarvinen and Ankley 1999).

nc = no criteria

Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.9-12 (Cont'd.)

			Composite NRPK[1]			Thresholds for the Protection of Fish[2]			
			Male (450-500 mm)	Male (500-550 mm)	Female (500-550 mm)	Lowest No-effects Thresholds		Lowest Effects Thresholds	
	Units	DL				Lethal	Sublethal	Lethal	Sublethal
Total Metals (Cont'd.)									
Nickel (Ni)	mg/kg	0.02	0.028	0.06	0.053	0.82	nc	118.1	nc
Phosphorus (P)	mg/kg	20	2130	210	2150	nc	nc	nc	nc
Potassium (K)	mg/kg	20	3770	353	3810	nc	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.134	0.14	0.082	0.28	0.08	0.92	0.32
Silver (Ag)	mg/kg	0.05	<0.050	<0.050	<0.050	0.003	0.003	nc	nc
Sodium (Na)	mg/kg	20	475	41	374	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.195	0.191	0.179	nc	nc	nc	nc
Thallium (Tl)	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc	nc
Tin (Sn)	mg/kg	0.05	<0.050	<0.050	<0.050	nc	nc	nc	nc
Titanium (Ti)	mg/kg	0.1	<0.10	<0.10	<0.10	nc	nc	nc	nc
Vanadium (V)[5]	mg/kg	0.1	<0.10	<0.10	<0.10	5.33	0.02	nc	0.41
Zinc (Zn)	mg/kg	0.5	3.6	0.37	4.02	60	60	nc	nc
Tainting Compounds									
Thiophene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc	nc
m+p-Xylenes	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.010	<0.010	<0.010	nc	nc	nc	nc
Naphthalene[6]	mg/kg	0.05	<0.050	<0.050	<0.050	nc	nc	nc	nc

value = exceeds sublethal lowest no-effects threshold

value = exceeds sublethal lowest effects threshold

value = exceeds lethal lowest no-effects threshold

shaded value = exceeds lethal lowest effects threshold

[1] Composite sampled taken from northern pike target size class (450-500 mm and 500-550 mm for males; and 500-550 mm for females).

[2] Threshold values were derived from effects data for fish muscle tissue presented in Jarvinen and Ankley (1999).

[3] Threshold values were derived from methylated forms of mercury (Jarvinen and Ankley 1999).

[4] Mercury results are average values from individual samples.

[5] Threshold values are presented for carcass and not muscle tissue (Jarvinen and Ankley 1999).

nc = no criteria

Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Figure 5.9-23 Length-normalized mercury concentrations in northern pike captured from regional watercourses, 1975 to 2012 (sample size represented by number on each bar; orange bar denotes current sampling year).

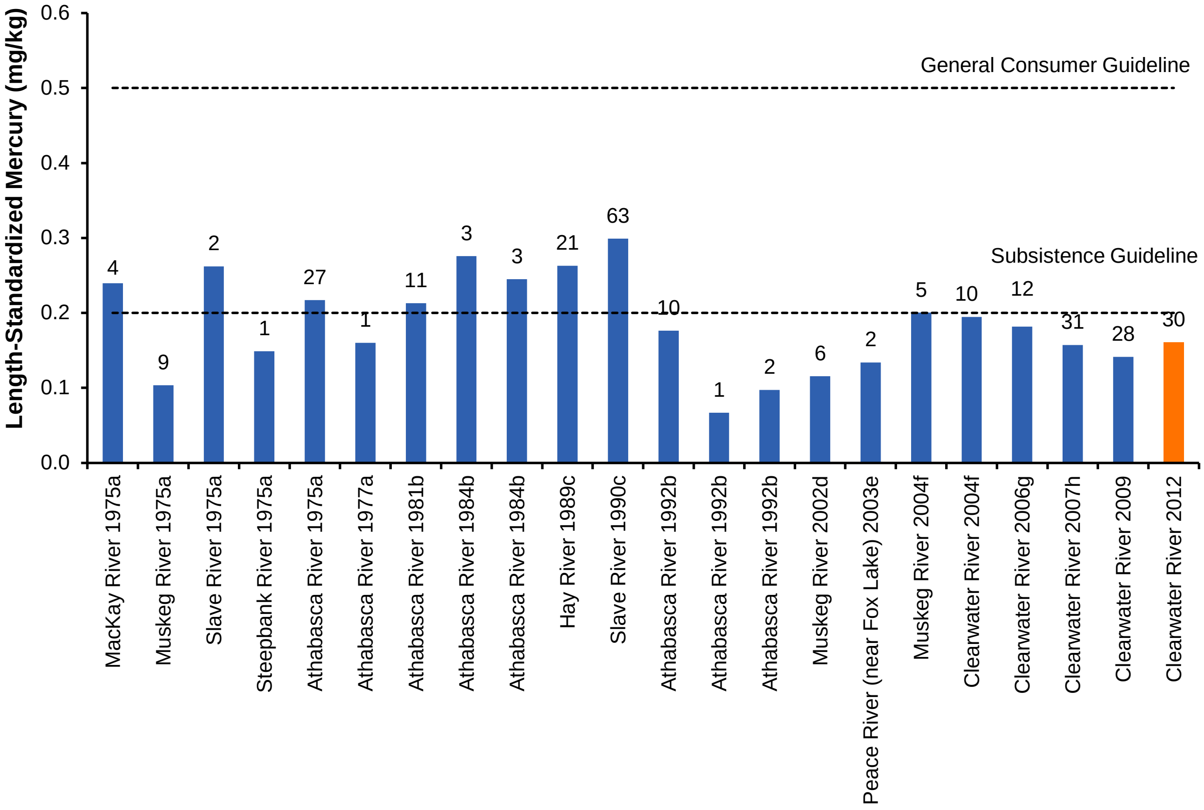


Table 5.9-13 Average habitat characteristics of fish assemblage monitoring locations of High Hills River, fall 2012.

Variable	Units	HHR-F1 *Baseline* Reach of High Hills River
Sample date	-	10-Oct-2012
Habitat type	-	run/riffle
Maximum depth	m	>1.3
Bankfull channel width	m	22
Wetted channel width	m	20
Substrate		
Dominant	-	coarse gravel
Subdominant	-	cobble
Instream cover		
Dominant	-	small and large woody debris
Subdominant	-	-
Field water quality		
Dissolved oxygen	mg/L	11.6
Conductivity	µS/cm	127
pH	pH units	7.65
Water temperature	^{0}C	2.7
Water velocity		
Left bank velocity	m/s	ns
Left bank water depth	m	ns
Centre of channel velocity	m/s	0.52
Centre of channel water depth	m	0.55
Right bank velocity	m/s	0.40
Right bank water depth	m	0.27
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	-

Table 5.9-14 Percent composition and mean CPUE (catch per unit effort) of all fish species at *baseline* reach HHR-F1 in the High Hills River, 2011 to 2012.

Common Name	Code	Total Species		Percent of Total Catch	
		2011	2012	2011	2012
Arctic grayling	ARGR	-	-	0	0
brook stickleback	BRST	-	-	0	0
burbot	BURB	-	1	0	2.0
fathead minnow	FTMN	-	-	0	0
finescale dace	FNDC	-	2	0	3.9
lake chub	LKCH	-	-	0	0
lake whitefish	LKWH	-	-	0	0
longnose dace	LNDC	8	-	8	0
longnose sucker	LNSC	22	-	22.0	0
northern pike	NRPK	-	-	0	0
northern redbelly dace	NRDC	-	-	0	0
pearl dace	PRDC	-	-	0	0
slimy sculpin	SLSC	47	48	47.0	94.1
spoonhead sculpin	SPSC	6	-	6	0
spottail shiner	SPSH	-	-	0	0
trout-perch	TRPR	-	-	0	0
walleye	WALL	-	-	0	0
white sucker	WHSC	17	-	17.0	0
yellow perch	YLPR	-	-	0	0
sucker sp. *	-	-	-	0	0
unknown sp. *	-	-	-	0	0
Total Count		100	51	100	100
Total Species Richness		5	3	-	-
Electrofishing effort (secs)		1,355	1,520	-	-
CPUE (#/100 secs)		7.38	3.36	-	-

* not included in total species richness count.

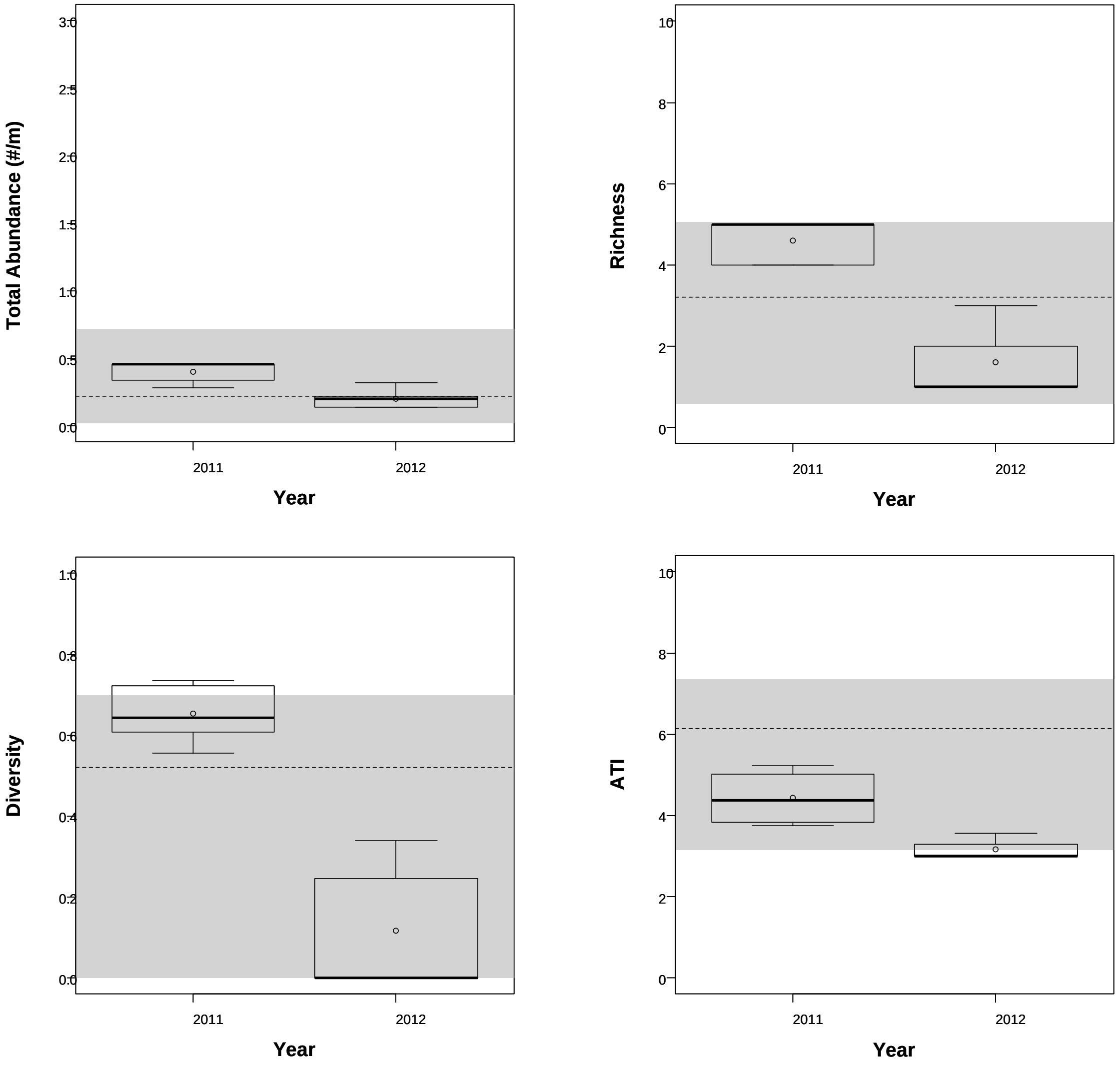
Table 5.9-15 Summary of fish assemblage measurement endpoints for *baseline* reach HHR-F1 in the High Hills River, 2011 to 2012.

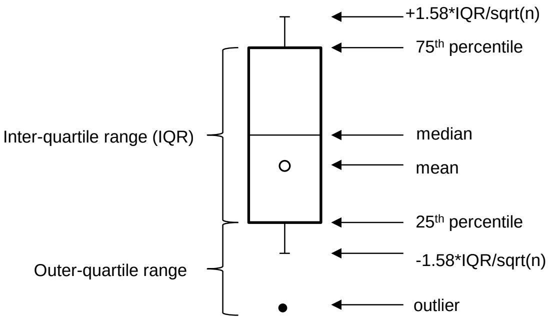
Year	Abundance		Richness*			Diversity*		ATI*	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
2011	0.40	0.08	5	5	0.55	0.65	0.08	4.44	0.67
2012	0.20	0.07	3	2	0.89	0.12	0.16	3.17	0.26

* not included in total species richness count.

SD = standard deviation across sub-reaches within a reach.

Figure 5.9-24 Box-plots showing variation in fish assemblage measurement endpoints in High Hills River, 2011 to 2012.





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

5.10 CHRISTINA RIVER WATERSHED

Table 5.10-1 Summary of results for the Christina River watershed.

Christina River Watershed	**Summary of 2012 Conditions**						
	Christina River		***Tributaries to Christina Lake***			***Lakes***	
Climate and Hydrology							
Criteria	**S47** near the Mouth	**07CE002/S29** near Chard				**07CE906** Christina Lake	no station sampled
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	**CHR-1** at the mouth	**CHR-2** upstream of Janvier	**SAC-1** Sawbones Creek	**SUC-1** Sunday Creek	**JAR-1** Jackfish River at the mouth	**CHL-1** Christina Lake	no station sampled
Water Quality Index	🟡	🟤	🟡	🟡	🟡	n/a	
Benthic Invertebrate Communities and Sediment Quality							
Criteria	**CHR-D1** at the mouth	**CHR-D2** upstream of Janvier	**SAC-D1** Sawbones Creek	**SUC-D1** Sunday Creek	**JAR-E1** Jackfish River at the mouth	**CHL-1** Christina Lake	no station sampled
Benthic Invertebrate Communities	🟠	🟡	🟡	🟡	🟡	🟡	
Sediment Quality Index	🟡	🟡	🟡	🟡	🟡	n/a	
Fish Populations							
Criteria	**CHR-F1** at the mouth	**CHR-F2** upstream of Janvier	**SAC-F1** Sawbones Creek	**SUC-F1** Sunday Creek	**JAR-F1** Jackfish River at the mouth	**CHL-1** Christina Lake	**GL** Gregoire Lake
Fish Assemblages	🟡	🟡	🟠	🟡	🟡	n/a	not sampled
Human Health	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	Sub/Gen[2] NRPK[1] 🟡 WALL[1] 🟡

Legend and Notes

🟡 Negligible-Low

🟠 Moderate

🟤 High

🟩 *baseline*

🟦 *test*

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with *baseline* reaches.

[1] Species (Sp.): NRPK=northern pike; WALL=walleye

[2] Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.4.7.3)

Hydrology: Measurement endpoints calculated on differences between observed test and estimated baseline hydrographs that would have been observed in the absence of focal projects and other 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.

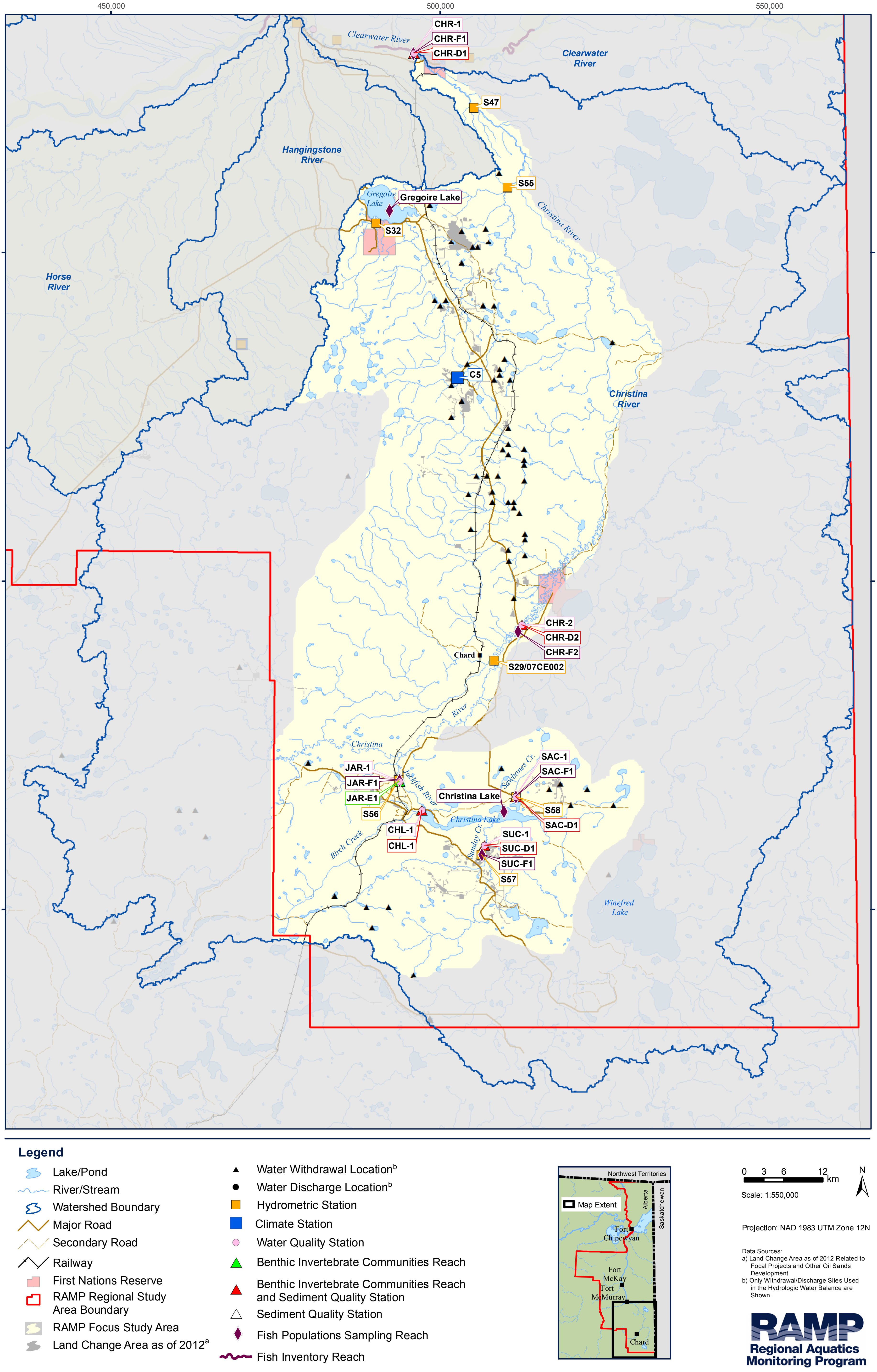
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baselines*; see Section 3.3.1.10 for a detailed description of the classification methodology.

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.

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.

Figure 5.10-1 Christina River watershed.



K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K10_Christina_20130418.mxd

Figure 5.10-2 Representative monitoring stations of the Christina River watershed, fall 2012.

Water Quality Station CHR-1 (Christina River): facing downstream

Benthic and Sediment Quality Reach CHR-D2 (Christina River): Left Downstream Bank

Water Quality Station JAR-1 (Jackfish River): facing upstream

Water Quality Station SAC-1 (Sawbones Creek): facing upstream

Hydrology Station S47 (Christina River at the mouth): aerial view

Water Quality Station SUC-1 (Sunday Creek): facing upstream

5.10.1 Summary of 2012 Conditions

As of 2012, approximately 0.6% (7,450 ha) of the Christina River watershed had undergone land change from focal projects and other oil sands developments (Table 2.5-2). The Christina River watershed downstream of the Cenovus, MEG, and Devon projects surrounding Christina Lake is designated as *test*. The tributaries flowing in and out of Christina Lake (i.e., Sawbones and Sunday creeks and Jackfish River) as well as the lake itself 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 of RAMP in the Christina River watershed in 2012. Table 5.10-1 is a summary of the 2012 assessment of the Christina River watershed, while Figure 5.10-1 denotes the location of the monitoring stations for each RAMP component, reported focal project water withdrawal and discharge locations and the areas with land change as of 2012. Figure 5.10-2 contains photos of representative monitoring stations in the watersheds.

Hydrology The calculated mean open-water season (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge at the mouth of the Christina River during the 2012 WY were 0.04% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. The mean winter discharge was 0.11% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

Water Quality In fall 2012, water quality at *test* stations CHR-1, JAR-1, SAC-1, and SUC-1 indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at *test* station CHR-2 indicated **High** differences from regional *baseline* water quality conditions. Concentrations of several water quality measurement endpoints (e.g., total and dissolved metals) were outside the range of previously-measured concentrations and regional *baseline* conditions in fall 2012.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D1 were classified as **Moderate** because abundance, richness, and the percentage of EPT taxa were lower in 2012 compared to previous years and diversity and abundance were below the range of variation for *baseline* depositional reaches. The benthic invertebrate community at *test* reach CHR-D1 has consistently been dominated by tubificid worms over time suggesting that the observed differences in 2012 may be due to natural variation. The reach also contained stoneflies (Plecoptera) suggesting reasonably good habitat quality. Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D2 were classified as **Negligible-Low** because the significantly higher percentage of EPT taxa in the *test* period compared to the *baseline* period was not consistent with a negative change. Differences in measurement endpoints at *test* reaches SUC-D1, SAC-D1, and JAR-E1 were classified as **Negligible-Low** because almost all measurement endpoints including CA Axis scores were either within or above regional *baseline* conditions. The benthic invertebrate community at *test* station CHL-1 in fall 2012 were classified as **Negligible-Low** given that Christina Lake contained a diverse benthic fauna including several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies). In fall 2012, concentrations of sediment quality measurement endpoints at both stations of the Christina River were generally lower than previously-measured concentrations and a decreasing trend in concentrations of total PAHs was observed over time at *test* station CHR-D1. Concentrations of sediment quality measurement endpoints at stations on tributaries to Christina Lake (i.e., *test* stations SAC-D1 and SUC-D1) were within regional *baseline* conditions. Sediment quality in fall 2012 showed **Negligible-Low** differences at all stations in the Christina River watershed, excluding Christina Lake, from regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages between *test* reaches CHR-F1 and CHR-F2 and regional *baseline* conditions were classified as **Negligible-Low** because only abundance at *test* reach CHR-F1 was below the range of variation for regional *baseline* reaches. The lower catch was likely due to difficulties in effectively sampling the river in high water conditions in fall 2012. Regional information for this part of the RAMP FSA was limited; therefore, comparisons to regional *baseline* conditions were made with areas further to the north (i.e., reaches sampled by RAMP to the north of Fort McMurray). Differences in measurement endpoints for fish assemblages between *test* reach SUC-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured and not consistent with a negative change. Differences in measurement endpoints for fish assemblages between *test* reach JAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within the regional *baseline* range of variation. Differences in measurement endpoints for fish assemblages between *test* reach SAC-F1 and regional *baseline* conditions were classified as **Moderate** because three of the four measurement endpoints were below the 5th percentile of regional *baseline* conditions. Given that historical data were limited for Sawbones Creek, a more complete assessment of fish assemblages in this creek will be conducted in fall 2013, once two years of data are acquired.

Fish Populations (Christina Lake Survey) A total of 784 fish from nine species were captured using the three methods during the fish assemblage survey in Christina Lake in summer 2012. Two species captured during the RAMP 2012 survey had not been previously documented in either Christina Lake or its tributaries, including the Iowa darter (*Etheostoma exile*) and northern redbelly dace (*Phoxinus eos*). Fishing locations were randomly selected throughout the lake for the 2012 survey. However, the lake has two main basins separated by a shallower narrow channel, with a smaller basin at the north end of the east basin.

Fish Populations (fish tissue) Mercury concentrations in northern pike and walleye from Gregoire Lake in 2012 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in fish from Gregoire Lake were near the lower end of the historical range of mercury concentrations in fish sampled from other regional lakes.

5.10.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Christina River watershed was conducted at RAMP Station S47, Christina River near the mouth, which was used for the water balance analysis. Additional hydrometric data for the Christina River watershed were available from stations 07CE002/S29, Christina River near Chard; S32, Surmont Creek at Highway 881; S55, Gregoire River near the mouth; S56/07CE005, Jackfish River below Christina Lake; S57, Sunday Creek above Christina Lake; S58, Sawbones Creek above Christina Lake; and 07CE906, Christina Lake near Winefred Lake. Hydrographs for Christina Lake (Station 07CE906) and Jackfish River (Station S56/07CE005) are provided in this section given these stations captured the conditions of the Christina Lake area prior to entering the Christina River and there were historical data (WSC and AESRD) available for these stations. Details for all of these RAMP stations can be found in Appendix C.

Continuous annual hydrometric data have been collected for Station S47, Christina River near the mouth, since July 2011. Historical hydrometric data have been estimated for the mouth of the Christina River from 1967 to 2011 by calculating the difference between the measured flow at Clearwater River above Christina River, WSC Station 07CD005 and Clearwater River at Draper, WSC Station 07CD001. Therefore, comparisons of the hydrologic conditions in the 2012 WY to historical values were less robust than for other hydrology stations in the RAMP FSA.

In the 2012 WY, the annual and open-water runoff volumes at RAMP Station S47 were 1,100 million m^3 and 921 million m^3, respectively. The annual runoff volume was 2% lower than the historical mean annual runoff and the open-water runoff volume was 4% lower than the historical mean open-water runoff. Flows decreased from November 2011 to March 2012 and flows from mid-November to mid-March were generally between historical median and upper quartile values (Figure 5.10-3). Flows then increased in late April and early May during spring freshet to a peak of 116.7 m^3/s on May 8, which was the maximum daily flow recorded in the 2012 WY. Following the freshet, flows decreased until the end of June, and then increased in response to rainfall events in July. Flows generally remained within the inter-quartile range from May until the end of the 2012 WY, with the exception of the middle of September when flows exceeded the historical upper quartile for 16 days (Figure 5.10-3).

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance for the Christina River is presented for two different cases: (i) only focal projects in the Christina River watershed; and (ii) focal projects plus other oil sands developments in the Christina River watershed (Table 5.10-2).

Case 1 – Only focal projects in the Christina River watershed:

1. The closed-circuited land area from focal projects as of 2012 in the Christina River watershed was estimated to be 7.9 km^2 (Table 2.5-1). The loss of flow to the Christina River that would have otherwise occurred from this land area was estimated at 0.66 million m^3.
2. As of 2012, the area of land change in the Christina River watershed from focal projects that was not closed-circuited was estimated to be 65.1 km^2 (Table 2.5-1). The increase in flow to the Christina River that would not have otherwise occurred from this land area was estimated at 1.10 million m^3.
3. In the 2012 WY, Nexen, ConocoPhillips, MEG, Canadian Natural, and Statoil withdrew 0.22 million m^3 of water from various surface water sources to support industrial activities.

The estimated cumulative effect of land change for this case was an increase of flow of 0.22 million m^3 to the Christina River. The resulting observed *test* and estimated *baseline* hydrographs for this case are presented in Figure 5.10-3. The 2012 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge were 0.04%, 0.04%, and 0.03%, respectively, greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.10-3). These differences were classified as **Negligible-Low** (Table 5.10-1). The mean winter discharge was 0.11% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.10-3). This difference was classified as **Negligible-Low** (Table 5.10-1).

Case 2 – Focal projects plus other oil sands developments in the Christina River watershed:

1. The closed-circuited land area from focal projects plus other oil sands developments as of 2012 in the Christina River watershed was estimated to be 7.9 km^2 (Table 2.5-1). The loss of flow to the Christina River that would have otherwise occurred from this land area was estimated at 0.66 million m^3.
2. As of 2012, the area of land change in the Christina River watershed from focal projects plus other oil sands developments that was not closed-circuited was estimated to be 66.6 km^2 (Table 2.5-1). The increase in flow to the Christina River that would not have otherwise occurred from this land area was estimated at 1.12 million m^3.
3. The water withdrawals by Nexen, ConocoPhillips, MEG, Canadian Natural, and Statoil of 0.22 million m^3 described above are applied to this case as well.

The estimated cumulative effect of land change for this case was an increase in flow of 0.24 million m^3 to the Christina River. The calculated mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge at the mouth of the Christina River during the 2012 WY were 0.04% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Figure 5.10-3). These differences were classified as **Negligible-Low** and were within 0.01% of Case 1 (Table 5.10-1)**.** The mean winter discharge was 0.11% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.10-3). This difference was classified as **Negligible-Low** (Table 5.10-1).

Continuous lake level data for Christina Lake have been collected for the WSC Station 07CE906 from 2002 to 2012. Within the 2012 WY, lake levels decreased from November 2011 to March 2012, with levels in November and December generally varying between historical lower quartile and minimum values, and levels from February to the beginning of the spring freshet in early April similar to the historical minimum values (Figure 5.10-4). Lake levels increased during freshet in April and early May to a peak level of 554.318 masl on May 9. This was the highest lake level recorded in the 2012 WY and was similar to the historical mean annual maximum lake level. Following the freshet, lake levels decreased until mid-June before increasing due to rainfall events in late June and July. Lake levels from June to mid-October were generally between the historical lower quartile and minimum values.

Continuous hydrometric data for Jackfish River have been collected from May 16 to October 31, 2012 at Station S56 with data missing from June 22 to July 3. 2012 was the first year that Station S56 was operational; however, seasonal data from March to October have been collected at the WSC Station 07CE005 from 1982 to 1995, which was in the same location as Station S56. The open-water runoff volume in the 2012 WY was 47.9 million m^3, which was 9% lower than the historical mean open-water runoff volume calculated from 13 years of available record. Flows decreased rapidly from the start of monitoring on May 22 to just below the historical median value by June 13, and then slightly increased until monitoring ceased on June 21 (Figure 5.10-5). Once monitoring resumed on July 4, flows generally decreased until the lowest open-water flow of 1.83 m^3/s on September 1. Flows increased slightly until the end of the 2012 WY, with values similar to the historical upper quartile values**.**

5.10.3 Water Quality

In fall 2012, 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);
- Sawbones Creek (new *test* station in SAC-1, sampled for the first time in 2012);
- Sunday Creek (new *test* station SUC-1, sampled for the first time in 2012);
- the Jackfish River near its mouth (new *test* station JAR-1, sampled for the first time in 2012); and
- Christina Lake (new *test* station CHL-1, sampled for the first time in 2012).

Test stations CHL-1, SAC-1, JAR-1, and SUC-1 were also sampled in spring and summer in 2012 in an effort to obtain three years of seasonal data at each new station.

Temporal Trends The only significant (α=0.05) trend in fall concentrations of water quality measurement endpoints was a decreasing concentration of chloride at *test* station CHR-2 (2001 to 2012). Trend analysis was not conducted on *test* stations CHL-1, SAC-1, JAR-1, or SUC-1 because 2012 was the first year of sampling.

2012 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 5.10-9), with the exception of:

- total suspended solids, total arsenic, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations at *test* station CHR-1; and
- pH, conductivity, sodium, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, and total strontium, with concentrations that were lower than previously-measured minimum concentrations and total aluminum and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations at *test* station CHR-2.

No historical comparisons were possible for the new *test* stations CHL-1, SAC-1, JAR-1, and SUC-1.

Ion Balance The ionic composition of water at stations on the Christina River watershed in fall 2012 was similar to those in previous years (Figure 5.10-6). The ionic composition at the new *test* stations was most similar to *test* station CHR-2.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum at *test* stations CHR-1, CHR-2, and SUC-1 exceeded the water quality guideline. The concentration of total mercury (ultra-trace) exceeded the guideline at *test* station CHR-1 (Table 5.10-4 to Table 5.10-9).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the Christina River watersheds in fall 2012 (Table 5.10-10):

- dissolved iron, total chromium, total iron, total phenols, and total phosphorus at *test* station CHR-1;

- sulphide, total chromium, total copper, total iron, total lead, total phenols, dissolved zinc, total zinc, dissolved thallium, total thallium, total cadmium, total silver, and total phosphorus at *test* station CHR-2;
- total phenols at *test* stations CHL-1, SAC-1, and SUC-1;
- total iron at *test* stations SAC-1 and SUC-1; and
- total phosphorus at *test* station SUC-1.

In addition, the following water quality guideline exceedances occurred in spring and summer at *test* stations CHL-1, SAC-1, JAR-1, and SUC-1 (Table 5.10-10):

- total phenols at all stations in spring and summer;
- sulphide at *test* station SAC-1 and total iron at *test* station SUC-1 in spring; and
- total iron at *test* stations SAC-1 and SUC-1 and total aluminum at *test* station SUC-1 in summer.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, most of the water quality measurement endpoints were within regional *baseline* concentrations, with the exception of the following measurement endpoints (Figure 5.10-7):

- total suspended solids, which exceeded the 95th percentile of regional *baseline* concentrations at *test* station CHR-1;
- total dissolved solids, which was below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1;
- total strontium, which was below the 5th percentile of regional *baseline* concentrations at *test* stations CHR-2 and SAC-1;
- total mercury (ultra-trace), which was below the 5th percentile of regional *baseline* concentrations at *test* station JAR-1;
- total magnesium, which was below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1;
- total boron, which was below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1;
- potassium, which was below the 5th percentile of regional *baseline* concentrations at *test* stations CHR-2 and SAC-1; and
- sodium and sulphate, which were below the 5th percentile of regional *baseline* concentrations at *test* stations CHR-2, JAR-2, SAC-1, and SUC-1.

Lakes do not contribute to the regional *baseline* concentrations; therefore, Christina Lake (*test* station CHL-1) was not compared to regional *baseline* concentrations (Figure 5.10-8).

Water Quality Index The WQI values at *test* station CHR-1, JAR-1, SAC-1, and SUC-1 in fall 2012 indicated **Negligible-Low** differences from regional *baseline* water quality conditions (Table 5.10-11). The WQI at *test* station CHR-2 (WQI value of 41.3) indicated **High** differences from regional *baseline* water quality conditions. Concentrations of total and dissolved metals were much higher at *test* station CHR-2 than regional *baseline* conditions and contributed to the lower WQI value. A WQI was not generated for *test* station CHL-1 (Christina Lake) because lakes were not compared to regional *baseline* concentrations.

Classification of Results In fall 2012, water quality at *test* stations CHR-1, JAR-1, SAC-1, and SUC-1 indicated **Negligible-Low** differences from regional *baseline* conditions. Water quality at *test* station CHR-2 indicated **High** differences from regional *baseline* water quality conditions. Concentrations of several water quality measurement endpoints (e.g., total and dissolved metals) were outside the range of previously-measured concentrations and regional *baseline* conditions in fall 2012.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- depositional *test* reach CHR-D1, sampled from 2002 to 2009, and in 2012 as a *test* reach;
- depositional *test* reach CHR-D2, sampled from 2002 to 2006, 2009 as a *baseline* reach, and in 2012 as a *test* reach;
- depositional *test* reach SAC-D1, initiated as a new RAMP reach in fall 2012;
- depositional *test* reach SUC-D1, initiated as a new RAMP reach in fall 2012;
- erosional *test* reach JAR-E1, initiated as a new RAMP reach in fall 2012; and
- Christina Lake (*test* station CHL-1, initiated as a new RAMP station in fall 2012).

Christina River

2012 Habitat Conditions Water at *test* reach CHR-D1 in fall 2012 was moderately flowing (0.47 m/s), alkaline (pH: 8.3), with moderate dissolved oxygen (7.7 mg/L), and moderate conductivity (226 µS/cm). The substrate was dominated by sand (83%), with some silt (9%) and clay (8%) and low total organic carbon content (~1%) (Table 5.10-12).

Water at *test* reach CHR-D2 in fall 2012 was deep (~1 m), slightly alkaline (pH: 7.8), with low conductivity (102 µS/cm), and moderate dissolved oxygen. The substrate was dominated by sand (93%), with low total organic carbon content (0.2%) (Table 5.10-12).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach CHR-Dl in fall 2012 was dominated by tubificid worms (57%), with subdominant taxa consisting of chironomids (21%) (Table 5.10-13). Bivalves (*Pisidium/Sphaerium*), Ephemeroptera (*Ephemerellidae*), Plecoptera (*Isoperla*), and Trichoptera (*Hydroptila*) were present in very low relative abundances (Table 5.10-13). Chironomids were diverse but primarily composed of the common form *Polypedilum* (Wiederholm 1983).

The benthic invertebrate community at *test* reach CHR-D2 in fall 2012 was dominated by chironomids (58%), with subdominant taxa consisting of tubificids worms (13%), naidids (9%), and Ephemeroptera (6%: *Ametropus neavei*). Bivalves (*Pisidium/Sphaerium*) and a few Trichoptera (*Brachycentrus*) were found at *test* reach CHR-D2 in fall 2012. Chironomids were more diverse than at *test* reach CHR-D1 and were primarily comprised of *Polypedilum, Paralauterborniella,* and *Lopesocladius / Rheosmittia.*

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 the Christina River.

Temporal comparisons for *test* reach CHR-D1 included testing for:

- changes over time in the *test* period (2002 to 2012, Hypothesis 1, Section 3.2.3.1); and
- changes between 2012 values and the mean of all previous years of sampling (2002 to 2009).

Spatial comparisons for *test* reach CHR-D1 included testing for differences between 2012 values and all available *baseline* data for the Christina River (2002 to 2009 at reach CHR-D2).

Temporal comparisons for *test* reach CHR-D2 included testing for changes from before (2002 to 2009) to after (2012) the reach was designated as *test* (Hypothesis 2, Section 3.2.3.1).

None of the measurement endpoints produced a significant difference, with a large statistical effect (i.e., >20%) at *test* reach CHR-D1 (Table 5.10-14). The percentage of the fauna as EPT taxa was significantly lower in 2012 than the mean of all previous years of sampling, explaining slightly less than 20% of the variance in annual means (Table 5.10-14).

The percentage of the fauna as EPT taxa was significantly higher in 2012 at *test* reach CHR-D2 than during the *baseline* period (2002 to 2009), explaining 32% of the variance in annual means (Table 5.10-15).

Comparison to Published Literature The benthic invertebrate community at *test* reach CHR-Dl in fall 2012 showed an indication of degradation, with a low overall abundance, a high relative abundance of tolerant taxa (tubificids), low diversity, and a low percentage of EPT taxa compared to previous years and compared to *test* reach CHR-D2. Although some sensitive taxa were found (bivalves, and some Ephemeroptera and Trichoptera), they were present in low relative abundances (>1%). The overall composition of the fauna at *test* reach CHR-D1 was indicative of what would generally be expected in a sand substrate river (i.e., which typically cannot support a high diversity of benthic fauna [Barton and Smith 1984]).

The benthic invertebrate community at *test* reach CHR-D2 in fall 2012 also had low abundance, diversity, and richness; however, the percentage of the fauna as EPT taxa was higher in 2012 compared to previous years. The higher percentage of EPT taxa may be a result of the overall low abundance. In several replicate samples, only a few (3 to 20) organisms were found, many of them being EPT taxa, thus elevating the percent abundance of those taxa. While chironomids were more diverse at *test* station CHR-D2 than *test* reach CHR-D1, they were primarily comprised of common forms and dominated by only a few taxa.

2012 Results Relative to Regional *Baseline* Conditions Abundance and Simpson's Diversity at *test* reach CHR-D1 in fall 2012 were below the 5th percentile of the *baseline* range for depositional reaches (Figure 5.10-9). CA Axis 1 and 2 scores were within the range of variation for depositional *baseline* reaches (Figure 5.10-10).

The percentage of the fauna as EPT taxa at *test* reach CHR-D2 in 2012 was above the 95th percentile of regional *baseline* depositional reaches (Figure 5.10-9). CA Axis 1 and 2 scores were within the range of variation for depositional *baseline* reaches (Figure 5.10-10).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D1 were classified as **Moderate** because abundance, richness, and the percentage of EPT taxa were lower in 2012 compared to previous years and diversity and abundance were below the range of variation for *baseline* depositional reaches. The benthic invertebrate community at *test* reach CHR-D1 has consistently been dominated by tubificid worms over time suggesting that the observed differences in 2012 may be due to natural variation. The reach also contained stoneflies (Plecoptera) suggesting reasonably good habitat quality. Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-D2 were classified as **Negligible-Low** because the significantly higher percentage of EPT taxa in the *test* period compared to the *baseline* period was not consistent with a negative change.

Christina Lake Tributaries

2012 Habitat Conditions Water at *test* reach SAC-D1 in fall 2012 was deep (1.3 m), basic (pH: 7.8), with negligible flow (<0.1 m/s), moderate dissolved oxygen (7.8 mg/L), and low conductivity (80 µS/cm) (Table 5.10-16). The substrate consisted primarily of sand (86%), with low total organic carbon (~2%) (Table 5.10-16).

Water at *test* reach SUC-D1 in fall 2012 was deep (0.7 m), basic (pH: 8.8), moderately flowing (0.38 m/s), with high dissolved oxygen (8.8 mg/L), and moderate conductivity (226 µS/cm) (Table 5.10-16). The substrate consisted almost entirely of sand (Table 5.10-16).

Water at *test* reach JAR-E1 in fall 2012 was shallow (0.2 m), fast flowing (0.9 m/s), basic (pH: 8.3), with high dissolved oxygen (8.3 mg/L), and moderate conductivity (176 µS/cm) (Table 5.10-16). The substrate consisted primarily of boulders (39%), large gravel, and small cobble (Table 5.10-16). Periphyton biomass averaged 151.7 mg/m^2, which was near the upper limit of the range of variation for *baseline* erosional reaches, with individual replicate samples exceeding the *baseline* range of variation (Figure 5.10-11).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach SAC-D1 was dominated by chironomids (68%), with subdominant taxa consisting of Cladocera (6%), Ceratopogonidae (5%), and Nematoda (3%) (Table 5.10-17). Chironomids were diverse and included *Micropsect*ra/*Tanytarsus*, *Tanytarsus*, *Cricotopus*/*Orthocladius*, *Larsia*, and *Paralauterborniella*. Ephemeroptera (*Eurylophella*) and Trichoptera (*Polycentropus*) were present in relatively low abundances (Table 5.10-17). Bivalves (*Pisidium*/*Sphaerium*) and the Gastropod (*Gyraulus*) were also found indicating good overall water quality conditions.

The benthic invertebrate community at *test* reach SUC-D1 was dominated by chironomids (80%), with subdominant taxa consisting of Tipulidae (7%) (Table 5.10-17). EPT taxa were sparse and only a few individual Ephemeropterans (*Hexagenia limbata*) and one Trichopteran. Chironomids consisted primarily of *Polypedilum*, *Cryptochironomus*, *Saetheria*, and *Cladotanytarsus*. Bivalves (*Pisidium*/*Sphaerium*) were found at *test* reach SUC-E1 but in very low relative abundances (Table 5.10-17).

The benthic invertebrate community at *test* reach JAR-E1 was dominated by Ephemeroptera (29%), Chironomidae (23%), and Trichoptera (19%), with subdominant taxa consisting of Hydracarina (11%) and Ostracoda (5%) (Table 5.10-17). Mayflies were diverse and dominated by *Acerpenna*, *Baetis*, and *Ephemerella*. Plecoptera (*Acroneuria abnormis* and *Isoperla*), Bivalvia (*Pisidium*/*Sphaerium*), and Gastropoda (*Ferrissia rivularis* and *Gyraulus*) were present in low relative abundances. Trichoptera were well accounted for and primarily comprised of the common forms *Hydrosyche*, *Oecetis*, and *Lepidostoma*. The beetle (*Optioservus*) was found at *test* reach JAR-E1 in fall 2012. Chironomids consisted primarily of *Rheotanytarsus*, *Polypedilum*, *Thienemannimyia* gr., and *Cricotopus* / *Orthocladius*.

Comparison to Published Literature The benthic invertebrate community at *test* reach SAC-D1 contained a benthic fauna that would be considered typical for a sand substrate river. Diversity was high in comparison to *baseline* depositional reaches and the community was almost completely composed of chironomids. The total worm abundance; however, was low (< 6%) indicating good habitat quality.

Similarly to Sawbones Creek (*test* reach SAC-D1), the benthic invertebrate community at *test* reach SUC-D1 contained a benthic fauna typical of a sand substrate river. Diversity was low and the community was comprised almost completely of chironomids, with EPT taxa nearly absent.

The benthic invertebrate community at *test* reach JAR-E1 contained a benthic fauna that reflected good water and sediment quality. The percent of the community as worms was low (<5%) and the percentage of EPT taxa was generally high. The presence of permanent aquatic organisms, including bivalves and gastropods, was indicative of good long-term water quality. The dominant forms of chironomidae present at this reach are known to represent fair to good water quality (Mandeville 2002). For example, the chironomid *Rheotanytarsus* tends to occur in rocky streams with good flow (Merritt and Cummins 1996).

Temporal and Spatial Comparisons Temporal and spatial comparisons were not conducted for *test* reaches SAC-D1, SUC-D1, and JAR-E1 because 2012 was the first year of sampling at these reaches and there were no upstream *baseline* reaches on these watercourses.

Comparison to Regional *Baseline* Conditions Richness and diversity were higher at *test* reach SAC-D1 than the range of variation for regional *baseline* depositional reaches (Figure 5.10-12). The other measurement endpoints were within the range of variation for *baseline* depositional reaches. CA Axis 1 and 2 scores were also within regional *baseline* conditions (Figure 5.10-13).

Values of measurement endpoints for benthic invertebrate communities at *test* reach SUC-D1 were within the range of variation for regional *baseline* depositional rivers (Figure 5.10-12). CA Axis 1 and 2 scores were also within the range of variation for *baseline* erosional reaches (Figure 5.10-13).

Abundance at *test* reach JAR-E1 was higher than the range of variation for *baseline* erosional reaches (Figure 5.10-14). CA Axis 1 and 2 scores were within the range of variation for *baseline* erosional reaches (Figure 5.10-15). The higher abundance was likely related to the location of this reach, downstream of Christina Lake and the relatively heavy growths of periphyton and *Cladophora* on rocks. The high diversity, richness, and percent EPT at *test* reach JAR-E1 indicated good habitat quality. The other measurement endpoints were within the range of variation for *baseline* erosional reaches.

Classification of Results Differences in measurement endpoints at *test* reaches SUC-D1, SAC-D1, and JAR-E1 were classified as **Negligible-Low** because almost all measurement endpoints including CA Axis scores were either within or above regional *baseline* conditions.

Christina Lake

2012 Habitat Conditions Samples were taken at a depth of 1 m at *test* station CHL-1. Water in Christina Lake in fall 2012 was slightly alkaline (pH = 8.4), with moderate conductivity (178 µS/cm) (Table 5.10-16). The substrate was dominated by sand (99%) with minor amounts of silt and clay, and low total organic carbon (< 1%) (Table 5.10-18).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* station CHL-1 in fall 2012 was dominated by chironomids (31%), with subdominant taxa consisting of amphipods (11%) and nematodes (11%), copepods and ostracods (Table 5.10-19). There were at least 27 kinds of chironomids, with *Tanytarsus* and *Cladotanytarsus* the most commonly observed. 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 diverse with at least six kinds (*Lymnaea*, *Physa*, *Gyraulus*, *Helisoma*, *Menetus cooperi*, *Valvata sincera*, *Valvata tricarinata*). At least four kinds of Ephemeroptera were present including the genera *Caenis*, *Baetis* and *Ephemera* and the family Leptophlebiidae. There were seven kinds of Trichoptera, with a dominance of *Oecetis* and *Mystacides*.

Comparison to Published Literature The benthic invertebrate community at *test* station CHL-1 was diverse, and contained several forms typical of sandy-nearshore lake habitat, including two kinds of amphipods, two genera of fingernail clam, and several kinds of snails (Gastropods). The habitat was in good condition, indicated by the presence of several large insects including Ephemeroptera and Trichoptera. The low relative abundances of worms also suggested good habitat quality (Niemi et al. 1990, Pennak 1989).

2012 Results Relative to Historical Conditions 2012 was the first year that Christina Lake was sampled in RAMP; therefore, no historical data were available to compare with results from fall 2012.

Classification of Results The benthic invertebrate community at *test* station CHL-1 in fall 2012 were classified as **Negligible-Low** because the lake contained a diverse benthic fauna including several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies).

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 communities were sampled in fall 2012:

- *test* station CHR-D1 on the Christina River near its mouth (sampled from 2002 to 2004, 2006 to 2007, 2009, and 2012);
- *test* station CHR-D2 on the Christina River upstream of Janvier (sampled from 2002 to 2004, 2006, 2009, and 2012);
- *test* station SAC-D1 on Sawbones Creek (sampling initiated in 2012);
- *test* station SUC-D1 on Sunday Creek (sampling initiated in 2012); and
- *test* station CHL-1 on Christina Lake (sampling initiated in 2012).

Temporal Trends Concentrations of total PAHs and total PAHs normalized to percent total organic carbon showed decreasing trends over time at *test* station CHR-D1. Insufficient data existed to conduct trend analysis for *test* stations CHR-D2 (n=6), SAC-D1 (n=1), SUC-D1 (n=1), and CHL-1 (n=1).

2012 Results Relative to Historical Concentrations Concentrations of **s**ediment quality measurement endpoints in fall 2012 at *test* stations CHR-D1 and CHR-D2 on the Christina River were within previously-measured concentrations, with the exception of the following (Table 5.10-20 and Table 5.10-21):

- sediments at *test* station CHR-D2 had more sand and less silt and clay than previously-measured proportions. Sediment size distribution at *test* station CHR-D1 was mainly within previously-measured ranges, although clay comprised a smaller proportion than previously measured;
- total metals normalized to percent fines exceeded previously-measured maximum concentrations at both stations due to the small percentage of silt and clay in 2012;
- total naphthalene, Fraction 2 hydrocarbons (containing between 10 and 16 carbon atoms) and total PAHs normalized to %TOC were lower than previously-measured minimum concentrations at *test* station CHR-D1.
- total metals, naphthalene, and total parent PAHs were lower than previously-measured minimum concentrations at *test* station CHR-D2. The predicted PAH toxicity was also lower than the previously-measured minimum value; and
- direct tests of sediment toxicity to invertebrates indicated good survival (i.e., ≥90%) of both the amphipod *Hyalella* and the midge *Chironomus* at both *test* stations CHR-D1 and CHR-D2. Ten-day growth of *Chironomus* and 14-day growth of *Hyalella* were within the range of previous-measured values at *test* station CHR-D2. Growth of *Chironomus* was lower than the previously-reported minimum value at *test* station CHR-D1, while *Hyalella* survival rates were higher than previously-reported maximum values. All toxicity measurement endpoints at *test* station CHR-D2 were within previously-reported values, with the exception of *Chironomus* survival, which was higher than previously-reported values.

Sediment quality results could not be compared to previously-measured values at *test* stations SAC-D1, SUC-D1, and CHL-1 because no data exists for these stations prior to 2012.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment quality measurement endpoints in fall 2012 had concentrations that exceeded the relevant CCME sediment quality guidelines at *test* stations CHR-D1, CHR-D2, CHL-1, SUC-D1, and SAC-D1 (Table 5.10-20 to Table 5.10-24).

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, most of the sediment quality measurement endpoints were within regional *baseline* concentrations, with the exception of total PAHs (normalized to %TOC), which was below the 5th percentile of regional *baseline* concentrations at *test* stations SAC-D1, SUC-D1, and CHR-D1 (Figure 5.10-17 to Figure 5.10-20). Concentrations of sediment quality measurement endpoints in Christina Lake (*test* station CHL-1) were not compared to regional *baseline* conditions because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers (Figure 5.10-21).

Sediment Quality Index The SQI values for CHR-D1, CHR-D2, SAC-D1, and SUC-D1 in fall 2012 indicated **Negligible-Low** differences from regional *baseline* conditions (Table 5.10-25). An SQI value was not calculated for Christina Lake because lakes were not compared to regional *baseline* conditions.

Classification of Results In fall 2012, concentrations of sediment quality measurement endpoints at both stations of the Christina River in fall 2012 were generally lower than previously-measured concentrations and a decreasing trend in concentrations of total PAHs was observed over time at *test* station CHR-D1. Concentrations of sediment quality measurement endpoints at stations on tributaries to Christina Lake (i.e., *test* stations SAC-D1 and SUC-D1) were within regional *baseline* conditions. Sediment quality in fall 2012 showed **Negligible-Low** differences at all stations in the Christina River watershed, excluding Christina Lake, from regional *baseline* conditions.

5.10.5 Fish Populations

In 2012, fish populations monitoring in the Christina River watershed consisted of fish assemblage monitoring at reaches of the Christina River as well as tributaries to Christina Lake; a fish assemblage survey on Christina Lake; and a fish tissue survey on Gregoire Lake.

5.10.5.1 Christina River Fish Assemblage Monitoring

Fish assemblages were sampled for the first time in fall 2012 at:

- depositional *test* reach CHR-F1 (this reach is in the same location as benthic invertebrate *test* reach CHR-D1); and
- depositional *test* reach CHR-F2 (this reach is in the same location as benthic invertebrate *test* reach CHR-D2).

2012 Habitat Conditions *Test* reach CHR-F1 was comprised of riffle and run habitat, with a wetted width of 90 m and a bankfull width of 114 m (Table 5.10-26). The substrate was dominated by cobble, with smaller amounts of coarse gravel and sand/silt/clay. Due to high flows, flow measurements could not be taken and only one depth measurement was taken (1 m). Water at *test* reach CHR-F1 was slightly alkaline (pH: 7.89), with moderate conductivity (182 µS/cm), high dissolved oxygen (9.8 mg/L), and a temperature of 10.3˚C (Table 5.10-26). Instream cover was dominated by boulders, overhanging vegetation, and large woody debris (Table 5.10-26).

Test reach CHR-F2 was comprised of run habitat, with wetted and bankfull widths of 50 m (Table 5.10-26). The substrate was dominated by silt/sand/clay. Water at *test* reach CHR-F2 in fall 2012 was an average of 2 m in depth, slightly alkaline (pH: 7.74), with low conductivity (101 µS/cm), high dissolved oxygen (11.1 mg/L), and a temperature of 10.2˚C (Table 5.10-26). Instream cover was dominated by overhanging vegetation, and large woody debris (Table 5.10-26).

Temporal and Spatial Comparisons Sampling was initiated at both *test* reaches of the Christina River in fall 2012; therefore, temporal comparisons could not be conducted. Spatial comparisons were not conducted given that in 2012, there was no upstream *baseline* reach sampled on the Christina River.

The dominant species at *test* reach CHR-F1 was goldeye, which was consistent with data from the Clearwater River fish inventory at the reach near the mouth of the Christina River (*test* reach CR-3A, see Section 5.9), where goldeye were typically observed. The dominant species at *test* reach CHR-F2 was trout-perch (Table 5.10-27). Values of measurement endpoints between the two reaches of the Christina River were generally consistent, with the exception of a much higher diversity at *test* reach CHR-F1 (Table 5.10-28).

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 RAMP. Based on past studies, a total of 21 fish species were recorded in the Christina River; whereas RAMP found only 12 species in 2012, including northern redbelly dace, which had not been previously reported. As noted in Section 5.2, possible reasons for discrepancies in species richness may include differences in sampling gear, as well as the total amount of the watercourse sampled (i.e., RAMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder [2004]). In addition, high flows in fall 2012 prevented effective sampling of the entire water column.

Golder (2004) documented homogeneous habitat, with substrate consisting of gravel, cobble, and boulders, with sand and silt in the pool areas. These conditions were similar to habitat conditions documented in fall 2012 (Table 5.10-26). The Christina River was determined to provide high fisheries potential with excellent refugia and spawning habitat (Golder 2004).

2012 Result Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at both *test* reaches CHR-F1 and CHR-F2 were within the range of regional *baseline* conditions, with the exception of total abundance at *test* reach CHR-F1, which was slightly lower than the 5th percentile of regional *baseline* conditions (Figure 5.10-22).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reaches CHR-F1 and CHR-F2 and regional *baseline* conditions were classified as **Negligible-Low** because only abundance at *test* reach CHR-F1 was below the range of variation for regional *baseline* reaches. The lower catch was likely due to difficulties in effectively sampling the river in high water conditions in fall 2012.

5.10.5.2 Christina Lake Tributaries Fish Assemblage Monitoring

Fish assemblages were sampled for the first time in fall 2012 at the following tributaries to Christina Lake:

- Sawbones Creek (depositional *test* reach SAC-F1);
- Sunday Creek (depositional *test* reach SUC-F1); and
- Jackfish River (erosional *test* reach JAC-F1), which is the outlet channel of Christina Lake.

2012 Habitat Conditions *Test* reach SUC-F1 was comprised of riffle and run habitat, with a wetted width of 9.3 m and a bankfull width of 10.0 m (Table 5.10-29). The substrate was dominated by cobble and sand. Water at *test* reach SUC-F1 in fall 2012 was an average of 0.62 m in depth, fast flowing (average flow: 0.75 m/s), slightly alkaline (pH: 7.86), with moderate conductivity (192 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 9.9°C (Table 5.10-29). Instream cover was dominated by small and large woody debris (Table 5.10-29).

Test reach SAC-F1 was comprised of run habitat with wetted and bankfull widths of 5 m and substrate composed entirely of organic material (Table 5.10-29). Water at *test* reach SAC-F1 in fall 2012 was an average of 1 m in depth, had no measurable flow, was slightly alkaline (pH: 7.53), with low conductivity (80 µS/cm), high dissolved oxygen (8 mg/L), and a temperature of 7.7°C (Table 5.10-29). Instream cover was dominated by macrophytes (Table 5.10-29).

Test reach JAR-F1 was comprised of riffle and run habitat and was near bankfull conditions with a wetted width of 23 m and a bankfull width of 23.5 m (Table 5.10-29). The substrate was dominated by cobble and gravel. Water at *test* reach JAR-F1 was an average of 0.49 m in depth, slow flowing (average flow: 0.25 m/s), alkaline (pH: 7.99), with moderate conductivity (182 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 9.9°C (Table 5.10-29). Instream cover was dominated by filamentous algae (Table 5.10-29).

Temporal and Spatial Comparisons Sampling was initiated at these reaches in fall 2012; therefore, temporal comparisons could not be conducted. Spatial comparisons were not conducted given that in 2012, there were no upstream *baseline* reaches on any of these watercourses that were sampled.

The deep water at *test* reach SAC-F1 prevented effective use of electrofishing and only a single fish (northern pike) was captured, which resulted in low values of almost all measurement endpoints (Table 5.10-27). The ATI value was low at *test* reach SUC-F1 and *test* reach JAR-F1 due largely to the dominance of slimy sculpin and burbot, respectively, in the total catch (Table 5.10-27, Table 5.10-28). Both of these are sensitive species with low tolerance values (Whittier et al. 2007).

Comparison to Published Literature *Baseline* information for these tributaries was limited to records in the FWMIS database (AESRD 2012). Previous studies in Sunday Creek have documented Arctic grayling, brook stickleback, Iowa darter, lake whitefish, northern pike, slimy sculpin, spottail shiner, walleye, and white sucker. Only three of these species were captured at *test* reach SUC-F1 in addition to three species not previously reported in Sunday Creek (longnose sucker, lake chub, and pearl dace). Similar species have been documented in Jackfish River as well including Arctic grayling, burbot, longnose sucker, northern pike, slimy sculpin, walleye, and white sucker. Five of these eight species were captured by RAMP in 2012, as well as longnose dace, which has not been previously reported. These studies used a variety of capture techniques and reach lengths across multiple seasons, which may explain the discrepancies in species composition.

2012 Result Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 for *test* reach SUC-F1 and *test* reach JAR-F1 were within the range of regional *baseline* conditions, with the exception of the ATI value for *test* reach SUC-F1, which was below the 5th percentile of regional *baseline* conditions (Figure 5.10-22 and Figure 5.10-23). Mean values of all measurement endpoints in fall 2012 for *test* reach SAC-F1 were below the 5th percentile of regional *baseline* conditions, with the exception of ATI (Figure 5.10-22).

Classification of Results Regional information for this part of the RAMP FSA was limited; therefore, comparisons to regional *baseline* conditions were made with areas further to the north (i.e., reaches sampled by RAMP to the north of Fort McMurray). Differences in measurement endpoints for fish assemblages between *test* reach SUC-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured and not consistent with a negative change. Differences in measurement endpoints for fish assemblages between *test* reach JAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because all measurement endpoints were within regional *baseline* range of variation. Differences in measurement endpoints for fish assemblages between *test* reach SAC-F1 and regional *baseline* conditions were classified as **Moderate** because three of the four measurement endpoints were below the

5th percentile of regional *baseline* conditions. Given that historical data were limited for Sawbones Creek, a more complete assessment of fish assemblages in this creek will be conducted in fall 2013, once two years of data are acquired.

5.10.5.3 Christina Lake Fish Assemblage Survey

With the addition of new RAMP member companies operating in the Christina Lake area, a fish assemblage study was conducted on Christina Lake in 2012. The program was designed to provide a *baseline* assessment of the fish assemblage in the lake prior to any major development in the area and to supplement existing AESRD fish population information that has been collected in the lake in 2003 and 2008.

2012 Habitat Conditions The shoreline of the lake was predominantly comprised of silt/sand substrate, with small areas of cobble along the north shore of the middle basin near sites E07 and S13 (Table 5.10-30). Some areas of the littoral zone were not well vegetated, possibly due to wind and wave action. Depth profiles of water quality in Christina Lake (temperature, dissolved oxygen, pH, and conductivity) in summer 2012 showed a stratification of water temperature and dissolved oxygen at approximately 7 m (Figure 5.10-24).

Total Catch and Species Composition Each of the three fishing methods targeted different areas of the lake and different size classes of fish (i.e., boat electrofishing and hoopnets target larger size classes and seine nets target smaller size classes); therefore, comparisons of CPUE among methods was not practical. Fishing using a boat electrofisher had the highest capture efficiency with a total of 424 fish from seven species (Table 5.10-31). The dominant species was yellow perch. Northern pike and walleye were additional sportfish that were captured (Figure 5.10-25). A total of 12 large-bodied fish were captured using hoopnets in the near-shore area, with a dominance of northern pike (Table 5.10-31). A total of 348 fish from six species were captured using seine netting along the shoreline, with ninespine stickleback as the dominant species and subdominant species consisting of trout-perch and Iowa darter (Table 5.10-31). All large-bodied fish species captured by seining were juveniles (Figure 5.10-25).

Temporal Comparisons 2012 was the first year that fish monitoring was undertaken in Christina Lake by RAMP. However, fish surveys (i.e., the Fall Walleye Index Netting survey) have been conducted by AESRD in 2003 and 2008 to determine the size of sportfish populations in the lake. Fish sampling by AESRD was conducted using index nets (multi-panel gill nets), targeting deeper areas in the middle of the lake; therefore, the results were not comparable to this study; however, data from all surveys provide a more complete assessment of fish assemblages in the lake.

A total of 784 fish from nine species were captured using the three fishing methods during the summer 2012 survey. The FWMIS database had eleven fish species previously documented in Christina Lake (AESRD 2012). Two species captured during the RAMP 2012 survey had not been previously documented in either Christina Lake or its tributaries, including the Iowa darter (*Etheostoma exile*) and northern redbelly dace (*Phoxinus eos*). There was limited existing information on small-bodied fish species in Christina Lake given that previous surveys did not target smaller size classes of fish; however, finescale dace (*Phoxinus neogaeus*), a close relative of the northern redbelly dace, was documented in tributaries to the lake, so it is not unexpected that northern redbelly dace were found in the lake. Although the Iowa darter is a rare species in the oil sands region, the documented distribution of Iowa darter overlaps Christina Lake (Scott and Crossman 1973). Both the Iowa darter and ninespine stickleback are small-bodied species that would not be captured by most fishing methods previously used for fish surveys in

Christina Lake. The 8 mm mesh beach seine used in this study was able to capture very small fish that easily evade larger nets and electrofishing gear.

Summary A total of 784 fish from nine species were captured using the three fishing methods during the summer 2012 survey. Two species captured during the RAMP 2012 survey had not been previously documented in either Christina Lake or its tributaries, including the Iowa darter (*Etheostoma exile*) and northern redbelly dace (*Phoxinus eos*). Fishing locations were randomly selected throughout the lake for the 2012 survey. However, the lake has two main basins separated by a shallower narrow channel, with a smaller basin at the north end of the east basin. A comparison of CPUE by boat electrofishing indicated much higher captured success in the east basin of the lake compared to the west basin. If a survey was conducted again, it is recommended that the two main basins be considered separately when selecting sites in order to examine for any potential differences between basins.

5.10.5.4 Gregoire Lake Fish Tissue

A fish tissue program to assess mercury in sportfish species (northern pike and walleye) was conducted in fall 2012 in Gregoire Lake as part of AESRD's Fall Walleye Index Netting (FWIN) Program. Gregoire Lake is located south of Fort McMurray in the Christina River watershed (Figure 5.10-1). This lake is in close proximity to oil sands development, the town of Fort McMurray, and adjacent to an Aboriginal community (IR176) and used for recreational and subsistence fishing. The sportfish fishery in Gregoire Lake is currently a catch and release fishery given the high historical fishing pressure on walleye and northern pike populations in the lake. Gregoire Lake is 2,580 ha in size and approximately 7 m deep in the deepest portion of the lake. Fish tissue samples have been previously collected and analyzed at this lake in 2002 and 2007 as part of the annual RAMP Regional Lakes Fish Tissue program (RAMP 2003, 2008).

This section includes results from 2012 for Gregoire Lake as well as comparisons to results from surveys conducted in 2002 and 2007; results from other lakes/rivers sampled by RAMP and AESRD in the RAMP RSA from 2002 to 2010; and results from other studies in Alberta (1975 to 2010).

Whole-Organism Metrics

In 2012, a total of 11 northern pike (five female, five male, and one unsexed) and 15 walleye (five female, five male, and five unsexed) from Gregoire Lake were sampled for fish tissue (muscle) analysis. The fork lengths of fish sampled were as follows (Table 5.10-32):

1. Northern pike – fork length ranged from a 261 mm mature one year old male to a 485 mm mature five year old female. On average, male northern pike (average fork length: 405 mm, average age: 4 years) were smaller than female fish (average fork length: 414 mm, average age: 3 years). The average length of all sampled fish was 410 mm and the average age was three years.
2. Walleye – fork length ranged from a 229 mm un-aged, unsexed fish to a 495 mm mature 11 year old female. On average, female walleye (average fork length: 467 mm, average age: 9 years) were larger than male fish (average fork length: 364 mm, average age: 6 years). The average length of all sampled fish was 416 mm and the average age was seven years.

In previous years, samples were also collected from lake whitefish; however, very few were captured and due to requirements by AESRD, were not provided to RAMP.

Mercury Concentrations

Concentrations of mercury in muscle of individual northern pike and walleye collected from Gregoire Lake in 2012 are presented in Table 5.10-32:

1. The mean mercury concentration in northern pike was 0.097 mg/kg and ranged from 0.038 mg/kg in a 261 mm mature male to 0.145 mg/kg in a 423 mm mature male.

2. The mean mercury concentration in walleye was 0.132 mg/kg and ranged from 0.037 mg/kg in 429 mm unsexed fish to 0.184 mg/kg in a 495 mm mature female.

Regressions between mercury concentration ($\log_{10}$-transformed) and fork length were statistically significant for northern pike ($p < 0.01$; $R^2 = 0.82$) and for walleye ($p < 0.01$, $R^2 = 0.66$), with positive slopes indicating that longer, or larger fish have greater concentrations of mercury than shorter, or smaller fish.

Potential Risks of Mercury in Fish Tissue to Human Health

Northern Pike Mercury concentrations in all northern pike (Figure 5.10-26) and walleye (Figure 5.10-27) captured from Gregoire Lake were below the Health Canada guideline for subsistence fishers (0.2 mg/kg) and; therefore, below the guideline for general consumers (0.5 mg/kg). The mercury concentrations for 2012 were lower than recorded in 2002 and 2007 at Gregoire Lake (Figure 5.10-26).

Temporal and Spatial Comparisons

Gregoire Lake Northern pike and walleye captured in 2007 were generally larger than those caught in 2002 and 2012, while the fish captured in 2012 were smaller than those captured in both previous years. An analysis of covariance (ANCOVA) on northern pike data indicated that differences in mercury concentrations in fish tissue relative to length were not statistically significant across years for northern pike ($p = 0.194$) or walleye ($p=0.063$). (Figure 5.10-28 and Figure 5.10-29).

Lakes in the RAMP RSA Length-normalized concentrations of mercury in northern pike and walleye sampled from lakes by RAMP and AESRD between 2002 and 2012 as shown in Figure 5.10-30 and Figure 5.10-31. Most of the sampled lakes are in the southern portion (i.e., Gregoire Lake, Christina Lake, and Winefred Lake) and northern portion (i.e., Jackson, Net, and Brutus lakes) of the RAMP RSA while some are on the western border of the RAMP RSA (Big Island and Gardiner lakes) and Lake Claire is in the Athabasca River Delta (RAMP 2009b).

Generally, mercury concentrations in walleye from Net Lake (2010) were higher than all other sampled lakes (RAMP 2011), with lower concentrations of mercury in fish from Gregoire Lake in 2012 than most other lakes across years, and lower than what has been observed in Gregoire Lake in 2002 and 2007. Fish captured from Gregoire Lake were generally younger than other lakes and fish from Net Lake in 2010 were generally older than fish from other lakes, resulting in higher mercury concentrations given the longer period for mercury to bio-accumulate in those fish (Figure 5.10-32 and Figure 5.10-33).

Spatial comparisons using an ANCOVA for each species indicated that there were significant differences in mercury concentrations in fish across lakes ($p<0.01$ for northern pike and walleye). However, there are several factors that could influence the concentration of mercury in fish, including the age and size of fish captured as well as the size, depth, temperature, and productivity of a waterbody. The characteristics of shallow, warm, and productive lakes facilitate mercury transformations from its inorganic to organic form, making the fish in these lakes more susceptible to higher concentrations of mercury in their tissues than fish occurring in large, deep, and cold lakes (Evans and Talbot 2012). The amount of vegetation or wetlands near the waterbody, the quality of the water (particularly the concentration of mercury), DOC and pH, as well as the amount of mercury found in the sediment can also influence mercury methylation rates, affecting mercury concentrations in fish (Beckvar et al. 1996, Heyes et al. 2000).

Wetlands are an important source of methylmercury production in boreal ecosystems (St. Louis et al. 1994, Grigal 2003). Prior to any development, wetlands are dewatered during the dewatering phase, water from wetlands drain into groundwater or nearby surface water sources. Studies in experimental lakes in Ontario have indicated that methylmercury inputs into lakes were higher from wetland areas than precipitation (i.e., atmospheric deposition) (St. Louis et al. 1994). In comparison to surface water, wetlands capture and hold the majority of atmospherically deposited mercury (Heyes et al. 2000). Removal of vegetation cover in preparation for development of focal projects could lead to increased mercury concentrations in water from eroded sediments or dissolved organic carbon (DOC) entering surface waters (Grigal 2003).

Information for these lakes, including water quality and physical characteristics, were not available and; therefore, could not be included in the analyses. However, age of fish in relation to mercury concentration was assessed to determine that the higher concentrations of mercury in lakes to the north were generally from older individuals being sampled.

Lakes in Alberta To provide a regional context, mercury concentrations from fish captured from Gregoire Lake in 2012 were compared to concentrations of mercury in fish from lakes in northern Alberta (AOSERP 1977, Grey *et al.* 1995, NRBS 1996, RAMP 2003, RAMP 2004, RAMP 2008, RAMP 2009a, RAMP 2010).

Mean mercury concentrations in northern pike were standardized to mean fork length of fish from all samples (593 mm) to allow for spatial comparisons. Standardized mean mercury levels ranged from 0.052 mg/kg (Reita Lake in 1981) to 1.83 mg/kg (Sturgeon Lake in 2003) (Figure 5.10-34). In waterbodies sampled for northern pike, 49% of length-standardized mean mercury concentrations were below Health Canada subsistence fisher guidelines (0.2 mg/kg), 42% were above subsistence guidelines and below general consumer guidelines (0.5 mg/kg), and 9% were above general consumer guidelines (Figure 5.10-34). The lakes with mercury concentrations exceeding Health Canada general consumer guideline, were primarily located outside and to the south of the RAMP FSA with the exception of Sturgeon and Net lakes, where exceedances were also observed in years prior to focal project development (1974 to 1981) (Figure 5.10-34). Mercury concentrations exceeded Health Canada general consumer guidelines in northern pike in Sturgeon Lake, in 2003, which is located approximately 400 km southwest of Fort McMurray, and in Net Lake, in 2010, which is located approximately 150 km north of Fort McMurray.

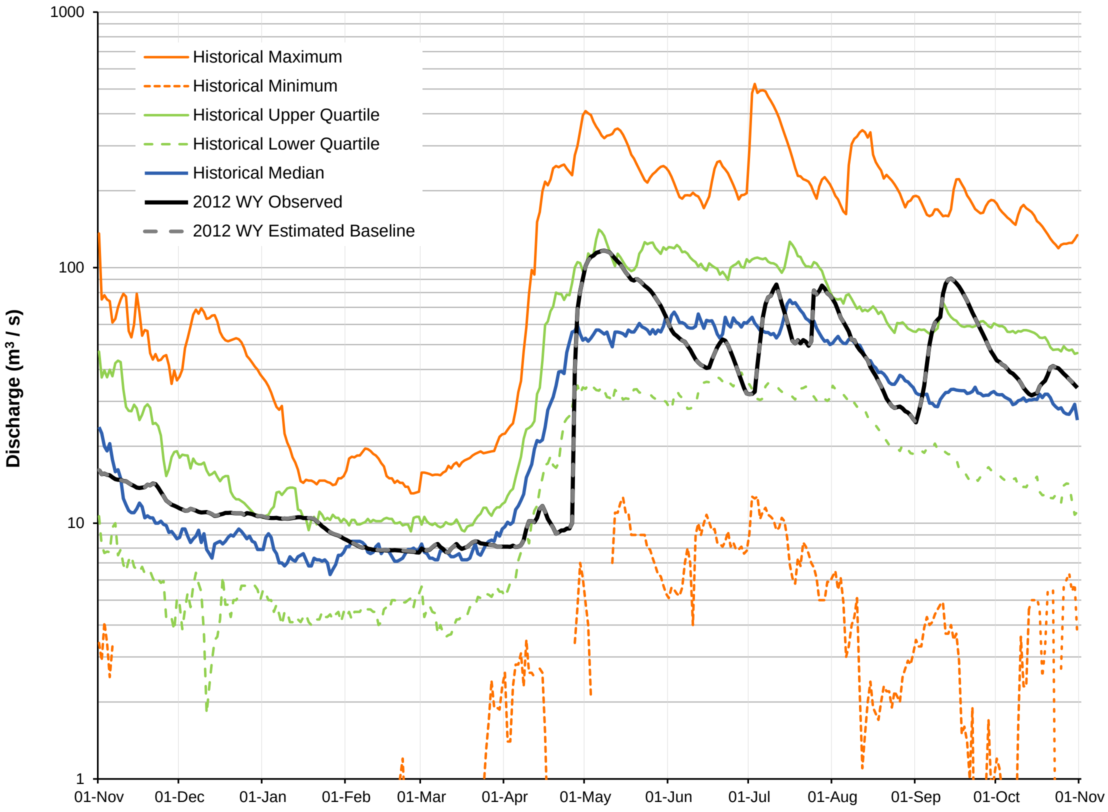
Mean mercury concentrations in walleye were standardized to mean fork length across all samples (441 mm) to allow for spatial comparisons. Standardized mean mercury concentrations ranged from 0.018 mg/kg (Graham Lake 1981a) to 0.83 mg/kg (Ironwood Lake 1982a) (Figure 5.10-35). In waterbodies sampled for walleye, 47% of standardized mean mercury concentrations were below the Health Canada subsistence fisher guideline (0.2 mg/kg), 36% were above the subsistence fisher guideline but below the general consumer guideline (0.5 mg/kg), and 16% exceeded the Health Canada general consumer guideline (Figure 5.10-35). The lakes for which standardized mean mercury concentration exceeded the Health Canada general consumer guideline were primarily located outside and to the south of the RAMP FSA and were in exceedance during years prior to focal project development (1973 to 1982), with the exception of Net Lake, sampled in 2010. An exceedance of the Health Canada general consumer guideline in walleye was measured in Lake Athabasca in 1977, which is located within the RAMP RSA and downstream of al oil sands development. Since then; however, the standardized mean mercury concentration in walleye in Lake Athabasca has been below the Health Canada general consumer guideline (Figure 5.10-35).

Although oil sands development could lead to increased availability of methylmercury to fish in the lakes and rivers in the region, RAMP has not observed an increase in mercury concentrations in fish from lakes or rivers in the vicinity of oil sands development. There has been published literature outlining the debate of whether mercury concentrations are indeed increasing or decreasing due to the expansion of the oil sands industry. A recent article by Timoney and Lee (2009) showed mercury concentrations to be increasing in walleye in the Athabasca River as a result of the expanding oil sands operations. However, a more comprehensive study (Evans and Talbot 2012) found that Timoney and Lee (2009) did not account for the increase in fish weight over the study period, and that sampling techniques over the years were sufficiently variable as to distort trends in mercury concentrations. Evans and Talbot (2012) found a significant decrease in mercury concentrations in walleye based on analyses conducted on samples from 1984 to 2011. Overall, trends in mercury concentrations in fish tissue over time may be due to a number of influential factors, including levels of mercury emissions, rates of deposition, and exposure, as well as general habitat conditions in lakes and variations in sampling design and objectives (Evans and Talbot 2012).

Classification of Results

Mercury concentrations in northern pike and walleye from Gregoire Lake in 2012 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in fish from Gregoire Lake were near the lower end of the historical range of mercury concentrations in fish sampled from other regional lakes.

Figure 5.10-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the mouth of the Christina River in the 2012 WY, compared to historical values.



Note: The observed 2012 WY hydrograph is based on Christina River near the mouth, Station S47, 2012 provisional data. The upstream drainage area is 13,038 km². Historical data for the mouth of the Christina River from 1967 to 2011 are estimated by calculating the difference between the measured flow at Clearwater River above Christina River, WSC Station 07CD005 and Clearwater River above Draper, WSC Station 07CD001. The historical data calculated are calculated based on 43 years of record (1967 to 2011) from March to October, and 21 years of record for other months (1976 to 1996).

Note: The estimated *baseline* hydrograph from focal projects in the Christina River watershed is shown in the figure; differences between this and the estimated *baseline* hydrograph from focal project plus other oil sands developments in the Christina River watershed are negligible.

Table 5.10-2 Estimated water balance at the mouth of the Christina River, 2012 WY.

Component	Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus Other Oil Sands Developments	
Observed *test* hydrograph (total discharge)	**1,100.39**	**1,100.39**	**Observed discharge at Christina River near the mouth, RAMP S47**
Closed-circuited area water loss from the calculated *test* hydrograph	-0.66	-0.66	Estimated 7.9 km^2 of the Christina River watershed is closed-circuited from focal projects or from focal projects plus other oil sands developments as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+1.10	+1.12	Estimated 65.1 km^2 and 66.6 km^2 of the Christina River watershed with land change from focal projects and from focal projects plus other oil sands developments as of 2012, respectively, that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Christina River watershed from projects	-0.22	-0.22	Approximately 0.218 million m^3 of water withdrawn by Nexen, ConocoPhillips, MEG, Canadian Natural, and Statoil from various water sources
Water releases into the Christina River watershed from projects	0	0	None reported
Diversions into or out of the watershed	0	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	0	No focal projects or other oil sands developments on tributaries of Christina River not accounted for by figures contained in this table.
Estimated *baseline* hydrograph (total discharge)	**1,100.17**	**1,100.14**	**Estimated *baseline* discharge at Christina River near the mouth, RAMP Station S47**
Incremental flow (change in total annual discharge)	+0.22	+0.24	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**+0.02%**	**+0.02%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Based on Christina River near the mouth, RAMP Station S47, 2012 WY provisional data.

Table 5.10-3 Calculated change in hydrologic measurement endpoints for the mouth of the Christina River, 2012 WY.

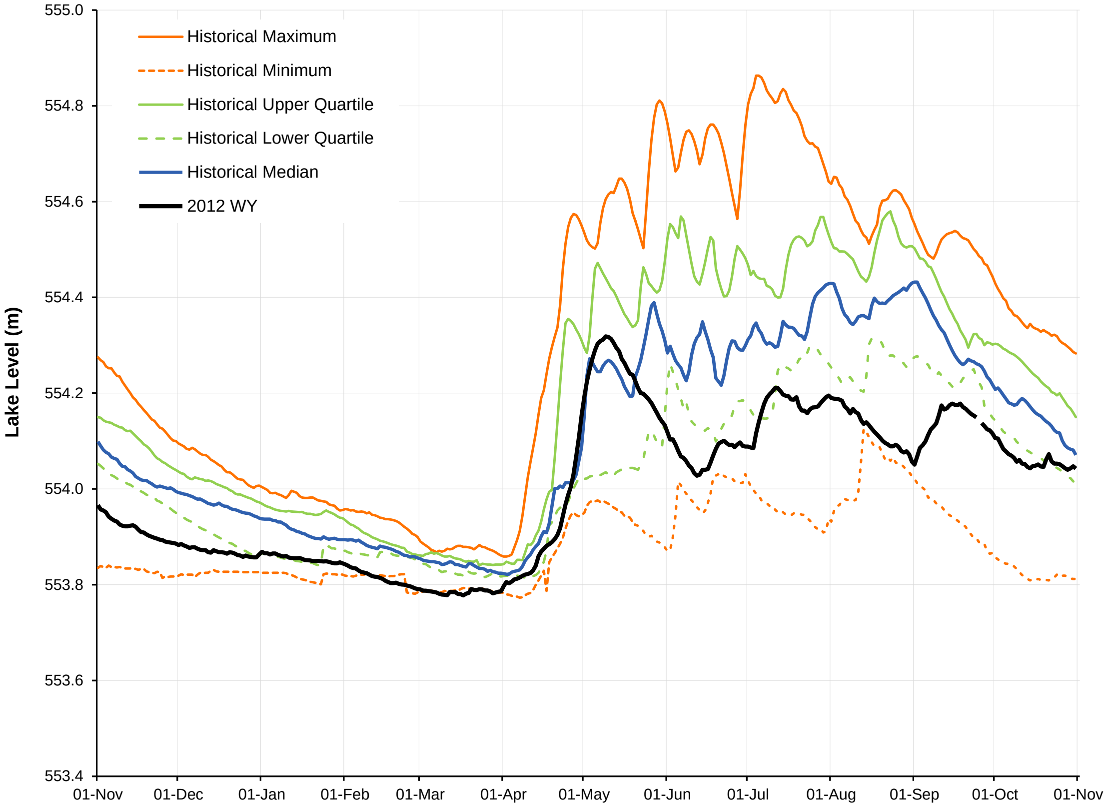
Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	57.88	57.91	+0.02%
Mean winter discharge	10.25	10.23	+0.04%
Annual maximum daily discharge	116.61	116.65	-0.11%
Open-water season minimum daily discharge	24.82	24.83	+0.03%

Note: Based on Christina River near the mouth, RAMP Station S47, 2012 WY provisional data.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to two decimal places.

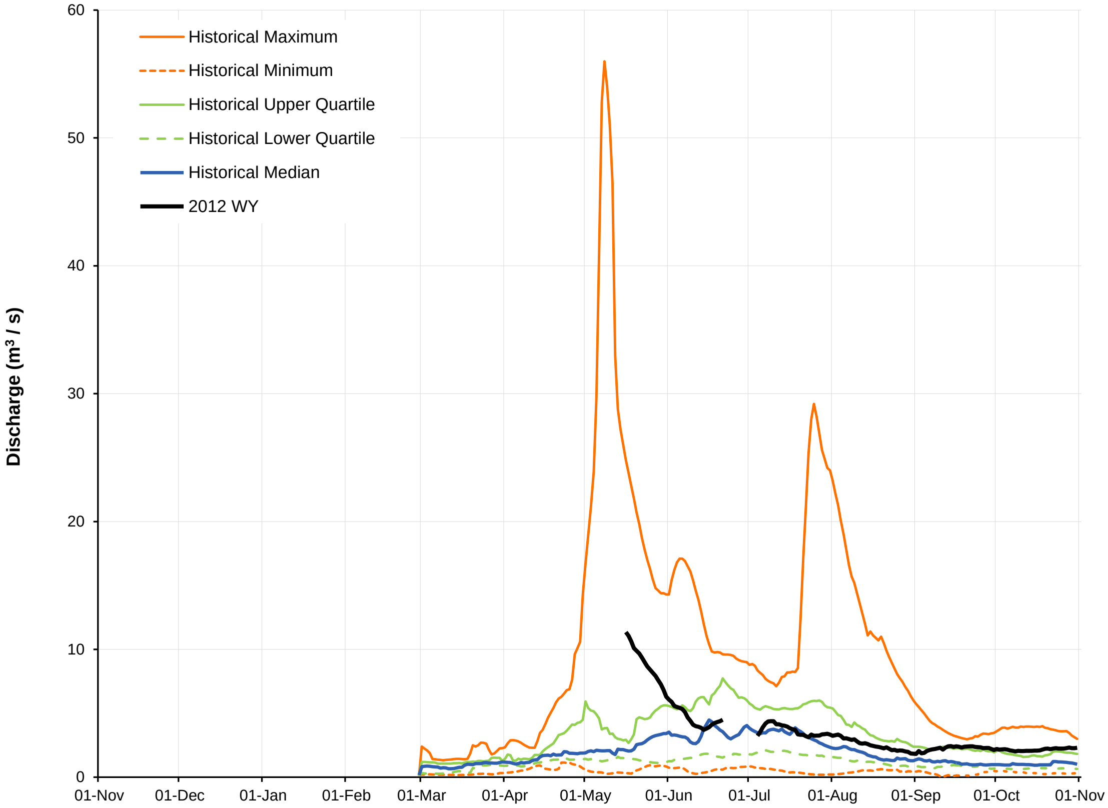
Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.10-4 **Christina Lake near Winfred Lake: 2012 hydrograph and historical context.**



Note: Based on provisional 2012 WY data recorded at Christina Lake near Winfred Lake WSC Station 07CE906. Historical values were calculated for the period 2001 to 2011.

Figure 5.10-5 Jackfish River below Christina Lake: 2012 hydrograph and historical context.



Note: Based on provisional 2012 WY data recorded at Jackfish River below Christina Lake RAMP Station S56. Historical values were calculated for the period 1982 to 1995 from WSC Station 07CE005.

Table 5.10-4 Concentrations of water quality measurement endpoints, mouth of Christina River (*test* station CHR-1), fall 2012.

Measurement Endpoint	**Units**	**Guideline**[a]	**September 2012**	**1997-2011 (fall data only)**			
			Value	**n**	**Min**	**Median**	**Max**
Physical variables							
pH	pH units	6.5-9.0	8.1	10	8.1	8.3	8.4
Total suspended solids	mg/L	-	123	10	<3	22	76
Conductivity	µS/cm	-	282	10	210	293	375
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.036	10	0.017	0.023	**0.054**
Total nitrogen	mg/L	1	0.951	10	0.60	**1.05**	**1.80**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	17.7	10	14.0	19.9	25.3
Ions							
Sodium	mg/L	-	18.8	10	12.8	25.5	34.0
Calcium	mg/L	-	26.5	10	22.0	26.7	30.2
Magnesium	mg/L	-	7.68	10	6.96	8.20	9.42
Chloride	mg/L	120	16.1	10	9.5	26.0	41.0
Sulphate	mg/L	270	6.86	10	2.20	6.71	8.49
Total dissolved solids	mg/L	-	199	10	140	190	250
Total alkalinity	mg/L	-	112	10	86.4	107	120
Selected metals							
Total aluminum	mg/L	0.1	**2.46**	10	**0.24**	**0.60**	**3.23**
Dissolved aluminum	mg/L	0.1	0.027	10	0.007	0.010	0.029
Total arsenic	mg/L	0.005	0.0018	10	0.0007	0.0011	0.0017
Total boron	mg/L	1.2	0.064	10	0.027	0.052	0.074
Total molybdenum	mg/L	0.073	0.00038	10	0.00016	0.00038	0.00040
Total mercury (ultra-trace)	ng/L	5, 13	**6.0**	9	<1.2	<1.2	**5.1**
Total strontium	mg/L	-	0.11	10	0.08	0.13	0.15
Total hydrocarbons							
BTEX	mg/L	-	<0.10	1	-	<0.10	-
Fraction 1 (C6-C10)	mg/L	-	<0.10	1	-	<0.10	-
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	-	0.03	1	-	<0.02	-
Oilsands Extractable	mg/L	-	0.37	1	-	1.10	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14	-
Retene	ng/L	-	3.44	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	52.14	1	-	6.01	-
Total PAHs	ng/L	-	316.3	1	-	154.6	-
Total Parent PAHs	ng/L	-	20.38	1	-	19.45	-
Total Alkylated PAHs	ng/L	-	295.9	1	-	135.2	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.75**	10	0.26	**0.37**	**0.96**
Total iron	mg/L	0.3	**3.81**	10	**0.78**	**1.35**	**3.10**
Total phenols	mg/L	0.004	**0.006**	10	<0.001	**0.0047**	**0.014**
Total phosphorus	mg/L	0.05	**0.149**	10	0.049	**0.063**	**0.131**
Total chromium	mg/L	0.001	**0.0037**	10	0.0005	**0.0011**	**0.0037**

[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, upper Christina River (*test* station CHR-2), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	10	8.0	8.2	8.35
Total suspended solids	mg/L	-	25	10	<3	8	30
Conductivity	µS/cm	-	125	10	152	208	268
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.02	10	0.02	0.03	0.05
Total nitrogen	mg/L	1	0.92	10	0.60	0.85	**1.40**
Nitrate+nitrite	mg/L	1.3	<0.071	10	<0.071	<0.1	<0.1
Dissolved organic carbon	mg/L	-	29.2	10	13.0	18.0	29.2
Ions							
Sodium	mg/L	-	2.9	10	4.8	6.5	10.0
Calcium	mg/L	-	16.3	10	20.8	27.95	35.1
Magnesium	mg/L	-	4.6	10	6.2	8.2	10.6
Chloride	mg/L	120	<0.5	10	<0.5	1.5	2
Sulphate	mg/L	195	<0.5	10	2.4	5.1	9.6
Total dissolved solids	mg/L	-	120	10	130	146	240
Total alkalinity	mg/L		59.3	10	75	104	138
Selected metals							
Total aluminum	mg/L	0.1	**0.51**	9	0.05	**0.19**	**0.47**
Dissolved aluminum	mg/L	0.1	0.015	9	0.003	0.008	0.019
Total arsenic	mg/L	0.005	0.0013	9	0.0007	0.0010	0.0016
Total boron	mg/L	1.2	0.03	9	0.02	0.03	0.05
Total molybdenum	mg/L	0.073	0.0003	9	0.0003	0.0004	0.0007
Total mercury (ultra-trace)	ng/L	5, 13	4.90	9	<0.6	<1.2	2.7
Total strontium	mg/L	-	0.06	9	0.08	0.10	0.16
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	-	0.06	1	-	0.25	-
Oilsands Extractable	mg/L	-	0.40	1	-	0.82	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.1	-
Retene	ng/L	-	3.8	1	-	<2.1	-
Total dibenzothiophenes	ng/L	-	35.4	1	-	5.84	-
Total PAHs	ng/L	-	210.6	1	-	153.7	-
Total Parent PAHs	ng/L	-	18.5	1	-	21.8	-
Total Alkylated PAHs	ng/L	-	192.2	1	-	131.9	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**2.64**	9	**0.683**	**1.19**	**2.62**
Dissolved thallium	mg/L	0.0008	**0.00199**	9	0.000002	<0.000003	<0.000100
Dissolved zinc	mg/L	0.03	**3.32**	9	<0.0002	0.0013	0.0037
Total zinc	mg/L	0.03	**628**	9	0.0007	0.0019	0.0046
Total phenols	mg/L	0.004	**0.0106**	10	<0.0010	**0.0085**	**0.0190**
sulphide	mg/L	0.002	**0.0059**	10	<0.0020	**0.0048**	**0.0400**
Total phosphorus	mg/L	0.05	**0.1280**	10	0.0397	0.0635	0.1080
Total cadmium	mg/L	0.00010	**0.00132**	9	<0.000006	<0.00001	<0.00010
Total chromium	mg/L	0.001	**0.0021**	9	0.0002	0.0004	0.0008
Total copper	mg/L	0.002	**0.0243**	9	0.0001	0.0004	**0.0043**
Total lead	mg/L	0.0016	**0.00964**	9	0.00007	0.00011	0.00032
Total Silver	mg/L	0.0001	**0.000342**	9	<0.000005	<0.000005	<0.00001
Total thallium	mg/L	0.0008	**0.00440**	9	<0.000003	<0.000006	<0.0001

[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 5.10-6 Concentrations of water quality measurement endpoints, Sawbones Creek (*test* station SAC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012
			Value
Physical variables			
pH	pH units	6.5-9.0	7.7
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	95
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.024
Total nitrogen*	mg/L	1	0.701
Nitrate+nitrite	mg/L	1.3	<0.071
Dissolved organic carbon	mg/L	-	20
Ions			
Sodium	mg/L	-	2.50
Calcium	mg/L	-	12.1
Magnesium	mg/L	-	3.72
Chloride	mg/L	120	0.5
Sulphate	mg/L	195	0.5
Total dissolved solids	mg/L	-	101
Total alkalinity	mg/L		48
Selected metals			
Total aluminum	mg/L	0.1	0.046
Dissolved aluminum	mg/L	0.1	0.006
Total arsenic	mg/L	0.005	0.0007
Total boron	mg/L	1.2	0.019
Total molybdenum	mg/L	0.073	0.0001
Total mercury (ultra-trace)	ng/L	5, 13	1.1
Total strontium	mg/L	-	0.037
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	-	0.05
Oilsands Extractable	mg/L	-	0.30
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<8.756
Retene	ng/L	-	<0.509
Total dibenzothiophenes	ng/L	-	35.30
Total PAHs	ng/L	-	203.4
Total Parent PAHs	ng/L	-	16.42
Total Alkylated PAHs	ng/L	-	187.0
Other variables that exceeded CCME/AESRD guidelines in fall 2012			
Total phenols	mg/L	0.004	**0.009**
Total iron	mg/L	0.3	**0.4**

[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, Sunday Creek (*test* station SUC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012
			Value
Physical variables			
pH	pH units	6.5-9.0	8.2
Total suspended solids	mg/L	-	8
Conductivity	µS/cm	-	267
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.019
Total nitrogen*	mg/L	1	0.571
Nitrate+nitrite	mg/L	1.3	<0.071
Dissolved organic carbon	mg/L	-	14
Ions			
Sodium	mg/L	-	6.8
Calcium	mg/L	-	33.4
Magnesium	mg/L	-	10.4
Chloride	mg/L	120	3.86
Sulphate	mg/L	270	1.12
Total dissolved solids	mg/L	-	157
Total alkalinity	mg/L		135
Selected metals			
Total aluminum	mg/L	0.1	**0.239**
Dissolved aluminum	mg/L	0.1	0.004
Total arsenic	mg/L	0.005	0.0009
Total boron	mg/L	1.2	0.027
Total molybdenum	mg/L	0.073	0.0003
Total mercury (ultra-trace)	ng/L	5, 13	1.9
Total strontium	mg/L	-	0.085
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	-	0.28
Oilsands Extractable	mg/L	-	0.65
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<8.756
Retene	ng/L	-	2.07
Total dibenzothiophenes	ng/L	-	35.30
Total PAHs	ng/L	-	205.8
Total Parent PAHs	ng/L	-	16.55
Total Alkylated PAHs	ng/L	-	189.3
Other variables that exceeded CCME/AESRD guidelines in fall 2012			
Total phenols	mg/L	0.004	**0.006**
Total phosphorus	mg/L	0.05	**0.053**
Total iron	mg/L	0.3	**0.949**

[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, Jackfish River (*test* station JAR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012
			Value
Physical variables			
pH	pH units	6.5-9.0	8.0
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	207
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.010
Total nitrogen*	mg/L	1	0.501
Nitrate+nitrite	mg/L	1.3	<0.071
Dissolved organic carbon	mg/L	-	16
Ions			
Sodium	mg/L	-	5.5
Calcium	mg/L	-	24.5
Magnesium	mg/L	-	7.29
Chloride	mg/L	120	1.05
Sulphate	mg/L	270	1.01
Total dissolved solids	mg/L	-	129
Total alkalinity	mg/L		107
Selected metals			
Total aluminum	mg/L	0.1	0.008
Dissolved aluminum	mg/L	0.1	0.001
Total arsenic	mg/L	0.005	0.0005
Total boron	mg/L	1.2	0.03
Total molybdenum	mg/L	0.073	0.0002
Total mercury (ultra-trace)	ng/L	5, 13	0.6
Total strontium	mg/L	-	0.075
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	-	0.04
Oilsands Extractable	mg/L	-	0.36
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<8.76
Retene	ng/L	-	0.916
Total dibenzothiophenes	ng/L	-	35.30
Total PAHs	ng/L	-	205.6
Total Parent PAHs	ng/L	-	16.59
Total Alkylated PAHs	ng/L	-	189.0

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-9 Concentrations of water quality measurement endpoints, Christina Lake (*test* station CHL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012
			Value
Physical variables			
pH	pH units	6.5-9.0	8.1
Total suspended solids	mg/L	-	15
Conductivity	µS/cm	-	206
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.004
Total nitrogen*	mg/L	1	0.631
Nitrate+nitrite	mg/L	1.3	<0.071
Dissolved organic carbon	mg/L	-	13
Ions			
Sodium	mg/L	-	6.1
Calcium	mg/L	-	23.6
Magnesium	mg/L	-	7.21
Chloride	mg/L	120	1.04
Sulphate	mg/L	270	1.01
Total dissolved solids	mg/L	-	141
Total alkalinity	mg/L		105
Selected metals			
Total aluminum	mg/L	0.1	0.0298
Dissolved aluminum	mg/L	0.1	<0.001
Total arsenic	mg/L	0.005	0.0005
Total boron	mg/L	1.2	0.0262
Total molybdenum	mg/L	0.073	0.0002
Total mercury (ultra-trace)	ng/L	5, 13	1.2
Total strontium	mg/L	-	0.074
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	-	0.11
Oilsands Extractable	mg/L	-	0.12
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<8.76
Retene	ng/L	-	<0.509
Total dibenzothiophenes	ng/L	-	35.30
Total PAHs	ng/L	-	225.2
Total Parent PAHs	ng/L	-	23.74
Total Alkylated PAHs	ng/L	-	201.4
Other variables that exceeded CCME/AESRD guidelines in fall 2012			
Total phenols	mg/L	0.004	**0.0052**

[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 Christina River watershed.

