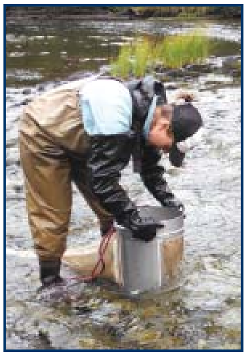
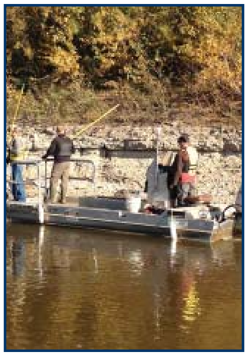
RAMP

Regional Aquatics Monitoring Program





2013 TECHNICAL REPORT

FINAL

REGIONAL AQUATICS MONITORING PROGRAM

2013 Technical Report

Prepared for:

RAMP STEERING COMMITTEE
IN SUPPORT OF THE JOSMP

Prepared by:

The RAMP 2013 Implementation Team

Consisting of:

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

APRIL 2014
RAMP6221.2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

Funding for RAMP in 2013 was provided by Brion Energy Corp. (Brion), Canadian Natural Resources Limited (Canadian Natural), Cenovus Energy (Cenovus), Connacher Oil and Gas Ltd. (Connacher), ConocoPhillips Canada (ConocoPhillips), Devon Energy Corp. (Devon Energy), Hammerstone Corporation (Hammerstone), Husky Energy (Husky), Imperial Oil Resources (Imperial Oil), Japan Canada Oil Sands Limited (JACOS), MEG Energy Corp. (MEG Energy), Nexen Inc. (Nexen), Shell Canada Energy (Shell), Statoil Canada Ltd. (Statoil), Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude), Teck Resources Ltd. (Teck), and Total E&P Canada Ltd. (Total E&P). The RAMP 2013 program was conducted in support of the Joint Oil Sands Monitoring Plan (JOSMP).

The RAMP chairperson during the 2013 program year was Sarah Aho (Suncor) until June and then Kim Westcott (AESRD) for the remainder of the year. Rod Hazewinkel (AESRD) was chair of the Technical Program Committee, National Public Relations served as Communications Coordinator for RAMP, and Hatfield Consultants managed and implemented the program on behalf of the Steering Committee. Implementation of the program was assisted by Kilgour and Associates Ltd (Benthic Invertebrate Communities component) and western Resource Solutions (Acid-Sensitive Lakes component).

RAMP is a multi-stakeholder environmental monitoring program that is composed of representatives from industry; municipal, provincial and federal governments, and local Aboriginal groups. 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, 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 the RAMP report;
- Environment Canada for assisting with field work required for the Fish Populations component;
- Water Survey of Canada (WSC) for access to their hydrology data for stations in the oil sands region;
- AESRD for conducting the field work required for the Acid-Sensitive Lakes component; and
- Local residents/anglers who provided information for the Fish Tag Return Program.

In addition, the 2013 RAMP Implementation Team would like to acknowledge the following contractors and laboratories that assisted with the program:

- Alberta Innovates Technology Futures (chemical analyses);
- ALS Laboratory Group (chemical analyses – water, sediment, fish tissue);
- AXYS Analytical Services Ltd. (chemical analyses);
- Dr. Jack Zloty (benthic invertebrate taxonomy);
- Flett Research Ltd. (non-lethal fish tissue analyses);
- HydroQual Laboratories Ltd. (toxicity testing);
- NorthSouth Consultants Inc. (fish ageing);
- University of Alberta Limnological Laboratory (chemical analyses for ASL component); and
- Dr. John Gibson, University of Victoria (run-off estimates for ASL component).

2013 IMPLEMENTATION TEAM

The RAMP Implementation Team for 2013 included the following personnel from Hatfield Consultants Partnership (HCP), Kilgour and Associates Ltd. (KAL), and Western Resource Solutions (WRS):

Program Director:	Wade Gibbons (HCP)
Program Manager/Fish Populations Manager:	Heather Keith (HCP)
Water and Sediment Quality Manager:	Martin Davies (HCP)
Water and Sediment Quality Assistant Manager:	Jasmin Gee (HCP)
Fish Populations Assistant Manager:	Chris Briggs (HCP)
Climate and Hydrology Manager:	Steven Guenther (HCP)
Climate and Hydrology Assistant Manager:	Shane MacLeod (HCP)
Benthic Invertebrate Communities Manager:	Bruce Kilgour (KAL)
Acid-Sensitive Lakes Manager:	Daniel Andrews (WRS)
Additional Component Assistance:	Alyson Thompson (HCP) Andrew Doucette (HCP) Aurora Jansen (HCP) Chris Jaeggle (HCP) Colin Schwindt (HCP) Daisy Ngai (HCP) Dan Bewley (HCP) David Wilson (HCP) Felicia Juelfs (HCP) Glen Bruce (HCP) Jackie Porteous (HCP) Jason Van Rooyen (HCP) Jennifer Carter (HCP) Jim Johnson (HCP) Jocelyn Beniuk (HCP) Kristy Wade (HCP) Laura Reimer (HCP) Lise Galand (HCP) Liza Hamilton (KAL) Muluken Yeheyis (HCP) Ryan Martin (HCP) Sarah Quesnelle (HCP) Serafina Dalla-Longa (HCP) Theoren Ellis (HCP) Tim Rowe (HCP) Wendy Taylor (HCP) Xavier Pinto (HCP)
Geomatics and Database	Zhanxun Lu (HCP) Susan Stanley (HCP) Jason Suwala (HCP) Aneeqa Syed (HCP)
Document Production	Tatyana Kovyneva (HCP) Devon Wells (HCP) Tania Pye (HCP) Kim Behnke (HCP)

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 2013, RAMP was funded by Brion, Canadian Natural Resources Limited, Cenovus, Connacher, ConocoPhillips, Devon Energy, Hammerstone, Husky, Imperial Oil, JACOS, MEG Energy, Nexen, Shell, Statoil, Suncor, Syncrude, Teck, and Total E&P. Non-funding participants included municipal, provincial, and federal government agencies, and two Aboriginal groups. In 2013, the RAMP program was conducted in support of the Joint Oil Sands Monitoring Plan (JOSMP) but was also operating independently to the extent that the results from monitoring activities were completed to meet the requirements of approval conditions for industry members. The enhanced monitoring conducted under the JOSMP is in addition to monitoring requirements outlined in regulatory approvals (e.g., RAMP).