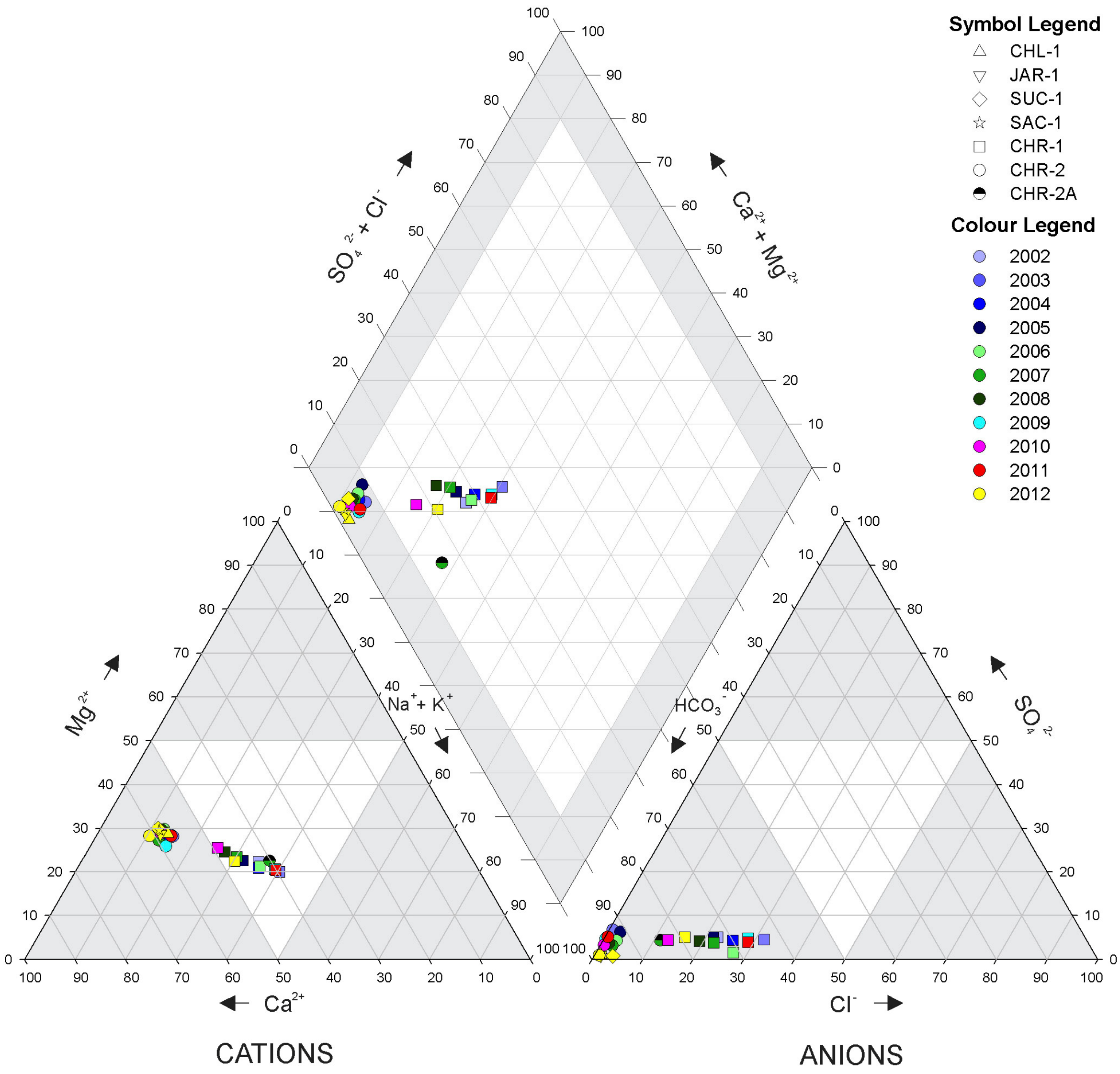


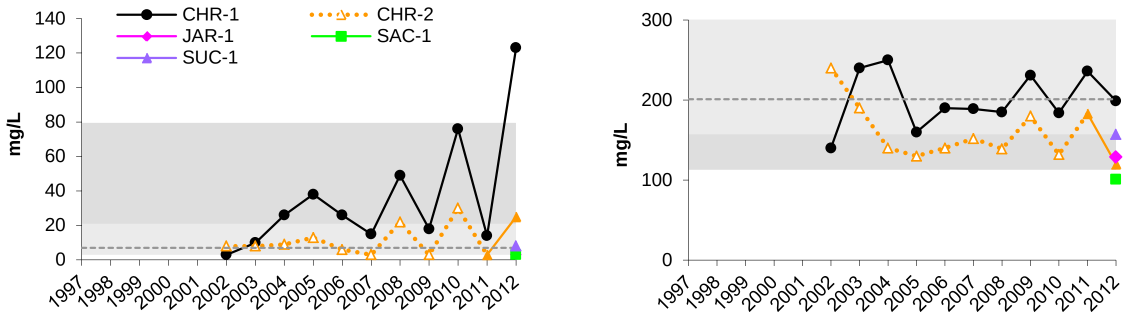
Table 5.10-10 Water quality guideline exceedances, Christina River watershed, 2012.

Variable	Units	Guideline[a]	CHR-1	CHR-2	CHL-1	JAR-1	SAC-1	SUC-1
Spring								
Dissolved iron	mg/L	0.3	ns	ns	-	-	-	-
Sulphide	mg/L	0.002	ns	ns	-	-	0.0031	-
Total aluminum	mg/L	0.1	ns	ns	-	-	-	-
Total iron	mg/L	0.3	ns	ns	-	-	-	0.515
Total phenols	mg/L	0.004	ns	ns	0.0077	0.0119	0.0078	0.0043
Total phosphorus	mg/L	0.05	ns	ns	-	-	-	-
Summer								
Dissolved iron	mg/L	0.3	ns	ns	-	-	-	-
Dissolved phosphorous	mg/L	0.05	ns	ns	-	-	-	-
Sulphide	mg/L	0.002	ns	ns	-	-	-	-
Total aluminum	mg/L	0.1	ns	ns	-	-	-	0.159
Total chromium	mg/L	0.001	ns	ns	-	-	-	-
Total iron	mg/L	0.3	ns	ns	-	-	0.56	0.53
Total phenols	mg/L	0.004	ns	ns	0.0051	0.0063	0.0079	0.0045
Total phosphorus	mg/L	0.05	ns	ns	-	-	-	-
Fall								
Dissolved aluminum	mg/L	0.1	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	0.753	-	-	-	-	-
Dissolved phosphorous	mg/L	0.05	-	-	-	-	-	-
Dissolved thallium	mg/L	0.0008	-	0.00199	-	-	-	-
Dissolved zinc	mg/L	0.03	-	3.32	-	-	-	-
Mercury (ultra-trace)	mg/L	5	6	-	-	-	-	-
Sulphide	mg/L	0.002	-	0.0059	-	-	-	-
Total aluminum	mg/L	0.1	2.46	0.511	-	-	-	-
Total cadmium	mg/L	0.00002	-	0.00132	-	-	-	-
Total chromium	mg/L	0.001	0.00368	0.00211	-	-	-	-
Total copper	mg/L	0.002	0.00221	0.0243	-	-	-	-
Total iron	mg/L	0.3	3.81	2.64	-	-	0.4	0.9
Total lead	mg/L	0.0017	-	0.00964	-	-	-	-
Total phenols	mg/L	0.004	0.0064	0.0106	0.0052	-	0.009	0.006
Total phosphorus	mg/L	0.05	0.149	0.128	-	-	-	0.053
Total silver	mg/L	0.0001	-	0.0003	-	-	-	-
Total thallium	mg/L	0.0008	-	0.0044	-	-	-	-
Total zinc	mg/L	0.03	-	628.0	-	-	-	-

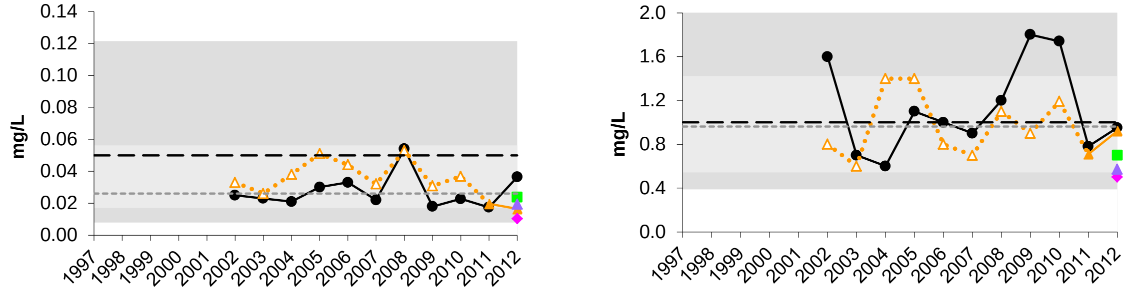
[a] Sources for all guidelines are outlined in Table 3.2-5.

ns = not sampled

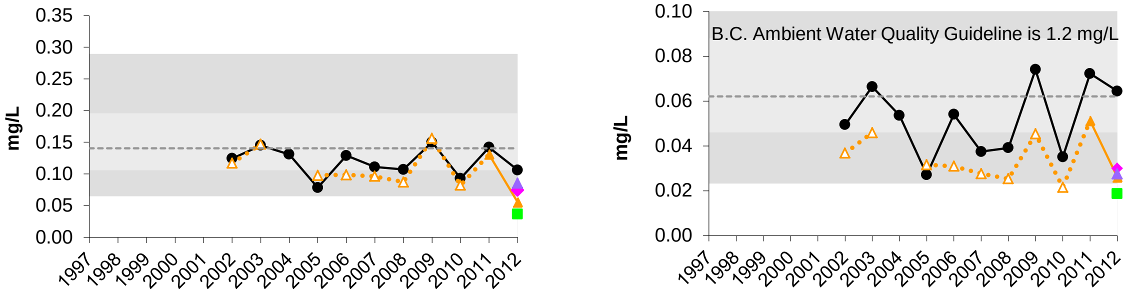
Figure 5.10-7 Concentrations of selected water quality measurement endpoints in the Christina River watershed (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

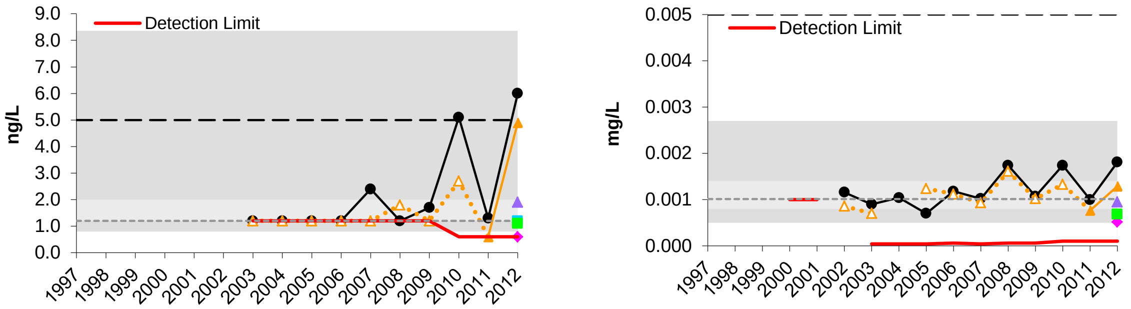
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

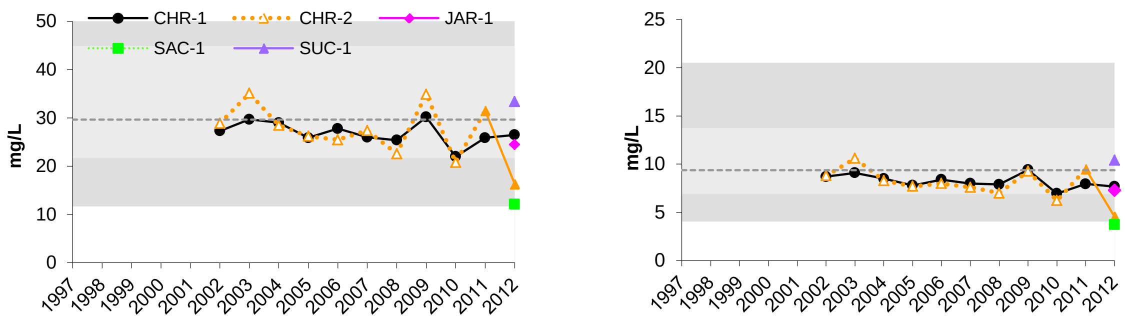
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

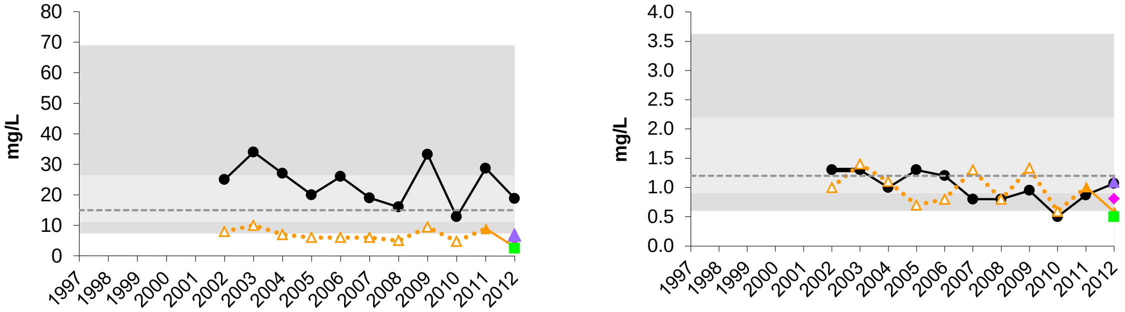
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.10-7 (Cont'd.)



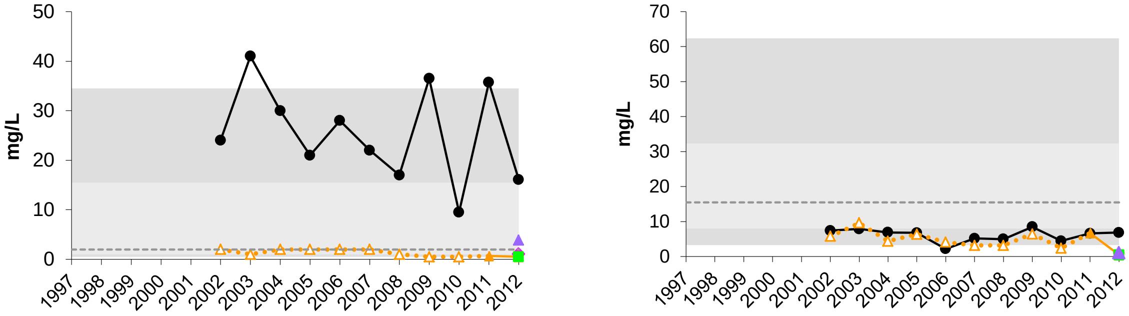
Calcium

Magnesium



Sodium

Potassium



Chloride

Sulphate

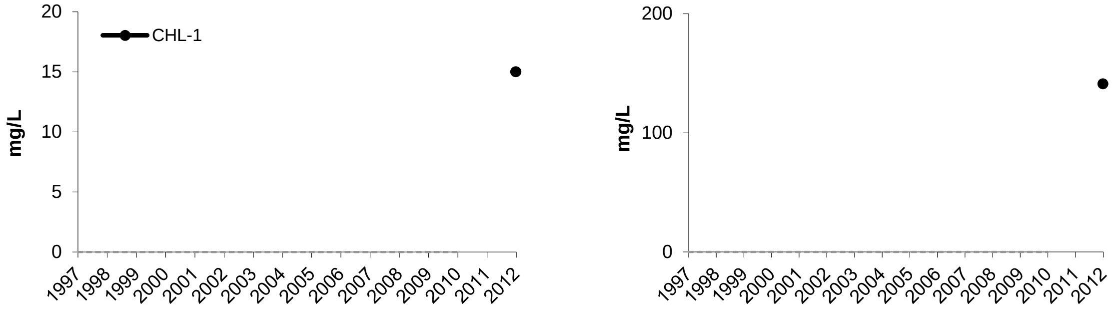
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

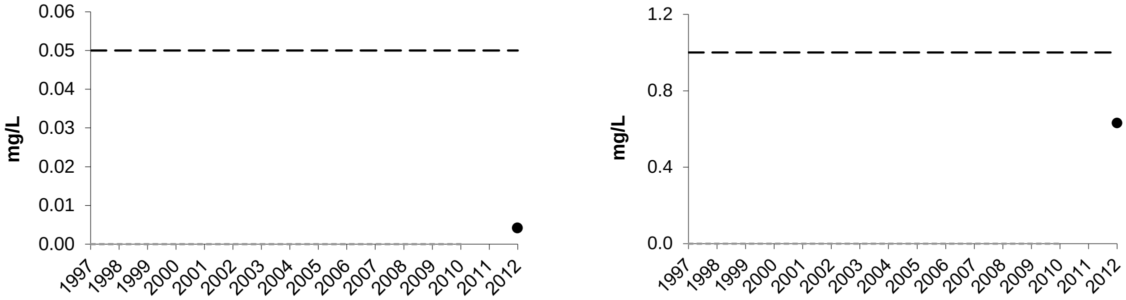
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

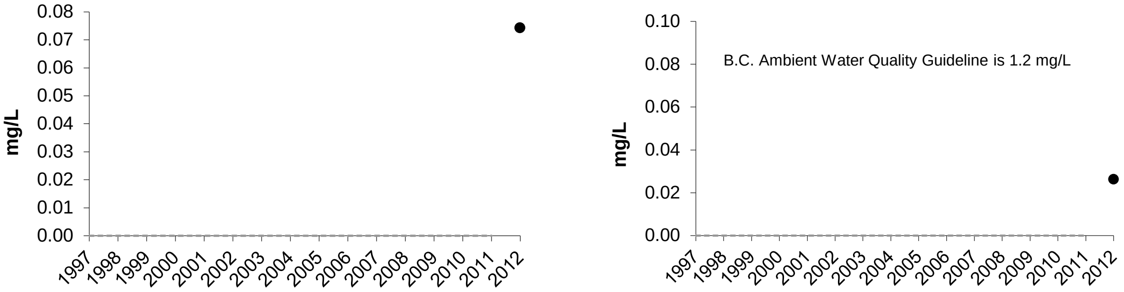
Figure 5.10-8 Concentrations of selected water quality measurement endpoints in Christina Lake (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

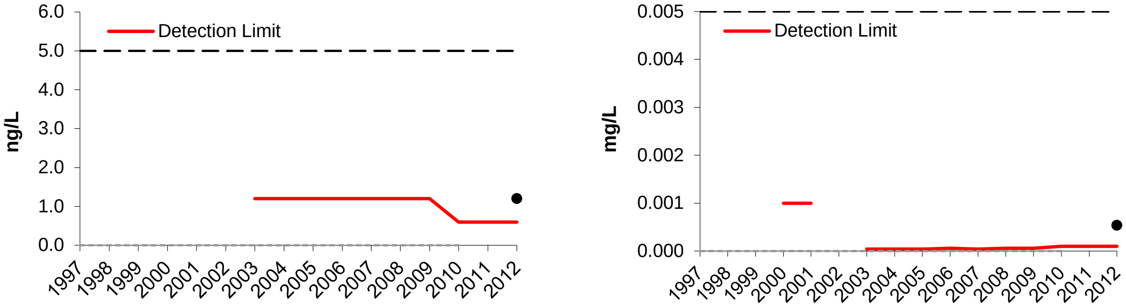

Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron

B.C. Ambient Water Quality Guideline is 1.2 mg/L


Total Mercury (Ultra-trace)

Total Arsenic

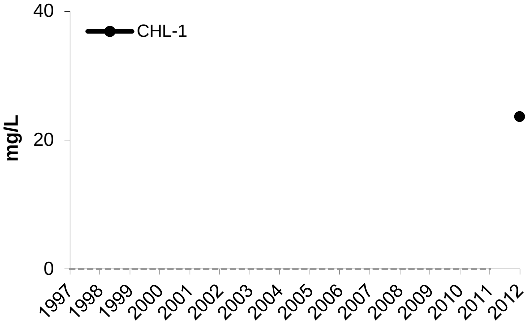
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

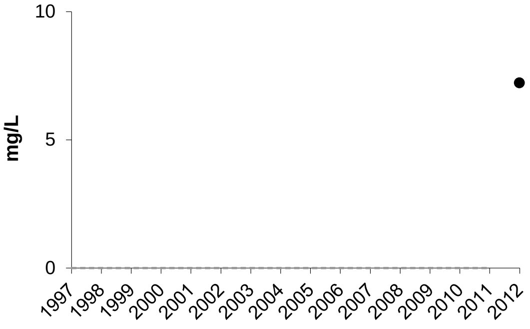
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.10-7 (Cont'd.)

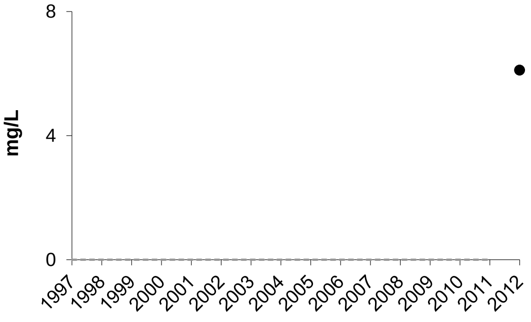
Calcium



Magnesium

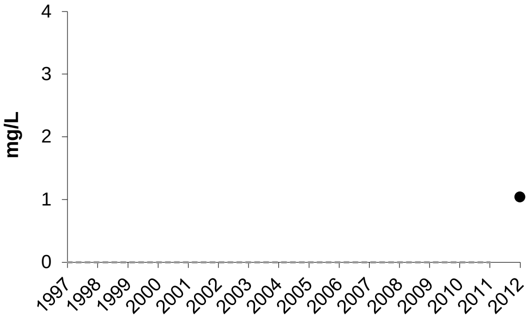


Sodium

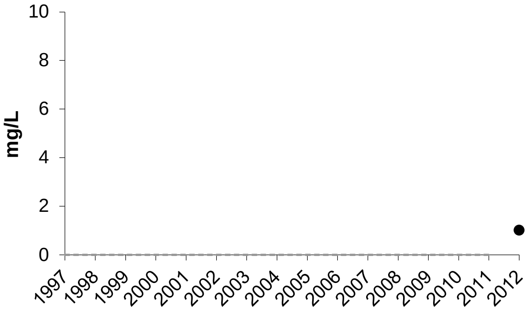


Potassium

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

Table 5.10-11 Water quality index (fall 2012) for stations in the Christina River watershed.

Station	Location	2012 Designation	Water Quality Index	Classification
CHR-1	near the mouth of the Christina River	*test*	93.7	Negligible-Low
CHR-2	upstream of Janvier	*test*	41.3	High
JAR-1	Jackfish River	*test*	100	Negligible-Low
SAC-1	Sawbones Creek	*test*	100	Negligible-Low
SUC-1	Sunday Creek	*test*	100	Negligible-Low

Table 5.10-12 Average habitat characteristics of benthic invertebrate community sampling locations in the Christina River, fall 2012.

Variable	Units	CHR-D1 Lower *Test* Reach of Christina River	CHR-D2 Upper *Test* Reach of Christina River
Sample date	-	07-Sept-2012	12-Sept-2012
Habitat	-	Depositional	Depositional
Water depth	m	-	0.9
Current velocity	m/s	0.47	0.38
Field Water Quality			
Dissolved oxygen	mg/L	7.70	7.15
Conductivity	µS/cm	226	102
pH	pH units	8.3	7.8
Water temperature	°C	14.3	10.2
Sediment Composition			
Sand	%	83	93
Silt	%	9	5
Clay	%	8	2
Total Organic Carbon	%	0.84	0.24

Table 5.10-13 Summary of major taxon abundances of benthic invertebrate community measurement endpoints at *test* reaches CHR-D1 and CHR-D2.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Reach CHR-D1			Reach CHR-D2		
	2002	2003 to 2009	2012	2002	2003 to 2009	2012
Nematoda	1	1 to 2	6	1	0 to 11	<1
Oligochaeta			<1			<1
Enchytraeidae		0 to <1			0 to 3	1
Naididae	<1	<1 to 5	2		0 to 4	9
Tubificidae	44	5 to 71	57	23	<1 to 33	13
Lumbriculidae		o to <1				
Hydracarina		o to <1	<1		0 to <1	<1
Erpobdellidae		0 to <1				
Glossiphoniidae	<1			<1		
Macrothricidae				<1		
Ostracoda	2	0 to 43	2	24	0 to 2	2
Cladocera		0 to 3		<1		
Copepoda	<1	0 to <1		<1	0 to <1	
Gastropoda	2	0 to 2		<1		
Bivalvia	11	0 to 1	1	3	0 to 7	2
Coleoptera		0 to <1			0 to <1	
Ceratopogonidae	<1	1 to 8	5	2	0 to 2	2
Chironomidae	39	15 to 70	21	44	28 to 99	58
Dolichopodidae		0 to <1	<1		0 to 4	
Empididae		0 to 3	<1	<1	0 to <1	
Ephydridae		0 to <1			0 to 4	
Tabanidae	<1	0 to <1		<1	0 to 1	<1
Tipulidae		0 to 1	<1	<1	0 to 2	
Ephemeroptera		<1 to 1	<1	2	<1	6
Anisoptera	<1	<1 to 1		<1	0 to <1	<1
Plecoptera	<1	<1 to 1	1		0 to <1	
Trichoptera	<1	0 to <1	<1	<1	0 to 4	5
Heteroptera		0 to <1		<1		
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	22,928	5,052 to 77,955	1,770	63,968	1,305 to 31,462	10,066
Richness	11	7 to 20	8	20	5 to 12	9
Simpson's Diversity	0.60	0.51 to 0.77	0.52	0.67	0.37 to 0.55	0.70
Equitability	0.31	0.17 to 0.49	0.44	0.20	0.26 to 0.57	0.54
% EPT	1	1 to 6	2	3	1 to 7	11

Table 5.10-14 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach CHR-D1.

Variable	**P-Value**			**Variance Explained (%)**			**Nature of Change(s)**
	Time Trend (*test* period)	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	**Time Trend (*test* period)**	**2012 vs. *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	0.058	**0.005**	**<0.001**	2	5	10	Lower in 2012 than mean of previous years and *baseline* years.
Richness	0.161	0.153	**0.001**	1	1	8	Lower in 2012 than mean of previous years.
Simpson's Diversity	0.619	0.777	0.226	1	0	4	No change.
Equitability	0.668	0.557	0.276	0	1	2	No change.
EPT	**0.038**	**0.044**	**0.020**	15	14	19	Increasing over time; lower in 2012 than mean of *baseline* years and previous years.
CA Axis 1	**0.010**	0.859	0.677	18	0	0	Increasing over time.
CA Axis 2	0.922	0.989	**0.005**	0	0	6	Lower in 2012 than mean of previous years.

Bold values indicate significant difference (p<0.05).

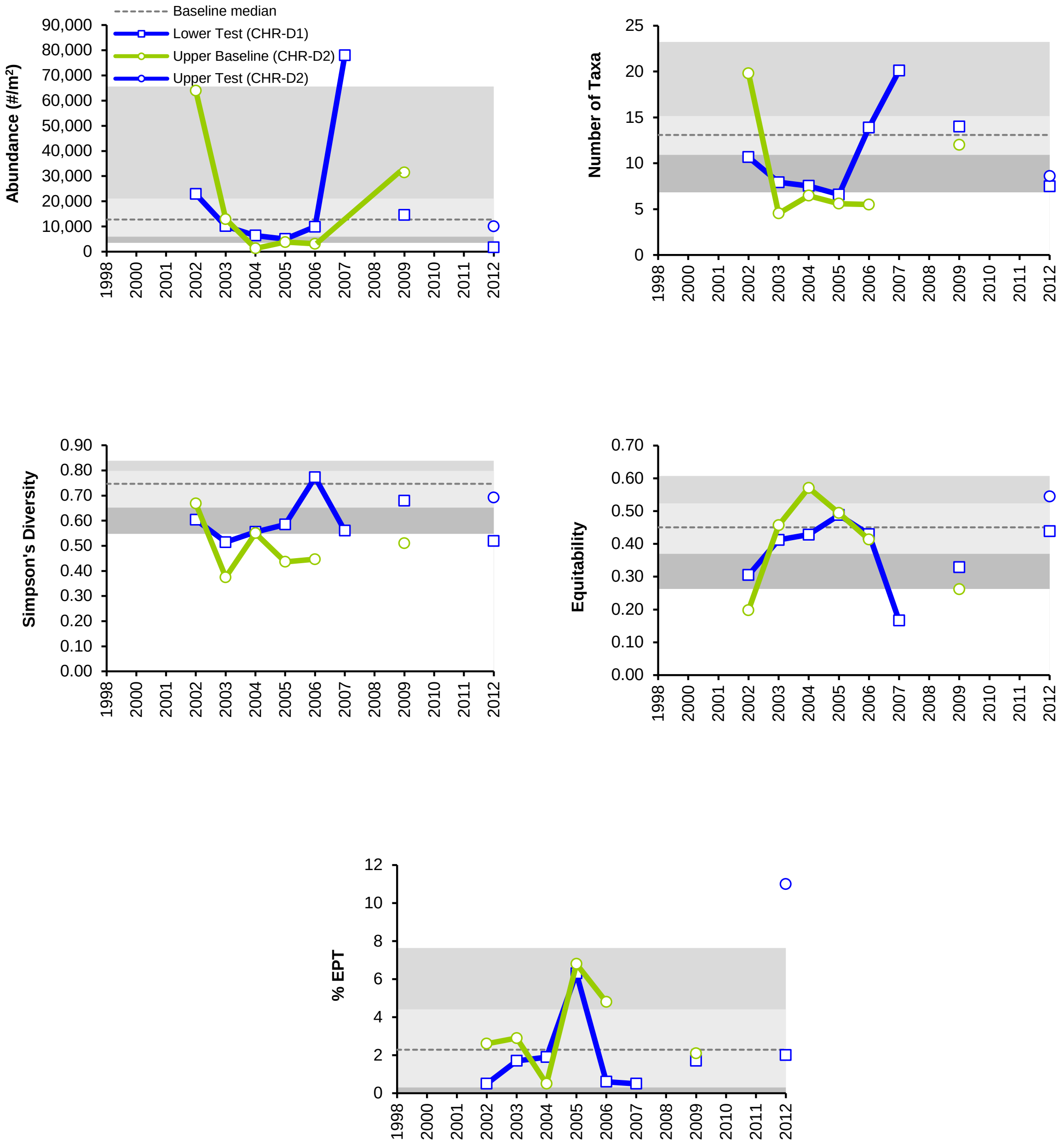
Table 5.10-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach CHR-D2.

Variable	P-Value	Variance Explained (%)	Nature of Change(s)
	***Baseline* Period vs. *Test* Period**	***Baseline* Period vs. *Test* Period**	
Abundance	**0.017**	4	Higher in *baseline* period.
Richness	0.572	0	No change.
Simpson's Diversity	**0.011**	18	Higher in *test* period.
Equitability	**0.033**	8	Higher in *test* period.
EPT	**0.001**	36	Higher in *test* period.
CA Axis 1	**0.032**	12	Higher in *test* period.
CA Axis 2	**<0.001**	9	Higher in *test* period.

Bold values indicate significant difference (p<0.05).

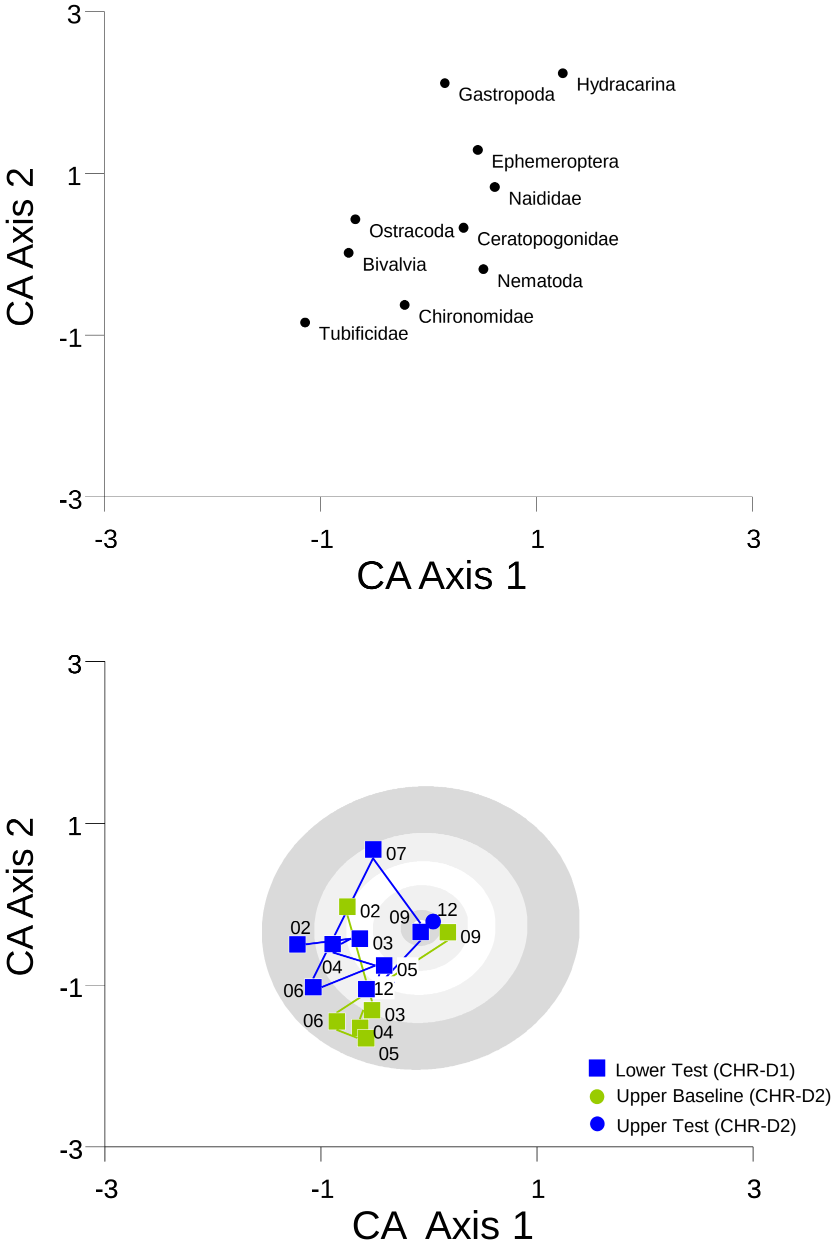
Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.10-9 Variation in benthic invertebrate community measurement endpoints in the Christina River.



Note: Regional *baseline* values for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.10-10 Ordination (Correspondence Analysis) of benthic invertebrate communities at *test* reaches CHR-D1 and CHR-D2 of the Christina River.

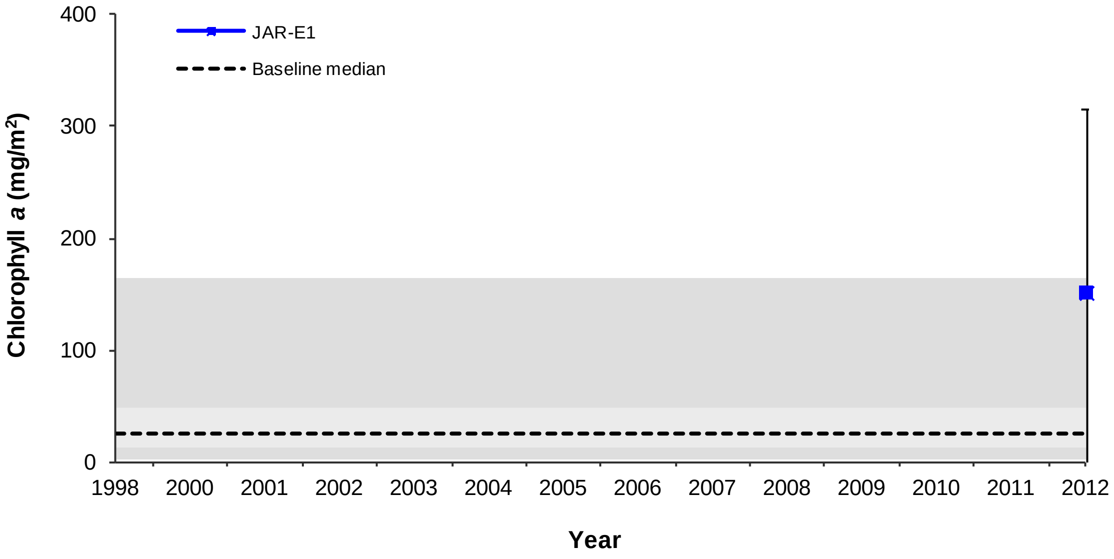


Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipse in the lower panel is for *baseline* data for depositional reaches in the RAMP FSA.

Table 5.10-16 Average habitat characteristics of benthic invertebrate community sampling locations in tributaries to Christina Lake, fall 2012.

Variable	Units	SAC-D1 *Test* Reach of Sawbones Creek	SUC-D1 *Test* Reach of Sunday Creek	JAR-E1 *Test* Reach of Jackfish River
Sample date	-	13-Sept-2012	05-Sept-2012	10-Sept-2012
Habitat	-	Depositional	Depositional	Erosional
Water depth	m	1.3	0.7	0.2
Current velocity	m/s	<1	0.38	0.90
Field Water Quality				
Dissolved oxygen	mg/L	7.9	8.8	8.3
Conductivity	µS/cm	80	226	176
pH	pH units	7.8	8.2	8.3
Water temperature	°C	9.7	12.5	14.9
Sediment Composition				
Sand	%	86	97	
Silt	%	10	2	
Clay	%	4	1	0
Small Gravel	%			2
Large Gravel	%			27
Small Cobble	%			21
Large Cobble	%			10
Boulder	%			39
Bedrock	%			0
Total Organic Carbon	%	1.91	0.21	

Figure 5.10-11 Periphyton chlorophyll *a* biomass at *test* reach JAR-E1 of the Jackfish River.

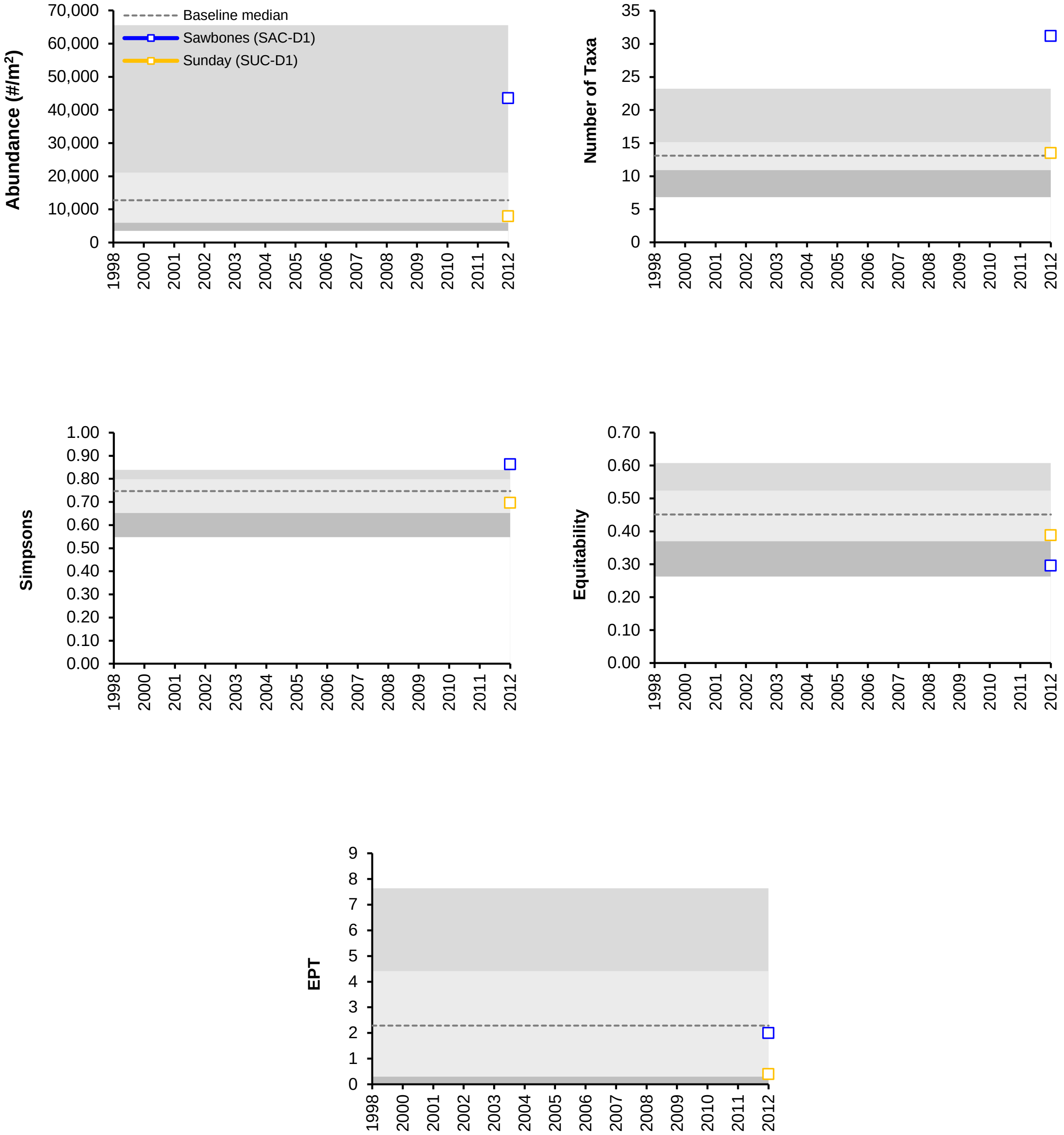


Note: Regional *baseline* values reflect pooled results for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Table 5.10-17 Summary of major taxon abundances of benthic invertebrate community measurement endpoints at *test* reaches SAC-D1, SUC-D1, and JAR-E1 of the Christina River watershed.

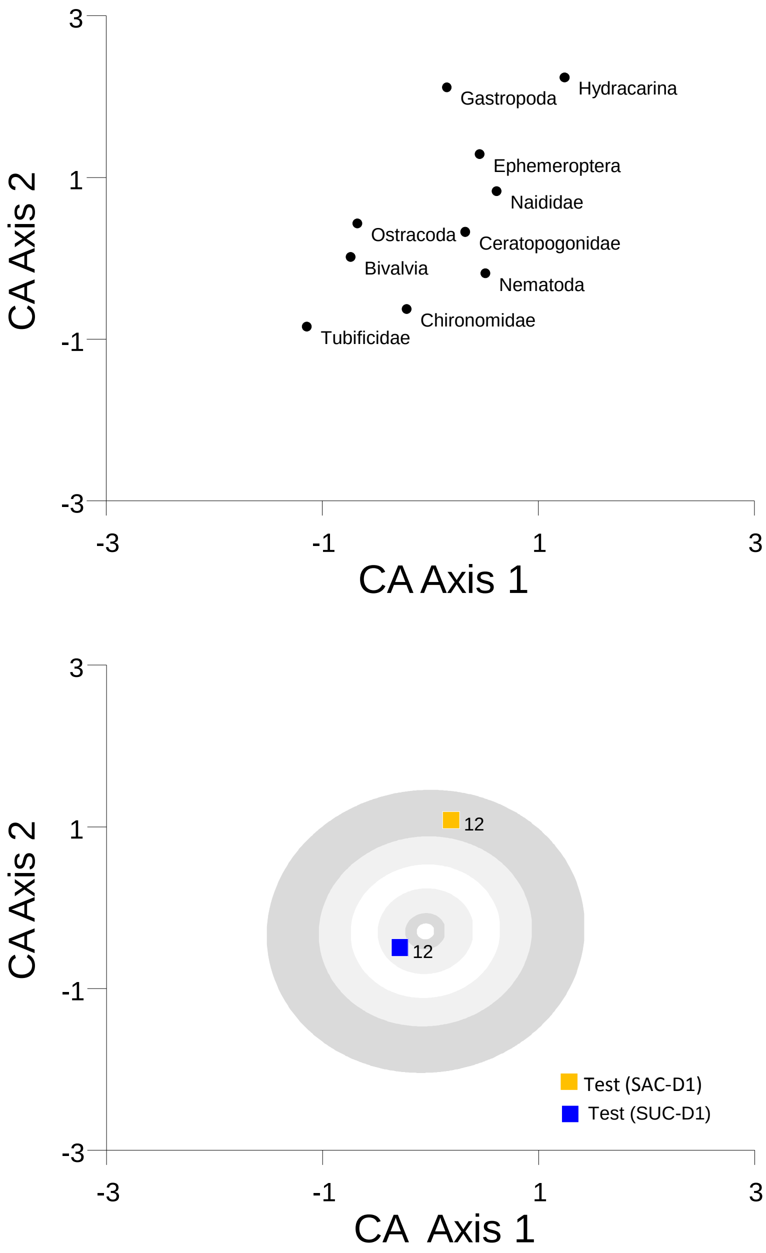
Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach JAR-E1	**Reach SAC-D1**	**Reach SUC-D1**
	2012	**2012**	**2012**
Hydra		<1	
Nematoda	1	3	<1
Naididae	2	2	2
Tubificidae	<1	2	2
Lumbriculidae	<1	1	
Erpobdellidae	<1	<1	
Enchytraeidae	<1		
Glossiphoniidae		<1	
Hydracarina	11	1	<1
Oligochaeta			<1
Ostracoda	5	3	1
Cladocera	3	6	<1
Copepoda	<1	2	<1
Amphipoda	<1	<1	
Gastropoda	1	1	<1
Bivalvia	<1	1	2
Coleoptera	<1	<1	
Ceratopogonidae	<1	5	2
Chironomidae	23	68	80
Empididae	<1	<1	<1
Tabanidae		<1	<1
Tipulidae	<1	<1	7
Simuliidae	2		
Ephemeroptera	29	2	<1
Anisoptera	<1	<1	<1
Zygoptera	<1		
Plecoptera	<1		
Trichoptera	19	<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	183,950	43,549	7,970
Richness	38	31	14
Simpson's Diversity	0.90	0.86	0.69
Equitability	0.28	0.3	0.39
% EPT	48	2	<1

Figure 5.10-12 Variation in benthic invertebrate community measurement endpoints in Sunday and Sawbones creeks.



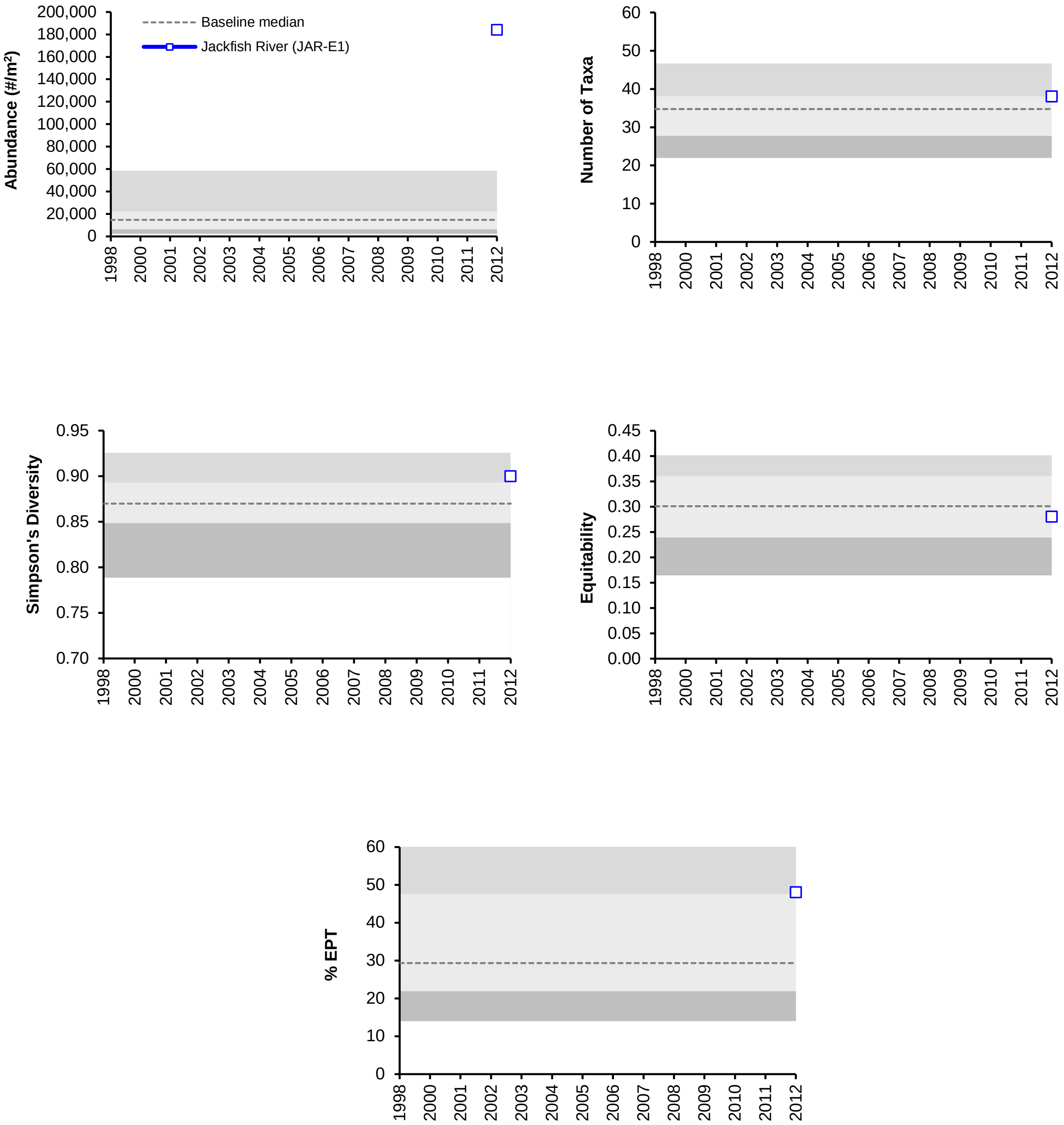
Note: Regional *baseline* values for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.10-13 Ordination (Correspondence Analysis) of benthic invertebrate communities at *test* reach SAC-D1 of Sawbones Creek and *test* reach SUC-D1 of Sunday Creek.



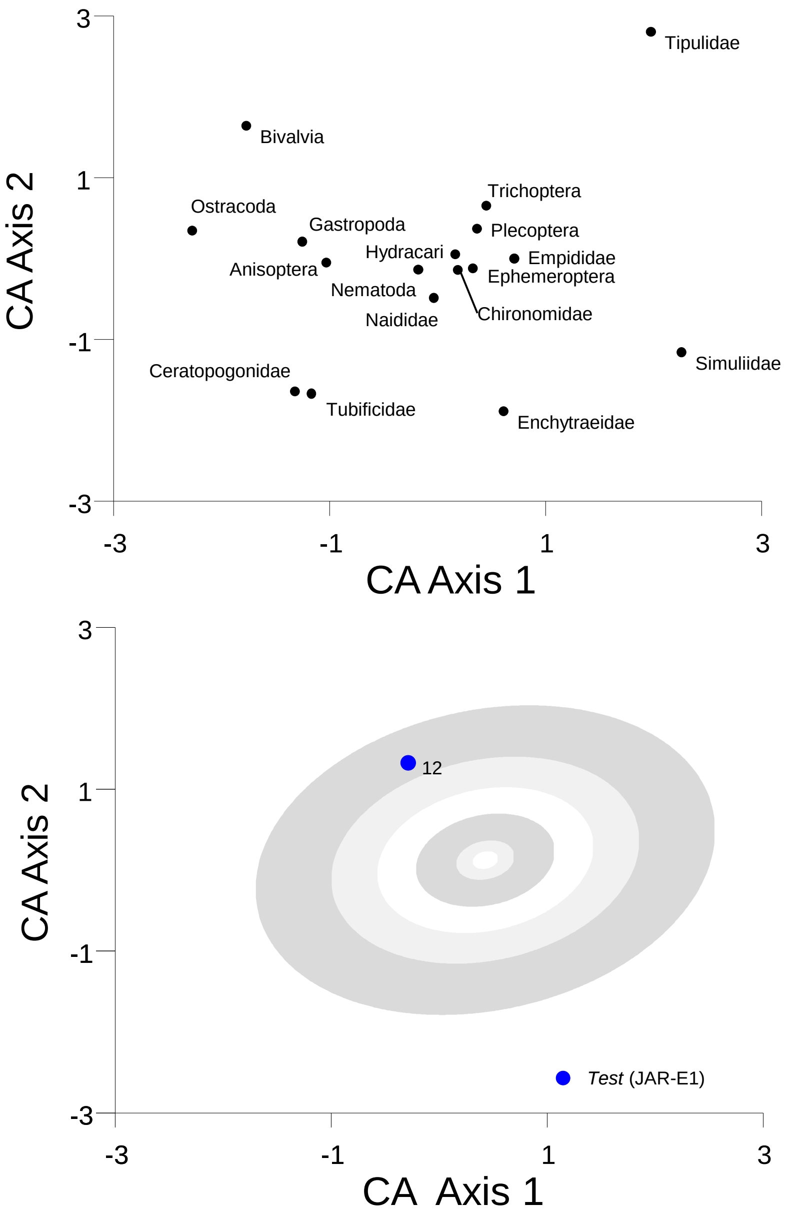
Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipse in the lower panel is for *baseline* data for depositional reaches in the RAMP FSA.

Figure 5.10-14 Variation in benthic invertebrate community measurement endpoints in Jackfish River.



Note: Regional *baseline* values for all *baseline* erosional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.10-15 Ordination (Correspondence Analysis) of benthic invertebrate communities at *test* reach JAR-E1 of the Jackfish River.



Note: lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipse in the lower panel is for *baseline* data for erosional reaches in the RAMP FSA.

Table 5.10-18 Average habitat characteristics of benthic invertebrate sampling locations in Christina Lake, CHL-1, fall 2012.

Variable	Units	CHI-1 *Test* Station of Christina Lake
Sample date	-	10-Sept-2012
Habitat	-	Depositional
Water depth	m	1.1
Field Water Quality		
Dissolved oxygen	mg/L	9.4
Conductivity	µS/cm	178
pH	pH units	8.36
Water temperature	°C	15.1
Sediment Composition		
Sand	%	99
Silt	%	<1
Clay	%	<1
Total Organic Carbon	%	0.25

Table 5.10-19 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Christina Lake.

Taxon	Percent Major Taxa Enumerated in Each Year
	Christina Lake
	2012
Hydra	1
Nematoda	11
Erpobdellidae	<1
Glossiphoniidae	<1
Enchytraeidae	2
Lumbriculidae	1
Naididae	5
Tubificidae	1
Hydracarina	2
Ostracoda	13
Cladocera	1
Copepoda	10
Amphipoda	11
Gastropoda	3
Bivalvia	4
Ephemeroptera	2
Trichoptera	1
Zygoptera	<1
Tabanidae	<1
Ceratopogonidae	1
Chironomidae	31
Benthic Invertebrate Community Measurement Endpoints	
Total Abundance (No./m^2)	43,493
Richness	33
Simpson's Diversity	0.87
Equitability	0.28
% EPT	3

Figure 5.10-16 Variation in benthic invertebrate community measurement endpoints in Christina Lake.

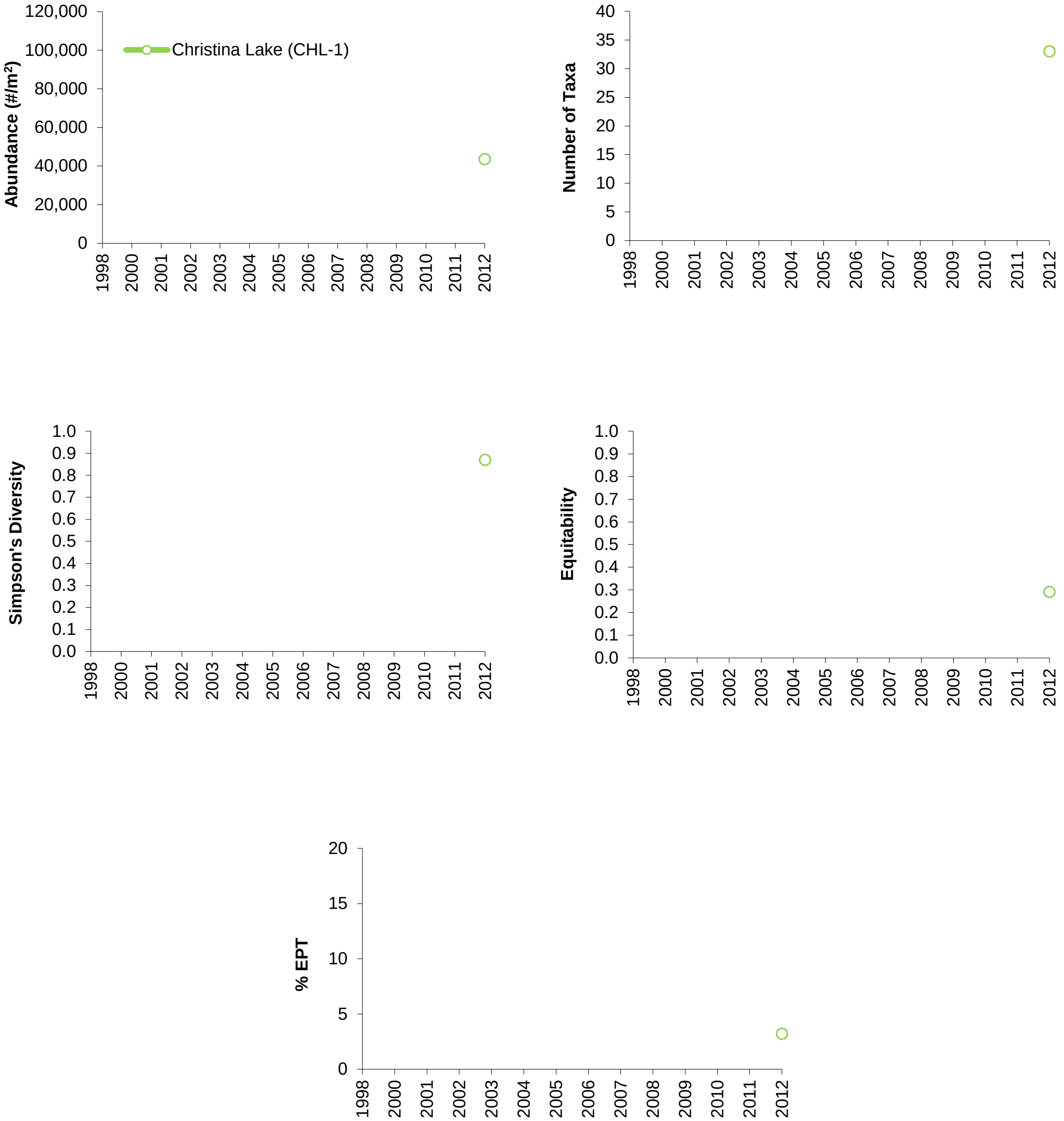


Table 5.10-20 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.8	6	8	11	17
Silt	%	-	32.7	6	16	23	38
Sand	%	-	61.5	6	54	64	74
Total organic carbon	%	-	0.7	6	0.7	1.4	2.0
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<5	7.5	13
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<5	7.5	13
Fraction 2 (C10-C16)	mg/kg	150[1]	37	4	40	73.5	100
Fraction 3 (C16-C34)	mg/kg	300[1]	232	4	200	**602**	**970**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	131	4	130	354	600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0006	6	0.0012	0.0018	0.0080
Retene	mg/kg	-	0.025	6	0.020	0.044	0.149
Total dibenzothiophenes	mg/kg	-	0.316	6	0.252	0.910	3.32
Total PAHs	mg/kg	-	1.31	6	0.999	3.23	11.7
Total Parent PAHs	mg/kg	-	0.057	6	0.045	0.110	0.321
Total Alkylated PAHs	mg/kg	-	1.25	6	0.955	3.12	11.4
Predicted PAH toxicity[3]	H.I.	1.0	0.954	6	0.647	**1.24**	**2.74**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.2	3	8.6	9.0	9.2
Chironomus growth - 10d	mg/organism	-	1.12	3	2.1	2.2	2.7
Hyalella survival - 14d	# surviving	-	9.4	3	6.0	8.4	9.0
Hyalella growth - 14d	mg/organism	-	0.22	3	0.1	0.2	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 5.10-21 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D2), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.5	5	2	4	13
Silt	%	-	0.27	5	1	17	30
Sand	%	-	99.2	5	57	79	97
Total organic carbon	%	-	<0.1	5	0.1	0.6	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	3	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	3	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	3	<5	13	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	26	3	<5	20	47
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	3	<5	20	32
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0004</u>	5	0.0007	0.0018	0.0030
Retene	mg/kg	-	0.0006	5	0.0012	0.0110	0.0920
Total dibenzothiophenes	mg/kg	-	0.002	5	0.001	0.014	0.021
Total PAHs	mg/kg	-	0.026	5	0.024	0.146	0.317
Total Parent PAHs	mg/kg	-	<u>0.003</u>	5	0.006	0.018	0.034
Total Alkylated PAHs	mg/kg	-	0.023	5	0.019	0.128	0.283
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.103</u>	5	0.320	0.457	0.570
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>9.2</u>	4	5.0	7.0	9.0
Chironomus growth - 10d	mg/organism	-	1.66	4	1.42	2.16	4.30
Hyalella survival - 14d	# surviving	-	9.8	4	8.0	9.4	10.0
Hyalella growth - 14d	mg/organism	-	0.29	4	0.11	0.27	0.40

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic 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 5.10-22 Concentrations of selected sediment measurement endpoints, Sawbones Creek (*test* station SAC-D1), fall 2012.

Variables	**Units**	**Guideline**	**September 2012** Value
Physical variables			
Clay[4]	%	-	6.0
Silt[4]	%	-	36.3
Sand[4]	%	-	57.8
Total organic carbon	%	-	6.0
Total hydrocarbons			
BTEX	mg/kg	-	<30
Fraction 1 (C6-C10)	mg/kg	30[1]	<30
Fraction 2 (C10-C16)	mg/kg	150[1]	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	249
Fraction 4 (C34-C50)	mg/kg	2,800[1]	145
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.001
Retene	mg/kg	-	0.280
Total dibenzothiophenes	mg/kg	-	0.017
Total PAHs	mg/kg	-	0.498
Total Parent PAHs	mg/kg	-	0.026
Total Alkylated PAHs	mg/kg	-	0.473
Predicted PAH toxicity[3]	H.I.	1.0	0.361
Metals that exceed CCME guidelines in 2012			
none	mg/kg	-	-
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	9.0
Chironomus growth - 10d	mg/organism	-	2.26
Hyalella survival - 14d	# surviving	-	9.6
Hyalella growth - 14d	mg/organism	-	0.29

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 5.10-23 Concentrations of selected sediment measurement endpoints, Sunday Creek (*test* station SUC-D1), fall 2012.

Variables	Units	Guideline	September 2012
			Value
Physical variables			
Clay[4]	%	-	1.1
Silt[4]	%	-	0.59
Sand[4]	%	-	98.3
Total organic carbon	%	-	0.1
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]	0.0002
Retene	mg/kg	-	0.001
Total dibenzothiophenes	mg/kg	-	0.002
Total PAHs	mg/kg	-	0.028
Total Parent PAHs	mg/kg	-	0.002
Total Alkylated PAHs	mg/kg	-	0.025
Predicted PAH toxicity[3]	H.I.	1.0	0.126
Metals that exceed CCME guidelines in 2012			
none	mg/kg	-	-
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	7.0
Chironomus growth - 10d	mg/organism	-	0.90
Hyalella survival - 14d	# surviving	-	8.6
Hyalella growth - 14d	mg/organism	-	0.45

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 5.10-24 Concentrations of selected sediment measurement endpoints, Christina Lake (*test* station CHL-1), fall 2012.

Variables	Units	Guideline	September 2012
			Value
Physical variables			
Clay[4]	%	-	0.9
Silt[4]	%	-	0.91
Sand[4]	%	-	98.2
Total organic carbon	%	-	0.2
Total hydrocarbons			
BTEX	mg/kg	-	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20
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	-	0.045
Total dibenzothiophenes	mg/kg	-	0.002
Total PAHs	mg/kg	-	0.039
Total Parent PAHs	mg/kg	-	0.006
Total Alkylated PAHs	mg/kg	-	0.033
Predicted PAH toxicity[3]	H.I.	1.0	0.179
Metals that exceed CCME guidelines in 2012			
none	mg/kg	-	-
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	8.6
Chironomus growth - 10d	mg/organism	-	1.60
Hyalella survival - 14d	# surviving	-	7.8
Hyalella growth - 14d	mg/organism	-	0.31

Values in **bold** indicate concentrations exceeding guidelines.

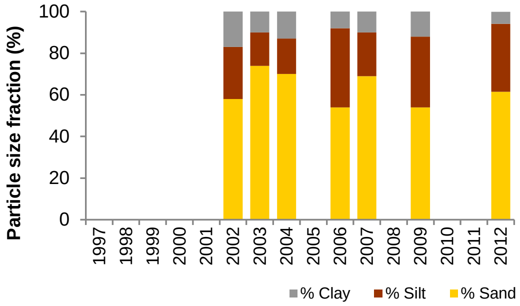
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

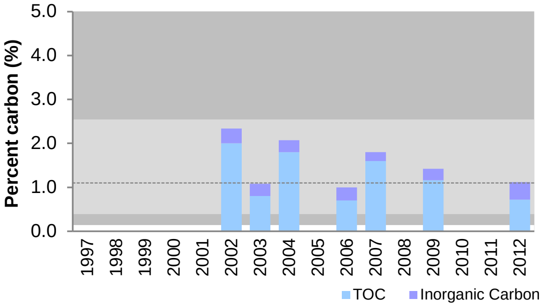
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-17 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D1.

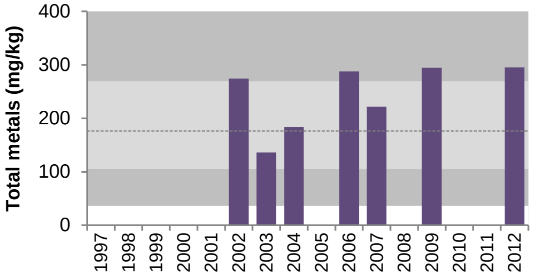
Particle size distribution



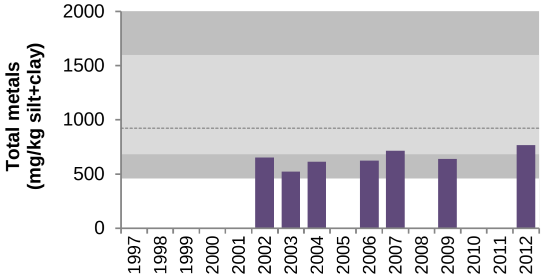
Carbon Content[1]



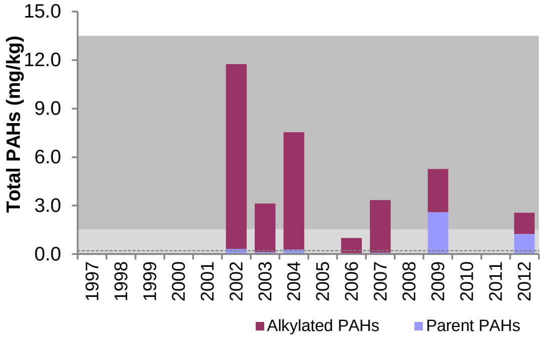
Total Metals[2]



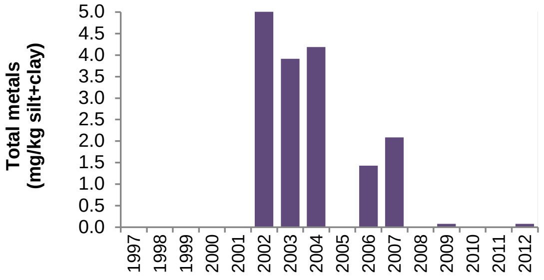
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



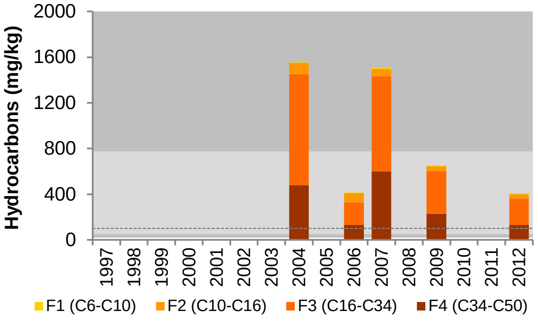
Total PAHs



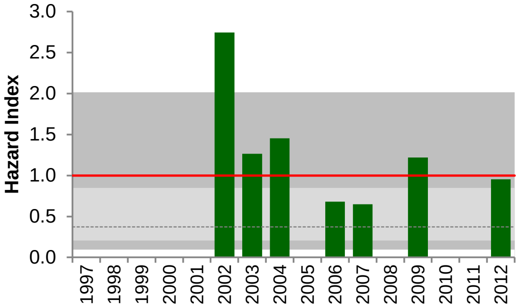
Total PAHs normalized to 1% TOC



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 (1997-2012).

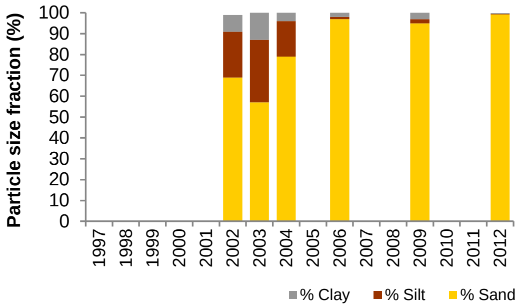
[1] Regional *baseline* values represent "total" values for multi-variable data.

[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).

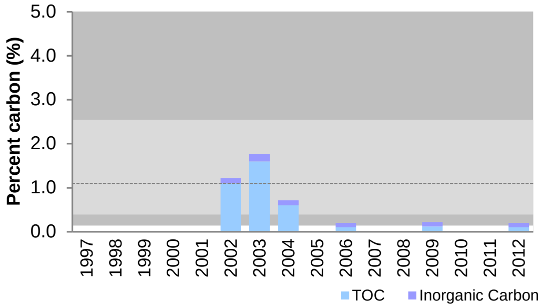
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-18 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D2.

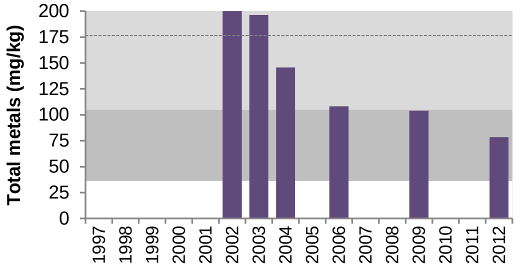
Particle size distribution



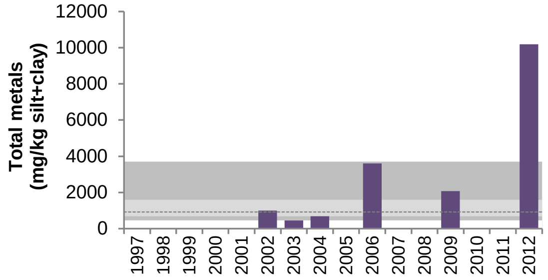
Carbon Content[1]



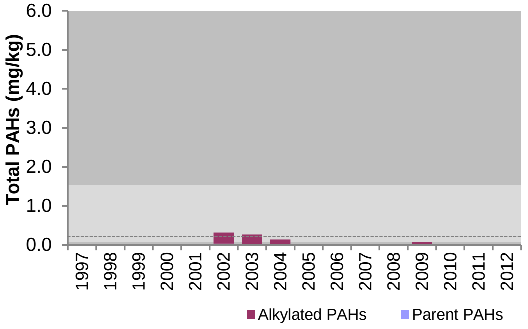
Total Metals[2]



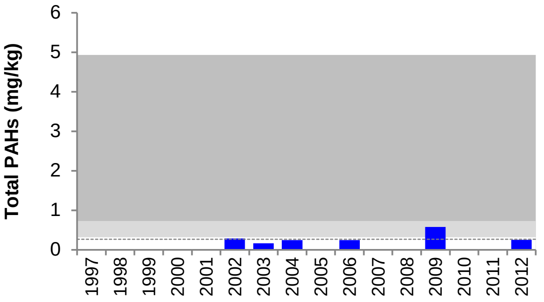
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



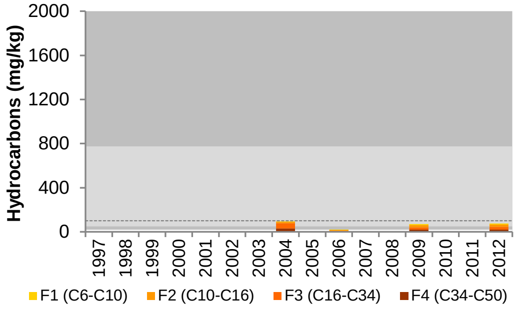
Total PAHs



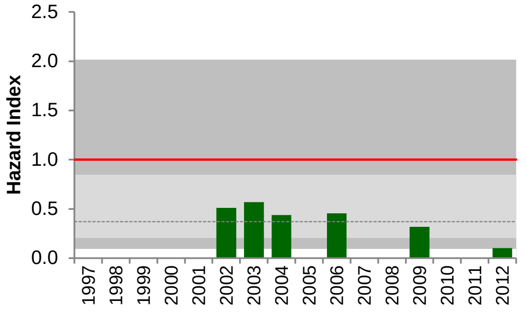
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



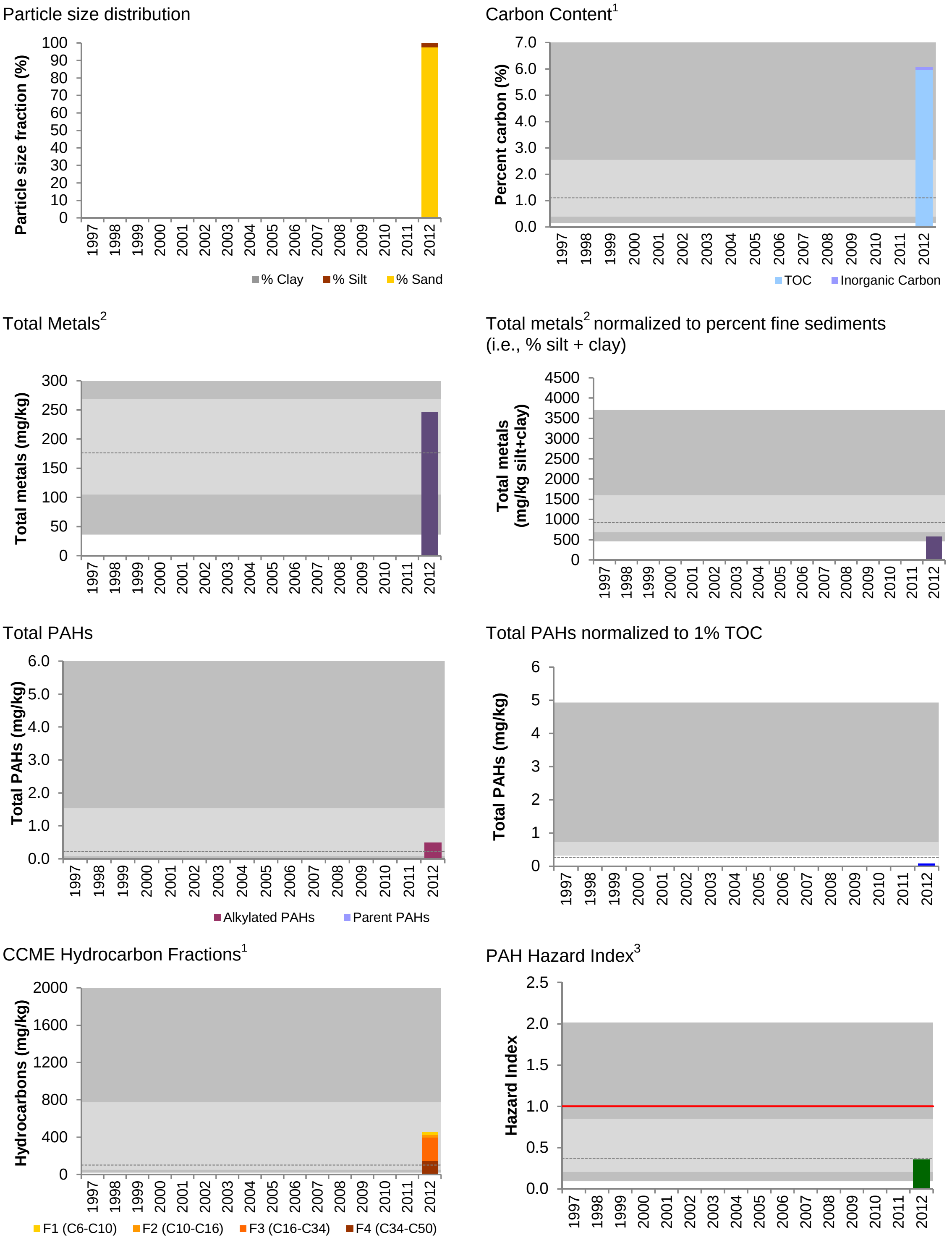
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2012).

[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 5.10-19 Variation in sediment quality measurement endpoints in Sawbones Creek, *test* station SAC-D1.



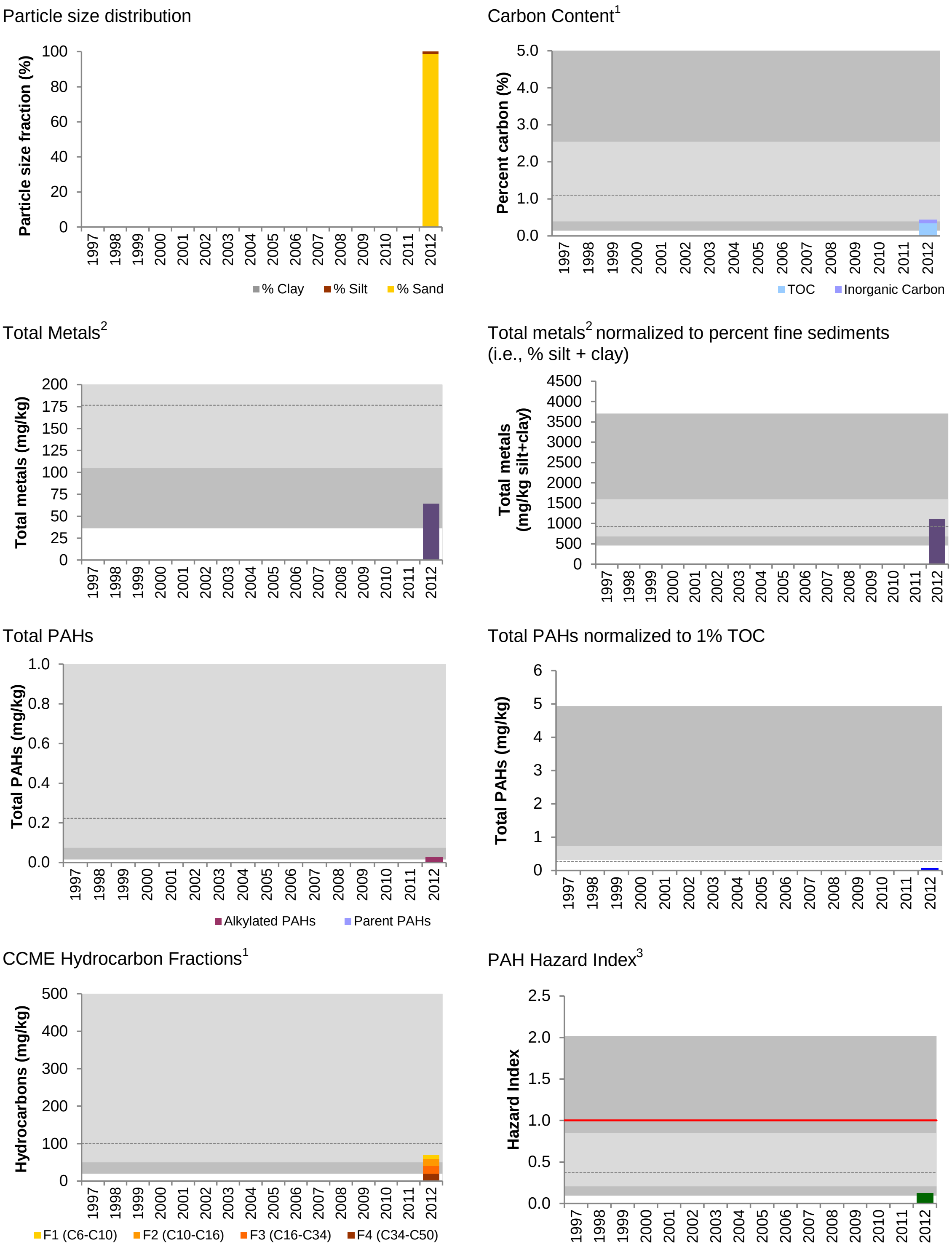
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2012).

[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 5.10-20 Variation in sediment quality measurement endpoints in Sunday Creek, *test* station SUC-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 (1997-2012).

[1] Regional *baseline* values represent "total" values for multi-variable data.

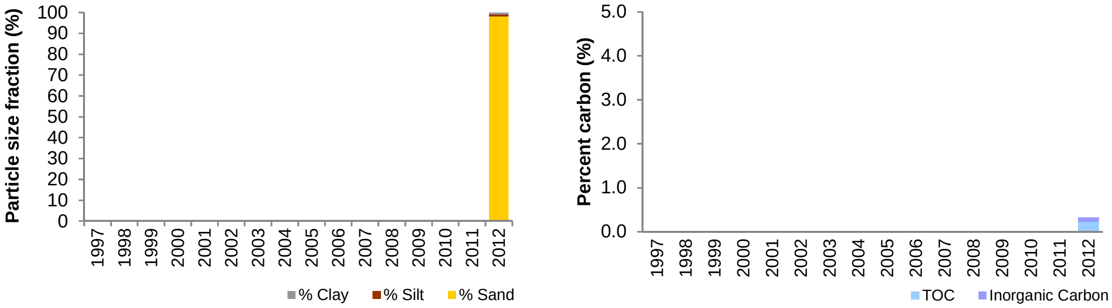
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-21 Variation in sediment quality measurement endpoints in Christina Lake, *test* station CHL-1.

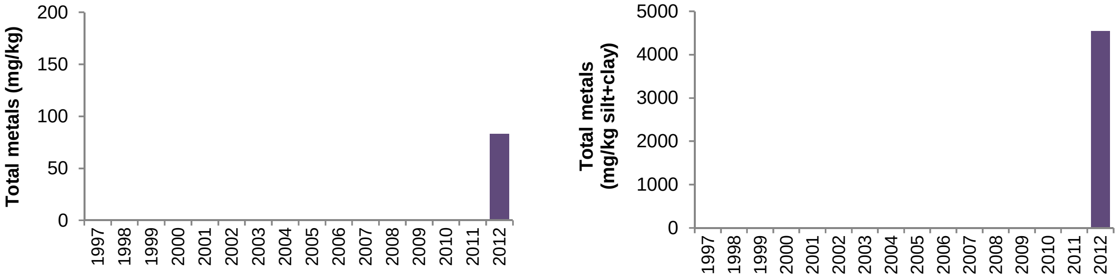
Particle size distribution

Carbon Content



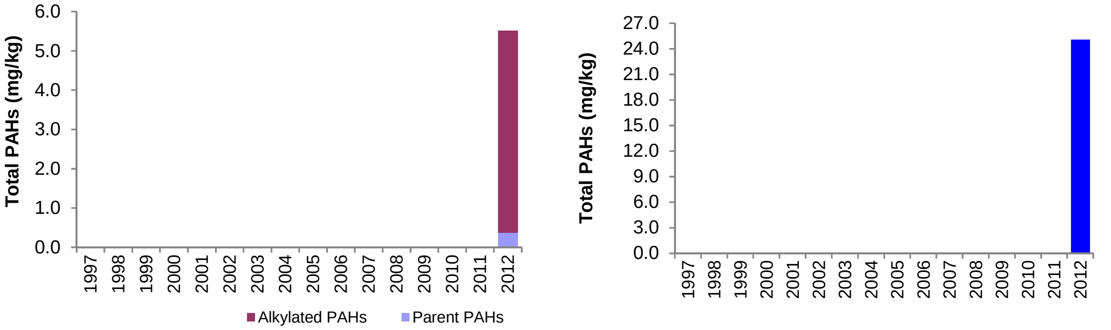
Total Metals[1]

Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



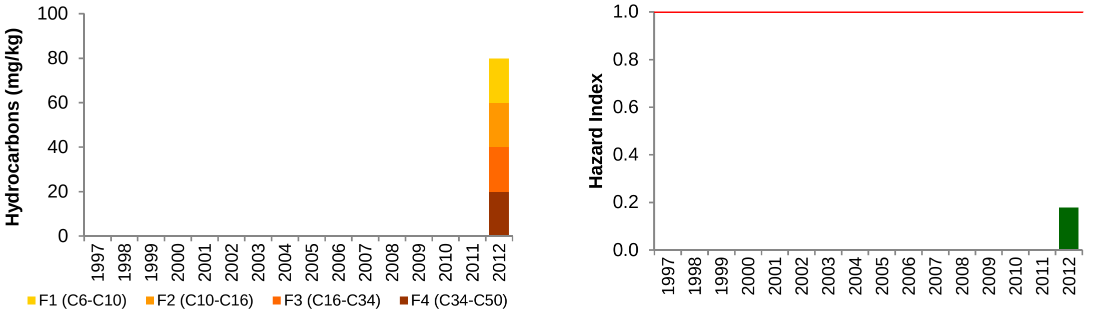
Total PAHs

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).

Table 5.10-25 Sediment quality index (fall 2012) for stations in the Christina River watershed.

Station	Location	2012 Designation	Sediment Quality Index	Classification
CHR-D1	Mouth of Christina River	*test*	97.8	Negligible-Low
CHR-D2	Upper Christina River	*test*	100.0	Negligible-Low
SAC-D1	Sawbones Creek	*test*	100.0	Negligible-Low
SUC-D1	Sunday Creek	*test*	100.0	Negligible-Low

Table 5.10-26 Average habitat characteristics of fish assemblage monitoring locations in the Christina River, fall 2012.

Variable	Units	CHR-F1 Lower *Test* Reach of Christina River	CHR-F2 Upper *Test* Reach of Christina River
Sample date	-	14-Sept-2012	12-Sept-2012
Habitat type	-	riffle/run	run
Maximum depth	m	1	2
Bankfull channel width	m	114	50
Wetted channel width	m	90	50
Substrate			
Dominant	-	cobble	fines
Subdominant	-	coarse gravel, fines	-
Instream cover			
Dominant	-	boulders	overhanging vegetation, large woody debris
Subdominant	-	overhanging vegetation, large woody debris	-
Field water quality			
Dissolved oxygen	mg/L	9.8	11.1
Conductivity	µS/cm	182	101
pH	pH units	7.89	7.74
Water temperature	^{0}C	10.3	10.2
Water velocity			
Left bank velocity	m/s	-	-
Left bank water depth	m	-	-
Centre of channel velocity	m/s	-	-
Centre of channel water depth	m	-	-
Right bank velocity	m/s	-	-
Right bank water depth	m	-	-
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.10-27 Percent composition and mean CPUE of all fish species at *test* reaches of the Christina River watershed, 2012.

Common Name	Code	Total Species					Percent of Total Catch				
		CHR-F1	CHR-F2	JAR-F1	SAC-F1	SUC-F1	CHR-F1	CHR-F2	JAR-F1	SAC-F1	SUC-F1
Arctic grayling	ARGR	-	2	-	-	1	0	3.7	0	0	2.27
brook stickleback	BRST	-	-	-	-	-	0	0	0	0	0
burbot	BURB	-	-	12	-	-	0	0	48	0	0
flathead chub	FLCH	1	-	-	-	-	3.8	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	0	0	0	0	0
finescale dace	FNDC	-	-	-	-	-	0	0	0	0	0
goldeye	GOLD	7	-	-	-	-	26.9	0	0	0	0
lake chub	LKCH	5	3		-	2	19.2	5.6	0	0	4.6
lake whitefish	LKWH	-	-	-	-	-	0	0	0	0	0
longnose dace	LNDC	-	-	2	-	-	0	0	8	0	0
longnose sucker	LNSC	1	1	1	-	1	3.8	1.9	4	0	2.3
northern pike	NRPK	2	-	1	1	2	7.7	0	4	100	4.6
northern redbelly dace	NRDC	-	1	-	-	-	0	1.9	0	0	0
pearl dace	PRDC	-	1	-	-	1	0	1.9	0	0	2.3
slimy sculpin	SLSC	3	-	6	-	36	11.5	0	24	0	81.8
spoonhead sculpin	SPSC	-	-	-	-	-	0	0	0	0	0
spottail shiner	SPSH	-	-	-	-	-	0	0	0	0	0
trout-perch	TRPR	4	45	-	-	-	15.4	83.3	0	0	0
walleye	WALL	3	-	-	-	-	11.5	0	0	0	0
white sucker	WHSC	-	1	3	-	-	0	1.9	12	0	0
yellow perch	YLPR	-	-	-	-	-	0	0	0	0	0
sucker sp. *		-	-	-	-	1	0	0	0	0	2.3
Total Count		**26**	**54**	**25**	**1**	**43**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**8**	**7**	**6**	**1**	**6**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,448**	**2,010**	**1,803**	**1,635**	**1,784**	**-**	**-**	**-**	**-**	**-**
CPUE (#/100 secs)		**1.80**	**2.69**	**1.39**	**0.06**	**2.47**	**-**	**-**	**-**	**-**	**-**

* Unknown species not included in total count.

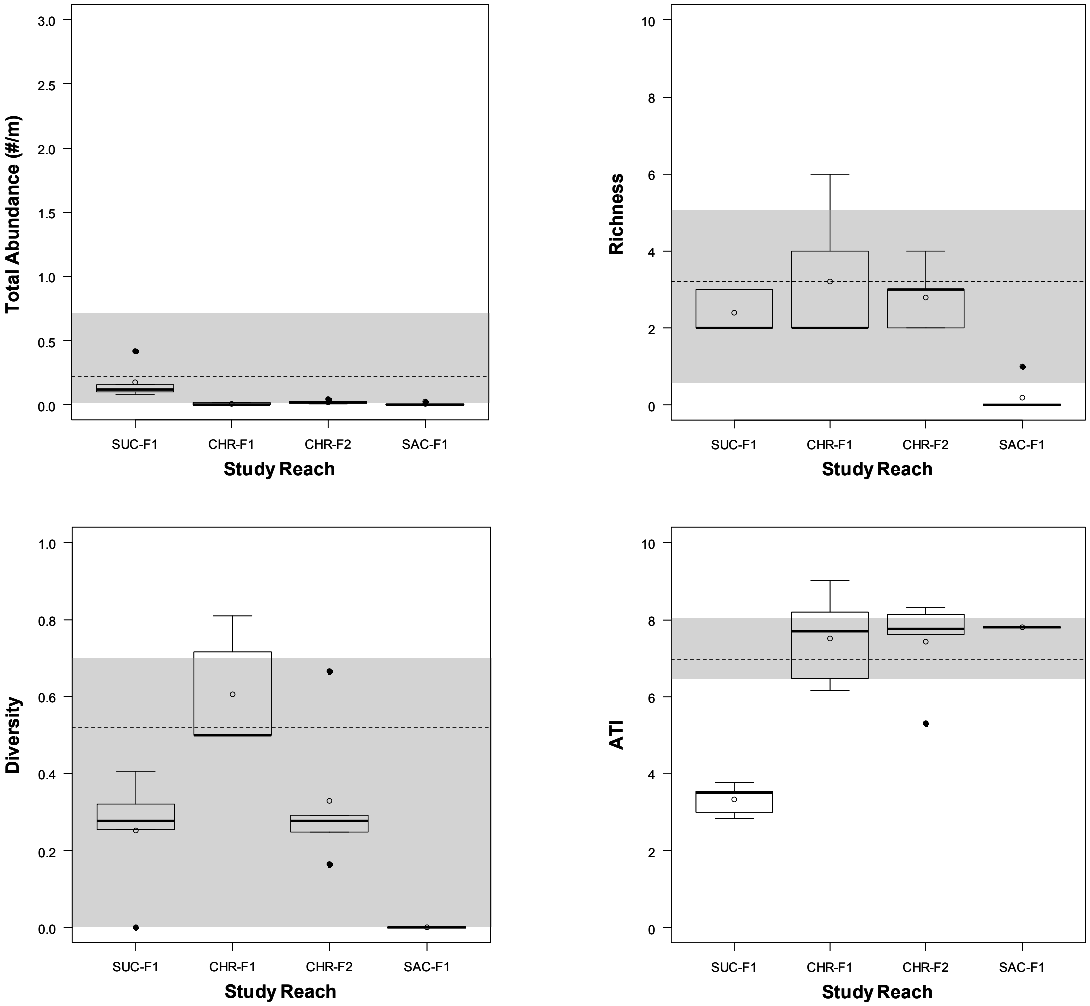
Table 5.10-28 Summary of fish assemblage measurement endpoints for *test* reaches of the Christina River watershed, 2012.

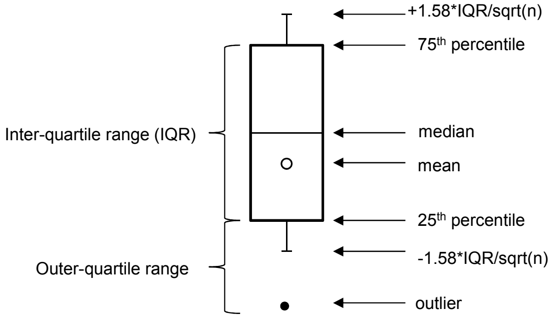
Reach	Abundance		Richness*			Diversity*		ATI*	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
CHR-F1	0.01	0.01	8	3	1.79	0.61	0.15	7.50	1.19
CHR-F2	0.02	0.01	7	3	0.84	0.33	0.19	7.43	1.22
JAR-F1	0.08	0.03	6	3	0.84	0.55	0.09	3.69	1.28
SAC-F1	0.01	0.01	1	<1	0.00	0.00	na	7.80	0.00
SUC-F1	0.18	0.14	7	2	0.55	0.25	0.15	3.33	0.39

* Unknown species not included in total count.

SD = standard deviation across sub-reaches within a reach.

Figure 5.10-22 Box-plots showing variation in fish assemblage measurement endpoints for depositional reaches of the Christina River watershed, 2012.





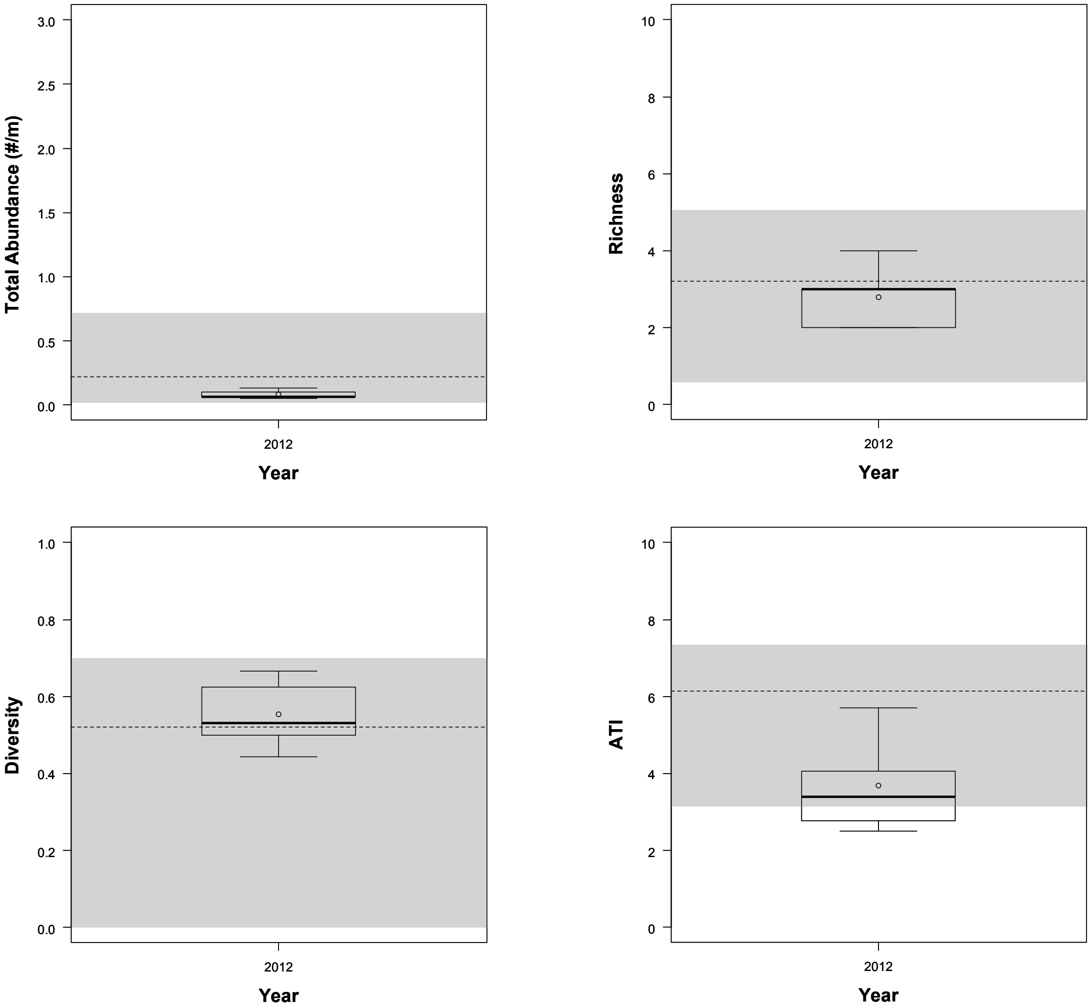
Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

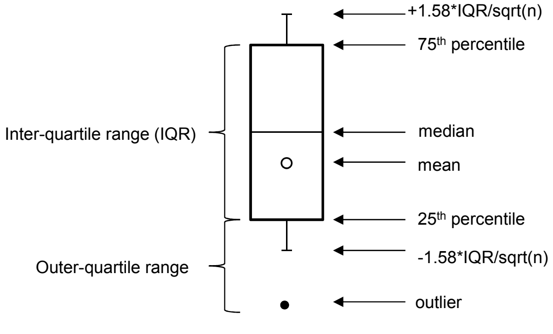
Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Table 5.10-29 Average habitat characteristics of fish assemblage monitoring locations in tributaries of Christina Lake, fall 2012.

Variable	**Units**	**SUC-F1 *Test* Reach of Sunday Creek**	**SAC-F1 *Test* Reach of Sawbones Creek**	**JAR-F1 *Test* Reach of Jackfish River**
Sample date	-	12-Sept-2012	12-Sept-2012	11-Sept-2012
Habitat type	-	riffle/run	run	riffle/run
Maximum depth	m	1.1	1.5	1.0
Bankfull channel width	m	10.0	5.0	23.5
Wetted channel width	m	9.3	5.0	23.0
Substrate				
Dominant	-	cobble	organic material	cobble
Subdominant	-	sand	-	gravel
Instream cover				
Dominant	-	small woody debris	macrophytes	filamentous algae
Subdominant	-	overhanging vegetation, undercut banks and boulders	small woody debris, overhanging vegetation, filamentous algae	macrophytes and boulders
Field water quality				
Dissolved oxygen	mg/L	9.2	8.0	8.3
Conductivity	µS/cm	192	80	182
pH	pH units	7.86	7.53	7.99
Water temperature	^{0}C	9.9	7.7	12.2
Water velocity				
Left bank velocity	m/s	0.48	0.00	0.30
Left bank water depth	m	0.59	1.00	0.63
Centre of channel velocity	m/s	0.99	0.00	0.22
Centre of channel water depth	m	0.92	1.00	0.54
Right bank velocity	m/s	0.77	0.00	0.24
Right bank water depth	m	0.36	1.00	0.31
Riparian cover- understory (<5 m)				
Dominant	-	woody shrubs and saplings	overhanging vegetation	woody shrubs and saplings
Subdominant	-	overhanging vegetation	-	overhanging vegetation

Figure 5.10-23 Box-plots showing variation in fish assemblage measurement endpoints for erosional *test* reach JAR-F1, 2012.





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all erosional *baseline* reaches.

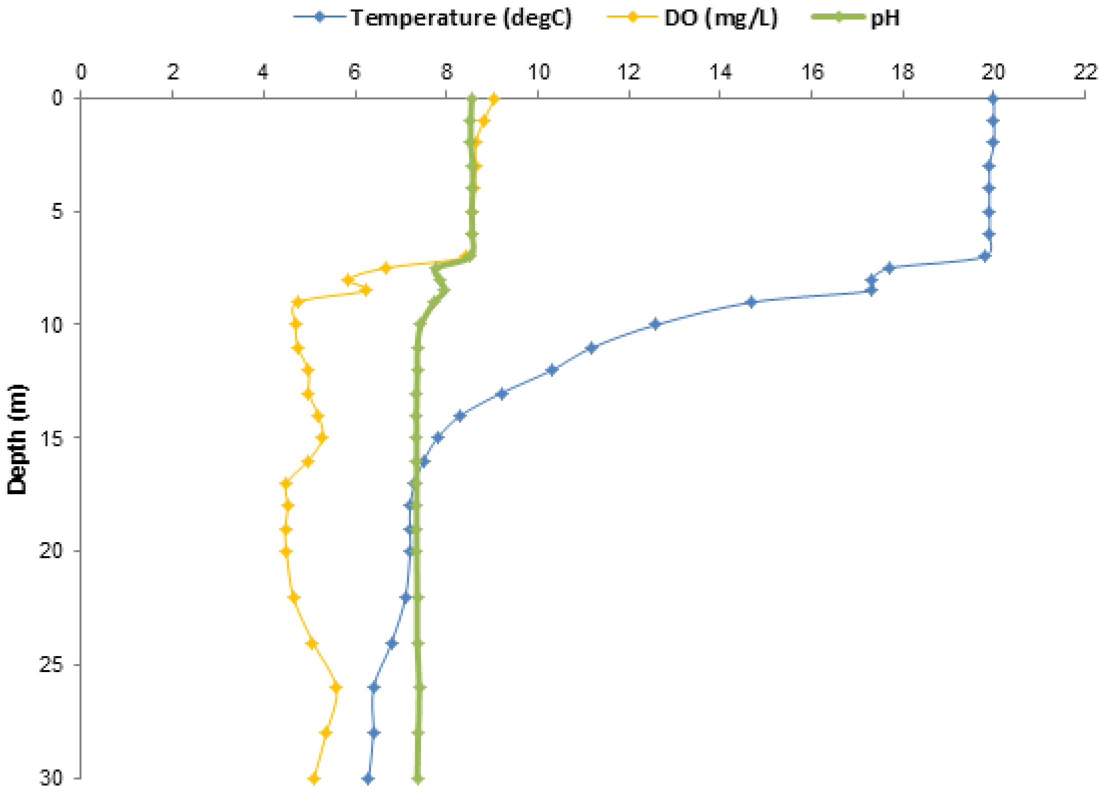
Table 5.10-30 Average habitat characteristics at fishing locations on Christina Lake, summer 2012.

Fishing Method	Field Information		Water Quality				Habitat Characteristics			
	Site	Date	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Temperature (°C)	Substrate	Cover Type	Cover %	Riparian
Electrofishing	E01	10-Aug-2012	21.0	197.4	10.06	8.79	sand, silt	submerged macrophytes, yellow lily, emergent rushes	50	mixed forest
	E02	10-Aug-2012	20.6	195.4	10.39	8.82	silt, cobble	submerged macrophytes	40	rock beach, coniferous forest
	E03	9-Aug-2012	21.5	195.7	9.51	8.86	sand, silt	submerged macrophytes	30	shrubs, coniferous forest
	E04	8-Aug-2012	24.2	189.1	8.59	8.67	sand, silt	submerged macrophytes, yellow lily	50	mixed forest, mainly coniferous
	E05	8-Aug-2012	23.9	184.0	10.06	8.82	sand, silt	submerged macrophytes, yellow lily	25	beach, shrub, mixed forest
	E06	9-Aug-2012	21.1	188.9	8.21	8.59	sand, silt	submerged macrophytes, yellow lily, emergent rushes	50	beach, shrub, mixed forest
	E07	9-Aug-2012	21.2	196.6	8.62	8.65	sand, silt, cobble	submerged/emergent macrophytes	90	rock beach, mixed forest
	E08	7-Aug-2012	na	na	na	na	sand, silt	submerged macrophytes	70	mixed forest
	E09	7-Aug-2012	na	na	na	na	sand, silt	mixed forest, deciduous forest	70	mixed forest
	E10	8-Aug-2012	20.7	197.0	9.26	8.67	sand, silt	submerged macrophytes, yellow lily	50	vegetation, shrubs, deciduous forest
Seine Net	S01	9-Aug-2012	22.3	187.5	9.45	8.91	sand, silt	yellow lily, submerged macrophytes	40	shrubs, coniferous forest
	S02	10-Aug-2012	20.6	198.8	8.97	8.69	sand, silt	submerged macrophytes	trace	coniferous forest
	S03	8-Aug-2012	22.7	187.7	9.39	8.82	sand, silt	submerged macrophytes, floating yellow lily	60	gravel/sand beach, shrubs, conifers
	S04	7-Aug-2012	21.6	186.9	8.6	8.79	sand, silt	submerged macrophytes	10	grasses, shrubs, deciduous forest
	S05	7-Aug-2012	21.2	187.8	8.43	8.77	sand, silt	submerged macrophytes	20	deciduous forest on beach
	S06	10-Aug-2012	20.0	199.0	8.4	8.57	silt, sand	submerged macrophytes, logs	25	mixed forest
	S07	9-Aug-2012	21.5	195.5	9.07	8.75	organics, silt	submerged/emergent macrophytes	5	beach, rushes, mixed forest
	S08	8-Aug-2012	23.7	187.7	9.81	8.78	sand, silt	submerged macrophytes, floating lilies	40	sand beach, mixed deciduous forest
	S09	6-Aug-2012	22.9	198.8	8.51	8.64	sand, silt	submerged macrophytes	30	-

Table 5.10-30 (Cont’d.)

Fishing Method	Field Information		Water Quality				Habitat Characteristics			
	Site	Date	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Temperature (°C)	Substrate	Cover Type	Cover %	Riparian
Seine Net (Cont’d.)	S10	10-Aug-2012	17.7	315.7	6.85	7.77	organics, silt	submerged macrophytes	10	grasses, shrubs, deciduous forest
	S11	8-Aug-2012	22.4	185.6	11.15	8.88	sand, silt	submerged macrophytes	20	grasses, mixed forest
	S12	10-Aug-2012	19.7	198.5	9.17	8.66	sand	submerged macrophytes	trace	shrubs, deciduous forest
	S13	9-Aug-2012	21.4	197.6	7.84	8.47	cobble, sand	fallen tree, yellow lily	55	shrubs, mixed forest
	S14	9-Aug-2012	21.6	188.4	8.92	8.79	sand	yellow lily, submerged macrophytes	20	grassland, shrubs, conifers
	S15	7-Aug-2012	22.1	189.6	8.59	8.69	sand, silt	submerged macrophytes	trace	emergent rushes, shrubs, deciduous forest
Hoopnet	T01	9-Aug-2012	22.0	199.0	8.47	8.69	cobble, sand	floating macrophytes	trace	shrub, mixed forest
	T02	6-Aug-2012	24.3	197.2	9.4	8.89	Clay, silt	submerged macrophytes	70	emergent reeds, rushes
	T03	9-Aug-2012	21.0	197.5	7.64	8.52	Sand, silt	submerged macrophytes	20	shrub, mixed forest, roads
	T04	8-Aug-2012	22.5	191.2	8.54	8.62	sand, silt	emergent horsetails	90	grass, shrubs
	T05	9-Aug-2012	20.9	198.6	6.94	8.29	sand, silt	submerged/emergent macrophytes	20	mixed forest
	T06	7-Aug-2012	22.6	89.3	8.09	8.73	sand, silt	submerged macrophytes, floating algae	70	mixed forest
	T07	6-Aug-2012	21.8	196.8	8.53	8.63	sand, silt	submerged macrophytes	20	rocky shoreline, few logs
	T08	7-Aug-2012	20.8	187.1	7.86	8.73	sand, silt	rocky	trace	rocky, deciduous forest
	T09	8-Aug-2012	22.0	175.5	8.58	8.85	sand, silt, organic	submerged/floating macrophytes	20	rocky/gravel, mixed forest
	T10	8-Aug-2012	21.2	186.4	7.72	8.71	sand, silt	emergent vegetation	10	beach, grass, shrubs, mixed forest
	T11	7-Aug-2012	20.9	188.1	6.76	8.73	sand, silt	submerged macrophytes, overhanging poplars	10	sand beach, shrubs, deciduous forest
	T12	6-Aug-2012	22.2	197.1	9.15	8.85	sand, silt	floating macrophytes	10	fallen trees

Figure 5.10-24 Depth profiles of temperature (ºC), dissolved oxygen (mg/L), pH, and conductivity (µS/cm) in Christina Lake, August 2012.



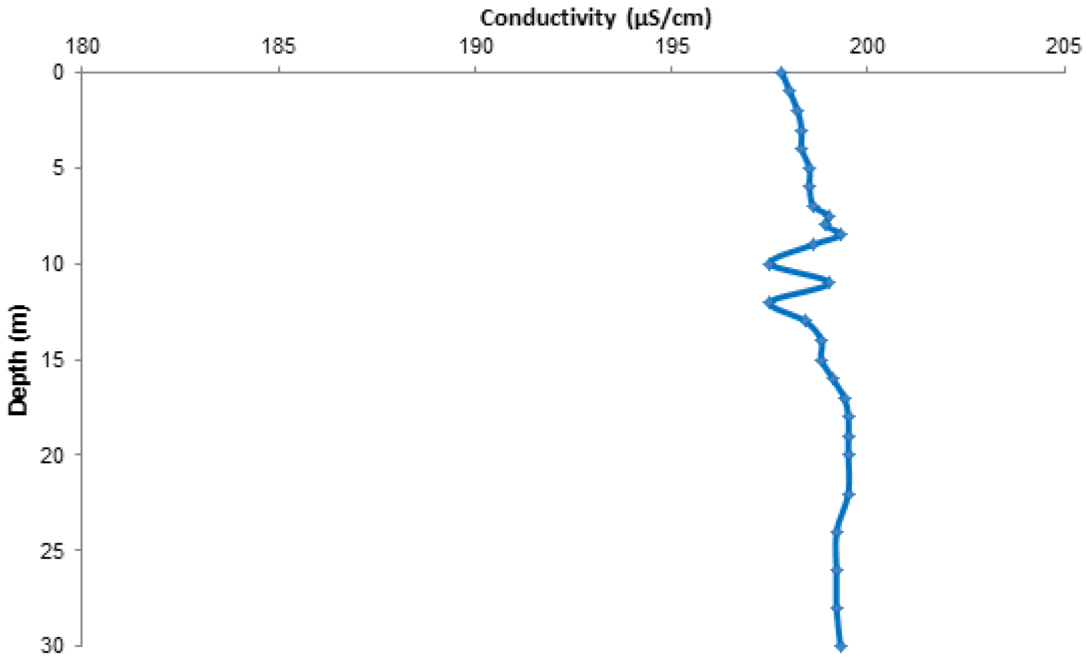


Table 5.10-31 Number of fish captured by fishing method, summer 2012.

Fishing Method	Species									Total Fish Caught
	iowa darter	ninespine stickleback	northern redbelly dace	spottail Shiner	trout-perch	yellow perch	northern pike	walleye	white sucker	
Hoopnet	0	0	0	0	0	0	9	1	2	12
Seine Net	61	190	0	73	15	7	2	0	0	348
Electrofishing	0	20	1	87	0	250	27	24	15	424

Figure 5.10-25 Total number of fish captured by species and fishing method (boat electrofishing, hoopnetting, and beach seining, summer 2012.

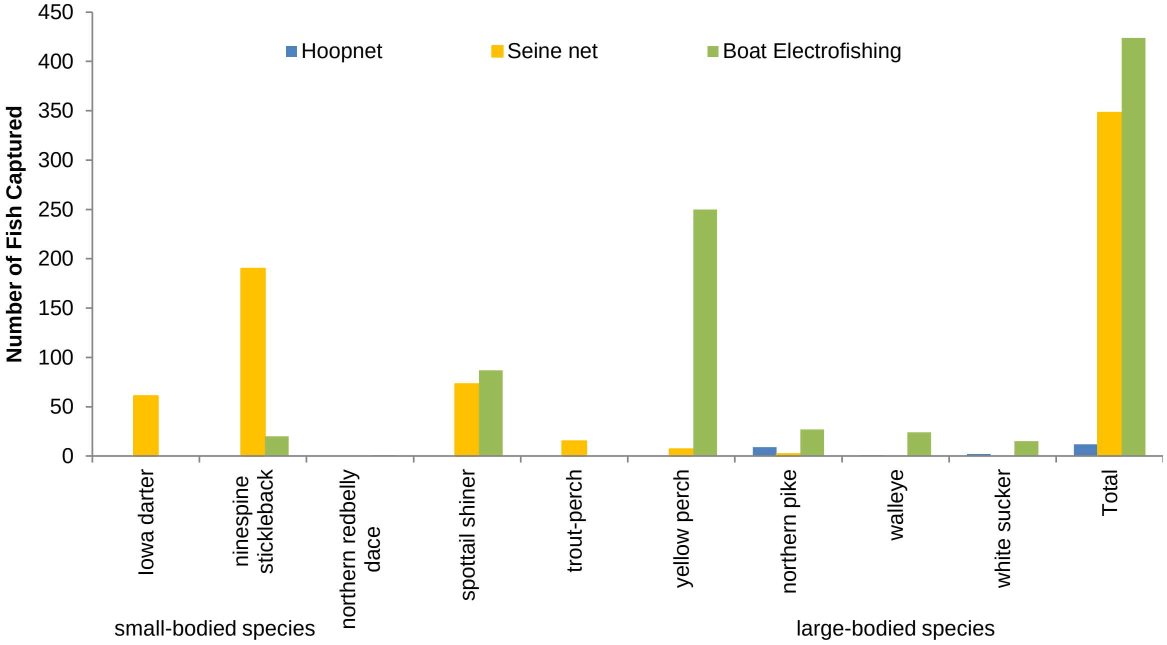


Table 5.10-32 Metrics and mercury concentrations in northern pike and walleye collected from Gregoire Lake, fall 2012, and screening of concentrations against criteria for fish consumption for the protection of human health.

Species	Sample ID	Sex	Length (mm)	Weight (g)	Age	Hg (mg/kg)
NRPK	GL-5	F	444	600	3	0.124
NRPK	GL-7	F	485	725	5	0.117
NRPK	GL-9	M	466	660	4	0.136
NRPK	GL-10	M	457	620	4	0.132
NRPK	GL-13	M	417	500	3	0.081
NRPK	GL-14	F	335	231	1	0.042
NRPK	GL-19	F	481	700	3	0.101
NRPK	GL-22	M	423	525	3	0.145
NRPK	GL-23	M	261	400	1	0.038
NRPK	GL-25	F	451	580	3	0.108
NRPK	GL-26	F	288	163	1	0.048
Mean			**410**	**519**	**3**	**0.097**
WALL	GL-1*	F	495	1,300	11	0.184
WALL	GL-2	M	363	600	6	0.072
WALL	GL-3	U	229	127	1	0.037
WALL	GL-4	F	420	900	8	0.147
WALL	GL-6*	F	441	1,100	8	0.103
WALL	GL-8*	F	470	1,200	8	0.163
WALL	GL-11*	F	481	1,300	8	0.126
WALL	GL-12	M	372	600	6	0.139
WALL	GL-15	F	488	145	10	0.172
WALL	GL-16	M	360	500	6	0.148
WALL	GL-17	M	350	500	6	0.100
WALL	GL-18*	F	470	1,150	10	0.168
WALL	GL-20	M	374	650	6	0.139
WALL	GL-21*	F	472	1,450	10	0.145
WALL	GL-24*	F	462	1,150	8	0.139
Mean			**416**	**845**	**7**	**0.132**

M – Male; F – Female; U – Undetermined

* Refer to Table 3.4-9 for fish consumption guidelines Gregoire Lake for walleye northern pike >908 g (GOA 2009).

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.10-26 **Temporal comparison of mercury concentration in northern pike from Gregoire Lake, 2002, 2007, and 2012.**

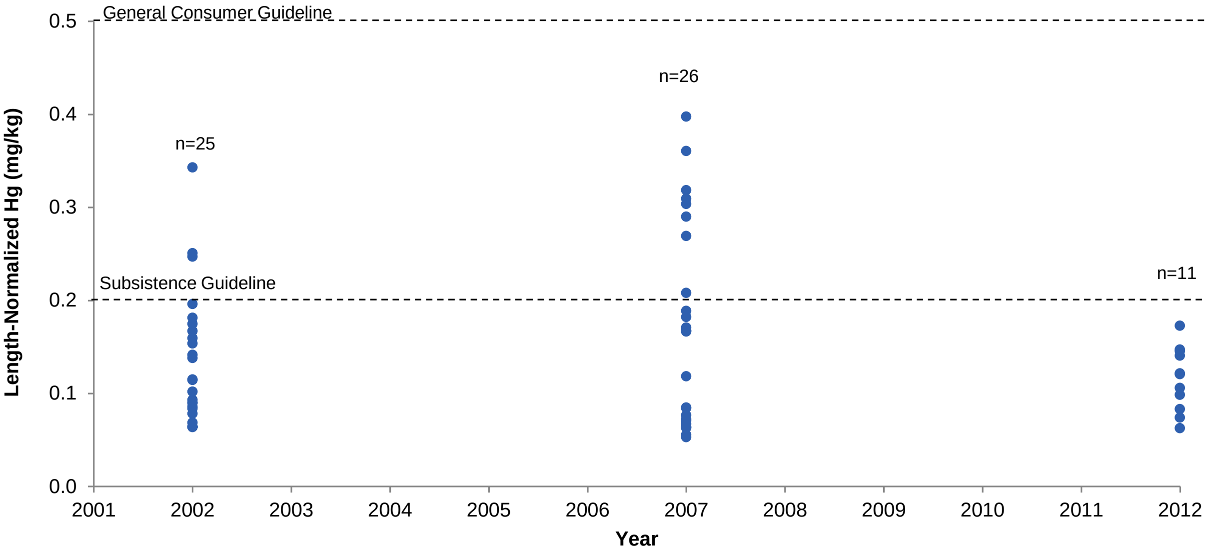


Figure 5.10-27 **Temporal comparison of mercury concentration in walleye from Gregoire Lake, 2002, 2007, 2012.**

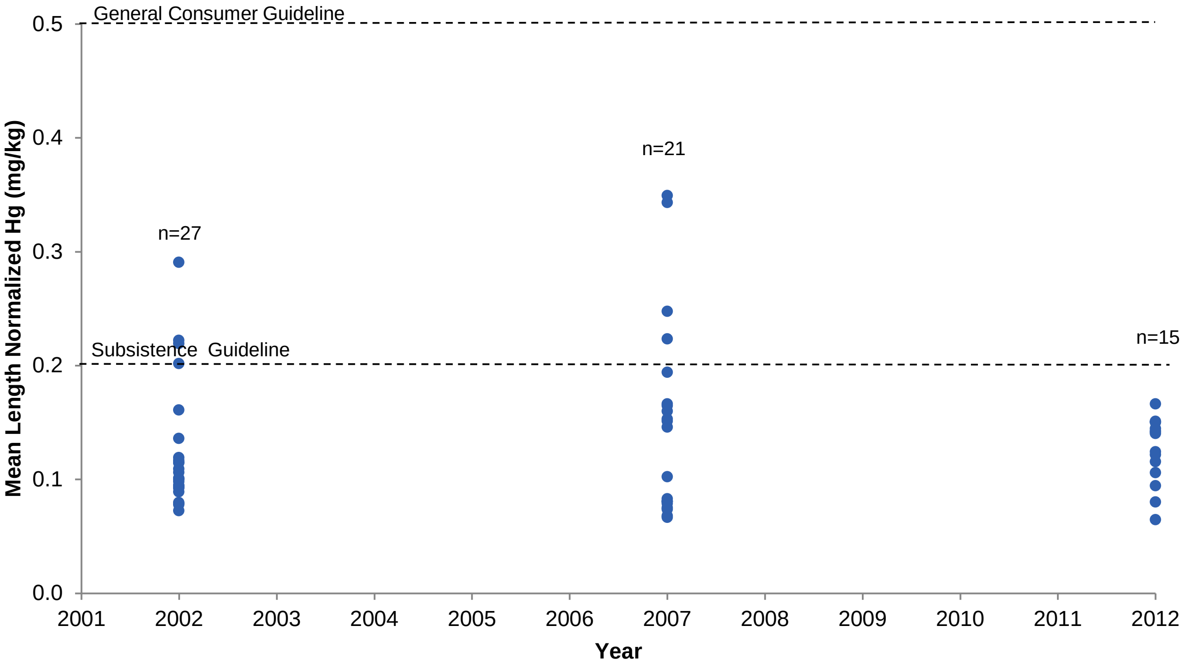


Figure 5.10-28 **Temporal comparison of the relationship between fork length and mercury concentrations in the tissue of northern pike from Gregoire Lake, 2002, 2007, and 2012.**

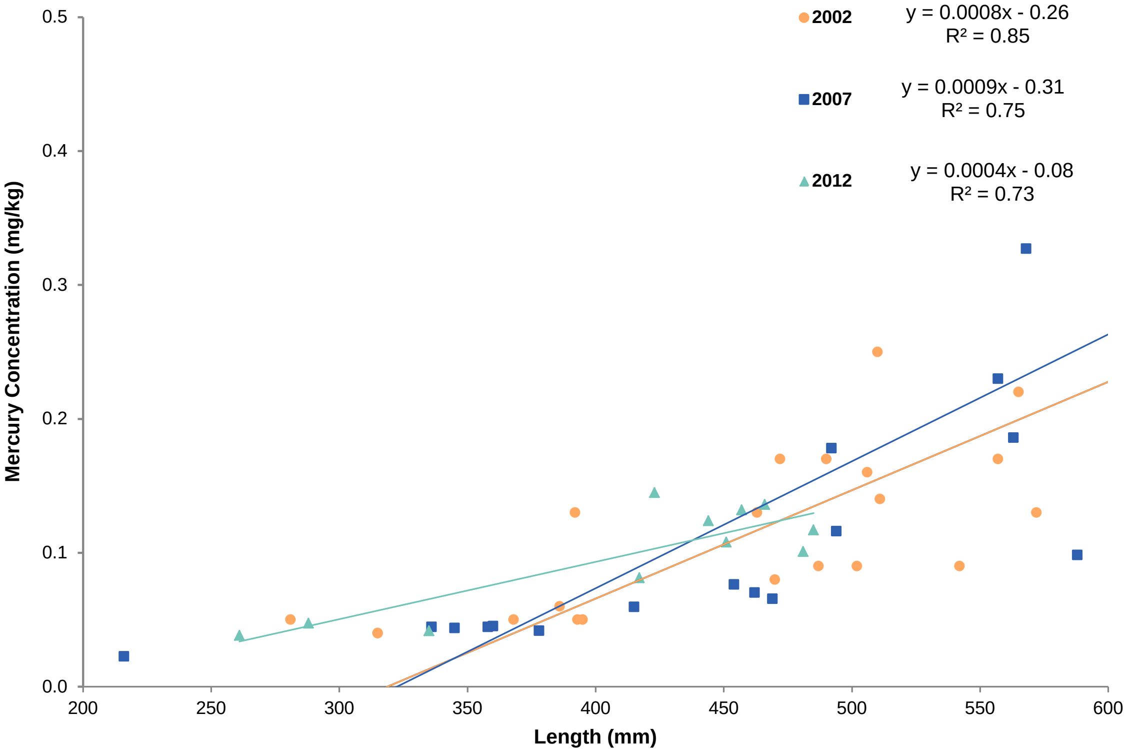


Figure 5.10-29 Temporal comparison of the relationship between fork length and mercury concentrations in the tissue of walleye from Gregoire Lake, 2002, 2007, and 2012.

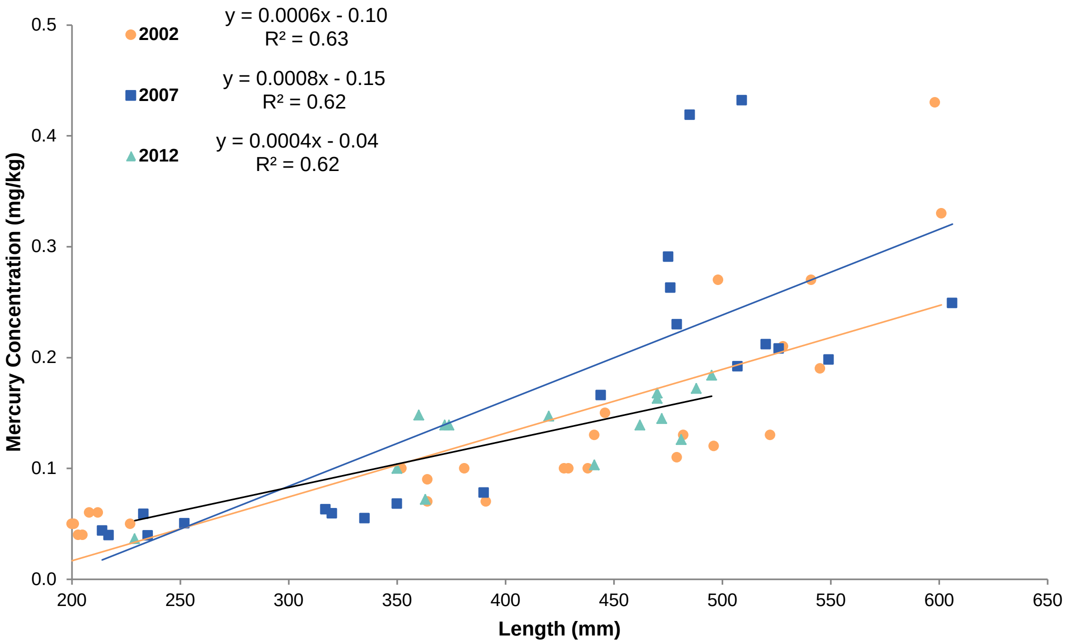


Figure 5.10-30 Regional comparison of mean length-normalized concentrations of mercury in northern pike across lakes sampled by RAMP/ESRD, 2002 to 2012.

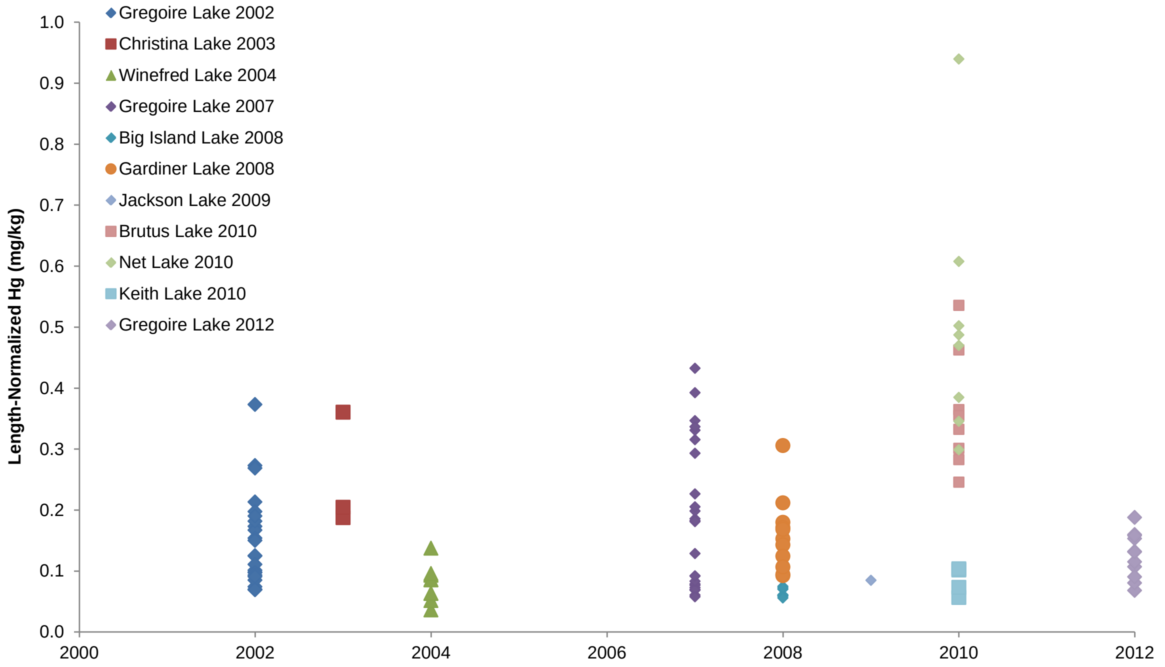
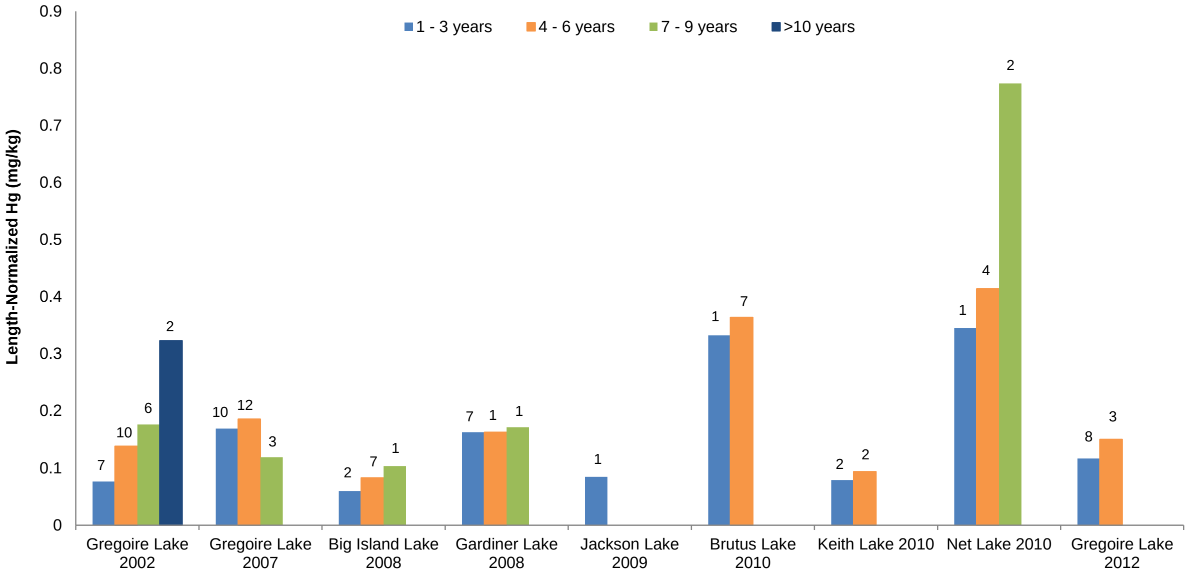


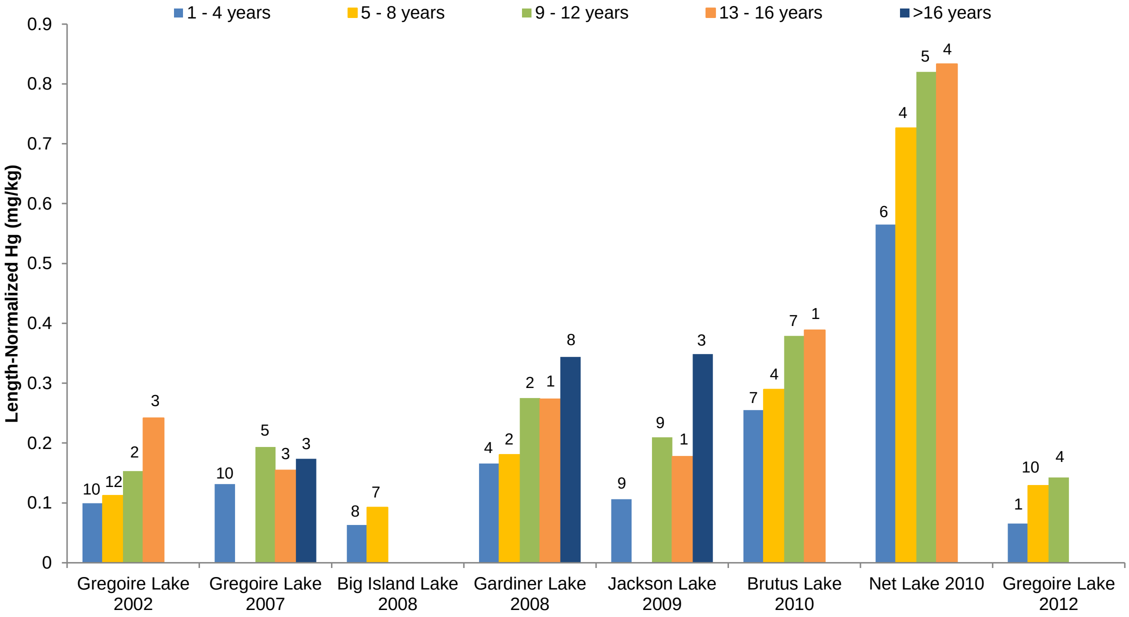
Figure 5.10-31 Regional comparison of mean length-normalized concentrations of mercury in walleye across lakes sampled by RAMP/AESRD, 2002 to 2012.

Figure 5.10-32 Regional comparison of mean length-normalized concentrations of mercury by age class of northern pike across lakes sampled by RAMP/AESRD, 2002 to 2012.



Note: the number above each bar represents the sample size.

Figure 5.10-33 Regional comparison of mean length-normalized concentrations of mercury by age class of walleye across lakes sampled by RAMP/AESRD, 2002 to 2012.



Note: the number above each bar represents the sample size.

Figure 5.10-34 Regional comparison of mean length-standardized concentrations of mercury in northern pike from lakes in Alberta, 1973 to 2012 (sample size represented by number on each bar; orange bar denotes current sampling year).

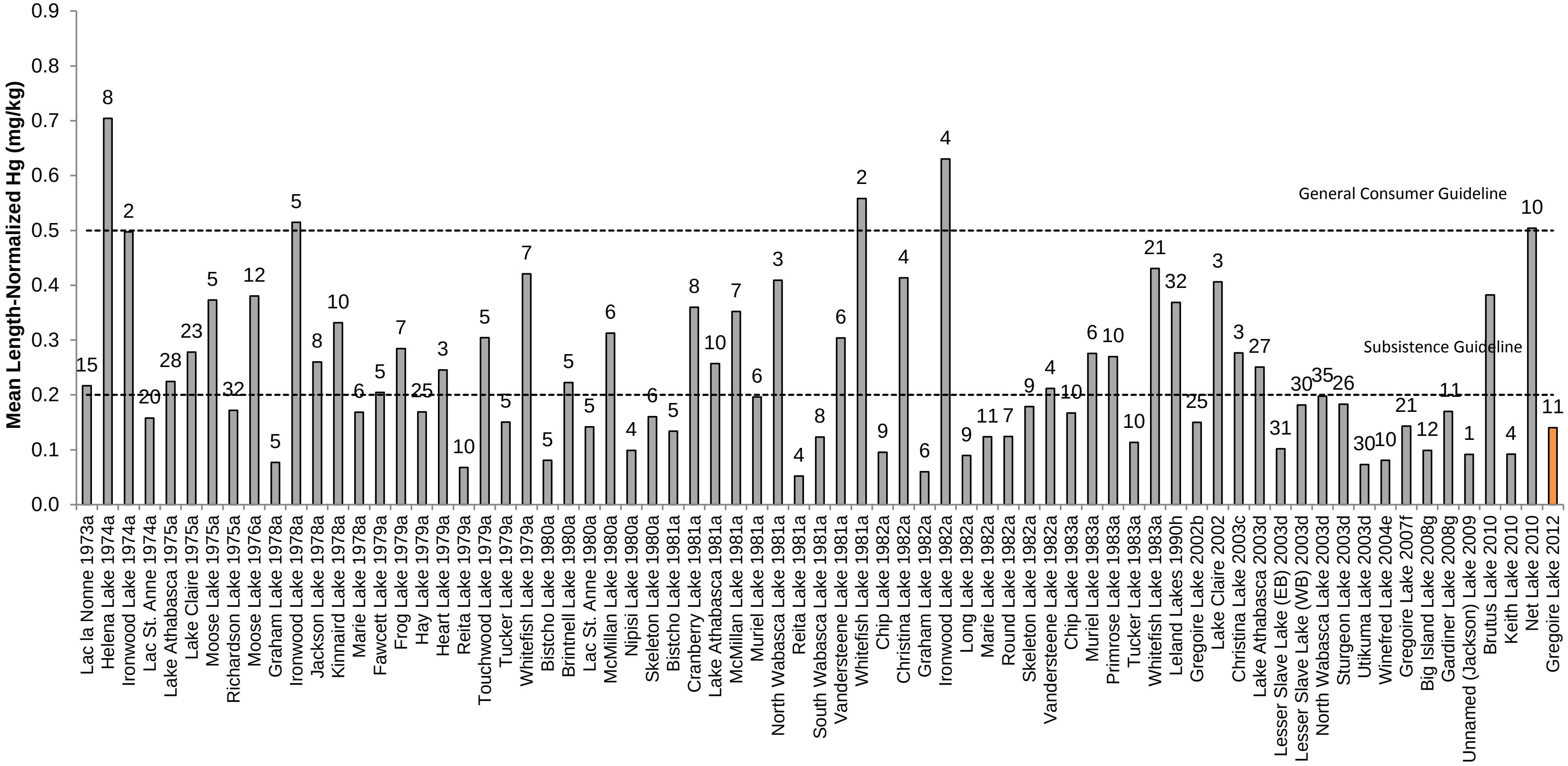
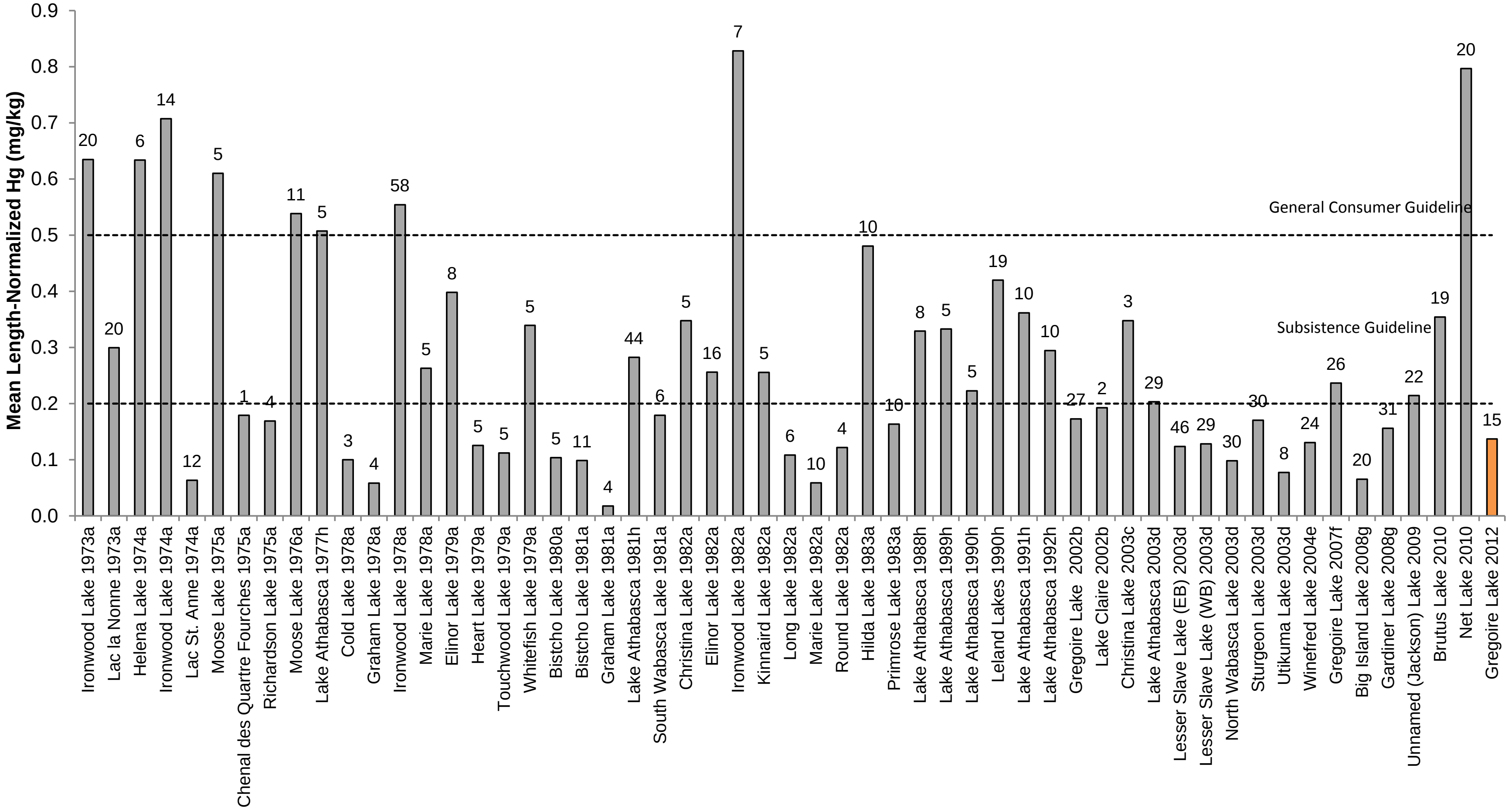


Figure 5.10-35 Regional comparison of mean length-normalized concentrations of mercury in walleye from lakes in Alberta, 1973 and 2012 (sample size represented by number on each bar; orange bar denotes current sampling year).



5.11 HANGINGSTONE RIVER WATERSHED

Table 5.11-1 Summary of results for the Hangingstone River watershed.

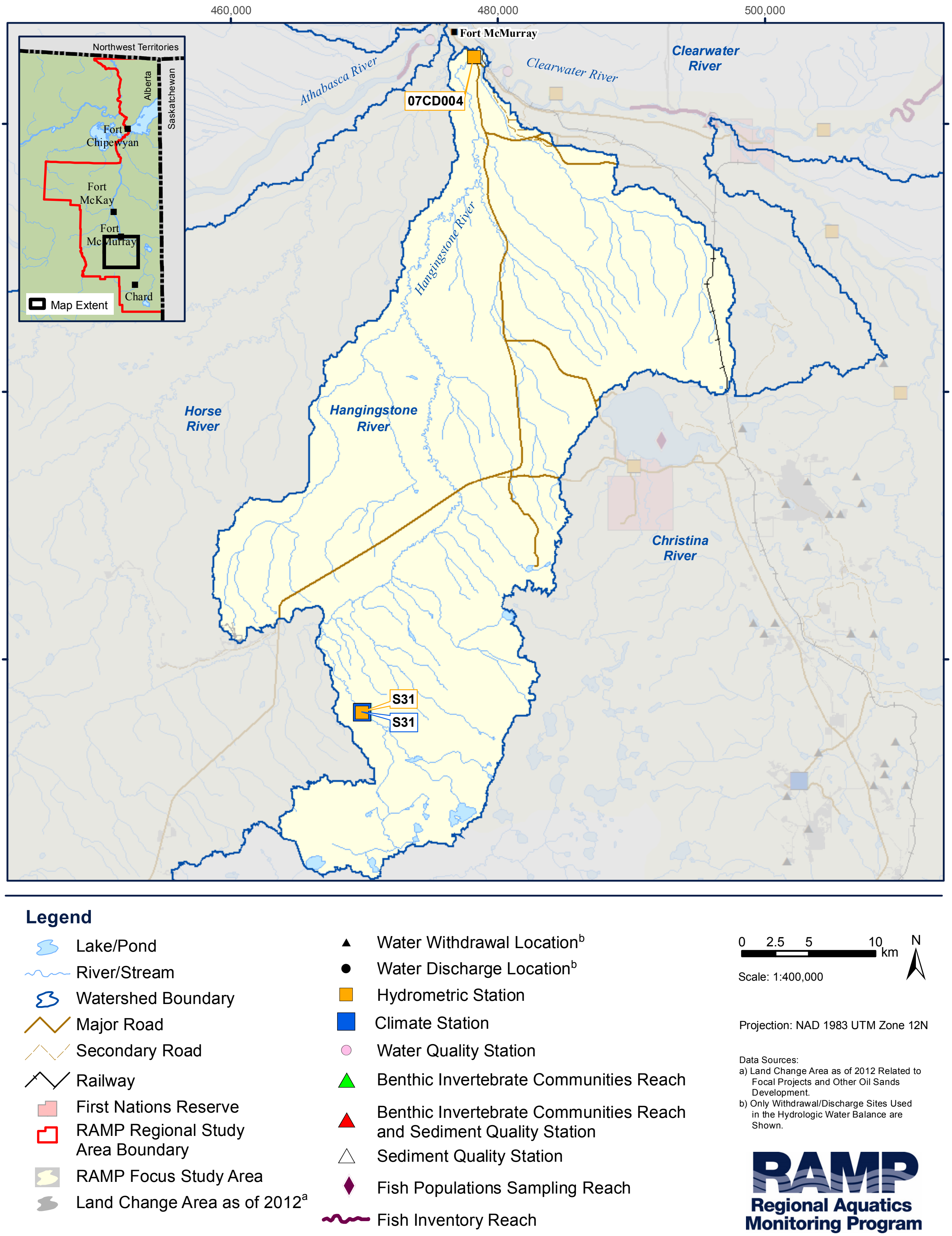
Hangingstone River	**Summary of 2012 Conditions**
Climate and Hydrology	
Criteria	**WSC 07CD004,** Hangingstone River at Fort McMurray
Mean open-water season discharge	🟡
Mean winter discharge	not measured
Annual maximum daily discharge	🟡
Minimum open-water season discharge	🟡
Water Quality	
No Water Quality component activities conducted in 2012	
Benthic Invertebrate Communities and Sediment Quality	
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2012	
Fish Populations	
No Fish Populations component activities conducted in 2012	

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.

Figure 5.11-1 Hangingstone River watershed.



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5.11.1 Summary of 2012 Conditions

Approximately 0.05% (56 ha) of the Hangingstone River watershed had undergone land change as of 2012 from focal projects, with no change from 2011 (Table 2.5-2). Land change has occurred in a small area in the upper portion of the watershed related to the JACOS Hangingstone project.

Monitoring activities were conducted for the Climate and Hydrology component of RAMP in the Hangingstone River watershed in 2012. Table 5.11-1 is a summary of the 2012 assessment of the Hangingstone River watershed, while Figure 5.11-1 denotes the location of the monitoring stations for each RAMP component and the area of land change for 2012 in the Hangingstone River watershed.

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

5.11.2 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring for the Hangingstone River watershed was conducted at the WSC Station 07CD004, Hangingstone River at Fort McMurray. The data from this station were used for the water balance analysis. Additional hydrometric data for the Hangingstone River watershed were available from RAMP Station S31, Hangingstone Creek at North Star Road, and details for this station can be found in Appendix C.

Continuous annual hydrometric data have been collected for WSC Station 07CD004 from 1970 to 1986, and seasonal data from March to October have been collected every year since 1970. Partial records exist from 1965 to 1969. The open-water (May to October) runoff volume recorded at WSC Station 07CD004 was 98 million m^3. This value was 2% lower than the historical mean open-water runoff volume. Flows increased during freshet in April and early May 2012 to a peak flow of 9.03 m^3/s on May 4, which was almost 2 m^3/s greater than the historical median flow on this date. Following the freshet, flows decreased to below historical lower quartile values in early June. Rainfall in early and late July increased flows to greater than the historical upper quartile values. Flows decreased sharply in August and into early September, which resulted in the lowest open-water flow of 1.01 m^3/s on September 1, 2012. Flows increased in response to rainfall events in September, reaching a maximum open-water daily flow of 30.40 m^3/s on September 13, 2012. This value was 23% higher than the historical mean open-water maximum daily flow. Flows decreased steadily until mid-October and then increased again in mid-October to above historical upper quartile values until the end of the 2012 WY (Figure 5.11-2).

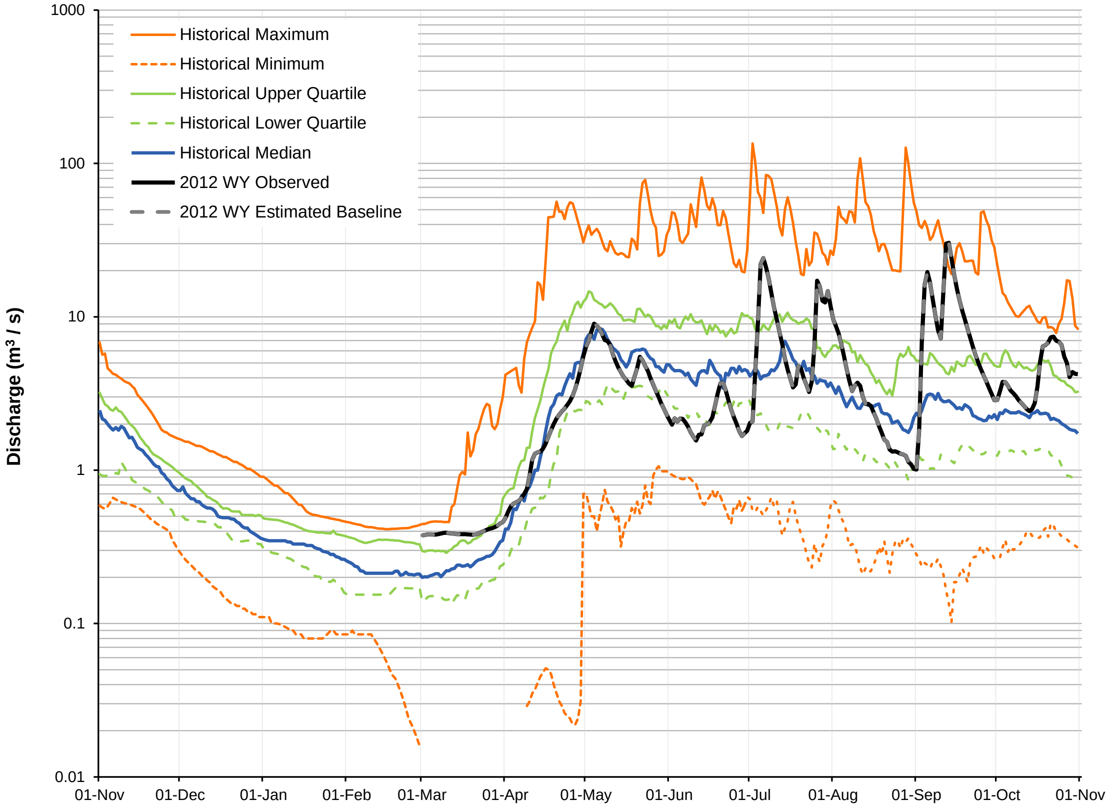
Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at WSC Station 07CD004, for March 1 to October 31, 2012 is provided in Table 5.11-2 and described as follows:

1. The closed-circuited land area from focal projects as of 2012 in the Hangingstone River watershed was estimated to be 0.47 km^2 (Table 2.5-1). The loss of flow to the Hangingstone River that would have otherwise occurred from this land area was estimated at 0.048 million m^3.

2. As of 2012, the area of land change in the Hangingstone watershed from focal projects that was not closed-circuited was estimated to be 0.09 km^2 (Table 2.5-1). The increase in flow to the Hangingstone River that would not have otherwise occurred was estimated at 0.002 million m^3.

The estimated cumulative effect was a decrease in flow of 0.046 million m^3 to the Hangingstone River. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.11-2. The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.11-3). These differences were classified as **Negligible-Low** (Table 5.11-1).

Figure 5.11-2 **The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Hangingstone River in the 2012 WY, compared to historical values.**



Note: Observed 2012 WY hydrograph based on Hangingstone River at Fort McMurray, WSC Station 07CD004, provisional data for March 1 to October 31, 2012. 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 calculated for the period from 1965 to 2011, and historical values for other months calculated for the period from 1970 to 1987.

Note: Historical minimum daily flows are zero from March 1 to April 8, and are not plotted here due to the logarithmic axis used in the graph.

Table 5.11-2 Estimated water balance at WSC Station 07CD004, Hangingstone River at Fort McMurray, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**98.28**	**Observed discharge, obtained from Hangingstone River at Fort McMurray, WSC Station 07CD004**
Closed-circuited area water loss from the observed hydrograph	-0.048	Estimated 0.47 km^2 of Hangingstone River watershed closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.002	Estimated 0.09 km^2 of Hangingstone River watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Hangingstone River watershed from focal projects	0	Assumed
Water releases into the Hangingstone River watershed from focal projects	0	Assumed
Diversions into or out of the watershed	0	Assumed
The difference between observed and estimated hydrographs on tributary streams	0	No focal projects on tributaries of Hangingstone River not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**98.33**	**Estimated discharge at Hangingstone River at Fort McMurray, WSC Station 07CD004**
Incremental flow (change in total discharge)	-0.046	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-0.05%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data for March 1 to October 31, 2012 for Hangingstone River at Fort McMurray, WSC Station 07CD004.

Table 5.11-3 Estimated change in hydrologic measurement endpoints for the Hangingstone River watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water period discharge	5.82	5.81	-0.05%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	30.41	30.40	-0.05%
Open-water period minimum daily discharge	1.01	1.01	-0.05%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Values are calculated from provisional data for March 1 to October 31, 2012 for Hangingstone River at Fort McMurray, WSC Station 07CD004.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to two 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.

5.12 PIERRE RIVER AREA

Table 5.12-1 Summary of results for watersheds in the Pierre River area.

Pierre River Area	Summary of 2012 Conditions			
Climate and Hydrology				
Criteria	**S48** Big Creek	**S44** Pierre River	**S50A** Red Clay Creek	**S49** Eymundson Creek at 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				
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2012				
Fish Populations				
No Fish Populations component activities conducted in 2012				

Legend and Notes

🟡	Negligible-Low
🟠	Moderate
🟤	High
🟩	*baseline*
🟦	*test*

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.

Figure 5.12-1 Pierre River area watersheds.

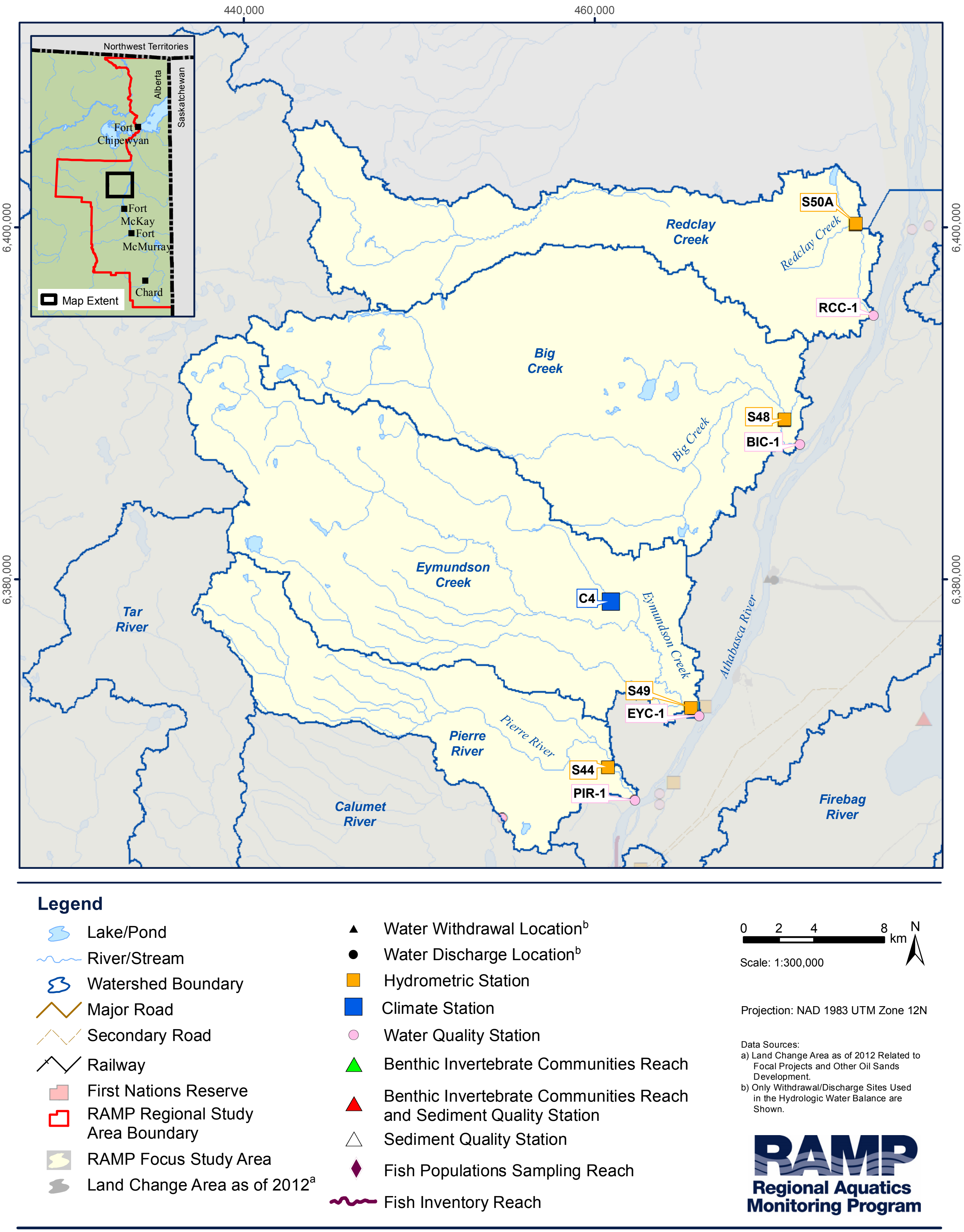


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Figure 5.12-2 Representative monitoring stations of the watersheds in the Pierre River area, fall 2012.

Hydrology Station S44: Pierre River

Hydrology Station S50: Red Clay Creek

Water Quality Station EYC-1 (Eymundson Creek): Left Downstream Bank

Water Quality Station RCC-1 (Red Clay Creek): mid-channel facing upstream

Water Quality Station BIC-1 (Big Creek): Right Downstream Bank

Water Quality Station PIR-1 (Pierre River): Left Downstream Bank

5.12.1 Summary of 2012 Conditions

As of 2012, there has been no land change in watersheds in the Pierre River area from focal projects and other oil sands developments. This section includes 2012 results for the Pierre River, Red Clay Creek, Big Creek, and Eymundson Creek, which are all designated as *baseline* watercourses.

Monitoring was conducted for the Climate and Hydrology and Water Quality components in watersheds in the Pierre River area in 2012. Monitoring in these watersheds is 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 is no development. Details for each hydrology station can be found in Appendix C.

Table 5.12-1 is a summary of the 2012 assessment of the watersheds in the Pierre River area, while Figure 5.12-1 denotes the location of the monitoring stations for each RAMP component. Figure 5.12-2 contains 2012 photos of various monitoring stations located in watersheds in the Pierre River area.

Water Quality Differences in water quality in fall 2012 between *baseline* stations BIC-1 (Big Creek), PIR-1 (Pierre River), RCC-1 (Red Clay Creek), and EYC-1 (Eymundson Creek) and regional *baseline* fall conditions were classified as **Negligible-Low**. *Baseline* station EYC-1 differed from the other stations (BIC-1, PIR-1 and RCC-1) in its ionic composition, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station.

5.12.2 Water Quality

In fall 2011, water quality sampling was initiated at several stations in the Pierre River area, in advance of focal project development. In 2012, water quality samples were taken from:

- Big Creek (*baseline* station BIC-1, sampled in spring, summer, and fall);
- Eymundson Creek (*baseline* station EYC-1, sampled in winter, spring, summer and fall);
- Pierre River (*baseline* station PIR-1, sampled in spring, summer, and fall); and
- Red Clay Creek (*baseline* station RCC-1, sampled in spring, summer, and fall).

Winter water quality sampling was not conducted at *baseline* stations BIC-1, PIR-1, and RCC-1 given that these creeks were frozen to depth.

Temporal Trends Trends could not be detected at these stations because there are only two years of data (Table 5.12-2 to Table 5.12-5).

2012 Results Relative to Historical Concentrations Historical comparisons were not possible at these stations because sampling was initiated in 2011.

Ion Balance The ionic composition of water at *baseline* stations BIC-1, PIR-1 and RCC-1 in fall 2012 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. Ionic composition in fall 2011 and fall 2012 was similar among all stations (Figure 5.12-3).

Comparison of 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 2012, with the exception of (Table 5.12-2 to Table 5.12-5):

- total aluminum at *baseline* station BIC-1;
- total aluminum, total nitrogen, and total dissolved phosphorous at *baseline* station PIR-1; and
- total aluminum and total mercury (ultra-trace) at *baseline* station EYC-1.

There were no exceedances of water quality guidelines in fall 2012 at *baseline* station RCC-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured at these four *baseline* stations (Table 5.12-6):

- total aluminum, total and dissolved iron, sulphide, total phenols, and total phosphorus at *baseline* station BIC-1 in spring;
- total aluminum, total iron, total phosphorus, sulphide, total nitrogen and total phenols at *baseline* station BIC-1 in summer;
- total and dissolved iron, total phenols, sulphide, and total phosphorus at *baseline* station BIC-1 in fall;
- total aluminum, total chromium, total iron, sulphide, total nitrogen, and total phenols at *baseline* station EYC-1 in winter;
- total aluminum, total iron, sulphide, total cadmium, total chromium, total copper, total nitrogen, total phenols, total phosphorus, total mercury (ultra-trace), and total zinc at *baseline* station EYC-1 in spring;
- total aluminum, total iron, total cadmium, total chromium, total lead, total zinc, total ultra-trace mercury, total nitrogen, total copper, total phenols, and total phosphorus at *baseline* station EYC-1 in summer;
- total and dissolved iron, total copper, total chromium, sulphide, total phenols, and total phosphorus at *baseline* station EYC-1 in fall;
- total aluminum, total and dissolved iron, sulphide, total phenols, and total phosphorus at *baseline* station PIR-1 in spring;
- total aluminum, total and dissolved iron, sulphide, total phenols, total and dissolved phosphorus, and total nitrogen at *baseline* station PIR-1 in summer;
- total and dissolved iron, total chromium, sulphide, total phenols, and total phosphorus at *baseline* station PIR-1 in fall;
- total aluminum, total phosphorus, total phenols, and total iron at *baseline* station RCC-1 in spring; and
- total iron and total phenols at *baseline* station RCC-1 in summer and fall.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, 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 mercury (ultra-trace), with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station EYC-1; and
- total arsenic, with a concentration that was lower than the 5th percentile of regional *baseline* concentrations at *baseline* station RCC-1.

Water Quality Index The WQI values for *baseline* stations BIC-1 (98.7), PIR-1 (97.2), EYC-1 (88.3), and RCC-1 (98.7) indicated **Negligible-Low** differences from regional *baseline* water quality conditions (Table 5.12-7).

Classification of Results Differences in water quality in fall 2012 between *baseline* stations BIC-1, PIR-1, EYC-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low**. *Baseline* station EYC-1 differed from the other stations (BIC-1, PIR-1 and RCC-1) in its ionic composition, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station.

Table 5.12-2 Concentrations of water quality measurement endpoints, Big Creek (*baseline* station BIC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.1	8.4
Total suspended solids	mg/L	-	9	15
Conductivity	µS/cm	-	391	446
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.025	0.023
Total nitrogen	mg/L	1	0.91	0.89
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	27	21
Ions				
Sodium	mg/L	-	10.4	11.1
Calcium	mg/L	-	52.5	55.2
Magnesium	mg/L	-	12.4	15.1
Chloride	mg/L	120	0.73	0.63
Sulphate	mg/L	410	8.3	21.5
Total dissolved solids	mg/L	-	265	307
Total alkalinity	mg/L		203	223
Selected metals				
Total aluminum	mg/L	0.1	**0.18**	**0.42**
Dissolved aluminum	mg/L	0.1	0.0040	0.0031
Total arsenic	mg/L	0.005	0.0010	0.0010
Total boron	mg/L	1.2	0.060	0.069
Total molybdenum	mg/L	0.073	0.00031	0.00042
Total mercury (ultra-trace)	ng/L	5, 13	2.0	0.6
Total strontium	mg/L	-	0.15	0.20
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	-	0.05	0.43
Oilsands Extractable	mg/L	-	0.31	1.81
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<8.8	<14.1
Retene	ng/L	-	1.06	3.45
Total dibenzothiophenes	ng/L	-	35.30	9.0
Total PAHs	ng/L	-	206.5	168.6
Total Parent PAHs	ng/L	-	16.41	20.11
Total Alkylated PAHs	ng/L	-	190.0	148.5
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Total iron	mg/L	0.3	**1.46**	**1.25**
Total phenols	mg/L	0.004	**0.0073**	**0.0043**
Total phosphorous	mg/L	0.05	**0.085**	**0.071**
Dissolved iron	mg/L	0.3	**0.575**	0.043
Sulphide	mg/L	0.002	**0.008**	<0.002

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.12-3 Concentrations of water quality measurement endpoints, Pierre River (*baseline* station PIR-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.1	8.3
Total suspended solids	mg/L	-	21	74
Conductivity	µS/cm	-	387	478
Nutrients				
Total dissolved phosphorus	mg/L	0.05	**0.064**	**0.060**
Total nitrogen	mg/L	1	**1.42**	**1.08**
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	41.3	31.7
Ions				
Sodium	mg/L	-	20.2	24.7
Calcium	mg/L	-	41.8	51.0
Magnesium	mg/L	-	12.1	15.2
Chloride	mg/L	120	5.46	7.48
Sulphate	mg/L	270	23.0	34.9
Total dissolved solids	mg/L	-	303	380
Total alkalinity	mg/L		173	206
Selected metals				
Total aluminum	mg/L	0.1	**0.476**	**1.380**
Dissolved aluminum	mg/L	0.1	0.022	0.008
Total arsenic	mg/L	0.005	0.0024	0.0026
Total boron	mg/L	1.2	0.100	0.113
Total molybdenum	mg/L	0.073	0.0010	0.0012
Total mercury (ultra-trace)	ng/L	5, 13	3.8	4.9
Total strontium	mg/L	-	0.164	0.223
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	-	0.06	0.51
Oilsands Extractable	mg/L	-	0.46	1.90
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<8.76	<14.1
Retene	ng/L	-	2.35	4.50
Total dibenzothiophenes	ng/L	-	43.35	51.32
Total PAHs	ng/L	-	260.2	309.5
Total Parent PAHs	ng/L	-	18.27	24.11
Total Alkylated PAHs	ng/L	-	242.0	285.4
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Dissolved iron	mg/L	0.3	**1.74**	**0.79**
Sulphide	mg/L	0.002	**0.017**	**0.018**
Total chromium	mg/L	0.001	**0.0011**	**0.0019**
Total iron	mg/L	0.3	**2.89**	**2.78**
Total phenols	mg/L	0.004	**0.0099**	**0.0068**
Total phosphorous	mg/L	0.05	**0.122**	**0.150**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.12-4 Concentrations of water quality measurement endpoints, Red Clay Creek (*baseline* station RCC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.07	8.3
Total suspended solids	mg/L	-	3	7
Conductivity	µS/cm	-	480	519
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.0098	0.015
Total nitrogen	mg/L	1	0.521	0.501
Nitrate+nitrite	mg/L	1.3	0.071	<0.071
Dissolved organic carbon	mg/L	-	15.7	12.9
Ions				
Sodium	mg/L	-	10.6	13.5
Calcium	mg/L	-	63.4	68.6
Magnesium	mg/L	-	16.5	19.3
Chloride	mg/L	120	1.64	1.62
Sulphate	mg/L	410	35.9	45.2
Total dissolved solids	mg/L	-	317	337
Total alkalinity	mg/L		225	235
Selected metals				
Total aluminum	mg/L	0.1	0.06	**0.30**
Dissolved aluminum	mg/L	0.1	0.0015	0.0012
Total arsenic	mg/L	0.005	0.00019	0.00026
Total boron	mg/L	1.2	0.085	0.083
Total molybdenum	mg/L	0.073	<0.0001	0.00012
Total mercury (ultra-trace)	ng/L	5, 13	1.20	1.00
Total strontium	mg/L	-	0.19	0.25
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	-	0.09	0.20
Oilsands Extractable	mg/L	-	0.48	1.91
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<8.76	<14.13
Retene	ng/L	-	0.51	<2.07
Total dibenzothiophenes	ng/L	-	35.30	6.22
Total PAHs	ng/L	-	220.8	151.5
Total Parent PAHs	ng/L	-	16.44	19.23
Total Alkylated PAHs	ng/L	-	204.4	132.3
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Total iron	mg/L	0.3	**0.31**	**0.58**
Total phenolics	mg/L	0.004	**0.0044**	0.0026

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.12-5 Concentrations of water quality measurement endpoints, Eymundson Creek (*baseline* station EYC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	September 2011
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.0	8.3
Total suspended solids	mg/L	-	54.0	144
Conductivity	µS/cm	-	318.0	531
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.009	0.025
Total nitrogen	mg/L	1	0.97	**1.10**
Nitrate+nitrite	mg/L	1.3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	31.2	26.1
Ions				
Sodium	mg/L	-	11.6	22.5
Calcium	mg/L	-	35.5	57.2
Magnesium	mg/L	-	9.9	17.3
Chloride	mg/L	120	1.5	3.61
Sulphate	mg/L	270	58.6	119
Total dissolved solids	mg/L	-	258.0	400
Total alkalinity	mg/L		98.7	151
Selected metals				
Total aluminum	mg/L	0.1	**1.78**	**4.24**
Dissolved aluminum	mg/L	0.1	0.0821	0.022
Total arsenic	mg/L	0.005	0.00231	0.0038
Total boron	mg/L	1.2	0.074	0.11
Total molybdenum	mg/L	0.073	0.00126	0.0025
Total mercury (ultra-trace)	ng/L	5, 13	**9.2**	**13**
Total strontium	mg/L	-	0.114	0.23
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	-	0.10	0.54
Oilsands Extractable	mg/L	-	0.51	1.39
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<8.76	<14.13
Retene	ng/L	-	4.700	13.60
Total dibenzothiophenes	ng/L	-	79.88	37.08
Total PAHs	ng/L	-	419.1	278.4
Total Parent PAHs	ng/L	-	23.73	24.54
Total Alkylated PAHs	ng/L	-	395.4	253.8
Other variables that exceeded CCME/AESRD guidelines in fall 2012				
Dissolved iron	mg/L	0.3	**1.85**	**0.87**
Total chromium	mg/L	0.001	**0.0031**	**0.0062**
Total iron	mg/L	0.3	**4.09**	**7.46**
Total phenols	mg/L	0.004	**0.0087**	**0.0070**
Total phosphorous	mg/L	0.05	**0.14**	**1.10**
Sulphide	mg/L	0.002	**0.0146**	**0.0280**
Total Copper	mg/L	0.00295[b]	**0.0036**	**0.0058**

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

Values in **bold** are above the guideline.

Figure 5.12-3 **Piper diagram of ion balance in Big Creek, Pierre River, Red Clay Creek, and Eymundson Creek.**

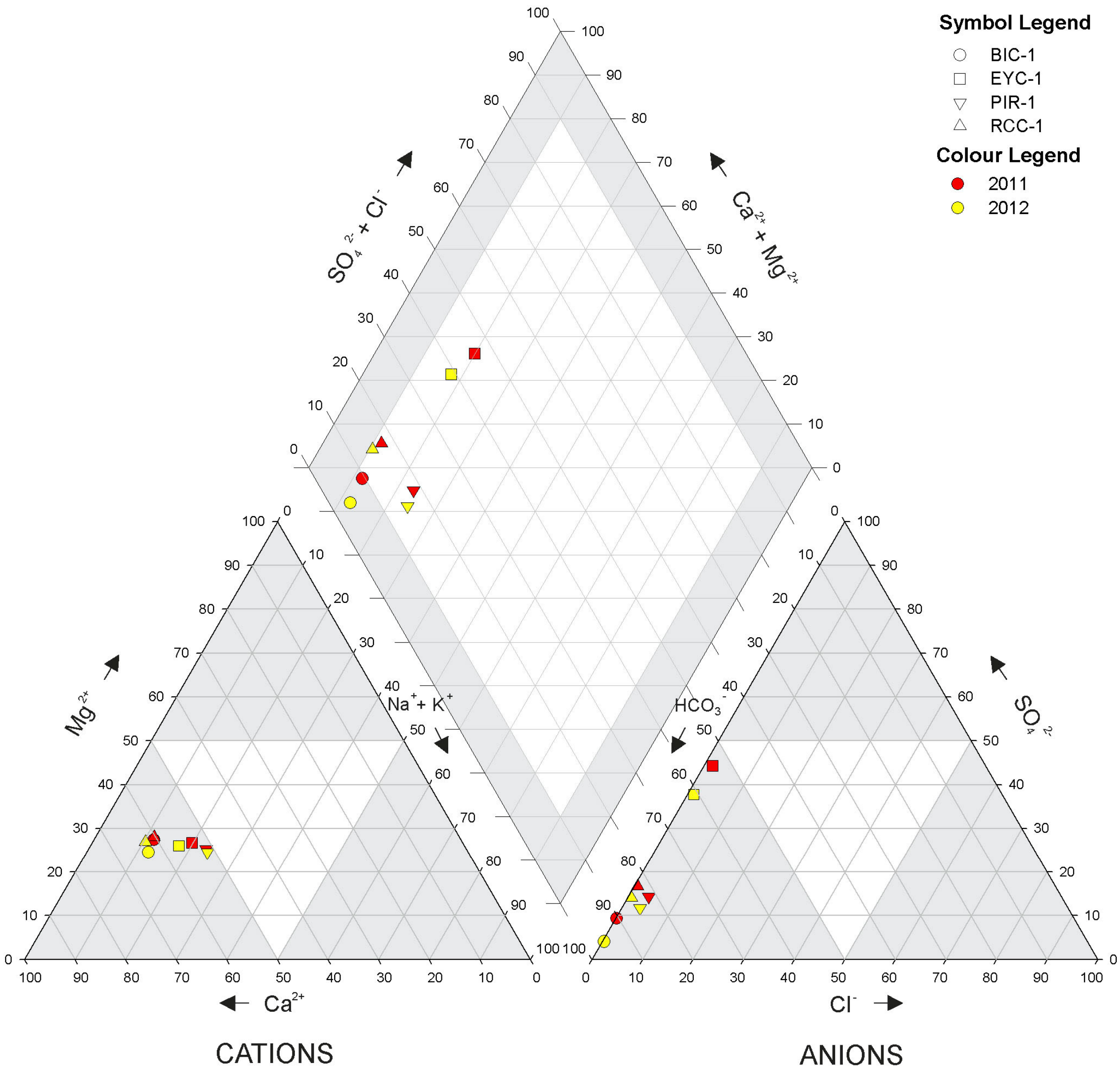


Table 5.12-6 Water quality guideline exceedances at *baseline* stations BIC-1, PIR-1, RCC-1, and EYC-1, 2012.

Variable	Units	Guideline[a]	BIC-1	EYC-1	PIR-1	RCC-1
Winter						
Sulphide	mg/L	0.002	ns	0.003	ns	ns
Total aluminum	mg/L	0.1	ns	0.392	ns	ns
Total chromium	mg/L	0.001	ns	0.001	ns	ns
Total iron	mg/L	0.3	ns	0.680	ns	ns
Total nitrogen	mg/L	1.0	ns	1.14	ns	ns
Total phenols	mg/L	0.004	ns	0.020	ns	ns
Spring						
Dissolved iron	mg/L	0.3	0.31	-	1.10	-
Sulphide	mg/L	0.002	0.005	0.009	0.005	-
Total aluminum	mg/L	0.1	0.30	6.53	0.35	0.54
Total cadmium	mg/L	0.00021[b]	-	0.00036	-	-
Total chromium	mg/L	0.001	-	0.0088	-	-
Total copper	mg/L	0.0032[b]	-	0.0083	-	-
Total iron	mg/L	0.3	1.77	11.40	2.49	4.00
Total mercury (ultra-trace)	ng/L	5, 13	-	27.8	-	-
Total nitrogen	mg/L	1.0	-	1.28	-	-
Total phenols	mg/L	0.004	0.013	0.017	0.008	0.013
Total phosphorus	mg/L	0.05	0.09	0.46	0.09	0.12
Total zinc	mg/L	0.03	-	0.0391	-	-
Summer						
Dissolved iron	mg/L	0.3	-	-	1.65	-
Dissolved phosphorus	mg/L	0.05	-	-	0.0639	-
Sulphide	mg/L	0.002 [1]	0.013	-	0.0148	-
Total aluminum	mg/L	0.1	0.28	8.28	0.16	-
Total cadmium	mg/L	0.00017[b]	-	0.00033	-	-
Total chromium	mg/L	0.001	-	0.015	-	-
Total copper	mg/L	0.0025[b]	-	0.0116	-	-
Total iron	mg/L	0.3	1.19	9.47	2.45	0.34
Total lead	mg/L	0.0034[b]	-	0.0100	-	-
Total mercury (ultra-trace)	ng/L	5, 13	-	7.1	-	-
Total nitrogen	mg/L	1.0	1.08	1.62	1.07	-
Total phenols	mg/L	0.004	0.0182	0.0091	0.0117	0.0042
Total phosphorus	mg/L	0.05	0.074	0.470	0.103	-
Total zinc	mg/L	0.03	-	0.0425	-	-
Fall						
Dissolved iron	mg/L	0.3	0.575	1.85	1.74	-
Dissolved phosphorus	mg/L	0.05	-	-	0.064	-
Sulphide	mg/L	0.002	0.0080	0.0146	0.0171	-
Total aluminum	mg/L	0.1	0.18	1.78	0.48	-
Total chromium	mg/L	0.001	-	0.0031	0.0011	-
Total copper	mg/L	0.0029[b]	-	0.0036	-	-
Total iron	mg/L	0.3	1.46	4.09	2.89	0.31
Total mercury (ultra-trace)	ng/L	5, 13	-	9.2	-	-
Total nitrogen	mg/L	1	-	-	1.42	-
Total phenols	mg/L	0.004	0.0073	0.0087	0.0099	0.0044
Total phosphorus	mg/L	0.05	0.085	0.140	0.122	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

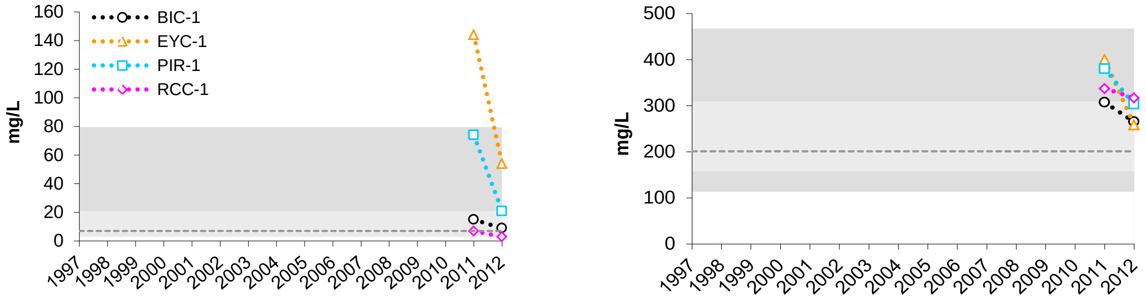
[b] Guideline is hardness-dependent (see Table 3.2-5 for equation).

ns = not sampled

Figure 5.12-4 Concentrations of selected water quality measurement endpoints in *baseline* stations BIC-1, PIR-1, RCC-1, and EYC-1 (fall data) relative to regional *baseline* fall concentrations.

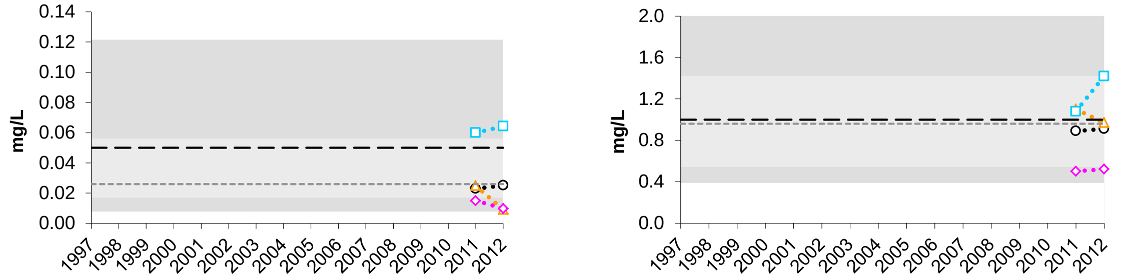
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



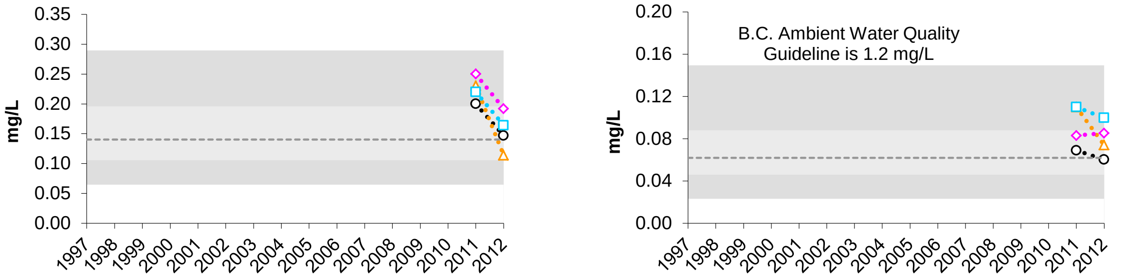
Dissolved Phosphorus

Total Nitrogen



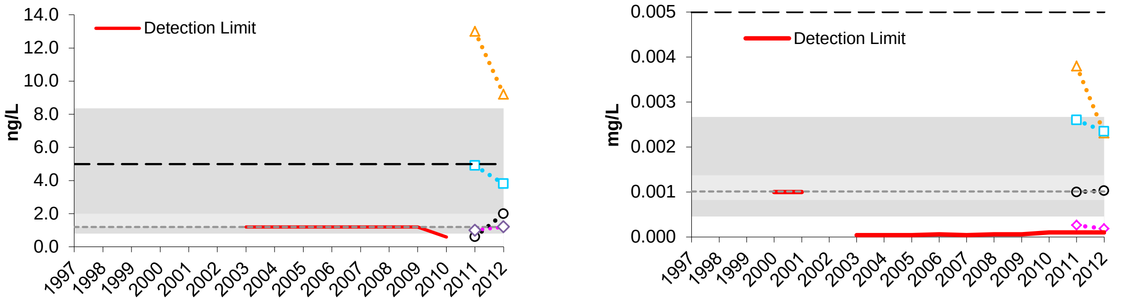
Total Strontium

Total Boron



Total Mercury (Ultra-trace)

Total Arsenic



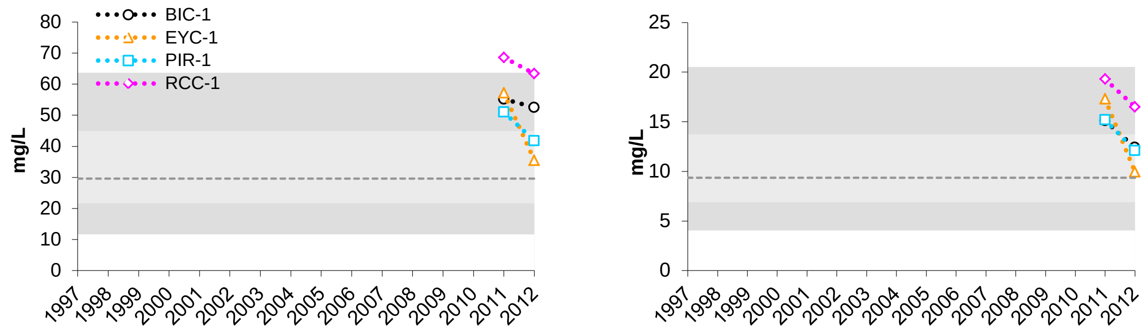
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

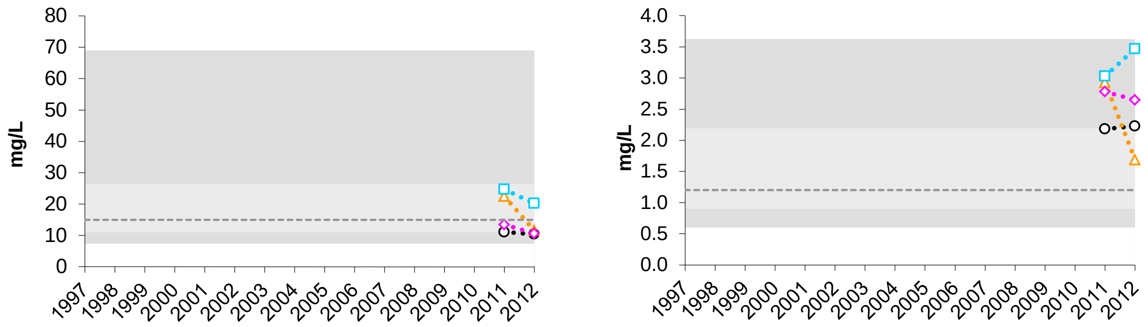
○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

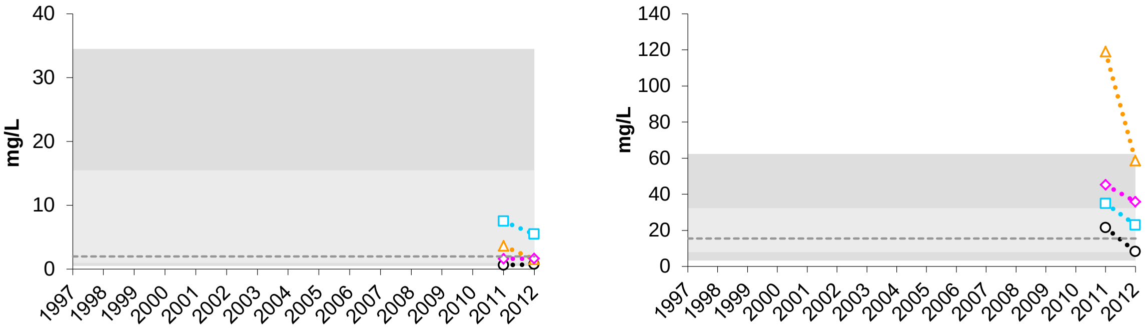
Figure 5.12-4 (Cont'd.)


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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.12-7 Water quality index (fall 2012) for the watersheds in the Pierre River area.

Station	Location	2012 Designation	Water Quality Index	Classification
PIR-1	near the mouth of Pierre River	*baseline*	97.2	Negligible-Low
EYC-1	near the mouth of Eymundson Creek	*baseline*	88.3	Negligible-Low
BIC-1	near the mouth of Big Creek	*baseline*	98.7	Negligible-Low
RCC-1	near the mouth of Red Clay Creek	*baseline*	98.7	Negligible-Low

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5.13 MISCELLANEOUS AQUATIC SYSTEMS

Table 5.13-1 Summary of results for the miscellaneous aquatic systems.

Miscellaneous Aquatic Systems	**Summary of 2012 Conditions**								
	Lakes		***Rivers/Creeks***						
Climate and Hydrology									
Criteria	**L3** Isadore's Lake		**S6** Mills Creek at Highway 63	**S11** Poplar Creek at Highway 63	**S12** Fort Creek at Highway 63	no station sampled	no station sampled	no station sampled	**S25** Susan Lake Outlet
Mean open-water season discharge	not measured		🟤	🟡	🟠				not measured
Mean winter discharge	not measured		🟤	not measured	not measured				not measured
Annual maximum daily discharge	not measured		🟤	🟡	🟠				not measured
Minimum open-water season discharge	not measured		🟤	🟡	🟠				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 sampled
Water Quality Index	n/a	n/a	🟠	🟡	🟡	🟠	🟡	🟠	
Benthic Invertebrate Communities and Sediment Quality									
Criteria	**ISL-1** Isadore's Lake	**SHL-1** Shipyard Lake	no reach sampled	**POC-D1** Poplar Creek lower reach	**FOC-D1** Fort Creek at the mouth	no reach sampled	**BER-D2** Beaver River upper reach	no reach sampled	no reach sampled
Benthic Invertebrate Communities	🟡	🟡		🟠	🟤		n/a		
Sediment Quality Index	n/a	n/a		🟡	🟡		🟡		
Fish Populations									
Criteria	no reach sampled	no reach sampled	no reach sampled	**POC-F1** Poplar Creek lower reach	**FOC-F1** Fort Creek at the mouth	no reach sampled	**BER-F2** Beaver River upper reach	no reach sampled	no reach sampled
Fish Assemblages				🟡	🟡		n/a		

Legend and Notes

🟡 Negligible-Low	*baseline*
🟠 Moderate	*test*
🟤 High	

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station. The WQI/SQI were not calculated given the limited existing *baseline* data.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other 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.

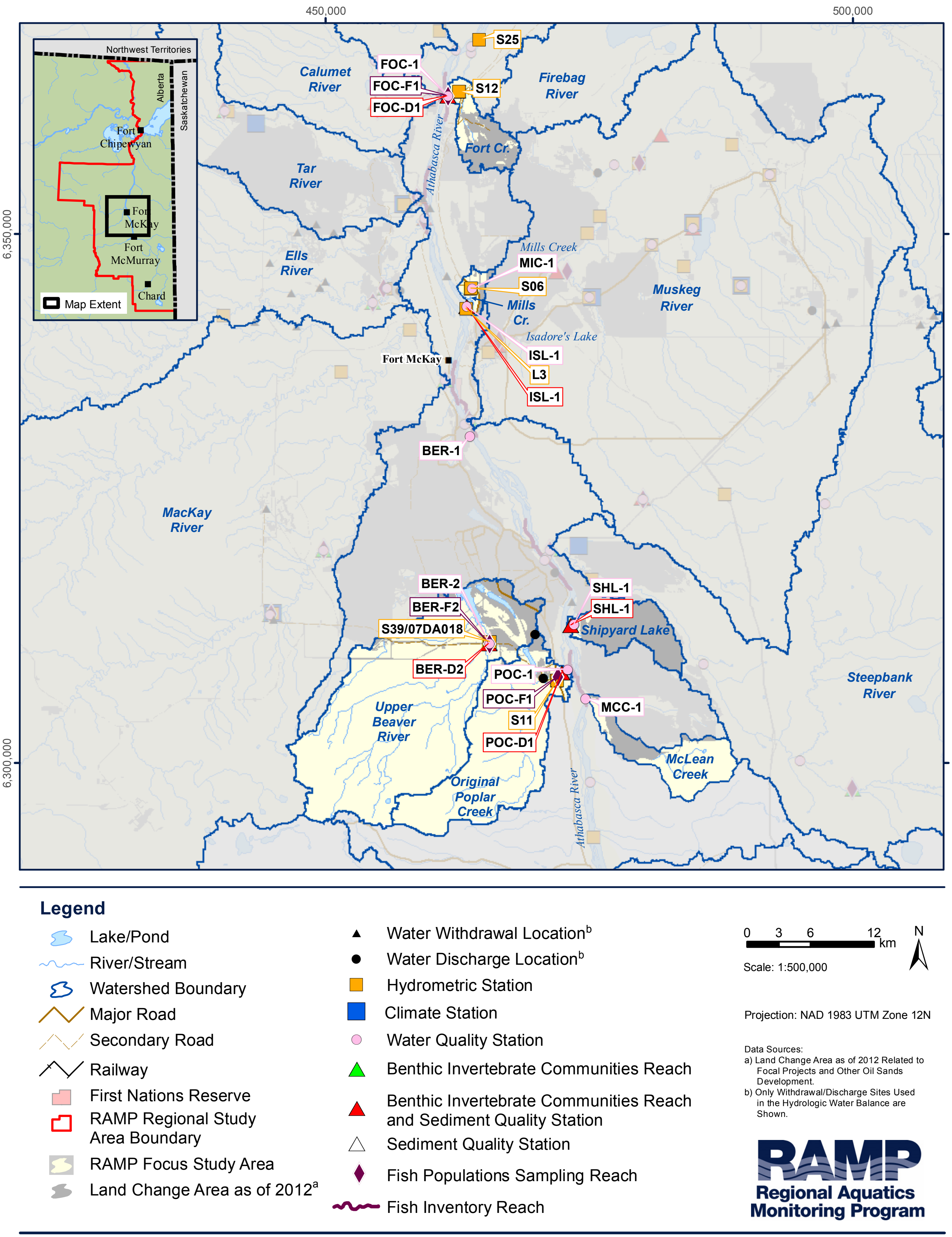
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional baseline conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas 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: 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.



K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_K13_Misc_20130314.mxd

Figure 5.13-2 Representative monitoring stations of miscellaneous aquatic systems, fall 2012.

Water Quality Station BER-2 (Beaver River): Left Downstream Bank

Hydrology Station S12 (Fort Creek): Downstream

Hydrology Station S6: Mills Creek

Water Quality Station SHL-1 (Shipyard Lake): Aerial View

Water Quality Station ISL-1 (Isadore's Lake): Aerial View

Water Quality Station POC-1 (Poplar Creek): Left Upstream Bank

5.13.1 Summary of 2012 Conditions

This section includes 2012 results for the following aquatic systems, each with a specific status:

- Mills Creek, Original Poplar Creek, McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake are designated as *test*. Land change as of 2012 comprised approximately 3.6% (492 ha) of the original Poplar Creek watershed, 65% (2,075 ha) of the Fort Creek watershed, 26.6% (1,255 ha) of the McLean Creek watershed, approximately 32.9% (293 ha) of the Mills Creek watershed, 93% (3,753 ha) of the original watershed draining into Shipyard Lake[1], and approximately 9.7% (2,790 ha) of the Upper Beaver watershed (Table 2.5-1).

Table 5.13-1 is a summary of the 2012 assessment of the miscellaneous aquatic systems in the RAMP FSA, while Figure 5.13-1 denotes the location of the monitoring stations for each RAMP component, reported focal project withdrawal and discharge locations, and the area of land change for 2012. Figure 5.13-2 contains 2012 photos of various monitoring stations located in the miscellaneous aquatic systems in the RAMP FSA.

Isadore's Lake and Mills Creek The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 37.2% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

In the 2012 WY, lake levels in Isadore's Lake generally decreased from November 2011 to early March 2012, with levels in November and December near historical median values and levels from January to late March varying between the historical minimum and lower-quartile values. Lake levels increased during freshet in late March and April followed by decreasing levels until mid-May. Lake levels increased from late May through July in response to rainfall events, and generally remained between the historical maximum and upper quartile values until the end of the 2012 WY.

Differences in water quality in fall 2012 between Mills Creek and regional *baseline* conditions were classified as **Moderate**, likely due to relatively high concentrations of many ions and other dissolved species 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 for the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because the significant (though subtle) increase in %EPT over time and the higher %EPT in 2012 than the mean of previous years does not suggest degrading conditions. The percentage of fauna as EPT taxa has always been <1% (normally EPT are absent), but in 2012, EPT taxa accounted for about half a percent of the fauna. Further, all measurement endpoints were within the range of historical values for the lake. Historically, Isadore's Lake has had a unique benthic invertebrate community compared to other lakes in the area, having low diversity and high abundance of nematodes. While there has been very little negative change over time, the benthic invertebrate community in Isadore's Lake has been representative of a degraded system since sampling was initiated in 2006. Concentrations of most sediment quality measurement endpoints in fall 2012 at *test* station ISL-1 were within previously-measured concentrations with only a few exceptions (i.e., carbon-normalized PAHs and

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[1] The boundary of the original Shipyard Lake watershed was estimated on an overlay of watershed boundaries prepared by CEMA with the 1:50,000 NTDB water and contour layers.

naphthalene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers and the limited *baseline* lake data.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2012 at *test* station SHL-1 were within previously-measured concentrations with only a few exceptions (i.e., magnesium and total aluminum). The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in sodium and chloride concentrations relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the Shipyard Lake watershed (the upper 93% of the Shipyard Lake watershed has been disturbed; see Table 2.5-2). A WQI was not calculated for lakes in 2012 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the limited *baseline* lake data.

Differences in the benthic invertebrate community at *test* station SHL-1 in 2012 were classified as **Negligible-Low**. The increasing trend over time of abundance and taxa richness were significant and strong (explaining > 20% of the total variation in annual means) and were not indicative of degraded water or habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams, and snails, indicating generally good water and sediment quality. Concentrations of most sediment quality measurement endpoints in fall 2012 at *test* station SHL-1 were within previously-measured concentrations with only a few exceptions (i.e., TOC and benzo[a]pyrene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers.

Poplar Creek and Beaver River The calculated mean open-water discharge (May to October) was 1.6% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The annual maximum daily discharge and open-water minimum daily discharge were 1.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Concentrations of several water quality measurement endpoints, primarily ions and other dissolved species, exceeded regional *baseline* concentrations at *test* station BER-1, resulting in a **Moderate** difference from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at *test* station POC-1 and *baseline* station BER-2, differences in water quality in fall 2012 and regional *baseline* conditions were classified as **Negligible-Low**.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach POC-Dl were classified as **Moderate** because of the significant and large differences in abundance, percentage of fauna as EPT taxa, and CA Axis scores compared to *baseline* reach BER-D2. The benthic invertebrate community at *test* reach POC-D1 was in generally good condition, reflected by low relative abundances of worms and higher relative abundances of fingernail clams. The low relative abundance of mayflies and caddisflies, and lack of stoneflies potentially indicated some level of disturbance, but over time the percentage of EPT taxa has been increasing. Differences in sediment quality observed in fall 2012 at *test* station POC-D1 and *baseline* station BER-D2 were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of most sediment quality measurement endpoints were within the range of previously-measured concentrations and within the range of regional *baseline* conditions.

Differences in measurement endpoints for fish assemblages between *test* reach POC-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the assemblage tolerance index (ATI) was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured, and not reflective of degrading conditions in Poplar Creek.

McLean Creek Concentrations of water quality measurement endpoints at *test* station MCC-1 were often higher than regional *baseline* concentrations in fall 2012. Concentrations of TSS, TDS, and many ions and dissolved species of water quality measurement endpoints were high relative to regional *baseline* conditions and exhibited guideline exceedances, indicating a **Moderate** difference from regional *baseline* concentrations.

Fort Creek The calculated mean open-water period (May to October) discharge volume was 11.7% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Moderate**. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed. This variability in daily flow was sufficiently large to adjust the expected flow characteristics previously evident at this station. The 2012 WY showed multiple precipitation-driven annual maximum daily discharges within the annual hydrograph, and did not display a defined open-water minimum daily flow following a sustained dry period as is typical in other systems.

Differences in water quality in fall 2012 between *test* station FOC-1 and regional *baseline* conditions were classified as **Negligible-Low**. However, relatively high concentrations of several water quality measurement endpoints were observed, but were within the range of previously-measured concentrations. A large increase in the concentration of sulphate has been observed at *test* station FOC-1 since 2008 (not a statistically significant trend), which appeared to have occurred in the absence of other apparent changes in ionic composition.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach FOC-Dl were classified as **High** because of the significantly lower abundance and richness during the *test* period compared to the *baseline* period at *test* reach FOC-D1. Additionally, four of the five measurement endpoints were outside of the range of variation for regional *baseline* depositional rivers. Although the percentage of fauna as EPT taxa has increased over time, this could be an artifact of the low overall abundance in the reach during many years of sampling (including 2012). Differences in sediment quality observed in fall 2012 between *test* station FOC-D1 and regional *baseline* conditions were classifies as **Negligible-Low** with nearly all sediment quality measurement endpoints within the range of previously-measured concentrations and regional *baseline* concentrations.