The original Regional Municipality of Wood Buffalo boundary (pre-2013) 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);
- Select minor tributaries to Christina Lake (Sunday Creek, Birch Creek, Jackfish River, Sawbones Creek, and two unnamed creeks);
- Specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- A selected group of 50 regional acid-sensitive lakes.

The RAMP FSA also includes the Athabasca River Delta as the receiving environment for 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 2013 Technical Report to define those projects owned and operated by the 2013 industry members of RAMP listed above that were under construction or operational in 2013 in the RAMP FSA. For 2013, these projects included a number of oil sands projects and a limestone quarry project.

2013 RAMP industry members do have other projects in the RAMP FSA that were in the application stage as of 2013, or had received approval in 2013 or earlier, but construction had not yet started as of 2013. These projects are noted throughout this technical report, but are not designated as focal projects, as these projects in 2013 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 2013 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 measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources.

The RAMP 2013 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 2013) or were (prior to 2013) 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 2013 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 2013, it was estimated that approximately 117,850 ha (3.3%) 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 2013 varied from less than 1% for many watersheds (MacKay, Christina, Hangingstone, Horse, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, and Ells watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

ASSESSMENT OF 2013 MONITORING RESULTS

A tabular summary of the 2013 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology The 2013 WY water balance was calculated for two different cases: (i) only focal projects in the Athabasca River watershed; and (ii) focal projects plus other oil sands developments in the Athabasca River watershed. 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 for the Athabasca River were 0.6%, 1.7%, 0.6% and 1.1% lower, respectively, than from the estimated *baseline* hydrograph. These differences were all classified as **Negligible-Low**. The results of the hydrologic assessment for focal projects 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 2013 at all stations in the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at *baseline* stations on the east and west banks of the Athabasca River upstream of Donald Creek and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded the guideline at all stations in fall 2013 and total boron continued to show an increasing trend at the *test* station on the west bank of the Athabasca River, downstream of all development, and at both *test* stations on the east and west banks of the Athabasca River, upstream of the Muskeg River.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2013:

1. Differences in measurement endpoints for benthic invertebrate communities in Big Point Channel were classified as **Negligible-Low** because although there was a significant change in CA Axis 2 scores between 2013 and previous sampling years, the change did not indicate degradation of the benthic invertebrate community. Additionally, all

measurement endpoints of benthic invertebrate communities were within historical range of variability for reaches of the ARD.

2. Differences in measurement endpoints of benthic invertebrate communities in Goose Island Channel were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa and decrease of CA Axis 1 and 2 scores were not indicative of a negative change. In addition, all measurement endpoints were within the range of variability from previous sampling years in the ARD.

3. Differences in measurement endpoints for benthic invertebrate communities in Fletcher Channel were classified as **Moderate** because of the significant increase in equitability, exceeding the historical range of variability, and a decrease in richness over time. However, the benthic invertebrate community contained EPT taxa in relatively high abundances (3%), which was higher than 2012.

4. Differences in measurement endpoints of benthic invertebrate communities in the Embarras River were classified as **Moderate** because of the significant decreases in abundance, richness, and CA Axis 1 scores over time. However, there were some EPT taxa present and all measurement endpoints were within the range of variation from previous years, which indicated that conditions of this river have not significantly degraded.

In 2013, stations of the ARD were predominantly comprised of sand, with the exception of the Embarras River and Fletcher Channel where silt substrate 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, with the exception of PAHs, which were generally higher in 2013 in the Embarras River and Fletcher Channel. The concentrations of PAHs at all stations in fall 2013 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 Big Point Channel, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2013, the concentration of total PAHs at Big Point Channel was below previously-measured concentrations. The PAH Hazard Index at all stations in the ARD exceeded the potential chronic toxicity threshold value of 1.0. Chronic toxicity data for sediments exceeded the maximum ten-day growth for the midge *Chironomus* at all stations in 2013. Generally survival of *Chironomus* and *Hyalella,* and fourteen-day growth of *Hyalella* were within previously-measured values in fall 2013. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

Fish Populations (fish inventory) The objective of the fish inventory program was to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individuals within these populations.

As of 2013, 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. Goldeye and lake whitefish were among the large-bodied KIR species that have exhibited the greatest increase in abundance over time. Significant increases were observed in total catch and catch-per-unit-effort (CPUE) of goldeye in the last three years (i.e., 2011 to 2013), potentially due to warm, calm, spring seasons over the last three years, which can provide favourable conditions for goldeye recruitment. Similarly, CPUE of lake whitefish in fall 2013 was higher than previous years. Both goldeye and lake whitefish have shown significant increases at the majority of *test* reaches in fall since 1997. Furthermore, shifts toward older dominant age classes and significant increases in mean condition were observed in both species.

The fish health assessment indicated that abnormalities observed among all species in 2013 were within the historical range and consistent with studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Fish Populations (sentinel species) The effects criteria for age, weight-at-age, relative gonad weight, and relative liver weight defined by Environment Canada (2010) are a ± 25% difference between a *test* site and the *baseline* site (upstream of Poplar Creek and oil sands development) and a ± 10% difference for condition (body weight at length). Differences greater than the effects criteria between *baseline* and *test* sites suggested an ecologically relevant change in the trout-perch population at the *test* site.

A difference in measurement endpoints that exceeded the Environment Canada effects criteria was observed for age of female trout-perch and gonad weight of male trout-perch at the *test* site downstream of the confluence with the Firebag River. The age of female trout-perch at this site was 25.2% younger than for trout-perch at the *baseline* site, which was also observed in female trout-perch at this *test* site in 2010. The gonad weight of male trout-perch at the *test* site, downstream of the confluence with the Firebag River, was 25.3% greater than trout-perch at the *baseline* site, which was also observed in 2002, but the opposite pattern was observed in 2010. With no other exceedances in response patterns, and given that the 25% criteria were only marginally exceeded, these results suggested very little variability in trout-perch populations among *test* sites, downstream of development relative to the *baseline* site in 2013.

Based on the results in 2013, which provided fairly consistent response patterns in energy use and energy storage (growth, gonad weight, and liver size) in female and male trout-perch at *test* sites of the Athabasca River, differences from the *baseline* site were classified as **Negligible-Low**.