Differences in measurement endpoints for fish assemblages between *test* reach FOC-F1 and regional *baseline* conditions were classified as **Negligible-Low** given that the mean value all measurement endpoints were within the range of variation for regional *baseline* reaches.

Susan Lake Outlet Flows decreased after monitoring began in the outlet of Susan Lake, with the exception of two rainfall induced peaks on June 4 and June 24. Daily flows recorded in July showed multiple peak flows due to rainfall events from late June to mid-July. Flows generally decreased from late July through August to below the historical minimum values in mid-August. Rainfall events in late August and early September resulted in flows exceeding the historical maximum values. Following this peak, flows decreased through September before steadily increasing until monitoring ended on October 16, 2012.

5.13.2 Mills Creek and Isadore's Lake

Monitoring was conducted in 2012 in the Mills Creek watershed for the Climate and Hydrology and Water Quality components and in Isadore's Lake for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.2.1 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring in the Mills Creek watershed was conducted at Station S6, Mills Creek at Highway 63, which was used for the water balance analysis. Additional hydrometric data were available from Station L3, Isadore's, Lake which is located downstream of Station S6. Details for this station can be found in Appendix C.

Continuous hydrometric data during the open-water season (May to October) have been collected at RAMP Station S6 from 1997 to 2012, with annual data collected from 2006 to 2012. The 2012 WY annual runoff volume of 0.50 million m^3 was 37% lower than the historical mean annual runoff volume of 0.80 million m^3. The open-water (May to October) runoff volume of 0.37 million m^3 was 48% lower than the historical mean open-water runoff volume of 0.70 million m^3. Flows in the 2012 WY decreased through the winter from 0.013 m^3/s on November 1, 2011 to a minimum of 0.006 m^3/s on March 19, 2012 (Figure 5.13-3). Flows from mid-March to April were generally below historical minimum values. Flows increased during the freshet in May to a peak of 0.061 m^3/s on May 20. Flows were variable for most of the remainder of the 2012 WY and responded to a number of rain events in summer 2012, particularly in July and September. The 2012 WY open-water maximum daily flow of 0.069 m^3/s on September 11 was 59% lower than the historical mean open-water maximum daily flow. The open-water minimum daily flow of 0.007 m^3/s on May 1 was 55% lower than the historical mean open-water minimum daily flow. Flows generally remained within the inter quartile range from mid-September to the end of the 2012 WY.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at Mills Creek is presented in Table 5.13-2 and described below:

1. The closed-circuited land area from focal projects as of 2012 in the Mills Creek watershed is estimated to be 2.4 km^2 (Table 2.5-1). The loss of flow to Mills Creek that would have otherwise occurred from this land area was estimated at 0.313 million m^3.

2. As of 2012, the area of land change in the Mills Creek watershed from focal projects that was not closed-circuited was estimated to be 0.6 km^2 (Table 2.5-1). The increase in flow to Mills Creek that would not have otherwise occurred was estimated at 0.015 million m^3.

The estimated cumulative effect of land change was a loss of flow of 0.298 million m^3 to Mills Creek. The resulting observed *test* and estimated *baseline* hydrographs for RAMP Station S6 are presented in Figure 5.13-3 The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 37.2% 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).

Continuous lake level data for Isadore’s Lake have been collected at Station L3 since February 2000. In the 2012 WY, lake levels generally decreased from November 2011 to early March 2012, with levels in November and December near historical median values and levels from January to late March varying between the historical minimum and lower-quartile values (Figure 5.13-4). Lake levels increased during freshet in late March and April to a peak of 233.822 masl on April 18, followed by decreasing levels until mid-May, with values near the historical median values. Lake levels increased from late May through July in response to rainfall events, and generally remained between the historical maximum and upper quartile values until the end of the 2012 WY. The minimum open-water lake level of 233.769 masl occurred on May 10 and was near the historical median lake level recorded for this time of the year.

5.13.2.2 Water Quality

In fall 2012, 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 because of changes that had been observed in the ionic character of water in Isadore’s Lake in recent years.

Temporal Trends Significant increasing trends ($\alpha=0.05$) in fall concentrations of water quality measurement endpoints were detected for chloride, sodium, and total boron at *test* station ISL-1 (2000, 2001, 2004 to 2012). Trend analysis was not performed for *test* station MIC-1 because only three years of data were available.

2012 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations in fall 2012 at *test* station ISL-1, with the exception of (Table 5.13-4):

- total dissolved phosphorus, with a concentration that was lower than the previously-measured minimum concentration; and
- total boron, chloride, and total mercury (ultra-trace), with concentrations that exceeded previously-measured maximum concentrations.

Concentrations of water quality measurement endpoints at *test* station MIC-1 were within the range of previously-measured concentrations in fall 2012, with the exception of (Table 5.13-5):

- pH, sodium, calcium, and magnesium, with concentrations that were lower than previously-measured minimum concentrations; and
- total dissolved phosphorus, chloride, sulphate, total dissolved solids, and total boron, with concentrations that exceeded previously-measured maximum concentrations.

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 (Figure 5.13-5). Since 2004, the anion composition has shifted to a greater proportion of sulphate, while calcium and magnesium continue to dominate the cation composition (Figure 5.13-5). The ionic composition of water at *test* station MIC-1 from 2010 to 2012 was consistent with *test* station ISL-1, with a slightly lower relative concentration of magnesium

(Figure 5.13-5). However, both stations were more dominant in bicarbonate in fall 2012. The consistent ionic composition between Mills Creek and Isadore's Lake supported the hypothesis that flows from Mills Creek have been responsible for determining the ion composition of Isadore's Lake in recent years.

Comparison of Water Quality Measurement Endpoints to Published Guidelines No water quality measurement endpoints exceeded guidelines for *test* stations MIC-1 and ISL-1 in fall 2012 (Table 5.13-4 and Table 5.13-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in fall 2012 (Table 5.13-6):

- total phenols at *test* station ISL-1; and
- total iron at *test* station MIC-1.

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, concentrations of all 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, sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations; and
- dissolved phosphorus, total nitrogen, total mercury (ultra-trace), with concentrations that were below the 5th 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 2012 was 70.4, indicating a **Moderate** difference in water quality compared to regional *baseline* conditions (Table 5.13-7). This WQI was consistent with fall 2011 (68.6) and the low value was likely related to a number of ions and dissolved measurement endpoints, which exceeded the 95th 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, but due to similar water quality in 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 2012 between Mills Creek and regional *baseline* conditions were classified as **Moderate**, likely due to relatively high concentrations of many ions and other dissolved species that exceeded the 95th percentile of regional *baseline* concentrations. The ionic compositions of *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 2012 in Isadore's lake at depositional *test* station ISL-1 (sampled since 2006).

2012 Habitat Conditions Water in Isadore's Lake in fall 2012 was alkaline (pH = 8.4) and had high conductivity (520 µS/cm). The substrate was dominated by silt (77%), with low total organic carbon (<3%) (Table 5.13-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Isadore's Lake in fall 2012 was dominated by nematodes (43%) and chironomids (24%), with subdominant taxa consisting of copepods (19%) and ostracods (6%) (Table 5.13-9). Dominant chironomids included genera such as *Einfeldia, Chironomus, Dicrotendipes*, and *Paratanytarsus*, which are commonly distributed in north-temperate lakes (Wiederholm 1983). Ephemeroptera (*Caenis*), Bivalvia (*Pisidium/Sphaerium*), and Gastropods (*Valvata tricarinata*) were found in low relative abundances. Permanent forms such as the amphipod (*Hyalella azteca*) were also found in Isadore's Lake.

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.

Temporal comparisons for *test* station ISL-1 included testing for:

- changes over time in the *test* period (i.e., since 2009); and
- changes between 2012 values and the mean of all previous years.

The percentage of the fauna as EPT taxa significantly increased (but subtly) over time and was higher in 2012 than the mean of previous years of sampling, explaining >20% of the variance in annual means for both cases (Table 5.13-10).

Comparison to Published Literature The benthic invertebrate community of Isadore's Lake in fall 2012 showed an indication of poor water quality (Pennak 1986), which was similar to 2011. Taxa composition consisted primarily of nematodes which are generally "tolerant" of degraded water quality (Pennak 1986) and the low relative abundance of tubificid worms indicated that the water has been oxic (Hynes 1960, Griffiths 1998).

2012 Results Relative to Historical Conditions Mean values of benthic invertebrate community measurement endpoints in fall 2012 were within the range of values that were previously measured at *test* station ISL-1 (Figure 5.13-8). CA Axis 1 and 2 scores were also within previously observed scores for the lake (Figure 5.13-9).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because the significant (though subtle) increase in %EPT over time and the high %EPT in 2012 than the mean of previous years does not suggest degrading conditions. The percentage of fauna as EPT has always been <1% (normally EPT are absent), but in 2012 EPT taxa accounted for about half a percent of the fauna. Further, all measurement endpoints were within the range of historical values for the lake. Historically, Isadore's Lake has had a unique benthic invertebrate community compared to other lakes in the area, having low diversity and high abundance of nematodes. While there has been very little negative change over time, the benthic invertebrate community in Isadore's Lake has been representative of a degraded system since sampling was initiated in 2006.

Sediment Quality

Sediment quality in fall 2012 was sampled in Isadore's Lake (*test* station ISL-1, sampled in 2001 and from 2006 to 2011) in the same location as the sampling for benthic invertebrate communities was conducted. *Test* station Mills Creek was not sampled for sediment quality because it has erosional habitat.

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality endpoints were detected at *test* station ISL-1 in fall 2012.

2012 Results Relative to Historical Concentrations In fall 2012, sediments for *test* station ISL-1 were dominated by silt, with lower proportions of sand than previously measured (Table 5.13-11 and Figure 5.13-10). Total organic carbon was below the range of previously-measured values, but total inorganic carbon was within the historical range for this station (Figure 5.13-10). Concentrations of low-molecular-weight hydrocarbons (Fraction 1 including BTEX, and Fraction 2) were below detection limits, while concentrations of heavier hydrocarbon fractions (Fraction 3 and Fraction 4) were within the range of previously-measured concentrations. Concentrations of total PAHs were within previously-measured concentrations; however, concentrations of total PAHs (carbon-normalized) exceeded previously-measured maximum concentrations. The predicted PAH toxicity of 1.21 exceeded the potential chronic toxicity threshold of 1.0, but was within the range of historical values observed in Isadore's Lake. The concentration of naphthalene was lower than the previously-measured minimum concentration at *test* station ISL-1

Survival and growth of both the amphipod *Hyalella* and the midge *Chironomus* were within the range previously-measured values.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines There were no sediment quality measurement endpoints with concentrations that exceeded sediment or soil quality guidelines in fall 2012, with the exception of arsenic.

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. A range of regional *baseline* conditions was not calculated for lakes that are sampled by RAMP due to the limited *baseline* data available.

Classification of Results Concentrations of most sediment quality measurement endpoints in fall 2012 at *test* station ISL-1 were within previously-measured concentrations with only a few exceptions (i.e., carbon-normalized PAHs and naphthalene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers.

5.13.3 Shipyard Lake

Monitoring was conducted in Shipyard Lake in fall 2012 for the Water Quality and the Benthic Invertebrate Communities and Sediment Quality components.

5.13.3.1 Water Quality

Water quality samples were taken from Shipyard Lake in fall 2012 at *test* station SHL-1 (sampled from 1998 to 2012).

Temporal Trends Temporal Trends The following statistically significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- A decreasing concentration of sulphate; and
- Increasing concentrations of chloride, potassium, sodium, and total boron.

2012 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints at *test* station SHL-1 in fall 2012 were within previously-measured concentrations (Table 5.13-12), with the exception of:

- magnesium, with a concentration that was below the previously-measured minimum concentration; and
- total aluminum, with a concentration that exceeded the previously-measured maximum concentration.

Ion Balance The ionic composition of water at *test* station SHL-1 in fall 2012 continued the recent trend towards increasing relative concentrations of sodium and chloride (Figure 5.13-5). As discussed in RAMP (2010, 2011) 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 watershed area.

Comparison of Water Quality Measurement Endpoints to Published Guidelines The concentration of total aluminum exceeded the water quality guideline at *test* station SHL-1 in fall 2012 (Table 5.13-12).

Other Water Quality Guideline Exceedances Concentrations of dissolved iron, sulphide, total iron, and total phenols exceeded the water quality guidelines in fall 2012 at *test* station SHL-1 (Table 5.13-6).

Water Quality Index Because lakes were not compared to regional *baseline* concentrations, there was no WQI value calculated for *test* station SHL-1.

Classification of Results Concentrations of most water quality measurement endpoints in fall 2012 at *test* station SHL-1 were within previously-measured concentrations with only a few exceptions (i.e., magnesium and total aluminum). The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in sodium and chloride concentrations relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the Shipyard Lake watershed (the upper 93% of the Shipyard Lake watershed has been disturbed; see Table 2.5-2). A WQI was not calculated for lakes in 2012 due to potential ecological differences in regional water quality characteristics between lakes and rivers and the limited *baseline* lake data.

5.13.3.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 in Shipyard Lake at depositional *test* station SHL-1 (sampled since 2000).

2012 Habitat Conditions Water in Shipyard Lake was slightly alkaline (pH = 7.9) and had moderate conductivity (~ 359 µS/cm) (Table 5.13-13).The substrate of Shipyard Lake in fall 2012 was dominated by silt (75%), with some clay (23%), and a small amount of sand (2%), and high total organic carbon (~15%) (Table 5.13-13).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* station SHL-1 in fall 2012 was dominated by chironomids (40%) and naidid worms (19%), with subdominant taxa consisting of Gastropoda (17%) (Table 5.13-14). EPT taxa were not found in Shipyard Lake in 2012; however, bivalves (*Pisidium/Sphaerium*) and amphipods (*Hyalella azteca*) were present (Table 5.13-14). Dominant chironomids included *Einfeldia*, *Chironomus,* and *Procladius*, which are commonly distributed in north temperate regions (Wiederholm 1983). Gastropoda (snails) included *Valvata tricarinata*, *Armiger crista, Valvata sincera,* and *Gyraulus*, which again, are common in northern parts of Canada (Clarke 1981).

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.

Temporal comparisons for *test* station SHL-1 included testing for:

- changes over time during the *test* period (i.e., since 2009); and
- changes between 2012 values and the mean of all previous sampling years.

Abundance and richness significantly increased over time, explaining 33% and 37% of the variance in annual means, respectively (Table 5.13-15). CA Axis 2 scores increased over time accounting for 26% of the variance in annual means. The shift in scores reflected an increase in naidid worms over time at *test* station SHL-1 (Figure 5.13-11).

Comparison to Published Literature The benthic invertebrate community at *test* station SHL-1 contained a fauna that would be expected for a lake benthic community in the Fort McMurray region (Parsons et al. 2010). The community contained several permanent aquatic forms including fingernail clams (Bivalvia: Sphaeriidae), snails (Gastropoda), and amphipods (*Hyalella azteca*). Larger flying insects (Ephemeroptera and Trichoptera) were absent in fall 2012 but have been absent or accounted for low abundances in previous years.

2012 Results Relative to Historical Conditions Values of measurement endpoints for benthic invertebrate communities at *test* station SHL-1 in fall 2012 were within the range of previously-measured values for the lake (Figure 5.13-12). CA Axis 1 and 2 scores were within the range of values from previous years (Figure 5.13-11).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at test station SHL-1 in 2012 were classified as **Negligible-Low**. The increasing trend over time of abundance and taxa richness were significant and strong (explaining > 20% of the total variation in annual means) and were not indicative of degraded water or 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 in fall 2012 was sampled in Shipyard Lake (*test* station SHL-1, sampled from 2001 to 2004 and 2006 to 2012) in the same location as the sampling for benthic invertebrate communities was conducted.

Temporal Trends The following significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected at *test* station SHL-1 in fall 2012:

- An increasing concentration of total PAHs (however carbon-normalized total PAHs did not show a significant increase); and
- Increasing concentrations of total alkylated PAHs, and Fraction 3 and 4 hydrocarbons.

2012 Results Relative to Historical Concentrations Sediments at *test* station SHL-1 in fall 2012 contained a higher proportion of silt, and lower proportions of clay and sand compared to previously-measured values at this station (Table 5.13-16 and Figure 5.13-13). Total organic carbon content was higher than the previously-measured maximum concentrations (Table 5.13-16). All hydrocarbons were within previously-measured concentrations at *test* station SHL-1 (Table 5.13-16). Concentrations of all other sediment quality measurement endpoints at *test* station SHL-1 in fall 2012 were within historical concentration ranges, with the exception of benzo[a]pyrene, which exceeded the previously-measured maximum concentration (Table 5.13-16).

Survival of the midge *Chironomus* exceeded the previously-measured maximum value, while ten-day growth of *Chironomus* and 14-day growth and survival of the amphipod *Hyalella* measured within the range of previously-measured values in fall 2012.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines There were no sediment quality measurement endpoints with concentrations that exceeded sediment or soil quality guidelines in fall 2012, with the exception of arsenic, Fraction 3 (C16-C34) hydrocarbons, benz[a]anthracene, benz[a]pyrene, pyrene, and chrysene.

Sediment Quality Index A SQI 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.

Classification of Results Concentrations of most sediment quality measurement endpoints in fall 2012 at *test* station SHL-1 were within previously-measured concentrations with only a few exceptions (i.e., TOC and benzo[a]pyrene). The SQI was not calculated for lakes in 2012 due to potential ecological differences in regional sediment quality characteristics between lakes and rivers.

5.13.4 Poplar Creek and Beaver River

Monitoring was conducted in the Poplar Creek and Beaver River watersheds in 2012 for the Climate and Hydrology (Poplar Creek only), Water Quality, and Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.4.1 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring in the Poplar Creek watershed was conducted at Station S11, Poplar Creek at Highway 63, which was used for the water balance analysis. Additional hydrometric data were available from the WSC Station 07DA018 (RAMP S39), Beaver River above Syncrude. Details for this station can be found in Appendix C.

Continuous hydrometric data during the open-water (May to October) period have been collected for the RAMP Station S11 (WSC 07DA007) from 1973 to 1986 and from 1996 to 2012, with annual data collected from 1973 to 1986. In the 2012 WY, data were collected from May 22 to October 31, with data missing from July 26 to August 7. Flows were near historical lower quartile levels when monitoring began on May 22, and varied between the historical minimum and lower quartile values until the end of June. Flows increased in response to rainfall events in early July to a peak of 3.763 m^3/s on July 10, followed by decreasing flows to a minimum value of 0.079 m^3/s on August 25, which was the lowest recorded flow in the 2012 WY. Flows increased in early September in response to rainfall events in early September to near historical upper quartile values and fluctuated around the historical median and upper quartile values for the remainder of the 2012 WY.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The 2012 WY estimated water balance at Station S11 (WSC 07DA007) is presented in Table 5.13-17 and described below:

1. The closed-circuited land area from focal projects as of 2012 in the Poplar Creek watershed was estimated to be 3.1 km^2 (Table 2.5-1). The loss of flow to Poplar Creek that would have otherwise occurred from this land area was estimated at 0.247 million m^3.
2. As of 2012, the area of land change from focal projects in the Poplar Creek watershed that was not closed-circuited was estimated to be 1.8 km^2 (Table 2.5-1). The increase in flow to Poplar Creek that would not have otherwise occurred from this land area was estimated at 0.029 million m^3.
3. Syncrude reported a total discharge of 0.437 million m^3 of water to Poplar Creek via the Poplar Creek spillway.

The estimated cumulative effects of land change and water discharges was an increase in flow of 0.220 million m^3 to Poplar Creek in the 2012 WY. The resulting observed *test* and estimated *baseline* hydrographs for Station S11 (WSC 07DA007), Poplar Creek at Highway 63 are presented in Figure 5.13-14. The calculated mean open-water discharge (May to October) was 1.6% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-17). This difference was classified as **Negligible-Low** (Table 5.13-18). The annual maximum daily discharge and open-water minimum daily discharge were 1.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low** (Table 5.13-1).

5.13.4.2 Water Quality

In fall 2012, water quality samples were taken from:

- the Beaver River near its mouth (*test* station BER-1, sampled from 2003 to 2012);
- Poplar Creek near its mouth (*test* station POC-1, sampled from 2000 to 2012); and
- the upper Beaver River, upstream of all focal project developments (*baseline* station BER-2, sampled from 2008 to 2012).

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 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 (Figure 5.13-16). Trend analyses could not be completed for *baseline* station BER-2 due to an insufficient length of time series data for this station.

2012 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within previously-measured concentrations at *test* station POC-1 and *baseline* station BER-2 (Table 5.13-19 and Table 5.13-21). The concentration of total molybdenum exceeded the previously-measured maximum concentration in fall 2012 at *test* station BER-1 (Table 5.13-20).

Ion Balance The ionic composition of water at *test* station POC-1 has been highly variable across sampling years; however, data from fall 2012 were within the range of previously-measured concentrations (Figure 5.13-15). The ion balance at *test* station BER-1 was strongly skewed toward high concentrations of sodium and chloride in 2011, but in fall 2012 has returned to more typical ionic concentrations observed at this station (Figure 5.13-15). There has been a greater influence of sodium at *baseline* station BER-2 in the past two sampling years (2011 and 2012) relative to previous sampling years.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of the following water quality measurement endpoints exceeded water quality guidelines in fall 2012 (Table 5.13-19, Table 5.13-21 and Table 5.13-20):

- total aluminum and chloride at *test* station BER-1;
- total aluminum and total nitrogen at *test* station POC-1; and
- total aluminum and total dissolved phosphorus at *baseline* station BER-2.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in fall 2012 (Table 5.13-6):

- total and dissolved iron, sulphide, and total phenols at *test* station POC-1;
- total and dissolved selenium, total iron, total chromium, total phenols, and total phosphorous at *test* station BER-1; and
- total and dissolved iron, sulphide, total phenols, and total phosphorous at *baseline* station BER-2.

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of several water quality measurement endpoints in fall 2012 at *test* station BER-1 exceeded regional *baseline* concentrations, while only one measurement endpoint at *baseline* station BER-2 and *test* station POC-1 exceeded regional *baseline* concentrations (Figure 5.13-16), including:

- total dissolved solids, total strontium, total boron, calcium, magnesium, sodium, chloride, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station BER-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 values for fall 2012 for *test* station POC-1 and *baseline* station BER-2 indicated **Negligible-Low** differences from regional *baseline* concentrations (Table 5.13-7). The WQI value for *test* station BER-1 was 79.9 indicating a **Moderate** difference from regional *baseline* concentrations, but was more similar to regional *baseline* concentrations than 2011 (WQI: 65.2).

Classification of Results Concentrations of several water quality measurement endpoints, primarily ions and other dissolved species, exceeded regional *baseline* concentrations at *test* station BER-1, resulting in a **Moderate** difference from regional *baseline* conditions. Although concentrations of several measurement endpoints were high at *test* station POC-1 and *baseline* station BER-2, differences in water quality in fall 2012 and regional *baseline* conditions were classified as **Negligible-Low**.

5.13.4.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at:

- depositional *test* reach POC-Dl, sampled since 2008; and
- depositional *baseline* reach BER-D2, sampled since 2008. This reach was used as *baseline* for comparison with *test* reach POC-D1.

2012 Habitat Conditions Water at *test* reach POC-D1 in fall 2012 was moderately deep (0.6 m), slightly acidic (pH: 6.5), with moderate conductivity (381 µS/cm). The substrate was nearly equally composed of sand (32%) and silt (47%), with a smaller amount of clay (21%) (Table 5.13-22).

Water at *baseline* reach BER-D2 in fall 2012 was deep (1.0 m), moderately alkaline (pH: 8.5), with high conductivity (403 µS/cm). The substrate was dominated by sand (89%) (Table 5.13-22).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach POC-D1 was dominated by chironomids (32%) and ostracods (27%), with subdominant taxa consisting of tubificid worms (13%) (Table 5.13-23). Dominant chironomid genera consisted primarily of *Procladius, Polypedilm*, *Micropsectra/Tanytarsus*, which are common in north-temperate waters (Wiederholm 1983). Ephemeroptera (*Caenis*) and Trichoptera (*Oecetis*) were found in low relative abundances. Bivalves *Pisidium/Sphaerium* were relatively abundant (Table 5.13-23).

The benthic invertebrate community at *baseline* reach BER-D2 was dominated by tubificid worms (36%) and chironomids (36%), with subdominant taxa consisting of Ceratopogonidae (7%) and Coleoptera (4%) (Table 5.13-23). Ephemeroptera (*Caenis* and *Hexagenia limbata)* and Trichoptera *(Oxyethira* and *Oecetis)* were found in low relative abundances. Dominant chironomid genera consisted primarily of *Tanytarsus*, *Micropsectra/Tanytarsus* and *Procladius*, which are common in north-temperate waters (Wiederholm 1983).

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.

Temporal comparisons for *test* reach POC-D1 included testing for:

- changes over time during the *test* period (i.e., since 2002, Hypothesis 1, Section 3.2.3.1); and
- changes in 2012 values and the mean of all previous years of sampling (2008 to 2011).

Spatial comparisons for *test* reach POC-D1 included testing for:

- differences from *baseline* reach BER-D2 over time (Hypothesis 1, Section 3.2.3.1);
- differences between 2012 values and the mean of all available *baseline* data; and
- differences from *baseline* reach BER-D2 in 2012 values.

Abundance was significantly higher at *test* reach POC-D1 and significantly increased over time at both reaches (Table 5.13-24). Abundance has been high at *test* reach POC-D1 since the beginning of sampling in 2008 (Figure 5.13-17).

Richness significantly increased over time at both reaches, explaining 30% of the variance in annual means (Table 5.13-24). Simpson's Diversity was significantly higher at *test* reach POC-D1 than *baseline* reach BER-D2, explaining 40% of the variance in annual means (Table 5.13-24).

The percentage of EPT taxa was significantly lower at *test* reach POC-D1 than *baseline* reach BER-D2 and has been since the onset of sampling in 2008 (Figure 5.13-17). The percent EPT taxa in 2012 was notably lower at *test* reach POC-D1 than *baseline* reach BER-D2 but has increased over time since the onset of sampling and was higher in 2012 than the mean of previous sampling years (Table 5.13-24 and Figure 5.13-17).

CA Axis 1 and 2 scores significantly increased over time at both reaches, reflecting changes in taxa composition towards a lower abundance of tubificids and an increase in gastropods and water mites (Hydracarina) (Figure 5.13-18). CA Axis 2 scores were also higher in 2012 than the mean of previous years at *test* reach POC-D1 (Table 5.13-24).

Comparison to Published Literature The benthic invertebrate community at *test* reach POC-D1 in fall 2012 was what would be expected in a sand-based stream. The percentage of the fauna as worms (15%) and chironomids (32%) (Table 5.13-23) were typical (Hynes 1960, Griffiths 1998). The benthic invertebrate community at *test* reach POC-D1 also included a relatively high abundance of fingernail clams (*Pisidium/Sphaerium*) (8%). Mayflies and caddisflies were present in low abundances relative to what might be expected in a *baseline* condition (e.g., Hynes 1960, Griffiths 1998).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for benthic invertebrate communities at *test* reach POC-Dl and *baseline* reach BER-D2 were within the range of variation for regional *baseline* depositional reaches (Figure 5.13-17).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach POC-Dl were classified as **Moderate** because of the significant and large differences in abundance, percentage of fauna as EPT taxa, and CA Axis scores compared to *baseline* reach BER-D2. The benthic invertebrate community at *test* reach POC-D1 was in generally good condition, reflected by low relative abundances of worms and higher relative abundances of fingernail clams. The low relative abundance of mayflies and caddisflies, and lack of stoneflies potentially indicated some level of disturbance, but over time the percent EPT taxa has been increasing.

Sediment Quality

Sediment quality was sampled in fall 2012, in the same locations as benthic invertebrate communities, at:

- *test* station POC-D1 (sampled in 1997, 2002, 2004, and 2008 to 2012); and
- *baseline* station BER-D2 (sampled from 2008 to 2012).

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station POC-D1 in fall 2012. Trend analysis could not be conducted for *baseline* station BER-D2 due to the insufficient data record for this station (n=5).

2012 Results Relative to Historical Concentrations Sediment at *test* station POC-D1 in fall 2012 was dominated by silt, having a historically high proportion of silt and historically low proportion of sand. Sediment distributions at *baseline* station BER-D2 were within previously-measured ranges and continued to be dominated by sand (Table 5.13-25 and Table 5.13-26, Figure 5.13-19 and Figure 5.13-20). Total organic carbon was within the range of previously-measured concentrations at both stations. Concentrations of all total hydrocarbon fractions, with the exception of Fraction-3 at *baseline* station BER-D2 and Fraction-3 and Fraction-4 at *test* station POC-D1, were below detections limits in fall 2012. Higher-molecular-weight hydrocarbon fractions (F3 and F4) were within the range of previously-measured concentrations at both stations. Concentrations of most PAHs were within the range of previously-measured concentrations at *test* station POC-D1 and *baseline* station BER-D2, with the exception of retene, which exceeded the previously-measured maximum concentration and total dibenzothiophenes, which was below the previously-measured minimum concentration at *test* station POC-D1. The predicted PAH toxicity was within the range of historical values at both stations.

Direct tests of sediment toxicity to invertebrates at *test* station POC-D1 and *baseline* station BER-D2 showed that growth and survival of the amphipod *Hyalella* were within the range of previously-measured values in 2012. Survival of the midge *Chironomus* was higher than historical maximum value at *test* station POC-D1. Ten-day growth of *Chironomus* was below the previously-measured minimum value at *baseline* station BER-D2 (Table 5.13-25 and Table 5.13-26).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines There were no sediment quality measurement endpoints with concentrations that exceeded sediment quality guidelines in fall 2012, with the exception of arsenic and the predicted PAH toxicity of sediments (exceeding the threshold value of 1.0) at *test* station POC-D1 (Table 5.13-25).

2012 Results Relative to Regional *Baseline* Concentrations Concentrations of sediment quality measurement endpoints in fall 2012 at *test* station POC-D1 were within the range of regional *baseline* concentrations, with the exception of total metals, which exceeded the 95th percentile of regional *baseline* concentrations. Concentrations of sediment quality measurement endpoints in fall 2012 at *baseline* station BER-D2 were within the range of regional *baseline* concentrations.

Sediment Quality Index The SQI values for *test* station POC-D1 and *baseline* station BER-D2 were 83.2 and 100.0, respectively (Table 5.13-27) indicating **Negligible-Low** differences in sediment quality conditions compared to regional *baseline* conditions.

Classification of Results Differences in sediment quality observed in fall 2012 at *test* station POC-D1 and *baseline* station BER-D2 were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of most sediment quality measurement endpoints were within the range of previously-measured concentrations and within the range of regional *baseline* conditions.

5.13.4.4 Fish Populations

Fish assemblages were sampled in fall 2012 at:

- depositional *test* reach POC-F1, also sampled in 2009 and in 2011 (this reach is in the same location as the benthic invertebrate community *test* reach POC-D1); and
- depositional *baseline* reach BER-F2, also sampled in 2009 and in 2011 (this reach is in the same location as the benthic invertebrate community *baseline* reach BER-D2).

2012 Habitat Conditions *Test* reach POC-F1 was comprised of riffle and run habitat with a wetted width of 9 m and a bankfull width of 11 m (Table 5.13-28). The substrate consisted of a mixture of sand and cobble. Water at *test* reach POC-F1 in fall 2012 was an average of 0.62 m in depth, slow flowing (average flow: 0.35 m/s), slightly alkaline (pH: 8.12), with high conductivity (404 µS/cm), high dissolved oxygen (9.4 mg/L), and a temperature of 13.6˚C (Table 5.13-28). Instream cover was dominated by macrophytes and small woody debris with smaller amounts of large woody debris, undercut banks, and boulders (Table 5.13-28).

Baseline reach BER-F2 was comprised of run habitat with a wetted width of 10.5 m and a bankfull width of 12.5 m (Table 5.13-28). The substrate consisted entirely of organic materials. Water at *baseline* reach BER-F2 in fall 2012 was an average of 0.83 m in depth, slow flowing (average flow: 0.10 m/s), neutral (pH: 7.89), with high conductivity (404 µS/cm), high dissolved oxygen (8.4 mg/L), and a temperature of 13.2˚C. Instream cover was dominated by macrophytes, with smaller amounts of small woody debris and overhanging vegetation (Table 5.13-28).

Temporal and Spatial Comparisons Sampling was initiated at *test* reach POC-F1 and *baseline* reach BER-F2 in 2009 during the RAMP Fish Assemblage Pilot Study and sampled again in 2011; therefore, temporal comparisons were conducted between 2009, 2011, and 2012 and spatial comparisons were conducted between reaches.

Lake chub was the dominant species at both reaches. There was a decrease in CPUE and abundance but higher species richness at *test* reach POC-F1 compared to 2011; however both 2011 and 2012 had lower values for all three measurement endpoints compared to 2009 (Table 5.13-29). The ATI has increased slightly since 2011 at both reaches but is still lower than 2009 (Table 5.13-30). Water levels at *test* reach POC-F1 were considerably higher in 2012 compared to 2011, which could explain the decrease in CPUE and abundance as the conditions of the creek made fishing difficult. There was an increase in abundance, species richness, and CPUE at *baseline* reach BER-F2 from 2009 to 2012 (Table 5.13-29). Measurement endpoint values were slightly lower for *test* reach POC-F1 than *baseline* reach BER-F2, but have been fairly similar between reaches across years, indicating similarities in fish assemblages between the lower and upper reaches.

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 RAMP. Based on past studies, a total of seventeen and fourteen fish species were recorded in Poplar Creek and the Beaver River, respectively; whereas RAMP found only eleven and eight species between 2009 and 2012 in Poplar Creek and the Beaver River, respectively. RAMP also documented pearl dace, spoonhead sculpin, and walleye at *test* reach POC-F1 and pearl dace at *baseline* reach BER-F2, which have not been previously documented. The small area sampled could be a possible reason for the discrepancy in number of species (i.e., RAMP samples a smaller, defined reach length relative to multiple locations/reaches documented in Golder [2004]).

Similar habitat conditions were historically documented to what was observed by RAMP at *baseline* reach BER-F2, which consisted of run habitat with silt/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).

Golder (2004) documented similar habitat conditions to what was observed by RAMP 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 is located, was documented as limited for feeding and overwintering activities (Golder 2004).

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 for *test* reach POC-F1 were within the range of regional *baseline* conditions, with the exception of ATI, which was below the 5th percentile of regional *baseline* conditions (Figure 5.13-21). Mean values of all measurement endpoints in fall 2012 for *baseline* reach BER-F2 were within the range of regional *baseline* conditions (Figure 5.13-22).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach POC-F1 and regional *baseline* conditions were classified as **Negligible-Low** because although the ATI was lower than regional *baseline* conditions, this difference was indicative of more sensitive species captured and not reflective of degrading conditions in Poplar Creek.

5.13.5 McLean Creek

Monitoring was conducted in the McLean Creek watershed in 2012 for the Water Quality component.

5.13.5.1 Water Quality

In fall 2012, water quality samples were collected near the mouth of McLean Creek at *test* station MCC-1 (sampled from 1999 to 2012).

Temporal Trends There were no significant (α=0.05) trends over time observed at *test* station MCC-1 in fall 2012.

2012 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints at *test* station MCC-1 in fall 2012 were within previously-measured concentrations, with the exception of (Table 5.13-31):

- total molybdenum and total selenium, with concentrations that exceeded the previously-measured maximum concentrations; and
- sulphide with a concentration that was below the previously-measured minimum concentration.

Ion Balance The ionic composition of water at *test* station MCC-1 shifted considerably in fall 2011 relative to previous years, but returned to an ionic composition that was similar to years prior to 2011 in fall 2012 (Figure 5.13-23).

Comparison of Water Quality Measurement Endpoints to Published Guidelines All water quality measurement endpoints were within water quality guidelines at *test* station MCC-1 in fall 2012, with the exception of total nitrogen and total aluminum (Table 5.13-31).

Other Water Quality Guideline Exceedances Concentrations of total iron, sulphide, total phosphorus, total selenium, and total phenols exceeded relevant water quality guidelines at *test* station MCC-1 in fall 2012 (Table 5.13-6).

2012 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 2012 included chloride, potassium, sodium, sulphate, total arsenic, total boron, total dissolved solids, total strontium, total suspended solids, and total mercury (ultra-trace) (Figure 5.13-6).

Water Quality Index The WQI value of 63.0 for *test* station MCC-1 in fall 2012 indicated a **Moderate** difference from regional *baseline* conditions (Table 5.13-7), which was likely due to exceedances of many ions and dissolved analytes from the 95th percentile of regional *baseline* concentrations.

Classification of Results Concentrations of water quality measurement endpoints at *test* station MCC-1 were often higher than regional *baseline* concentrations in fall 2012. Concentrations of TSS, TDS, and many ions and dissolved species of water quality measurement endpoints were high relative to regional *baseline* conditions and exhibited guideline exceedances, indicating a **Moderate** difference from regional *baseline* conditions.

5.13.6 Fort Creek

Monitoring was conducted in the Fort Creek watershed in 2012 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.6.1 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring in the Fort Creek watershed was conducted at Station S12, Fort Creek at Highway 63, which was used for the water balance analysis. There were no additional hydrometric monitoring stations in this watershed.

Hydrometric data have been collected during the open-water period (May to October) at RAMP Station S12 from 2000 to 2001 and 2006 to 2012. The 2012 WY open-water runoff volume was 1.41 million m^3, which was 2.1% lower than the historical mean open-water runoff volume of 1.44 million m^3. Flows were variable throughout the 2012 WY, with periods throughout the open-water season below and above the historical daily minimum and maximum values, respectively (Figure 5.13-24). Flows increased sharply from 0.022 m^3/s on September 1 to 0.219 m^3/s on September 6 in response to rainfall events in late August and early September. The maximum open-water daily flow of 0.220 m^3/s recorded on October 18 was 52% below the historical mean maximum daily flow. The minimum open-water daily flow of 0.016 m^3/s recorded on August 10 was 30% lower than the historical mean open-water minimum daily flow. The variability in daily flows was possibly due to the increase in development in the watershed (i.e., as of 2012, 65% of the watershed has been affected by land change resulting from oil sands development).

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at RAMP Station S12 is presented in Table 5.13-32 and described below:

1. The closed-circuited land area from focal projects as of 2012 in the Fort Creek watershed was estimated to be 0.3 km^2 (Table 2.5-1). The loss of flow to Fort Creek that would have otherwise occurred from this land area was estimated at 0.014 million m^3.

2. As of 2012, the area of land change from focal projects in the Fort Creek watershed that was not closed-circuited was estimated to be 20.4 km^2 (Table 2.5-1). The increase in flow to Fort Creek that would not have otherwise occurred from this land area was estimated at 0.169 million m^3.

The estimated cumulative effect of this land change was an increase in flow of 0.16 million m^3 to Fort Creek. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.13-24. The calculated mean open-water period (May to October) discharge volume was 11.7% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Moderate** (Table 5.13-1). In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed. This variability in daily flow was sufficiently large to adjust the expected flow characteristics previously evident at this station. The 2012 WY showed multiple precipitation-driven annual maximum daily discharges within the annual hydrograph, and also does not display a defined open-water minimum daily flow following a sustained dry period as is typical in other systems. For this reason, the two daily measurement endpoints (annual maximum daily discharge and open-water season minimum discharge) would not be valid points of comparison with historical data for this station for the 2012 WY.

5.13.6.2 Water Quality

In fall 2012, water quality samples were taken from the mouth of Fort Creek at *test* station FOC-1 (sampled intermittently from 2000 to 2012).

Temporal Trends The following significant (α=0.05) temporal trends in concentrations of water quality measurement endpoints were detected at *test* station FOC-1:

- A decreasing concentration of total dissolved phosphorus;
- Increasing concentrations of calcium and total dissolved solids; and
- A decreasing concentration of arsenic, which can be attributed to a shift in detection limit after 2001. Data analyzed excluding 2000 and 2001 does not show any trend over time.

2012 Results Relative to Historical Concentrations In fall 2012, concentrations of water quality measurement endpoints were within previously-measured concentrations with the exception of (Table 5.13-33):

- sulphate, with a concentration that exceeded the previously-measured maximum concentration; and
- total dissolved phosphorus, with a concentration that was below the previously-measured minimum concentration.

Ion Balance The ionic composition of water at *test* station FOC-1 in fall 2012 showed a shift over time towards a greater influence of sulphate, with no changes in cation composition (Figure 5.13-23).

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 2012, with the exception of total aluminum (Table 5.13-33).

Other Water Quality Guideline Exceedances The concentration of total iron exceeded the water quality guideline at *test* station FOC-1 in fall 2012 (Table 5.13-6).

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, 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, potassium, sulphate, and chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations; and
- total dissolved phosphorus, total nitrogen, and total strontium, with concentrations that were below the 5th percentile of regional *baseline* concentrations.

Water Quality Index The WQI value for *test* station FOC-1 (80.8) indicated **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2012 (Table 5.13-7).

Classification of Results Differences in water quality in fall 2012 between *test* station FOC-1 and regional *baseline* conditions were classified as **Negligible-Low**. However, relatively high concentrations of several water quality measurement endpoints were observed, but were within the range of previously-measured concentrations. A large increase in the concentration of sulphate have been observed at *test* station FOC-1 since 2008 (not a statistically significant trend), which appeared to have occurred in the absence of other apparent changes in ionic composition.

5.13.6.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2012 at depositional *test* reach FOC-D1 (designated as *baseline* from 2001 to 2003 and *test* from 2004 to 2012).

2012 Habitat Conditions Water at *test* reach FOC-D1 in fall 2012 was shallow (0.4 m) and moderately flowing (0.54 m/s) (Table 5.13-7). The substrate was dominated by sand (97%) with low amounts of organic carbon (1.52%) (Table 5.13-34).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach FOC-Dl was dominated by chironomids (58%) and tubificid worms (20%), with subdominant taxa consisting of stoneflies (*Isoperla*; 7%) and lumbricid worms (7%) (Table 5.13-35). Chironomid abundance was primarily comprised of the common form *Polypedilum*. Bivalves (*Pisidium/Sphaerium*) were present in very low relative abundances (Table 5.13-35).

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.

Temporal comparisons 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 2, Section 3.2.3.1);
- changes over time during the *test* period (i.e., since 2002, Hypothesis 1, Section 3.2.3.1);

- changes between 2012 values and the mean of all *baseline* years (2001 to 2003); and
- changes between 2012 values and the mean of all previous years of sampling.

Abundance and richness were significantly higher during the *baseline* period at *test* reach FOC-D1, explaining >20% of the variance in annual means (Table 5.13-36). Equitability was higher during the *test* period and higher in 2012 than previous years of sampling (Table 5.13-36). The percentage of the fauna as EPT taxa significantly increased over time, explaining 44% of the variance in annual means (Table 5.13-36).

Comparison to Published Literature The benthic invertebrate community at *test* reach FOC-D1 had a fauna that was somewhat indicative of degrading conditions but was expected for an almost completely sandy-bottom river. Chironomid and worm abundances were relatively high and the community lacked mayflies and caddisflies. The high relative abundance of stoneflies was an artifact of the general low total abundance, particularly where in one replicate, an *Isoperla* stonefly was one of only three individuals in the sample.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for benthic invertebrate communities were outside the range of variation for regional *baseline* depositional rivers (higher for equitability and lower for abundance, richness, and diversity), with the exception of the percentage of fauna as EPT taxa (Figure 5.13-25). The multivariate CA axis scores were within regional *baseline* conditions in 2012 (Figure 5.13-26).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach FOC-Dl were classified as **High** because of the significantly lower abundance and richness during the *test* period compared to the *baseline* period at *test* reach FOC-D1. Additionally, four of the five measurement endpoints were outside of the range of variation for regional *baseline* depositional rivers. Although the percentage of fauna as EPT taxa has increased over time, this could be an artifact of the low overall abundance in the reach during many years of sampling (including 2012).

Sediment Quality

Sediment quality was sampled in fall 2012 at *test* station FOC-D1 in the same location as the benthic invertebrate communities were collected. *Test* station FOC-D1 was designated as *baseline* in 2000 and 2002 and *test* from 2006 to 2008 and 2010 to 2012.

Temporal Trends No significant trends ($\alpha=0.05$) in concentrations of sediment quality measurement endpoints were detected for *test* station FOC-D1 in fall 2012.

2012 Results Relative to Historical Concentrations Sediments at *test* station FOC-D1 were dominated by high proportions of sand (97.9%) and contained low levels of silt in fall 2012 (Table 5.13-37 and Figure 5.13-27). Low-molecular-weight hydrocarbons (Fraction 1 including BTEX) were below detection limits at *test* station FOC-D1 in fall 2012, while concentrations of heavier hydrocarbons, Fraction 2 and Fraction 4, exceeded previously-measured maximum concentrations. All PAHs were within previously-measured concentrations and total PAHs at *test* station FOC-D1 were comprised almost exclusively of alkylated species, indicating a petrogenic origin of these compounds. Total metals were within the range of previously-measured concentrations, but total metals normalized to percent fines in sediment exceeded the previously-measured maximum concentration.

Direct tests of sediment toxicity to invertebrates at *test* station FOC-D1 showed that growth and survival of the amphipod *Hyalella* and the midge *Chironomus* were within previously-measured values.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines In fall 2012, concentrations of all sediment quality measurement endpoints at *test* station FOC-D1 were within sediment quality guidelines, with the exception of Fraction 2 and Fraction 3 hydrocarbons and chrysene (Table 5.13-37).

2012 Results Relative to Regional *Baseline* Concentrations In fall 2012, concentrations of sediment quality measurement endpoints at *test* station FOC-D1 were within regional *baseline* concentrations, with the exception of total metals (normalized to percent fines) and total PAHs (normalized to %TOC), with concentrations that exceeded the 95th percentile of regional *baseline* concentrations (Figure 5.13-27, Table 5.13-33).

Sediment Quality Index A SQI value of 87.5 for *test* station FOC-D1 for fall 2012 indicated a **Negligible-Low** difference from regional *baseline* conditions (Table 5.13-27). The SQI values for *test* station FOC-D1 have been variable since monitoring began in 2000, ranging from 59.8 to 100 (n=8).

Classification of Results Differences in sediment quality observed in fall 2012 between *test* station FOC-D1 and regional *baseline* conditions were **Negligible-Low** with nearly all sediment quality measurement endpoints within the range of previously-measured concentrations and regional *baseline* concentrations.

5.13.6.4 Fish Populations

Fish assemblages were sampled in fall 2012 at depositional *test* reach FOC-F1, which was sampled for the first time in 2011 (this reach is at the same location as the benthic invertebrate community *test* reach FOC-D1).

2012 Habitat Conditions *Test* reach FOC-F1 was comprised of run and riffle habitat with a wetted width of 2 m and a bankfull width of 4 m (Table 5.13-38). The substrate was dominated by sand with smaller amounts of silt and clay. Water at *test* reach FOC-F1 in fall 2012 had an average depth of 0.37 m, was slow flowing (average flow: 0.18 m/s), slightly alkaline (pH: 8.11), with high conductivity (581 µS/cm), high dissolved oxygen (8.85 mg/L), and a temperature of 10.9°C. Instream cover consisted of small woody debris with smaller amounts of large woody debris, vegetation, and undercut banks (Table 5.13-38).

Temporal and Spatial Comparisons Sampling was initiated at *test* reach FOC-F1 in 2011; therefore, temporal comparisons were conducted between 2011 and 2012. There were no spatial comparisons given that there is no upstream *baseline* reach on Fort Creek.

The dominant species captured at *test* reach FOC-F1 in 2012 was northern redbelly dace, with juvenile longnose sucker as the subdominant species, whereas lake chub and finescale dace dominated the catch in 2011 (Table 5.13-39). Mean abundance decreased slightly in 2012 compared to 2011, but there was an increase in species richness (Table 5.13-40). All other measurement endpoints were consistent between 2011 and 2012.

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 RAMP. Based on past studies, a total of eight fish species were recorded in Fort Creek. In 2011, RAMP found an additional two species (finescale dace and white sucker), which had not been previously documented. In 2012, RAMP found a total of nine species, including three that have not previously been documented (fathead minnow, northern redbelly dace, and spottail shiner). Although similar fishing methods were reported in Golder (2004) to those used by RAMP (i.e., backpack electrofishing), fishing effort by RAMP was higher. In addition, given that *test* reach FOC-F1 is in close proximity to the Athabasca River, any small-bodied species or juvenile large-bodies species from the Athabasca River could potentially be using Fort Creek, near the mouth, as resting/feeding grounds and were captured at *test* reach FOC-F1.

Golder (2004) documented similar habitat conditions to what has been observed by RAMP, 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.

2012 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2012 at *test* reach FOC-F1 were within the range of regional *baseline* conditions (Figure 5.13-28).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach FOC-F1 and regional *baseline* conditions were classified as **Negligible-Low** given that the mean value all measurement endpoints were within the range of variation for regional *baseline* reaches.

5.13.7 Susan Lake Outlet

Monitoring was conducted at the Susan Lake outlet in 2012 for the Climate and Hydrology component.

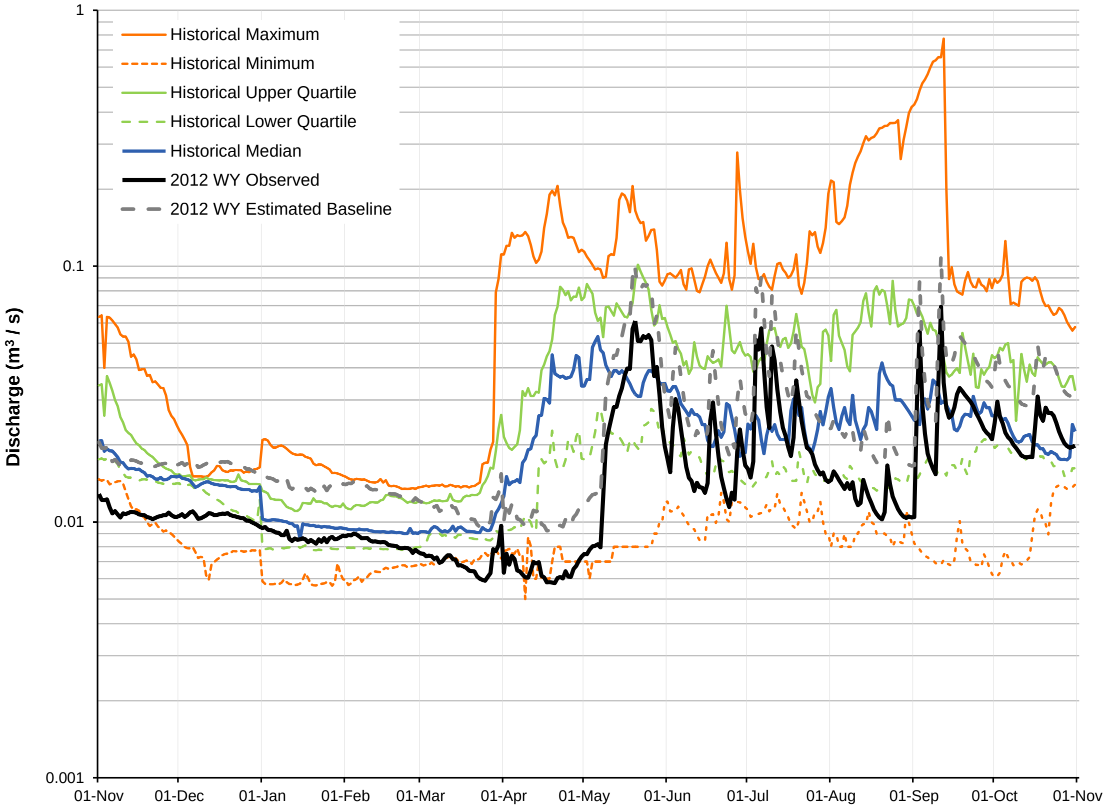
5.13.7.1 Hydrologic Conditions: 2012 Water Year

Hydrometric monitoring in the Susan Lake Outlet watershed was conducted at Station S25, Susan Lake Outlet, which was used for the water balance analysis. There were no additional hydrometric monitoring stations in this watershed.

Continuous hydrometric data during the open-water season (May to October) have been collected for RAMP Station S25 in 2002 and 2006 to 2012, but the data record was intermittent in all preceding seven years.

In the 2012 water year (WY), data were collected from May 19 to October 16. Comparison of the 2012 WY hydrologic conditions to historical values was less robust due to this limited historic record. Flows decreased after monitoring began on May 19 until June 24, with the exception of two rainfall induced peaks on June 4 and June 24 (Figure 5.13-29). Daily flows recorded in July showed multiple peak flows due to rainfall events from late June to mid-July. Flows generally decreased from late July through August to below the historical minimum values in mid-August. Rainfall events in late August and early September resulted in flows exceeding the historical maximum values, with flow reaching a peak of 0.168 m^3/s on September 4. Following this peak, flows decreased through September before steadily increasing until monitoring ended on October 16 2012.

Figure 5.13-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Mills Creek in the 2012 WY, compared to historical values.



Note: The drainage area for Station S6, Mills Creek at Highway 63 is assumed to be approximately 6 km^2 (two-thirds of the catchment). This value was calculated, using a Digital Elevation Model (DEM), to be that portion of the catchment located to the north and east of Highway 63. Field observations further supported this drainage area estimate; however, this value may be further updated in the future using a higher-resolution DEM analysis.

Note: Historical values from May to October were calculated from data collected from 1997 to 2011 and from 2006 to 2011 for other months.

Table 5.13-2 Estimated water balance at Station S6, Mills Creek at Highway 63, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**0.502**	**Observed discharge, obtained from Mills Creek at Highway 63, RAMP Station S6**
Closed-circuited area water loss from the observed *test* hydrograph	-0.313	Estimated 2.4 km^2 of the Mills Creek watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.015	Estimated 0.6 km^2 of the Mills Creek watershed with land change from focal projects as of 2012, that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Mills Creek watershed from focal projects	0	None reported
Water releases into the Mills Creek watershed from focal projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Mills Creek not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**0.799**	**Estimated *baseline* discharge at RAMP Station S6, Mills Creek at Highway 63**
Incremental flow (change in total discharge)	-0.298	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-37.2%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: The observed discharge volume is calculated from 2012 WY provisional data for Mills Creek at Highway 63, RAMP Station S6.

Note: The drainage area for Station S6, Mills Creek at Highway 63 is assumed to be approximately 6 km^2 (two-thirds of the catchment). This value was calculated, using a Digital Elevation Model (DEM), to be that portion of the catchment located to the north and east of Highway 63. Field observations further supported this drainage area estimate; however, this value may be further updated in the future using a higher-resolution DEM analysis.

Table 5.13-3 Calculated change in hydrologic measurement endpoints for the Mills Creek watershed, 2012 WY.

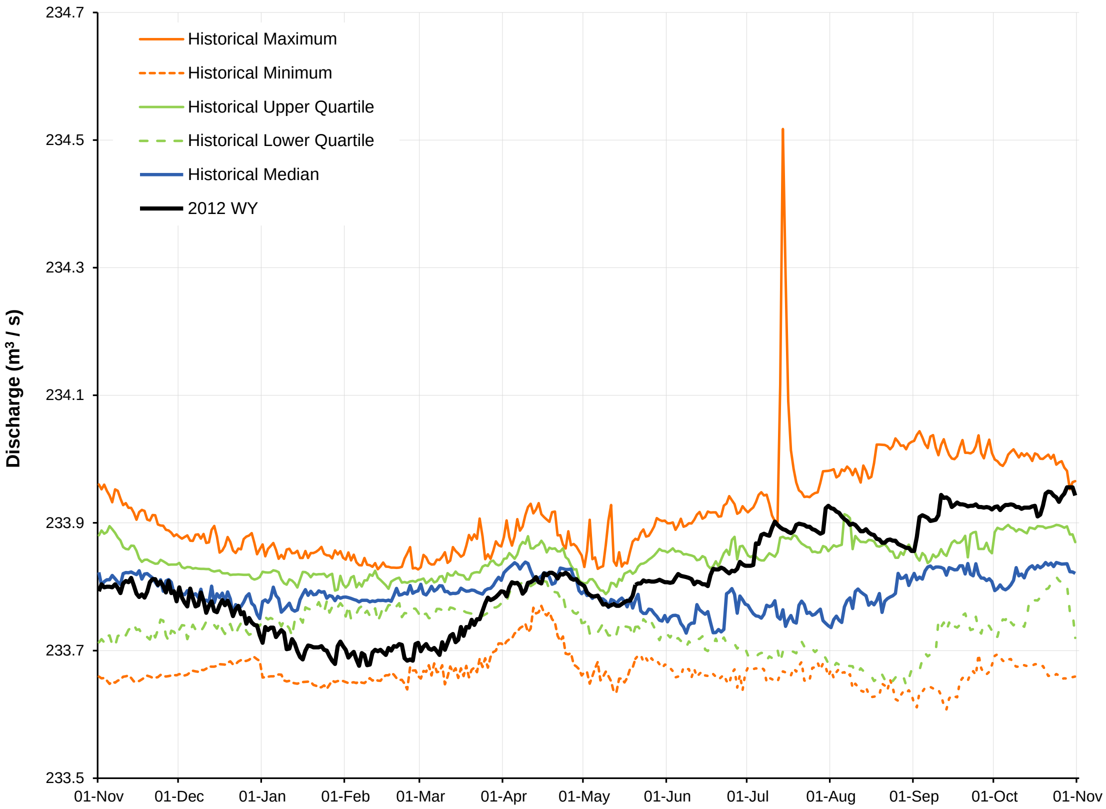
Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.037	0.023	-37.2%
Mean winter discharge	0.014	0.009	-37.2%
Annual maximum daily discharge	0.111	0.069	-37.2%
Open-water season minimum daily discharge	0.012	0.007	-37.2%

Note: Values are calculated from 2012 WY provisional data for Mills Creek at Highway 63, RAMP Station S6.

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows are 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 Isadore's Lake: 2012 hydrograph and historical context.



Note: Based on provisional 2012 WY data recorded at Isadore's Lake, RAMP Station L3. Historical values were calculated for the period 2000 to 2011.

Table 5.13-4 Concentrations of water quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	10	7.7	8.2	8.3
Total suspended solids	mg/L	-	5	10	<3	6	10
Conductivity	µS/cm	-	584	10	353	552	672
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.003	10	0.004	0.008	**0.067**
Total nitrogen	mg/L	1	0.9	10	0.3	**1.1**	**1.3**
Nitrate+nitrite	mg/L	1.3	<0.07	10	<0.05	<0.10	<0.30
Dissolved organic carbon	mg/L	-	12.9	10	8.0	11.0	12.9
Ions							
Sodium	mg/L	-	11.6	10	6.0	11.0	13.0
Calcium	mg/L	-	59.1	10	37.0	63.5	85.4
Magnesium	mg/L	-	27.5	10	25.0	29.9	36.0
Chloride	mg/L	120	23.3	10	4.0	16.0	22.6
Sulphate	mg/L	410	130	10	64	106	148
Total dissolved solids	mg/L	-	375	10	250	359	456
Total alkalinity	mg/L		141	10	122	164	227
Selected metals							
Total aluminum	mg/L	0.1	0.013	10	0.006	0.018	**0.182**
Dissolved aluminum	mg/L	0.1	0.002	10	<0.001	<0.001	0.020
Total arsenic	mg/L	0.005	0.00054	10	0.00046	0.00081	0.00116
Total boron	mg/L	1.2	0.055	10	0.035	0.043	0.054
Total molybdenum	mg/L	0.073	<0.00010	10	<0.00001	0.00006	0.00013
Total mercury (ultra-trace)	ng/L	5, 13	1.6	8	1.0	<1.2	1.4
Total strontium	mg/L	-	0.219	10	0.162	0.235	0.277
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	-	0.07	1	-	0.13	-
Oilsands Extractable	mg/L	-	0.38	1	-	1.29	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	<0.51	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.45	1	-	6.02	-
Total PAHs	ng/L	-	308.2	1	-	176.7	-
Total Parent PAHs	ng/L	-	18.04	1	-	21.75	-
Total Alkylated PAHs	ng/L	-	290.1	1	-	155.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total phenols	mg/L	0.004	**0.0062**	10	<0.001	**0.0047**	**0.0070**

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	2010-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.13	2	8.14	8.17	8.19
Total suspended solids	mg/L	-	<3.0	2	<3.0	4.0	5.0
Conductivity	µS/cm	-	898	2	859	885	910
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.005	2	<0.001	0.001	0.001
Total nitrogen	mg/L	1	0.301	2	0.301	0.376	0.451
Nitrate+nitrite	mg/L	1.3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	7.2	2	7.2	7.8	8.4
Ions							
Sodium	mg/L	-	9.3	2	9.4	10.0	10.5
Calcium	mg/L	-	135.0	2	138.0	138.5	139.0
Magnesium	mg/L	-	33.4	2	35.9	36.0	36.1
Chloride	mg/L	120	21.2	2	19.4	20.3	21.1
Sulphate	mg/L	410	212	2	169	181	192
Total dissolved solids	mg/L	-	617	2	598	603	607
Total alkalinity	mg/L		277	2	254	284	313
Selected metals							
Total aluminum	mg/L	0.1	0.0043	2	0.0030	0.0069	0.0107
Dissolved aluminum	mg/L	0.1	<0.0010	2	0.0010	0.0017	0.0024
Total arsenic	mg/L	0.005	0.00031	2	0.00029	0.00033	0.00037
Total boron	mg/L	1.2	0.0489	2	0.0360	0.0390	0.0419
Total molybdenum	mg/L	0.073	<0.0001	2	<0.0001	<0.0001	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	<0.60	2	<0.60	<0.60	0.60
Total strontium	mg/L	-	0.299	2	0.318	0.355	0.392
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	-	0.06	1	-	0.07	-
Oilsands Extractable	mg/L	-	0.32	1	-	0.82	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	<0.51	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	35.30	1	-	6.81	-
Total PAHs	ng/L	-	205.7	1	-	177.8	-
Total Parent PAHs	ng/L	-	16.41	1	-	24.18	-
Total Alkylated PAHs	ng/L	-	189.3	1	-	153.6	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**1.04**	2	**0.52**	**0.78**	**1.04**

[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.

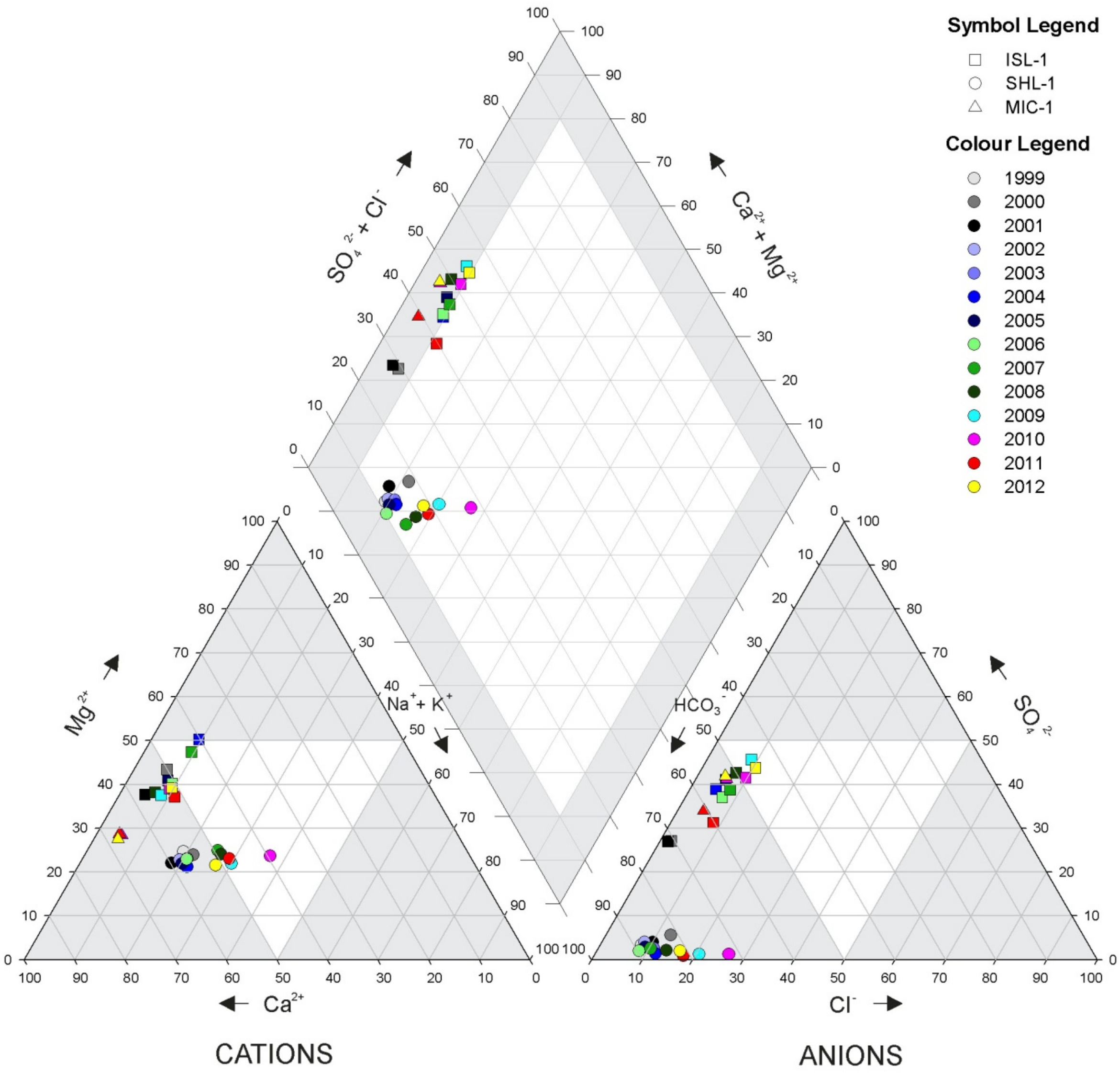


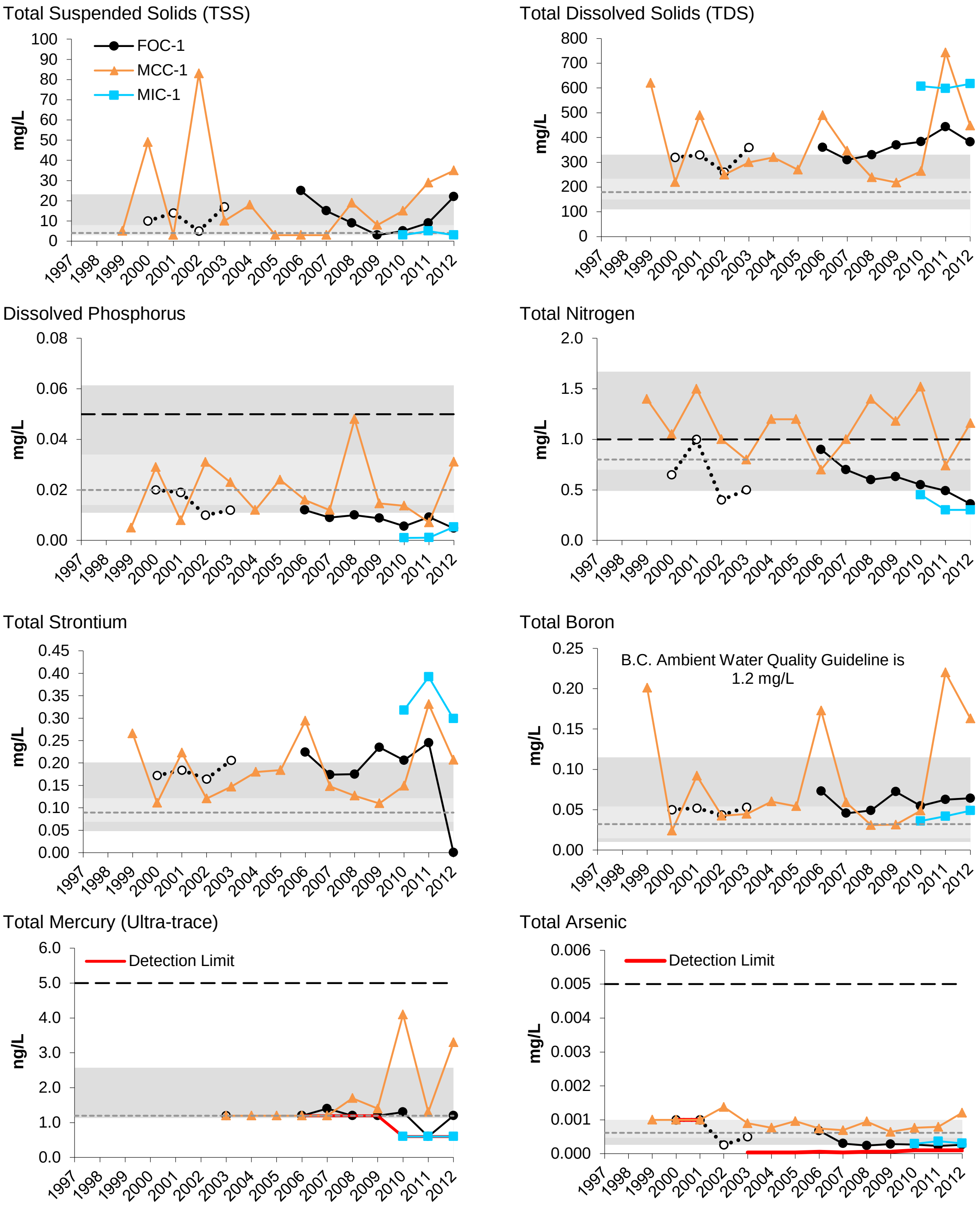
Table 5.13-6 Water quality guideline exceedances in *baseline* station BER-1, *test* station BER-2, *test* station POC-1, *test* station MCC-1, *test* station ISL-1, *test* station SHL-1, *test* station MIC-1, and *test* station FOC-1, fall 2012.

Variable	Units	Guideline[a]	POC-1	BER-1	BER-2	MCC-1	ISL-1	SHL-1	MIC-1	FOC-1
Chloride	mg/L	120	-	135	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	0.38	-	0.86	-	-	0.45	-	-
Dissolved selenium	mg/L	0.001	-	0.001	-	-	-	-	-	-
Sulphide	mg/L	0.002	0.0030	-	0.0065	0.0024	-	0.0044	-	-
Total aluminum	mg/L	0.1	0.21	1.75	0.33	0.67	-	0.19	-	0.173
Total chromium	mg/L	0.001	-	0.0022	-	-	-	-	-	-
Total dissolved phosphorus	mg/L	0.05	-	-	0.064	-	-	-	-	-
Total iron	mg/L	0.3	0.88	4.29	1.80	0.84	-	1.10	1.04	0.69
Total nitrogen	mg/L	1	1.21	-	-	1.161	-	-	-	-
Total phenols	mg/L	0.004	0.0127	0.0077	0.0097	0.0108	0.0062	0.0077	-	-
Total phosphorus	mg/L	0.05	-	0.0624	0.1470	0.0502	-	-	-	-
Total selenium	mg/L	0.001	-	0.0013	-	0.0012	-	-	-	-

[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 (MIC-1), McLean Creek (MCC-1), and Fort Creek (FOC-1) (fall data), relative to historical concentrations and regional *baseline* fall concentrations.**



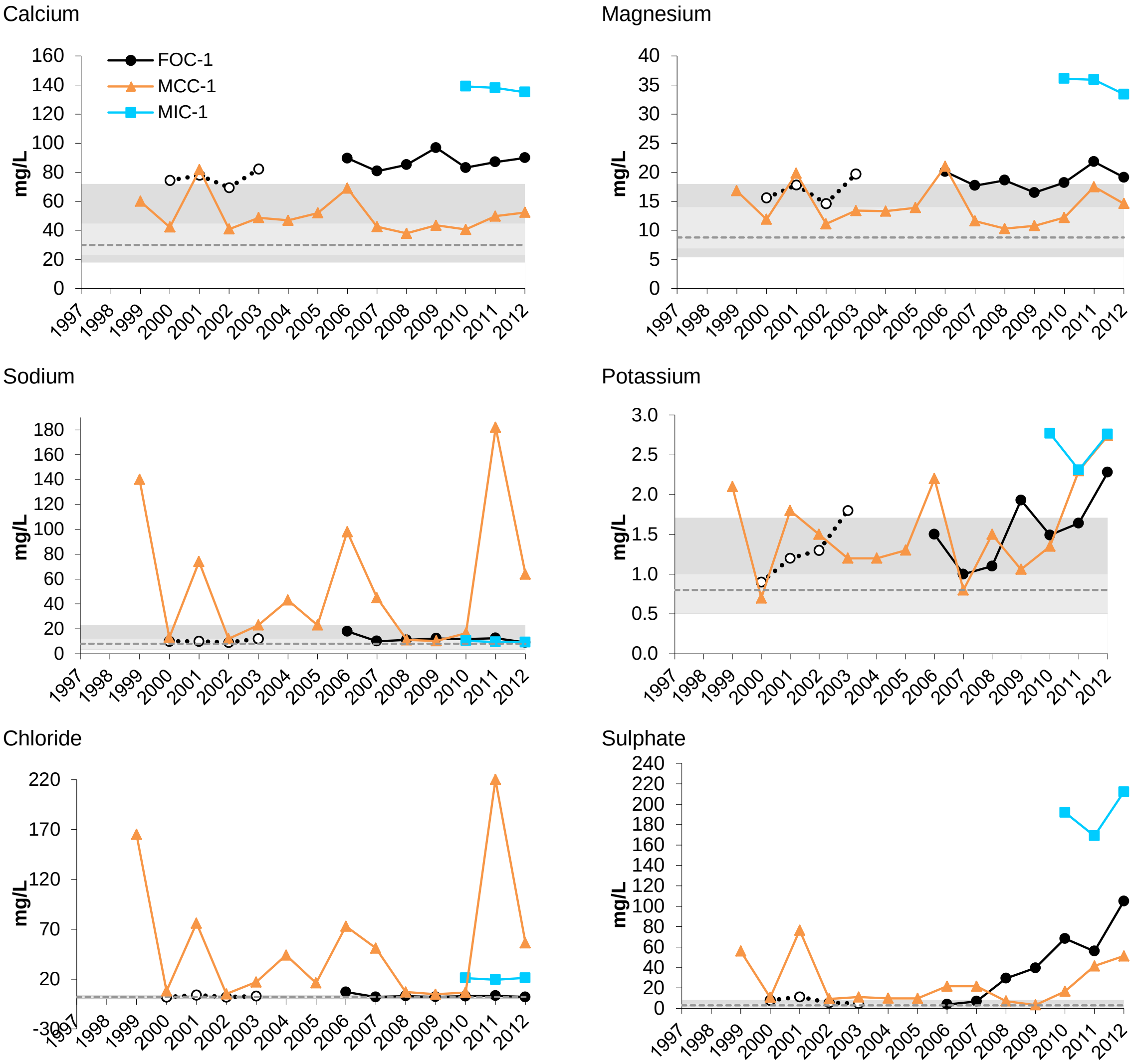
Non-detectable values are shown at the detection limit.

– – – – – 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.13-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

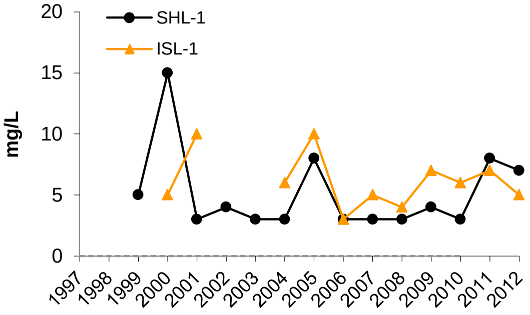
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

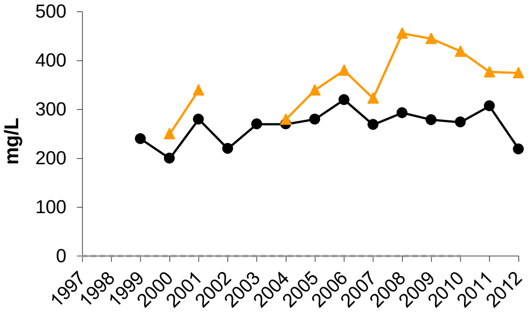
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.13-7 Concentrations of selected fall water quality measurement endpoints, Isadore’s Lake (ISL-1) and Shipyard Lake (SHL-1) (fall data), relative to historical concentrations.

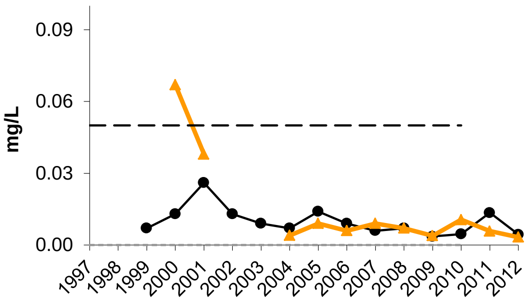
Total Suspended Solids (TSS)



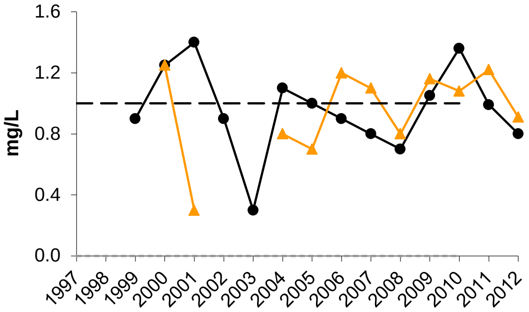
Total Dissolved Solids (TDS)



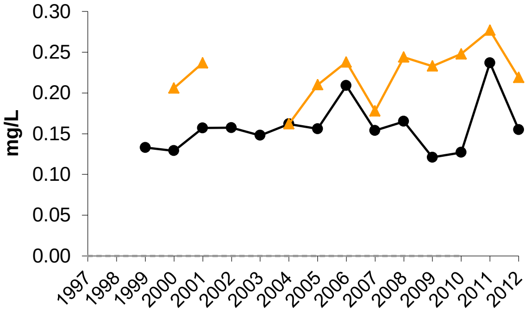
Dissolved Phosphorus



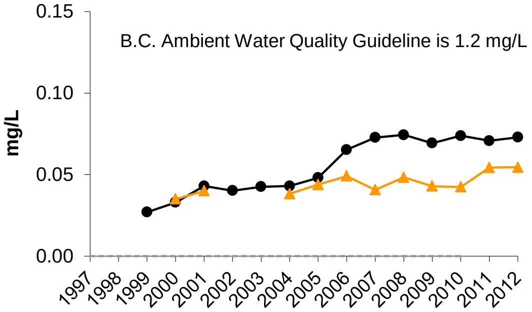
Total Nitrogen



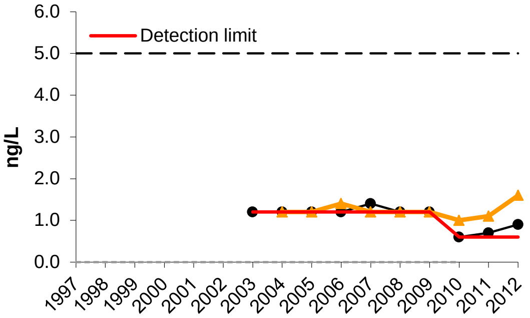
Total Strontium



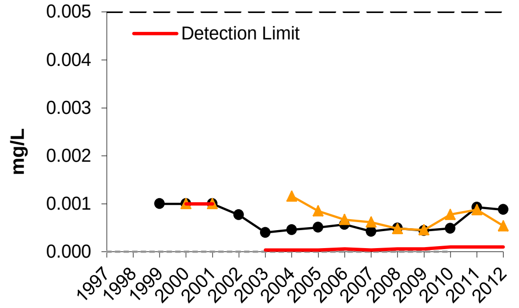
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



Non-detectable values are shown at the detection limit.

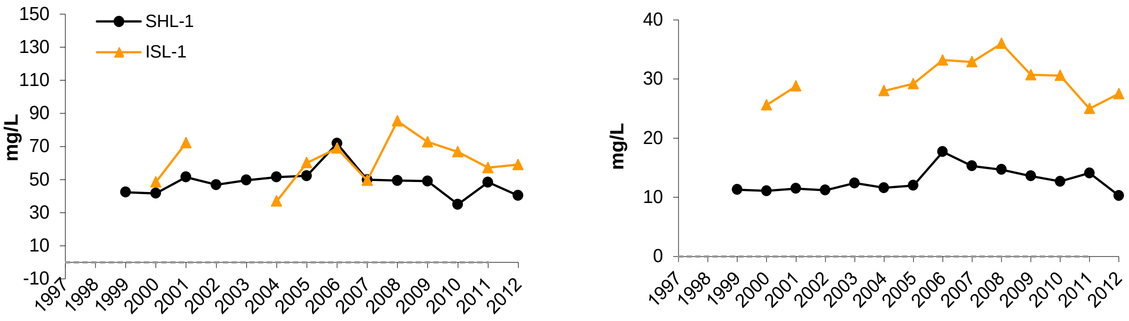
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.13-7 (Cont'd.)

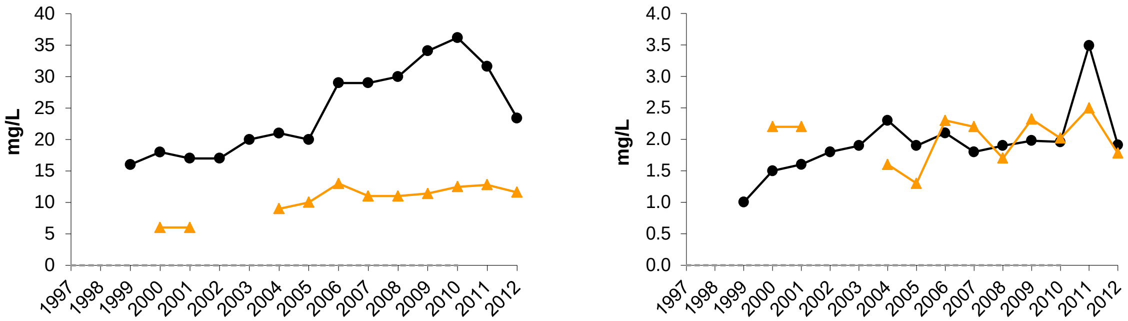
Calcium

Magnesium



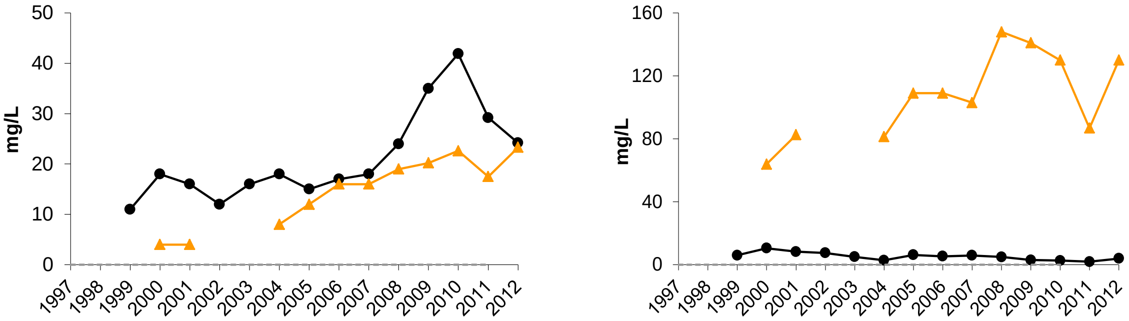
Sodium

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

Table 5.13-7 Water quality index (fall 2012) for miscellaneous watershed stations.

Station	Location	2012 Designation	Water Quality Index	Classification
POC-1	near the mouth of Poplar Creek	*test*	97.5	Negligible-Low
FOC-1	near the mouth of Fort Creek	*test*	80.8	Negligible-Low
BER-1	near the mouth of Beaver River	*test*	79.9	Moderate
BER-2	upper Beaver River	*baseline*	95.8	Negligible-Low
MCC-1	near the mouth of McLean Creek	*test*	63.0	Moderate
MIC-1	Mills Creek	*test*	70.4	Moderate

Table 5.13-8 Average habitat characteristics of benthic invertebrate sampling locations in Isadore's Lake, fall 2012.

Variable	Units	Isadore's Lake
Sample date	-	12-Sept-2012
Habitat	-	Depositional
Water depth	m	2.0
Field Water Quality		
Dissolved oxygen	mg/L	7.9
Conductivity	µS/cm	520
pH	pH units	8.36
Water temperature	°C	14.7
Sediment Composition		
Sand	%	2
Silt	%	77
Clay	%	21
Total Organic Carbon	%	2.83

Table 5.13-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Isadore’s Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Isadore's Lake		
	2006	2007 to 2011	2012
Nematoda	72	12 to 69	43
Glossiphoniidae		0 to <1	
Naididae	4	0 to 8	4
Tubificidae		0 to <1	<1
Hydracarina		0 to 8	<1
Amphipoda	<1	0 to <1	<1
Ostracoda	1	2 to 14	6
Cladocera		0 to 4	<1
Copepoda	3	<1 to 67	19
Gastropoda		0 to <1	<1
Bivalvia		0 to <1	<1
Ceratopogonidae	<1	0 to <1	
Chaoboridae	<1	0 to <1	2
Chironomidae	2	7 to 57	24
Ephemeroptera		0 to 1	<1
Anisoptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	33,987	10,948 to 20,110	16,592
Richness	10	5 to 9	10
Simpson's Diversity	0.41	0.38 to 0.66	0.56
Equitability	0.23	0.36 to 0.57	0.39
% EPT	0	0 to 1	<1

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).

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2012 vs. Previous Years	Time Trend	2012 vs. Previous Years	
Abundance	0.968	0.843	0	1	No change.
Richness	0.364	0.631	7	2	No change.
Simpson's Diversity	0.722	0.688	1	1	No change.
Equitability	0.669	0.693	1	1	No change.
EPT	**0.008**	**<0.001**	41	98	Increasing over time; lower in 2012 than mean of previous years.
CA Axis 1	0.182	0.883	9	0	No change.
CA Axis 2	0.137	0.979	10	0	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).

Figure 5.13-8 Variation in benthic invertebrate community measurement endpoints in Isadore's Lake (*test* station ISL-1).

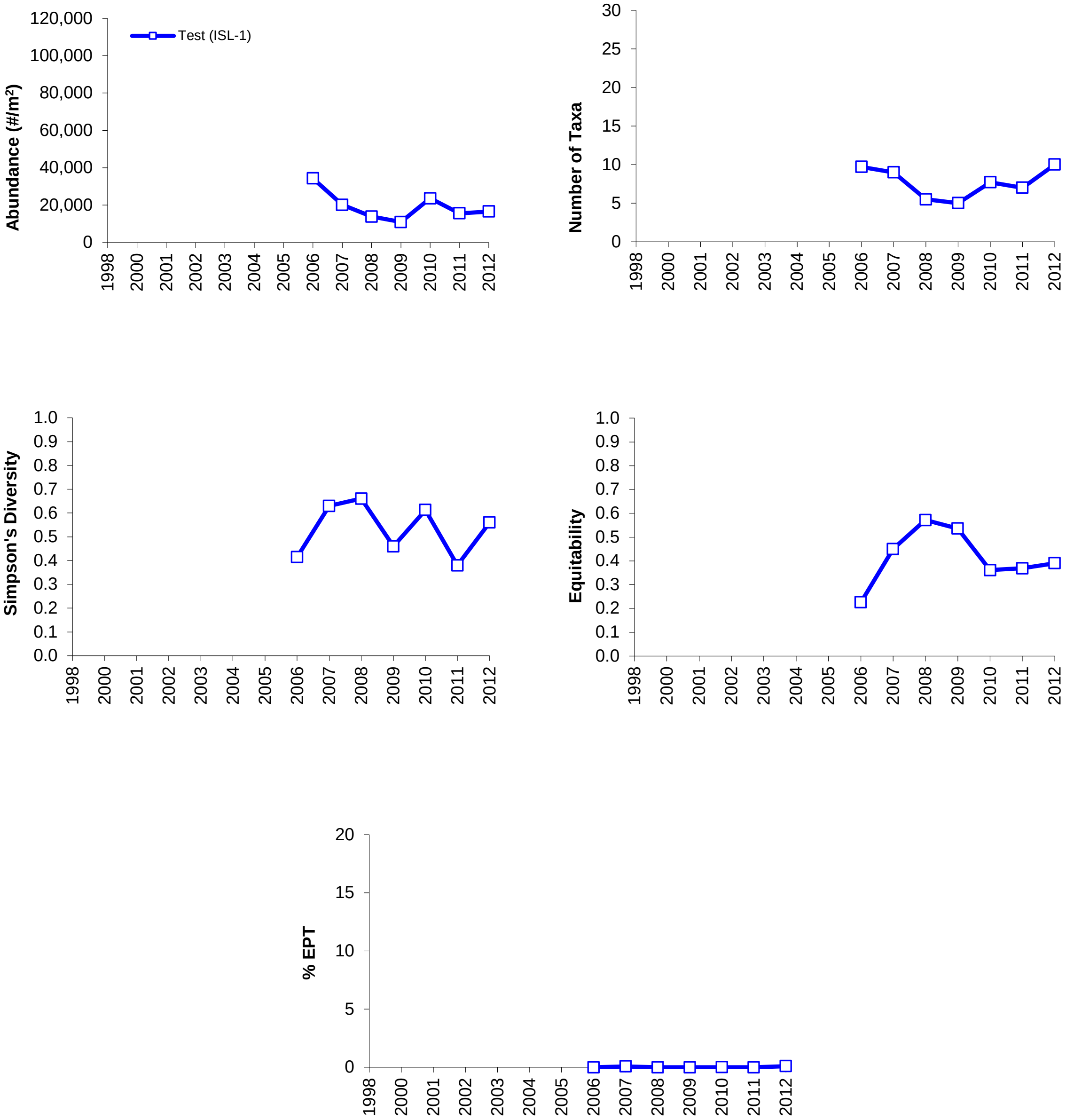
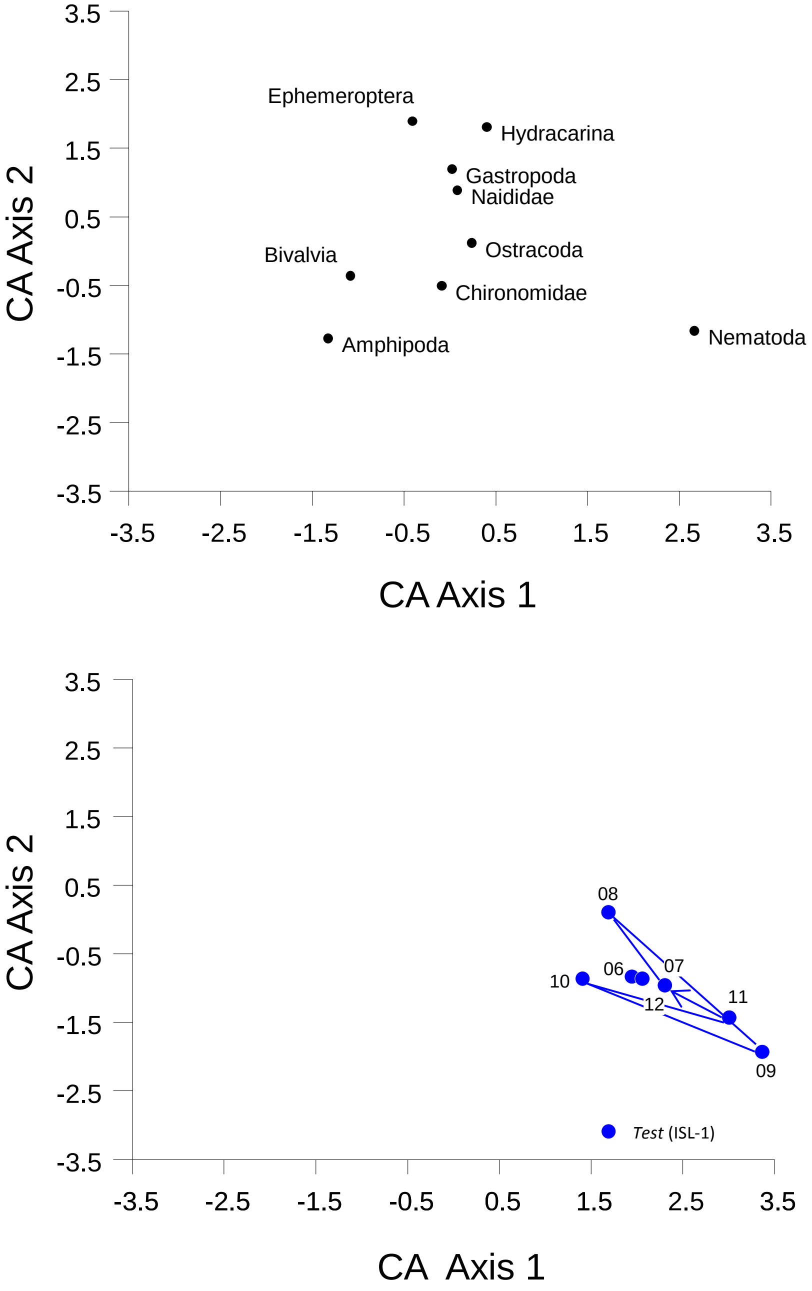


Figure 5.13-9 Ordination (Correspondence Analysis) of benthic invertebrate communities in Isadore's Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.13-11 Concentrations of sediment quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	25	7	11.3	26	57
Silt	%	-	73	7	39	61	86
Sand	%	-	2	7	3	12	35
Total organic carbon	%	-	2.0	7	1.3	4.7	18.8
Total hydrocarbons							
BTEX	mg/kg	-	<20	6	<5	<10	<100
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	6	<5	<10	<100
Fraction 2 (C10-C16)	mg/kg	150[1]	<25	6	<5	47.5	91
Fraction 3 (C16-C34)	mg/kg	300[1]	215	6	150	**431**	**4,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	119	6	89	286	3,500
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.005	7	0.006	0.007	0.011
Retene	mg/kg	-	0.050	7	0.037	0.056	0.071
Total dibenzothiophenes	mg/kg	-	0.193	7	0.115	0.170	0.261
Total PAHs	mg/kg	-	1.54	7	0.779	1.36	2.06
Total Parent PAHs	mg/kg	-	0.124	7	0.068	0.143	0.175
Total Alkylated PAHs	mg/kg	-	1.41	7	0.711	1.26	1.88
Predicted PAH toxicity[3]	H.I.	1.0	**1.21**	7	0.072	0.559	**1.29**
Metals that exceed CCME guidelines in 2012							
Total Arsenic	mg/kg	5.9	**6.30**	7	3.58	**6.21**	**7.40**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.4	4	6.4	7.0	9.0
Chironomus growth - 10d	mg/organism	-	2.58	4	1.06	2.16	2.63
Hyalella survival - 14d	# surviving	-	9.2	4	7.6	8.8	9.8
Hyalella growth - 14d	mg/organism	-	0.32	4	0.20	0.31	0.44

Values in **bold** indicate concentrations exceeding guidelines.

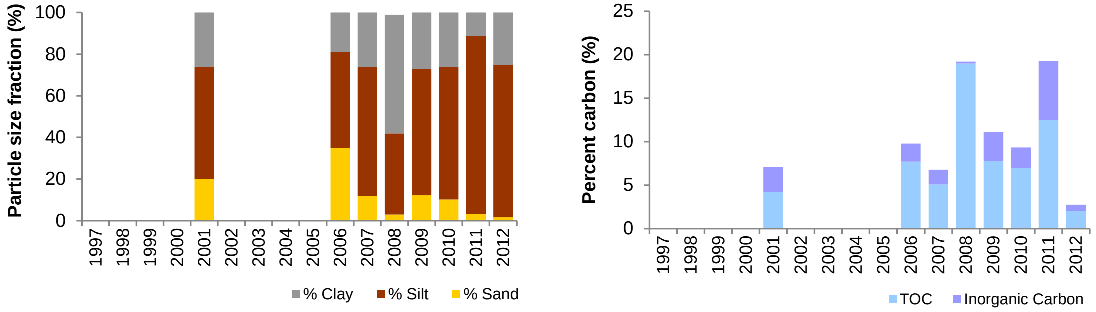
Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

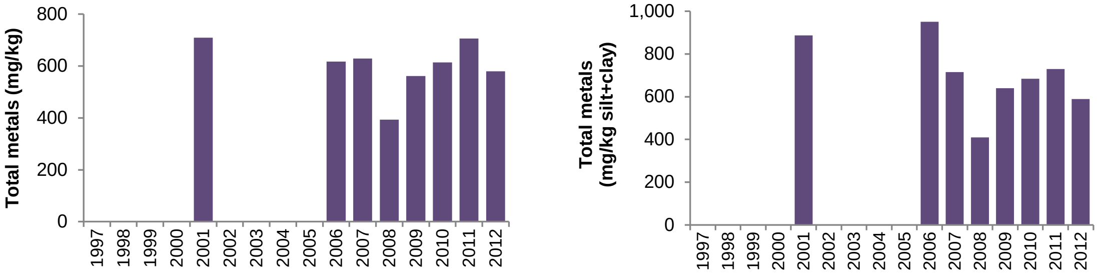
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-10 Variation in sediment quality measurement endpoints in Isadore's Lake, *test* station ISL-1.



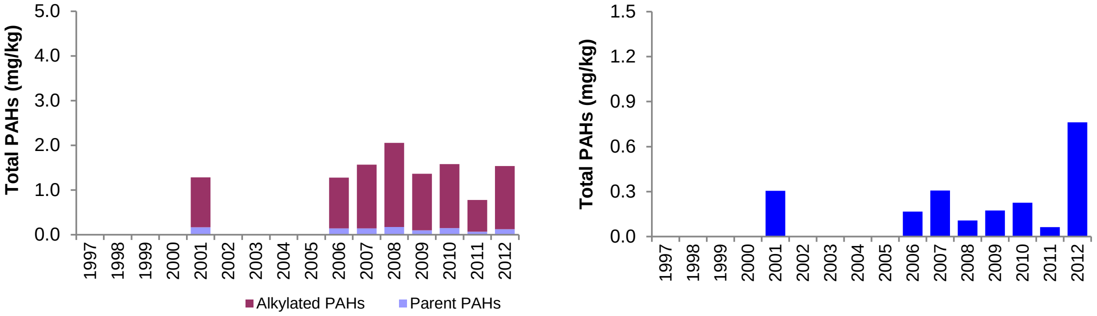
Particle size distribution

Carbon Content



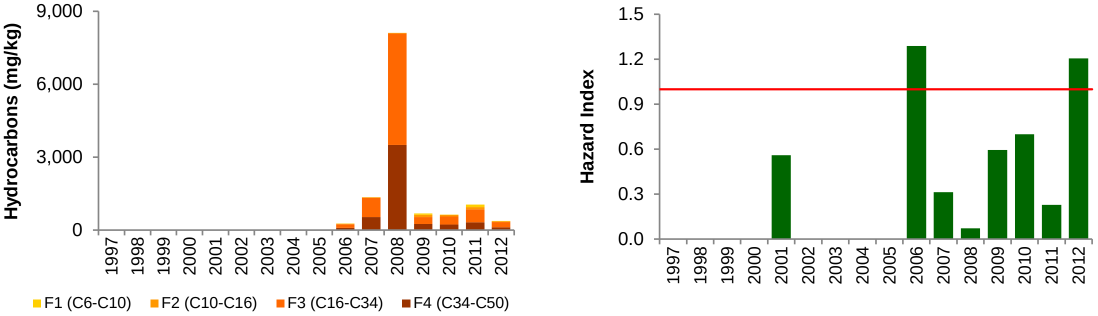
Total Metals[1]

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 5.13-12 Concentrations of water quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	13	7.7	8.1	8.2
Total suspended solids	mg/L	-	7	13	<3	3	15
Conductivity	µS/cm	-	400	13	358	421	509
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.004	13	0.004	0.009	0.026
Total nitrogen	mg/L	1	0.80	13	0.30	0.99	**1.40**
Nitrate+nitrite	mg/L	1.3	<0.07	13	<0.05	<0.10	<0.10
Dissolved organic carbon	mg/L	-	19.3	13	16.7	19.3	24.0
Ions							
Sodium	mg/L	-	23.4	13	16.0	21.0	36.2
Calcium	mg/L	-	40.4	13	35.0	49.4	71.8
Magnesium	mg/L	-	10.3	13	11.1	12.4	17.7
Chloride	mg/L	120	24.2	13	11.0	18.0	41.9
Sulphate	mg/L	270	4.0	13	1.9	5.3	10.5
Total dissolved solids	mg/L	-	219	13	200	274	320
Total alkalinity	mg/L		166	13	159	186	251
Selected metals							
Total aluminum	mg/L	0.1	**0.190**	13	<0.002	0.010	**0.140**
Dissolved aluminum	mg/L	0.1	0.007	13	<0.001	0.0015	<0.010
Total arsenic	mg/L	0.005	0.0009	13	0.0004	0.0005	0.0010
Total boron	mg/L	1.2	0.073	13	0.027	0.048	0.074
Total molybdenum	mg/L	0.073	0.00018	13	0.00002	0.00009	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	0.9	9	<0.6	<1.2	1.4
Total strontium	mg/L	-	0.155	13	0.121	0.156	0.237
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	-	0.17	1	-	0.88	-
Oilsands Extractable	mg/L	-	0.69	1	-	2.52	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	0.56	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	36.50	1	-	8.43	-
Total PAHs	ng/L	-	224.8	1	-	163.3	-
Total Parent PAHs	ng/L	-	17.81	1	-	21.32	-
Total Alkylated PAHs	ng/L	-	207.0	1	-	142.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.449**	13	<0.010	0.159	**0.863**
Sulphide	mg/L	0.002	**0.004**	13	<0.003	**0.009**	**0.014**
Total iron	mg/L	0.3	**1.10**	13	0.27	**0.42**	**1.54**
Total phenols	mg/L	0.004	**0.008**	13	<0.001	**0.006**	**0.012**

[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 2012.

Variable	Units	Shipyard Lake
Sample date	-	12-Sept-2012
Habitat	-	Depositional
Water depth	m	1.5
Field Water Quality		
Dissolved oxygen	mg/L	-
Conductivity	µS/cm	359
pH	pH units	7.8
Water temperature	°C	12.5
Sediment Composition		
Sand	%	2
Silt	%	75
Clay	%	23
Total Organic Carbon	%	14.6

Table 5.13-14 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Shipyard Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Shipyard Lake		
	2000	2001 to 2011	2012
Hydra		0 to <1	
Nematoda		0 to 5	3
Erpobdellidae		0 to 1	
Glossiphoniidae		0 to <1	<1
Naididae	8	0 to 33	19
Tubificidae	1	0 to 7	2
Enchytraeidae		0 to 7	
Lumbriculidae		0 to <1	<1
Hydracarina		0 to 4	
Amphipoda	7	0 to 3	1
Ostracoda	6	<1 to 87	4
Cladocera	3	0 to 10	2
Copepoda	1	0 to 27	7
Gastropoda	18	<1 to 7	17
Bivalvia	7	<1 to 8	1
Ceratopogonidae		0 to 6	<1
Chaoboridae	3	0 to 53	2
Chironomidae	25	3 to 48	40
Ephemeroptera	16	0 to 6	
Anisoptera	<1	0 to 1	
Zygoptera	3	0 to 1	
Trichoptera	2	0 to 1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	4,552	1,530 to 67,703	14,701
Richness	13	4 to 27	17
Simpson's Diversity	0.84	0.21 to 0.84	0.81
Equitability	0.56	0.16 to 0.75	0.40
% EPT	19	<1 to 5	0

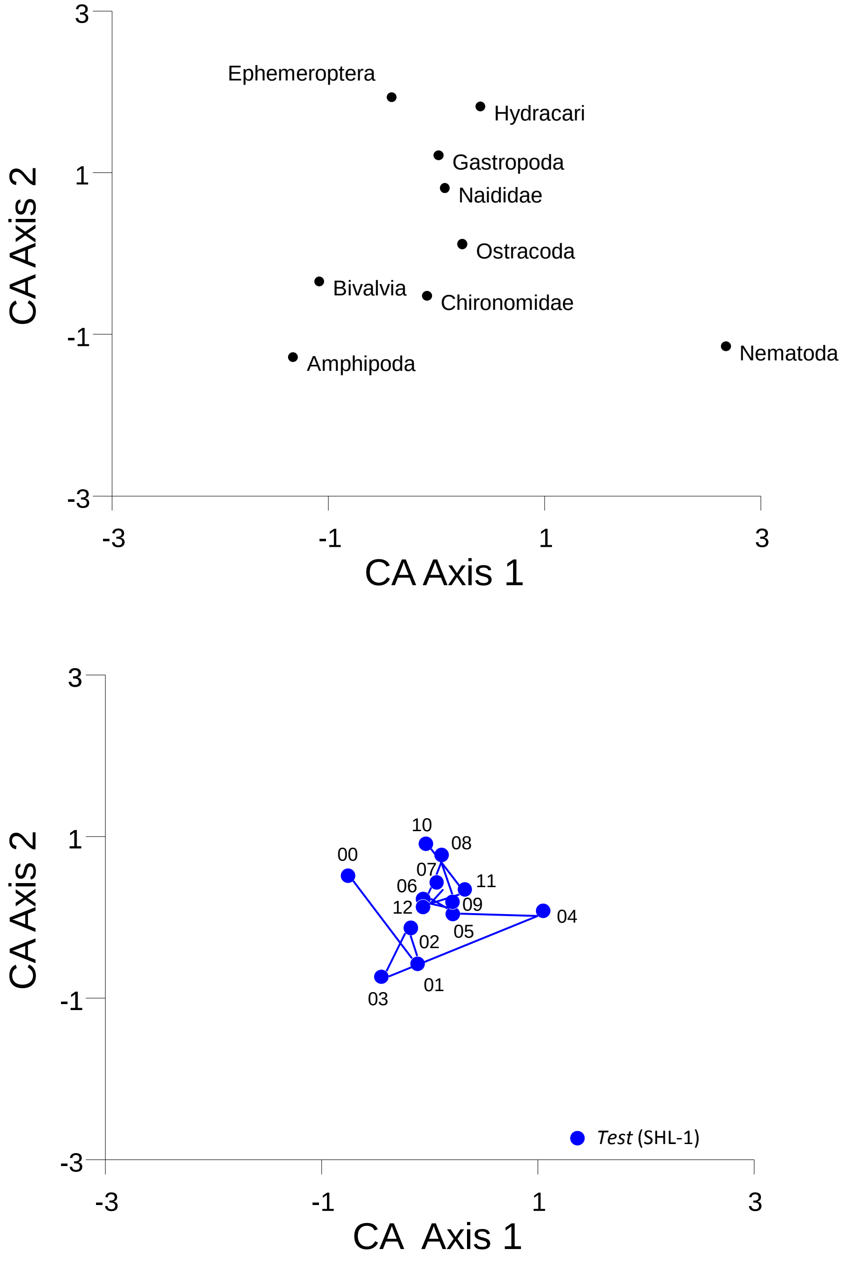
Table 5.13-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Shipyard Lake (SHL-1).

Variable	**P-value**		**Variance Explained (%)**		**Nature of Change(s)**
	Time trend	**2012 vs. Previous Years**	**Time trend**	**2012 vs. Previous Years**	
Abundance	**<0.001**	0.833	33	0	Increasing over time; lower in 2012 than the mean value of previous years.
Richness	**<0.001**	**0.048**	37	3	Increasing over time; higher in 2012 than the mean of previous years.
Simpson's Diversity	**<0.001**	**0.004**	15	5	Increasing over time; higher in 2012 than the mean of previous years.
Equitability	**<0.001**	0.677	17	0	Decreasing over time.
EPT	**0.006**	**0.004**	5	6	Decreasing over time; lower in 2012 than the mean of previous years.
CA Axis 1	**0.022**	0.753	11	0	Increasing over time.
CA Axis 2	**0.001**	0.945	26	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).

Figure 5.13-11 Ordination (Correspondence Analysis) of benthic invertebrate communities in Shipyard Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Figure 5.13-12 Variation in benthic invertebrate community measurement endpoints in Shipyard Lake (*test* station SHL-1).

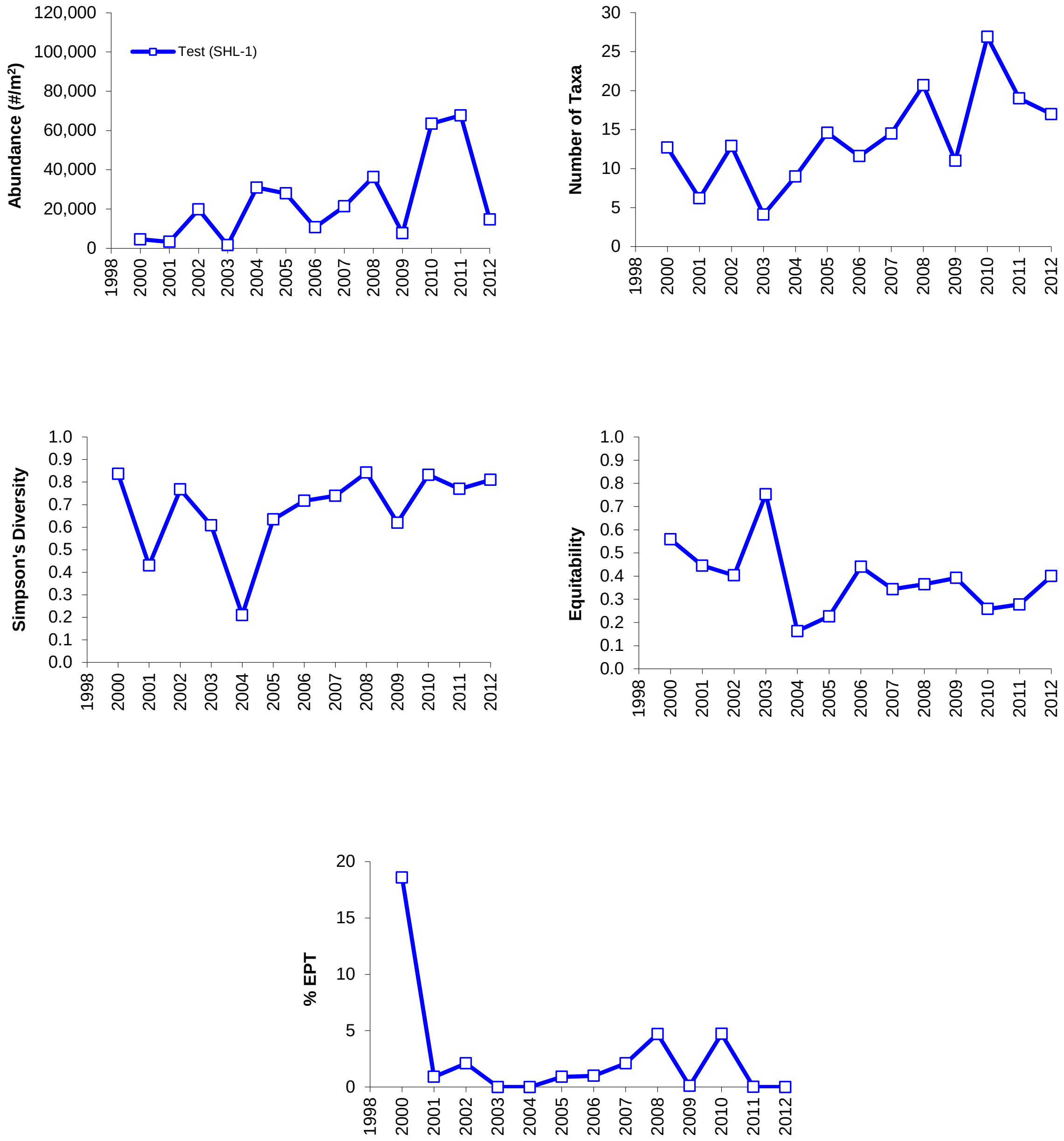


Table 5.13-16 Concentrations of sediment quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	13	9	18	37	60
Silt	%	-	86	9	36	41	69
Sand	%	-	1	9	2	5	41
Total organic carbon	%	-	19.6	10	5.5	12.5	18.8
Total hydrocarbons							
BTEX	mg/kg	-	<180	7	<5	<10	<240
Fraction 1 (C6-C10)	mg/kg	30[1]	<180	7	<5	<10	<240
Fraction 2 (C10-C16)	mg/kg	150[1]	<179	7	<5	69	<313
Fraction 3 (C16-C34)	mg/kg	300[1]	**2,070**	7	290	**939**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	1,090	7	<5	280	1,180
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.020	8	0.011	0.017	0.031
Retene	mg/kg	-	0.080	10	0.046	0.088	0.199
Total dibenzothiophenes	mg/kg	-	1.490	10	0.265	0.655	2.62
Total PAHs	mg/kg	-	8.21	10	2.28	4.90	10.7
Total Parent PAHs	mg/kg	-	0.596	10	0.231	0.272	0.672
Total Alkylated PAHs	mg/kg	-	7.62	10	2.02	4.61	10.1
Predicted PAH toxicity[3]	H.I.	1.0	0.695	10	0.097	0.763	**3.786**
Metals that exceed CCME guidelines in 2012							
Total Arsenic	mg/kg	5.9	**6.93**	10	5.50	**6.65**	**7.80**
Other analytes that exceeded CCME guidelines in 2012							
Benz[a]anthracene	mg/kg	0.0317	**0.063**	10	0.010	0.020	**0.064**
Benzo[a]pyrene	mg/kg	0.0319	**0.079**	10	0.013	0.025	**0.070**
Chrysene	mg/kg	0.0571	**0.139**	10	0.033	0.050	**0.163**
Pyrene	mg/kg	0.053	**0.053**	10	0.014	0.025	**0.061**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.8	6	5.6	7.6	8.2
Chironomus growth - 10d	mg/organism	-	2.18	6	1.25	1.95	2.56
Hyalella survival - 14d	# surviving	-	8.3	6	6.0	8.0	8.4
Hyalella growth - 14d	mg/organism	-	0.28	6	0.10	0.24	0.45

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

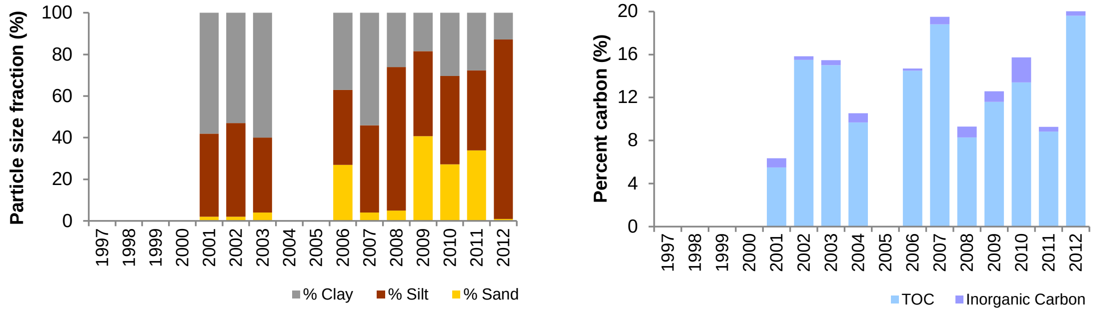
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

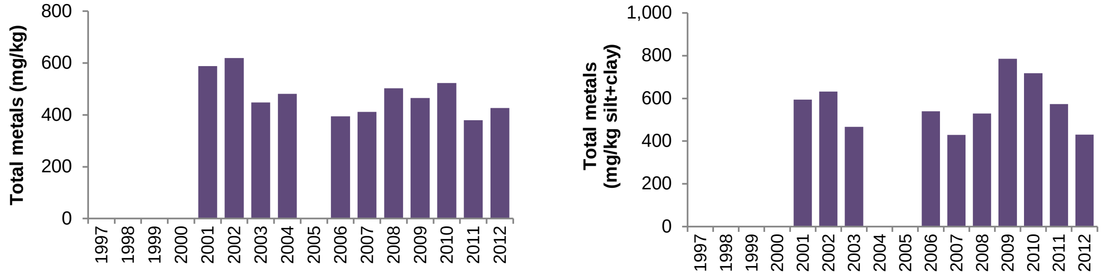
Particle size distribution

Carbon Content



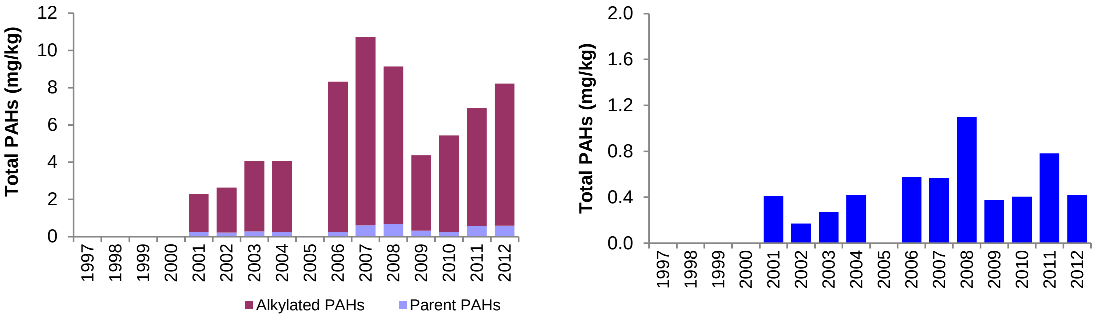
Total Metals[1]

Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



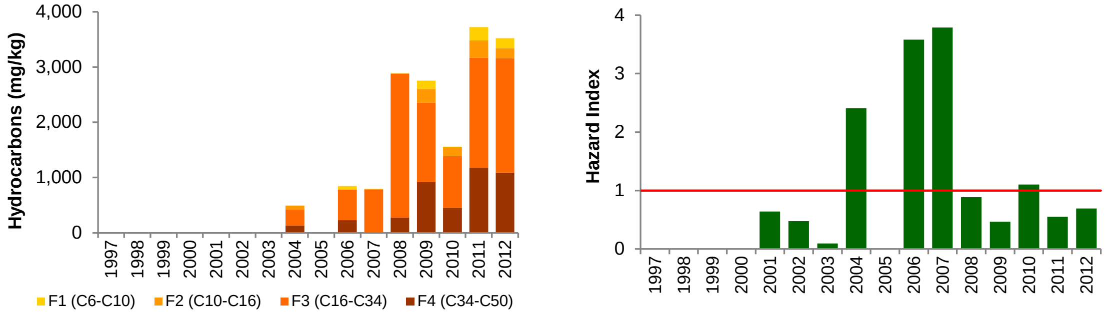
Total PAHs

Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions

PAH Hazard Index[2]



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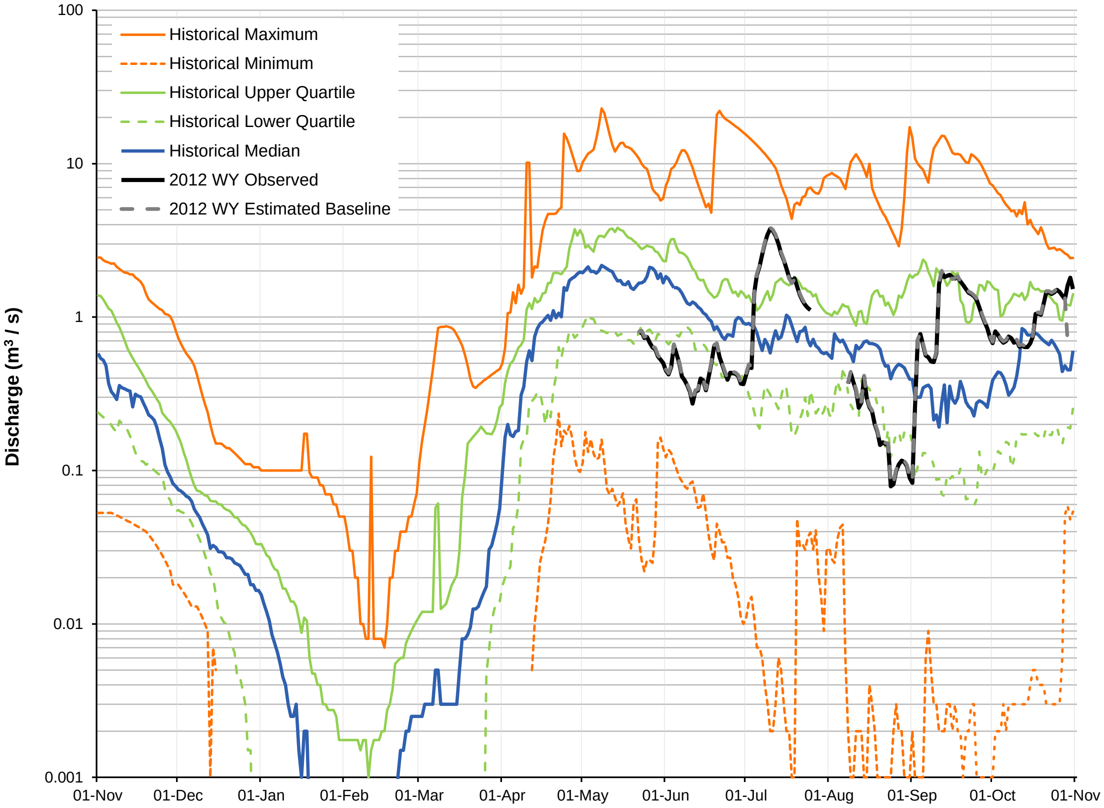
[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[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 2012, compared to historical values.



Note: Observed values are calculated from provisional data for May 22 to October 31, 2012 WY for Poplar Creek at Highway 63, 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 2011, and from 1973 to 1986 for other months.

Note: Minor differences (within expected measurement error) were calculated between observed flows at Station S11 and flow releases from the Poplar Creek Spillway that led estimated *baseline* values to be slightly negative for a number of days during the fall, 2012. *Baseline* values on these days were set to zero, in accordance with previous reports (e.g., RAMP 2008, RAMP 2009a, RAMP 2010, RAMP 2011), and do not appear on the graph due to the logarithmic scale used.

Table 5.13-17 Estimated water balance at WSC Station 07DA007 (RAMP Station S11), Poplar Creek at Highway 63, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**12.198**	**Observed daily discharges, obtained from Poplar Creek at Highway 63, WSC Station 07DA007 (RAMP Station S11).**
Closed-circuited area water loss from the observed *test* hydrograph	-0.247	Estimated 3.1 km^2 of the Poplar Creek watershed is closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.029	Estimated 1.8 km^2 of the Poplar Creek watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Poplar Creek watershed from focal projects	0	None reported
Water releases into the Poplar Creek watershed from focal projects	0	None reported
Diversions into or out of the watershed	+0.437	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	0	No focal projects or other oil sands projects on tributaries of Poplar Creek not accounted for by figures contained in this table
Estimated *baseline* hydrograph (total discharge)	**12.008**	**Estimated *baseline* discharge at Poplar Creek at Highway 63, WSC Station 07DA007 (RAMP Station S11).**
Incremental flow (change in total discharge)	+0.220	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**+1.6%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Values are calculated from provisional data for May 22 to October 31, 2012 for Poplar Creek at Highway 63, Station S11 (WSC 07DA007). The upstream drainage area is 151 km^2.

Note: Minor differences (within expected measurement error) were calculated between observed flows at Station S11 and flow releases from the Poplar Creek Spillway that led estimated *baseline* values to be slightly negative for a number of days during the fall, 2012. *Baseline* values on these days were set to zero, in accordance with previous reports (e.g., RAMP 2008, RAMP 2009a, RAMP 2010, RAMP 2011).

Table 5.13-18 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed, 2012 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.927	0.941	+1.6%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	3.832	3.763	-1.8%
Open-water season minimum daily discharge	0.080	0.079	-1.8%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Values are calculated from provisional data for May 22 to October 31, 2012 for Poplar Creek at Highway 63, Station S11 (WSC 07DA007). The upstream drainage area is 151 km^2.

Note: Minor differences (within expected measurement error) were calculated between observed flows at Station S11 and flow releases from the Poplar Creek Spillway that led estimated *baseline* values to be slightly negative for a number of days during the fall, 2010. *Baseline* values on these days were set to zero, in accordance with previous reports (e.g., RAMP 2008, RAMP 2009a, RAMP 2010, RAMP 2011).

Note: The relative change for each measurement endpoint is calculated using observed and *baseline* flow values, which are estimated to several decimal places. However, for clarity in this table, all flows and percentage change values are presented to three and one decimal places, respectively.

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 5.13-19 Concentrations of water quality measurement endpoints, Poplar Creek (*test* station POC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	12	8.2	8.3	8.4
Total suspended solids	mg/L	-	8	12	4	10	61
Conductivity	µS/cm	-	455	12	308	471	1590
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.010	12	0.007	0.013	0.027
Total nitrogen	mg/L	1	**1.21**	12	0.30	**1.05**	**2.11**
Nitrate+nitrite	mg/L	1.3	<0.07	12	<0.05	0.10	0.10
Dissolved organic carbon	mg/L	-	4.7	12	4.7	23.5	32.0
Ions							
Sodium	mg/L	-	46.8	12	10.0	46.5	238.0
Calcium	mg/L	-	31.0	12	28.2	40.2	74.4
Magnesium	mg/L	-	11.6	12	9.7	14.6	29.3
Chloride	mg/L	120	19.2	12	2.0	29.0	**321.0**
Sulphate	mg/L	270	11.5	12	7.8	14.7	44.2
Total dissolved solids	mg/L	-	306	12	200	295	890
Total alkalinity	mg/L		201	12	135	195	304
Selected metals							
Total aluminum	mg/L	0.1	**0.21**	12	0.05	**0.36**	**1.44**
Dissolved aluminum	mg/L	0.1	0.007	12	0.002	0.007	0.090
Total arsenic	mg/L	0.005	0.0011	12	0.0008	0.0011	0.0023
Total boron	mg/L	1.2	0.18	12	0.04	0.12	0.18
Total molybdenum	mg/L	0.073	0.00019	12	0.00010	0.00027	0.00072
Total mercury (ultra-trace)	ng/L	5, 13	1.8	9	0.8	1.2	2.0
Total strontium	mg/L	-	0.18	12	0.15	0.24	0.51
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	-	0.19	1	-	0.81	-
Oilsands Extractable	mg/L	-	0.51	1	-	1.81	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.1	-
Retene	ng/L	-	1.30	1	-	2.17	-
Total dibenzothiophenes	ng/L	-	51.68	1	-	16.96	-
Total PAHs	ng/L	-	281.8	1	-	184.6	-
Total Parent PAHs	ng/L	-	18.16	1	-	20.41	-
Total Alkylated PAHs	ng/L	-	263.7	1	-	164.2	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.38**	12	0.05	0.21	**2.32**
Sulphide	mg/L	0.002	**0.0030**	12	<0.003	**0.0066**	**0.0102**
Total iron	mg/L	0.3	**0.88**	12	**0.70**	**1.33**	**3.63**
Total phenols	mg/L	0.004	**0.0127**	12	<0.001	**0.0070**	**0.0190**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.13-20 Concentrations of water quality measurement endpoints, lower Beaver River (*test* station BER-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.59.0	8.1	9	8.0	8.2	8.4
Total suspended solids	mg/L	-	47	9	<3	11	77
Conductivity	µS/cm	-	1,140	9	566	871	1,930
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.007	9	0.004	0.008	0.022
Total nitrogen	mg/L	1	0.91	9	0.70	**1.10**	**1.68**
Nitrate+nitrite	mg/L	1.3	<0.071	9	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	23.5	9	15.0	31.0	52.0
Ions							
Sodium	mg/L	-	132	9	53	77	267
Calcium	mg/L	-	72.9	9	49.1	70.2	91.5
Magnesium	mg/L	-	21.7	9	15.5	19.1	28.1
Chloride	mg/L	120	**135**	9	55	94	**364**
Sulphate	mg/L	410	113	9	50.7	69.2	**117**
Total dissolved solids	mg/L	-	654	9	450	650	1110
Total alkalinity	mg/L	-	267	9	158	239	349
Selected metals							
Total aluminum	mg/L	0.1	**1.75**	9	0.03	**0.27**	**5.13**
Dissolved aluminum	mg/L	0.1	0.005	9	0.002	0.006	0.045
Total arsenic	mg/L	0.005	0.0014	9	0.0007	0.0010	0.0021
Total boron	mg/L	1.2	0.21	9	0.09	0.14	0.24
Total molybdenum	mg/L	0.073	0.00066	9	0.00019	0.00031	0.00043
Total mercury (ultratrace)	ng/L	5, 13	4.0	9	<1.2	1.3	**8.1**
Total strontium	mg/L	-	0.33	9	0.23	0.29	0.63
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	-	1.26	1	-	7.26	-
Oilsands Extractable	mg/L	-	0.96	1	-	9.34	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	15.7	-
Retene	ng/L	-	5.03	1	-	8.26	-
Total dibenzothiophenes	ng/L	-	49.63	1	-	39.94	-
Total PAHs	ng/L	-	363.4	1	-	372.3	-
Total Parent PAHs	ng/L	-	25.11	1	-	30.31	-
Total Alkylated PAHs	ng/L	-	338.3	1	-	342.0	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total chromium	mg/L	0.001	**0.0022**	9	0.0004	**0.0011**	**0.0075**
Total iron	mg/L	0.3	**4.29**	9	**1.79**	**2.39**	**6.97**
Total phenols	mg/L	0.004	**0.0077**	8	0.0020	**0.0086**	**0.0147**
Total phosphorus	mg/L	0.05	**0.062**	9	0.016	0.029	**0.128**
Dissolved selenium	mg/L	0.001	**0.0010**	9	<0.0003	0.0006	0.0008
Total selenium	mg/L	0.001	**0.00128**	9	0.00031	0.00069	**0.00120**

[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 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	7.8	8.2	8.4
Total suspended solids	mg/L	-	6	4	6	10	93
Conductivity	µS/cm	-	462	4	255	380	511
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.064**	4	0.037	**0.061**	**0.074**
Total nitrogen	mg/L	1	0.95	4	**0.89**	**1.73**	**2.44**
Nitrate+nitrite	mg/L	1.3	<0.071	4	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	20.5	4	20.5	28.3	34.0
Ions							
Sodium	mg/L	-	58.7	4	20.9	42.3	67.7
Calcium	mg/L	-	29.4	4	22.5	31.9	35.8
Magnesium	mg/L	-	10.4	4	7.5	10.8	12.2
Chloride	mg/L	120	1.26	4	0.68	1.51	2.00
Sulphate	mg/L	270	14.6	4	12.5	14.0	15.3
Total dissolved solids	mg/L	-	324	4	210	285	348
Total alkalinity	mg/L		237	4	118	188	266
Selected metals							
Total aluminum	mg/L	0.1	**0.33**	4	**0.27**	**0.47**	**2.17**
Dissolved aluminum	mg/L	0.1	0.023	4	0.012	0.022	0.034
Total arsenic	mg/L	0.005	0.0014	4	0.0014	0.0017	0.0018
Total boron	mg/L	1.2	0.31	4	0.09	0.19	0.42
Total molybdenum	mg/L	0.073	0.00045	4	0.00020	0.00043	0.00063
Total mercury (ultra-trace)	ng/L	5, 13	3.4	4	0.9	1.7	**10.6**
Total strontium	mg/L	-	0.15	4	0.15	0.21	0.27
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	-	0.37	1	-	0.44	-
Oilsands Extractable	mg/L	-	0.87	1	-	0.88	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	9.58	1	-	<14.13	-
Retene	ng/L	-	1.26	1	-	2.86	-
Total dibenzothiophenes	ng/L	-	35.31	1	-	5.84	-
Total PAHs	ng/L	-	205.1	1	-	151.1	-
Total Parent PAHs	ng/L	-	17.69	1	-	19.20	-
Total Alkylated PAHs	ng/L	-	187.4	1	-	131.9	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Dissolved iron	mg/L	0.3	**0.857**	4	**0.737**	**0.899**	**1.160**
Sulphide	mg/L	0.002	**0.007**	4	**0.006**	**0.012**	**0.017**
Total iron	mg/L	0.3	**1.80**	4	**1.79**	**2.00**	**3.23**
Total phenols	mg/L	0.004	**0.0097**	4	**0.0047**	**0.0071**	**0.0092**
Total phosphorus	mg/L	0.05	**0.147**	4	**0.102**	**0.121**	**0.144**

[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 5.13-15 Piper diagram of fall ion balance at *test* station BER-1, *baseline* station BER-2, and *test* station POC-1, 1999 to 2012.

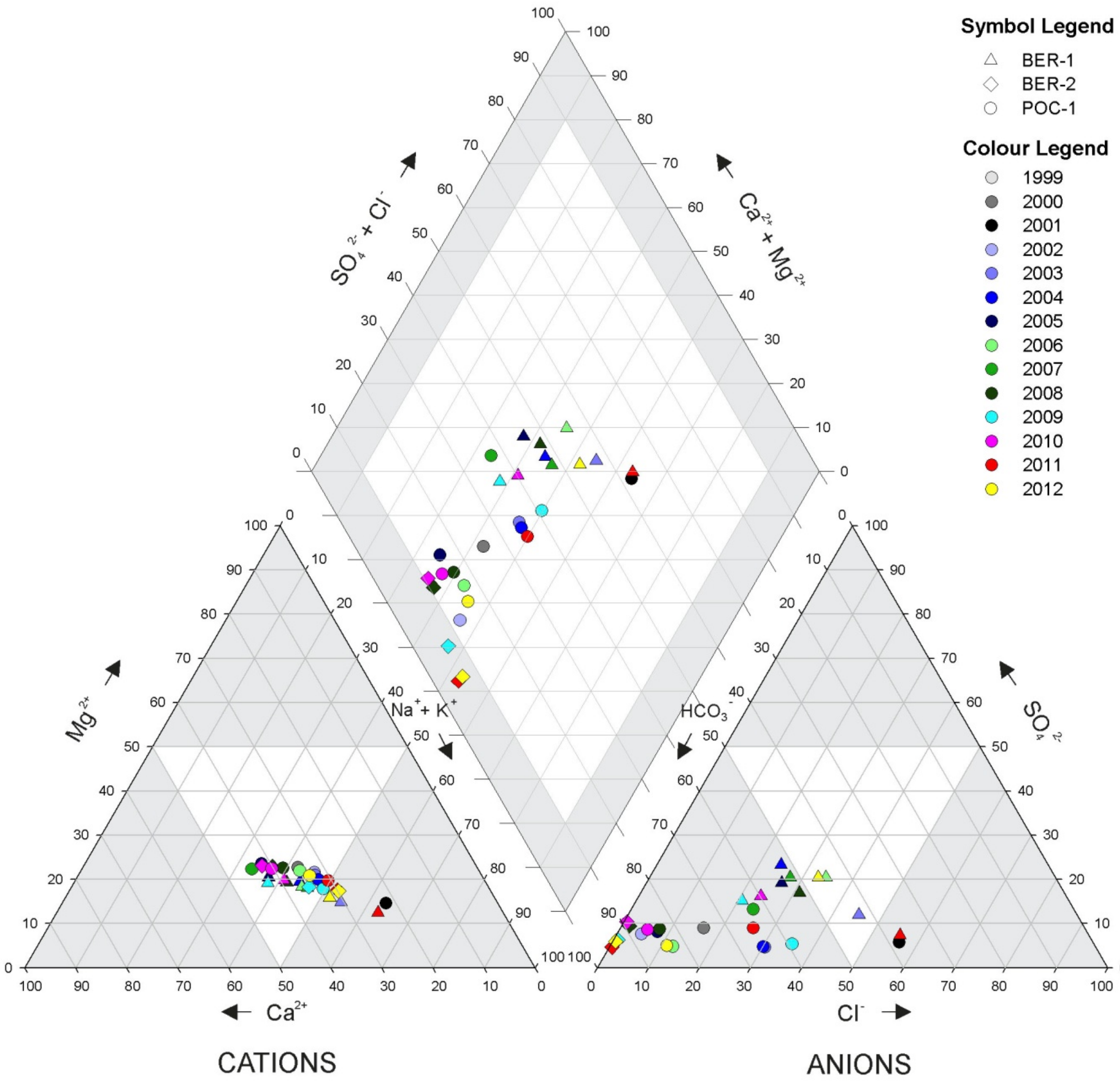
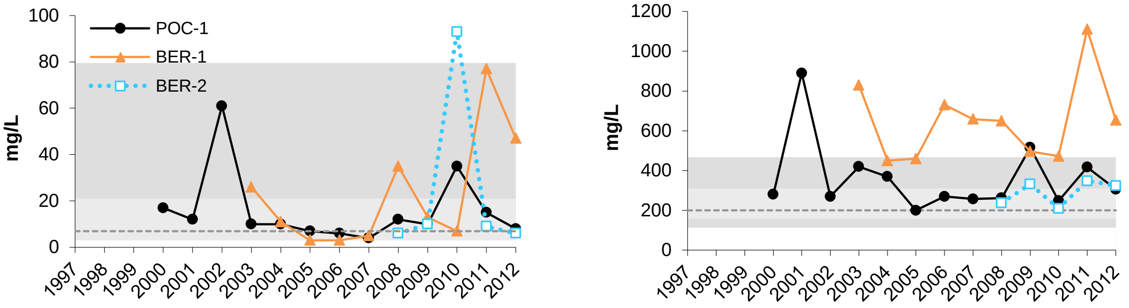
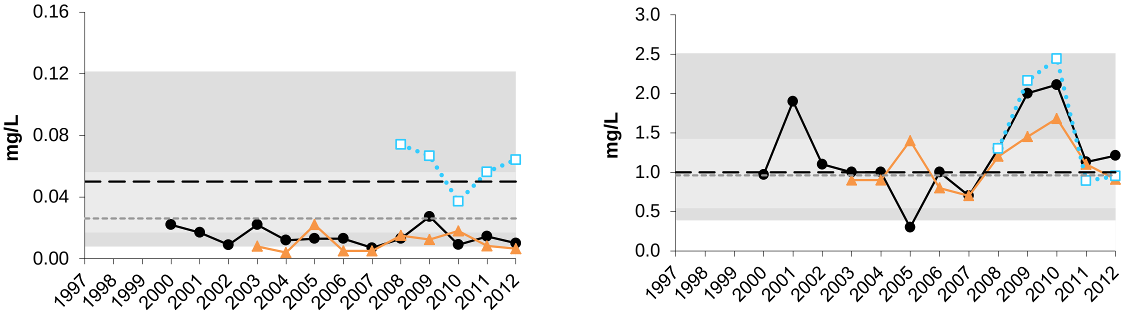


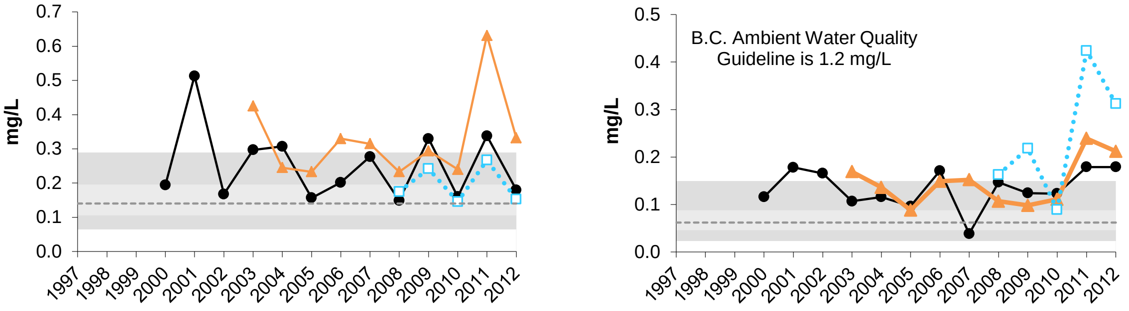
Figure 5.13-16 Concentrations of selected water quality measurement endpoints in *test* station BER-1, *test* station POC-1, and *baseline* station BER-2 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

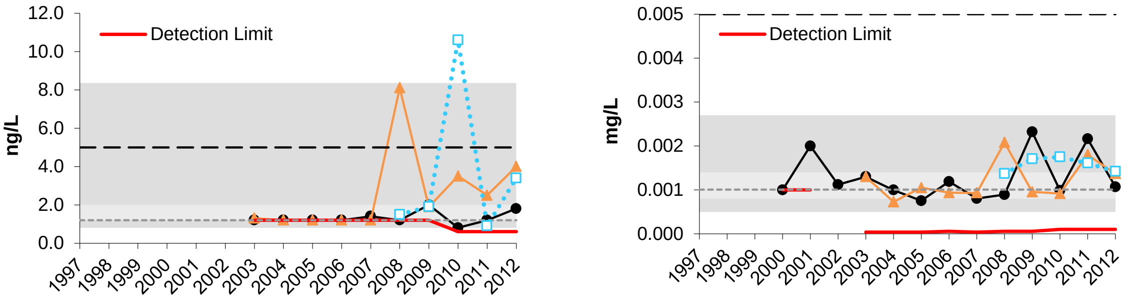
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

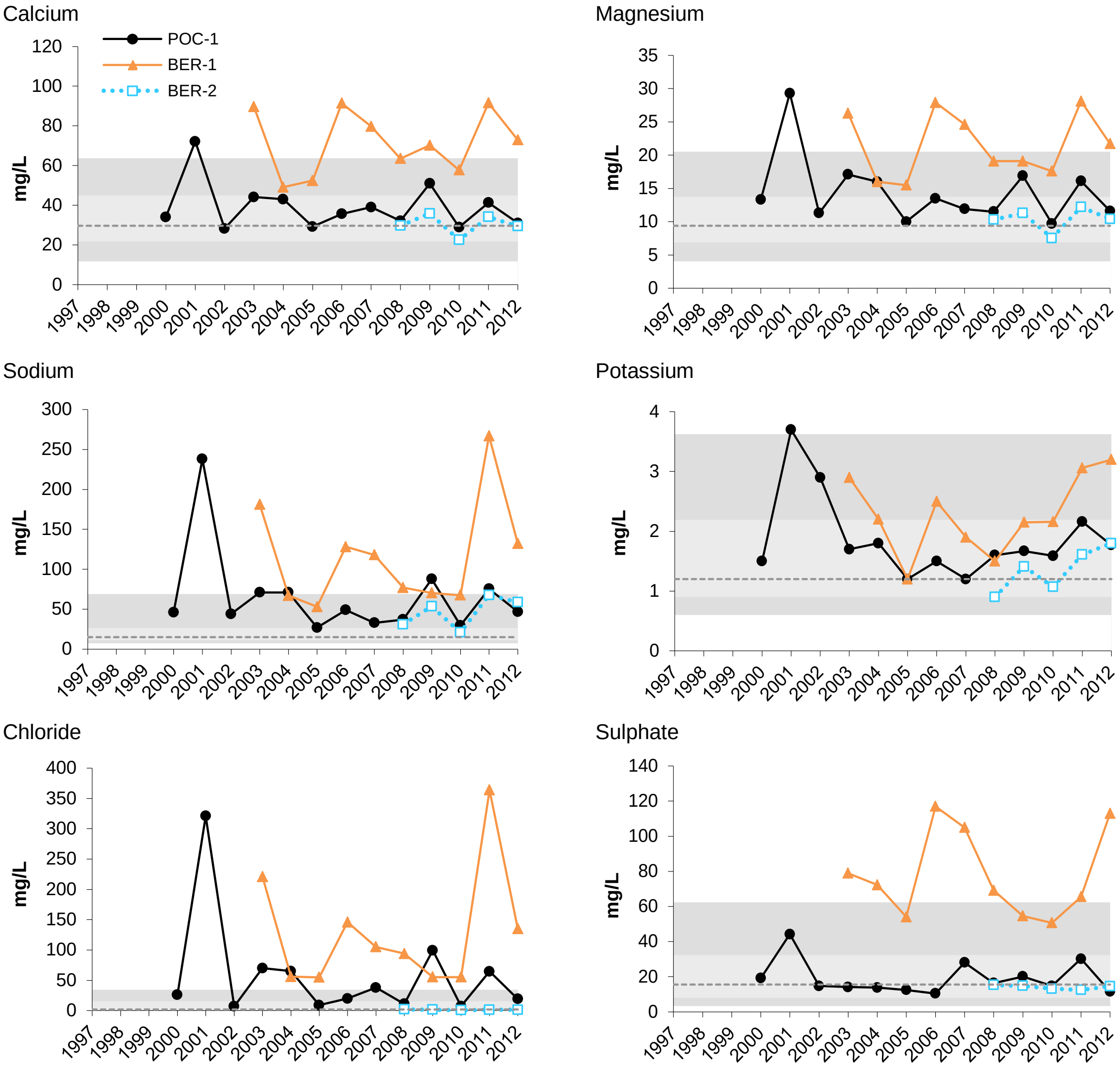
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ 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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Figure 5.13-16 (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 RAMP sampling. See sections 3.2.7.3 and 3.2.7.4 for a discussion of this approach.

Table 5.13-22 **Average habitat characteristics of benthic invertebrate sampling locations in the Beaver River and Poplar Creek, fall 2012.**

Variable	Units	BER-D2 Upper *Baseline* Reach of Beaver River	POC-D1 Lower *Test* Reach of Poplar Creek
Sample date	-	04-Sept-2012	08-Sept-2012
Habitat	-	Depositional	Depositional
Water depth	m	1.0	0.6
Current velocity	m/s	-	-
Field Water Quality			
Dissolved oxygen	mg/L	8.5	6.5
Conductivity	µS/cm	403	381
pH	pH units	8.0	8.2
Water temperature	°C	13.4	13.0
Sediment Composition			
Sand	%	89	32
Silt	%	6	47
Clay	%	4	21
Total Organic Carbon	%	0.46	3.1

Table 5.13-23 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Upper Beaver River and Lower Poplar Creek.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Reach BER-D2			Reach POC-D1		
	2008	2009 to 2011	2012	2008	2009 to 2011	2012
Hydra		0 to <1	<1		0 to <1	
Nematoda	1	<1	<1	2	1 to 5	3
Oligochaeta		0 to <1	<1		0 to <1	
Erpobdellidae			<1			
Glossiphoniidae	<1	0 to <1	<1		0 to <1	<1
Naididae	<1	4 to 8	6	<1	<1 to 1	2
Tubificidae	1	2 to 20	36	72	17 to 22	13
Enchytraeidae	<1	0 to <1			0 to 17	
Hydracarina	1	<1 to 8	1		0 to <1	<1
Amphipoda			<1		0 to <1	<1
Ostracoda	1	0 to 6	<1	1	4 to 14	27
Cladocera		0 to 2	1		0 to 3	5
Copepoda	<1	<1 to 7	1		0 to 3	4
Gastropoda	<1	<1 to 3	1		<1	<1
Bivalvia	1	<1	<1	1	4 to 13	8
Coleoptera		2 to 10	4	<1	<1 to 2	<1
Ceratopogonidae	6	3 to 11	7	2	0 to 5	5
Chaoboridae			<1			<1
Chironomidae	84	32 to 71	36	21	20 to 64	32
Dixidae			<1			
Dolichopodidae			<1			
Empididae	1	0 to <1			0 to <1	<1
Tipulidae		0 to <1	<1			
Tabanidae		<1 to 1	<1	<1	0 to <1	<1
Simuliidae					0 to <1	
Ephemeroptera	4	4 to 6	2	<1	<1	<1
Anisoptera			<1		0 to <1	<1
Plecoptera		0 to <1				
Trichoptera	<1	0 to <1	<1	<1	<1	<1
Lepidoptera		0 to <1				
Neuroptera			<1			
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	7687	4,696 to 33,032	28,545	8,345	20,518 to 60,133	48,032
Richness	13	8 to 26	20	8	18 to 25	21
Simpson's Diversity	0.7	0.55 to 0.83	0.72	0.41	0.80 to 0.82	0.83
Equitability	0.38	0.26 to 0.63	0.30	0.4	0.26 to 0.77	0.30
% EPT	3	<1 to 4	3	<1	<1	<1

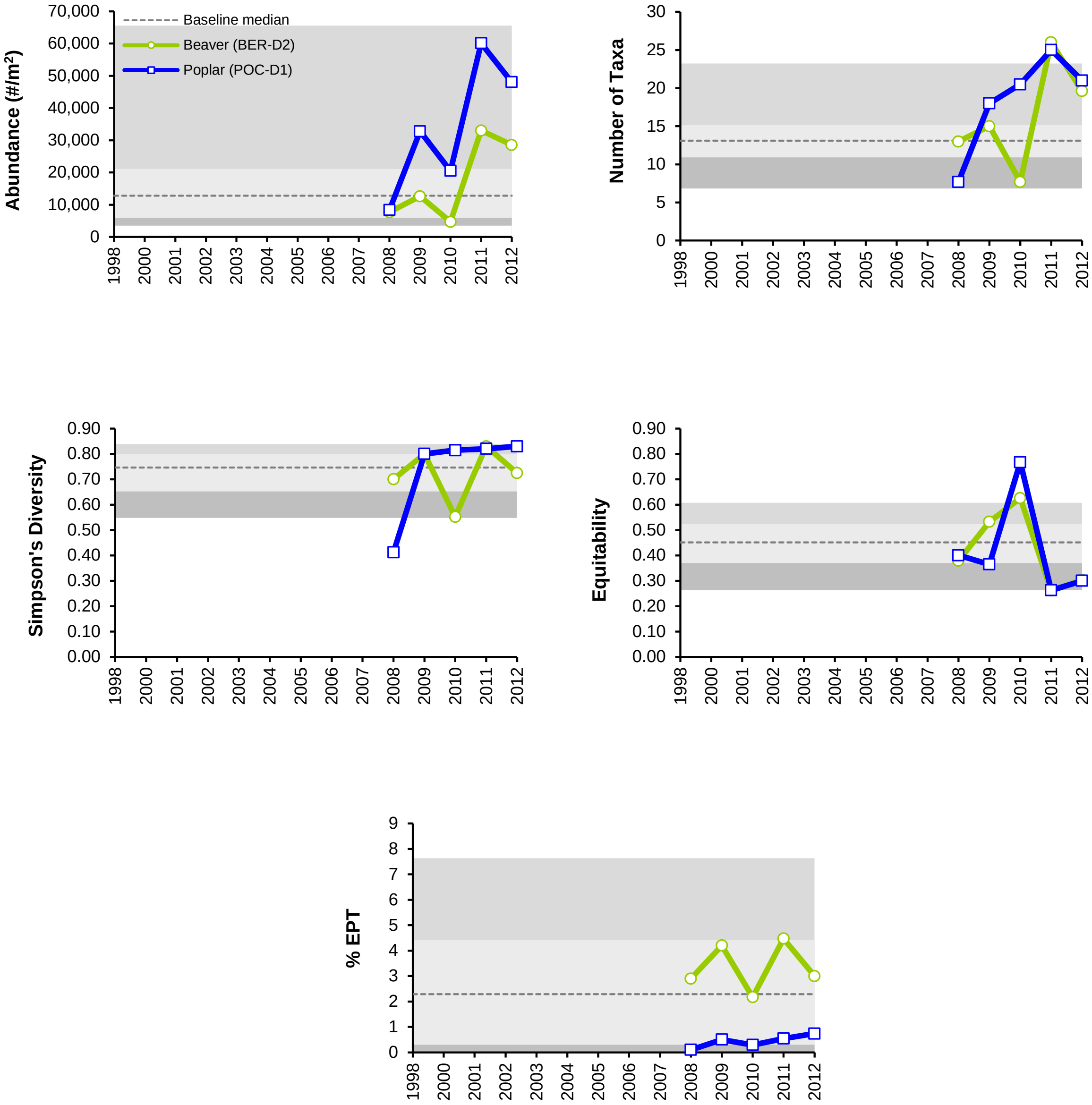
Table 5.13-24 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in *test* reach POC-D1 and *baseline* reach BER-D2.

Variable	P-value					Variance Explained (%)					Nature of Change(s)
	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*test* period)**	**Difference in Time Trend Between *Baseline* and *Test* Reaches**	**2012 vs. All *Baseline* Years**	**2012 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*test* period)**	**Difference in Time Trend Between *Baseline and Test* Reaches**	**2012 vs. All *Baseline* Years**	**2012 vs. Previous Years**	
Abundance	**<0.001**	**<0.001**	0.497	0.062	0.135	25	21	1	4	3	Higher at *test* reach; increasing over time at both reaches.
Richness	0.052	**<0.001**	0.100	0.324	0.172	6	30	4	1	3	Increasing over time.
Simpson's Diversity	0.618	**<0.001**	**0.001**	0.130	**0.038**	40	0	11	7	2	Higher in 2012 than mean of previous years; increasing at *test* reach at a greater rate than *baseline* reach
Equitability	1.000	0.264	0.848	1.000	0.350	0	9	0	0	6	No change.
EPT	**<0.001**	0.354	**0.011**	**<0.001**	**<0.001**	59	2	12	48	31	Increasing over time at *test* reach while remaining stable at *baseline* reach; higher at *baseline* reach; higher in 2012 than mean of previous years.
CA Axis 1	**0.037**	0.112	**0.023**	0.698	0.572	13	8	16	0	1	Higher at *test* reach and increasing over time but stable at *baseline* reach.
CA Axis 2	**<0.001**	**<0.001**	0.067	0.969	**0.003**	29	46	8	0	21	Higher at *baseline* reach; increasing over time at both reaches; higher in 2012 than mean of previous years.

Bold values indicate significant difference (p<0.05).

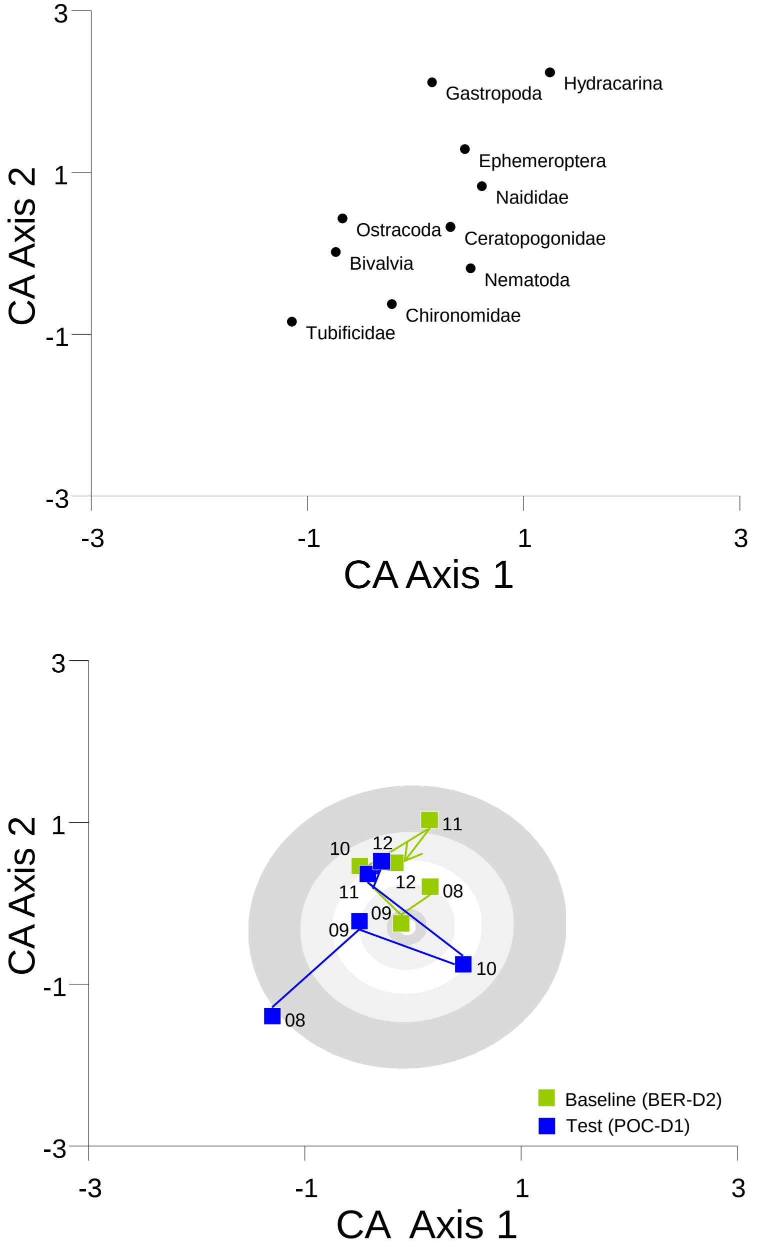
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Figure 5.13-17 Variation in benthic invertebrate community measurement endpoints in Beaver River and Poplar Creek.



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.13-18 **Ordination (Correspondence Analysis) of benthic invertebrate communities in Beaver River and Poplar Creek.**



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Table 5.13-25 Concentrations of sediment quality measurement endpoints, lower Poplar Creek (*test* station POC-D1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	31	7	10	20	35
Silt	%	-	<u>68</u>	7	13	27	63
Sand	%	-	<u>1</u>	7	12	62	73
Total organic carbon	%	-	2.4	7	1.1	2.1	2.5
Total hydrocarbons							
BTEX	mg/kg	-	<20	5	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	5	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	5	<5	39	143
Fraction 3 (C16-C34)	mg/kg	300[1]	209	5	170	**924**	**2,830**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	167	5	54	970	**2,820**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.010	7	0.002	0.008	0.021
Retene	mg/kg	-	<u>0.167</u>	6	0.048	0.107	0.135
Total dibenzothiophenes	mg/kg	-	<u>0.249</u>	7	0.307	0.944	3.90
Total PAHs	mg/kg	-	1.79	7	1.75	3.40	13.3
Total Parent PAHs	mg/kg	-	0.137	7	0.122	0.201	0.440
Total Alkylated PAHs	mg/kg	-	1.65	7	1.61	3.19	12.8
Predicted PAH toxicity[3]	H.I.	1.0	**1.29**	7	0.16	0.65	**4.15**
Metals that exceed CCME guidelines in 2012							
Total Arsenic	mg/kg	5.9	**<u>8.3</u>**	7	2.4	**6.1**	**7.1**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>9.2</u>	5	6.8	7.4	9.0
Chironomus growth - 10d	mg/organism	-	1.74	5	1.61	1.70	2.45
Hyalella survival - 14d	# surviving	-	9.0	6	8.0	8.6	9.6
Hyalella growth - 14d	mg/organism	-	0.13	6	0.10	0.20	0.66

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic observations.

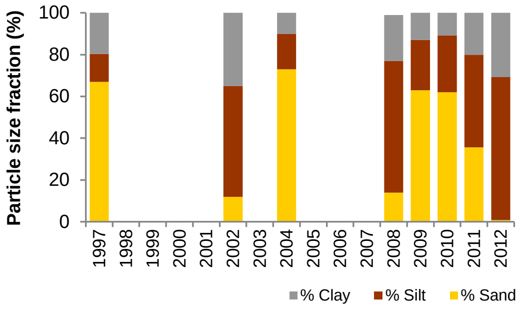
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

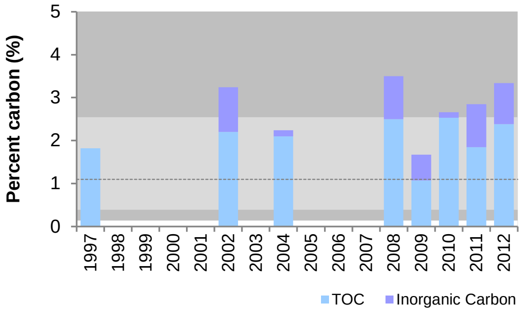
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-19 Variation in sediment quality measurement endpoints at *test* station POC-D1.

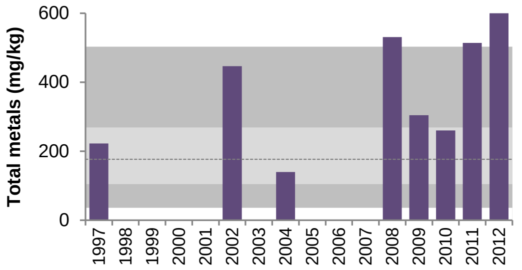
Particle size distribution



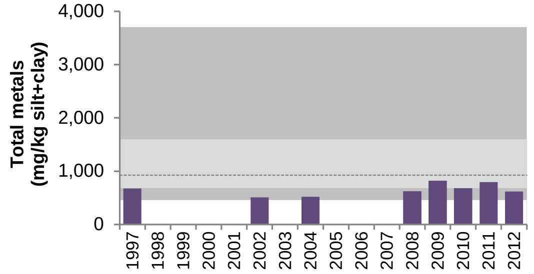
Carbon Content[1]



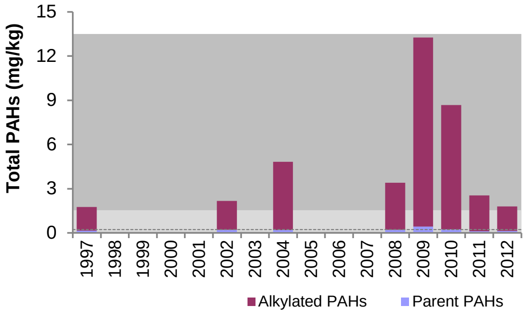
Total Metals[2]



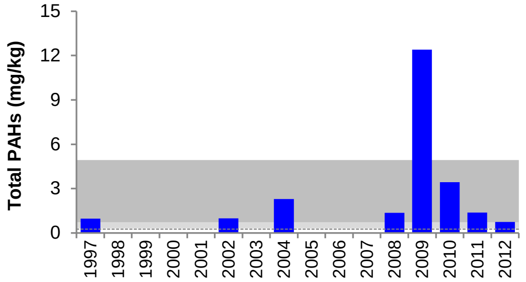
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



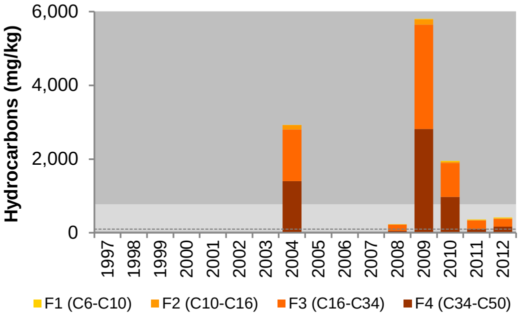
Total PAHs



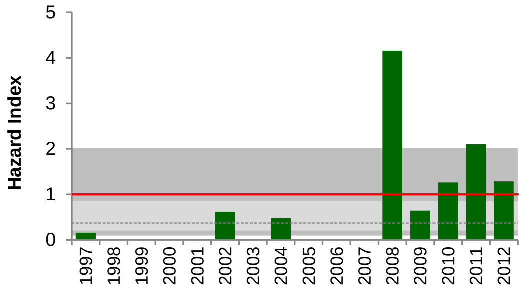
Total PAHs normalized to 1% TOC



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 (1997-2012).

[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 5.13-26 Concentrations of sediment quality measurement endpoints, upper Beaver River (*baseline* station BER-D2), fall 2012.

Variables	Units	Guideline	September 2012	2008-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.8	4	2.4	5.5	9.0
Silt	%	-	9.6	4	1.0	4.5	21.0
Sand	%	-	84.6	4	70.0	90.7	95.3
Total organic carbon	%	-	0.6	4	<0.1	0.3	2.0
Total hydrocarbons							
BTEX	mg/kg	-	<10	3	<10	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	3	<10	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	3	<20	<20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	22	3	<20	<20	119
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	3	<20	<20	94
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	4	0.0003	0.0010	0.0030
Retene	mg/kg	-	0.045	4	0.005	0.008	0.520
Total dibenzothiophenes	mg/kg	-	0.007	4	0.001	0.003	0.015
Total PAHs	mg/kg	-	0.077	4	0.018	0.073	0.704
Total Parent PAHs	mg/kg	-	0.007	4	0.004	0.006	0.017
Total Alkylated PAHs	mg/kg	-	0.070	4	0.014	0.067	0.686
Predicted PAH toxicity[3]	H.I.	1.0	0.358	3	0.159	0.489	0.881
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.60	4	7.40	7.80	8.80
Chironomus growth - 10d	mg/organism	-	1.60	4	1.71	2.11	2.63
Hyalella survival - 14d	# surviving	-	7.80	4	6.60	8.80	9.60
Hyalella growth - 14d	mg/organism	-	0.31	4	0.17	0.32	0.44

Values in **bold** indicate concentrations exceeding guidelines.

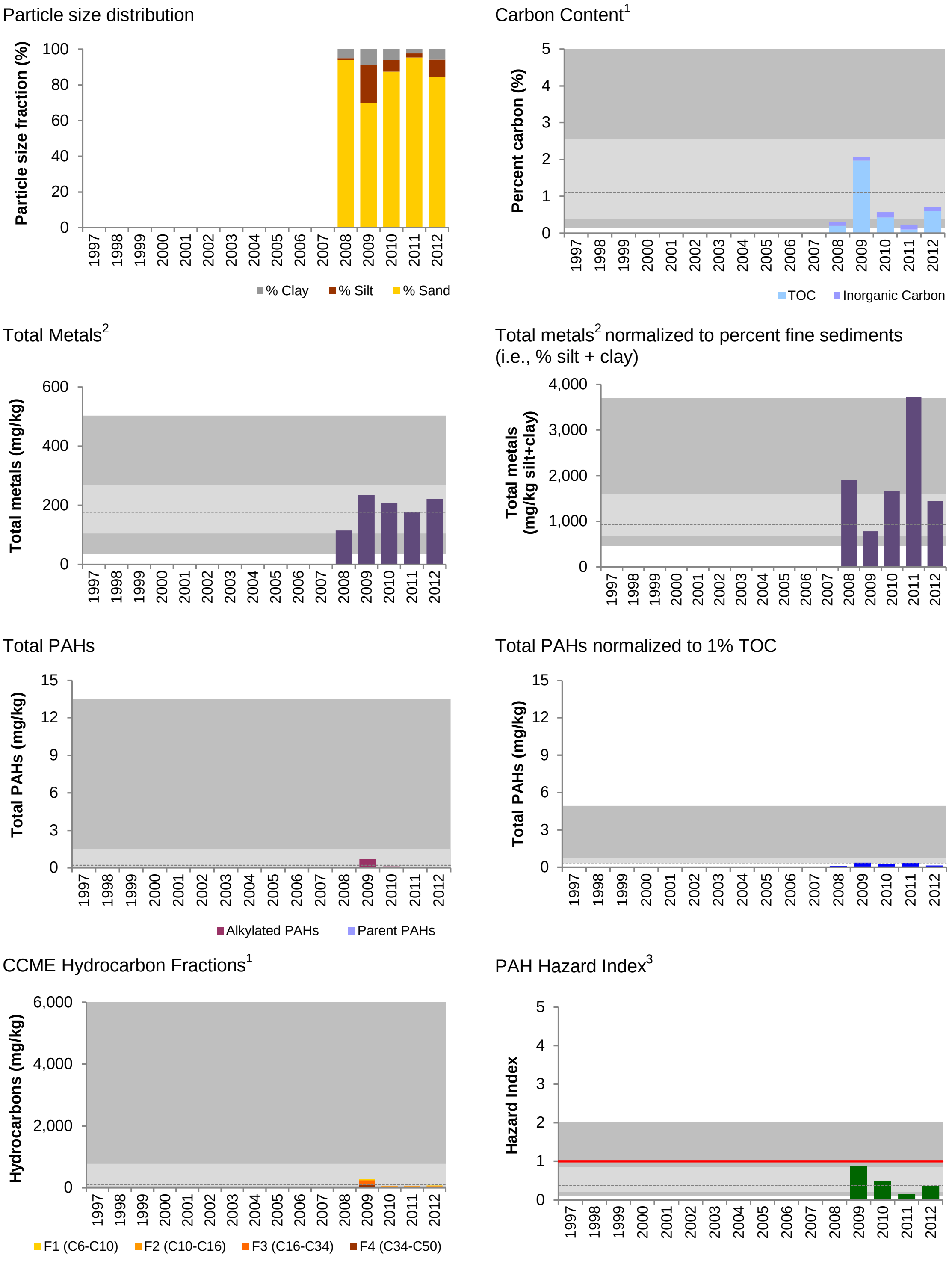
Values underlined indicate concentrations outside the range of historic observations.

[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 5.13-20 Variation in sediment quality measurement endpoints at *test* station BER-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 (1997-2012).

[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 5.13-27 Sediment quality index (fall 2012) for miscellaneous watershed stations.

Station	Location	2012 Designation	Sediment Quality Index	Classification
POC-D1	mouth of Poplar Creek	*test*	83.2	Negligible-Low
FOC-D1	mouth of Fort Creek	*test*	87.5	Negligible-Low
BER-D2	upper Beaver River	*baseline*	100	Negligible-Low

Table 5.13-28 Average habitat characteristics of fish assemblage monitoring locations of Poplar Creek and Beaver River, fall 2012.

Variable	Units	POC-F1 Lower *Test* Reach of Poplar Creek	BER-F2 Upper *Baseline* Reach of Beaver River
Sample date	-	05-Sept-12	05-Sept-12
Habitat type	-	riffle/run	run
Maximum depth	m	1.2	1.4
Bankfull channel width	m	11.0	12.5
Wetted channel width	m	9.0	10.5
Substrate			
Dominant	-	cobble	silt/clay/organic material
Subdominant	-	sand	-
Instream cover			
Dominant	-	macrophytes and small woody debris	macrophytes
Subdominant	-	large woody debris, undercut banks and boulders	over hanging vegetation and small woody debris
Field water quality			
Dissolved oxygen	mg/L	9.4	8.4
Conductivity	µS/cm	404	402
pH	pH units	8.12	7.89
Water temperature	^{0}C	13.6	13.2
Water velocity			
Left bank velocity	m/s	0.20	0.05
Left bank water depth	m	0.87	0.58
Centre of channel velocity	m/s	0.55	0.10
Centre of channel water depth	m	0.78	0.96
Right bank velocity	m/s	0.30	0.15
Right bank water depth	m	0.22	0.96
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	overhanging vegetation
Subdominant	-	overhanging vegetation	woody shrubs and saplings

Table 5.13-29 Percent composition and mean CPUE of fish species at *test* reach POC-F1 of Poplar Creek and *baseline* reach BER-F2 of the Beaver River, 2009 to 2012.

Common Name	Code	Total Species						Percent of Total Catch					
		BER-F2			POC-F1			BER-F2			POC-F1		
		2009	2011	2012	2009	2011	2012	2009	2011	2012	2009	2011	2012
Arctic grayling	ARGR	-	-	-	-	-	-	0	0	0	0	0	0
brook stickleback	BRST	1	2	8	4	-	-	3.3	6.1	19.0	20.0	0.0	0
burbot	BURB	-	-	-	-	-	-	0	0	0	0	0	0
fathead minnow	FTMN	2	2	4	-	-	2	7	6.1	9.5	0	0	11.1
finescale dace	FNDC	-	-	-	-	2	-	0	0	0.0	0	7.7	0
lake chub	LKCH	10	-	20	1	-	9	33.3	0	47.6	5.0	0	50.0
lake whitefish	LKWH	-	-	-	-	-	-	0	0	0	0	0	0
longnose dace	LNDC	-	-	-	-	-	-	0	0	0	0	0	0
longnose sucker	LNSC	-	-	1	-	15	4	0	0	2.4	0	57.7	22.2
northern pike	NRPK	-	-	-	1	-	-	0	0	0	5.0	0	0
northern redbelly dace	NRDC	-	-	-	-	-	-	0	0	0	0	0	0
pearl dace	PRDC	-	28	2	-	4	-	0	84.8	4.8	0	15.4	0
slimy sculpin	SLSC	-	-	-	-	-	-	0	0	0	0	0	0
spoonhead sculpin	SPSC	-	-	-	1	-	-	0	0	0	5.0	0	0
spottail shiner	SPSH	-	-	-	-	-	-	0	0	0	0	0	0
trout-perch	TRPR	2	-	-	5	-	-	6.7	0	0	25.0	0	0
walleye	WALL	-	-	-	4	-	-	0	0	0	20.0	0	0
white sucker	WHSC	15	-	5	4	5	2	50.0	0	11.9	20.0	19.2	11.1
yellow perch	YLPR	-	-	-	-	-	1	0	0	0	0	0	5.6
brassy minnow	BRMN	-	-	1	-	-	-	0	0	2.4	0	0	0
sucker sp. *		-	1	1	-	-	-	0	3.0	2.4	0	0	0
Total Count		30	33	42	20	26	18	100	100	100	100	100	100
Total Species Richness		5	3	7	7	4	5	-	-	-	-	-	-
Electrofishing Effort (secs)		1,678	1,412	1,618	1,534	1,003	1,535	-	-	-	-	-	-
CPUE (#/100 secs)		1.19	1.84	2.6	1.30	3.29	1.17	-	-	-	-	-	-

* Unknown species not included in total count.

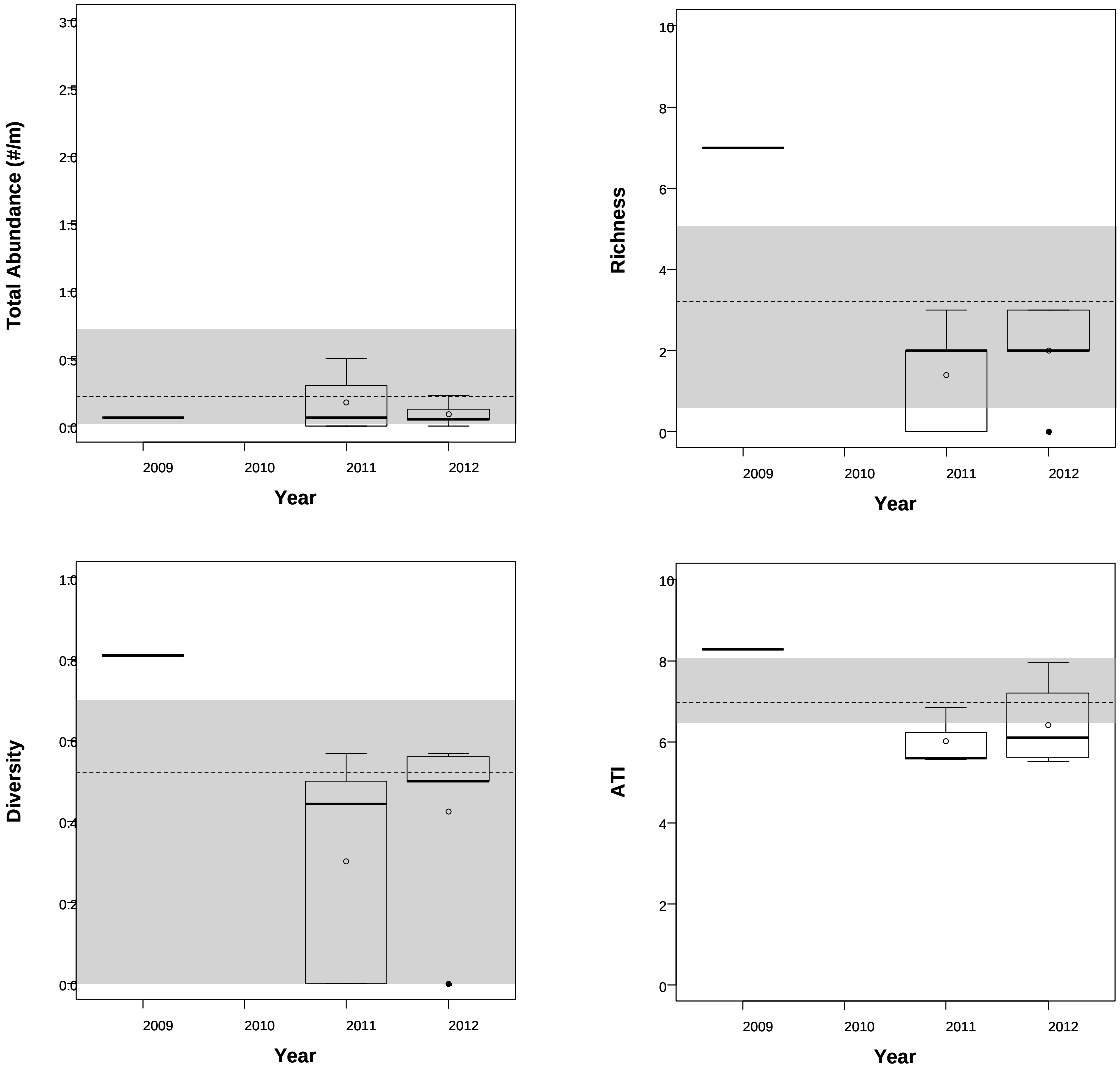
Table 5.13-30 Summary of fish assemblage measurement endpoints in reaches of the Beaver River and Poplar Creek, 2009 and 2012.

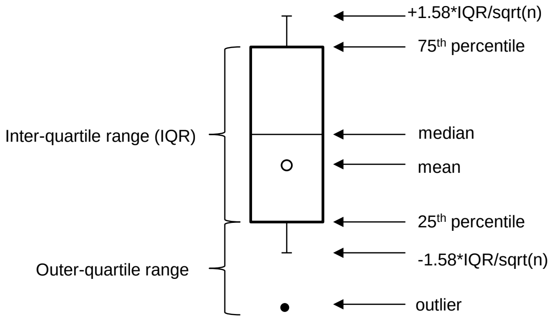
Reach	Year	Abundance		Richness*			Diversity*		ATI*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
BER-F2	2009	0.10	-	5	5	-	0.62	-	7.04	-
	2011	0.22	0.38	4	1	0.84	0.13	0.22	6.19	3.63
	2012	0.19	0.13	7	3	1.10	0.58	0.11	6.45	0.95
POC-F1	2009	0.07	-	7	7	-	0.81	-	8.29	-
	2011	0.17	0.22	4	1	1.34	0.30	0.28	3.60	3.33
	2012	0.09	0.09	6	2	1.22	0.43	0.24	5.13	3.02

* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

Figure 5.13-21 Box-plots showing variation in fish assemblage measurement endpoints in Poplar Creek, 2009 to 2012.

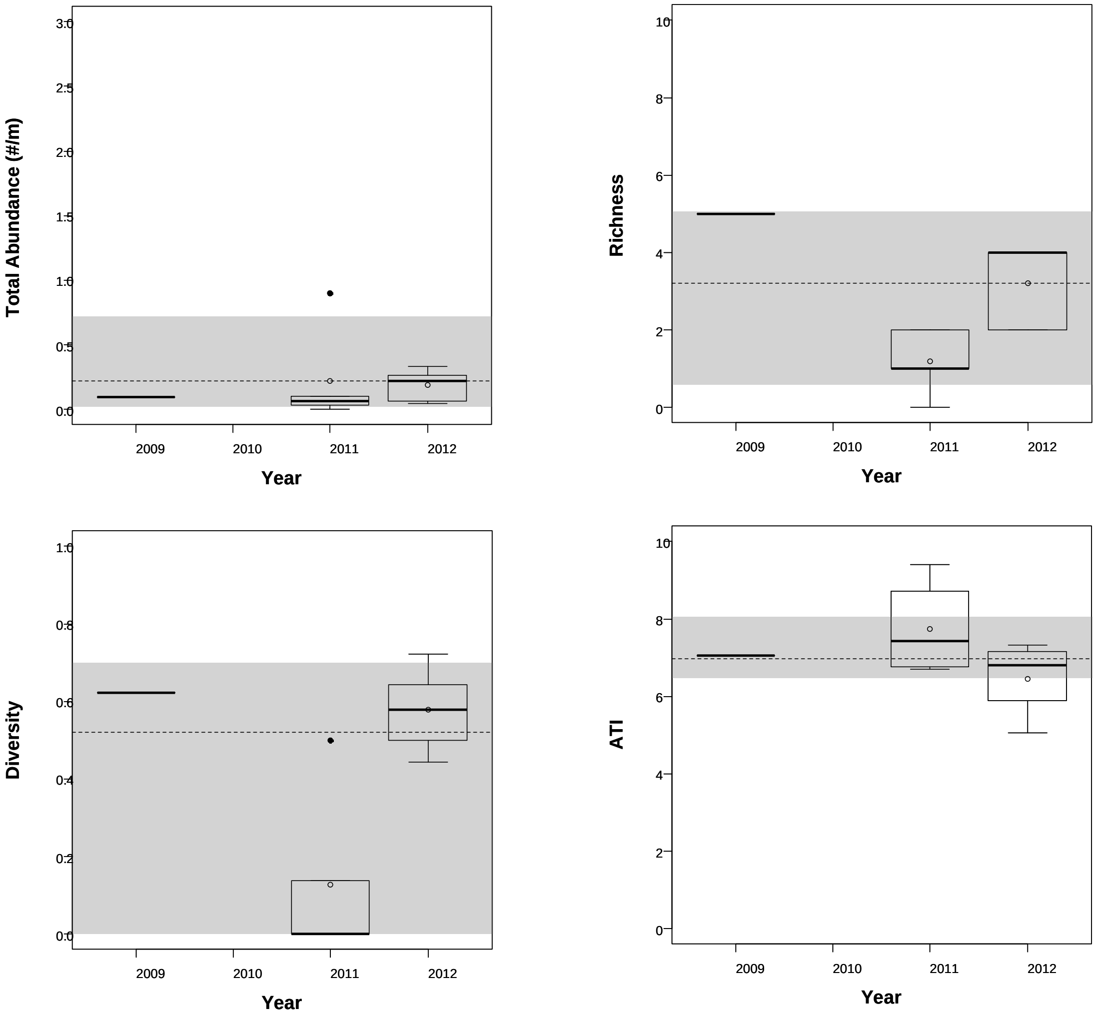


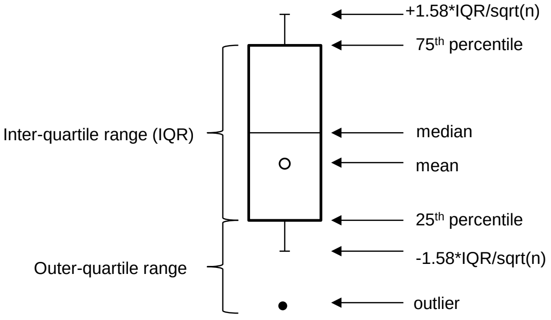


Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Figure 5.13-22 Box-plots showing variation in fish assemblage measurement endpoints in Beaver River, 2009 and 2012.





Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Table 5.13-31 Concentrations of water quality measurement endpoints, McLean Creek (*test* station MCC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	13	8.0	8.3	8.6
Total suspended solids	mg/L	-	35	13	<3	10	83
Conductivity	µS/cm	-	677	13	289	402	1,220
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.031	13	0.005	0.015	0.048
Total nitrogen	mg/L	1	**1.16**	13	0.70	**1.18**	**1.52**
Nitrate+nitrite	mg/L	1.3	<0.07	13	<0.05	<0.10	<1.00
Dissolved organic carbon	mg/L	-	4.9	13	4.9	25.0	35.0
Ions							
Sodium	mg/L	-	63.9	13	10.3	23.0	182.0
Calcium	mg/L	-	52.3	13	37.9	46.9	81.7
Magnesium	mg/L	-	14.6	13	10.3	13.3	21.0
Chloride	mg/L	120	56.2	13	4.8	17.0	**220.0**
Sulphate	mg/L	410	51.2	13	3.2	10.9	76.4
Total dissolved solids	mg/L	-	448	13	218	300	743
Total alkalinity	mg/L		213	13	141	174	319
Selected metals							
Total aluminum	mg/L	0.1	**0.67**	13	0.07	**0.35**	**2.58**
Dissolved aluminum	mg/L	0.1	0.016	13	0.003	0.008	0.016
Total arsenic	mg/L	0.005	0.0012	13	0.0006	0.0009	0.0014
Total boron	mg/L	1.2	0.16	13	0.02	0.05	0.22
Total molybdenum	mg/L	0.073	0.00085	13	0.00012	0.00020	0.00050
Total mercury (ultra-trace)	ng/L	5, 13	3.3	9	<1.2	<1.2	4.1
Total strontium	mg/L	-	0.21	13	0.11	0.15	0.33
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	-	0.07	1	-	7.94	-
Oilsands Extractable	mg/L	-	0.38	1	-	11.90	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	5.10	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	140.51	1	-	32.28	-
Total PAHs	ng/L	-	629.1	1	-	302.3	-
Total Parent PAHs	ng/L	-	26.71	1	-	25.58	-
Total Alkylated PAHs	ng/L	-	602.4	1	-	276.7	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Sulphide	mg/L	0.002	**0.0024**	13	**0.0030**	**0.0090**	**0.0250**
Total iron	mg/L	0.3	**0.841**	13	**0.360**	**0.660**	**3.459**
Total phenols	mg/L	0.004	**0.011**	13	0.001	**0.007**	**0.012**
Total phosphorus	mg/L	0.05	**0.050**	13	0.008	0.037	**0.072**
Total selenium	mg/L	0.001	**0.0012**	13	0.0002	0.0005	0.0008

[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 5.13-23 Piper diagram of ion balance in McLean Creek and Fort Creek.

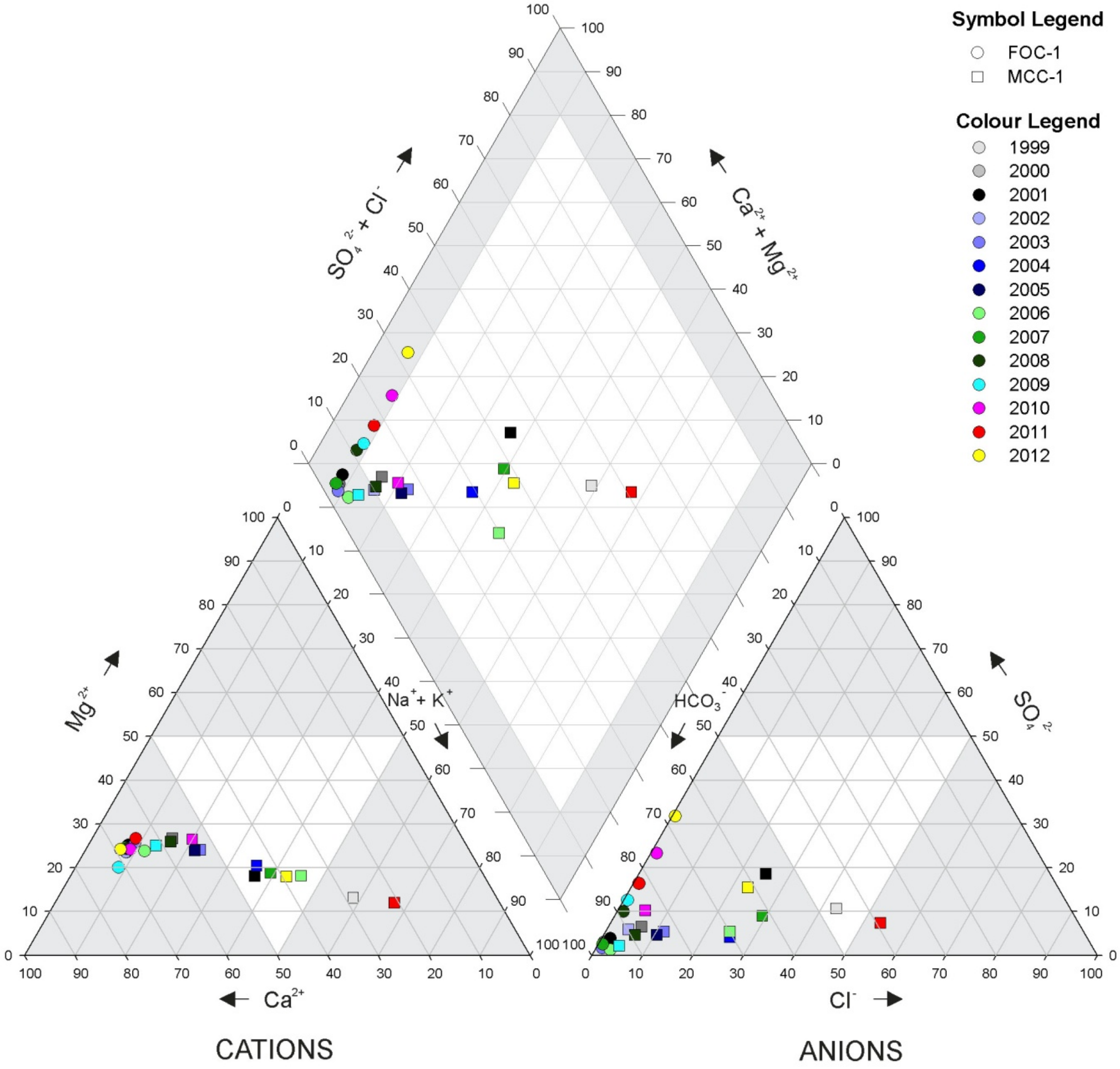
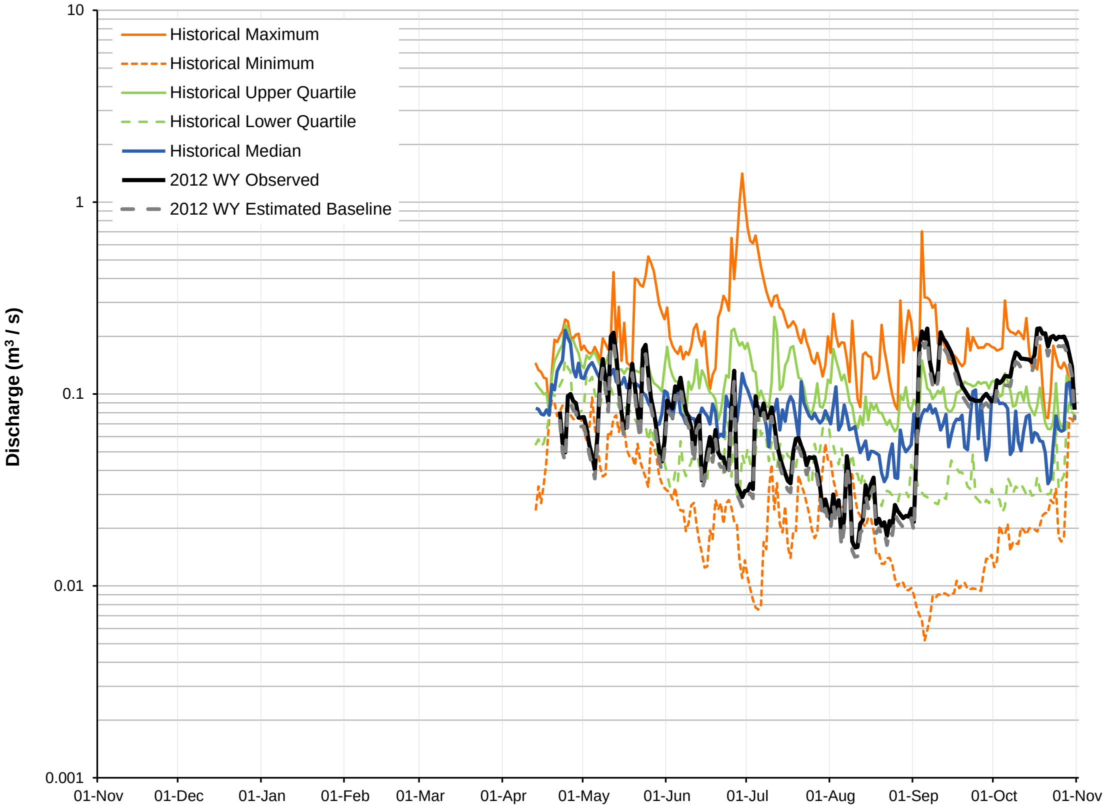


Figure 5.13-24 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Fort Creek in the 2012 WY, compared to historical values.



Note: Observed 2012 WY hydrograph based on Fort Creek at Highway 63, RAMP Station S12, 2012 WY provisional data from April 22 to October 31. The upstream drainage area is 31.9 km^2. Historical values from April 22 to October 31 were calculated using data collected from 2000 to 2002 and from 2006 to 2011.

Table 5.13-32 Estimated water balance at Station S12, Fort Creek at Highway 63, 2012 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* discharge	1.473	**Observed *test* discharge, obtained from Fort Creek at Highway 63, RAMP Station S12.**
Closed-circuited area water loss from the observed *test* discharge	-0.014	Estimated 0.3 km^2 of Fort Creek watershed closed-circuited by focal projects as of 2012 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.169	Estimated 20.4 km^2 of Fort Creek watershed with land change from focal projects as of 2012 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Fort Creek watershed from oil sands development projects	0	None reported
Water releases into the Fort Creek watershed from oil sands development projects	0	None reported
Diversions into or out of the watershed	0	None reported
The difference between observed and estimated discharge on tributary streams	0	No focal projects on tributaries of Fort Creek not accounted for by figures contained in this table
Estimated *baseline* discharge	1.318	**Estimated *baseline* discharge at Fort Creek at Highway 63, RAMP Station S12.**
Incremental flow (change in total discharge)	+0.155	Total discharge from observed *test* volume less total discharge of estimated *baseline* volume
Incremental flow (% of total discharge)	**+11.7%**	**Incremental flow as a percentage of total discharge of estimated *baseline* volume**

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume is calculated from provisional data from April 22 to October 31, 2012 for Fort Creek at Highway 63 RAMP Station S12.

Table 5.13-33 Concentrations of water quality measurement endpoints, Fort Creek (*test* station FOC-1), fall 2012.

Measurement Endpoint	Units	Guideline[a]	September 2012	1997-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	10	8.1	8.3	8.4
Total suspended solids	mg/L	-	22.0	10	<3	11.5	35.5
Conductivity	µS/cm	-	631	10	432	554	649
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.005	10	0.006	0.010	0.019
Total nitrogen	mg/L	1	0.4	10	0.4	0.6	1.0
Nitrate+nitrite	mg/L	1.3	<0.07	10	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	10.5	10	10.5	13.0	14.0
Ions							
Sodium	mg/L	-	9.1	10	9.0	11.4	18.0
Calcium	mg/L	-	89.9	10	69.4	82.7	96.8
Magnesium	mg/L	-	19.1	10	14.6	18.0	21.8
Chloride	mg/L	120	2.0	10	2.0	2.9	7.0
Sulphate	mg/L	410	105.0	10	3.7	9.5	68.3
Total dissolved solids	mg/L	-	382	10	260	345	443
Total alkalinity	mg/L		234	10	231	280	309
Selected metals							
Total aluminum	mg/L	0.1	**0.173**	10	0.031	0.079	**0.850**
Dissolved aluminum	mg/L	0.1	0.0032	10	<0.0010	0.0014	0.0500
Total arsenic	mg/L	0.005	0.00027	10	0.00023	0.00029	<0.0010
Total boron	mg/L	1.2	0.064	10	0.038	0.053	0.073
Total molybdenum	mg/L	0.073	<0.00001	9	0.00003	0.0000978	0.00010
Total mercury (ultra-trace)	ng/L	5, 13	1.2	7	0.6	<1.2	1.4
Total strontium	mg/L	-	<0.00001	10	0.16	0.20	0.25
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	-	0.25	1	-	0.40	-
Oilsands Extractable	mg/L	-	0.58	1	-	1.92	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<8.76	1	-	<14.13	-
Retene	ng/L	-	8.79	1	-	<2.07	-
Total dibenzothiophenes	ng/L	-	445.16	1	-	42.54	-
Total PAHs	ng/L	-	1528.8	1	-	298.1	-
Total Parent PAHs	ng/L	-	36.29	1	-	22.55	-
Total Alkylated PAHs	ng/L	-	1492.5	1	-	275.6	-
Other variables that exceeded CCME/AESRD guidelines in fall 2012							
Total iron	mg/L	0.3	**0.69**	10	0.07	**0.66**	**1.94**

[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 5.13-34 Average habitat characteristics of benthic invertebrate sampling locations in Fort Creek, fall 2012.

Variable	Units	FOC-D1 Lower *Test* Reach of Fort Creek
Sample date	-	16-Sept-2012
Habitat	-	Depositional
Water depth	m	0.4
Current velocity	m/s	0.54
Field Water Quality		
Dissolved oxygen	mg/L	-
Conductivity	µS/cm	-
pH	pH units	-
Water temperature	°C	-
Sediment Composition		
Sand	%	97
Silt	%	2
Clay	%	1
Total Organic Carbon	%	1.52

Table 5.13-35 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Fort Creek (*test* reach FOC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Reach FOC-D1		
	2001	2002 to 2011	2012
Nematoda	2	1 to 24	2
Erpobdellidae		0 to <1	
Glossiphoniidae		0 to <1	
Oligochatea		0 to 2	
Naididae	1	0 to 2	1
Tubificidae		<1 to 66	20
Enchytraeidae	1	0 to 1	2
Lumbricidae			7
Hydracarina	<1	0 to 2	2
Ostracoda	1	0 to 6	<1
Macrothricidae		0 to <1	
Copepoda	<1	0 to 4	
Gastropoda	<1	0 to 3	
Bivalvia	5	0 to 8	<1
Ceratopogonidae	<1	0 to 8	
Chironomidae	80	18 to 95	58
Empididae	1	0 to 1	
Tipulidae	8	0 to 3	
Tabanidae		0 to 1	
Simuliidae		0 to <1	
Ephemeroptera	<1	0 to 1	
Plecoptera		0 to 1	7
Trichoptera		0 to <1	
Heteroptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	4,069	591 to 69,802	1,444
Richness	15	4 to 13	5
Simpson's Diversity	0.84	0.44 to 0.76	0.44
Equitability	0.50	0.30 to 0.80	0.74
% EPT	<1	0 to 9	7

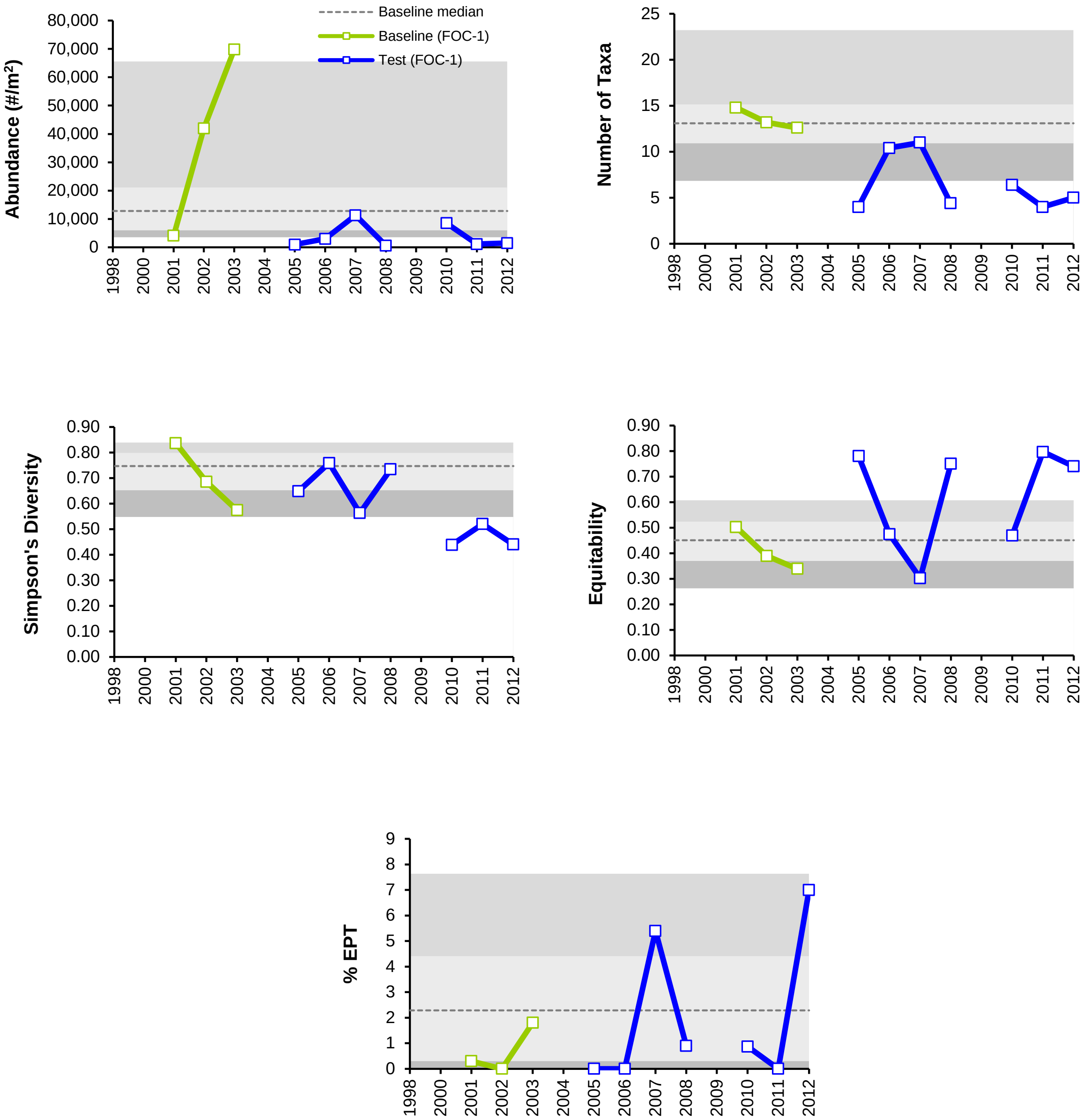
Table 5.13-36 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in lower Fort Creek (*test* reach FOC-D1).