Fish Populations (fish assemblages) Results of the fish assemblage monitoring in the ARD indicated high species richness and abundance across all channels, with the highest catches observed in Big Point Channel and the Embarras River. The dominant species included small-bodied fish species (emerald shiner and lake chub) as well as northern pike as the dominant large-bodied species. Measurement endpoints were fairly consistent across channels, with high assemblage tolerance index (ATI) values reflecting the tolerant nature of fish species in the delta. The fish assemblage observed in the channels of the ARD was consistent with the species composition in the Athabasca River, as documented during the RAMP fish inventory surveys.

Muskeg River Watershed

Hydrology The calculated mean open-water discharge and the annual maximum daily discharge were 6.12% and 7.40% lower, respectively, in the observed *test* hydrograph for the Muskeg River than in the estimated *baseline* hydrograph. These differences were classified as **Moderate**. The mean winter discharge was 0.25% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low.** The open-water period minimum daily discharge was 15.32% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **High**.

In the 2013 WY, the water level in Kearl Lake steadily decreased from November 2012 to mid-February 2013, and then fluctuated between historical minimum and historical lower quartile values until the beginning of the freshet in mid-April. Lake water levels exceeded the historical maximum values from June 11 to June 26 in response to rainfall events in early to mid-June. Rainfall events in early October also increased the lake level to above the historical median level until the end of the 2013 WY.

Water Quality In fall 2013, concentrations of most water quality measurement endpoints for stations in the Muskeg River watershed were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2013 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

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

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2013:

1. Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase in total abundance over time and the high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies were indicative of good water and habitat conditions. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. Equitability was lower than the historical range of variability, indicating that diversity in the reach was increasing, which was considered a positive change.

2. Differences in measurement endpoints of benthic invertebrate communities at the middle *test* reach of the Muskeg River were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa was indicative of a positive change and all measurement endpoints were within the historical range of variation for this reach.

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

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 increases in abundance and richness and a decrease in equitability over time during the period that this reach was designated as *test*, these changes were not indicative of degraded conditions.

5. Differences in measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Negligible-Low** because there were no statistically large changes in any measurement endpoints. Additionally, the benthic invertebrate community of Kearl Lake included diverse fauna, with several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves). All measurement endpoints for benthic invertebrate communities in Kearl Lake were within the historical range of variation for Kearl Lake.

Concentrations of sediment quality measurement endpoints at all sampled stations in the Muskeg River watershed in fall 2013 were similar or lower than previously measured and within the range of regional *baseline* conditions. Differences in sediment quality in fall 2013 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 of the fish assemblage at the lower *test* reach of the Muskeg River were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there was a decrease in abundance and CPUE over time, which are indicative of a potential negative change in the fish assemblage. Differences in measurement endpoints for fish assemblages between the middle *test* reach of the Muskeg River and regional *baseline* conditions were classified as **Moderate** because CPUE and abundance were lower than the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between the upper *test* reach of the Muskeg River and regional *baseline* conditions were classified as **High** given that only one fish was captured at this reach in 2013, and CPUE, abundance, diversity, and richness were near the 5th percentile of regional *baseline* conditions in 2012 and 2013. The low capture success was likely due to greater water depths in the last two years, which decreased capture efficiency. Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Jackpine Creek were classified as **High** because richness and CPUE were below the 5th percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints over time, which were indicative of a potential negative change in the fish assemblage.

Steepbank River Watershed

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

Water Quality Concentrations of most water quality measurement endpoints at stations in the Steepbank River watershed in fall 2013 were within previously-measured concentrations. When compared with regional *baseline* conditions, concentrations of water quality measurement endpoints were generally consistent. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2013 was similar to previous years. Differences in water quality in fall 2013 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 of the benthic invertebrate community at the lower *test* reach of the Steepbank River were classified as **Moderate** because of significantly lower abundance, richness, and percent EPT compared to the upper *baseline* reach. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach. Differences in the benthic invertebrate communities between the upper and lower reaches may be related to natural differences in substrate texture. The substrate at the lower *test* reach was slightly more dominated by finer cobble, gravel, and sand than the upper *baseline* reach, and was more embedded; therefore, there was less surface area for benthic organisms to colonize.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at the lower *test* reach of the Steepbank River were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there were significant decreases in abundance, richness, and CPUE over time, which were indicative of a potential negative change in the fish assemblage, although the increased embedded substrate at this reach could have resulted in less cover and suitable habitat for fish over time.

Tar River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 28.8% lower in the observed *test* hydrograph for the Tar River than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Water Quality Differences in water quality observed in fall 2013 between the lower *test* station of the Tar River and regional *baseline* conditions were classified as **Moderate**. In fall 2013, most water quality measurement endpoints at the upper *baseline* station and the lower *test* station were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations, with the exception of total suspended solids and various total metals, which were higher than previously measured at the lower *test* station in fall 2013. A classification was not completed for the upper *baseline* station due to a laboratory error resulting in an incomplete set of data; only total and dissolved metals were analyzed for this station in 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Tar River were classified as **Moderate** because abundance, richness, and equitability differed between the *baseline* and *test* periods for this reach. The percentage of EPT taxa was lower in 2013 than it has been since 2006 and diversity decreased from 2012. All measurement endpoints of benthic invertebrate communities were within the historical range of variation for the lower Tar River, with the caveat that there were no mayflies or caddisflies, which were present during the *baseline* period and in most previous sampling years. Differences in sediment quality observed in fall 2013 between the lower *test* station and regional *baseline* conditions were classified as **Moderate**. Concentrations of benz[a]anthracene, benzo[a]pyrene, chrysene, dibenzo(a,h)anthracene, and total arsenic exceeded previously-measured maximum concentrations for the lower *test* station and also exceeded relevant 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 all measurement endpoints were within the range of regional *baseline* variability and there were no significant trends over time in any of the measurement endpoints.