Variable	P-value				Variance Explained (%)				Nature of Change(s)
	Baseline **Period vs.** ***Test*** **Period**	**Time Trend (*test* period)**	**2012 vs.** ***Baseline*** **Years**	**2012 vs. Previous years**	***Baseline*** **Period vs.** ***Test*** **Period**	**Time Trend (*test* period)**	**2012 vs.** ***Baseline*** **Years**	**2011 vs. Previous Years**	
Abundance	**0.003**	0.250	**0.008**	0.275	37	5	29	5	Higher in *baseline* period.
Richness	**0.001**	0.064	**0.001**	0.057	45	13	50	14	Higher in *baseline* period.
Simpson's Diversity	0.080	0.069	0.056	0.282	26	29	32	10	No change.
Equitability	**0.026**	0.362	**0.031**	0.304	28	4	26	6	Higher in *test* period.
EPT	**0.026**	**0.001**	0.541	0.365	17	44	1	3	Higher in *test* period; increasing over time.
CA Axis 1	0.122	0.651	0.483	0.754	21	2	4	1	No change.
CA Axis 2	0.572	0.500	0.360	0.480	12	17	32	19	No change.

Bold values indicate significant difference ($p<0.05$).

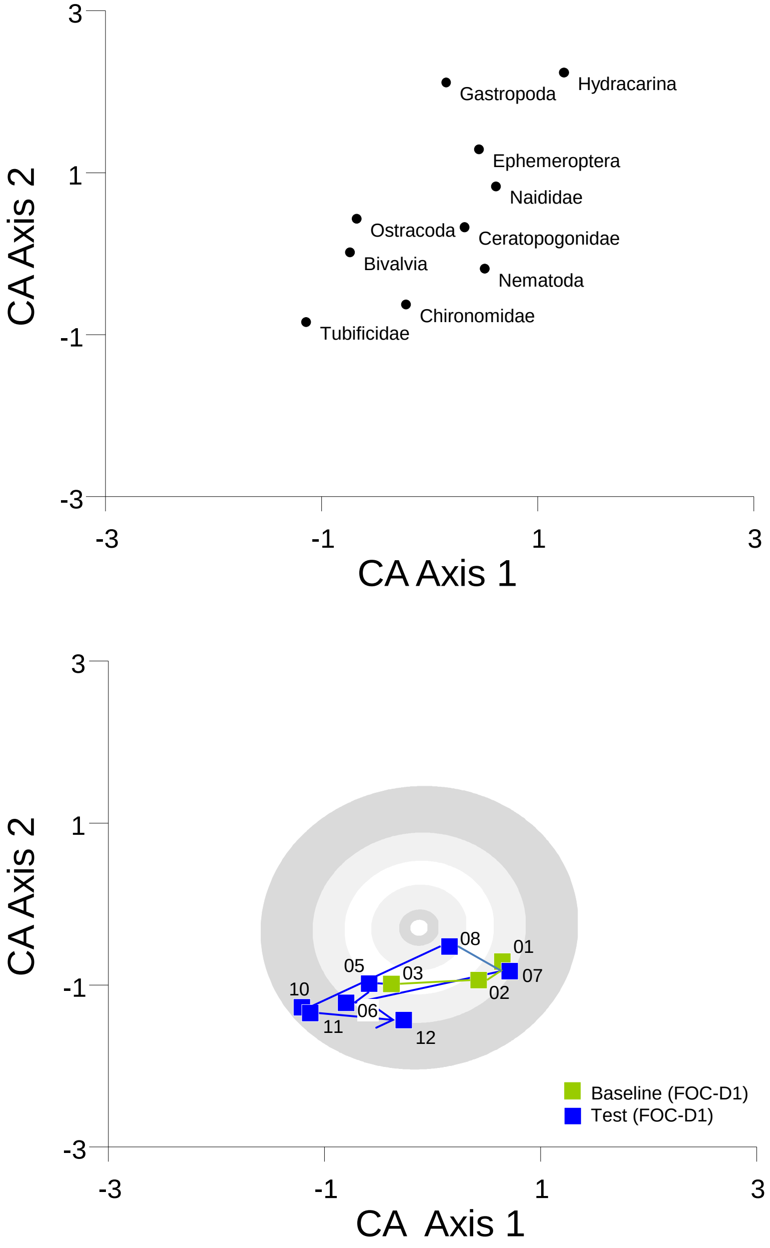
Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

Figure 5.13-25 Variation in benthic invertebrate community measurement endpoints in Fort Creek.



Note: Regional *baseline* values reflect pooled results for all *baseline* depositional reaches sampled in the RAMP FSA. See Section 3.2.3.1 for a description of the approach.

Figure 5.13-26 Ordination (Correspondence Analysis) of lake benthic invertebrate communities in lower Fort Creek (*test* reach FOC-D1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipse in the lower panel is for the *baseline* depositional reaches in the RAMP FSA.

Table 5.13-37 Concentrations of sediment quality measurement endpoints, Fort Creek (*test* station FOC-D1), fall 2012.

Variables	Units	Guideline	September 2012	2001-2011 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1.1	5	1	4	15
Silt	%	-	1.0	5	1.3	7.0	29.0
Sand	%	-	97.9	5	56.0	88.0	97.8
Total organic carbon	%	-	1.7	7	1.48	3.2	7.1
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	**311**	4	16	67	**170**
Fraction 3 (C16-C34)	mg/kg	300[1]	**2,300**	4	**440**	**1,404**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	2,140	4	450	1,137	1,980
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.001	7	0.001	0.008	0.017
Retene	mg/kg	-	0.096	7	0.033	0.081	0.679
Total dibenzothiophenes	mg/kg	-	1.83	7	0.16	2.19	3.22
Total PAHs	mg/kg	-	9.28	7	1.85	8.25	14.26
Total Parent PAHs	mg/kg	-	0.277	7	0.159	0.224	0.874
Total Alkylated PAHs	mg/kg	-	9.01	7	1.69	8.05	13.38
Predicted PAH toxicity[3]	H.I.	1.0	0.570	6	0.425	0.810	**1.501**
Metals that exceed CCME guidelines in 2012							
none	mg/kg	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2012							
Chrysene	mg/kg	0.0571	**0.105**	7	0.018	**0.076**	**0.230**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9.6	6	6.8	9.0	10.0
Chironomus growth - 10d	mg/organism	-	2.65	6	1.24	1.70	2.98
Hyalella survival - 14d	# surviving	-	8.6	6	6.0	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.16	6	0.10	0.21	0.28

Values in **bold** indicate concentrations exceeding guidelines.

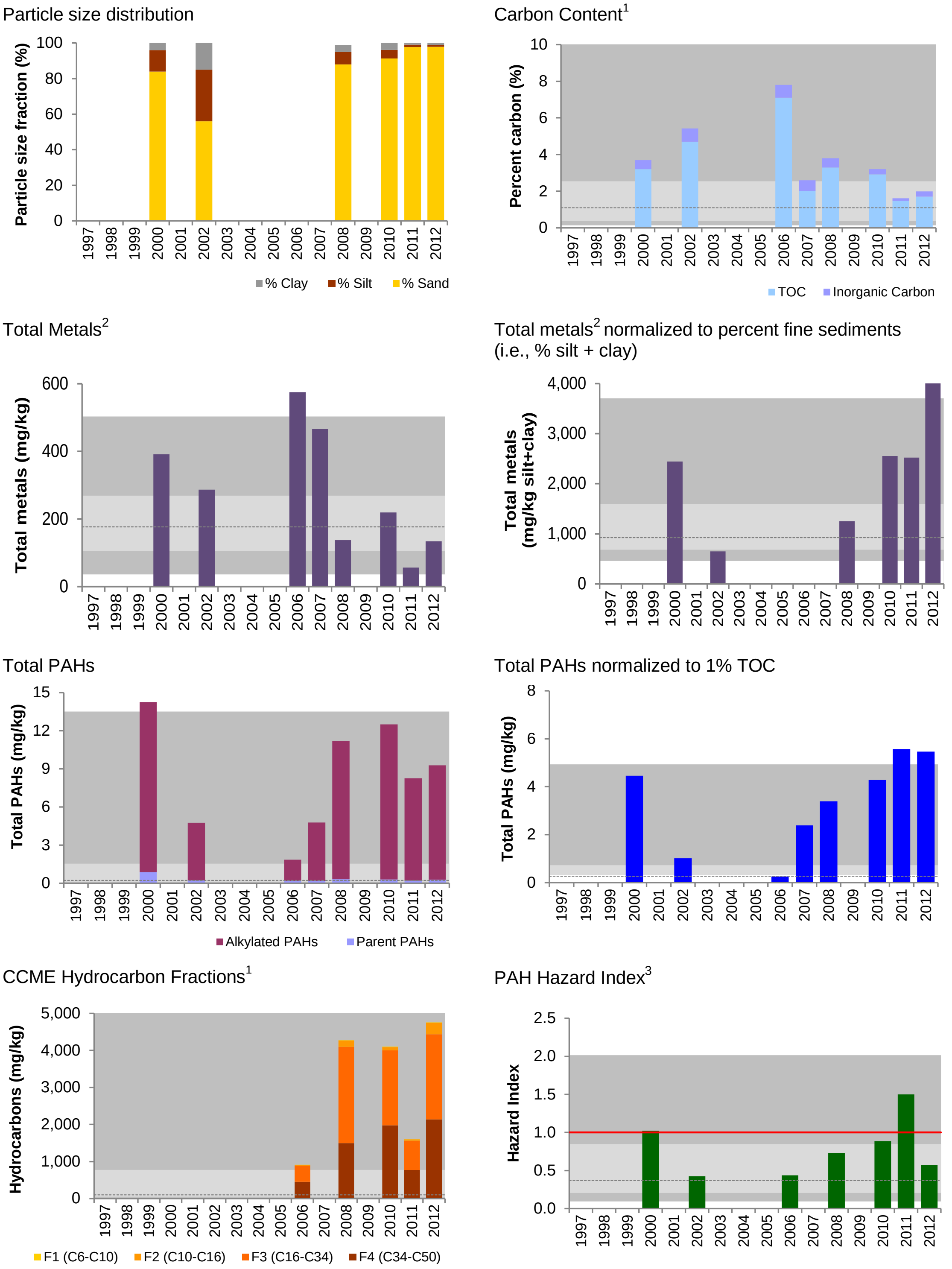
Values underlined indicate concentrations outside the range of historic observations.

[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 5.13-27 Variation in sediment quality measurement endpoints in Fort Creek, *test* station FOC-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 (1997-2012).

[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 5.13-38 Average habitat characteristics of fish assemblage monitoring locations in Fort Creek, fall 2012.

Variable	Units	FOC-F1 Lower *Test* Reach of Fort Creek
Sample date	-	13-Sept-2012
Habitat type	-	riffle/run
Maximum depth	m	0.55
Bankfull channel width	m	4
Wetted channel width	m	2
Substrate		
Dominant	-	sand/silt
Subdominant	-	-
Instream cover		
Dominant	-	small woody debris
Subdominant	-	large woody debris, overhanging vegetation, undercut banks
Field water quality		
Dissolved oxygen	mg/L	8.85
Conductivity	µS/cm	582
pH	pH units	8.11
Water temperature	^{0}C	10.9
Water velocity		
Left bank velocity	m/s	0.15
Left bank water depth	m	0.19
Centre of channel velocity	m/s	0.20
Centre of channel water depth	m	0.38
Right bank velocity	m/s	0.20
Right bank water depth	m	0.53
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	overhanging vegetation

Table 5.13-39 Percent composition and mean CPUE (catch per unit effort) of species at *test* reach FOC-F1 of Fort Creek, 2012.

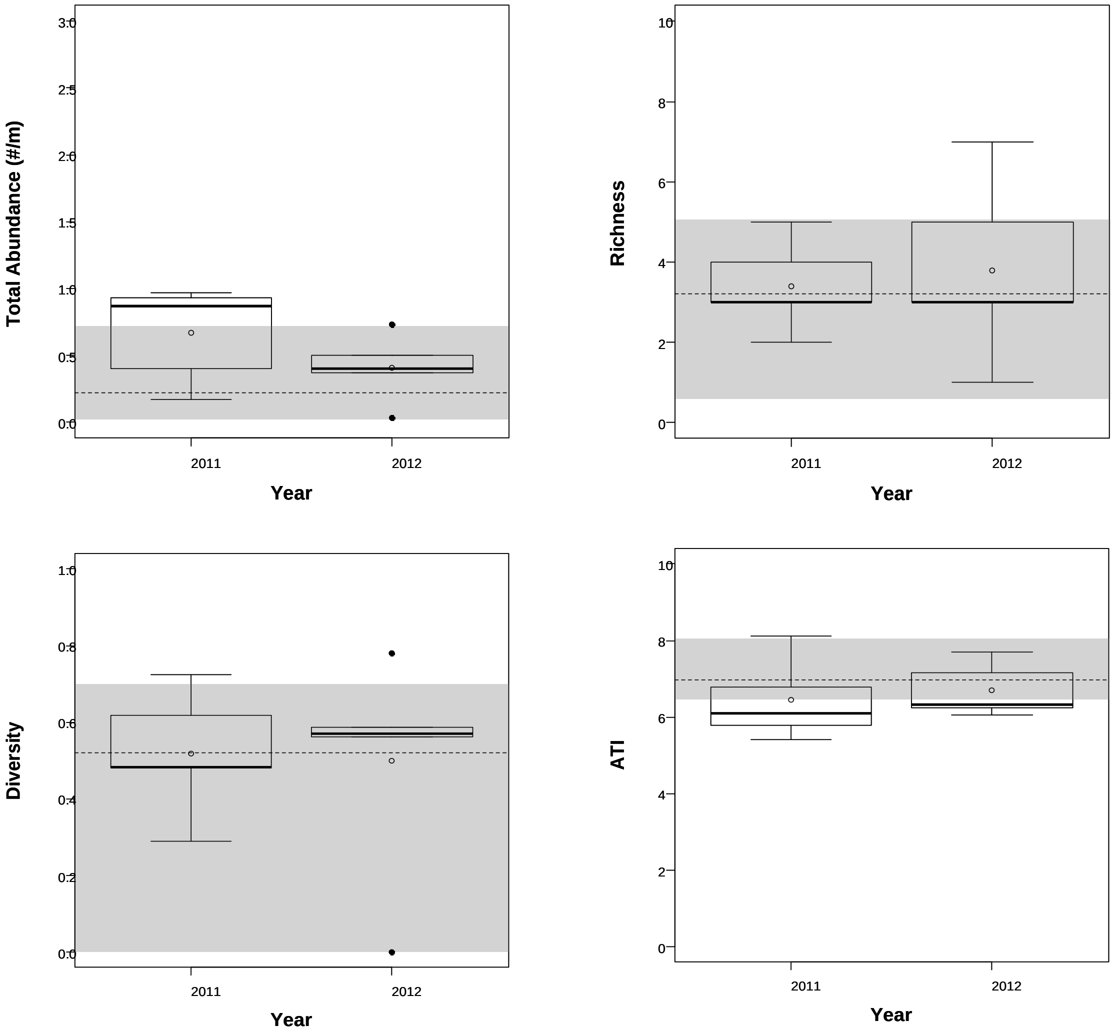
Common Name	Code	Total Species		Percent of Total Catch	
		2011	2012	2011	2012
Arctic grayling	ARGR	-	-	0	0.0
brook stickleback	BRST	8	-	9.8	0.0
burbot	BURB	-	-	0	0.0
fathead minnow	FTMN	-	4	0	6.6
finescale dace	FNDC	23	-	28.0	0.0
lake chub	LKCH	33	1	40.2	1.6
lake whitefish	LKWH	-	-	0	0.0
longnose dace	LNDC	-	-	0	0.0
longnose sucker	LNSC	16	15	19.5	24.6
northern pike	NRPK	-	-	0	0.0
northern redbelly dace	NRDC	-	22	0	36.1
pearl dace	PRDC	-	7	0	11.5
slimy sculpin	SLSC	1	2	1.2	3.3
spoonhead sculpin	SPSC	-	-	0	0.0
spottail shiner	SPSH	-	7	0	11.5
trout-perch	TRPR	-	1	0	1.6
walleye	WALL	-	-	0	0.0
white sucker	WHSC	1	2	1.2	3.3
yellow perch	YLPR	-	-	0	0.0
Total		**82**	**61**	**100**	**100**
Total Species Richness		**6**	**9**	**-**	**-**
Electrofishing effort (secs)		**1,097**	**1,255**	**-**	**-**
CPUE (#/100 secs)		**7.47**	**4.86**	**-**	**-**

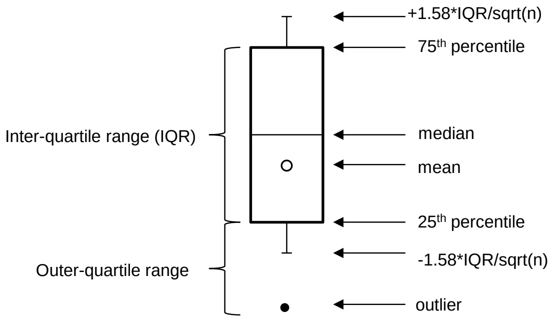
Table 5.13-40 Summary of fish assemblage measurement endpoints in reaches of Fort Creek, 2011 and 2012.

Year	Abundance		Richness			Diversity		ATI	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD
2011	0.67	0.36	6	3	1.14	0.52	0.16	6.44	1.06
2012	0.41	0.25	9	4	2.28	0.50	0.29	6.70	0.70

SD = standard deviation across sub-reaches within a reach.

Figure 5.13-28 Box-plots showing variation in fish assemblage measurement endpoints in Fort Creek, 2012.

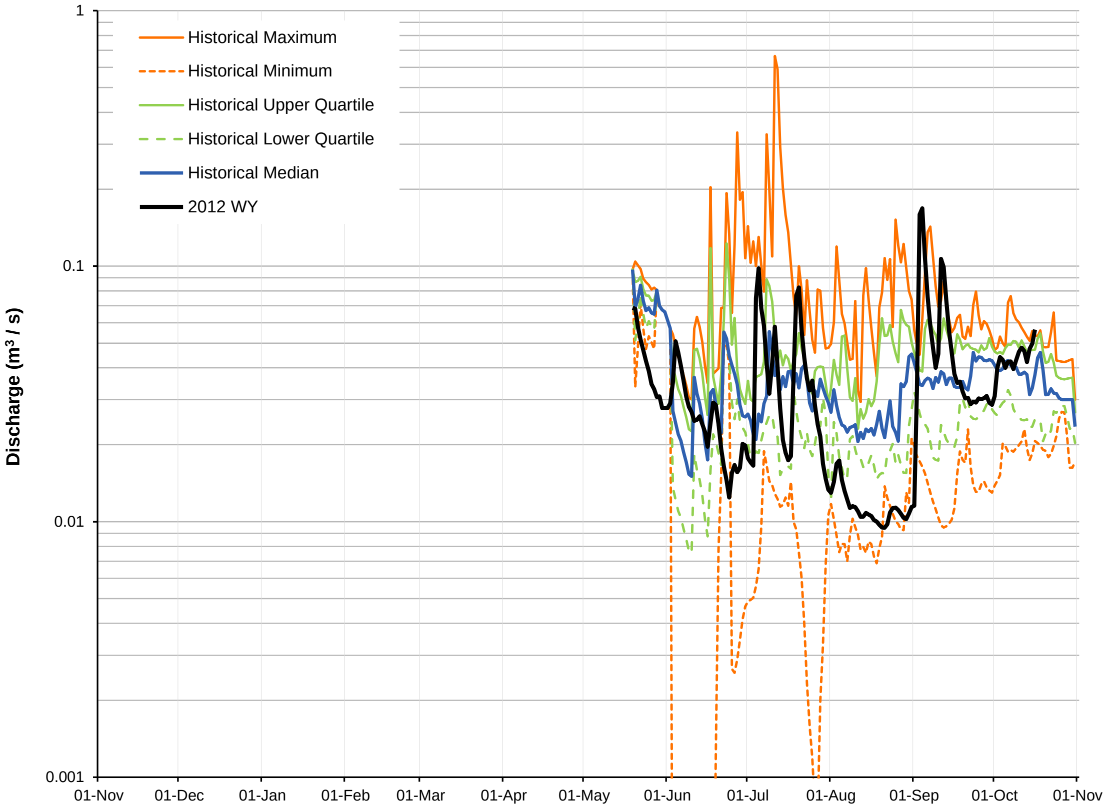




Note: The whiskers of the boxplots extend to +/-1.58 IQR/sqrt(n) based on Chambers et al. (1983), and represent roughly a 95% confidence interval for the difference in the two medians (R Development Core Team 2012).

Regional *baseline* values reflect pooled results for all *baseline* reaches for abundance, richness, and diversity; *baseline* values for ATI are for all depositional *baseline* reaches.

Figure 5.13-29 Susan Lake Outlet: 2012 WY hydrograph.



Note: Observed 2012 WY hydrograph based on available provisional data for Station S25, Susan Lake Outlet. Historical values are calculated from data collected in 2002 and from 2006 to 2011.

5.14 ACID-SENSITIVE LAKES

This section presents the results of the Acid-Sensitive Lakes (ASL) component of RAMP for 2012.

5.14.1 General Characteristics of the RAMP ASL Component Lakes in 2012

The lakes monitored for the RAMP ASL component (referred to as the "RAMP lakes") are typically small and shallow with a median area of 1.32 km^2 and maximum 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. The freezing to depth in most lakes results in large changes in lake chemistry (e.g., anoxia, decrease in pH, increase in alkalinity) that reverse when melting occurs in spring (See Appendix H in RAMP 2008).

The chemical variables measured in the 50 RAMP lakes from 1999 to 2012 are summarized in Table 5.14-2. The RAMP lakes cover a large variety of lake types from soft water to hard water. Historically, the pH of the lakes has ranged from 3.97 to 9.46 with a median value of 6.82. The median pH in 2012 was 7.24, which was higher than previous years. Gran alkalinity has historically ranged from negative values to 2,023 μeq/L, with a median value of 203 μeq/L. The median Gran alkalinity in 2012 was 262 μeq/L, which was higher than previous years. The highest value of Gran alkalinity ever measured in the RAMP lakes (2,023 μeq/L) was observed in 2012 in Kearl Lake. Conductivity has historically ranged from 10.3 μS/cm to 196 μS/cm, with a median value of 33.4 μS/cm. Consistent with pH and Gran alkalinity, the median conductivity in 2012 (38.8 μS/cm) was higher than previous years. The highest value of conductivity ever recorded in the RAMP lakes (196 μS/cm) was measured in 2012 in Kearl Lake. Similarly, the median concentrations of total dissolved solids (TDS) and all base cations (i.e., calcium, magnesium, sodium, and potassium) were higher in 2012, most being the maximum value recorded across years. Historically, the concentration of sulphate has been relatively low, ranging from non-detectable to 19.0 mg/L, with a median concentration of 1.18 mg/L. The median concentration in 2012 was 1.04 mg/L. By conventional standards, most of the RAMP lakes are considered humic, with a median concentration of dissolved organic carbon (DOC) of 21.6 mg/L (Kortelainen et al. 1989, Forsius et al. 1992, Driscoll et al. 1991). In 2012, the median DOC concentration was 23.1 mg/L, which was slightly higher than the historical median. Some of the highest concentrations of DOC observed in individual RAMP lakes were recorded in 2012, including 71 mg/L in Lake 185/NE7 and 92.2 mg/L in Lake 209/NE8, both located in the Northeast of Fort McMurray subregion. In general, concentrations of nitrates have historically been quite low, ranging from non-detectable to 733 μg/L, with a median of 3.0 μg/L, although individual lakes may have concentrations of nitrates two orders of magnitude greater than the median concentration. Nitrates are highly variable both between lakes and between years within each lake. Nitrates and sulphate constitute the principal acidifying agents from airborne emissions.

Total phosphorus ranges from 3.0 μg/L to 341 μg/L, with a historical median of 39.0 μg/L. Using phosphorus as a guide, the RAMP lakes; therefore, cover the range of nutrient conditions from oligotrophic to eutrophic lakes (Wetzel 2001). The median phosphorus concentration in 2012 was 35 μg/L. The lower concentrations of dissolved phosphorus (historical median: 11 μg/L) indicate that a large fraction of the phosphorus is bound to suspended particulates.

Lakes having "unusual" chemistry were identified in the 2012 monitoring data as those below or above the 5th and 95th percentile for the three measurement endpoints of pH, Gran alkalinity, and DOC (Table 5.14-3). Generally, these were the same lakes identified in previous years as having "unusual" chemistry. Three lakes (168/SM10, 169/SM9 and Clayton Lake/BM7) had very low levels of pH and Gran alkalinity and are the most poorly buffered of the RAMP lakes (Table 5.14-3). All three lakes are found in organic soils in upland regions, with two in the Stony Mountains subregion and one in the Birch Mountains subregion. The highest values of Gran alkalinity and buffering capacities were found in lakes 270/NE9, 271/NE10 and Kearl Lake/NE11, all located in mineral soils in the Northeast of Fort McMurray subregion. Lakes 182/NE6 and 271/NE10, both located in the same subregion and Lake 199/BM11, located in the Birch Mountain subregion, had the highest values of pH of the RAMP 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 (Weekes Lake/S1). The highest concentrations of DOC were found in Lake 268/NE5 located in the Northeast of Fort McMurray subregion, Lake 166/SM7 located in the Stony Mountains subregion, and Lake 223/WF4 in the West of Fort McMurray subregion.

The lowest levels of Gran alkalinity and pH are found in organic soils in the upland regions. Unique to the RAMP 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).

In general, the lakes in 2012 showed higher values of pH, conductivity, Gran alkalinity, base cations, and DOC than previous years.

The chemistry of the RAMP lakes is discussed further in Appendix F.

5.14.2 Temporal Trends

5.14.2.1 Among-Year Comparisons of Measurement Endpoints using ANOVA

Comparisons of the seven ASL measurement endpoints and five other variables among years were conducted using a one-way ANOVA or one-way Kruskal-Wallis non-parametric test, when variances were significantly different. The one-way ANOVA is a coarse analysis that will only detect region-wide changes in the measurement endpoints among years. The results were similar to those reported in previous years. Nitrates was the only measurement endpoint that showed a significant decrease across 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 RAMP lakes, both between lakes and between years within each lake, which makes it difficult to detect a change in nitrates in the RAMP lakes attributable to acidification. Significant differences were also observed in TDS between years and potassium across years. Changes in TDS and base cations are 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 50 RAMP lakes;
- Case 2 – the ten *baseline* lakes from the Caribou Mountains and 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. When the interaction term was significant, the percentage of the variability that was explained by this interaction is indicated in brackets. A significant interaction between lake and year can be ignored when it accounts for less than a few percent of the variability explained by the regression (Barrett et al. 2010). The interaction term accounted for more than 5% of the variability for potassium, nitrates and DOC in Case 1 (all RAMP lakes), for conductivity and sulphate in Case 2 (*baseline* lakes) and for Gran alkalinity, potassium, nitrates and DOC in Case 3 (*test* lakes). For these variables, the significant/non-significant designation was; therefore, less reliable.

There was a significant increase in pH in all three cases from 2002 to 2012. An increase in pH is the opposite effect expected under an acidification scenario. Given that a significant increase in pH was observed in both *baseline* lakes that are remote from the main sources of acidifying emissions and *test* lakes that are potentially receiving acidifying emissions, indicates that factors other than acidifying emissions from oil sands development may be causing the increases in pH.

There was a significant increase in Gran alkalinity in all three cases. Similar to pH, an increase in Gran alkalinity is inconsistent with an acidification scenario. Given that both *baseline* lakes and *test* lakes showed significant increases in Gran alkalinity, likely indicates that factors other than the deposition of acidifying emissions are causing the increases in Gran alkalinity.

There was no significant increase in sulphate in the RAMP lakes from 2002 to 2012. Sulphate is the principal acidifying agent in oil sands emissions.

There was no significant decrease in DOC across sampling years.

Significant increases over time were observed for sodium (all three Cases), potassium (Case 2 and Case 3), TDS (all three Cases), conductivity (Case 2), and the sum of base cations (Case 1 - all lakes). While increases in base cations are suggestive of acidification of soils within a catchment, this scenario is unlikely as none of the other measurement variables (i.e., Gran alkalinity, sulphate, pH) indicated that acidification was occurring. Base cations originate either from surface runoff or from groundwater (shallow or deep) inputs to each lake; therefore, it is likely that the increase in base cations is likely related to long-term changes in hydrologic conditions that have resulted in an increase in the proportion of the groundwater input (vs. surface runoff) to each lake. Groundwater is considerably more saline and higher in base cation content than surface runoff. Under these conditions, increased inputs of base cations actually increase the buffering capacity and decrease the acid sensitivity of each lake. This increase in buffering capacity can also be seen in the critical load values observed in 2012 (See Section 5.14.3).

5.14.3 Critical Loads of Acidity and Critical Load Exceedances

The critical loads of acidity (CL) were calculated for each RAMP lake for the years 2002 to 2012 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 is an inherent property of the each lake that defines the greatest load of acidifying substances that will not cause ecological damage to the lake. In essence the CL represents a measure of the acid-sensitivity of a lake; the lower the critical load, the more sensitive the lake to acidification.

The runoff to each lake, an influential term in the Henriksen model, was calculated using the isotopic mass balance (IMB) technique of Gibson et al. (2002, 2005, 2010) and the values for each lake are presented in Appendix F. As noted by Gibson et al. (2010) and RAMP (2012), water yields vary considerably between years with the highest values of yield occurring in years with high precipitation. Significant changes in the runoff to a lake result in changes to the critical load and; therefore, the acid sensitivity of each lake will vary depending upon the hydrologic regime.

Table 5.14-5 provides the estimates of the critical loads of acidity for each individual RAMP lake between 2002 and 2012; summary statistics are provided in Table 5.14-6. Critical loads in 2012 ranged from -1.014 keq H^+/ha/yr to 4.25 keq H^+/ha/yr with a median CL of 0.669 keq H^+/ha/y. The median and mean critical loads were considerably higher in 2012 than 2011 and most of the previous sampling years. The high values of critical loads in 2012 likely resulted from the overall increase in base cation concentrations in these lakes, noted in sections 5.14.1 and 5.14.2.

Mean critical loads in 2012 in the six subregions are presented in Table 5.14-7. Consistent with the findings of previous years, the lowest critical loads are found in lakes in the Stony Mountains subregion, followed by the West of Fort McMurray and the Canadian Shield 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 (base cation content) is less than the biological threshold assumed in the model to maintain the ecological integrity of the lake (See Section 3.5.5.2). The Stony Mountain lakes, having the lowest critical loads, are the most acid-sensitive of the RAMP lakes.

5.14.4 Comparison of Critical Loads of Acidity to Modeled Net Potential Acid Input

The critical loads of acidity for each individual lake were compared to modeled rates of acid deposition for each lake published in Teck (2011) and CEMA (2010b). In both cases, a maximum emissions scenario was assumed representing existing emissions sources as well as emissions from industrial sources that have been approved by regulators. Acid input was expressed as the Net Potential Acid Input (PAI), which corrects for the nitrogen uptake by plants in the lake catchments (AENV 2007b, CEMA 2004b).

Lakes having a modeled Net PAI greater than the critical load are identified individually in Table 5.14-8 and results are summarized in Table 5.14-9. The percentage of such lakes ranged from a low of 18.4% (9 of 49 lakes) in 2005 to a high of 32.6% (15 of 46 lakes) in 2007. In 2012, ten (20%) of the lakes had a Net PAI greater than the critical load (Figure 5.14-5). Differences between years reflect differences in the runoff and the base cation concentrations in each lake.

The percentage of RAMP lakes in which the modeled Net PAI is greater than the critical load (18.4 to 32.6%) is considerably higher than the 8% of 399 regional lakes reported in a study conducted for the CEMA NO_xSO_x Management Working Group (WRS 2006). The higher proportion of the RAMP lakes largely reflects a bias in the selection of lakes for the RAMP program in which the most poorly-buffered lakes in the region were chosen in the initial phase of the program. Estimates of Net PAI published in Teck (2011) and CEMA (2010b) may also be biased towards the high end. By incorporating both approved and existing emissions sources in the calculation of the PAI, the estimates of Net PAI reported in Table 5.14-5 represent future risk (not current risk) to the RAMP lakes. For comparison to other regions, 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. Their study did not include modifications to the model for organic anions or the use of isotopic estimates of runoff.

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. Table 5.14-8 summarizes the key chemical characteristics of the lakes having the modelled Net PAI greater than the critical load. As expected, these are generally small lakes with low pH, low conductivity, low alkalinity, and high DOC. While these lakes are scattered throughout the oil sands region, the majority (six of ten) are found in the Stony Mountains subregion (Table 5.14-5).

5.14.5 Mann-Kendall Trend Analysis on Measurement Endpoints

Mann-Kendall trend analysis was applied to test for changes in each measurement endpoint over time in the 50 RAMP lakes. Table 5.14-9 presents the value of the S or Z statistic for each measurement endpoint for each lake in which a significant trend was detected. Significant changes in a measurement endpoint in a direction (positive or negative) consistent with an acidification scenario are indicated in red. Other significant changes are indicated in green. 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 significant ecologically or 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 with care. In order to help interpret the results of the trend analyses, control charts of measurement endpoints have been prepared in 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. This technique avoids the false conclusions that may arise from the Mann-Kendall analysis. The interpretation of these control charts is discussed in detail in Section 3.2.5.7.

There were fewer significant trends detected in values of ASL measurement endpoints in 2012 than in previous years. These include the following:

1. No significant decreases in pH indicative of acidification were detected in any of the RAMP lakes in 2012. Significant increases in pH were observed in Lakes 167/SM5, 165/WF1, 227/WF7, 436/BM2, 442/BM9, 444/BM1, 473/S4, 118/S1, 84/S290/S3, CM1/146. An increase in pH over time was detected using ANOVA, in *test* lakes and *baseline* lakes located in the Caribou Mountains (S1, S3, S4) and the Canadian Shield (CM1). It was suggested that hydrological changes were likely responsible for the observed changes in pH.
2. No significant decreases in the concentration of Gran alkalinity over time, indicative of acidification, were detected in any of the RAMP lakes. Gran alkalinity increased significantly in 13 lakes located in almost all of the subregions, including the Stony Mountains (Table 5.14-9). Lakes from the Stony Mountains are considered the most acid-sensitive and would likely show the earliest indications of acidification (See Section 5.14.5). An increase in Gran alkalinity over time was also detected from ANOVAs (Section 5.12.2) of *baseline* and *test* lakes. Similar to pH, both *baseline* lakes and *test* lakes showed a significant increase in Gran alkalinity suggesting that hydrological conditions were likely responsible for the observed increases in Gran alkalinity.
3. A significant increase in the concentration of sulphate over time was detected in Lake 146/CM 1 in the Caribou Mountains. A significant trend is

also indicated in the control chart (Figure 5.12-2) for this variable in which concentrations of sulphate exceeded the ±2 SD limit in two consecutive years (2011 and 2012). This increase in sulphate in Lake 146/CM1 was small (<2 mg/L) and was accompanied by significant increases in Gran alkalinity and pH, which are inconsistent with an acidification scenario. The lake is also located in the Caribou Mountains subregion, an area remote from oil sands developments and; based on current emissions modelling, unaffected by acidic emissions. The increase in sulphate is; therefore, likely attributed to other sources of acidification.

4. A significant increase in the concentration of nitrates over time was detected in Lake 289/SM3 in the Stony Mountains subregion and Lake 209/NE1 located northeast of Fort McMurray. The control chart for Lake 289 indicated that concentration of nitrates in this lake were extremely low and variable with a mean concentration less than 3 µg/L (Figure 5.14-2). Lake 289 provided an example of a small, relatively consistent increase in the concentration of nitrates that is likely insignificant ecologically, or within the range of analytical error. Given that the Mann-Kendall analysis does not take into account the magnitude of change, it can result in a false conclusion that a significant acidifying trend is occurring. While the concentration of nitrates in 2011 exceeded the ±2 SD limit of 8 µg/L, the value in 2012 returned to near the historical mean value. The high variability of nitrates and the limitations of its use as a measurement endpoint were noted in previous reports (RAMP 2012). Following the rules of interpretation, the control charts suggested that there is no significant trend in nitrate occurring in this lake (Figure 5.14-2).

5. Significant decreases in DOC over time were detected in Lake 354/SM1 in the Stony Mountains subregion and Lake 270/NE9, located northeast of Fort McMurray. However, there were no significant decreases in pH or Gran alkalinity associated with the decrease in DOC in either lake. Under an acidification scenario, changes in these two variables should be observed before changes in concentrations of DOC are observed. The control charts provided no supporting evidence that a significant trend in DOC was occurring in these two lakes (Figure 5.14-2). The changes in DOC were likely attributed to factors other than acidification, but will be monitored in future years.

6. Significant increases in the sum of base cation concentrations (SBC) over time were detected in Lake 171/WF2 and Lake 227/WF7, located in the West of Fort McMurray subregion; Kearl Lake (418/NE11), located in the Northeast of Fort McMurray subregion; Namur Lake (436/BM2), located in the Birch Mountains subregion; and Fleming Lake (146/CM1), Rocky Island Lake (152/CM2), and Lake 97/CM4, located in the Caribou Mountains subregion. In theory, acidification should initially result in an increase in SBC in a lake as these ions are stripped from soils in catchments receiving acid deposition. The result is an increased loading of calcium and magnesium sulphate to the lake, which reduce (rather than increase) Gran alkalinity and pH, indicating that acidification is occurring. Only one lake (i.e., CM1) showed an increase in SBC that was associated with a significant increase in sulphate concentrations. Three of the lakes (Kearl lake, Namur Lake, and Fleming Lake) also showed significant increases (rather than decreases) in pH and/or Gran alkalinity suggesting that the increase in SBC in these lakes was attributed to increased loadings of alkalinity (calcium and magnesium bicarbonates) from the catchments rather than calcium and magnesium sulphate. The increases in SBC will be tracked in future

monitoring years particularly in Kearl Lake (418/NE11) and Namur Lake (BM2), which are large lakes of importance to Aboriginal communities in the region (Figure 5.14-2).

7. Significant increases in dissolved aluminum were detected in Lake 452/NE1, located in the Northeast of Fort McMurray subregion and Lake 457/BM5 in the Birch Mountains subregion. Similar to nitrates, aluminum in the RAMP lakes is highly variable both between lakes and among years within each lake. The increase in dissolved aluminum in these two lakes was not associated with significant decreases in pH or Gran alkalinity. The control charts suggest that there is no significant trend in aluminum occurring in these lakes (Figure 5.14-2). These two lakes will be tracked in future years to determine whether the observed trends in dissolved aluminum continue.

In summary, the results of the Mann-Kendall trend analyses do not indicate that acidification is occurring in the RAMP lakes. Monitoring of measurement endpoints should be maintained, particularly in lakes (i.e., Kearl and Namur lakes) where trends may be occurring.

5.14.6 Control Charting of ASL Measurement Endpoints

Ten lakes were selected for control charting based on an acidification risk factor calculated from the ratio of PAI to the value of the critical load (Table 5.14-10). The greater this ratio in a lake, the greater is the risk for acidification. The ten lakes with the highest risk factors are indicated with shading in Table 5.14-10. These ten lakes are scattered throughout the oil sands region and are found in the Stony Mountains (6), Birch Mountains (2), Northeast of Fort McMurray (1), and West of Fort McMurray (1) subregions. If acidification was occurring, it should be evident first in these lakes.

Control charts for pH, SBC, sulphate, DOC, nitrates, Gran alkalinity, and dissolved aluminum (when sufficient data are available) are presented in Figure 5.14-3 to Figure 5.14-9. The interpretation of these control charts follows the rules outlined in Section 3.2.5.7. As in previous years, the control plots for all the measurement endpoints show isolated exceedances beyond ±2 SD during the ten to 13 years of monitoring. Some of these exceedances were in a direction consistent with acidification, while other exceedances were not.

There were no exceedances in 2012 that were consistent with acidification and exceeding the ±2 SD limits, with the exception of DOC in Lake 185.

The following is a list of measurement endpoints/lakes where exceedances occurred in a direction consistent with acidification at some point during the RAMP data record:

- pH in lakes 167, 290, 172, and 448;
- SBC in lakes 170, 290, and 448;
- Sulphate in lakes 167, 168, 287, and 447;
- DOC in lakes 170, 172, 185, and 447;
- Gran alkalinity in lakes 170, 287, 290, and 447;
- Nitrates in lakes 168, 290, and 172; and
- Dissolved aluminum in Lake 168.

In all cases, concentrations of these measurement endpoints returned to values within ±2 SDs in the following year. Concentrations of nitrates were extremely variable and a logarithmic scale was used to present this measurement endpoint (e.g., Lake 185, Figure 5.14-7). The control charts do not indicate that trends indicative of acidification are occurring in any of these lakes that are most at risk to acidification.

5.14.7 Classification of Results

Results of the analysis of the RAMP lakes in 2012 compared to historical data suggested that there were no significant changes in the overall chemistry of the lakes across years that were attributable to acidification. Significant increases in pH, Gran alkalinity, sodium, TDS, conductivity, and sum of base cations were observed; however, these changes appeared to be the result of factors other than acidifying emissions (e.g., hydrology).

A summary of the state of the RAMP lakes in 2012, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of 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 general, data in 2012 were less variable than in 2011, resulting in fewer exceedances of the two standard deviation criterion. The highest number of exceedances (3) occurred in lakes in the Canadian Shield subregion, which are remote from emissions sources and considered *baseline* lakes. Exceedances were observed in base cation concentrations in two lakes, which are increasing due to factors other than acidification (See Section 5.14.2). Taking into account these factors, the subregions were all classified as having a **Negligible-Low** indication of incipient acidification.

Table 5.14-1 Morphometry statistics for the RAMP 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	13.20	1.83

Table 5.14-2 Summary of the chemical characteristics of the RAMP acid-sensitive lakes.

Variable	Mean		Median		Minimum		Maximum		5th percentile 2012	95th percentile 2012
	1999 to 2012	2012	1999 to 2012	2012	1999 to 2012	2012	1999 to 2012	2012		
Lab pH	6.64	7.02	6.82	7.24	3.97	4.47	9.46	8.73	5.03	8.28
Total alkalinity (µeq/L)	333	434	224	292	0	0	2,032	2,032	39.9	1,293
Gran alkalinity (µeq/L)	319	410	203	262	-57.2	2	2,023	2,023	9.89	1,272
Specific conductivity (µS/cm)	45.3	53.3	33.4	38.8	10.3	10.3	196	196	13.3	123
Total dissolved solids (mg/L)	69.9	92.4	62.0	91.5	0.02	14.0	219	164	45.4	156
Turbidity (NTU)	4.37	5.46	2.10	3.23	0.01	0.524	53	38.6	0.718	15.7
Total suspended solids (mg/L)	7.85	7.28	2.77	0.75	0.025	0.025	175	170	0.025	17.4
Colour (TCU)	151	155	123	122	8.0	11.1	948	625	16.6	448
Sodium (mg/L)	2.06	1.98	1.38	1.06	0.18	0.18	12.35	12.35	0.26	7.91
Potassium (mg/L)	0.52	0.63	0.43	0.59	0.0015	0.11	2.45	2.45	0.17	1.12
Calcium (mg/L)	5.80	7.03	4.70	5.86	0.0015	0.35	32.2	22.7	1.02	18.1
Magnesium (mg/L)	1.89	2.40	1.48	1.98	0.01	0.16	13.64	8.81	0.30	6.25
Bicarbonate (mg/L)	20.16	26.34	13.70	17.81	0.00	0.00	124	124	2.43	77.5
Chloride (mg/L)	0.34	0.32	0.17	0.14	0.02	0.05	2.64	2.59	0.06	1.37
Sulphate (mg/L)	2.38	2.22	1.18	1.04	0.02	0.02	19.0	15.0	0.1	11.5
Total dissolved nitrogen (µg/L)	827	759	695	708	105	108	2,891	2,070	124	1,686
Ammonia (µg/L)	36.2	15.8	16.0	7.0	0.4	1.0	1,509	86	1.0	67.4
Nitrate + Nitrite (µg/L)	19.6	7.7	3.0	4.0	0.02	0.5	733	79	0.5	24.6
Total phosphate (µg/L)	54.8	54.9	39.0	35.0	3.0	5.0	341	246	11.5	166
Dissolved phosphorous (µg/L)	20.6	21.4	11.0	11.5	1.0	1.0	167	132	1.73	76.2
Dissolved inorganic carbon (mg/L)	3.43	4.46	2.10	2.95	0.027	0.3	21.6	20.6	0.345	14.2
Dissolved organic carbon (mg/L)	23.2	27.4	21.6	23.1	6.8	6.9	92.2	92.2	10.2	68.2
Chlorophyll *a* (µg/L)	20.9	24.4	9.5	13.6	0.1	0.1	371	202	1.5	89.3
Iron (mg/L)	0.396	0.423	0.184	0.116	0.001	0.001	3.88	2.84	0.001	1.86
Total nitrogen (µg/L)	1,207	1,130	967	902	274	356	6,558	5,560	431	2,672
Total Kjeldahl Nitrogen (µg/L)	1,186	1,123	935	889	273	356	6,552	5,554	427	2,670
Sum base cations (µeq/L)	548	650	439	530	38	43	2,411	2,411	95	1,544
Dissolved aluminum (µg/L)	70.1	63.2	23.4	14.7	0.1	0.4	734	646	1.06	225

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.

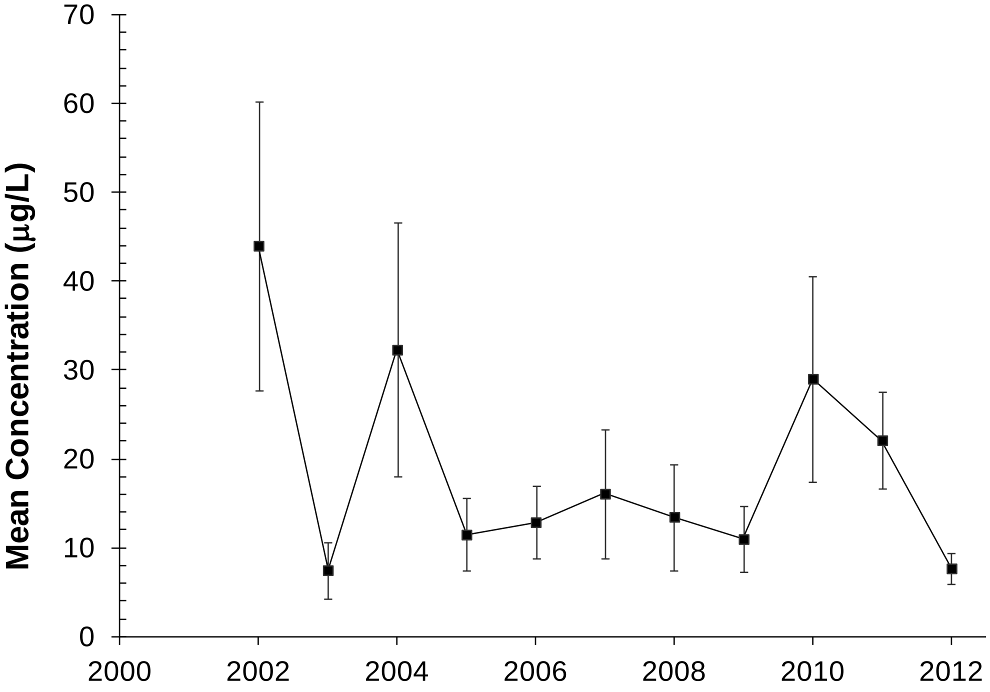
Table 5.14-3 RAMP acid-sensitive lakes with chemical characteristics either below the 5th or above the 95th percentile in 2012.

Lake	Subregion	pH	Gran Alkalinity (µeq/L)	DOC (mg/L)
5th percentile 2012		**5.03**	**9.9**	**10.2**
95th percentile 2012		**8.28**	**1,272**	**68.2**
168 (SM10)	Stony Mountains	5.01	14.4	19.9
169 (SM9)	Stony Mountains	4.66	2.0	20.9
287 (SM8)	Stony Mountains	5.06	6.2	13.3
223 (WF4)	West of Fort McMurray	7.55	679	69.4
182 (NE6)	Northeast of Fort McMurray	8.66	1,244	24.9
270 (NE9)	Northeast of Fort McMurray	8.02	1,295	21.4
271 (NE10)	Northeast of Fort McMurray	8.39	1,349	22.3
418 (NE11/Kearl L.)	Northeast of Fort McMurray	8.15	2,023	26.1
185 (NE7)	Northeast of Fort McMurray	5.37	74	71.0
209 (NE8)	Northeast of Fort McMurray	6.71	246	92.2
436 (BM2/Namur L.)	Birch Mountains	7.71	463	6.9
444 (BM1/Legend L.)	Birch Mountains	7.37	227	7.2
448 (BM7/Clayton L.)	Birch Mountains	4.47	2.0	34.3
199 (BM11)	Birch Mountains	8.73	1,002	47.6
118 (S1/Weekes L.)	Canadian Shield	7.74	479	9.6

Yellow shading denotes values below the 5th percentile in 2012.

Green shading denotes values above the 95th percentile in 2012.

Figure 5.14-1 Concentrations of nitrates (± 1SE) in all 50 RAMP acid-sensitive lakes combined.



Note: Error bars represent one standard error of the mean.

Table 5.14-4 Results of the ANOVA using the GLM for all 50 RAMP acid-sensitive lakes, *baseline* lakes, and *test* lakes.

Variable	**ANOVA - All Lakes**	**Case 1 - All Lakes**			**Case 2 - *Baseline* Lakes**			**Case 3 - *Test* Lakes**		
	Significance	**Significance**	**Direction (slope)**	**Interactive Term**	**Significance**	**Direction (slope)**	**Interactive Term**	**Significance**	**Direction (slope)**	**Interactive Term**
pH	NS	S	Positive	NS	S	Positive	NS	S	Positive	NS
Gran alkalinity	NS	S	Positive	S (1.7%)	S	Positive	S (4.5%)	S	Positive	NS
Conductivity	NS	NS	Positive	S (1.8%)	S	Positive	S (6.1%)	NS	Positive	S (1.6%)
TDS	S	S	Positive	NS	S	Positive	NS	S	Positive	NS
Colour	NS	NS	Positive	NS	NS	Negative	NS	NS	Positive	NS
Sodium	NS	S	Positive	NS	S	Positive	NS	S	Positive	NS
Potassium	S	NS	Positive	S (5.3%)	S	Positive	S (4.7%)	NS	Positive	S (5.2%)
Sulphate	NS	NS	Positive	NS	NS	Positive	S (9.5%)	NS	Positive	NS
Nitrates	S	NS	Negative	S (21.8%)	NS	Positive	NS	NS	Negative	S (21.8%)
DOC	NS	NS	Positive	S (6.4%)	NS	Negative	NS	NS	Positive	S (6.6%)
Sum Base Cations	NS	S	Positive	S (1.8%)	NS	Positive	NS	NS	Positive	S (1.7%)
Dissolved aluminum	NS	NS	Negative	S (3.4%)	NS	Positive	S (3.9%)	NS	Negative	S (3.5%)

Note: S = statistically significant ($p<0.05$), NS = not statistically significant. Percentage of the variation in the variable attributable 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.

Table 5.14-5 Critical loads[1] of acidity in the RAMP acid-sensitive lakes, 2002 to 2012.

NO_xSO_x GIS No.	Original RAMP Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y)											
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Net PAI
								Stony Mountains Subregion							
168	A21	SM10	18.2	-0.069	-0.080	-0.097	-0.130	-0.099	-0.051	-0.110	-0.096	-0.137	-0.119	-0.119	0.134
169	A24	SM9	8.3	-0.182	-0.137	-0.391	-0.509	-0.252	-0.069	-0.226	-0.199	-0.254	-0.420	-0.324	0.121
170	A26	SM6	13.1	-0.015	-0.019	-0.028	-0.052	-0.041	-0.008	0.004	-0.025	-0.049	-0.034	-0.046	0.125
167	A29	SM5	3.7	-0.072	-0.052	-0.006	0.016	0.099	-0.005	-0.210	0.062	-0.278	-0.089	-0.113	0.105
166	A86	SM7	6.9	0.065	0.146	0.192	0.262	0.213	0.150	0.515	0.560	0.340	0.055	0.292	0.043
287	25	SM8	9.6	-0.089	-0.128	-0.190	-0.273	-0.194	-0.025	-0.145	-0.201	-0.260	-0.193	-0.208	0.120
289	27	SM3	7.4	0.036	0.078	0.087	0.159	0.093	0.095	0.112	0.144	0.008	0.066	0.124	0.118
290	28	SM4	11.7	0.001	0.020	-0.004	-0.004	0.007	-0.007	0.002	0.001	-0.032	-0.007	-0.015	0.115
342	82	SM2	15.4	0.065	0.059	0.119	0.158	0.119	0.012	0.117	0.140	0.140	0.095	0.107	0.027
354	94	SM10	9.6	0.709	0.680	0.816	1.045	0.428	0.153	1.425	1.443	1.035	0.729	0.825	0.043
								West of Fort McMurray Subregion							
165	A42	WF1	10.4	0.385	0.890	1.418	2.189	1.006	0.730	2.227	2.281	1.943	1.359	1.183	0.044
171	A47	WF2	4.3	0.107	0.173	0.132	0.496	0.153	-	0.829	0.403	0.180	0.246	0.324	0.082
172	A59	WF3	51.6	0.006	0.000	0.001	-0.017	-0.026	-0.017	0.038	0.023	0.012	0.013	-0.012	0.049
223	P94	WF4	1.8	0.113	0.091	0.118	1.285	0.197	0.088	0.338	0.327	0.158	0.271	0.316	0.151
225	P96	WF5	5.0	0.123	0.265	0.230	1.509	0.386	0.203	0.418	0.455	0.556	0.882	0.707	0.172
226	P97	WF6	4.2	0.088	0.342	0.206	2.710	0.194	0.168	0.290	0.402	0.470	0.375	0.362	0.240
227	P98	WF7	1.6	0.290	1.147	0.583	0.862	0.956	0.465	1.076	1.489	1.675	1.246	1.374	0.209
267	1	WF8	23.1	0.197	0.401	0.350	0.937	0.415	0.147	-	0.760	0.348	0.518	0.522	0.161
								Northeast of Fort McMurray Subregion							
452	L4	NE1	16.8	0.098	0.096	0.073	0.270	0.093	0.067	0.272	0.130	0.080	0.215	0.253	0.188
470	L7	NE2	15.1	0.176	0.143	0.075	0.316	0.771	0.159	0.235	0.205	0.210	0.290	0.361	0.166
471	L8	NE3	24.0	0.344	0.609	0.438	1.137	0.626	0.229	0.593	0.496	0.428	0.584	0.816	0.145
400	L39	NE4	3.2	1.154	0.959	0.788	0.769	1.570	0.793	1.456	1.461	0.851	1.352	1.261	0.059
268	E15	NE5	7.3	1.363	2.226	1.488	2.383	0.273	0.419	2.052	2.923	2.310	2.043	2.364	0.163
182	P23	NE6	8.3	0.361	1.256	1.445	4.107	0.350	2.012	0.066	2.376	3.188	2.818	2.576	0.251
185	P27	NE7	5.9	0.044	0.016	-0.071	0.281	-0.028	0.034	0.052	0.018	0.051	0.094	-0.142	0.189

Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2011) or CEMA (2010b) representing the 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$_x$SO$_x$ GIS No.	Original RAMP Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y)											
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Net PAI
				Northeast of Fort McMurray Subregion (Cont'd.)											
209	P7	NE8	0.8	0.899	0.808	0.355	0.651	0.428	0.422	2.594	0.877	1.323	0.976	0.758	0.178
270	4	NE9	11.2	3.385	4.496	5.000	8.066	4.615	1.341	3.973	6.751	5.369	4.544	4.251	0.137
271	6	NE10	17.1	2.464	2.663	6.406	7.369	3.572	2.334	3.087	4.968	3.638	4.001	3.901	0.064
418	Kearl L.	NE11	77.2		2.858	2.407	5.302	1.775	0.814	2.663	2.823	2.082	3.046	3.213	0.618
				Birch Mountains Subregion											
436	L18	BM2	165.5	1.813	2.803	2.333	2.805	2.394	1.327	3.242	3.216	3.055	2.795	2.806	0.066
442	L23	BM9	33.3	0.268	0.366	0.277	0.378	0.330	0.305	0.445	0.458	0.245	0.125	0.411	0.056
444	L25	BM1	58.7	0.632	1.072	0.988	0.977	1.107	0.635	1.401	1.627	1.088	1.173	1.407	0.067
447	L28	BM6	13.7	-0.083	-0.155	0.006	-0.246	-0.214	0.006	0.044	-0.130	0.162	-0.038	-0.032	0.050
448	L29	BM7	4.7	-0.683	-0.502	-0.487	-0.713	-0.419	-0.076	-0.385	-0.694	-0.483	-0.308	-1.014	0.046
454	L46	BM8	32.5	0.511	0.677	0.394	1.160	0.492	0.355	0.594	0.762	0.391	0.621	0.721	0.053
455	L47	BM4	37.3	0.725	0.857	1.753	2.266	1.146	0.493	1.401	2.061	1.227	1.499	1.469	0.054
457	L49	BM5	30.6	0.628	0.938	0.495	1.580	0.721	0.278	0.962	1.155	0.569	0.734	1.012	0.052
464	L60	BM3	29.8	0.366	0.692	0.509	0.833	0.417	0.245	0.620	0.693	0.498	0.636	0.834	0.055
175	P13	BM10	5.2	0.403	0.348	0.666	1.500	0.627	0.300	0.826	3.154	0.526	0.942	0.981	0.084
199	P49	BM11	0.6	0.112	0.152	0.174	0.200	0.215	0.080	0.141	0.148	0.105	0.155	1.848	0.086
				Canadian Shield Subregion											
473	A301	S4	114.6	0.105	0.131	0.102	0.332	0.166	-	0.214	0.197	0.148	0.197	0.220	0.014
118	L107	S1	13.4	2.115	2.350	1.852	2.754	2.077	1.479	2.812	2.230	2.301	2.375	2.468	0.007
84	L109	S2	112.6	0.181	0.208	0.148	0.334	0.156	-	0.245	0.320	0.166	0.279	0.309	0.014
88	O-10	S5	4.5	0.275	0.316	0.204	-	0.289	-	0.408	0.551	0.213	0.331	0.379	0.014
90	R1	S3	37.9	0.348	0.482	0.354	0.560	0.451	0.567	0.617	0.595	0.466	0.549	0.595	0.014
				Caribou Mountains Subregion											
146	E52	CM1	24.1	1.151	1.438	1.046	2.555	2.019	2.429	4.211	3.441	3.934	3.325	3.823	0.027
152	E59	CM2	46.8	0.550	0.637	0.465	1.064	0.665	0.633	0.863	1.100	1.087	0.964	0.632	0.027
89	E68	CM3	28.0	0.532	0.485	0.271	1.423	0.786	0.583	0.466	0.740	0.794	0.709	0.716	0.027
97	O-2 E67	CM4	38.1	0.553	0.585	0.309	0.202	0.313	0.364	0.480	0.402	0.972	0.745	0.916	0.027
91	O-1/E55	CM5	2.8	0.105	0.147	0.121	8.886	1.070	0.342	0.430	0.795	0.313	1.097	1.413	0.027

Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2011) or CEMA (2010b) representing the 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 in the RAMP acid-sensitive lakes, 2002 to 2012.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
No. of lakes	49	50	50	49	50	46	49	50	50	50	50
Minimum CL	-0.683	-0.502	-0.487	-0.713	-0.419	-0.076	-0.385	-0.694	-0.483	-0.420	-1.010
Maximum CL	3.385	4.496	6.406	8.886	4.615	2.429	4.211	6.751	5.369	4.540	4.250
Average CL	0.462	0.681	0.678	1.432	0.650	0.457	0.893	1.076	0.863	0.877	0.937
Median CL	0.268	0.357	0.274	0.833	0.368	0.261	0.466	0.555	0.410	0.566	0.669
No. of lakes in which the PAI is greater than the CL	15	14	15	9	13	18	12	11	11	11	10
Percent of lakes in which the PAI is greater than the CL	30.6	28.0	30.0	18.4	26.0	39.1	24.5	22.0	22.0	22.0	20.0

Table 5.14-7 Mean critical loads for each subregion, 2012.

Subregion	Critical Load keq H^+/ha/y
Stony Mountains	0.052
West of Fort McMurray	0.597
Northeast of Fort McMurray	1.783
Birch Mountains	0.949
Canadian Shield	0.794
Caribou Mountains	1.500

Table 5.14-8 Chemical characteristics of the RAMP acid-sensitive lakes having the modeled PAI greater than the critical load in 2012.

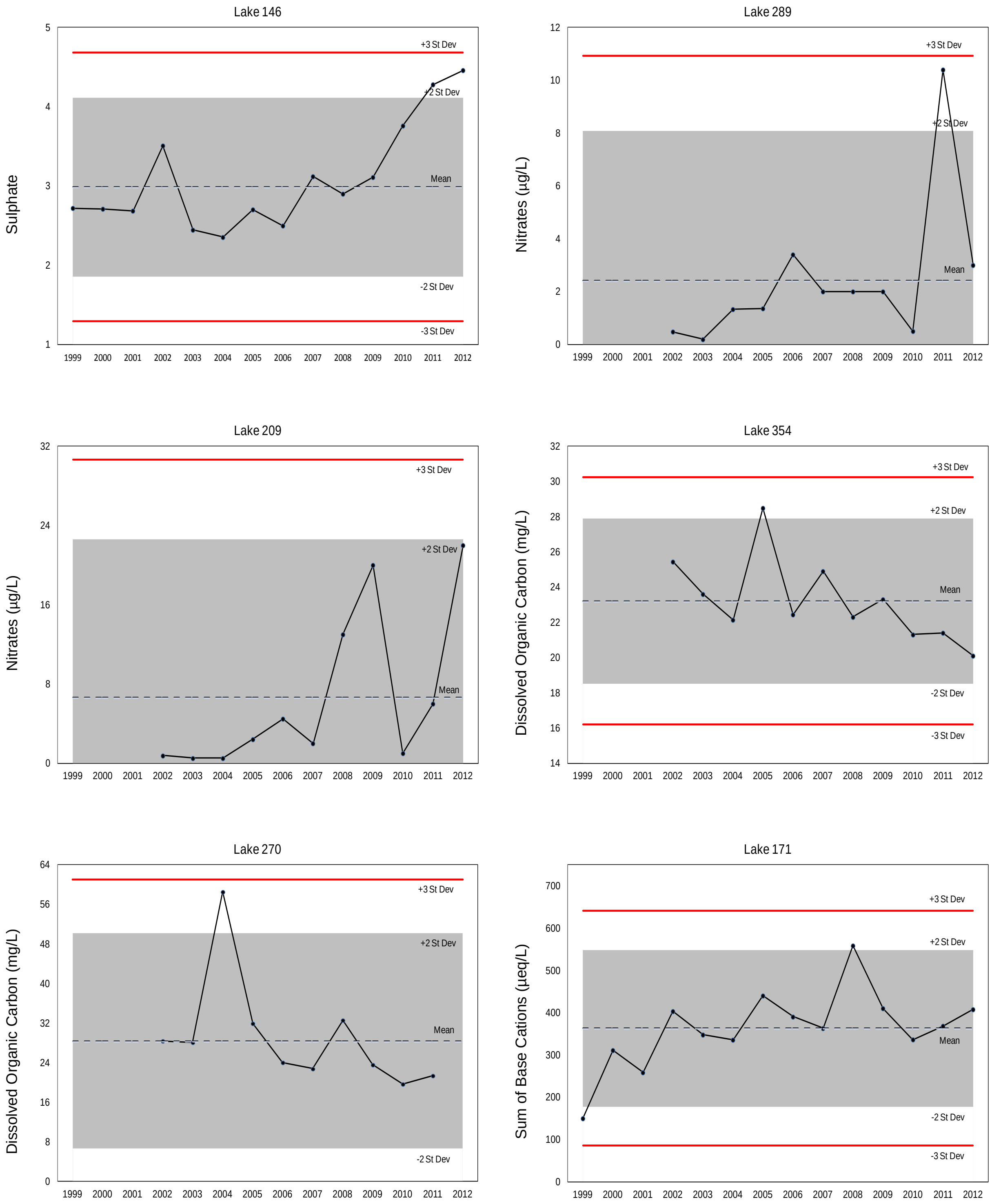
NO_xSO_x GIS No.	Original RAMP Designation	Subregion	pH	Gran Alkalinity (µeq/L)	Conductivity (µS/cm)	DOC (mg/L)	Lake Area (km^2)
168	A21	Stony Mts.	5.01	14.4	14.9	19.9	1.380
169	A24	Stony Mts.	4.66	2.00	16.1	20.9	1.450
170	A26	Stony Mts.	5.42	26.6	12.3	15.3	0.710
167	A29	Stony Mts.	6.10	47.2	10.3	13.7	1.050
287	25	Stony Mts.	5.06	6.2	11.5	13.3	2.176
290	28	Stony Mts.	5.89	49.6	14.6	17.4	0.544
172	A59	West Ft. Mc.	5.19	33.2	20.0	28.4	2.060
185	P27	N.E. Ft. Mc.	5.37	74.0	29.6	71.0	0.094
447	L28	Birch Mts.	5.63	54.0	21.2	30.1	1.300
448	L29	Birch Mts.	4.47	2.0	16.1	34.3	0.650

Table 5.14-9 Results of Mann-Kendall trend analyses on measurement endpoints for the RAMP acid-sensitive lakes, 2012.

Lake ID	AESRD Designation	pH	Gran alkalinity (mg/L)	Sulphate (mg/L)	Nitrates (mg/L)	DOC (mg/L)	SBC (µeq/L)	Dissolved aluminum (mg/L)	Potential Acid Input (keq/ha/y)
		Z	Z	Z	Z	Z	Z	S	
168	SM10	0.71	0.00	-2.85	0.05	-0.99	-2.19	-9	0.134
170	SM6	0.44	2.14	-1.64	-0.27	0.00	-1.20	10	0.125
167	SM5	2.58	3.11	-0.99	0.34	-0.38	0.00	6	0.105
166	SM7	1.47	1.99	-0.18	0.98	0.43	1.77	-6	0.043
289	SM3	1.40	1.71	0.00	2.13	-0.31	-0.16	-10	0.118
342	SM2	-0.86	-1.02	-2.44	-0.08	-1.56	-2.65	-18	0.027
354	SM1	0.86	-0.93	-0.23	0.23	-2.34	-2.02	-1	0.043
165	WF1	2.63	1.40	-1.20	1.17	-0.77	0.66	-8	0.044
171	WF2	1.64	1.77	0.00	-0.55	0.44	2.08	-20	0.082
227	WF7	2.02	1.56	-1.56	0.00	-0.16	2.18	-5	0.209
452	NE1	1.59	1.53	0.66	-0.33	0.66	1.20	18	0.188
209	NE8	1.17	2.18	0.39	2.42	0.00	1.56	6	0.178
270	NE9	-1.64	-0.78	-0.31	0.24	-2.26	-1.09	8	0.137
418	NE11	1.35	2.15	-2.15	0.00	1.25	2.33	11	0.618
436	BM2	2.69	3.72	2.47	-0.80	-1.20	2.30	2	0.066
442	BM9	2.41	1.47	-0.77	1.87	-1.20	-1.75	2	0.056
444	BM1	2.47	2.26	0.27	-0.24	-1.37	1.86	-10	0.067
447	BM6	1.75	2.14	-0.33	-0.27	0.88	0.99	8	0.050
448	BM7	1.89	-0.29	-2.32	0.37	2.01	0.06	-11	0.046
457	BM5	-0.38	-1.40	-0.27	0.11	0.71	-2.19	20	0.052
175	BM10	0.16	0.00	-2.65	0.47	0.00	-0.31	-10	0.084
473	S4	2.49	2.18	1.40	1.02	-1.56	1.25	-13	0.014
118	S1	2.75	2.69	1.48	0.18	0.79	0.79	0	0.007
84	S2	2.36	0.79	-0.05	-0.55	0.00	0.77	-6	0.014
88	S5	1.71	0.78	0.27	0.82	0.75	-0.48	-19	0.014
90	S3	2.74	2.14	0.77	0.44	-1.20	1.64	-5	0.014
146	CM1	2.08	3.60	2.19	0.00	-0.88	2.96	-8	0.027
152	CM2	1.20	1.89	-2.58	-0.44	1.42	2.52	0	0.027
89	CM3	0.24	-0.67	-1.89	0.06	-0.06	-1.28	4	0.027
97	CM4	1.15	1.47	0.55	-0.22	0.66	3.28	2	0.027
91	CM5	2.47	2.62	1.09	-1.92	-0.77	-1.86	2	0.027

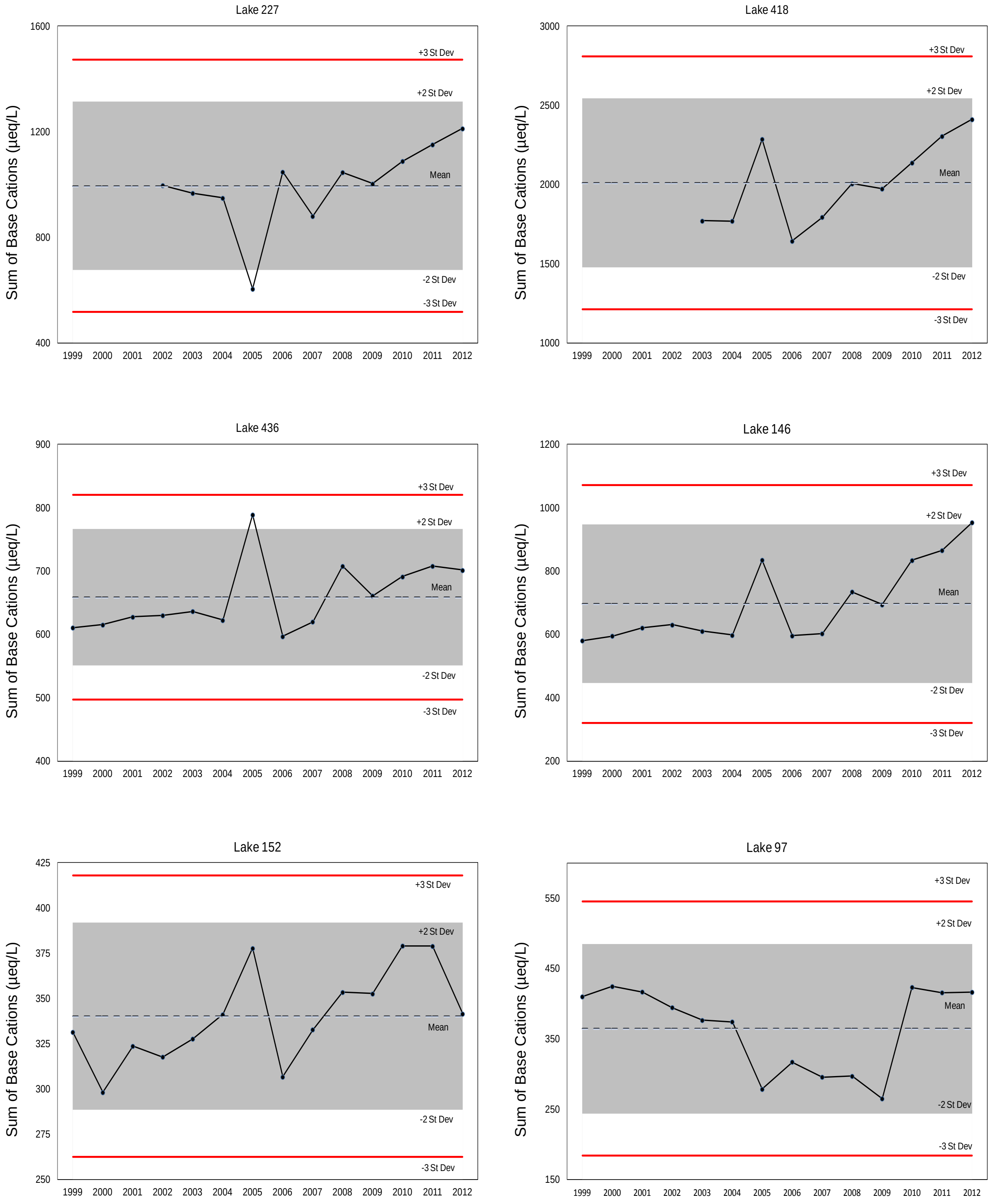
Note: Numbers represent the S or Z statistic used in the analysis. Negative values represent overall decreases in a variable and positive values represent increases.

Figure 5.14-2 Control charts for acid-sensitive lakes showing significant trends in measurement endpoints using Mann-Kendall trend analysis.



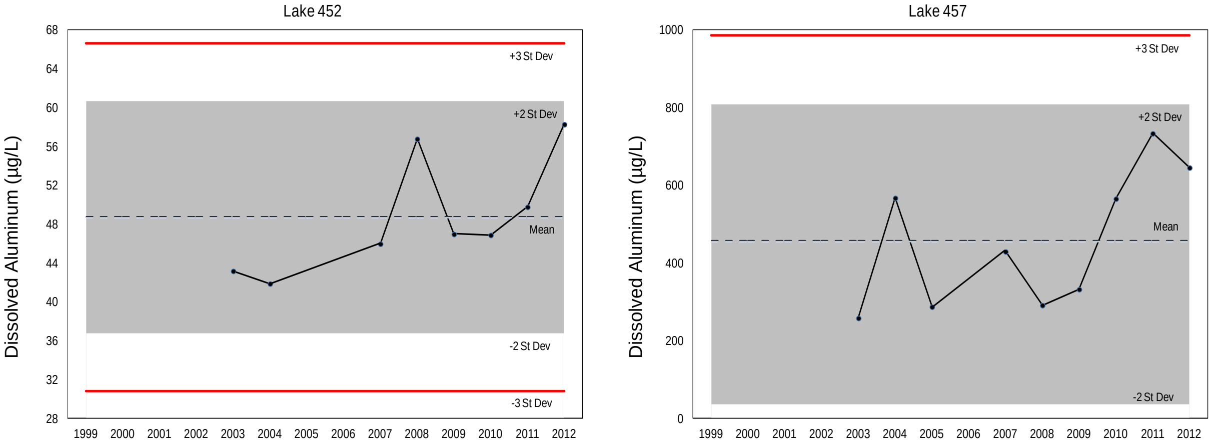
Note: Only significant trends in a direction indicative of acidification are presented.

Figure 5.14-2 (Cont'd.)



Note: Only significant trends in a direction indicative of acidification are presented.

Figure 5.14-2 (Cont'd.)



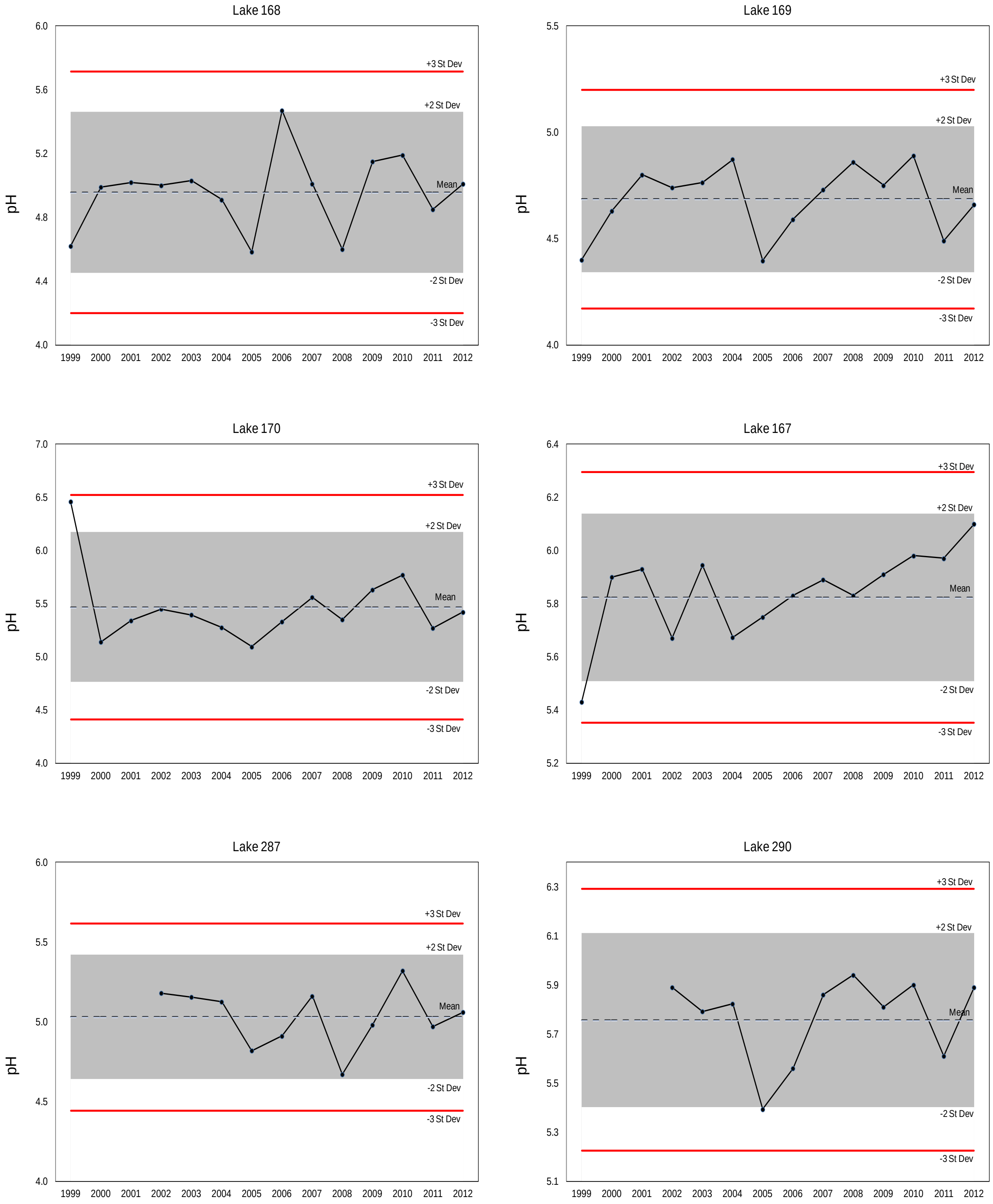
Note: Only significant trends in a direction indicative of acidification are presented.

Table 5.14-10 Acidification risk factor for individual RAMP acid-sensitive lakes.

RAMP Lake No.	Original Designation	AESRD Designation	Subregion	Critical Load (keq/Ha/y) IMB	PAI	Acidification Risk Factor PAI/CL
168	A21	SM 10	Stony Mountains	-0.119	0.134	134.3
169	A24	SM 9	Stony Mountains	-0.324	0.121	120.6
170	A26	SM 6	Stony Mountains	-0.046	0.125	124.5
167	A29	SM 5	Stony Mountains	-0.113	0.105	105.4
166	A86	SM 7	Stony Mountains	0.292	0.043	0.147
287	25	SM 8	Stony Mountains	-0.208	0.120	119.5
289	27	SM 3	Stony Mountains	0.124	0.118	0.949
290	28	SM 4	Stony Mountains	-0.015	0.115	115.3
342	82	SM 2	Stony Mountains	0.107	0.027	0.252
354	94	SM 1	Stony Mountains	0.825	0.043	0.052
165	A42	WF1	West of Fort McMurray	1.183	0.044	0.037
171	A47	WF-2	West of Fort McMurray	0.324	0.082	0.253
172	A59	WF-3	West of Fort McMurray	-0.012	0.049	49.0
223	P94	WF-4	West of Fort McMurray	0.316	0.151	0.478
225	P96	WF-5	West of Fort McMurray	0.707	0.172	0.243
226	P97	WF-6	West of Fort McMurray	0.362	0.240	0.663
227	P98	WF-7	West of Fort McMurray	1.374	0.209	0.152
267	1	WF-8	West of Fort McMurray	0.522	0.161	0.308
452	L4	NE 1	Northeast of Fort McMurray	0.253	0.188	0.746
470	L7	NE2	Northeast of Fort McMurray	0.361	0.166	0.459
471	L8	NE 3	Northeast of Fort McMurray	0.816	0.145	0.177
400	L39	NE 4	Northeast of Fort McMurray	1.261	0.059	0.047
268	E15	NE-5	Northeast of Fort McMurray	2.364	0.163	0.069
182	P23	NE6	Northeast of Fort McMurray	2.576	0.251	0.097
185	P27	NE-7	Northeast of Fort McMurray	-0.142	0.189	189.2
209	P7	NE-8	Northeast of Fort McMurray	0.758	0.178	0.235
270	4	NE 9	Northeast of Fort McMurray	4.251	0.137	0.032
271	6	NE 10	Northeast of Fort McMurray	3.901	0.064	0.017
418	Kearl L.	NE 11	Northeast of Fort McMurray	3.213	0.618	0.192
436	L18	BM 2	Birch Mountains	2.806	0.066	0.024
442	L23	BM 9	Birch Mountains	0.411	0.056	0.137
444	L25	BM 1	Birch Mountains	1.407	0.067	0.048
447	L28	BM 6	Birch Mountains	-0.032	0.050	50.2
448	L29	BM 7	Birch Mountains	-1.014	0.046	46.1
454	L46	BM 8	Birch Mountains	0.721	0.053	0.074
455	L47	BM 4	Birch Mountains	1.469	0.054	0.037
457	L49	BM 5	Birch Mountains	1.012	0.052	0.051
464	L60	BM 3	Birch Mountains	0.834	0.055	0.066
175	P13	BM-10	Birch Mountains	0.981	0.084	0.086
199	P49	BM-11	Birch Mountains	1.848	0.086	0.046
473	A301	S-4	Canadian Shield	0.220	0.014	0.064
118	L107	S-1	Canadian Shield	2.468	0.007	0.003
84	L109	S-2	Canadian Shield	0.309	0.014	0.045
88	O-10	S-5	Canadian Shield	0.379	0.014	0.037
90	R1	S-3	Canadian Shield	0.595	0.014	0.024
146	E52	CM-1	Caribou Mountains	3.823	0.027	0.007
152	E59	CM-2	Caribou Mountains	0.632	0.027	0.043
89	E68	CM-3	Caribou Mountains	0.716	0.027	0.038
97	O-2 E67	CM-4	Caribou Mountains	0.916	0.027	0.029
91	O-1/E55	CM-5	Caribou Mountains	1.413	0.027	0.019

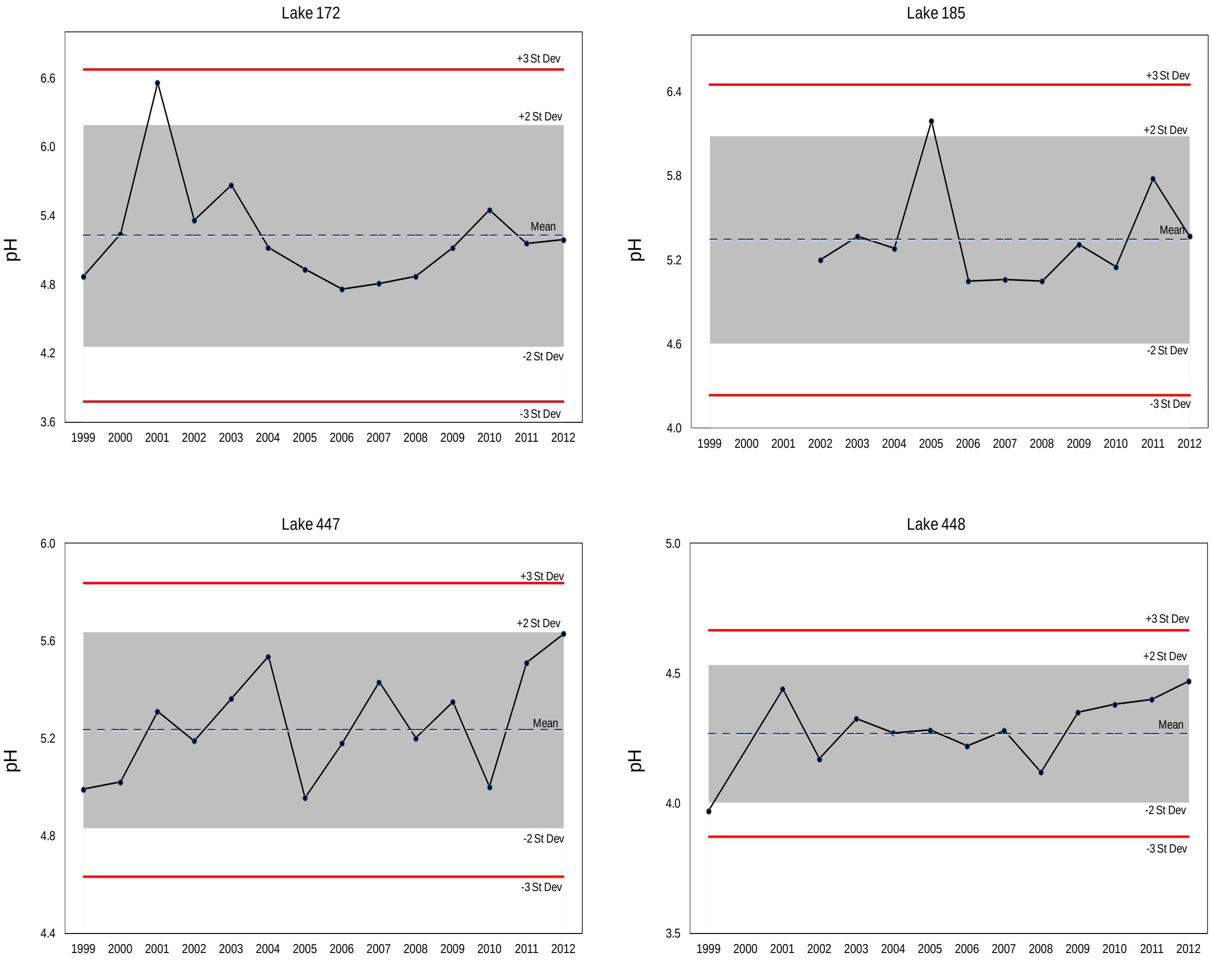
Shading denotes those lakes most at risk to acidification.

Figure 5.14-3 Control charts of pH in ten RAMP acid-sensitive lakes most at risk to acidification.



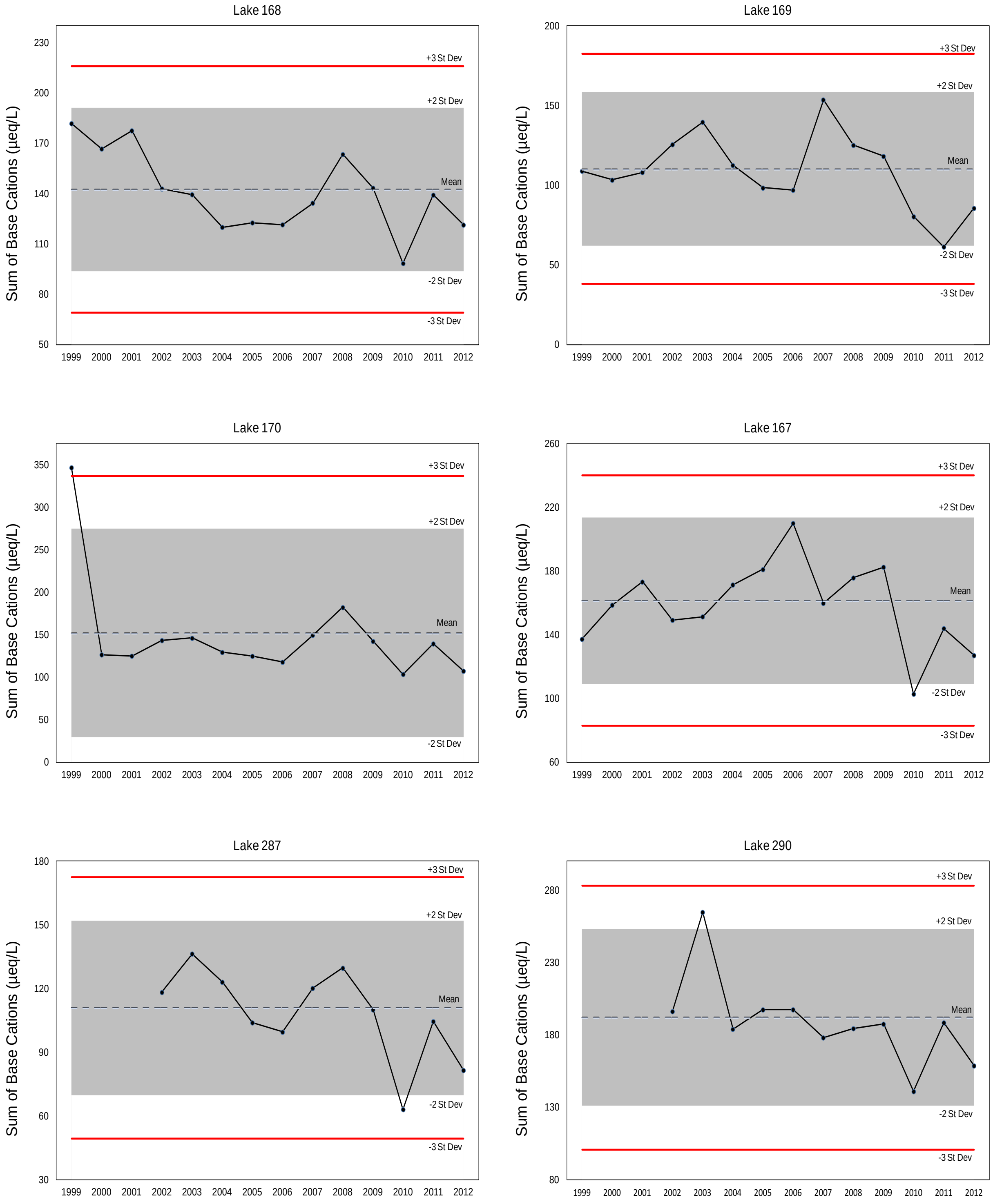
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-3 (Cont'd.)



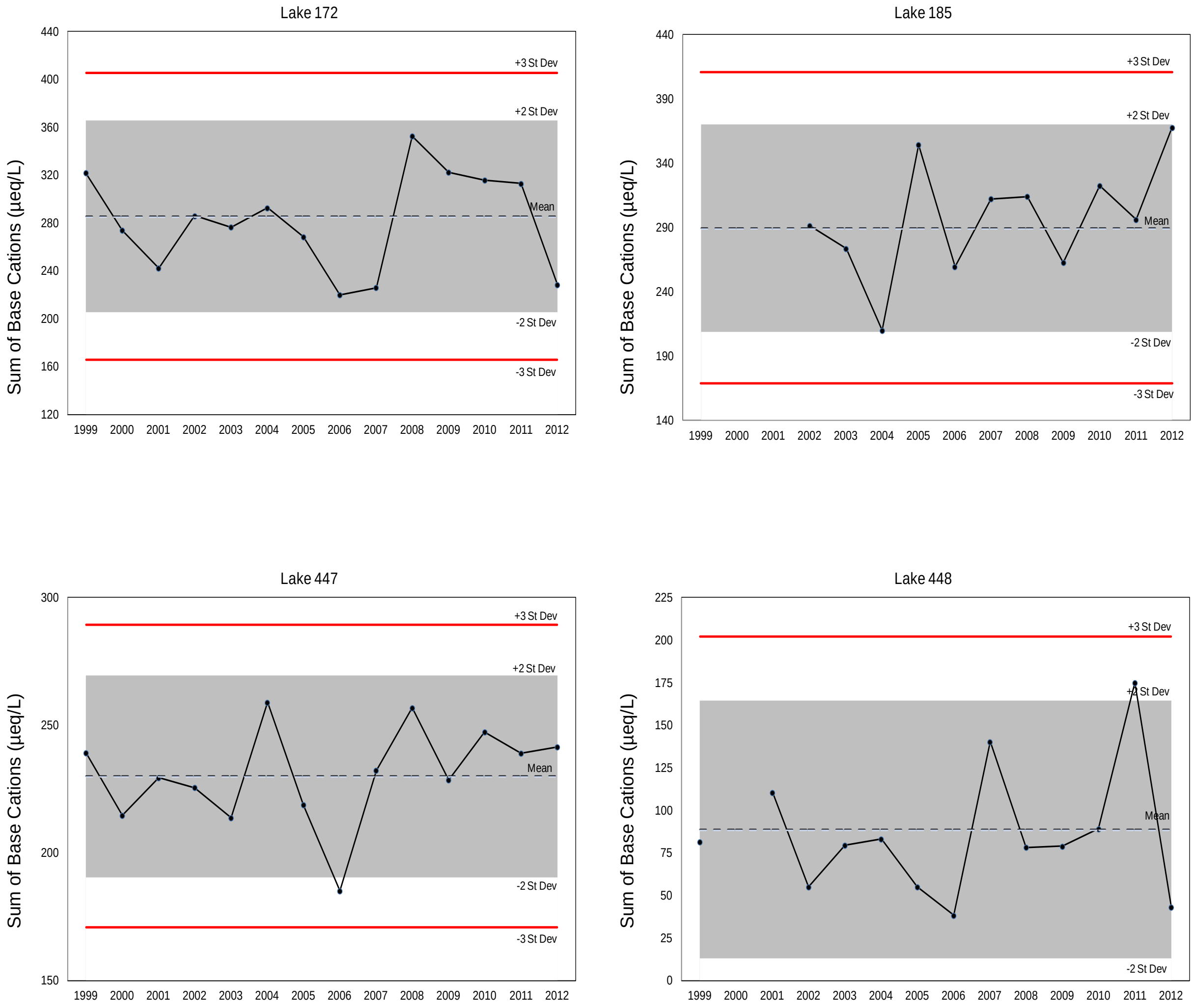
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-4 Control charts of the sum of base cations in ten RAMP acid-sensitive lakes most at risk to acidification.



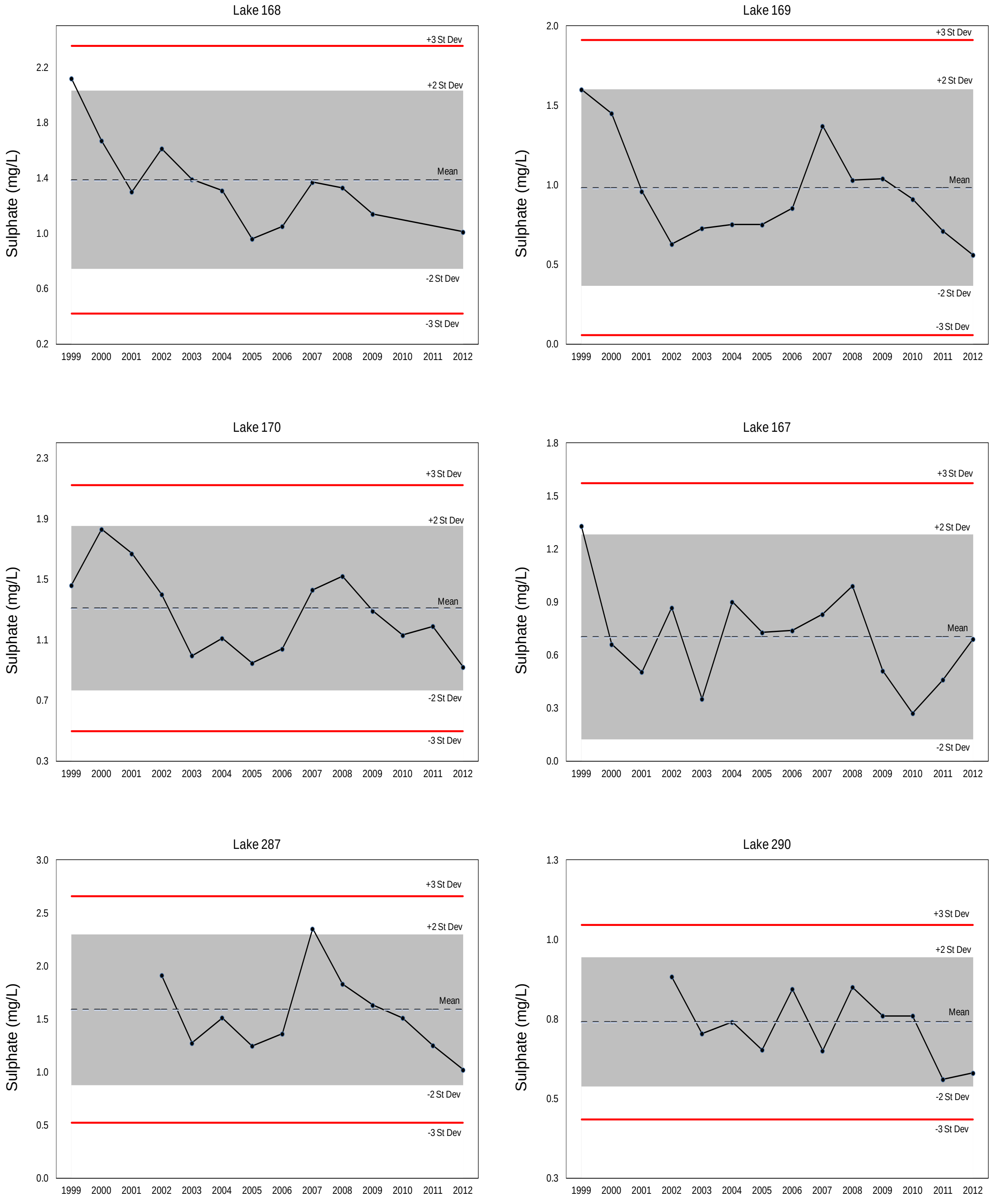
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-4 (Cont’d.)



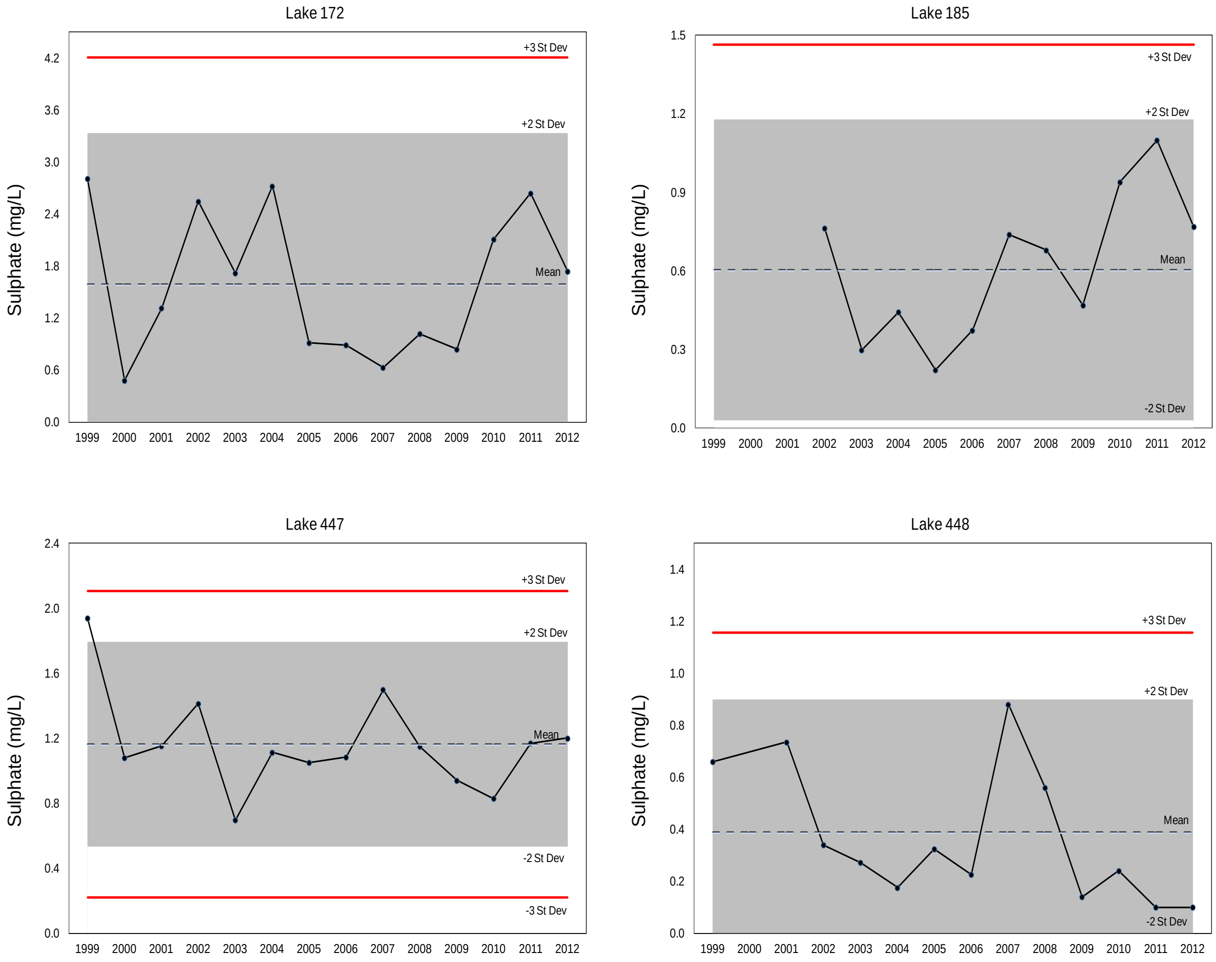
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-5 Control charts of sulphate in ten RAMP acid-sensitive lakes most at risk to acidification.



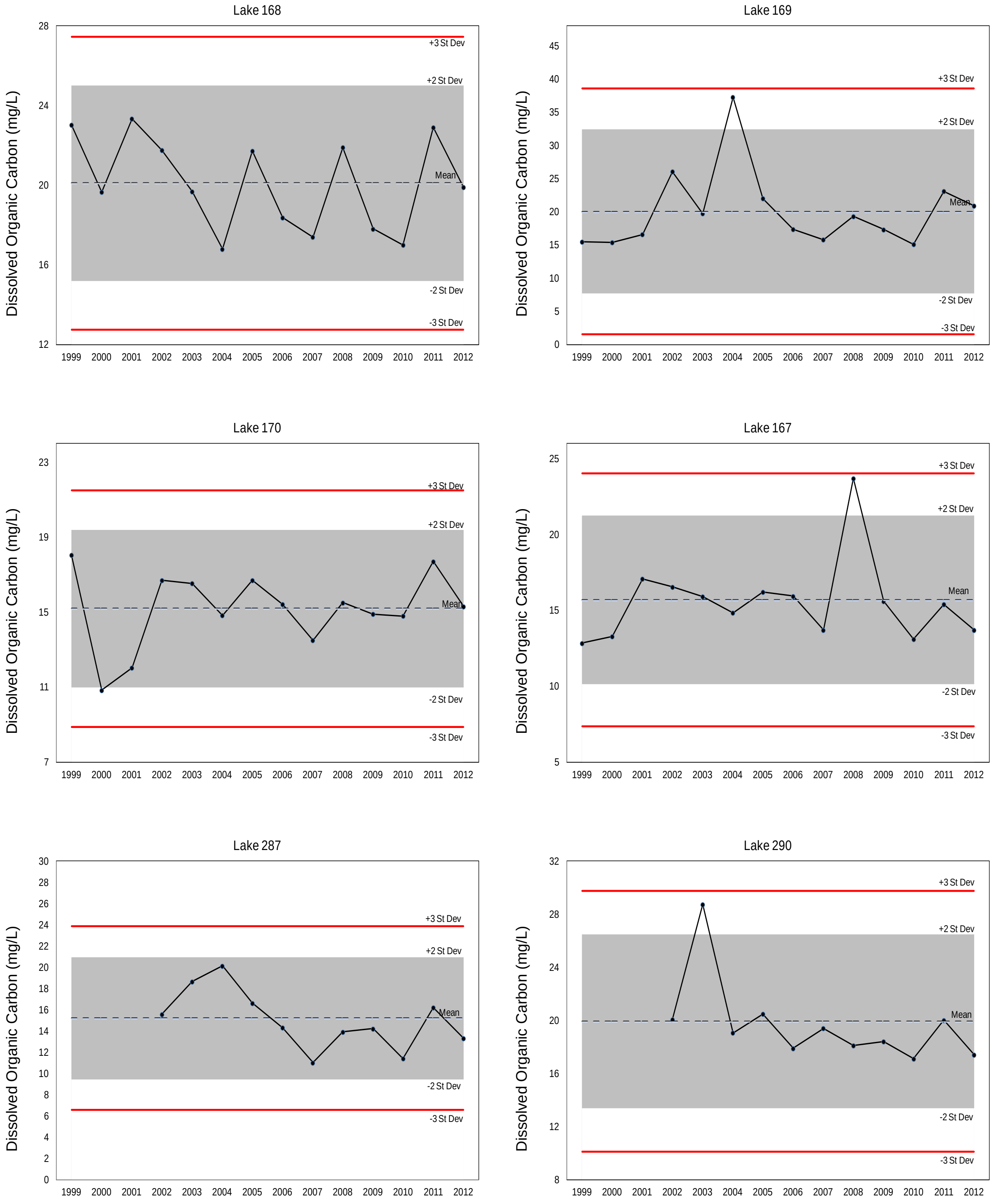
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-5 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-6 Control charts of dissolved organic carbon in ten RAMP acid-sensitive lakes most at risk to acidification.



Lake 168

Lake 169

Lake 170

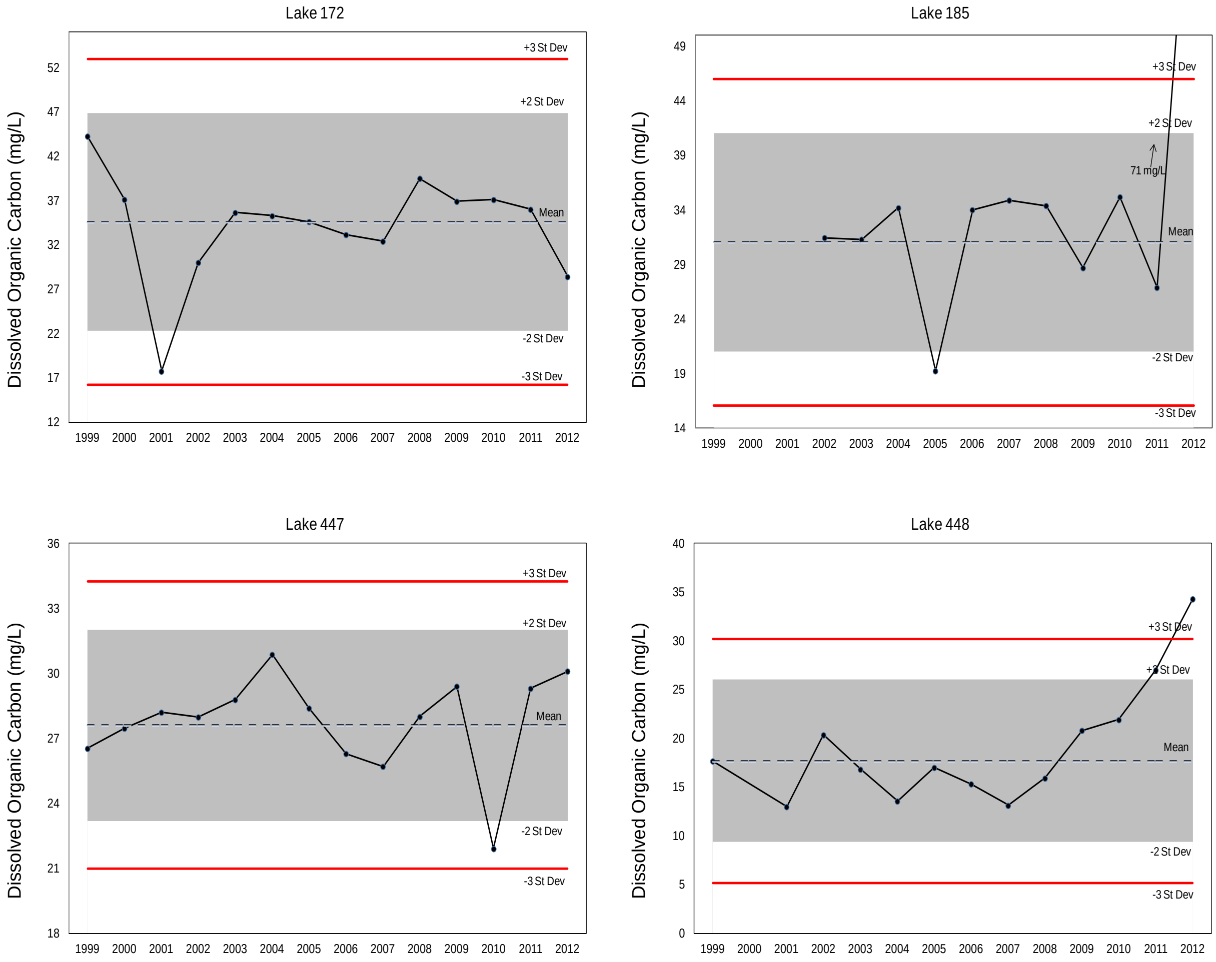
Lake 167

Lake 287

Lake 290

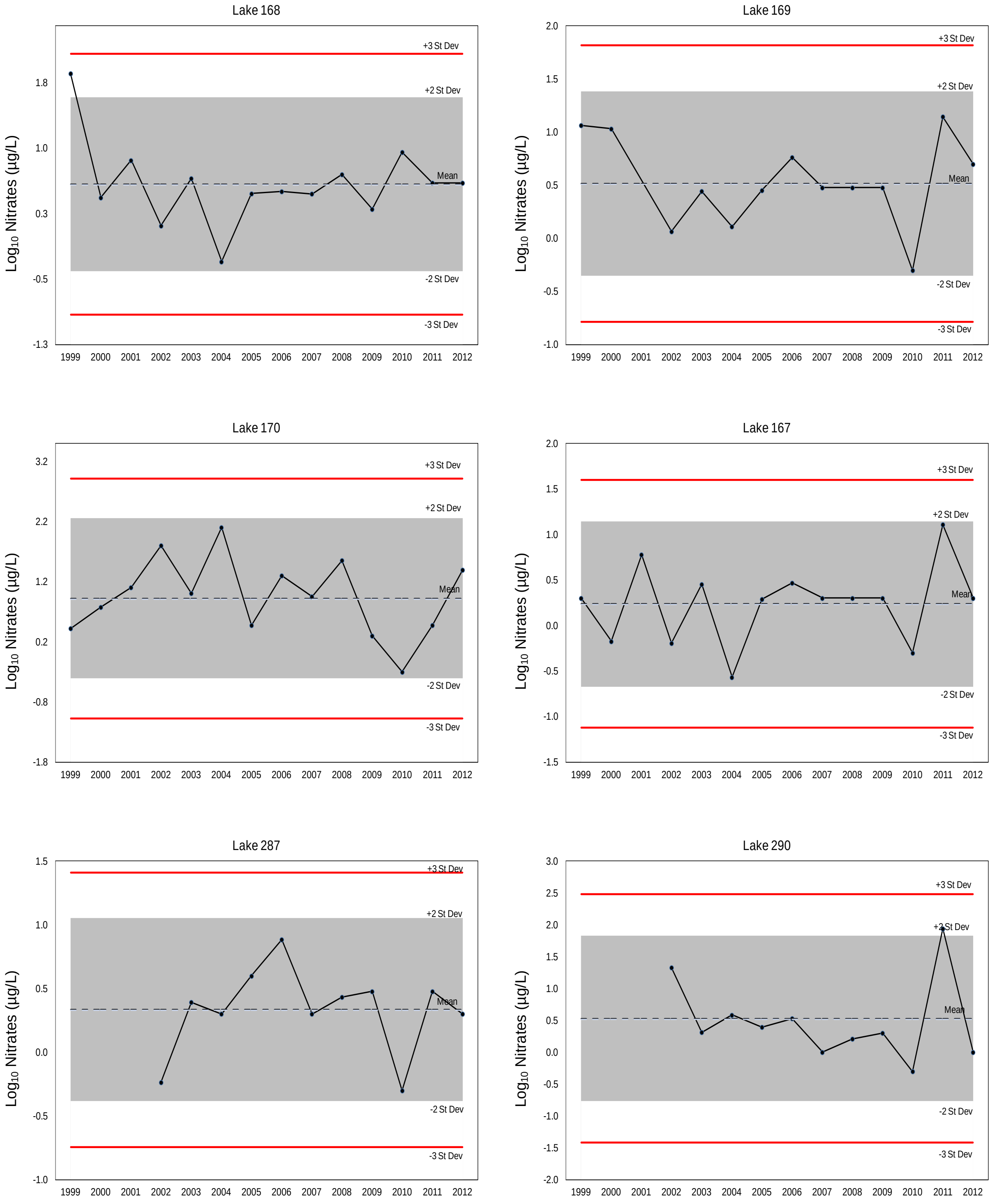
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-6 (Cont’d.)



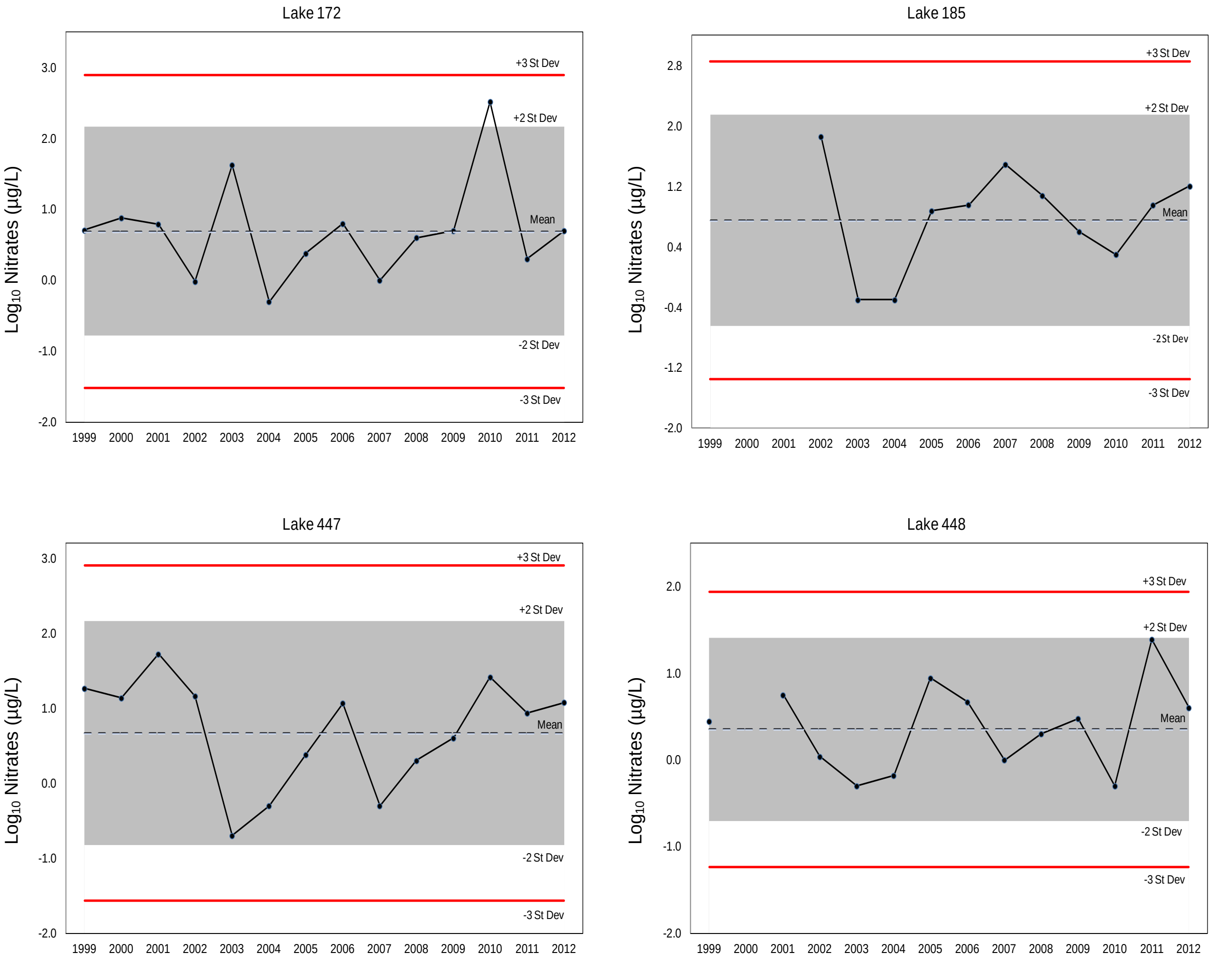
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-7 Control charts of nitrates in ten RAMP acid-sensitive lakes most at risk to acidification.



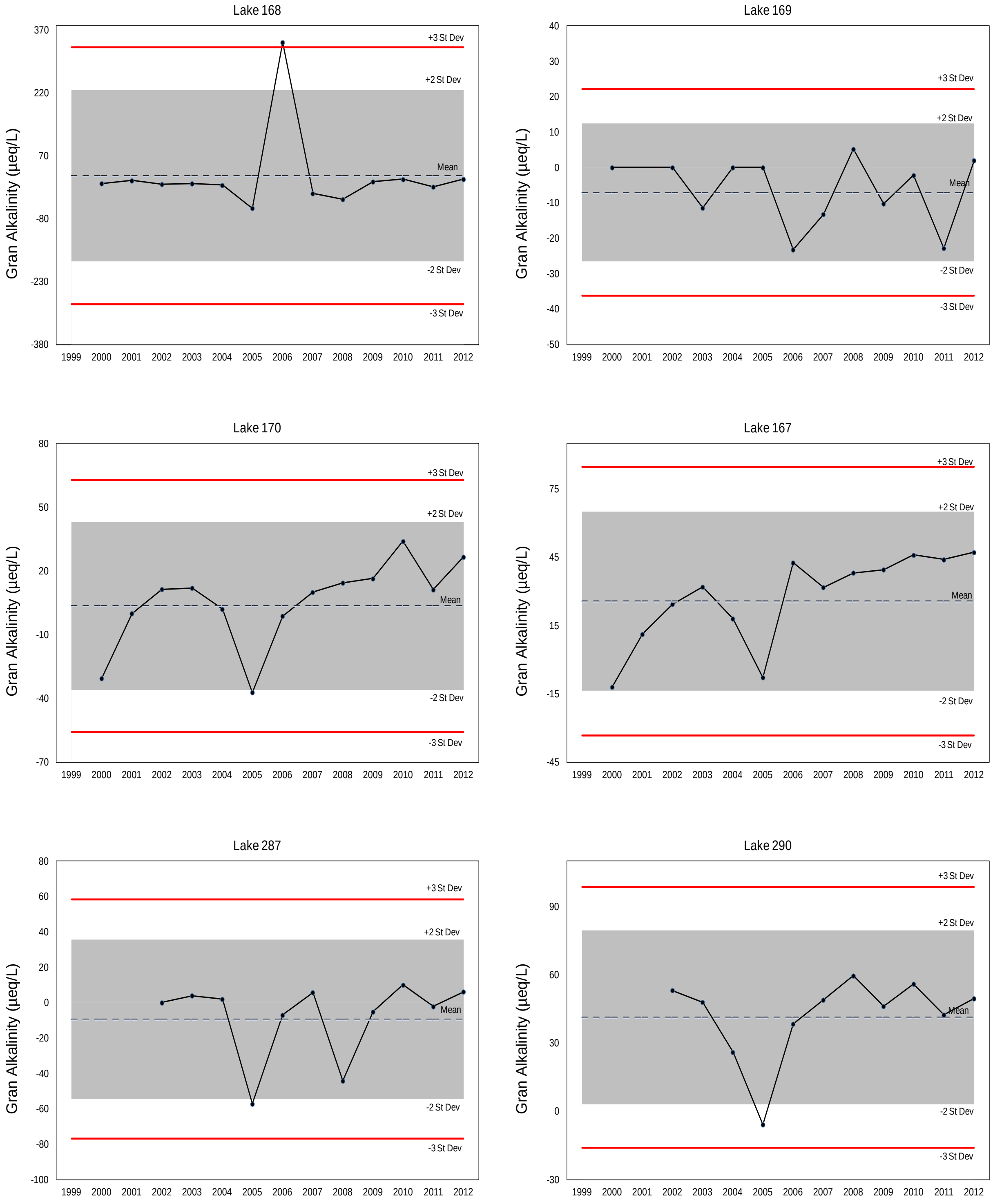
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-7 (Cont'd.)



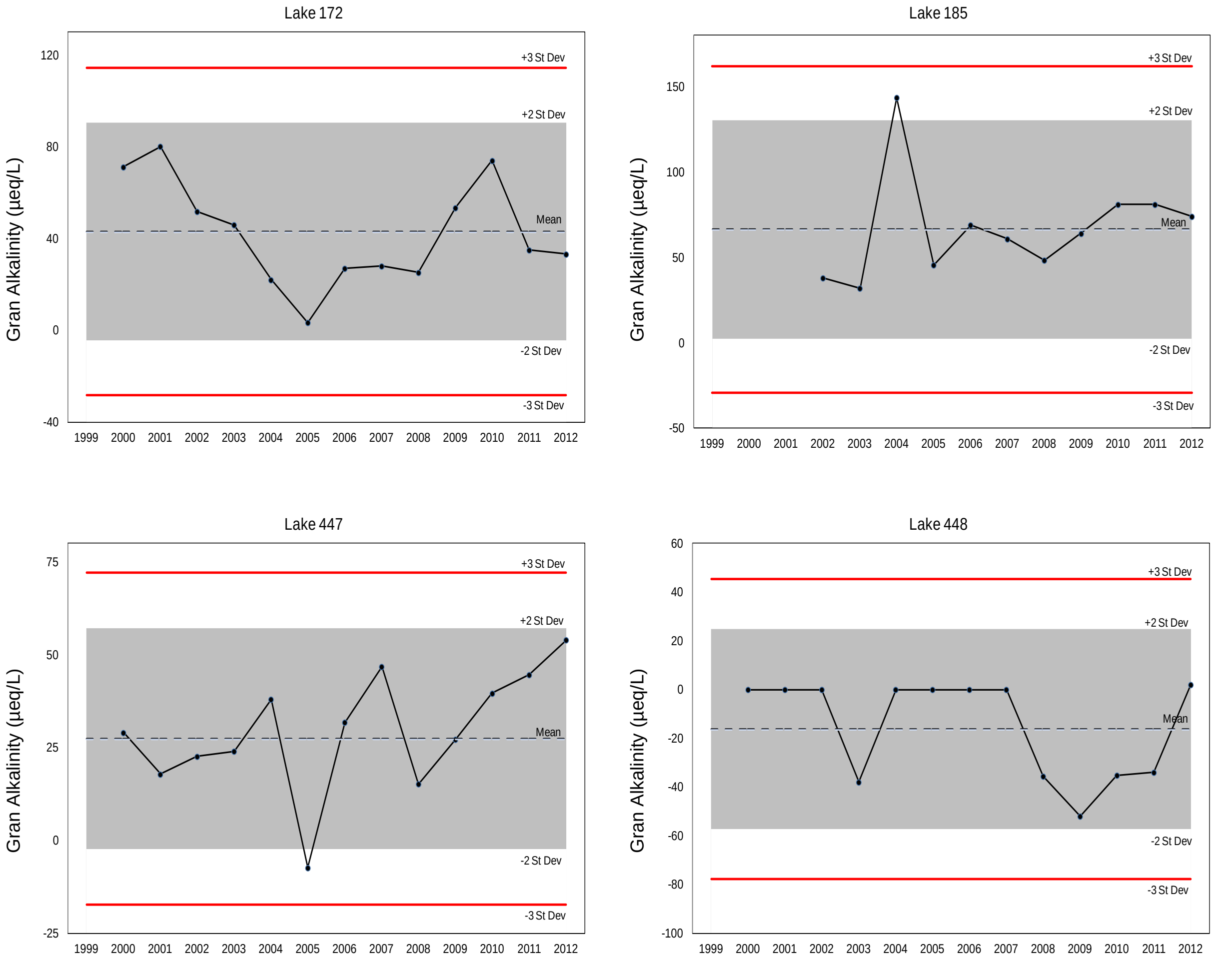
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-8 Control charts of Gran alkalinity in ten RAMP acid-sensitive lakes most at risk to acidification.



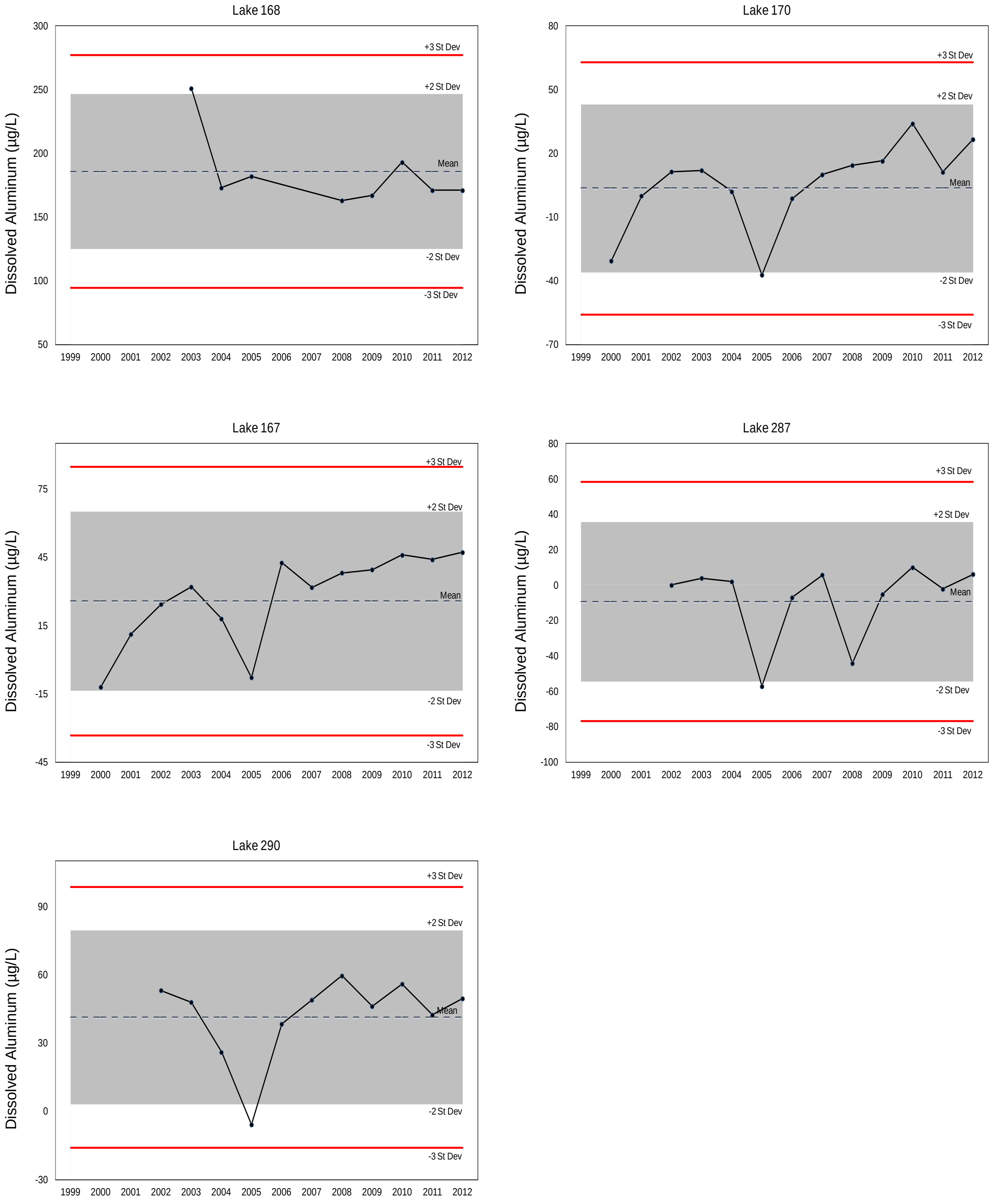
Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-8 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Figure 5.14-9 Control charts of dissolved aluminum in six RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

6.0 SPECIAL STUDIES

This part of the RAMP 2012 Technical Report presents results from special studies that were conducted in 2012, but were not part of the core monitoring program that is described in Section 3. These assessments were conducted to evaluate the feasibility of new approaches to aquatic monitoring, document non-core monitoring activities or to refine current methods used by RAMP.

In 2012, there were four studies conducted by RAMP that were not part of the core monitoring program: a hydrologic survey conducted in winter to verify freezing in small tributaries as part of the Hydrology Component, a *baseline* station reconnaissance survey conducted on the Christina River for all monitoring components, a fish assemblage pilot study conducted in the Athabasca River Delta as part of the Fish Populations component, and a spring acid pulse study as part of the Acid-Sensitive Lakes Component.

6.1 INVESTIGATION OF WINTER DISCHARGE AT SEASONAL HYDROMETRIC STATIONS

6.1.1 Background

The RAMP Climate and Hydrology component provided monitoring for 46 hydrometric stations in 2012. Of these 46 stations, 23 stations were operated year-round, six stations were visited only in the winter to supplement WSC open-water monitoring undertaken by the Water Survey of Canada, and the remaining 17 stations were operated by RAMP only during the open-water season, from April to October. These “open-water only” stations have traditionally been monitored seasonally based on the assumption that winter flow-rates are minimal (in some cases below rates that can be measured) or assumed to be non-existent with channels freezing to depth. In order to test these assumptions, an investigation was conducted to assess winter flow at streams that are currently monitored by RAMP during only the open-water season.

6.1.2 Station Selection and Methods

A combination of variables were used to identify the most likely streams to have measurable flow during winter months, including: pre-winter discharge measurements taken in late October and early November; catchment area of a station; stream size and morphology; knowledge of the station; and observations during spring break-up. Seven streams were selected to investigate for winter flow (Table 6.1-1, Figure 3.1-2). Flow measurements were conducted using standard winter methods and procedures (see Section 3.1.1.2) and were conducted in late February and early March to coincide with the period of minimum winter flow.

Table 6.1-1 Streams and related RAMP hydrometric stations selected to investigate potential flow in winter.

Station ID and Name	End of October 2011 Discharge Measurement (m³/s)	Catchment Area of Station (km²)
S20 Muskeg River Upland	0.010	157
S22 Muskeg Creek near the mouth	0.047	369
S31 Hangingstone Creek at North Star Road	0.226	160
S32 Surmount Creek at Highway 881	0.133	158
S36 McClelland Lake Outlet above the Firebag River	0.384	330
S48 Big Creek near the mouth	0.194	304
S49 Eymundson Creek near the mouth	0.284	243

6.1.3 Results and Discussion

Table 6.1-2 summarizes the estimated discharge of each stream based on manual flow measurements collected in late October-early November 2011 prior to freeze-up and again from measurements collected in winter 2012. Results indicated that five of the seven streams that were investigated had measurable flow in February and March 2012.

Table 6.1-2 Results of winter flow investigation at RAMP seasonal hydrometric stations.

Station ID and Name	October / November 2011 Discharge (m³/s)	Winter 2012 Discharge (m³/s)	Comment
S20 Muskeg River Upland	0.010 (05-Nov-2011)	0.011 (08-Mar-2012)	Water contained slush, low flow velocities measured
S22 Muskeg Creek near the mouth	0.047 (05-Nov-2011)	0.068 (13-Feb-2012)	Small flowing channel
S31 Hangingstone Creek at North Star Road	0.226 (02-Nov-2011)	0.146 (12-Feb-2012)	Channel was open
S32 Surmount Creek at Highway 881	0.133 (02-Nov-2011)	0.120 (12-Feb-2012)	Augured to gain access to flowing water
S36 McClelland Lake Outlet above the Firebag River	0.384 (29-Oct-2011)	0.358 (11-Feb-2012)	Augured to gain access to flowing water
S48 Big Creek near the mouth	0.194 (29-Oct-2011)	No flow (11-Feb-2012)	Channel frozen to depth
S49 Eymundson Creek near the mouth	0.284 (29-Oct-2011)	No flow (11-Feb-2012)	Channel frozen to depth

Variability in winter climatic conditions in the region could result in marked variability in ice thickness and discharge conditions such that results collected in 2012 may not be representative of typical discharge conditions. Based on climate data summarized in Section 4, winter 2011/2012 was warmer than the historical average, although snow depths and snow water equivalents were considered to be average. Consequently, the insulation of the snowpack on the development of ice thickness was similar to previous years, but the warmer temperatures observed in 2012 may have resulted in thinner than average ice thickness and higher than average winter discharges. Given the warmer than average winter in 2012, it is uncertain whether measurable flow will exist at these stations during colder winters. However, it seems unlikely that winter flows exist on Big Creek and Eymundson Creek (stations S48 and S49, respectively) given no flow was measured during better than average conditions in winter 2012.

Based on these findings, the RAMP Climate and Hydrology Technical Subgroup decided that stations S22 Muskeg Creek at Canterra Rd., S31 Hangingstone Creek at North Star Road, and S36 McClelland Lake Outlet above the Firebag River, should be operated year-round. Two stations, S20 Muskeg River Upland and S32 Surmount Creek at Hwy 881, were considered for winter operation, but the decision was made to conduct an additional assessment in winter 2012/2013 and review the operational status with a second year of results. Because no flow was measured at Station S48 on Big Creek and Station S49 on Eymundson Creek in February 2012, RAMP will continue to operate both stations only during the open-water period from late April to late October.

Based on these investigations it was assumed that other stations not selected for this investigation due to their smaller size, would remain as seasonal stations. It is expected that these smaller systems, with flows typically less than those observed at Big Creek and Eymundson Creek, would also freeze to the bottom and/or have no measureable winter flow. It was also decided that new stations that are installed and operated as open-water stations will be tested in the first winter of operation to ensure no measurable winter discharge is present.

6.2 *BASELINE* RECONNAISSANCE SURVEY ON THE CHRISTINA RIVER

In response to increasing RAMP membership and oil sands development in the Christina River watershed, a reconnaissance survey was conducted in September 2012 to identify additional *baseline* monitoring stations on the Christina River upstream of existing and planned development. Six locations along the Christina River were evaluated regarding their similarity to current monitoring reaches on the Christina River, which includes two *test* stations downstream of Christina Lake. To gain an understanding of changes in water quality along the river, six stations, located from upstream of the confluence of Gregoire River to the border of the Stony Mountain Provincial Park were sampled, with the three most upstream stations as candidate *baseline* stations (Figure 6.2-1).

Four criteria were established to determine whether the candidate stations were suitable to incorporate into the Water Quality, Benthic Invertebrate Communities and Sediment Quality, Fish Populations, and Hydrology components of RAMP:

- Similar water quality conditions to current monitoring stations on the Christina River (*test* stations CHR-1 and CHR-2);
- Habitat characteristics that were similar to current monitoring reaches for benthic invertebrates and fish assemblages (*test* reaches CHR-D1/F1 and CHR-D2/F1), which are primarily depositional habitat and in the same location as the water quality stations;
- Suitable conditions to install and operate a hydrology station; and
- Will remain in *baseline* condition for at least three years to acquire adequate *baseline* date prior to an oil sands development.

6.2.1 Methods

Candidate *baseline* stations were selected by reviewing topographical maps of the area (Figure 6.2-1 and Table 6.2-1). Station selection was based primarily on location of current and future development in the Christina River watershed.

Station locations were identified using GPS coordinates. Exact locations were chosen based on the ability to find a good landing spot as all stations were accessed by helicopter. At all water quality stations, in situ measurements of dissolved oxygen (DO), temperature, pH, and conductivity were collected using a handheld pH/conductivity meter (pH, conductivity and temperature) and a LaMotte portable Winkler titration kit (dissolved oxygen). Grab samples were collected following standard RAMP methods previously described in Section 3.1.2 of this report. Samples were analyzed for the RAMP standard variables (Table 3.1-4), with the exception of PAHs.

A quantitative assessment of habitat characteristics were conducted to compare to current benthic and fish assemblage monitoring reaches by collecting measurements of habitat type (i.e., riffle, run, pool), wetted and bankfull width, dominant substrate (%). Photographs of representative habitat conditions were taken at each location (Figure 6.2-2).

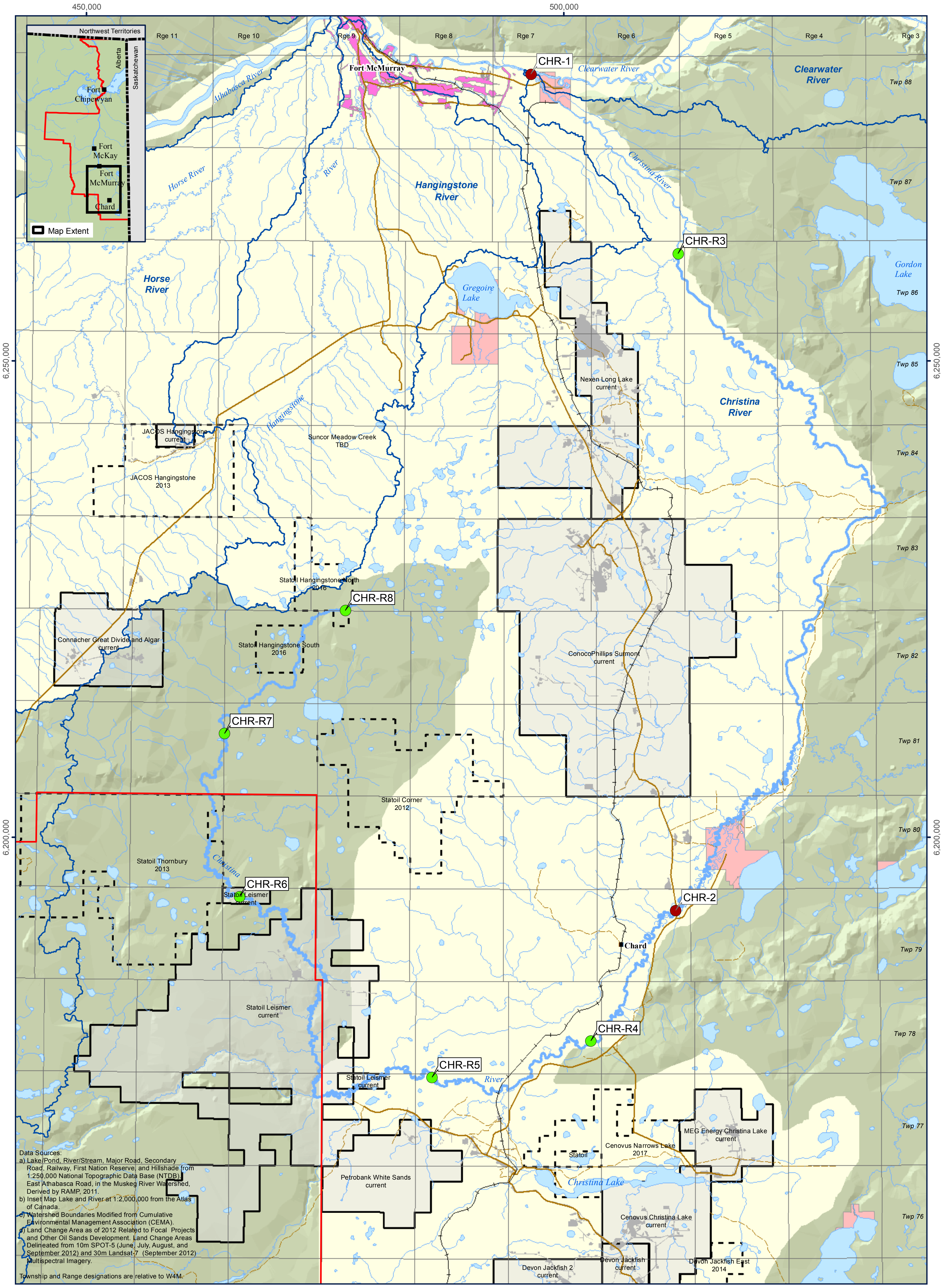
An assessment of suitability for a hydrology station was conducted by collecting information on the following characteristics:

- Evidence of backwater or potential for beaver activity;
- Challenges with installing and operating equipment (i.e., large boulders or debris that would damage equipment and unstable banks), and the likelihood of establishing telemetry capabilities; and
- Adequate spatial coverage on the river to collect appropriate data.

Table 6.2-1 Locations of reconnaissance stations on the Christina River, September 2012.

Station	Station Description	UTM Coordinate (NAD83 Zone 12)	
		Easting	Northing
CHR-1/CHR-D1/ CHR-F1/S47	Current RAMP monitoring station, at the mouth	496563	6280114
CHR-R3	Downstream of Gregoire River confluence	511959	6261307
CHR-2/CHR-D2/ CHR-F2/S29	Current RAMP monitoring station, upstream of Janvier	511752	6192346
CHR-R4	Downstream of Jackfish River confluence	502826	6178669
CHR-R5	Upstream of Jackfish River confluence, below current Statoil operations	486208	6174839
CHR-R6	Upstream of current Statoil operations and downstream of future Statoil development (2013 to 2016)	466037	6193791
CHR-R7	Downstream of future Statoil development (2016)	464447	6210944
CHR-R8	Border of Stony Mountain Provincial Park, upstream of all development	477136	6223834

Figure 6.2-1 Location of *baseline* reconnaissance stations on the Christina River, September 2012.



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 Modified from Cumulative Environmental Management Association (CEMA).
d) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

Legend

Lake/Pond
River/Stream
Watershed Boundary
Major Road
Secondary Road
Railway
First Nations Reserve
RAMP Regional Study Area Boundary
RAMP Focus Study Area
Town of Fort McMurray
Land Change Area as of 2012[d]
● Reconnaissance Survey Monitoring Stations
● Current RAMP Monitoring Stations

0 2.5 5 10 km
N

Scale: 1:400,000
Projection: NAD 1983 UTM Zone 12N

RAMP
Regional Aquatics Monitoring Program

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_U_ChristinaRecon_20130418.mxd

6.2.2 Results

Habitat Conditions

A summary of habitat characteristics are provided in Table 6.2-2. The current Christina River stations (CHR-1 and CHR-2) are both depositional and dominated by sand and silt substrate. Candidate stations CHR-R3 and CHR-R5 were dominated by larger substrate then the other stations. Station CHR-R3 was located in an erosional section of the river and CHR-R5 had both erosional and depositional sections. Stations CHR-R4, CHR-R6, CHR-R7, and CHR-R8 were all depositional runs dominated by sand and silt substrate. The upper section of the river, where stations CHR-R7 and CHR-R8 were located, was a confined, narrow channel, with steep banks and deeper water and generally dissimilar habitat relative to the downstream stations (Figure 6.2-2). Stations CHR-R4 and CHR-R6 had similar channel characteristics to the existing stations and were both easily accessible by helicopter with wide open landing areas.

Water Quality

Water quality results for select analytes measured at the candidate stations on the Christina River are provided in Figure 6.2-3. Several longitudinal changes (i.e., from downstream to upstream on the Christina River) of various analytes were observed, including a decrease in concentrations of TSS, TDS, total strontium, total boron, conductivity, and all ions, with increasing distance from the mouth of the river. Station CHR-1, the most downstream station and existing RAMP monitoring station, had the highest concentrations of many of these analytes while station CHR-2 had concentrations similar to candidate stations located further upstream.

Hydrology

The assessment of hydrologic conditions and the suitability of each location for installation of a hydrology station are summarized in Table 6.2-2. Station CHR-R3 was not an ideal location for a hydrology station given that it is close enough to the current RAMP hydrology station S47 that it may not provide data that are markedly different given the limited spatial distance between these locations. Stations CHR-R4, CHR-R5, and CHR-R6 were assessed as suitable locations given that the river was wide enough that beaver activity would be minimal; the locations had stable banks for installing the hydrology equipment; and river conditions were comparable to those at the lower stations. Additionally, these stations would provide adequate spatial coverage along the course of the Christina River, accounting for inputs to the river from major tributaries and oil sands development. Stations CHR-R7 and CHR-R8 near the headwaters were deemed unsuitable given the river conditions were not similar to downstream stations and the potential for backwater and beaver activity was higher given it was predominantly muskeg habitat, with a narrower river channel that could be more easily spanned by beaver dams.

Figure 6.2-2 **Representative photographs of stations evaluated during the reconnaissance survey on the Christina River, fall 2012.**

RAMP Station CHR-1: Left Downstream Bank

CHR-R3: Right Downstream Bank

RAMP Station CHR-2: Right Downstream Bank

CHR-R4: Left Downstream Bank

CHR-R5: Mid-Channel, facing upstream

CHR-R6: Left Downstream Bank

CHR-R7: Left Downstream Bank

CHR-R8: Right Downstream Bank

Table 6.2-2 Description of habitat characteristics at reconnaissance stations on the Christina River, September 2012.

Station	Wetted Width (m)	Morphology	Substrate	Substrate Type	Suitability for a Hydrology Station
CHR-1	65	Riffle	sand and silt	Depositional	existing station
CHR-R3	40	Riffle	boulder and silt	Erosional	no
CHR-2	35	Run	sand and silt	Depositional	existing station
CHR-R4	35	Run	silt and sand	Depositional	yes
CHR-R5	30	Run	cobble and sand	Erosional\ Depositional	yes
CHR-R6	25	Run	sand and silt	Depositional	yes
CHR-R7	9	Run	silt and sand	Depositional	yes[1]
CHR-R8	8	Run	silt and sand	Depositional	yes[1]

[1] A hydrology station could be installed at stations CHR-R7 and CHR-R8; however, given the narrow channel in theses sections of the river and the muskeg habitat, it is likely that beaver activity will cause backwater effects and poor hydrologic data.

Figure 6.2-3 Concentrations of selected water quality measurements at reconnaissance stations on the Christina River, September 2012.

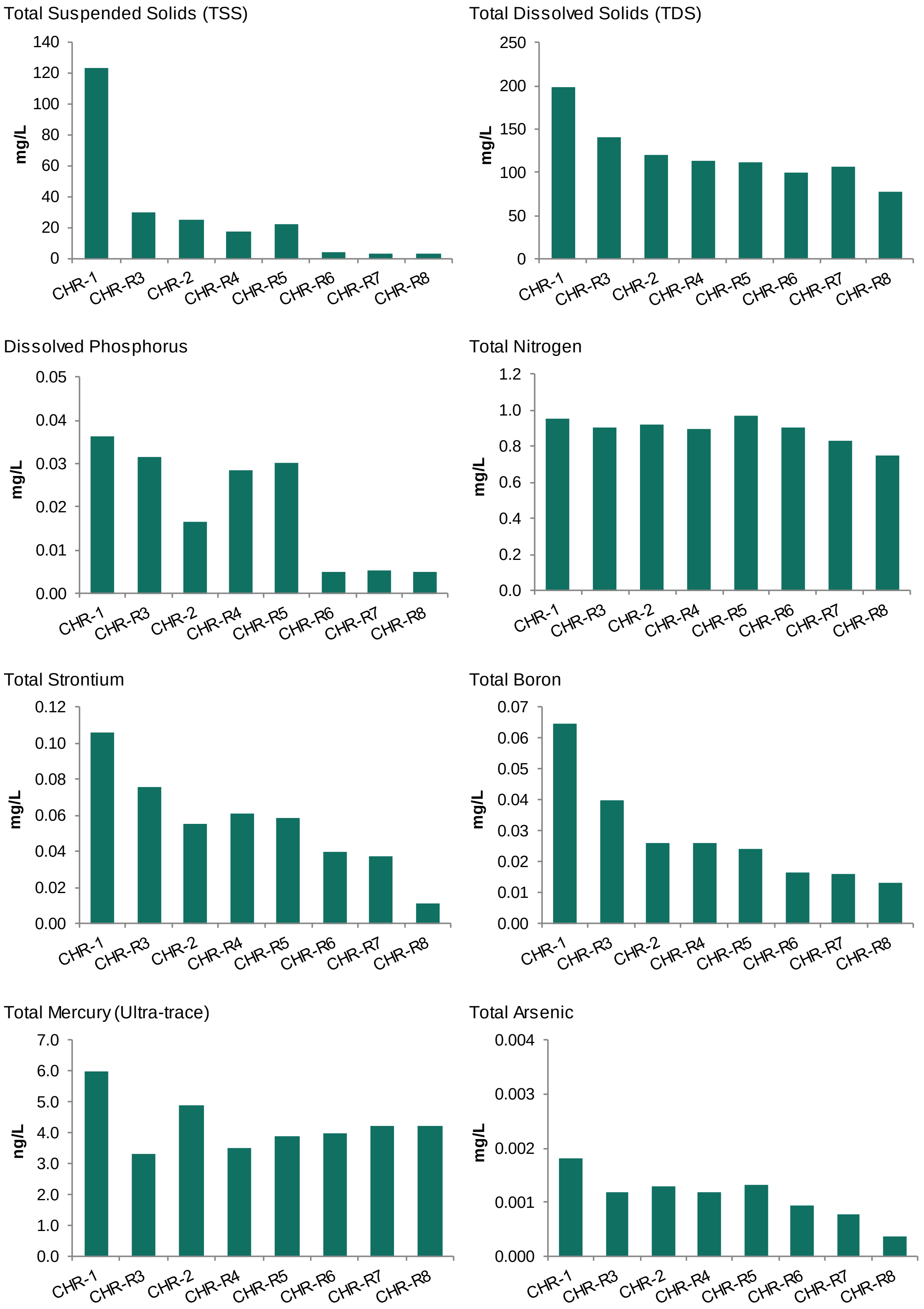
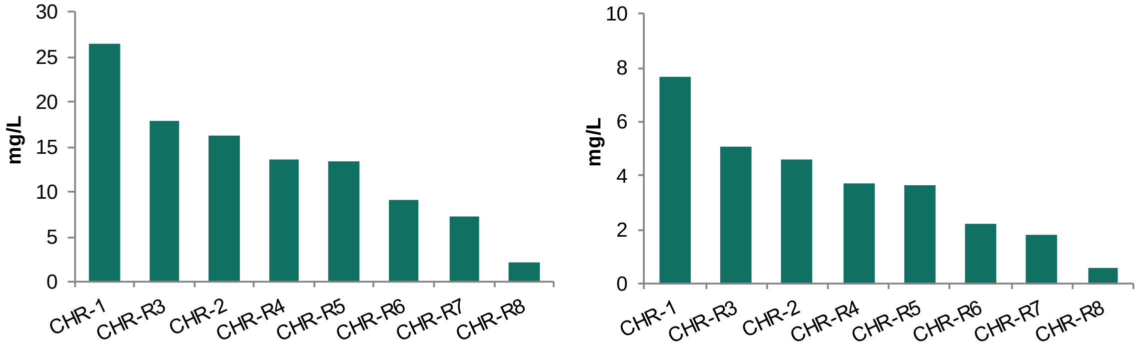
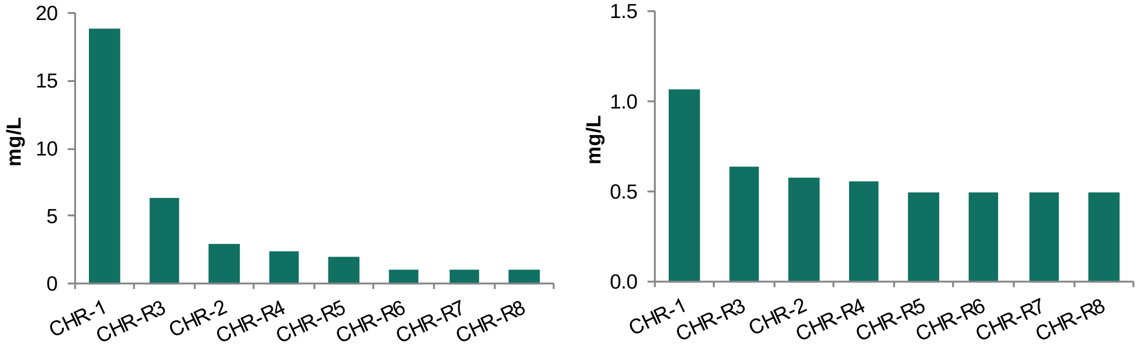


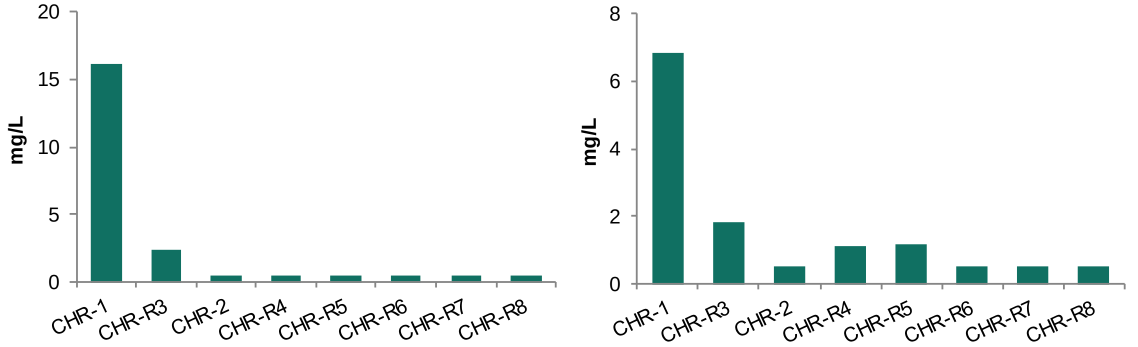
Figure 6.2-3 (Cont'd.)


Calcium

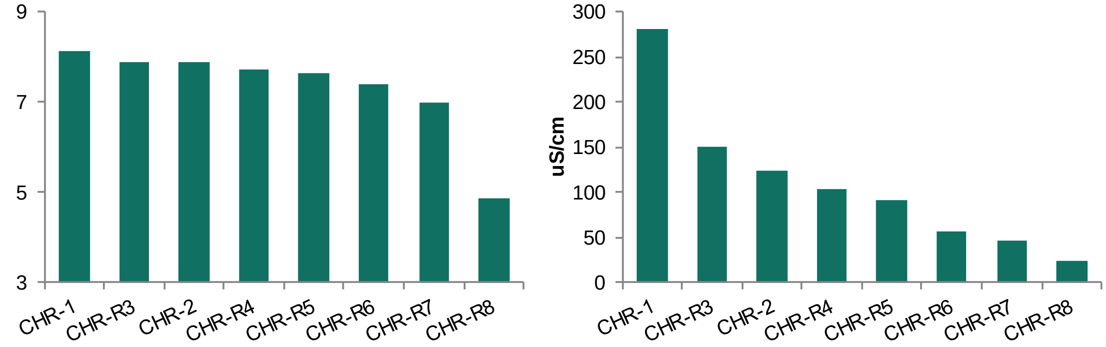
Magnesium


Sodium

Potassium


Chloride

Sulphate


pH

Conductivity

6.2.3 Discussion and Recommendations

Based on the reconnaissance survey conducted on the Christina River in September 2012, stations CHR-R4, CHR-R5, and CHR-R6 were considered to be similar in habitat and channel characteristics to the existing RAMP stations (CHR-1 and CHR-2). Station CHR-R3 was erosional, dominated by boulders, with riffle habitat, which was inconsistent with other stations. Station CHR-R5 also had some erosional characteristics but was predominantly depositional. Stations CHR-R7 and CHR-R8 were both more narrow and had deep incised channels, which was different from the current Christina River stations. Although these stations will remain as *baseline* stations for a longer period of time, they were least similar to the existing stations, with respect to habitat and water quality.

Water quality results for most variables showed decreasing concentrations with distance from the mouth of the river. Conductivity and ion concentrations were much higher at CHR-1 than all other stations. Station CHR-2 had similar water quality to the other stations, particularly CHR-R4, CHR-R5, CHR-R6, and CHR-R7.

Overall, stations CHR-R4 and CHR-R6 were identified as the most appropriate locations for new *baseline* stations for all RAMP components because they have similar habitat characteristics and water quality to the current RAMP monitoring stations, and they are suitable locations to install hydrology equipment. Additionally, station CHR-R6 would remain in *baseline* condition for approximately three to five years prior to planned oil sands development.

6.3 FISH ASSEMBLAGE PILOT STUDY IN THE ATHABASCA RIVER DELTA

In 2012, the RAMP Fish Populations Technical Subgroup decided to expand the tributary fish assemblage monitoring program 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 by the Joint Oil Sands Monitoring Plan (Environment Canada and Government of Alberta, 2012). Fish and fish habitat assessments were conducted in four channels flowing into Lake Athabasca, including the Embarras River, Fletcher Channel, Big Point Channel, and Goose Island Channel.

6.3.1 Methods

Fish and fish habitat assessments were conducted at reaches in the Athabasca River Delta where benthic invertebrate communities and sediment were samples were collected in fall 2012 (Table 6.3-1 and Figure 6.3-1).

Fishing Methods

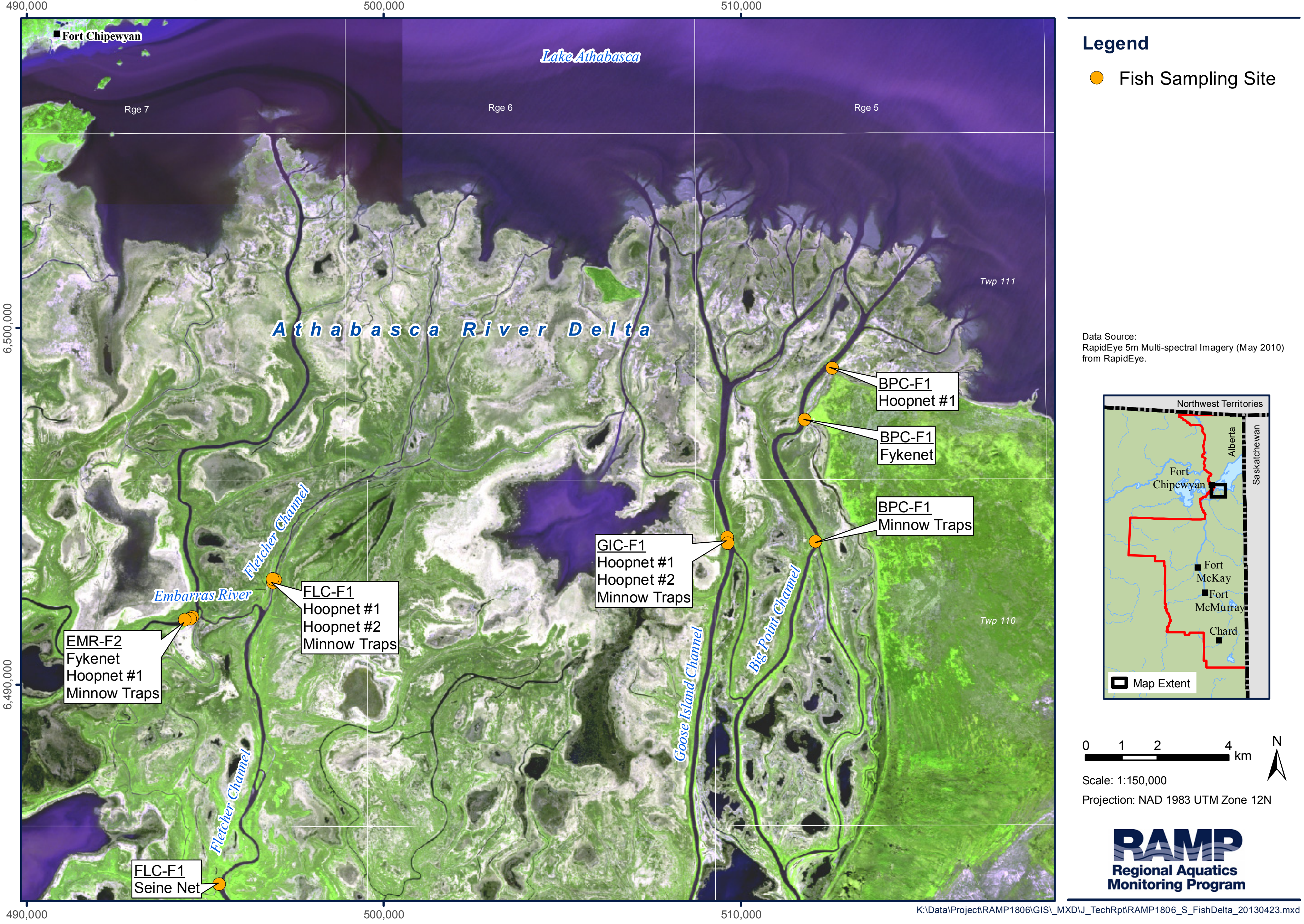
The depth of the channels prevented wading; therefore, non-lethal fish sampling was conducted using a combination of hoop nets and fyke nets for large-bodied fish and minnow traps and seine nets for small-bodied fish, set from the boat. At each channel reach, ten minnow traps, five on each bank of the channel, as well two hoopnets or fyke nets, one facing upstream and one facing downstream, were set along the length of the reach for period of 24 hours. Where water levels were low enough and the substrate was hard enough to allow wading, seining was also completed.

All captured fish were measured for length (± 1 mm) and weight (± 0.01 g) and an external health assessment was conducted on each fish as per methods previously described in Section 3.1.4.1. All fish were released at point of capture.

Table 6.3-1 Reach description and fishing methods used during the fish assemblage monitoring program in the Athabasca River Delta, September 2012.

Watershed	Reach	Habitat Type	Reach Designation	Fishing Method	UTM Coordinates (NAD 83, Zone 12)
Embarras River	EMR-F2	depositional	*test*	fykenet	494640 E / 6491903 N
				hoopnet	494570 E / 6491847 N
				minnow traps (x 10)	494423 E / 6491819 N
Fletcher Channel	FLC-F1	depositional	*test*	hoopnet #1	496931 E / 6492892 N
				hoopnet #2	496895 E / 6492868 N
				minnow traps (x 5)	496962 E / 6492936 N
				minnow traps (x 5)	496880 E / 6492962 N
				seine net	495383 E / 6484408 N
Goose Island Channel	GIC-F1	depositional	*test*	hoopnet #1	509609 E / 6494099 N
				hoopnet #2	509605 E / 6494135 E
				minnow traps (x 10)	509620 E / 6493975 N
Big Point Channel	BPC-F1	depositional	*test*	fykenet	511779 E / 6497444 N
				hoopnet	512560 E / 6498900 N
				minnow traps (x 10)	512078 E / 6494017 N

Figure 6.3-1 Location of reaches in the Athabasca River Delta sampled during the fish assemblage monitoring program, September 2012.



Legend

● Fish Sampling Site

Data Source:
RapidEye 5m Multi-spectral Imagery (May 2010)
from RapidEye.

Scale: 1:150,000

Projection: NAD 1983 UTM Zone 12N

RAMP
Regional Aquatics Monitoring Program

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Fish Habitat

Habitat assessments were completed at one transect in the middle 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 (run, riffle, pool);
- Wetted width (m);
- Maximum depth (m);
- Velocity and depth (m/sec) (at 25%, 50%, and 75% of the wetted width);
- Overhead and instream cover (%);
- Substrate (dominant and subdominant particle size);
- Bank slope (°);
- Bank height (m); and
- Presence of large and small woody debris (count of debris in length/size classes).

In situ water quality variables including temperature (°C), dissolved oxygen (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).

6.3.2 Results

2012 Habitat Conditions

Test reach EMR-F2 was comprised entirely of deep run habitat, with a wetted width of 75 m and a bankfull width of 92 m (Table 6.3-2). The substrate was dominated by silt and sand. Water at *test* reach EMR-F2 was an average of 1.56 m deep, slow flowing (0.10 m/s), alkaline (pH: 8), with moderate conductivity (262 µS/cm), moderate dissolved oxygen (7.0 mg/L), and a temperature of 16.1˚C. Instream cover consisted of small amounts of small woody debris with overhanging vegetation along the banks.

Test reach FLC-F1 was comprised entirely of deep run habitat with silt and sand substrate (Table 6.3-2). Water at *test* reach FLC-F1 was on average of 1.67 m deep, slow flowing (0.17 m/s), alkaline (pH: 8.02), with moderate conductivity (254 µS/cm), moderate dissolved oxygen (7.9 mg/L), and a temperature of 15.4˚C. Instream cover consisted of small amounts of macrophytes, small woody debris, with overhanging vegetation along the banks.

Test reach GIC-F1 was comprised entirely of deep run habitat, with a wetted width of 57 m and a bankfull width of 60 m (Table 6.3-2). The substrate was dominated entirely by silt and sand. Water at *test* reach GIC-F1 was on average of 1.50 m deep, slow flowing (0.20 m/s), alkaline (pH: 8.02), with moderate conductivity (254 µS/cm), moderate dissolved oxygen (8.0 mg/L), and a temperature of 16.2˚C. Instream cover consisted of small amounts of small woody debris, with overhanging vegetation along the banks.

Table 6.3-2 Average habitat characteristics of fish assemblage monitoring reaches of the Athabasca River Delta, September 2012.

Variable	Units	***Test* Reach EMR-F2** **Embarras River**	***Test* Reach FLC-F1** **Fletcher Channel**	***Test* Reach GIC-F1** **Goose Island Channel**	***Test* Reach BPC-F1** **Big Point Channel**
Sample date	-	06-Sept-2012	06-Sept-2012	07-Sept-2012	07-Sept-2012
Habitat type	-	deep run	deep run	deep run	deep run
Maximum depth	m	2	2	2	2
Bankfull channel width	m	92	60	-	190
Wetted channel width	m	75	57	-	185
Substrate					
Dominant	-	Fines	Fines	Fines	Fines
Subdominant	-	Sand	-	-	-
Instream cover					
Dominant	-	macrophytes, small woody debris and overhanging veg	macrophytes, small woody debris large woody debris and overhanging veg	small woody debris and overhanging veg	large woody debris
Subdominant	-	-	-	-	macrophytes, small woody debris, overhanging veg
Field water quality					
Dissolved oxygen	mg/L	7	7.9	8.0	7.8
Conductivity	µS/cm	262	254	254	259
pH	pH units	8	8.02	8.02	7.85
Water temperature	^{0}C	16.1	15.4	16.2	16.6
Water velocity					
Left bank velocity	m/s	0.00	0.20	0.10	0.10
Left bank water depth	m	0.67	2.00	1.50	2.00
Centre of channel velocity	m/s	0.20	0.10	0.20	0.10
Centre of channel water depth	m	2.00	2.00	1.50	2.00
Right bank velocity	m/s	0.10	0.20	0.30	0.30
Right bank water depth	m	2.00	1.00	1.50	2.00
Riparian cover – understory (<5 m)					
Dominant	-	woody shrubs / saplings	woody shrubs / saplings	woody shrubs / saplings	woody shrubs / saplings

Table 6.3-3 Number of fish captured at fish assemblage monitoring reaches of the Athabasca River Delta, September 2012.

Reach	Fishing Method	Species											Total No. fish	Total No. Species
		brook stickleback	emerald shiner	flathead chub	goldeye	longnose sucker	northern pike	spottail shiner	trout-perch	walleye	white sucker	yellow perch		
BPC-F1	fykenet	2	83	-	-	-	1	163	14	-	-	1	**264**	**6**
	hoopnet	-	-	-	-	-	2	-	-	-	-	-	**2**	**1**
	minnow trap	-	-	-	-	-	-	-	7	-	-	-	**7**	**1**
EMR-F2	fykenet	-	-	-	-	-	-	4	1	-	-	-	**5**	**2**
	hoopnet	-	-	-	-	-	-	-		-	-	-	**0**	**0**
	minnow trap	-	-	-	-	-	-	15	1	-	-	-	**16**	**2**
FLC-F1	hoopnet	-	-	-	1	-	-	-	-	-	-	-	**1**	**1**
	seine	-	7	31	-	1	-	45	58	-	1	-	**143**	**6**
	minnow trap	-	-	-	-	-	-	1	-	-	-	-	**1**	**1**
GIC-F1	hoopnet	-	-	-	3	-	-	-	-	1	-	-	**4**	**2**
	minnow trap	-	-	-	-	-	-	-	2	-	-	-	**2**	**1**

Test reach BPC-F1 was comprised entirely of deep run habitat, with a wetted width of 185 m and a bankfull width of 190 m (Table 6.3-2). The substrate was dominated by silt and sand. Water at *test* reach BPC-F1 was an average of 2 m deep, slow flowing (0.20 m/s), alkaline (pH: 7.85), with moderate conductivity (259 µS/cm), moderate dissolved oxygen (7.8 mg/L), and a temperature of 16.6˚C. Instream cover consisted primarily of large woody debris, with small amounts of macrophytes, small woody debris, with overhanging vegetation along the banks.

Fish

A total of 445 fish comprised of 11 fish species were captured across the four channels of the delta. Of the 11 species, there were six small-bodied and five large-bodied fish species captured (Table 6.3-3). Species richness was generally low across reaches, ranging from one to six species, and primarily dominated by trout-perch and spottail shiner at all reaches, with a high number of flathead chub at *test* reach FLC-F1. Spatial comparisons across reaches were not completed given that different gear types were used in each reach. The highest catch was observed in Fletcher Channel (*test* reach FLC-F1) using a seine net and at *test* reach BLC-F1 in Big Point Channel using a fykenet.

6.3.3 Discussion and Recommendations

There have been very few surveys conducted on fish populations in channels of the delta and no catch records exist in the FWMIS database to provide context to the data collected by RAMP in fall 2012. A study 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 RAMP in September 2012. Additional species historically documented in the delta included lake whitefish, mountain whitefish, longnose dace, burbot, and ninespine stickleback. Similar fish species are regularly captured by RAMP during the Athabasca River fish inventory program (see Section 5.1), likely indicating that these fish species still reside in the delta and given the limitations of the fishing methods used in the 2012 survey, were not captured, indicating that the 2012 survey likely did not capture the full fish assemblage nor provided adequate spatial coverage of the sampled channels given the water depth and wetted width. The study completed by AOSERP used a combination of seining, angling, and gill netting (Bond 1980).

With the exception of seining, fykenets, hoopnets, and minnow traps were deployed from the boat given that the steep banks, high water levels, and soft substrate prevented wading into the water to set fishing gear. As a result, it was difficult to set the nets and traps effectively in the channel. Seine netting appeared to be an effective way to sample the littoral zone; however, steep banks and high water levels limited the areas where seining could be done. One area of Fletcher Channel provided suitable conditions; however, the soft substrate still posed some difficulty to pull the seine through the water by wading.

The RAMP tributary fish assemblage monitoring program used backpack electrofishing given that the average depth of each sampling reach was less than one metre. Given that the average depth of the channels in the delta was greater than 1.5 m, backpack electrofishing was not an effective method of fishing. Boat electrofishing was not conducted given the logistical difficulties of transporting an electrofishing boat to the delta from Fort McMurray (i.e., navigating the Athabasca River in fall is often difficult if water levels are low). Gillnetting was another option and would be more effective in capturing large-bodied fish moving through the channels; however, AESRD typically does not allow gillnetting in river habitat given the potential for high mortality rates.

The results of the fall 2012 program indicated that alternative fishing methods would be required to effectively sample the channels of the delta in future monitoring years. Recommendations for future years included:

- If water levels are adequate, an electrofishing boat should be taken to the delta to conduct the sampling. This approach is consistent with methods used for the Athabasca River fish inventory program, and will allow better spatial coverage and increased capture success such that data collected will more accurately represent the fish assemblage present in the delta. Two boats with a crew of six could be used to conduct the sampling; or
- If water levels are too low, RAMP will discuss with AESRD the possibility of using gillnets in the channels, and checking the nets frequently (i.e., every two hours) to minimize mortality rates.

The RAMP Fish Populations Subgroup will determine the most appropriate means to conduct a fish assemblage monitoring program in fall 2013 dependent on the river conditions.

6.4 SPRING ACID PULSE STUDY

6.4.1 Introduction

Management of acidic deposition on regional water bodies is a goal of the regional sustainable development strategy for the Athabasca oil sands (AENV 1999a). The Acid Sensitive Lake (ASL) component of the Regional Aquatic Monitoring Program (RAMP) routinely monitors 50 regional lakes for variations in chemistry that would indicate chronic acidification of the lakes and their catchments.

The ASL program under RAMP was not set up to detect episodic acidification (acid pulse) during the spring snow melt. A spring acid pulse can occur when snow, laden with sulphates and nitrates from industrial emissions that have accumulated in winter, is flushed into streams and lakes during spring runoff. The result of this phenomenon is an episodic decline in Acid Neutralizing Capacity (ANC) or buffering capacity and pH. This decline in pH and accompanying release of metals has been implicated in fish mortality.

In 2012, RAMP initiated a study of the spring acid pulse in lakes within the oil sands region. The objectives of the study were:

- undertake a brief literature review of relevant studies of spring acid pulse to provide context for the current study;
- to determine whether a distinct acid pulse occurs during the spring melt;
- to quantify the magnitude of acid pulse; and
- to determine whether the source of acid pulse is natural (base cation dilution or organic acids release) or anthropogenic (nitrates and sulphates deposited in the snowpack).

6.4.2 Background

A spring acid pulse can occur in streams and lakes during the spring melt when meltwaters are released to the stream or lake over a short period of time. The phenomenon has been reported in several regions of the world (Johannessen et al. 1980, Jeffries and Snyder 1981, Tranter et al. 1987, 1994, Davies et al. 1992, Wigington et al. 1992, 1996a,b, Laudon et al. 1999). Recent analysis in the northeastern USA suggests that acid pulses are likely to be much more widespread than chronic acidification (Lawrence 2002).

A spring acid pulse can be caused by several factors including base cation dilution, release of mineral acids (sulphates and nitrates stored in the snowpack), deposition of chloride (primarily of marine origin), and the release of organic acids from the soil. Base cation dilution, chloride deposition, and organic acid release are natural phenomena, while sulphate and nitrate release are typically the result of acidic deposition from anthropogenic sources (Molot et al. 1989, Laudon et al. 1999, Bishop et al. 2000).

Studies on spring acid pulse typically deal with declines in ANC and pH in affected streams and lakes. The most significant cause of episodic ANC decline is base cation dilution, which accounts for a large fraction (>50%) of the ANC decline (Molot et al. 1989, Wigington et al. 1996a,b, Sullivan 2000, Laudon et al. 1999). Hydrological episodes such as a spring melt entail rapid water flow through upper soil horizons. Under these flow conditions, dilute water that is low in base cation concentrations (ANC) discharge to the stream. The effect is measurable in the stream as a decrease in ANC. A decline in ANC does not necessarily produce acidity but will leave the stream water more susceptible to decreases in pH if strong acids are also introduced during the runoff episode.

Spring snowmelt can also act to flush nitrates and sulphates deposited in the snowpack from atmospheric deposition or mineralized in the forest floor or soil in winter, into lakes and streams. In studies from northern Europe and the northeastern United States, nitrates were identified as the principal mineral acid anion responsible for decreases in pH while sulphates remained relatively constant during hydrographic episodes (Galloway et al. 1980, Jeffries 1990, Sullivan 2000). However, other studies have shown that sulphates are the primary acidifying agent. For example, sulphate was the dominant ion responsible for the ANC decline in streams in central Ontario (Molot et al. 1989). A study of 13 streams in the northern Appalachian mountains of Pennsylvania, the Catskills, and the Adirondack mountains for USEPA’s Episodic Response Project (ERP) found that streams in the Catskill and Adirondack mountains had large episodic pulses of nitrates, while steams in Pennsylvania experienced high episodic pulses of sulphate (Wigington et al. 1996a,b).

Altered hydrological flow during melt episodes may also cause increased concentrations of organic acids in a stream because the upper soil horizons tend to be relatively rich in organic carbon. The fraction of ANC depression caused by organic acid enrichment varies among regions and watersheds and has been related to the degree of wetland coverage of the drainage basin. Campbell et al. (1992) demonstrated that the acid pulse of three salmon rivers on the northshore of Quebec during spring snowmelt resulted mainly from increased inputs of organic acids rather than mineral acids. In the ERP streams studied by Wigington et al. (1996a,b), organic acid pulses were important in the Adirondack streams but not in the streams from the Catskills and northern Appalachian mountains of Pennsylvania. Kortelainen and Saukkonen (1995) found that organic acids and base cation dilution explained 67 to 83% of the variation in pH in headwater streams in Finland.

Using a Boreal Dilution Model (BDM) to partition ANC changes during each spring melt episode, Laudon et al. (1999), and Bishop et al. (2000), determined that a pH decline from 6.4 to 4.6 in headwater streams from northern Sweden was driven almost exclusively by organic acids originating from the soil. Despite a significant decline in ANC, anthropogenic deposition of sulphate and nitrates made only small (5 to 8%) contributions to the ANC and pH decline.

The BDM has been used extensively to study the relative effects of base cation dilution, organic ions, and anthropogenic mineral acids (sulphate and nitrates), in both melt and rain events in northern Sweden (Laudon et al. 2000, Lauden et al. 2001, Laudon and Hemond 2002, Laudon and Bishop 2002), Nova Scotia (Laudon et al. 2002), Ontario (Laudon et al. 2004), and Maine (Laudon and Norton 2010). In a number of these studies, the anthropogenic fraction of the ANC decline during runoff events correlated positively to sulphates deposited in the snow. This correlation was used to examine the success of current regimes of emissions reduction (Laudon and Hemond 2002, Laudon et al. 2002, Laudon et al. 2004, Kline et al. 2007).

In addition to decreases in ANC in spring, streams subject to acid pulses commonly exhibit elevated concentrations of aluminum during snowmelt; either a result of ion exchange processes in near-surface soil horizons or desorption from the bottom substrate of the stream. Monomeric aluminum can reach levels toxic to fish (Henriksen et al. 1984, Baker et al. 1996, Wigington et al. 1996a,b). Henriksen et al. (1984) found levels of monomeric aluminum increased from 0 to 50 μg/L during a pH decline from 5.9 to 5.1 in the River Vikedal of southwestern Norway. Wigington et al. (1996a,b) found aluminum concentrations as high as 485 μg/L in four Adirondack streams during melt episodes. In the three salmon rivers from the northshore of Quebec, aluminum attained levels of 49 μg/L (Campbell et al. 1992), although toxic effects were not observed. In a more recent study of the West Bear catchment in Maine, dissolved aluminum attained levels higher than 567 μg/L during spring melt (Reinhardt et al. 2004).

There are many hydraulic, climatic, edaphic, and physical factors which affect the nature of the snowpack and the spring acid pulse. These factors interact in a complicated manner making each stream and melt season unique. Some of these factors include the following:

- Many studies have reported a differential fractionation or elution of ions from the snowpack in which a large percentage of the ions are lost at the beginning of the major melt period (Jeffries and Semkin 1983, Johannessen and Henriksen 1978, Tranter et al. 1985, Stottlemyer and Toczydlowski 1990). Johannes et al. (1980) reported a small loss in total water content in the initial melt (21 to 35%), but relatively high losses of major ions (sulphates: 66 to 83%, H^+: 40 to 52%, nitrates: 50 to 61%). Jeffries (1990) found that early meltwaters in snow lysimeters were up to ten times more concentrated in major ions than the bulk parent snowpack. These observations are consistent with Colbeck (1981), which describes how solutes concentrate on the surface of ice crystals during alternating melting and freezing periods in winter and subsequently wash out during the early spring melt. In contrast to these studies, Jeffries et al. (1979) found that the largest loads of acidity occurred at the highest discharge rates in outlet streams from three central Ontario shield streams, which was also found in three salmon streams in Quebec (Campbell et al. 1992).

- Topographic and vegetative factors influence the depositional pattern of acidifying substances within a drainage basin. Johannes et al. (1980) noted significant heterogeneity in snowpack storage of major ions within a drainage basin, with less storage occurring in snow located under tree cover.

- The response of the stream to episodic events is greatly dependent on the amount and type of overburden (soil cover) within the catchment. Thinner mineral soils have lower pH depression and more rapid stream response to ion removal from the snowpack. Thicker mineral soils have greater opportunity for chemical alteration of meltwater (e.g., through neutralization and ion exchange). Chemical alteration of water in its path to the stream is also a function of the permeability of the underlying soil, water input rates, and flow path. If the underlying soil is impermeable (e.g., thin soils or absent soils), overland flow will occur and the water reaching a stream will resemble the meltwater in the snowpack. Under these conditions, concentration peaks of major ions will typically precede hydrographic peaks (Jeffries 1990). Freezing can also affect soil permeability, and the degree of freezing in a particular year may depend on the weather conditions prior to initial snowfall.

- Boreal streams can show considerable heterogeneity in chemistry and spatial variability during the spring flood acid pulse. Ishi et al. (2008) found the highest spring flood pH in larger, lower altitude catchments underlain by fine sorted soils; and the lowest pH in small, higher altitude catchments for a Swedish boreal stream, with a mixture of peat wetlands and forested till.

- Various mesostructural characteristics of the snowpack (e.g., density layers, pipeflow around organic material, and ice layers) can lead to heterogeneous meltwater flow patterns (Jones 1984).

- Rain facilitates movement of materials through the snowpack by supplying both heat and liquid; therefore, the differential release of ions is strongly influenced by rain. Rainfall inputs during the snowmelt can account for a large proportion (up to 50%) of the solute flux leaving the snowpack (Jeffries 1990).

6.4.2.1 Effects of Acid Pulse on Aquatic Biota

The effects of snowmelt-induced changes in surface water chemistry on aquatic biota have been well documented. Episodic fish kills of salmonids in western Norwegian rivers were noted in the late 1970s and early 1980s (Leivestad and Muniz 1976, Henricksen et al. 1984). The fish kills were attributed to increased concentrations of monomeric aluminum during episodes of low pH (Baker and Schofield 1982). In Canada, Harvey and Whelpdale (1986) demonstrated that snowmelt runoff in south-central Ontario caused fish mortality. In the northeastern United States, Stansley and Cooper (1990) reported the loss of an entire year-class of rainbow trout following a short-term pH depression in a New Jersey stream. As part of the USEPA's ERP, Baker et al. (1996) studied the effects of acid pulses on fish in 13 streams in the northeastern United States including the Adirondack region of New York. Study streams with moderate to severe acidification during high flow events demonstrated greater fish mortality in bioassays, a net downstream movement of brook trout, and lower brook trout densities compared to non-acidifying streams. In general, trout abundance was reduced and acid sensitive fish species were eliminated in streams with a pH between 5.0 and 5.2 and an inorganic aluminum concentration greater than 100 to 200 μg/L during high flow events. Madarish and Kimmel (2000) reported lower densities of macroinvertebrates at acid pulse stations in a Pennsylvania stream.

6.4.2.2 Evidence of a Spring Acid Pulse in Alberta

The most relevant studies on spring acid pulse in the oil sands region were conducted by Alberta Environment and Sustainable Resource Development (AESRD) on three streams near major oil sands developments and on ten of the RAMP lakes.

AESRD conducted a stream study between 1989 and 2001 on three rivers east of the Athabasca River (i.e., Steepbank, Firebag, and Muskeg rivers) in which datasonde probes were deployed to measure pH, conductivity, and temperature during the spring melt (WRS 2003). The data consisted of very frequent recordings of conductivity, pH, and temperature, as well as weekly analyses of total alkalinity, sulphate, nitrates, dissolved organic carbon (DOC), chloride, base cations, and aluminum. River discharge data were collected from the confluence of each river with the Athabasca River.

The study indicated a very pronounced decline in conductivity and ANC in all three rivers during the spring melt, with decreases in ANC as large as 5,000 μeq/L on the Steepbank River. However, the pattern of the spring melt was very different among years. In some years (e.g., 1989), there was a gradual decline in conductivity, ANC, and base cations that preceded a significant increase in flow by days or weeks. Rapid declines in conductivity and peaks in H^+ concentration coincided with distinct hydrological events (rapid increases in flow). Peaks of H^+ concentration represented decreases in pH that averaged 0.63. As the baseflow pH and buffering capacity of the rivers were relatively high, these decreases in pH did not represent a significant threat to aquatic organisms. Sulphate and nitrate levels in the three rivers dropped dramatically during the melt season. Normalized for dilution by meltwaters, nitrate declined while sulphate increased gradually across the entire melt season. DOC increased during the melt, with peaks often associated with peaks in H^+ concentration and peak aluminum release roughly coincided with peak flow.

The ANC declines in the Steepbank and Firebag rivers during 1999 and 2001 were partitioned into contributing factors by using two models: one described by Molot et al. (1989), and the Boreal Dilution Model (BDM) described by Laudon et al. (1999). The factors affecting the ANC declines included base cation dilution, sulphate loading, nitrate loading, chloride loading, and organic acid loadings. Most (>90%) of the ANC decline was attributed to dilution by meltwaters. Unlike other regions (e.g., northeastern United States), nitrate loading in the Steepbank, Firebag, and Muskeg rivers was not a significant factor in the decline of ANC. In fact, decreases in nitrate over the melt cycle contributed to the ANC in all cases. The effects of sulphate loading on ANC decline were small but measurable and accounted for 0.8% to 4.5% of the decrease in ANC. Generally, the contribution of sulphate to the ANC decline was less than 1% and occurred late in the melt season when sulphate reached its maximum value.

Organic acids of natural origin accounted for 1.4 to 6.5% of the decline in ANC from baseflow conditions. The decline in ANC due to organic acids was always greater than that attributed to sulphate. The peaks in H^+ and DOC in the time-concentration tracings suggests that strong organic acids rather than sulphates, are the primary cause of the small peaks in H^+ and depressions in pH observed during periods of rapid melt. Many of these decreases in pH occurred early in the melt before increases in sulphate were noted. These findings, including the major role of organic acids and base cation dilution (rather than sulphates or nitrates) in melt episodes, are similar to those reported by Laudon et al. (1999, 2001) and Bishop et al. (2000) in Swedish boreal streams.

6.4.2.3 Seasonal Water Quality in Ten RAMP Lakes

Water quality in ten of the RAMP lakes sampled for the Acid-Sensitive Lakes (ASL) component, was analyzed seasonally (winter, spring, summer, fall) for five years (March 2004 to August 2008). The study was carried out in order to determine if the water quality sampling program conducted in fall for the ASL component was adequate to characterize lake chemistry and to detect acidifying trends. The study presented relevant information on chemical variations during the spring melt and is described in detail in RAMP (2009a). Given that the lakes were very shallow (generally less than 1.5 m), a large proportion of the water column froze in winter, and large variations in lake chemistry were observed between winter and spring. Chemical variations included increases in pH as great as 2.3 and decreases in Gran alkalinity as high as 5,000 µeq/L. In most lakes, the lowest pH was observed in winter. The highest levels of Gran alkalinity, DOC, sulphate, and major ions (including base cations) were also observed in winter due to the concentrating effect that occurred during freezing. The results from the seasonal sampling program suggested that a small decrease in pH and Gran alkalinity attributed to an acid pulse would be largely masked by the large changes in chemistry (including the increase in pH and decrease in Gran alkalinity) associated with the recovery of the lake from its winter state.

6.4.3 Methods

The 2012 RAMP spring acid pulse study in the oil sands region involved two distinct tasks:

1. A field study to examine the acid pulse in one representative lake; and
2. Re-examination of the AESRD seasonal water quality data on ten RAMP lakes between 2004 and 2008 (RAMP 2009a), to study the chemical changes associated with the melt episodes recorded in these data. Given that these lakes were scattered throughout the oil sands region and cover a wide range of lake types, they provide a broad regional perspective on the acid pulse phenomenon.

6.4.3.1 Field Collections in Rat Lake

The acid pulse phenomenon was examined in detail in spring 2012 on Rat Lake, located on the Nexen Long Lake lease (Figure 6.4-1). This lake was selected for the following reasons:

- Rat Lake is a headwater lake with a well-defined drainage basin and no secondary lakes to modify potential effects of a spring acid pulse;
- Rat Lake has a defined outlet, which can be monitored for changing lake chemistry;
- Historical data were already available on Rat Lake from studies conducted by Nexen; and
- Rat Lake is easily accessible by truck or all-terrain vehicle (ATV).

The field study consisted of two parts:

- deployment of a datasonde to record changes in pH, conductivity, dissolved oxygen, and temperature throughout the melt; and
- weekly collection of water quality samples (grab samples).

The progress and timing of the spring melt event in Rat Lake was determined from discharge data recorded on the upper Gregoire River (Nexen station GGR-2; Figure 6.4-1). The magnitude and timing of major runoff events were deduced from precipitation and temperature data collected at a nearby weather station at Sucker Lake (provided by Nexen) (Figure 6.4-1).

Continuous Water Quality Monitoring

A YSI 6600 series datasonde was placed in the outflow stream of Rat Lake on April 17, 2012, to obtain measurements of temperature (ºC), pH, dissolved oxygen (mg/L), and conductivity (µS/cm) at half-hour intervals throughout the spring melt. A channel was cut through the ice allowing the steel and coaxial cables to rest on the sediments; thereby preventing the ice from carrying the probe downstream during the melt (Figure 6.4-2). The datasonde was deployed at a water depth of approximately 1 m. The datasonde was removed, recalibrated, and the data downloaded concurrently with the dates of the discrete water quality sampling. The datasonde was removed on May 25, 2012.

Representative photos of the datasonde deployment are provided in Figure 6.4-2.

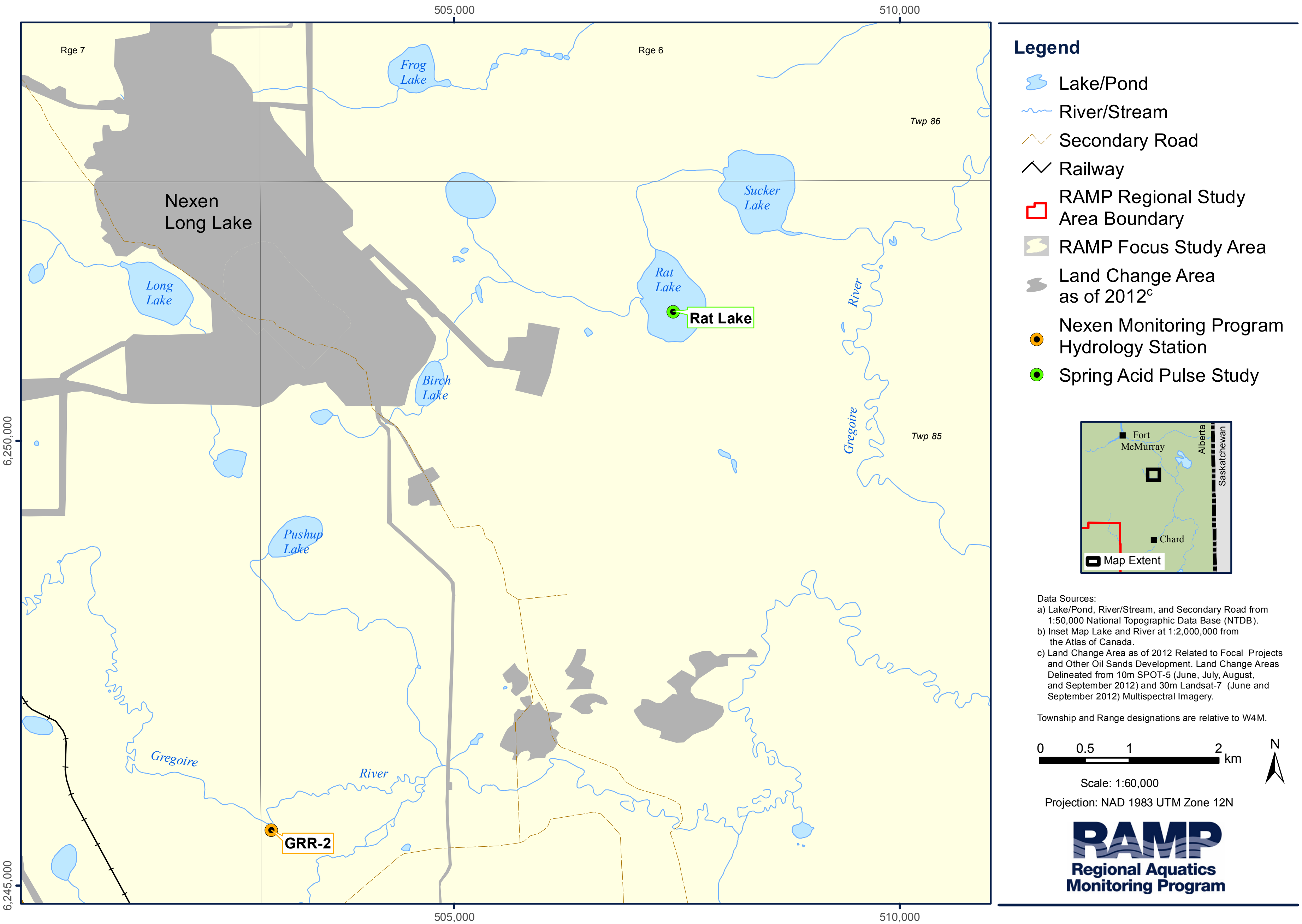
Discrete Water Quality Monitoring

Analytical water quality sampling was conducted on March 5, April 17, April 27, May 2, May 9, May 15, and May 25, 2012 by collecting grab samples through a hole drilled in the ice using a gas-powered auger. Field measurements of pH, conductivity (µS/cm), and oxygen (mg/L) were taken through the ice using a YSI 5600 meter, calibrated according to the manufacturer's instructions. The samples were kept cool (<4 ˚C) and shipped to Maxxam Analytical Laboratories in Fort McMurray where they were analyzed for conventional variables, major ions, and total and dissolved metals (Table 6.4-1).

Table 6.4-1 Water quality variables measured in Rat Lake.

pH	Bicarbonate	Total/Dissolved Boron	Total/Dissolved Sulphur
Alkalinity	Dissolved Chloride	Total/Dissolved Calcium	Total/Dissolved Antimony
Gran alkalinity	Dissolved Sulphate	Total/Dissolved Cadmium	Total/Dissolved Selenium
Conductivity	Nitrate plus Nitrite	Total/Dissolved Cobalt	Total/Dissolved Silicon
Total Dissolved Solids	Dissolved Nitrate	Total/Dissolved Chromium	Total/Dissolved Tin
Hardness	Dissolved Nitrite	Total/Dissolve Copper	Total/Dissolved Strontium
Dissolved Hardness	Dissolved Nitrate	Total/Dissolved Iron	Total/Dissolved Thallium
Dissolved Sodium	Dissolved Nitrite	Total/Dissolved Potassium	Total/Dissolved Titanium
Dissolved Potassium	Dissolved Organic Carbon	Total/Dissolved Lithium	Total/Dissolved Uranium
Dissolved Calcium	Total Hardness	Total/Diss. Magnesium	Total/Dissolved Vanadium
Dissolved Magnesium	Total Aluminum	Total/Diss. Manganese	Total/Dissolved Zinc
Dissolved Manganese	Total Arsenic	Total/Diss. Molybdenum	Total/Dissolved Zirconium
Dissolved Iron	Total Barium	Total/Dissolved Sodium	
Dissolved Silicon	Total Beryllium	Total/Dissolved Nickel	
Dissolved Aluminum	Total Bismuth	Total/Dissolved Lead	

Figure 6.4-1 Location of the spring acid pulse study, Rat Lake, 2012.



Data Sources:
a) Lake/Pond, River/Stream, and Secondary Road from 1:50,000 National Topographic Data Base (NTDB).
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Land Change Area as of 2012 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (June, July, August, and September 2012) and 30m Landsat-7 (June and September 2012) Multispectral Imagery.

Township and Range designations are relative to W4M.

Scale: 1:60,000

Projection: NAD 1983 UTM Zone 12N

K:\Data\Project\RAMP1806\GIS_MXD\J_TechRpt\RAMP1806_T_ASL_AcidPulse_20130402.mxd

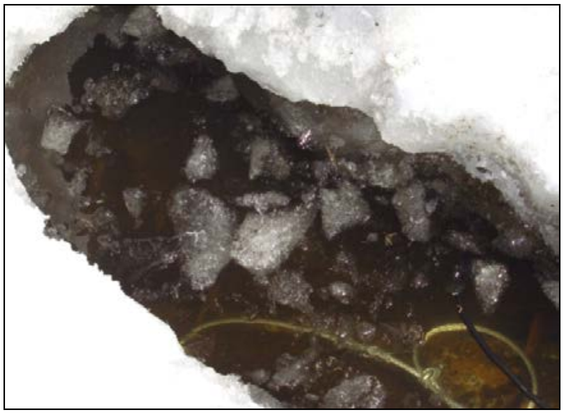
Figure 6.4-2 **Representative photographs of water quality sampling and datasonde deployment in Rat Lake, winter and spring 2012.**

Water quality sampling in Rat Lake, March 4, 2012

Water quality sampling in Rat Lake, April 15, 2012

Digging the trench for datasonde deployment in Rat Lake outlet, April 16, 2012

Datasonde cable attachment, Rat Lake outlet, April 16, 2012



Datasonde in Rat Lake outlet, April 16, 2012

Ice melt in the littoral zone of Rat Lake, May 2, 2012

6.4.3.2 Datasonde Analysis

Datasonde data were presented graphically to assess trends in temperature, oxygen, conductivity, pH, and hydrogen ion concentration. The data were smoothed to present daily variability in these variables by finding the average value for each day. The values of the field measurements taken on the days when analytical water sampling was conducted were also included in the graphs.