MacKay River Watershed

Hydrology The 2013 WY water balance was calculated for two different cases: (i) only focal projects in the MacKay River watershed; and (ii) focal projects plus other oil sands developments in the MacKay River watershed. The 2013 WY water balance mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge for the first case were 0.006%, 0.004%, 0.004%, and 0.004% lower, respectively, in the observed *test* hydrograph for the MacKay River than in the estimated *baseline* hydrograph. For the second case these same measurement endpoints were 0.010%, 0.012%, 0.012%, and 0.012% larger, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. For both cases, these differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints for stations in the MacKay River watershed were within the range of previously-measured concentrations, with the exception of phosphorus, which was higher than previously-measured maximum concentrations at all stations in fall 2013. Water quality measurement endpoints for stations in the MacKay River watershed in fall 2013 were within the range of regional *baseline* concentrations, with the exception of potassium, which was below the 5th percentile at all stations and chloride, which was below the 5th percentile of regional *baseline* concentrations at the middle *test* and upper *baseline* stations of the MacKay River. Differences in water quality in fall 2013 at the lower *test*, middle *test*, and upper *baseline* station relative to regional *baseline* water quality conditions were classified as **Negligible-Low**. Monthly concentrations of most water quality measurement endpoints exhibited fluctuations throughout 2013 at the upper *baseline* station of the MacKay River. Typically, the maximum concentration of total and dissolved metals occurred in April or May. Generally the maximum concentration of ions occurred in May and minimum concentrations occurred in April. The decrease in alkalinity and other ions in spring likely resulted from base-cation dilution by snowmelt and not from consumption of alkalinity by acidic compounds in snow. Despite the observed changes in ion concentrations, the ionic composition remained relatively stable throughout the year but was slightly less dominated by calcium in winter months

Benthic Invertebrate Communities Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of the MacKay River were classified as **Moderate** because equitability has significantly increased over time; percent EPT was significantly lower in 2013 compared to the upper *baseline* reach; and richness was lower than the historical and regional *baseline* variability. It should be noted; however, that there was an increase in the relative proportion of EPT taxa and a decrease in relative worm abundance from 2012 indicating an improvement in taxa composition from 2012 to 2013 at the lower *test* reach. Differences in measurement endpoints of benthic invertebrate communities at the middle *test* reach of the MacKay River were classified as **Negligible-Low** because the significant increase in percent EPT over time was not indicative of a negative change. The benthic invertebrate community at this *test* reach was representative of good overall water quality, with a high proportion of EPT taxa and a low relative abundance of worms.

Fish Populations Differences in measurement endpoints for the fish assemblage at the lower *test* reach of the MacKay River were classified as **High** because four of the five measurement endpoints (catch-per-unit-effort [CPUE], abundance, ATI, and diversity) were near the 5th percentile of regional *baseline* variability; there were significant decreases in diversity and richness over time; and diversity was significantly lower than at the upper *baseline* reach. Differences in measurement endpoints for the fish assemblage at the middle *test* reach of the MacKay River were classified as **Moderate** because abundance was near the 5th percentile of regional *baseline* variability and there were significant decreases in CPUE and abundance of fish over time.

Calumet River Watershed

Hydrology For the 2013 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge for the observed *test* hydrograph for the Calumet River were estimated to be 0.3% lower than from the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2013, water quality at the lower *test* station of the Calumet River showed **Negligible-Low** differences from regional *baseline* conditions**,** while the upper *baseline* station showed **Moderate** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured ranges at both stations; however, concentrations of many water quality measurement endpoints were outside the range of regional *baseline* concentrations at the upper *baseline* station in fall 2013 (e.g., major ions). The ionic composition of water at the lower *test* station was consistent with previous years while the ionic composition of water at the upper *baseline* station was less dominated by bicarbonate ions in 2013 than in the previous two sampling years.

Firebag River Watershed

Hydrology The 2013 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph for the Firebag River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water levels recorded at McClelland Lake were generally near the upper quartile and maximum values in the 2013 WY due to rainfall events in mid-June. Lake levels from July to mid-September varied between the historical median and upper quartile values.

Water Quality In fall 2013, 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 2013 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 2013. Concentrations of water quality measurement endpoints from McClelland Lake and Johnson Lake were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities for the lower *test* reach of the Firebag River were classified as **Negligible-Low** because the significant increase in taxa richness over time and the shift in CA Axis 2 scores due to a decrease in chironomids were not indicative of degradation. Total abundance and equitability were within the range of variability of previous sampling years and the lower *test* reach contained a variety of EPT taxa.

Differences in benthic invertebrate communities of McClelland Lake are classified as **Negligible-Low** because although there were statistically significant changes in some measurement endpoints, these changes were not indicative of negative conditions in the lake. Richness and the percentage of fauna as EPT taxa were significantly higher in 2013 than previous sampling years. The general composition of the benthic invertebrate community in terms of the presence of fully aquatic forms and presence of generally sensitive taxa including the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent with *baseline* conditions. The benthic invertebrate community of Johnson Lake had no EPT taxa in fall 2013, which have been observed in previous years; however, given that the number of EPT taxa has been very low in previous years, the absence of these taxa was not considered a negative change in the benthic invertebrate community of Johnson Lake. Worms (Tubifidae and Naididae) had a higher relative abundance in fall 2013 than previous years; however, bivalve clams had the highest abundance of all taxa, indicating that Johnson Lake is generally in fair condition.

Concentrations of sediment quality measurement endpoints at McClelland Lake, the lower *test* station of the Firebag River, and Johnson Lake were generally within the range of previously-measured concentrations in fall 2013. An exception was observed in McClelland Lake, where concentrations of PAHs exceeded previously-measured maximum concentrations and resulted in a higher PAH toxicity index. In fall 2013, sediment toxicity testing showed higher growth rates at all stations for the midge *Chironomus*, and higher growth rates for the amphipod *Hyalella* at McClelland Lake and the lower *test* station of the Firebag River. The sediment quality index value for the lower *test* station of the Firebag River indicated a **Negligible-Low** difference from regional *baseline* conditions.

Ells River Watershed

Hydrology The calculated mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.10% higher in the observed *test* hydrograph for the Ells River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2013 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 *test* station of the Ells River and were within the range of previously-measured concentrations and regional *baseline* conditions. The upper b*aseline* station of the Ells River, initiated in 2013, showed similar water quality to the lower *test* station, and was within regional *baseline* conditions in fall 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at the lower *test* reach of the Ells River were classified as

Moderate because the significant decrease in abundance, EPT taxa, and richness over time were indicative of potentially degrading conditions. Abundance in fall 2013 (48 organisms per sample or about 2,000 individuals/m^2) was the lowest observed at the lower *test* reach, and has previously ranged from 8,000 to 32,000 individuals/m^2. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) that have previously been sparse were absent in 2013 at this reach. All of the smaller and previously abundant organisms remained abundant in 2013. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Water velocity at the lower *test* reach in 2013 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and likely considered to be the explanation for the absence of larger forms of benthic invertebrates at the lower *test* reach in 2013. Flows were generally high in the 2013 open-water season due to significant rain events in June.

Differences in sediment quality observed in fall 2013 between the lower *test* station of the Ells River and regional *baseline* conditions were classified as **Moderate** likely due to high PAH concentrations compared to the regional range of *baseline* variability.

Fish Populations Differences in the fish assemblage in fall 2013 at the lower *test* reach of the Ells River were classified as **Moderate** because although the lower ATI value indicated a greater proportion of sensitive fish species (i.e., burbot, spoonhead sculpin), there were significant decreases in abundance and diversity over time.

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Namur Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in lake trout from Namur Lake in 2013 were above Health Canada consumption guidelines for subsistence fishers and general consumers indicating a **High** risk to the health of both consumers of lake trout.

Clearwater River Watershed

Hydrology There was no land change or water withdrawals or discharges in the Clearwater River watershed related to focal projects and other oil sands development in 2013. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

Water Quality In fall 2013, water quality at all stations in the Clearwater River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. All stations showed very similar ionic composition and no trends in measurement endpoints over time, with the exception of a decreasing trend in potassium at the lower *test* station of the Clearwater River. In 2013, there were many water quality guideline exceedances, particularly at the *baseline* station of the High Hills River in spring and summer. Concentrations of many water quality variables fluctuated across months in 2013 at the lower *test* and upper *baseline* stations of the Clearwater River. Despite these fluctuations, the ionic composition at both stations in the Clearwater River remained fairly consistent across the year. Concentrations of many water quality variables (e.g., metals) in May at the upper *baseline* station of the Clearwater River exceeded guidelines and frequently exceeded the regional *baseline* range for fall water quality.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate community at the *baseline* reach of the High Hills River contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and a relatively high diversity of chironomids. Historically, this reach contained a high relative abundance of naidid worms (42%), but the percentage of the fauna comprised by naidids in 2013 was considerably lower (19%) than previous years. The *baseline* reach of the 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) The Clearwater fish inventory is a community-based initiative primarily suited for assessing general trends in population variables such as species richness, abundance, and composition. Coupled with a decrease in total catch, species richness and abundance were relatively low in the Clearwater River watershed in 2013. Compared to 2012, total catch was notably lower in summer and fall, likely due to a decrease in available habitat resulting from lower discharge in the sampling reaches. White sucker and longnose sucker continued to dominate overall species composition while the abundance of goldeye had returned to historical ranges after an increase in catch in summer and fall 2012. The transient increase in goldeye abundance could be related to the warm, calm spring seasons that occurred in 2011 and 2012, that was not observed in 2013.

Following a shift towards a younger dominant age class in 2012, there was an increase in catch of older northern pike in 2013. In addition, significant increases in size-at-age across the last three years indicated that northern pike were larger at age in 2013. Conversely, a dominance of younger size classes continued to persist for walleye. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

Mean condition factor was relatively similar for the large-bodied Key Indicator Resource (KIR) fish species between *test* and *baseline* reaches in summer and fall 2013; northern pike and walleye showed slight differences, with higher condition at the *test* reach compared to the *baseline* reaches in summer. Historical data indicated considerable increases in condition for both longnose sucker and walleye in 2013. The percentage of external abnormalities increased slightly in 2013 compared to 2012, with the majority of abnormalities observed in white sucker and a higher percentage of abnormalities observed in summer.

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

Christina River Watershed

Hydrology The 2013 WY water balance was calculated for two difference cases: (i) only focal projects in the Christina River watershed; and (ii) focal projects plus other oil sands developments in the Christina River watershed. The calculated mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge for the first case were 0.05%, 0.05%, and 0.06% greater, respectively, in the observed *test* hydrograph for the Christina River than in the estimated *baseline* hydrograph and for the second case were 0.05%, 0.06%, and 0.06% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.** The mean winter discharge for both cases was 0.06% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

In the 2013 WY, water levels in Christina Lake generally decreased from November 2012 to mid-April 2013. Lake levels increased during freshet in early May to a freshet peak level of 554.907 masl on May 13, before decreasing until early June. Rainfall events in mid-June increased lake levels beyond the historical maximum levels and peaked at 555.335 masl on June 17. This peak lake level was the maximum daily level recorded in the 2013 WY and was 0.661 m higher than the historical mean annual maximum daily lake level. Lake levels steadily decreased from mid-July until the end of the 2013 WY.

Flows in Jackfish River increased during spring freshet and exceeded the historical maximum on May 13. Flows also increased in response to rainfall events in mid-June, exceeding the historical maximum flows from June 11 to July 21, 2013. The peak flow of 65.2 m^3/s on June 17, was the highest flow recorded from available data in the 2013 WY, and was 370% higher than the historical mean open-water maximum daily flow. Following this peak, flows sharply decreased until early July, and then increased due to rainfall events in mid-July. Flows generally decreased from mid-July to September, with values generally remaining above the historical median values.