The effect of dilution by snowmelt water on release of H^+ and DOC at the outlet stream of Rat Lake was determined by normalizing the concentrations of these variables by the conductivity (datasonde) or the sum of the base cations (analytical). Peaks or declines in these variables once normalized were assumed to indicate changes in the net loading of these variables to the outlet stream from the lake once accounting for dilution. Similar techniques were used by Campbell et al. (1992), Laudon et al. (1999), Bishop et al. (2000), and WRS (2003).

6.4.3.3 ANC Partitioning

In order to determine the source of the ANC decline during the spring runoff, the observed ANC decline at each discrete sampling date was partitioned between base cation dilution and release of strong inorganic acids (SO_4^{2-}, Cl^-, and NO_3^-) and organic acids during the snowmelt. ANC partitioning was determined using the ANC dilution model (ADM) derived from the BDM of Laudon et al. (1999), Bishop et al. (2000), Laudon and Hemond (2002), Laudon et al. (2004), and Laudon and Norton (2010).

The ADM was designed specifically to determine the relative importance of base cation dilution and the individual strong acids in the ANC decline during spring snowmelt. The method utilized the charge balance definition of ANC and was calculated using the following equation (Stumm and Morgan 1981, Munson and Guerini 1993):

$$\text{ANC} = [\text{SBC}] - [\text{SO}_4^{2-}] - [\text{CL}^-] - [\text{NO}_3^-] - [\text{A*}]$$

where,

SBC is the sum of the base cation concentrations (calcium, magnesium, potassium and sodium); and

A* is the concentration of strong organic acids expressed as the relationship between A* and DOC where, [A*] = 5* DOC (mg/L) (Cantrell et al. 1990).

The validity of the ANC and A* equations were determined by plotting the calculated ANC vs. Gran alkalinity. The Gran alkalinity is a laboratory measure of the ANC that should be very close to the calculated charge balance ANC. Plotting the calculated ANC vs. the Gran alkalinity provides a test of the assumptions of the ADM methodology.

In the ADM, the change in ANC attributed to dilution alone was calculated using the following equation:

$$\Delta\text{ANC}_{\text{dil}}\ (t) = \text{ANC}_{\text{baseflow}} * \text{DI}\ (t)$$

where,

$\text{ANC}_{\text{baseflow}}$ is the ANC at the time before the melt has started; and

DI (t) is the dilution ratio at time (t), calculated on a hydraulically conservative variable as $\text{SBC}(t)/\text{SBC}_{\text{baseflow}}$.

The combined effects of dilution and an individual strong acid on the ANC decline (excluding the contributions from the remaining strong acids) were calculated, for the case of SO_4, using the following equation:

$$\Delta ANC_{dil\ +SO4}\ (t) = (SBC_{basefllow} - NO_3^-{}_{baseflow} - Cl^-{}_{baseflow} - A^*{}_{baseflow}) * DI(t) – SO_4^{2-}(t)$$

The individual ANC decline attributed to SO_4 during the episode was then calculated using the equation:

$$\Delta ANC_{SO4}(t) = ANC_{dil\ +SO4}\ (t) - ANC_{dil}\ (t)$$

Similar relationships were derived for NO_3^-, Cl^-, and A*. The combined effect of all driving mechanisms on the total ANC decline was calculated from the equation:

$$\Delta ANC_{\ total}\ (t) = \Delta ANC_{dil}\ (t) + \Delta ANC_{SO4}(t) + \Delta ANC_{NO3}(t) + \Delta ANC_{CL}(t) + \Delta ANC_{A^*}(t)$$

The anthropogenic effect on ANC (ΔANC_{anth}) was calculated as:

$$\Delta ANC_{anth} = \Delta ANC_{SO4}(t) + \Delta ANC_{NO3}(t)$$

The ADM model makes the following assumptions:

- baseflow ANC and pH have not been affected by anthropogenic acidification;
- observed dilution of a specific, conservative constituent of the runoff (sum of base cations) is directly proportional to the dilution of all components; and
- anthropogenic influences have not affected the amount and character of the DOC in the lake.

6.4.3.4 ANC Partitioning Analysis of Seasonal Water Quality Data

A total of 28 spring melting episodes from significant decreases in base cation content were identified in ten RAMP lakes (Table 6.4-2, RAMP 2009a). Each melting episode was analyzed using methods described in Section 6.4.3.3, where changes in ANC were partitioned between the various factors (base cation dilution, sulphates, nitrates, chloride, and organic acids). Changes in ANC were presented in tabular and graphical format.

Table 6.4-2 Spring melt episodes identified from the AESRD Seasonal Study on ten RAMP lakes[1].

Lake ID	Episode			Lake ID	Episode		
166/SM7	23-Mar-04	to	18-Jun-04	199/BM11	13-Apr-06	to	13-Jun-06
166/SM7	07-Apr-05	to	26-May-05	199/BM11	04-Apr-07	to	22-May-07
166/SM7	13-May-06	to	13-Jun-06	223/WF4	24-Mar-04	to	17-Jun-04
169/SM9	23-Mar-04	to	18-Jun-04	223/WF4	08-Apr-05	to	26-May-05
169/SM9	07-Apr-05	to	26-May-05	223/WF4	04-Apr-07	to	22-May-07
169/SM9	13-Apr-06	to	13-Jun-06	271/NE10	24-Mar-04	to	18-Jun-04
169/SM9	22-May-07	to	25-Jun-07	271/NE10	07-Apr-05	to	26-May-05
175/BM10	24-Mar-04	to	17-Jun-04	287/SM8	08-Apr-05	to	26-May-05
175/BM10	13-Apr-06	to	13-May-06	287/SM8	13-Apr-06	to	13-Jun-06
175/BM10	04-Apr-07	to	22-May-07	418/Kearl	08-Apr-05	to	26-May-05
185/NE7	08-Apr-05	to	26-May-05	448/BM7	23-Mar-04	to	17-Jun-04
185/NE7	04-Apr-07	to	22-May-07	448/BM7	07-Apr-05	to	26-May-05
199/BM11	24-Mar-04	to	17-Jun-04	448/BM7	13-Apr-06	to	13-Jun-06
199/BM11	08-Apr-05	to	26-May-05	448/BM7	04-Apr-07	to	22-May-07

[1] The location of these lakes can be found in RAMP (2009a; Section 3).

6.4.4 Results

6.4.4.1 Habitat Conditions of Rat Lake

Rat Lake is a small, brown water (humic) lake located on the Nexen Long Lake lease (Figure 6.4-1). The lake has an area of 54 ha and a drainage basin of approximately 300 ha. The drainage basin is composed of woody or shrub fens dominated by black spruce (*Picea mariana*) and tamarack (*Larix larcina*). The lake is quite shallow and was only 1 m deep at the sampling location, approximately 200 m from shore. The bottom sediments were comprised of silt and clay. At the time of the initial sampling on March 5, the ice was 60 to 70 cm thick. Consistent with observations from other regional lakes, a large proportion of Rat Lake freezes during the winter and dissolved variables are concentrated in the remaining water. Anoxic conditions (i.e., low dissolved oxygen) were observed at this time.

The historical data for Rat Lake indicated that lake water was alkaline (spring pH=8.15), highly coloured with a DOC of 24.7 mg/L (spring value), and relatively high alkalinity (spring alkalinity=1,650 μeq/L; Appendix F). The ionic composition was dominated by calcium and magnesium bicarbonates.

6.4.4.2 Climate and Hydrology

In 2012, the mean daily air temperature increased slowly from late February to July (Figure 6.4-3). Air temperature was above zero degrees occasionally after March 11 and consistently after April 19, 2012. Precipitation events in winter were infrequent and the total accumulation was 20.1 mm of snow in January and 6.1 mm of snow in February. At the time of the first sampling event on March 5, there was very little snow left on the ground. Precipitation increased in March (38.4 mm), April (54.1 mm), and May (66.8 mm). Major precipitation events occurred on March 12, April 4, April 13, May 19, and June 18, 2012, and coincided with rapid increases in air temperature.

Daily flow data from the upper Gregoire River (Nexen station GRR-2; Figure 6.4-1) indicated that a baseflow of approximately 0.5 m^3/s occurred throughout the winter months until March 17 when the flow began increasing following the major precipitation event on March 12, 2012 (Figure 6.4-4). Flow continued to increase in response to the additional rainfall/snowfall events in March and early April. A large peak in flow on April 14 was associated with a precipitation/melt event, with 23.4 mm of precipitation recorded over two days. Flow then decreased until June. The response in flow from precipitation on April 13 and 14 was much greater than the larger precipitation event that occurred on June 18, 2012. The reduced flow response in June suggested that the runoff to Rat Lake was mediated by the soils, which had thawed by this time.

The monthly flow rates observed on the Gregoire River in 2012 were relatively consistent with the average values observed in the previous five to seven years (Figure 6.4-5) suggesting that the runoff between January and July 2012 was similar to previous years.

Figure 6.4-3 Daily mean air temperature and precipitation recorded at Sucker Lake climate station.

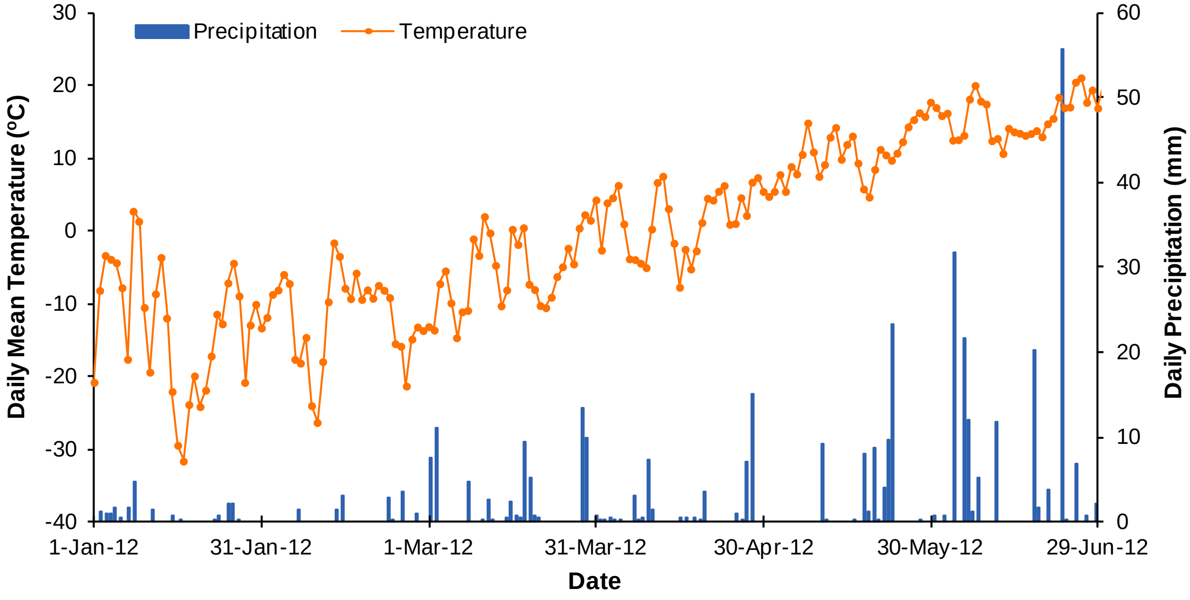


Figure 6.4-4 Discharge measured at the upper Gregoire River (Nexen station GRR-2, Hatfield 2013, provisional data).

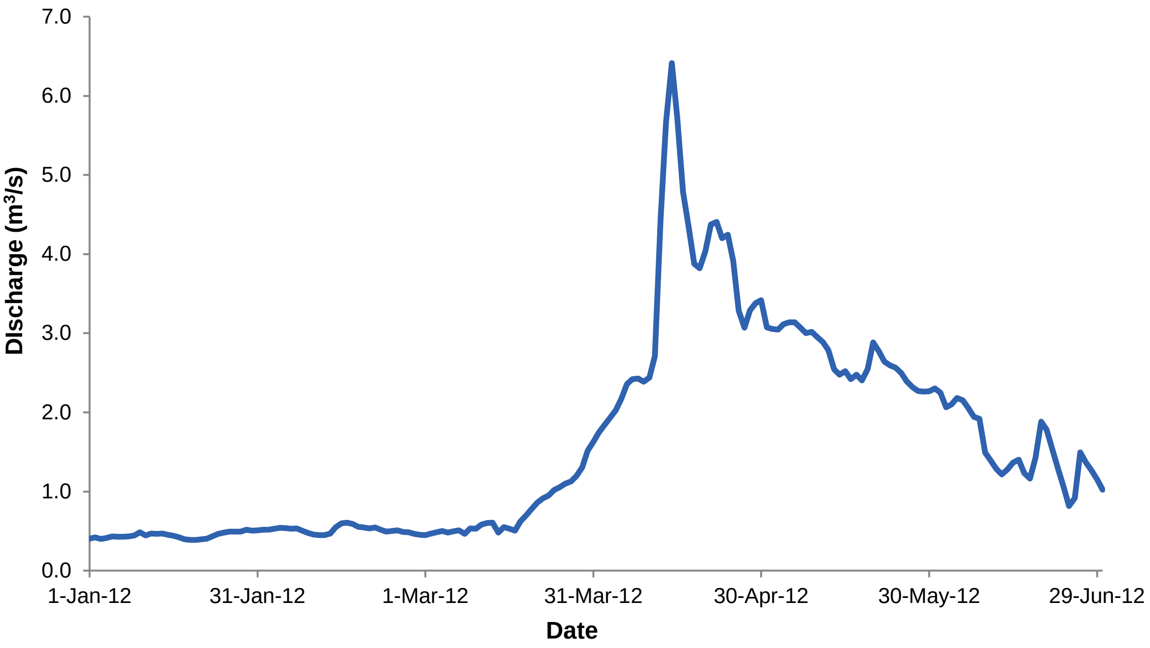
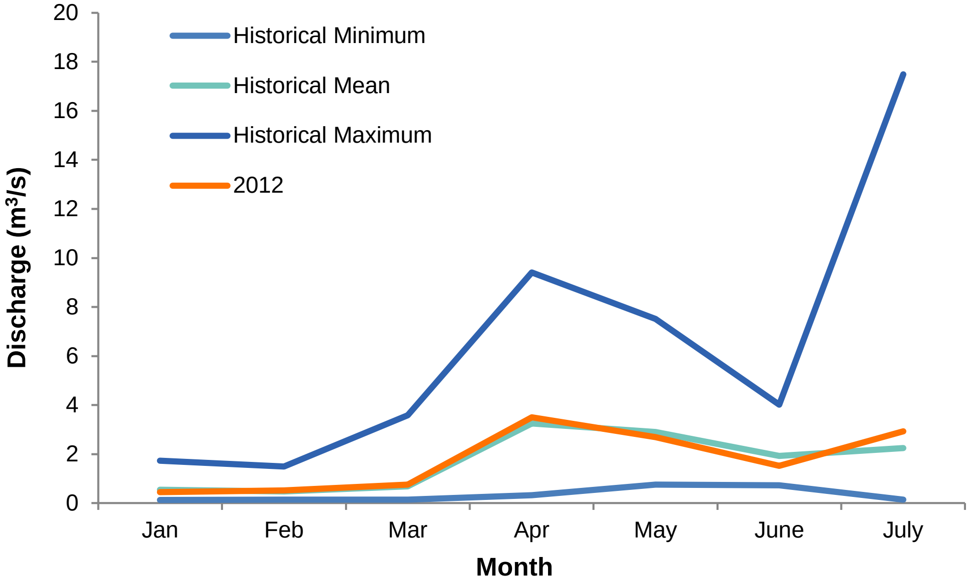


Figure 6.4-5 Mean monthly discharge of the Gregoire River (Nexen station GRR-2, Hatfield 2013, provisional data) from January to July 2012, compared to historical values.



Note: Data provided by Nexen.

6.4.4.3 Water Quality in Rat Lake

Datasonde data are presented as daily averages in Figure 6.4-6 and Figure 6.4-7. When comparing the datasonde data to the field measurements taken during discrete water quality sampling, the datasonde data suggested that certain probes were sitting in the sediments, resulting in unreliable readings for the initial period of data collection (Figure 6.4-6, Figure 6.4-7). A summary of the continuous water quality results were as follows:

- Water temperature increased almost linearly across the spring melt from near-zero to approximately 14.5˚C. Diurnal fluctuations in temperature were observed and increased in magnitude as the melt progressed. At the end of the melt, diurnal fluctuations in temperature were as large as 6˚C;

- Dissolved oxygen was very low (approximately 1 mg/L) in the early stages of the spring melt, but quickly increased during ice break-up at the outlet; an increase in dissolved oxygen was also observed in the field measurements on April 27, 2012 when open water was first observed at the outlet, although the lake itself was still under ice. Later in the melt, large diurnal fluctuations in dissolved oxygen were evident, presumably in response to increasing rates of phytoplankton photosynthesis. During daylight hours photosynthesis releases oxygen, which is consumed in respiration during the night;

- Conductivity decreased during the melt due to meltwater runoff from the land or melting surface ice on the lake and dilution of the concentrated waters beneath the ice;

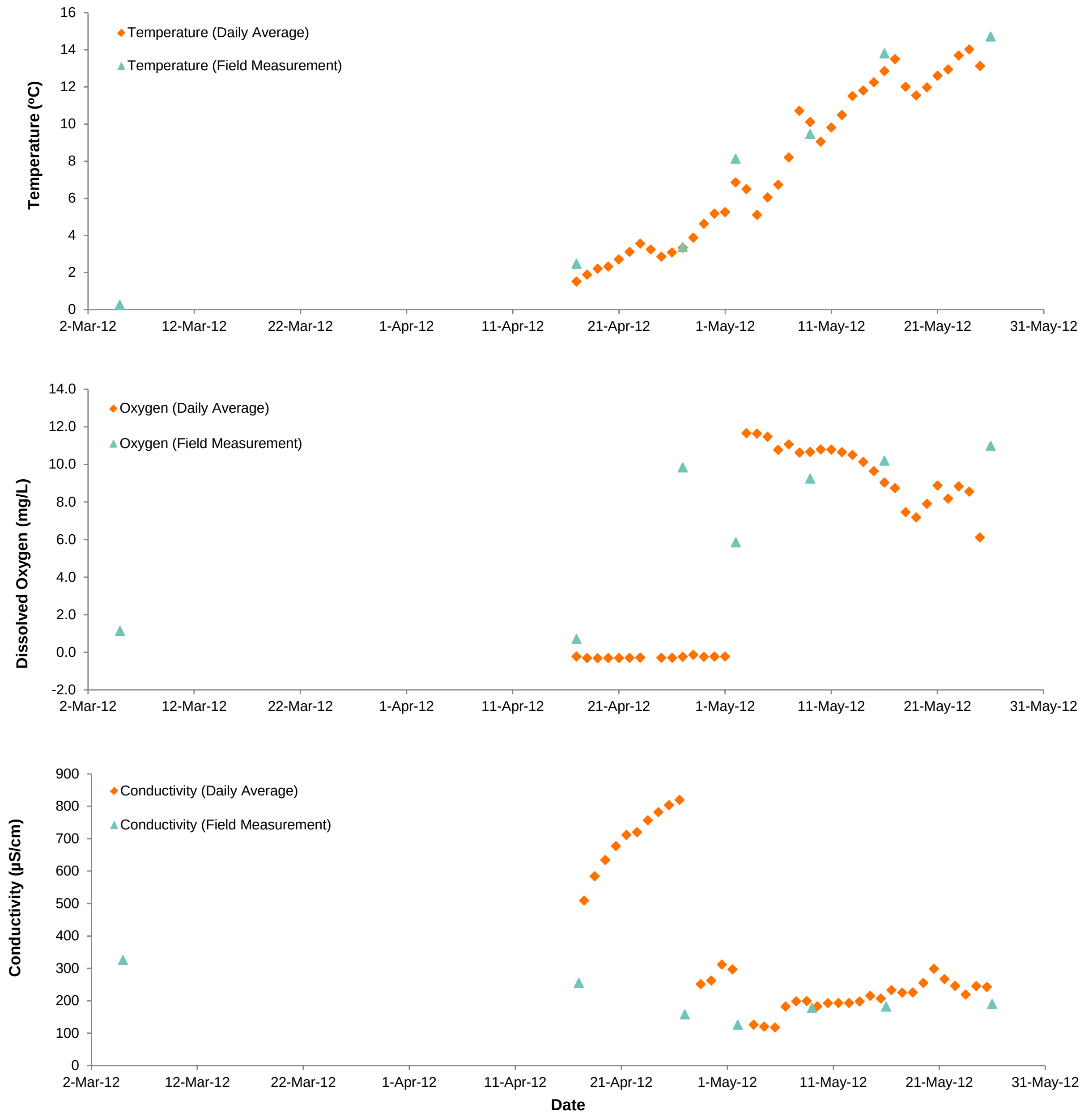
- pH increased over the spring melt in both the datasonde data and the field measurements; and
- The hydrogen ion concentration (calculated from pH) showed a decrease in concentration over the spring melt from 0.708 µeq/L to 0.078 µeq/L. The H+ ion concentration, normalized for dilution by melt waters, showed that the melt process was actually more complex than anticipated. The normalized H+ data showed daily changes and peaks in H+ concentration, exclusive of dilution. These changes represented sources or sinks of H+ in the lake that were hidden by dilution during the course of the melt. Inputs or removal processes for H+ include photosynthesis (decreases H+), respiration (increases H+), inputs of mineral acids, potentially sulphates and nitrates (increases H+), and input of strong organic acids (increases H+).

The input of strong organic acids was evident as a possible source of H^+ ions during the spring melt in Rat Lake in 2012 (Figure 6.4-7 bottom panel). Concentrations of H^+ and DOC in the discrete water samples, normalized for dilution, peaked between April 17 and May 9, 2012. These parallel changes in normalized variables suggested that an input of strong organic acids from the surrounding fens occurred during this period and served as a source of H^+ ions. As sulphates and nitrates were below detection limits in the discrete samples during this period, they could not have contributed significant levels of H^+ to the lake.

In summary, the 2012 spring melt in Rat Lake demonstrated:

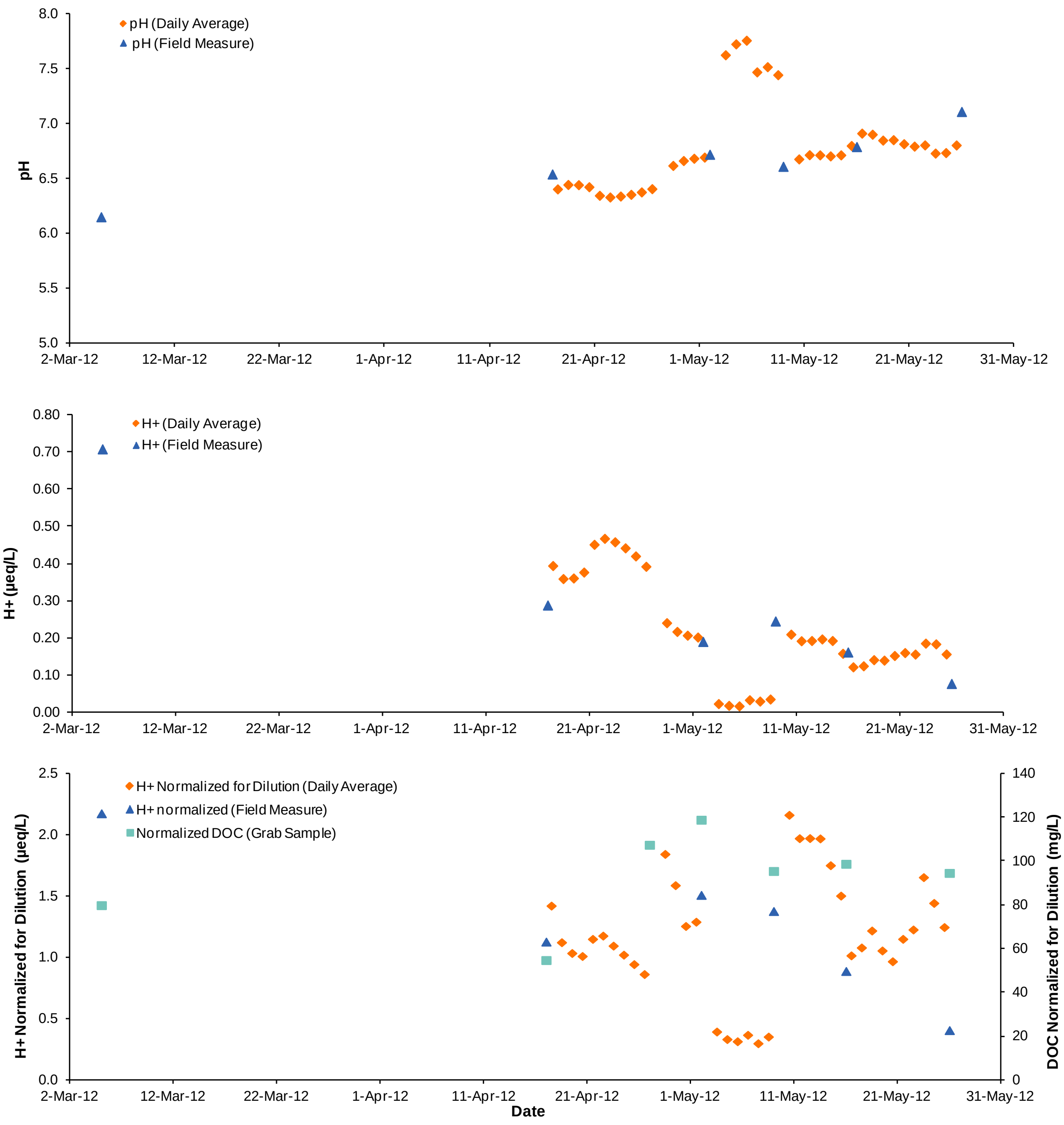
- an increase in water temperature;
- an increase in oxygen from near anoxic conditions;
- a decrease in conductivity, from dilution from runoff or internal melting of surface ice;
- an increase in pH, although there is evidence of complex sources/sinks of H+ that were masked by the process of dilution from meltwaters; and
- possible inputs of strong organic ions that provide a source of H+ to the lake.

Figure 6.4-6 Continuous measurements of temperature (ºC), dissolved oxygen (mg/L), and conductivity (µS/cm) in Rat Lake during the spring melt, 2012.



Note: Datasonde data for conductivity and dissolved oxygen collected from April 17 to May 3, 2012 were considered unreliable based on verification with field measurements, which were considered accurate.

Figure 6.4-7 Continuous measurements of pH, H^+, H^+ normalized for dilution, and DOC normalized for dilution in Rat Lake during the spring melt, 2012.

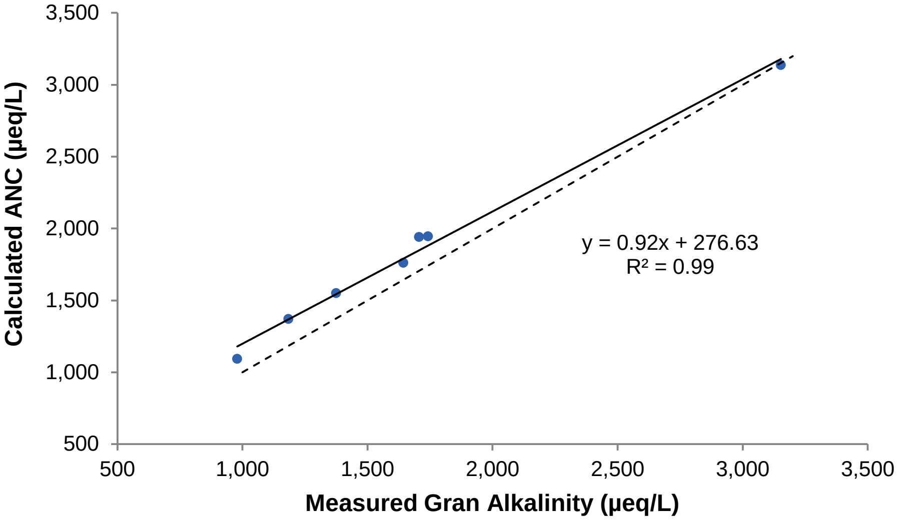


Note: Datasonde data for pH, H^+, and H^+ normalized for dilution collected from April 17 to May 10, 2012, were considered unreliable based on verifications with field measurements, which were considered accurate.

6.4.4.4 Partitioning of ANC Changes in Rat Lake during the Spring Melt

Following the ADM methodology outlined in Section 6.4.3.6, the calculated ANC was plotted against the measured Gran alkalinity (Figure 6.4-8) and indicated a close relationship between the two variables (R^2= 0.99, slope=0.92). The close relationship suggested that the assumptions behind the ANC and strong organic acid (A*) equations in the ADM are valid and the model can be used to partition the ANC changes in Rat Lake.

Figure 6.4-8 Comparison of calculated ANC versus measured Gran alkalinity in Rat Lake, 2012.



The results of ANC partitioning for each discrete sampling event are presented in Figure 6.4-9 and Table 6.4-3. Between the two discrete sampling events on March 5 and April 17, 2012, the ANC declined by 1,469 µeq/L. The base cation dilution, a natural phenomenon, was responsible for a decrease in ANC of 1,420 µeq/L, or 96.6 % of the total ANC decline during this period. Chlorides and strong organic acids, also considered natural, accounted for approximately 3% of the decline in ANC. The release of organic acids was the result of DOC exported to the lake, or in situ generation of DOC in the lake. Sulphates and nitrates, considered anthropogenic in origin, accounted for approximately 0.4 % of the ANC decline; however, given that most of the sulphate measurements and all nitrate measurements in the discrete samples were below detection limits, the small contribution to the ANC decline was likely overestimated. Similar results were observed between all sampling events, with the base cation dilution accounting for 94.1% to 99.6% of the decrease in ANC; chloride and organic acids accounting for 0.2 to 5.3% of the decrease; and sulphates and nitrates accounting for 0.2 to 0.5 % of the decline indicating that there was no demonstrated release of mineral acids (sulphates and nitrates) from the snowpack to Rat Lake during the 2012 spring melt. Large declines in ANC were recorded during the spring melt relative to baseflow conditions measured in March 2012, but these declines were almost entirely accounted for by base cation dilution and to a minor extent, by the release of chloride and strong organic acids, with all three considered to be natural phenomena.

Figure 6.4-9 Changes in ANC attributed to dilution (dil), sulphate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and strong organic acids (A*) relative to baseflow ANC in Rat Lake, 2012.

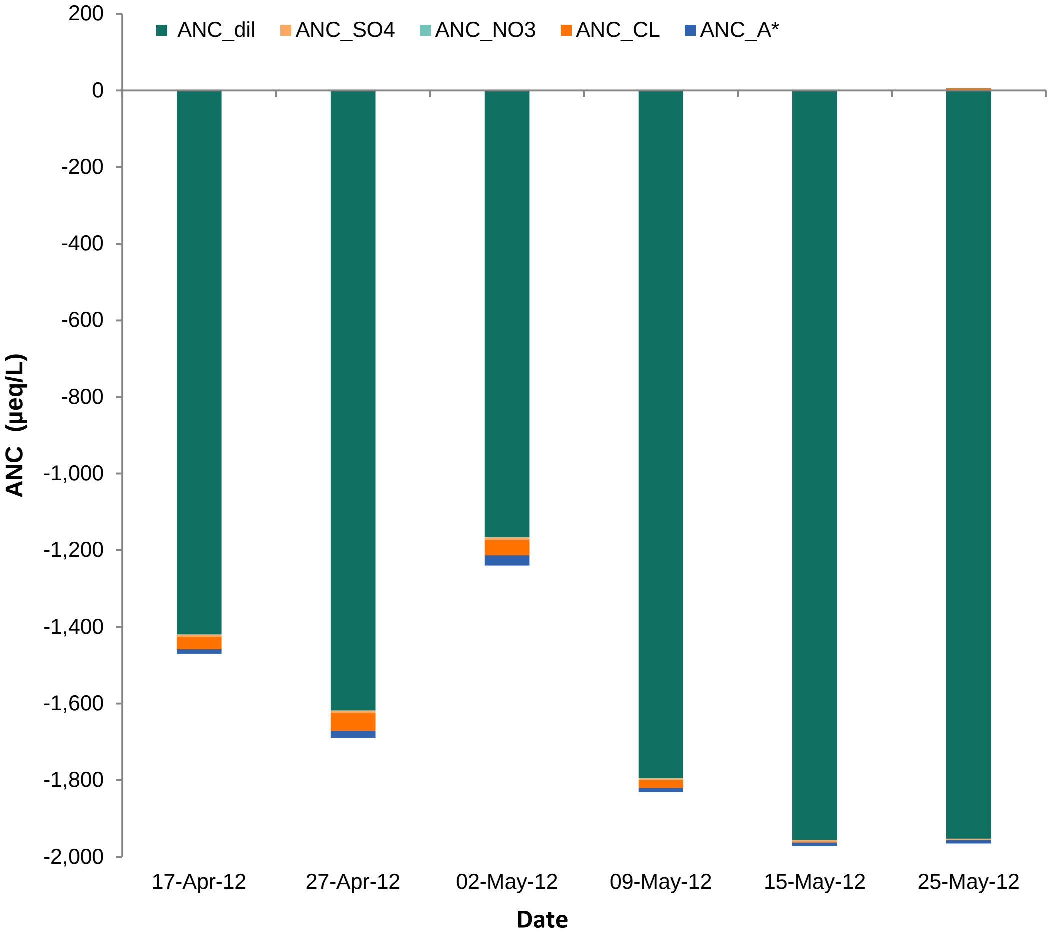


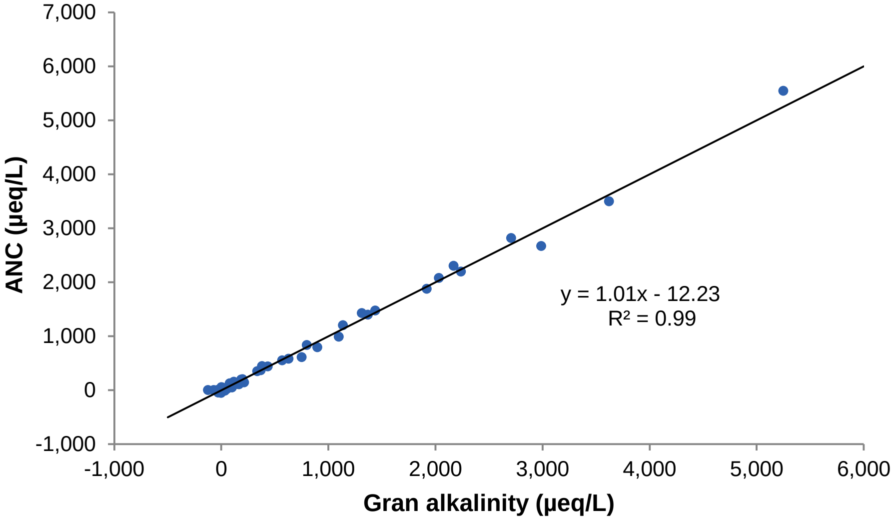
Table 6.4-3 Changes in ANC in Rat Lake attributed to base cation dilution, sulphate, nitrate, chloride, and strong organic acids, compared to baseflow conditions.

Source of ANC Change	17-Apr-12		27-Apr-12		02-May-12		09-May-12		15-May-12		25-May-12	
	Change in ANC (µeq/L)	% Decrease in ANC	Change in ANC (µeq/L)	% Decrease in ANC	Change in ANC (µeq/L)	% Decrease in ANC	Change in ANC (µeq/L)	% Decrease in ANC	Change in ANC (µeq/L)	% Decrease in ANC	Change in ANC (µeq/L)	% Decrease in ANC
Base Cation dilution	-1,420	96.6	-1,618	95.8	-1,166	94.1	-1,795	98.1	-1,956	99.2	-1,952	99.6
Sulphate release	-5.69	0.40	-5.03	0.30	-6.54	0.50	-4.45	0.20	-3.92	0.20	-3.93	0.20
Nitrate release	-0.059	0.004	-0.052	0.003	-0.067	0.005	-0.046	0.003	-0.040	0.002	-0.040	0.002
Chloride release	-32.7	2.2	-47.2	2.8	-40.2	3.2	-20.4	1.1	-2.6	0.1	5.7	-0.3
Strong organic acids	-11.1	0.8	-17.9	1.1	-26.6	2.1	-10.6	0.6	-8.9	0.5	-9.1	0.5
Total from all sources	-1,469	-	-1,689	-	-1,240	-	-1,831	-	-1,971	-	-1,959	-

6.4.4.5 ANC Partitioning Analysis of Seasonal Water Quality Data

ANC partitioning analyses were applied to the ten RAMP lakes using the ADM and showed a close relationship between the two variables (R^2=0.99, slope-=1.01) (Figure 6.4-10). The relationship suggested that the assumptions behind the ANC and strong organic acid (A*) equations in the ADM were valid and the model can be used to partition the ANC changes in the seasonal data from the ten RAMP lakes.

Figure 6.4-10 Comparison of calculated ANC versus measured Gran alkalinity in seasonal water quality data of ten RAMP lakes, 2004 to 2008.



The results of ANC partitioning over the ten RAMP lakes are presented in detail in Table 6.4-4 and Figure 6.4-11. In 19 of the 27 spring melt episodes, lake pH either increased over the spring melt or showed a negligible change (Table 6.4-4). In most of these 19 cases, the lakes had relatively high baseflow ANC and were; therefore, well buffered (e.g., Kearl lake). The average decline in ANC over the 19 episodes was 641 µeq/L. Similar to Rat Lake, most declines in ANC were attributed to natural factors, in particular, base cation dilution. On average, natural factors accounted for 94% of the ANC decline in these 19 episodes. In six of these 19 episodes, decreases in sulphate and/or nitrate concentrations over the spring melt increased the ANC; and contributed negatively to the total ANC decline (Table 6.4-4).

A significant pH decline was observed in eight of the 27 episodes; however, the pH depression was generally small (i.e., less than 0.5), with the exception of episodes at BM7-1 and BM7-2 (Lake 448), which had slightly larger pH depressions. Only four of the ten lakes had melt episodes with a pH decline including lakes 169 and 287 in the Stony Mountains; Clayton Lake (448) in the Birch Mountains; and Lake 185, northeast of Fort McMurray (see Figure 3.1-7). These four lakes were acidic, humic lakes and have been identified by RAMP as having exceptionally low pH, low ANC, and high DOC (see Section 5.14). With the exception of Lake 185, all melt episodes with pH depression occurred in lakes with a baseflow ANC less than 20 µeq/L (Table 6.4-4). The average of the total ANC decline in these eight episodes was 40 µeq/L, while the average decline in ANC attributed to anthropogenic sources (sulphates and nitrates) was 2 µeq/L. For these four lakes with generally low ANC, this small decline in anthropogenic ANC represented a large proportion of the total decline in ANC (Table 6.4-4). For example, during episode

SM9-3 on Lake 169 in the Stony Mountains, the decline in ANC from all sources was 4.16 µeq/L and the anthropogenic contribution to the ANC decline was 2.49 µeq/L, representing 59.9 % of the total ANC decline.

In summary, an ANC decline occurred in all of the melt episodes for all of the lakes, and a small pH depression occurred only in acidic lakes having little or no buffering capacity (i.e., ANC < 20 µeq/L). In lakes with high ANC, the anthropogenic ANC decline was greater than in lakes with low ANC, but constituted a smaller proportion of the total ANC decline. In acidic lakes with low ANC, the anthropogenic ANC decline was quite small, but constituted a larger proportion of the total ANC decline. In general, given that pH depressions were quite small (i.e., less than 0.5), and only occurred in acidic lakes with low ANC, which are quite rare, a spring acid pulse did not appear to be a significant phenomenon within the oil sands region.

Table 6.4-4 Results of the ANC partitioning of melt episodes in ten RAMP lakes, 2004 to 2008[1].

Lake ID	Melt Episode ID	Dates of Melt Episode	Depth (m)	Net Drainage Basin (ha)	Initial pH	Final pH	Baseflow ANC (μeq/L)	ΔANC Dilution (μeq/L)	ΔANC SO_4 (μeq/L)	ΔANC NO_3 (μeq/L)	ΔANC Cl (μeq/L)	ΔANC A* (μeq/L)	Total ANC Change (μeq/L)	Anthropogenic ANC Change (μeq/L)	Natural ANC Change (μeq/L)	Anthropogenic Contribution to ANC Change (%)
166	SM7-1	23-Mar-04 to 18-Jun-04	3	546.4	6.24	6.58	201	-160	-5.21	16.5	-7.08	-15.5	-171	11.3	-182	-6.6
	SM7-2	07-Apr-05 to 26-May-05	3	546.4	6.25	6.66	188	-144	-0.33	9.2	-0.21	-19.7	-155	8.87	-164	-5.7
	SM7-3	13-May-06 to 13-Jun-06	3	546.4	6.63	6.67	150	-135	1.23	1.54	-4.93	-12.5	-149	2.77	-152	-1.9
169	SM9-1	23-Mar-04 to 18-Jun-04	1.2	720.9	4.65	4.66	-6.2	1.89	-1.4	0.22	-10.8	-8.69	-18.7	-1.18	-17.57	6.3
	SM9-2	07-Apr-05 to 26-May-05	1.2	720.9	5.14	4.79	10.7	-4.54	-1.67	1.11	1.46	-17.8	-21.4	-0.56	-20.9	2.6
	SM9-3	13-Apr-06 to 13-Jun-06	1.2	720.9	4.86	4.66	6	-3.68	-2.82	0.33	-2.57	4.58	-4.16	-2.49	-1.67	59.9
	SM9-4	22-May-07 to 25-Jun-07	1.2	720.9	4.62	4.73	11.7	-11.01	-4.29	0	0.53	6.25	-8.53	-4.3	-4.23	50.4
175	BM10-1	23-Mar-04 to 17-Jun-04	1.5	475.7	6.88	8.32	5252	-1048	-65.3	0.12	-22	-160	-1296	-65.2	-1230	5
	BM10-2	13-Apr-06 to 13-May-06	1.5	475.7	6.75	7.66	1441	-1139	-37.2	0.88	1.88	-4.09	-1178	-36.3	-1141	3.1
	BM10-3	4-Apr-07 to 22-May-07	1.5	475.7	6.82	7.22	3625	-955	-41.6	-0.03	-2.18	-11.08	-1010	-41.6	-968	4.1
185	NE7-1	8-Apr-05 to 26-May-05	2	579.8	5.06	5.12	115	-60.4	4.01	1.31	-2.12	-7.08	-64.3	5.32	-69.6	-8.3
	NE7-2	4-Apr-07 to 22-May-07	2	579.8	5.23	5.12	214	-113	-10.5	-0.02	0.3	0.51	-123	-10.6	-112	8.6

[1] Locations of these lakes can be found in Figure 3.1-7.

Shading represents episodes having a significant decrease in pH.

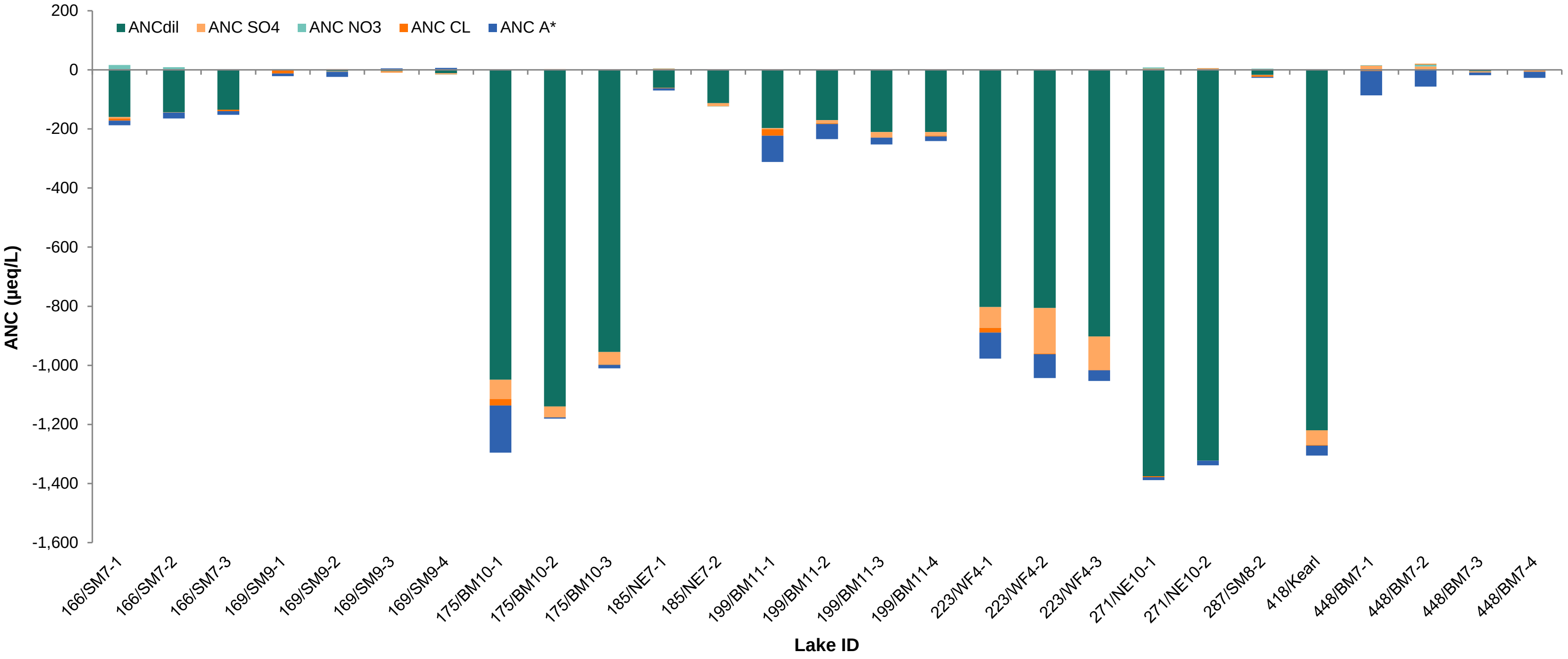
Table 6.4-4 (Cont'd.)

Lake ID	Melt Episode ID	Dates of Melt Episode	Depth (m)	Net Drainage Basin (ha)	Initial pH	Final pH	Baseflow ANC (µeq/L)	ΔANC Dilution (µeq/L)	ΔANC SO_4 (µeq/L)	ΔANC NO_3 (µeq/L)	ΔANC Cl (µeq/L)	ΔANC A* (µeq/L)	Total ANC Change (µeq/L)	Anthropogenic ANC Change (µeq/L)	Natural ANC Change (µeq/L)	Anthropogenic Contribution to ANC Change (%)
199	BM11-1	23-Mar-04 to 17-Jun-04	5	51.5	6.42	6.54	337	-197	-3.3	0.02	-22.4	-89.3	-312	-3.29	-309	1.1
	BM11-2	8-Apr-05 to 26-May-05	5	51.5	6.41	6.46	384	-170	-10.7	-0.02	-2.38	-50.7	-234	-10.8	-223	4.6
	BM11-3	13-Apr-06 to 13-Jun-06	5	51.5	6.3	6.49	372	-210	-17.8	0.06	-0.83	-23.1	-252	-17.8	-234	7
	BM11-4	4-Apr-07 to 22-May-07	5	51.5	6.44	6.46	437	-211	-11.8	-0.02	-2.46	-15.4	-241	-11.9	-229	4.9
223	WF4-1	23-Mar-04 to 17-Jun-04	1.5	175.6	6.97	7.14	2239	-803	-70.5	-0.41	-15.5	-87.4	-977	-70.9	-906	7.3
	WF4-2	8-Apr-05 to 26-May-05	1.5	175.6	7.09	7	1920	-806	-154	0.65	-2.79	-80.4	-1042	-153	-889	14.7
	WF4-3	4-Apr-07 to 22-May-07	1.5	175.6	7.03	7.09	2990	-903	-114	0.64	-0.68	-35.6	-1052	-113	-939	10.8
271	NE10-1	23-Mar-04 to 18-Jun-04	1.5	1290.3	7.48	8.52	2710	-1376	4.14	4	-3.18	-9.68	-1380	8.14	-1388	-0.6
	NE10-2	7-Apr-05 to 26-May-05	1.5	1290.3	7.56	8.05	2173	-1323	4.94	0.13	0.48	-15.2	-1333	5.07	-1338	-0.4
287	SM8-2	13-Apr-06 to 13-Jun-06	2.5	771.8	5.06	4.94	18.2	-16.79	-0.85	4.58	-6.38	-2.79	-22.2	3.73	-26	-16.8
418	Kearl	8-Apr-05 to 26-May-05	3.5	7142.1	7.49	7.82	2033	-1220	-50.1	2.44	-1.83	-33.7	-1303	-47.7	-1256	3.7
448	BM7-1	23-Mar-04 to 17-Jun-04	1.5	398.3	5.33	4.2	4.5	-1.16	13.7	2.21	-3.06	-82.4	-70.7	15.9	-86.6	-22.5
	BM7-2	7-Apr-05 to 26-May-05	1.5	398.3	4.99	4.26	0.5	-0.21	11.7	6.13	3.1	-56.7	-36	17.8	-53.8	-49.6
	BM7-3	13-Apr-06 to 13-Jun-06	1.5	398.3	4.59	4.32	9.03	-5.14	-3.56	0.05	1.23	-8.96	-16.4	-3.51	-12.9	21.4
	BM7-4	4-Apr-07 to 22-May-07	1.5	398.3	4.67	4.25	2.82	-1.06	-3.68	-0.06	-1.4	-21.2	-27.4	-3.74	-23.6	13.7

[1] Locations of these lakes can be found in Figure 3.1-7.

Shading represents episodes having a significant decrease in pH.

Figure 6.4-11 Change in ANC attributable to dilution (dil), sulphates (SO_4^{2-}), nitrates (NO_3^-), chloride (Cl^-), and strong organic acids (A*) for each melt episode in ten RAMP lakes, 2004 to 2008.



6.4.5 Discussion

The results of this study were supported by results of a previous study on spring acid pulse in streams in the oil sands region (WRS 2003). Datasonde and discrete water sampling at Rat Lake showed that by the end of winter, dissolved oxygen was almost completely depleted in the water column and the dissolved variables in the remaining water layer beneath the ice were highly concentrated. The 2012 spring melt brought a rapid increase in water temperature, a decrease in conductivity, a decrease in ANC and an increase in pH in Rat Lake. Conductivity decreased as a result of the dilution of Rat Lake through internal melting of the surface ice and/or runoff of meltwater from the watershed. pH likely increased due to the re-introduction of oxygen to the lake, which is the opposite of what is expected if the lake receives an acid pulse from mineral acids in the snowpack during the spring melt. An increase in pH during the spring was routinely observed in the seasonal study by AESRD on ten RAMP lakes (RAMP 2009a). Trends in H^+ normalized for dilution by meltwaters showed evidence of complex sources/sinks of H^+ in Rat Lake that were masked by the process of dilution from meltwaters. Comparison of the normalized H^+ in grab samples with normalized concentrations of DOC suggested that inputs of strong organic acids may serve as a minor source of H^+ to Rat Lake. This source was considered to be natural in origin.

Partitioning of ANC changes in Rat Lake using the ADM provided additional details on the spring melt process. In the period between March 5 and April 17, 2012, the ANC declined by 1,469 µeq/L, with the base cation dilution accounting for 94.1 % to 99.6 % of the decrease in ANC; and chloride and organic acids accounting for 0.2 to 5.3 % of the decline in ANC. All three sources of ANC decline were considered natural in origin. Sulphates and nitrates accounted for only 0.2 to 0.5 % of the ANC decline in Rat Lake indicating that there was no demonstrated release of mineral acids (sulphates and nitrates) of anthropogenic origin to Rat Lake during the spring melt in 2012. Large ANC declines, relative to baseflow conditions in March 2012, were almost entirely accounted for by base cation dilution and to a minor extent, by the release of chloride and strong organic acids. All three changes were considered natural phenomena.

The ADM applied to 27 melt episodes from ten RAMP lakes provided an additional dimension to the melt process by assessing the effect of differing lake chemistry. This dimension was absent in many of the stream studies on spring acid pulse (e.g., Laudon et al. 2000). In 19 of the 27 melt episodes, lake pH increased over the melt episode. Most of these episodes involved well buffered, high ANC lakes. The ANC partitioning of these lakes was similar to Rat Lake with most (i.e., an average of 94%) of the ANC decline attributed to natural sources, in particular, base cation dilution. Consistent with the Rat Lake study, the release of mineral acids of anthropogenic origin during spring melt had a minimal effect on ANC and a negligible effect on pH in lakes with high ANC.

Four lakes with low ANC and low pH demonstrated a very different pattern of melt chemistry, including a small but distinct decline in pH in eight melt episodes. The average ANC decline in the eight melt episodes was 40 µeq/L, while the average decline in anthropogenic ANC was 2 µeq/L. For these four lakes with generally low ANC, this small decline in anthropogenic ANC represented a large proportion of the total decline in ANC.

An ANC decline was observed in all of the melt episodes for all of the lakes, but a pH depression occurred only in acidic lakes with little or no buffering capacity (ANC<20 µeq/L). In lakes with high ANC, the anthropogenic ANC decline was greater than in lakes with low ANC, but constituted a smaller proportion of the total ANC decline. In acidic lakes with low ANC, the anthropogenic ANC decline was small, but constituted a larger proportion of the total ANC decline. In general, given that pH depressions were quite small (i.e., less than 0.5), and only occurred in acidic lakes with low ANC, which are quite rare, a spring acid pulse does not appear to be a significant phenomenon in lakes in the oil sands region.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The 2012 RAMP monitoring program results have been discussed in detail in sections 5 and 6. This section provides a summary of results for each component of RAMP. Based on results presented in Section 5, Table 7.1-1 provides a summary of the 2012 RAMP results by watershed and by component. In addition, overall conclusions, general comments, and recommendations for each component are presented for consideration by the RAMP Technical Program Committee and the RAMP Steering Committee. Given that the sampling program is designed one year in advance, recommendations for each component presented to the RAMP Technical Committee are implemented immediately if possible within the current sampling program, or introduced into the program design for the following year. Recommendations provided in this section may also be beyond the current scope of RAMP; however, given that RAMP is now working with the provincial and federal governments during a transition period to the new Joint Canada-Alberta Implementation Plan for the oil sands region, some recommendations may have taken this larger scope into account.

7.1 CLIMATE AND HYDROLOGY

7.1.1 Summary of 2012 Results

Hydrologic changes in the RAMP FSA in the 2012 WY were assessed as **Negligible-Low** in nine of 13 watersheds assessed. The exceptions to this were the Muskeg River, Tar River, Mills Creek, and Fort Creek watersheds in which at least one of the four measurement endpoints was classified as **Moderate** or **High** (Table 7.1-2). In the 2012 WY, the activities of focal projects and other oil sands developments contributing to hydrologic changes in the RAMP FSA, in order of decreasing hydrologic effect, 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 focal projects and other 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 focal projects and other oil sands developments.

The cumulative hydrologic effects of focal projects with respect to the Athabasca River mainstem were evaluated by comparing the observed *test* hydrograph and estimated *baseline* hydrograph for Station S46, Athabasca River near Embarras Airport. In the 2012 WY, Station S46, Athabasca River near Embarras Airport, was used to evaluate the effect of oil sands development on the Athabasca River instead of Station S24, Athabasca River below Eymundson Creek, which was used in previous years. This change was undertaken because the S46 station was located further downstream than the S24 station and encompassed all development in the RAMP FSA. The water balance analysis was conducted using both stations for the 2012 WY to determine if a bias was present between the two stations and if the results calculated from S46 represented the same level of effect as the calculations conducted using the S24 station from past years. Results from this assessment indicated that the level of effect was the same between the two stations and the results across years were comparable.

Relative changes from *baseline* to *test* conditions for all four measurement endpoints (i.e., the 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 for the 2012 WY (Table 7.1-2). 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 focal projects. The calculated percent change from *baseline* to *test* ranged from -0.3% (annual maximum daily discharge) to -1.8% (mean winter discharge) (Figure 7.1-1). Those values were essentially unchanged when the effects of non-focal project oil sands developments were included. There was no discernible trend from 2004 to 2012 in changes from *baseline* to *test* conditions in the four measurement endpoints (Figure 7.1-1).

Table 7.1-1 Summary assessment of RAMP 2012 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Fish Populations: Human Health Risk from Mercury in Fish Tissue[8]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[9]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Assemblages[5]	Sentinel Fish Species[6]	Species	Subs. Fishers	General Cons.	
Athabasca River	🟡	🟡 / 🟠	-	-	-	-	-			-
Athabasca River Delta	-	-	🟡 / 🟠 / 🟤	🟡	n/a	-	-			-
Muskeg River	🟤	🟡	🟠 / 🟡	🟡	🟡 / 🟠	-[7]	-			-
Jackpine Creek	nm	🟡	🟡	🟡	🟡	-	-			-
Kearl Lake	nm	🟡	🟠	n/a	-	-	-			-
Steepbank River	🟡	🟡	🟠	-	🟡	🟠	-			-
Tar River	🟤	🟡	🟡	🟡	-	-	-			-
MacKay River	🟡	🟡 / 🟠	🟠	-	🟡	-	-			-
Calumet River	🟡	🟡	🟡	🟠	🟡	-	-			-
Firebag River	🟡	🟡	nm	nm	nm	-	-			-
McClelland Lake	nm	n/a	🟠	n/a	-	-	-			-
Johnson Lake	-	n/a	n/a	n/a	-	-	-			-
Ells River	🟡	🟡	🟠	🟠	🟡	-	-			-
Christina River	🟡	🟡 / 🟤	🟠 / 🟡	🟡	-	-	-			-
Christina Lake	nm	n/a	n/a	n/a	n/a	-	-			-
Christina Lake Tributaries[10]	nm	🟡	🟡	🟡	🟠 / 🟡	-	-			-
Gregoire Lake	-	-	-	-	-	-	WALL NRPK	🟡	🟡	-
Clearwater River	nm	🟠	nm	nm	-	-	NRPK (>500 mm)	🟤	🟠	-
High Hills River	-	🟡	n/a	-	n/a	n/a	-			-
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	-	🟡	-	-	-	-	-			-
Pierre River	-	🟡	-	-	-	-	-			-
Red Clay Creek	-	🟡	-	-	-	-	-			-
Eymundson Creek	-	🟡	-	-	-	-	-			-
Stony Mountains	-	-	-	-	-	-	-			🟡
West of Fort McMurray	-	-	-	-	-	-	-			🟡
Northeast of Fort McMurray	-	-	-	-	-	-	-			🟡
Birch Mountains	-	-	-	-	-	-	-			🟡
Canadian Shield	-	-	-	-	-	--	-			🟡
Caribou Mountains	-	-	-	-	-	-	-			🟡

Legend and Notes

🟡 Negligible-Low change
🟠 Moderate change
🟤 High change

"-" program was not completed in 2012.

nm - not measured in 2012.

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 are calculated for each watershed because of differing lengths of the hydrographic record for 2012, hydrology results above are for those measurement endpoints that were calculated.

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

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

Note: Water quality at all stations in the Athabasca River was assessed as Negligible-Low with the exception of station ATR-MR-E, which was assessed as Moderate.

Note: Water quality at the lower station of the MacKay River was assessed as Negligible-Low and water quality at the middle station was assessed as Moderate.

Note: Water quality at the lower station of the Christina River was assessed as Negligible-Low and water quality at the upper station was assessed as High.

[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 comparison to regional *baseline* conditions.

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

Note: Benthic invertebrate communities at the lower reach of the Muskeg River were assessed as Moderate and benthic invertebrate communities at the middle and upper reaches were assessed as Negligible-Low.

Note: Benthic invertebrate communities at the lower reach of the Christina River were assessed as Moderate and benthic invertebrate communities at the upper reach were assessed as Negligible-Low.

[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 3.2.4.3 for a detailed description of the classification methodology.

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

Note: Fish assemblages Sawbones Creek were assessed as Moderate and fish assemblages at Sunday Creek and Jackfish River were assessed as Negligible-Low.

[6] **Fish Populations (sentinel species):** Classification based on effects criteria established for Environment Canada's Environmental Effects Monitoring Program for pulpmills (Environment Canada 2010); see Section 3.2.4.4 for a description of the classification methodology.

[7] A classification of results could not be completed for the lower Muskeg River site given the low sample size of slimy sculpin captured for the sentinel species program.

[8] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. NRPK – northern pike; WALL – walleye; Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada.

[9] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2012 were more than twice the standard deviation from their long-term mean in each lake.

[10] Christina Lake tributaries include Sawbones Creek, Sunday Creek, and Jackfish River.

Table 7.1-2 Summary assessment of the RAMP 2012 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	Moderate (+)	High (+)	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
Ells River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Firebag 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	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Mills Creek	High (-)	High (-)	High (-)	High (-)
Fort Creek	Moderate (+)	not measured	not measured	not measured

Assessments based on comparisons of calculated incremental change in hydrologic measurement endpoints with criteria used in Section 5.0: Negligible-Low: ± 5%; Moderate: ±15%; High: > ± 15%.

“not measured” means hydrologic information was not obtained for times of year for which the measurement endpoint is 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 are shown only for differences of 5% or greater (i.e., Moderate or High).

7.1.2 Recommendations

Oil sands development is continuing to expand in the RAMP FSA region; therefore, it is recommended that the RAMP Climate and Hydrology monitoring network continue to expand to support the provision of *baseline* and *test* hydrometric information and regional climate data. Continued monitoring at existing climate and hydrometric stations is also recommended to support enhanced record length and data availability.

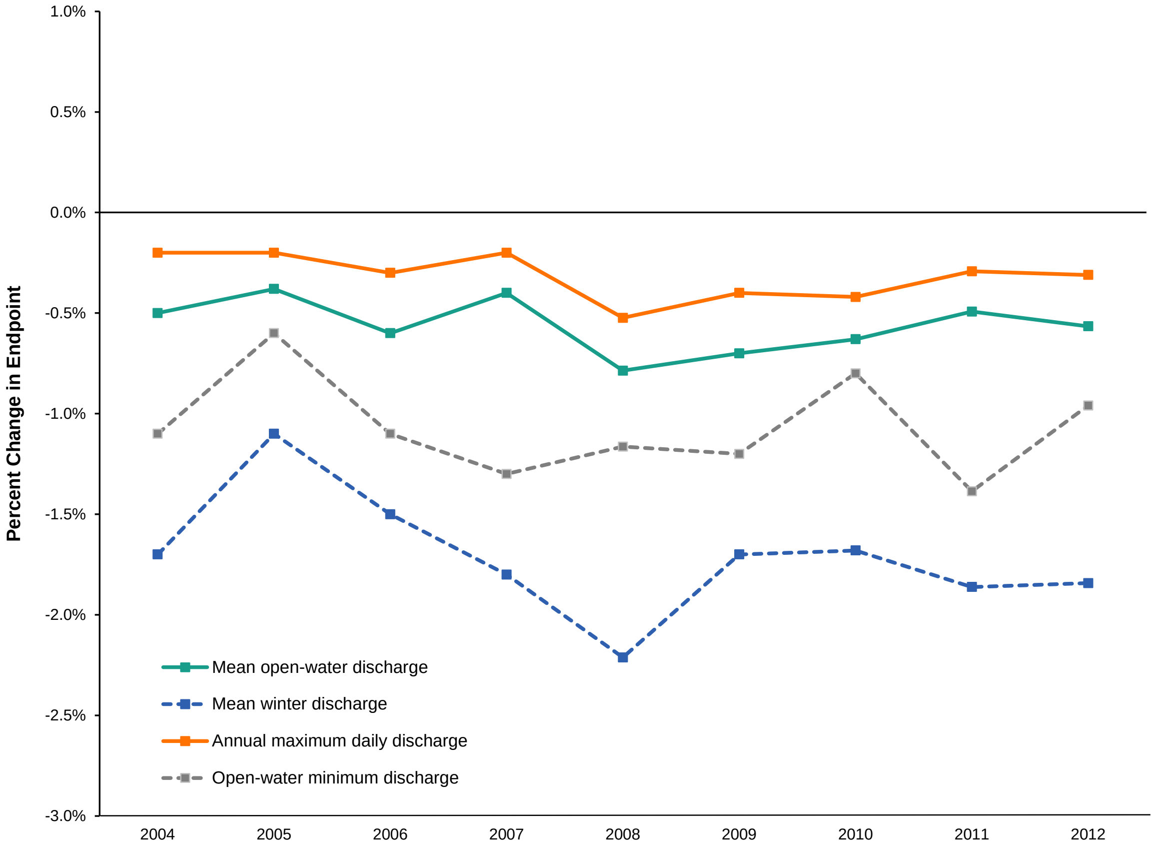
The water balance approach, particularly with the provision of daily time-step industrial data, provides a consistent basis for analysis of industrial effects on flows in watersheds within the RAMP FSA, including those stations with a limited length of data record. As recommended in RAMP (2010), evaluative research is underway to identify additional approaches, measurement endpoints, and indicators that might further support the evaluation of potential shifts in the timing, magnitude, and frequency of flow conditions in watersheds of the RAMP FSA. The application of additional methods is predominantly limited by the length of the data record (Kundzewicz and Robson 2004), with current applicability of statistical methods limited to a sub-set of tributaries within the RAMP FSA. By comparison, the water balance approach provides a basis for analysis that can be completed for all monitored tributaries within the RAMP FSA. There is an expectation that methods currently under review will serve to complement the existing approach, increase the understanding of hydrologic characteristics of the watersheds in the RAMP FSA, and potentially provide additional assessment criteria for selected locations.

Future refinement of the water balance approach may introduce a time-lag on releases in a watershed to reach the measurement location (i.e., RAMP hydrology station). In most watersheds, the water balance is conducted near the mouth of a river; however, not all water releases to a river occur near the mouth. Therefore, the time that it would take for these releases to reach the mouth may further refine the results of the water balance analysis. This will be especially useful for water releases from settling ponds on mine sites that store precipitation water prior to releasing it; and releases that occur during the winter months that are stored as ice until the onset of the spring melt. The efficacy of this revision will be assessed prior to the 2013 annual report and will be incorporated if proven beneficial to the water balance analysis.

The RAMP Climate and Hydrology component to date has focused its analysis on surface water impacts; however, without the incorporation of groundwater interaction to the surface water analysis, a substantial influence on surface water impacts is not incorporated. The integration of RAMP into the larger scope of the JOSM Plan may allow for a more harmonized analysis of the hydrologic impacts of oil sands development with the use of an integrated groundwater and surface water model. This approach may also help determine if the current water balance approach utilized by RAMP is adequately representing the impacts on the surface water environment.

Many of the RAMP hydrometric monitoring stations have calculated watershed areas that were passed down since the inception of the RAMP Hydrology and Climatology component. These values were derived using methods and data that are not well documented. Newer topographic elevation data and hydrologically-corrected digital elevation data have become available for the RAMP FSA. These data would add value to runoff calculations and other metrics that are developed using watershed areas.

Figure 7.1-1 Changes in values of hydrologic measurement endpoints in the Athabasca River as a result of focal projects plus other oil sands developments.



Note: Measurement endpoints are 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 for 2012.

7.2 WATER QUALITY

7.2.1 Summary of 2012 Results

Water quality measured by RAMP at various waterbodies in fall 2012, especially in some tributaries to the Athabasca River, was strongly influenced by very high flows and rainfall in September, which generally caused an increase in particulates and particulate-associated total metals, and a decrease in concentrations of dissolved ions and metals. This effect was most pronounced in tributaries along the eastern bank of the Athabasca River, and in locations sampled in the second and third weeks of September, following heavy rain events, rather than the first week of September.

The following waterbodies in 2012 exhibited changes from historical and/or regional *baseline* conditions:

- **Athabasca River** – *Test* station ATR-MR-E (upstream of the Muskeg River along the east bank) showed **Moderate** differences from regional *baseline* conditions due to high concentrations of TSS, organic carbon, nutrients, and associated particulate metals. In addition, concentrations of total boron showed an increasing trend over time at *test* stations ATR-MR-E, ATR-MR-W, and ATR-DD-W.

- **MacKay River** – Differences in water quality at middle *test* station MAR-2A from measured regional *baseline* conditions were classified as **Moderate**, likely due to very high flow conditions at the time of sampling, which resulted in high total suspended solids and total metals that are associated with particulates. Water quality at stations upstream (MAR-2) and downstream (MAR-1) of MAR-2A, sampled in the previous week, were within regional *baseline* conditions.

- **Muskeg River tributaries** – *Baseline* station JAC-2 (upper Jackpine Creek) and *test* station IYC-1 (Iyinimin Creek) showed **Moderate** differences from regional *baseline* conditions in fall 2012, associated with high concentrations of particulates and particulate-associated metals in these samples. These high particulate levels were likely related to very high stream flows at the time of sampling.

- **Clearwater River** – Water quality at both water quality monitoring stations on the Clearwater River (i.e., *test* station CLR-1 and *baseline* station CLR-2) indicated **Moderate** differences from regional *baseline* water quality conditions, with concentrations of several measurement endpoints (particulate-related) exceeding the range of previously-measured concentrations and the range of regional *baseline* conditions, likely due to high flows at the time of sampling.

- **Christina River** – Differences in water quality between *test* station CHR-2 (located near Chard) and regional *baseline* conditions in fall 2012 were classified as **High**, with concentrations of several water quality measurement endpoints (e.g., total and dissolved metals) outside the range of previously-measured concentrations and regional *baseline* conditions.

- **Mills Creek** – Differences in water quality in fall 2012 between Mills Creek and regional *baseline* conditions were classified as **Moderate**, likely due to relatively high concentrations of many ions and other dissolved species that exceeded the 95th percentile of regional *baseline* concentrations.

- **Beaver River** – Concentrations of several water quality measurement endpoints, primarily ions and other dissolved species, exceeded regional *baseline* concentrations at *test* station BER-1, resulting in a **Moderate** difference from regional *baseline* conditions.

- **McLean Creek** – Concentrations of TSS, TDS, and many ions and dissolved species of water quality measurement endpoints were high relative to regional *baseline* conditions and exhibited guideline exceedances, indicating a **Moderate** difference from regional *baseline* concentrations.

Of these stations, Mills Creek, Beaver River, and McLean Creek have consistently shown differences from regional *baseline* conditions across years, with results likely indicating anthropogenic influences on water quality. Aside from these localized changes, water quality in the RAMP FSA in 2012 was largely consistent with regional *baseline* conditions (Table 7.1-1).

7.2.2 Recommendations

The following recommendations are outlined to further improve monitoring conducted for the Water Quality component:

- Continue to add *baseline* stations for ongoing RAMP water quality sampling, particularly stations that are expected to remain *baseline* well into the future. This is particularly important given the steady decline in the number of stations designated as *baseline* in the current RAMP water quality design, and the need to continually update the ranges of natural variability of water quality in the RAMP FSA.

- Continue to expand seasonal or monthly sampling within the RAMP water quality program, particularly for larger tributaries, to better capture the range of conditions in these locations and allow better discrimination of natural versus anthropogenic changes in water quality in future.

7.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

7.3.1 Benthic Invertebrate Communities

7.3.1.1 Summary of 2012 Results

The Benthic Invertebrate Communities component characterizes changes in river reaches and lakes that are considered most likely to be affected by focal projects. Within the major tributaries, samples are 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 in upper reaches that are classified as *baseline*. 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 is 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 2012 are provided below.

Athabasca River Delta: Differences in measurement endpoints for benthic invertebrate communities in Big Point Channel, Goose Island Channel, and Embarras River were classified as **Moderate** because one or more measurement endpoints varied over time, in a direction consistent with a negative change or were lower in 2012 than in previous years. Differences in measurement endpoints in benthic invertebrate communities in Fletcher Channel were classified as **High** because of decreasing abundance, richness, diversity, and multivariate CA Axis scores over time, and because abundance, richness, and %EPT (Ephemeroptera, Plecoptera, Trichoptera) were below previously-measured values for ARD reaches. Total abundance of benthic invertebrate communities in all four channels of the ARD was negatively correlated with percent substrate as sand. The higher sand content in 2012 in the channels of the ARD was likely related to high discharge events in 2012 prior to the fall sampling period, potentially flushing finer sediments and associated benthos. Although the statistical analyses classified the differences in measurement endpoints as **Moderate** Big Point Channel, Goose Island Channel, Embarras River) and **High** (Fletcher Channel), the differences in the composition of benthic fauna may be related to natural conditions. Monitoring in subsequent years will be useful to further understand the causes of variation in composition of the benthic invertebrate communities in the channels of the ARD.

Lakes: Differences in measurement endpoints for benthic invertebrate communities of lakes are difficult to classify because there is a general lack of information on *baseline* lake conditions in the RAMP FSA. Some new benthic invertebrate community data were published by Parsons et al. (2010) for acid-sensitive lakes, but the field methods used in this study were not similar to the methods used in RAMP and thus cannot be directly or easily compared. Therefore, differences were assessed based on historical years in each lake, which was difficult in lakes with shorter sampling periods, such as Isadore’s Lake.

Differences in the benthic invertebrate communities in Kearl Lake were classified as **Moderate** because of the significant decrease in percent EPT (i.e., mayflies and caddisflies) and the increase in multivariate Correspondence Analysis (CA) Axis scores compared to the period when Kearl Lake was designated as *baseline*. However, the benthic invertebrate community contained a diverse fauna and included several taxa that were typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and caddisflies). The relative abundance of ostracods, which has decreased since 2011, was still high compared to *baseline* lakes in the RAMP FSA.

Differences in the benthic invertebrate communities in Isadore’s Lake were classified as **Negligible-Low** because the significant (though subtle) increase in %EPT over time and the higher %EPT in 2012 than the mean of previous years does not suggest degrading conditions. The percentage of fauna as EPT has always been < 1% (normally EPT are absent), but in 2012 EPT taxa accounted for about half a percent of the fauna. Further, all measurement endpoints were within the range of historical values for the lake. Historically, Isadore’s Lake has had a unique benthic invertebrate community compared to other lakes in the area, having low diversity and high abundance of nematodes. While there has been very little negative change over time, the benthic invertebrate community in Isadore’s Lake has been representative of a degraded system since sampling was initiated in 2006.

Differences in benthic invertebrate communities of McClelland Lake in 2012 were classified as **Negligible-Low** because total abundance was higher in the *test* period than the *baseline* period and although the percentage of fauna as EPT taxa was lower 2012 than all previous years of sampling, it was consistent with 2002, 2003, and 2010. CA Axis 1 scores were significantly different from the *baseline* period and CA Axis 2 scores were different in 2012 than all previous years; however, the composition of the community in terms of relative abundances, included fully aquatic forms and generally sensitive taxa including the mayfly *Caenis* and the caddisfly *Mystacides* suggesting that the community of McClelland Lake was still in good condition and generally similar to *baseline* conditions.

Differences in benthic invertebrate communities of Shipyard Lake in 2012 were classified as **Negligible-Low**. The increasing trend over time of abundance and taxa richness were significant and strong (explaining > 20% of the total variation in annual means) and were not indicative of degraded water or habitat quality. The lake contained a number of fully aquatic forms including amphipods, clams, and snails, indicating generally good water and sediment quality.

Differences in benthic invertebrate communities of Christina Lake in 2012 were classified as **Negligible-Low** given that the lake contained a diverse benthic fauna including several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies).

Rivers: Consistent with 2011, differences in measurement endpoints for benthic invertebrate communities of Fort Creek were classified as **High** because of the significantly lower abundance and richness during the *test* period compared to the *baseline* period. Additionally, four of the five measurement endpoints were outside of the range of variation for regional *baseline* depositional rivers. Although the percentage of fauna as EPT taxa has increased over time, this could be an artifact of the low overall abundance in the reach during many years of sampling (including 2012).

Changes in the benthic invertebrate communities of the following *test* reaches were classified as **Moderate** because:

- **Muskeg River (lower)** – there was a significant increase in total abundance and CA Axis 1 and 2 scores over time and significant differences in abundance, EPT taxa, and CA Axis 1 and 2 scores in 2012 relative to previous sampling years. The benthic invertebrate community; however, appeared to be in good condition, with high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies. The percentage of the fauna as worms (tubificids and naidids) was relatively similar to previous years indicating no significant change in the quality of the habitat.

- **Steepbank River** – total abundance, percent EPT, and CA Axis 1 and 2 scores were significantly lower at the lower *test* reach than the upper *baseline* reach. The benthic invertebrate community; however, was diverse and although it was dominated by somewhat tolerant tubificids, many other taxa were noted that require cool, clean water and not suggesting any degradation of habitat conditions at this reach.

- **MacKay River (lower and middle)** – there was a decrease in percent EPT taxa below regional *baseline* conditions and significantly lower abundance of EPT taxa at the lower *test* reach compared to the upper *baseline* reach. In addition, CA Axis 1 scores were significantly lower at the lower *test* reach in 2012 compared to the upper *baseline* reach reflecting a difference in taxa composition, with fewer water mites. The CA Axis 1 scores were significantly lower at the middle *test* reach compared to the upper *baseline* reach.

- **Ells River (lower and middle)** – there were significant decreases in Simpson's Diversity and percent EPT taxa in 2012 at the lower *test* reach compared to previous years and a decrease in the percentage of fauna as EPT taxa over time. Additionally, Simpson's Diversity was also lower than the range of *baseline* conditions for depositional rivers and habitat was of marginal quality for benthic invertebrate communities at the lower reach. The low diversity, high relative abundance of tubificid worms (> 60% in 2012), absence of caddisflies and stoneflies, and low relative abundance of mayflies were indicative of an environment that was somewhat limiting to depositional fauna. There was a significant difference in abundance, richness, equitability, percent EPT, and CA Axis 1 and 2 scores between the middle *test* reach and the upper *baseline* reach. In addition, abundance and percent EPT were higher and lower, respectively, at the *test* middle *test* reach than the regional *baseline* range.

- **Christina River (lower)** – abundance, richness, and percent EPT taxa were lower in 2012 compared to previous years and diversity and abundance were below the range of variation for *baseline* depositional reaches. The benthic invertebrate community has consistently been dominated by tubificid worms over time suggesting that the observed differences in 2012 may be due to natural variation. The reach also contained stoneflies (Plecoptera) suggesting reasonably good habitat quality.

- **Poplar Creek** – there were significant and large differences in abundance, percentage of fauna as EPT taxa, and CA Axis scores compared to the upper *baseline* reach. The benthic invertebrate community was in generally good condition, reflected by low relative abundances of worms and higher relative abundances of fingernail clams. The low relative abundance of mayflies and caddisflies, and lack of stoneflies potentially indicated some level of disturbance, but over time the percentage of EPT taxa has been increasing.

Changes in the benthic invertebrate communities of the following *test* reaches were classified as **Negligible-Low** because:

- **Muskeg River (middle and upper)** – all benthic measurement endpoints were within the range of variation for depositional *baseline* reaches at the middle and upper *test* reaches and there was no evidence of negative change over time in any measurement endpoints. In addition, the relative abundance of tubificids were lower than 2011 at the upper *test* reach.

- **Jackpine Creek** – although there were significant differences from the upper *baseline* reach (i.e., higher CA Axis 1 scores, increased in abundance and richness at the lower *test* reach), the differences were not indicative of degraded habitat quality at the lower *test* reach. The strong statistical signal in CA Axis 1 scores was due to a lower abundance of tubificids in 2012, suggesting good habitat quality. The presence of sensitive taxa including mayflies, caddisflies, clams, and snails, also suggested a benthic fauna indicative of good depositional habitat conditions.

- **Tar River** – although there were significant differences in measurement endpoints over time, the differences were not in a direction consistent with a negative change but rather suggested improvements in habitat quality and species diversity compared to previous years. Values of measurement endpoints for benthic invertebrate communities at both reaches of the Tar River were within the range of regional *baseline* conditions.

- **Calumet River** – although there were significant differences in measurement endpoints compared to the upper *baseline* reach (e.g., higher diversity, EPT taxa, and lower equitability), these differences were generally not in a direction consistent with a negative change or degraded habitat quality. In addition, values of measurement endpoints were within the range of variation for *baseline* depositional reaches and the benthic invertebrate community was considered diverse and supported by good water quality.
- **Christina River (upper)** – the significantly higher percent EPT taxa during the *test* period compared to the *baseline* period was not consistent with a negative change.
- **Tributaries to Christina Lake (Sawbones Creek, Sunday Creek, Jackfish River)** – almost all measurement endpoints including CA Axis scores were either within or above regional *baseline* conditions.

7.3.1.2 Study Design Considerations

The JOSM Plan collected CABIN kick and sweep samples at the Steepbank River (STR-E1, STR-E2), MacKay River (MAR-E1, MAR-E3), and Ells River (ELR-E2, ELR-E2A) reaches in fall 2012, synoptically with RAMP's Hess sampling. The purpose of sampling concurrently was to enable a direct comparison between the two sampling techniques. The analyses and comparison of the two sets of samples has the potential to: (i) develop models that could be used to predict measurement endpoint values for one method, given values generated from the other method and allow for comparison of results from different programs that use different methods, with the development of this conversion factor (or predictive model); and (ii) determine which of the two sampling techniques results in estimates of measurement endpoints that are more discriminating between lower *test* and upper *baseline* reaches. The outcome of this comparison would be to determine whether RAMP should maintain Hess sampling in erosional reaches or change sampling methods.

Hess samplers cannot be used to collect a sample if the channel is deeper than about 60 cm. RAMP has periodically missed sampling or reduced the number of replicates collected in some reaches because of high flows in some years. There was some consideration that CABIN kick samples might be more appropriate for sampling riffle habitats given that kick samples could be collected at any flow. However, the concurrent Hess and kick sampling in 2012 showed that when flows were too high to use the Hess sampler, flows were also too high to safely wade the riffles to obtain a 3-minute kick sample. For example, there were more Hess samples collected at the upper Steepbank River reach (STR-E2) in fall 2012 than CABIN kick samples due to safety issues. The study indicated that Hess can be more frequently collected than kick samples, even in higher flows, because regardless of flow, there is normally still a small area along the margin of the river where samples can be collected.

7.3.1.3 Recommendations

Assessment of lakes is somewhat more challenging than river habitats because of varying depths, with differing exposures to contaminants and other associated stressors. Deeper habitats in lakes (i.e., below the thermocline and greater than about 6 to 8 m) are "trapped" in the summer time where anoxia can occur, depending on nutrient levels in the lakes. RAMP currently samples relatively shallow-water (1 to 2 m) habitat in lakes but should potentially consider the addition of deep-water samples in lakes in which a thermocline has had an opportunity to develop. Such sampling would ensure that any changes in deep-water habitats are detected, if they occur.

7.3.2 Sediment Quality

7.3.2.1 Summary of 2012 Results

Sediments in the RAMP FSA naturally contain concentrations of hydrocarbons and PAHs that may exceed environmental-quality guidelines.

In fall 2012, differences in sediment quality from regional *baseline* conditions were classified as **Moderate** at the *test* stations of the Calumet and Ells rivers, due primarily to regionally high concentrations of hydrocarbons and PAHs. Long-term sampling of sediments from lower reaches of tributaries in this portion of the RAMP FSA (i.e., Tar, Ells, and Calumet rivers) by RAMP and others has demonstrated regionally high PAH concentrations in these watersheds. Sediment quality at all other stations showed **Negligible-Low** differences in sediment quality from regional *baseline* conditions (Table 7.1-1).

7.3.2.2 Recommendations

Given ongoing changes in the hydrology of the Athabasca River Delta, and the apparent influence of hydrology on sediment transport, deposition, and quality in the delta, consideration should be given to the use of sediment traps in some channels (especially Fletcher Channel), to estimate sediment deposition rates and also to specifically assess concentrations of hydrocarbons and metal in sediments deposited in the ARD in a given year.

7.4 FISH POPULATIONS

The 2012 RAMP Fish Populations component consisted of:

- fish inventories on the Athabasca and Clearwater rivers;
- fish assemblage monitoring on tributaries to the Athabasca and Clearwater rivers and on channels of the Athabasca Delta;
- a fish assemblage survey on Christina Lake;
- a sentinel species program using slimy sculpin on tributaries to the Athabasca and Clearwater rivers; and
- a fish tissue program on the Clearwater River and Gregoire Lake.

7.4.1 Summary of 2012 Results

7.4.1.1 Fish Inventory

In 2012, the analysis of the Athabasca River and Clearwater River fish inventories focused on seasonal and spatial trends over time of catch per unit effort, 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.

As of 2012, current and historical fish inventory data from the Athabasca River indicated species-specific variability in relative abundance, age-frequency distributions, and condition of fish among years. There has been a significant increase in the catch and

CPUE of goldeye in the last two years (i.e., 2011 and 2012) and although it is uncertain what has caused the observed increase in goldeye numbers in the Athabasca River, it could be related to the higher tolerance value of this species (9.3) compared to other species found in this region. However, it is important to note that the despite the increase in goldeye in the river, the absolute abundances of other KIR species has not concomitantly decreased and also have tolerance values that are almost as high as goldeye. More data are necessary to determine any trends and evaluate the cause of the increase in goldeye numbers.

The fish health assessment indicated that abnormalities observed in 2012 in all species were within the historical range and consistent with studies done prior to the major oil sands development in the upper Athabasca River, the ARD, and the Peace Slave rivers.

Total fish captured in the Clearwater River during the fall fish inventory has varied across years, which can be partially attributed to variability in discharge. In lower flow years, the amount of available fish habitat and the accessibility of the river is limited. Species richness across reaches in spring 2012 was higher than previous years, with the exception of 2007 and 2008. Species richness was also higher than previous sampling years in fall 2012. Species richness at the *test* reach was generally consistent with *baseline* reaches across years for spring and summer. In fall, species richness was generally higher in the *baseline* reaches than the *test* reach.

The relative abundance of fish species in the Clearwater River was variable without any clear trends observed over time. Similarly, there has been no marked shift in species dominance from year to year. Additionally, there have been no significant differences in condition of large-bodied KIR fish species in the *test* reach of the Clearwater River when compared to *baseline* data. It is important to note; however, that condition cannot necessarily be attributed to the environmental conditions in the capture location, as these fish populations are highly migratory throughout the region

7.4.1.2 Fish Assemblage Monitoring

Assessing potential changes in fish populations from focal projects and other oil sands developments is an ongoing challenge due to limitations in the ability to effectively sample all fish populations in the RAMP FSA and the fact that not all elements of the Fish Populations component are conducted every year, resulting in limited temporal data. In addition to these challenges, large-bodied fish are highly migratory between and within waterbodies in the RAMP FSA, making it difficult to differentiate differences between natural variability in fish populations and potential changes related to focal projects and other oil sands developments. Recognizing these limitations, a Fish Assemblage Monitoring program was initiated in 2011 following a two-year pilot study as a new approach to monitoring fish populations in the RAMP FSA. Fish assemblage monitoring was conducted on major tributaries in the oil sands region, on channels of the Athabasca River Delta, and in Christina Lake. Fish assemblage monitoring was conducted for the first time in 2012 in the delta and Christina Lake. A summary of the key findings from the 2012 results are provided below.

River Reaches

Fish assemblage monitoring characterizes changes in river reaches that are considered most likely to be affected by focal projects. Within the major tributaries, samples are 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 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, 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:

- Muskeg River – lower reach;
- Jackpine Creek;
- Steepbank River;
- Tar River;
- MacKay River;
- Calumet River;
- Ells River;
- Christina River;
- Sunday Creek;
- Jackfish River;
- Poplar Creek; and
- Fort Creek.

Differences in measurement endpoints for fish assemblages were classified as **Moderate** compared to regional *baseline* conditions at the following *test* reaches given that at least three of the four measurement endpoints exceeded the range of variability for *baseline* reaches, in a direction suggesting negative change:

- Muskeg River – middle and upper reaches; and
- Sawbones Creek.

There were no differences in fish assemblages between *test* reaches and regional *baseline* conditions that were classified as **High**.

Delta Channels

In 2012, the RAMP Fish Populations subgroup decided to expand the tributary fish assemblage monitoring program 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 by the Joint Oil Sands Monitoring Plan (Environment Canada and Government of Alberta 2012).

Alternative fishing methods to backpack electrofishing were required given the size and depth of the channels in the delta. Seining, fykenets, hoopnets, and minnow traps were used to capture fish. Gillnetting was not used given the potential for high mortality rates in river systems. There were difficulties in effectively sampling these channels given the limited spatial coverage that these fishing methods allowed and the difficulty in effectively using these fishing methods in non-wadeable and soft substrate habitat conditions. In fall 2012, a total of 445 fish comprised of 11 fish species were captured across the four channels of the delta. Of the 11 species, there were six small-bodied and five large-bodied fish species captured. Based on fish data collected during the Athabasca River fish inventory program, the total catch and species composition was much lower in these channels and likely did not adequately capture the full fish assemblage nor provided adequate spatial coverage of the sampled channels given the water depth and wetted width. Recommendations to improve the program in future years of monitoring are provided in Section 7.4.2.

Christina Lake

With the addition of new RAMP member companies operating in the Christina Lake area, a fish assemblage study was conducted on Christina Lake in 2012. The program was designed to provide a *baseline* assessment of the fish assemblage in the lake prior to any major development in the area and to supplement existing AESRD fish population information that has been collected in the lake in 2003 and 2008.

A total of 784 fish in nine species were captured using the three methods during the fish assemblage survey in Christina Lake in summer 2012. Two species captured during the RAMP 2012 survey had not been previously documents in either Christina Lake or its tributaries, including the Iowa darter (*Etheostoma exile*) and northern redbelly dace (*Phoxinus eos*). Fishing locations were randomly selected throughout the lake for the 2012 survey. However, the lake has two main basins separated by a shallower narrow channel, with a smaller basin at the north end of the east basin. A comparison of CPUE by boat electrofishing indicated much higher captured success in the east basin of the lake compared to the west basin.

7.4.1.3 Sentinel Species Monitoring

A sentinel species monitoring program using slimy sculpin was undertaken at *test* sites on the lower Muskeg and lower Steepbank rivers. Slimy sculpin from the lower *test* site on the Steepbank River were compared to *baseline* sculpin from the upper Steepbank River, Horse River, High Hills River and the Dunkirk River. Similar comparisons were not possible for the *test* site on the Muskeg River given the small sample size of slimy sculpin captured at this location.

There were several significant differences between sculpin from the *test* site on the lower Steepbank River and sculpin from individual *baseline* sites; however, when the *baseline* sites were pooled, there were very few differences observed at the *test* site (i.e., only an increase in LSI in male slimy sculpin). These results suggest there was substantial variability in slimy sculpin populations among *baseline* sites, likely related to variability in habitat conditions. Accordingly, to minimize the range of *baseline* variability, the classification of results focused on comparisons between the lower (*test*) and upper (*baseline*) Steepbank River sites given both sites are part of the same river system and; therefore, share similar habitat characteristics. Results from this comparison, within the context of established effects criteria, indicated that slimy sculpin at the lower *test* site of the Steepbank River exhibited an increase in weight-at-age (growth) in males and females and a decrease in GSI (gonadal development) in males. Growth and GSI typically covary as they both reflect energy use. As such, it is uncertain as to why this is not the case in this instance; however, slimy sculpin, particularly males, are in a stage of early gonadal development in fall, which could lead to increased variability in this measurement endpoint. Generally, slimy sculpin at the *test* site were larger, heavier and exhibited higher growth compared to slimy sculpin at the *baseline* site, which suggests a response to increased availability of food resources at this site.

Based on the results of the 2012, which provided inconsistent response patterns in energy use (growth, LSI, and GSI) in female and male slimy sculpin at *test* site SR-E, the differences from the *baseline* site were classified as **Negligible-Low**. Although the lower GSI could be indicative of a negative change, the higher growth of slimy sculpin at the *test* site was not indicative of a negative change and could suggest an increase in food resources at this site.

7.4.1.4 Fish Tissue

In 2012, the potential risk to human health related to fish consumption was assessed using muscle samples of northern pike collected from the Clearwater River and northern pike and walleye collected from Gregoire Lake.

Measurement endpoints used in the fish tissue assessment included metals and tainting compounds in both individual and composite samples. In 2012, the mean concentration of mercury in northern pike was lower than in previous sampling years, with the exception of 2009. The mercury concentration in size classes of northern pike greater than 550 mm exceeded the subsistence fishers guideline for consumption, indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

Mercury concentrations in northern pike and walleye from Gregoire Lake in 2012 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in fish from Gregoire Lake were near the lower end of the historical range of mercury concentrations in fish sampled from other regional lakes.

7.4.2 Recommendations

The following recommendations are outlined to further improve monitoring conducted for the Fish Populations component:

1. Given the increase in fish monitoring in the region as a consequence of the Joint Oil Sand Monitoring Plan, there are concerns that fishing pressure related to monitoring activities will result in stress to fish populations, particularly in smaller streams, where there are typically small-bodied fish species, with short lifespans or juvenile large-bodied fish species. To minimize potential impacts related to monitoring it is recommended that RAMP continues to collaborate with Environment Canada and AESRD on lethal fish sampling in rivers and lakes in the region.

2. It is recommended that RAMP continues to work with AESRD and Environment Canada on fish monitoring activities to further harmonize fishing methods and data collection, which will eventually result in more efficient sampling in the region and increased data and information sharing to meet the objectives of all stakeholder needs.

3. In response to community concerns regarding the health of fish in watercourses within the RAMP FSA, RAMP is continuing to collect data on fish abnormalities and working with a fish pathologist to develop a better understanding of abnormalities in fish in Northern Alberta. RAMP is facilitating the analyses of fish

with abnormalities submitted by community members and continues to find means to work with communities to assess fish health.

4. For fishing in the delta, if water levels are adequate, an electrofishing boat should be taken to the delta to conduct the sampling. This approach is consistent with methods used for the Athabasca River fish inventory program, and will allow better spatial coverage and increased capture success such that data collected will more accurately represent the fish assemblage present in the delta. Two boats with a crew of six could be used to conduct the sampling. Alternatively, if water levels are too low, RAMP will discuss with AESRD the possibility of using gillnets in the channels, and checking the nets frequently (i.e., every two hours) to minimize mortality rates.
5. If a survey was conducted again on Christina Lake, it is recommended that the two main basins be considered separately when selecting sites in order to examine for any potential differences between basins.

7.5 ACID-SENSITIVE LAKES

7.5.1 Summary of 2012 Results

The chemistry of the 50 ASL component lakes (RAMP lakes) in 2012 was significantly different than observed in previous years. The median concentrations of pH, Gran alkalinity, conductivity, TDS, sum of base cations, and DOC were higher in 2012 than all previous years of sampling (2002 to 2012). In among-year comparisons, pH, Gran alkalinity, TDS, conductivity, sodium, potassium, and sum of base cations significantly increased over time, and in most cases, in both *baseline* and *test* lakes. None of these changes suggested acidification of the RAMP lakes from NO_xSO_x emissions but rather hydrological changes over time, in particular, a possible increase in the role of surficial groundwater on lake chemistry.

Critical loads were calculated using values of runoff for each year derived from an isotopic mass balance technique (Gibson et al. 2010). Critical loads in 2012 ranged from -1.014 keq H^+/ha/yr to 4.25 keq H^+/ha/yr with a median CL of 0.669 keq H^+/ha/y. The median critical load was greater in 2012 than in previous years because of the higher concentrations of base cations and alkalinity in the RAMP lakes in 2012. 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, are the most acid-sensitive of the RAMP lakes.

The critical load of acidity for each individual lake was compared to the modeled rate of acid deposition in each catchment published in the Teck Frontier EIA (i.e., net potential acid input to net PAI ration). A total of 10 (20%) of the 50 lakes had critical loads exceeded by the Net PAI. Six of the 10 lakes were found in the Stony Mountains subregion.

Time trend analysis was applied to key measurement endpoints in the 50 individual RAMP lakes to detect changes indicative of acidification. As in previous years, all of the 14 significant trends in measurement endpoints in a direction indicative of acidification were either small and within the range of analytical error or inconsistent with any reasonable acidification scenario. Consistent with the results from the ANOVA, there were significant increases (rather than decreases) in Gran alkalinity and pH in 12 and 13 lakes, respectively.

Shewhart control charting was applied to the measurement endpoints in order to detect acidifying trends in ten individual lakes most at risk to acidification. The ten lakes were selected for control charting based on an acidification risk factor calculated from the ratio of potential acid input to the value of the critical load. The ten lakes were scattered throughout the oil sands region in the Stony Mountains (6), Birch Mountains (2), Northeast of Fort McMurray (1) and West of Fort McMurray (1) subregions. While the control charts showed a number of isolated exceedances of the two standard deviation limits in individual lakes, there was no suggestion of real trends in these lakes indicative of acidification. Concentrations of nitrates were highly variable and could range over three orders of magnitude within a lake.

Based on the analysis of among-year differences in concentrations of measurement endpoints, trend analysis and control plotting of measurement endpoints on individual lakes, there is no evidence to suggest that acidification is occurring in the RAMP lakes although chemical changes in these lakes were evident.

A summary of the state of the RAMP lakes in 2012 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 (in a direction indicative of acidification) for each lake. All six subregions were classified as having a **Negligible-Low** indication of incipient acidification.

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9.0 GLOSSARY AND LIST OF ACRONYMS

9.1 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 9^{o} (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).

CONRAD	Canadian Oil Sands Network for Research and Development
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., longnose sucker, 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.
Health Assessment Index	A quantitative summary of pathology where variables examined are assigned numerical values (either 0, 10, 20 or 30) to indicate normal or abnormal condition. In this system, variables that exhibit an increasing degree of pathology are assigned higher values. The HAI is calculated by summing the index values for each species and dividing by the total number of individuals captured of that species. The HAI value increases as the number and severity of anomalies increases. Based on the Health Assessment Index (HAI) developed by Adams *et al*. (1993).
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.
Sport/Game Fish	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.

9.2 LIST OF ACRONYMS

ABMI	Alberta Biodiversity Monitoring Institute
ADL	analytical detection limit
ADC	Acoustic Digital Current
ADV	Acoustic Doppler Velocimeter
AED	Alberta Economic Development
AESRD	Alberta Environment and Sustainable Resource Development
AEP	Alberta Environment Protection
AITF	Alberta Innovates Technology Futures
Albian	Albian Sands Energy Inc.
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
ARC	Alberta Research Council
ARD	Athabasca River Delta
ASL	Acid Sensitive Lakes
ASRD	Alberta Sustainable Resource Development
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
Birch Mountain	Birch Mountain Resources Ltd.
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
CFRAW	Carbon Dynamics, Food Web Structure, and Reclamation Strategies in Athabasca Oil Sands Wetlands (CFRAW)

CL	Critical Load
CNRL	Canadian Natural Resources Limited
COC	chain of custody
CONRAD	Canadian Oil Sands Network for Research and Development
COSI	Centre for Oil Sands Innovation
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 Protection Agency (US)
EPT	Ephemeroptera, Plecoptera and Trichoptera
ERCB	Energy Resources Conservation Board
EROD	Ethoxyresorufin-O-deethylase
FAM	Fish Assemblage Monitoring
FWMIS	Fisheries and Wildlife Management Information System
FSA	Focus Study Area
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
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
MFO	Mixed-function Oxygenase
NAD	North American Datum
NRBS	Northern River Basins Study
NSERC	Natural Sciences and Engineering Research Council of Canada
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
RSA	Regional Study Area
RSDS	Regional Sustainable Development Strategy
SAGD	Steam Assisted Gravity Drainage
SD	Standard Deviation
SM	Surface Mine
SOP	Standard Operating Procedures
SPOT-5	Satellite Pour l'Observation de la Terre
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