Water Quality In fall 2013, water quality at *test* and *baseline* stations of the Christina River and tributaries of Christina Lake (i.e., Sawbones Creek, Sunday Creek, Unnamed Creek east of Christina Lake, Unnamed Creek south of Christina Lake, and Jackfish River) exhibited **Negligible-Low** differences from regional *baseline* conditions. The upper *baseline* station of the Christina River and the *baseline* station of Birch Creek (tributary of Christina Lake) indicated **Moderate** differences from regional *baseline* water quality conditions given that concentrations of several water quality measurement endpoints (e.g., total metals and nutrients) exceeded relevant guidelines and regional *baseline* conditions in 2013.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at the lower *test* station of the Christina River. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months. The highest number of water quality guideline exceedances occurred in May, June, and July, which were also the months where maximum yearly concentrations were most frequently reached.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at the *test* reach of the Christina River, upstream of the Jackfish River confluence, were classified as **Negligible-Low** because all measurement endpoints were within the range of variation for regional *baseline* erosional reaches. In addition the benthic fauna at this *test* reach in fall 2013, were representative of good overall water quality, with high taxa richness and percentage of the fauna as EPT taxa. Differences in measurement endpoints at the lower *test* reach of Sunday Creek were classified as **Negligible-Low** because the reach contained a benthic invertebrate community representative of a healthy depositional reach. Flying insects and permanent aquatic forms (snails, fingernail clams) complimented a diverse fauna of chironomids. Low overall abundance of worms suggested favourable water quality conditions in fall 2013 at this *test* reach. Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Sawbones Creek were classified as **Negligible-Low.** All measurement endpoints, with the exception of richness, were within the range of regional *baseline* conditions for depositional reaches. Richness has been high at this *test* reach in both 2012 and 2013, which was not considered to be a negative change in the benthic invertebrate community. In addition, the benthic invertebrate community of the *test* reach of Sawbones Creek was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects, and a low diversity of worms. Differences in measurement endpoints of benthic invertebrate communities at *test* reaches of unnamed creeks to the east and south of Christina Lake were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of variability for regional *baseline* depositional reaches. Richness was above the range and equitability was just below the range of *baseline* variability in 2013, both of which were indicative of a more diverse community compared to regional *baseline* reaches. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects. Differences in measurement endpoints of the benthic invertebrate community of Christina Lake in fall 2013 were classified as **Negligible-Low**, given that the community was relatively similar to 2012 and contained a diverse benthic fauna including several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies and caddisflies). Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Jackfish River were classified as **Negligible-Low** because the community was highly diverse and the decrease in percent EPT from 2012 was a minor change. All measurement endpoints, with the exception of abundance, were within regional *baseline* ranges. Abundance was higher than the 95th percentile of regional *baseline* reaches.

In fall 2013, concentrations of sediment quality measurement endpoints for depositional stations in the Christina River watershed were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations. Sediment quality in fall 2013 showed **Negligible-Low** differences at all stations from regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012.

Fish Populations (fish assemblages) Information on fish assemblages for the southern oil sands region is just beginning to be collected; therefore, a comparison with *baseline* conditions in the northern region was conducted. Differences in measurement endpoints at the *test* reach of the Christina River, upstream of the confluence of Jackfish River, were classified as **Negligible-Low** given that most measurement endpoints were with the range of *baseline* variability and the low ATI value was not indicative of a negative change in the fish assemblage. Differences in measurement endpoints of fish assemblages for *test* reaches on Sunday Creek and Jackfish River (tributaries of Christina Lake) were classified as **Negligible-Low** compared to regional *baseline* conditions, with almost all measurement endpoints within the range of *baseline* variability, and lower ATI values, reflecting a greater proportion of sensitive fish species. Differences in measurement endpoints of fish assemblages for depositional *test* reaches on Sawbones Creek and unnamed creeks east and south of Christina Lake were classified as **High** because almost all measurement endpoints were lower than the range of variability for *baseline* depositional reaches (i.e., CPUE and abundance at all three; in addition to diversity and richness at reaches of Sawbones Creek and Unnamed Creek east of Christina Lake). In addition, only one fish was captured at the *test* reach of Unnamed Creek east of Christina Lake and no fish were captured at the *test* reach of Sawbones Creek. It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. In future years of monitoring, an effort will be made to sample in better fish habitat to assess fish assemblages in these creeks

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Christina Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in northern pike and walleye from Christina Lake in 2013 were above Health Canada consumption subsistence guidelines indicating a **High** risk to the health of subsistence fishers consuming northern pike and walleye. Given that all northern pike and most walleye exceeded the guideline for subsistence fishers, there was a **Moderate** risk to general consumers of northern pike and walleye, dependent on the quantity of fish consumed. Mercury concentrations in fish from Christina Lake were generally within 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% higher in the observed *test* hydrograph for the Hangingstone River than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Differences in water quality in fall 2013 between the lower and upper *test* stations of the Hangingstone River and regional *baseline* fall conditions were classified as **High**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative the regional *baseline* concentrations. Concentrations for water quality measurement endpoints were generally outside of their historical range (2004 to 2008) for the upper *test* station. Despite higher concentrations of dissolved ions than previously observed, the ionic composition at the upper *test* station in 2013 was similar to previous years.

Pierre River Area

Water Quality Differences in water quality in fall 2013 between the *baseline* stations of Big Creek, Pierre River, and Red Clay Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. Differences in water quality in fall 2013 between the *baseline* station of Eymundson Creek and regional *baseline* fall conditions were classified as **Moderate** as a result of several guideline exceedances and high concentrations of total arsenic, total suspended solids, total mercury (ultra-trace), etc. Eymundson Creek differed from the other stations (Big Creek, Pierre River, and Red Clay Creek) in this area in its ionic composition of water, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station. Eymundson Creek also had a higher concentration of total suspended solids than the other stations.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at the *baseline* reaches of Big Creek, Eymundson Creek, and Pierre River were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; and a low percentage of EPT taxa. The benthic invertebrate community at the *baseline* reach of Red Clay Creek was indicative of good water quality, with a lower abundance of worms and a high percentage of EPT taxa. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the RAMP FSA. Stations on Big Creek, Eymundson Creek, and the Pierre River had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions. No concentrations of sediment quality measurement endpoints exceeded sediment or soil quality guidelines at Big Creek, while only total arsenic exceeded the guideline at Eymundson Creek. Pierre River had many guideline exceedances, including CCME F3 hydrocarbons, total arsenic, chrysene, and phenanthrene. Survival of the midge *Chironomus* was fairly low at all stations (ranging from 46% to 64%) and predicted PAH toxicity values exceeded the chronic toxicity threshold at Eymundson Creek and Pierre River. No trend analysis or historical comparisons were possible at these stations because sediment quality sampling was initiated in these locations in fall 2013.

Fish Populations (fish assemblages) The fish assemblages at the *baseline* reaches of Big Creek, Eymundson Creek, Pierre River, and Red Clay Creek were similar to other *baseline* reaches in the area, and with each other. As with other reaches near the confluence to the Athabasca River, there was a high proportion of juvenile burbot captured at these reaches in fall 2013. Burbot is a sensitive species and likely contributed to the low ATI values at all of these reaches, which were near the 5th percentile of regional *baseline* conditions.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 1.63 million m^3 to Mills Creek. The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 56.5% lower in the observed *test* hydrograph for Mills Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**.

In the 2013 WY, lake levels of Isadore's Lake decreased from November to December 2012 and remained near historical minimum values until mid-March 2013. Lake levels exceeded the historical maximum lake levels from May 1 to May 8. Following this peak, lake levels decreased sharply until the lowest open-water lake level of 233.674 masl on June 4. Rainfall events in early to mid-June increased lake levels to above historical values by June 13, and remained between the historical upper quartile and maximum values until mid-October 2013.

Differences in water quality in fall 2013 between Mills Creek and regional *baseline* fall conditions were classified as **High**, due to relatively high concentrations of many ions and dissolved species that exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water in Isadore's Lake and Mills Creek showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

Differences in measurement endpoints of the benthic invertebrate community of Isadore's Lake were classified **Negligible-Low** because the significant increases in richness and percent EPT were indicative of positive changes in the lake. The percentage of the fauna as EPT taxa has always been <1% (normally EPT are absent); however, in 2013, EPT taxa accounted for 3% of the benthic community. CA Axis 1 and 2 scores were higher in 2013; however, this was due to a minor shift in taxa composition. All measurement endpoints were within historical variability for the lake. Isadore's Lake, historically, has had low diversity and a high abundance of nematodes making it unique compared to other lakes monitored by RAMP. In 2013, the relative abundance of nematodes was still high; however, other aspects of the benthic invertebrate community such as the percentage of the fauna as EPT taxa and richness have increased making the lake more consistent to other RAMP lakes. Sediment quality measurement endpoints were generally within the range of previously-measured concentrations at Isadore's Lake, with the exception of PAHs, which exceeded previously-measured concentrations except when normalized to 1% TOC. Concentrations of total arsenic, CCME F3 hydrocarbons, and dibenz(a,h)anthracene exceeded sediment/soil quality guidelines in fall 2013. An SQI was not calculated for Isadore's Lake because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2013 at the *test* station of Shipyard Lake were within previously-measured concentrations, with the exception of some ions and metals. The ionic composition of water at Shipyard Lake continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the watershed (90% of the Shipyard Lake watershed has been disturbed). The WQI was not calculated for lakes in 2013 due to potential ecological differences in regional water quality characteristics between lakes and rivers.

Differences in measurement endpoints for benthic invertebrate communities in Shipyard Lake in 2013 were classified as **Negligible-Low**. The significant increases in abundance and taxa richness were strong and implied that the observed changes were not caused by degradation of 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. In fall 2013, most sediment quality measurement endpoints were within the range of previously-measured concentrations at Shipyard Lake. Concentrations of total arsenic, F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene) exceeded sediment quality guidelines. Increasing trends were apparent for total alkylated PAHs, and F3 and F4 hydrocarbons. Shipyard Lake was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

Poplar Creek and Beaver River The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 247.8%, 77.0%, 18.6%, and 27.6% higher, respectively, in the observed *test* hydrograph for Poplar Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Concentrations of several water quality measurement endpoints, primarily ions, 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

Beaver River, differences in water quality in fall 2013 between the lower *test* station of Poplar Creek, the upper *baseline* station of Beaver River and regional *baseline* conditions were classified as **Negligible-Low**. Monthly concentrations of most water quality measurement endpoints exhibited some variability throughout the year at the lower *test* station of Poplar Creek, which were more apparent in the ionic composition of water and showed seasonal variability. Generally the highest concentrations of ions and metals occurred in December. Guideline exceedances occurred most frequently in April, May, and July; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

Differences in measurement endpoints of the benthic invertebrate community at the lower *test* reach of Poplar Creek were classified as **Moderate** because of the significant and large differences in abundance, equitability, percentage of fauna as EPT taxa, and CA axis scores compared to the upper *baseline* reach of the Beaver River. Richness and abundance have been decreasing since 2001 at the lower *test* reach of Poplar Creek and EPT taxa, which were increasing until 2012 have decreased in 2013. The lower equitability, which was below the 5th percentile of regional *baseline* conditions, did not denote a negative change, but suggested that the lower *test* reach of Poplar Creek was becoming more diverse. The benthic invertebrate community at the lower *test* reach of Poplar Creek was typical of a sand-bottom creek and dominated by worms and chironomids. Differences in sediment quality observed in fall 2013 between the lower *test* station of Poplar Creek, the upper *baseline* station of Beaver River and regional *baseline* conditions were classified as **Negligible-Low** with nearly all sediment quality measurement endpoints falling within the range of previously-measured concentrations. Some sediment and soil quality guidelines were exceeded at the lower *test* station of Poplar Creek, including chrysene and F3 hydrocarbons.

Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Poplar Creek were classified as **Negligible-Low** because the significant increases in richness, diversity, and CPUE were not indicative of a negative change in the fish assemblage. In addition, the lower ATI value and the higher diversity compared to the range of regional *baseline* variability indicated that the fish assemblage had a greater number of species and a greater proportion of more sensitive species (e.g., burbot).

McLean Creek Concentrations of water quality measurement endpoints at the *test* station of McLean Creek were generally within regional *baseline* concentrations, and within the range of previously-measured concentrations in fall 2013. The Water Quality Index value indicated **Negligible-Low** differences between the lower *test* station and regional *baseline* concentrations. Despite generally being with within regional *baseline* variability, fall concentrations of total dissolved solids and several ions have shown consistent increases since 2009.

Fort Creek The 2013 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum daily discharge were 16.6% lower in the observed *test* hydrograph for Fort Creek than in the estimated *baseline* hydrograph. These differences were classified as **High**. The difference in measurement endpoint values between the 2013 WY and previous years was due to the updated watershed areas and changes in land disturbance from focal project activities. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed.

Differences in water quality in fall 2013 between the lower *test* station of Fort Creek and regional *baseline* conditions were classified as **Moderate**. Relatively high concentrations of several water quality measurement endpoints, primarily ions, were observed in fall 2013. Many of these measurement endpoints were outside of the range of previously-measured concentrations and contributed to the lower WQI value observed in 2013.

Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of Fort Creek were classified as **Negligible-Low** because the higher richness and CA Axis 2 scores in 2013 compared to previous years were not indicative of degradation and abundance, and diversity (i.e., equitability) have been increasing over the last three years, and the number of EPT taxa was generally higher in more recent years compared to the *baseline* period. The increase in CA Axis 2 scores reflected higher relative abundances of mayflies and caddisflies, which was also consistent with improving conditions. Differences in sediment quality observed in fall 2013 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.

Differences in measurement endpoints of the fish assemblage at the lower *test* reach of Fort Creek were classified as **Moderate** because there was a significant decrease in abundance, which could be indicative of a potential negative change in the fish assemblage. There were also decreases, although not statistically significant, in CPUE, richness, and diversity. The ATI value was lower than the regional range of *baseline* variability; however, which indicated a greater proportion of sensitive fish species in 2013 compared to previous years.

Acid-Sensitive Lakes

Results of the analysis of the RAMP lakes in 2013 compared to historical data suggested that there were no significant changes in the overall water chemistry of the lakes across years that were attributable to acidification. Significant increases in pH, Gran alkalinity, TDS, conductivity, and selected base cations were observed; however, these changes appeared to be the result of factors other than acidifying emissions (e.g., hydrology). Concentrations of nitrates appeared to be unusually variable both between lakes and between years within individual lakes.

A summary of the state of the RAMP lakes in 2013, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation (2SD) criterion was used in each case. In general, there was a greater number of exceedances of the 2SD criterion in 2013 than in 2011 and 2012. The highest number of exceedances (6) occurred in lakes in the Northeast of Fort McMurray subregion. Four of these exceedances were attributed to high concentrations of dissolved aluminum, which exceeded the 2SD criterion in two lakes in the Stony Mountain subregion and two lakes in the Birch Mountain subregion. The reasons for the high concentrations of aluminum in 2013 are unknown, although they are likely related to hydrologic changes. Exceedances were also observed in base cation concentrations in two lakes (one in the Caribou Mountains subregion and one in the West of Fort McMurray subregion), which were also likely due to factors other than acidification. Taking into account these factors, five of the subregions were classified as having a **Negligible-Low** indication of incipient acidification while the Northeast of Fort McMurray subregion was classified as having a **Moderate** indication of incipient acidification due to relatively high concentrations of nitrates in one lake.

Summary and Recommendations

The following table provides a summary of the 2013 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 regional monitoring activities for oil sands development. These recommendations are for consideration during the design of monitoring in future years under the JOSMP:

- 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.

- Consider the incorporation of groundwater interaction to the surface water analysis for a more harmonized analysis of the hydrologic impacts of oil sands development.

- Consider maintaining water quality stations in smaller watersheds in the design of the JOSMP to continue to monitor observed localized changes.

- Continue to expand monthly water quality sampling in larger tributaries, to better capture the range of conditions in these locations and allow better discrimination of natural versus anthropogenic changes in water quality.

- 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.

- Maintain consistent sampling depths of benthic invertebrate communities in each reach, lake, or channel, to the extent feasible from year to year, recognizing that there are natural variations in depths and flows from year to year in many of the habitats.

- 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.

Summary assessment of RAMP 2013 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Fish Populations: Human Health Risk from Mercury in Fish Tissue[7]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[8]
	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	🟠	🟡	🟡	🟡	🟠 / 🟤	-	-			-
Jackpine Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Kearl Lake	nm	🟡	🟡	n/a	-	-	-			-
Steepbank River	🟡	🟡	🟠	-	🟠	-	-			-
Tar River	🟤	🟠	🟠	🟠	🟡	-	-			-
MacKay River	🟡	🟡	🟠 / 🟡	-	🟤 / 🟠	-	-			-
Calumet River	🟡	🟡 / 🟠	nm	nm	nm	-	-			-
Firebag River	🟡	🟡	🟡	🟡	🟡	-	-			-
McClelland Lake	nm	n/a	🟡	n/a	-	-	-			-
Johnson Lake	-	n/a	n/a	n/a	-	-	-			-
Ells River	🟡	🟡	🟠	🟠	🟠	-	-			-
Namur Lake	-	-	-	-	-	-	LKWH LKTR	🟡 🟤	🟡 🟤	
Clearwater River	nm	🟡	nm	nm	-	-	-			-
High Hills River	-	🟡	n/a	-	n/a	-	-			-
Christina River	🟡	🟡 / 🟠	🟠 / 🟡	🟡	-	-	-			-
Christina Lake	nm	n/a	🟡	n/a	n/a	-	LKWH NRPK WALL	🟡 🟤 🟤	🟡 🟠 🟠	-
Jackfish River	nm	🟡	🟡	🟡	🟡	-	-			-
Sawbones Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Sunday Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Birch Creek	nm	🟠	n/a	🟡	n/a	-	-			-
Unnamed Creeks (east and south of Christina Lake)	nm	🟡	🟡	🟡	🟡 / 🟤	-	-			-
Hangingstone River	🟡	🟤	-	-	-	-	-			-
Fort Creek	🟤	🟠	🟡	🟡	🟠	-	-			-
Beaver River	-	🟠	-	-	-	-	-			-
McLean Creek	-	🟡	-	-	-	-	-			-
Mills Creek	🟤	🟤	-	-	-	-	-			-
Isadore's Lake	nm	n/a	🟡	n/a	-	-	-			-
Poplar Creek	🟤	🟡	🟠	🟡	🟡	-	-			-
Shipyard Lake	-	n/a	🟡	n/a	-	-	-			-
Big Creek	-	🟡	n/a	🟡	n/a	-	-			-
Pierre River	-	🟡	n/a	🟡	n/a	-	-			-
Red Clay Creek	-	🟡	n/a	🟡	n/a	-	-			-
Eymundson Creek	-	🟠	n/a	🟡	n/a	-	-			-
Stony Mountains	-	-	-	-	-	-	-			🟡
West of Fort McMurray	-	-	-	-	-	-	-			🟡
Northeast of Fort McMurray	-	-	-	-	-	-	-			🟠
Birch Mountains	-	-	-	-	-	-	-			🟡
Canadian Shield	-	-	-	-	-	--	-			🟡
Caribou Mountains	-	-	-	-	-	-	-			🟡

Legend and Notes

🟡 Negligible-Low change
🟠 Moderate change
🟤 High change

"-" program was not completed in 2013.

nm - not measured in 2013.

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 the 2013 WY, hydrology results above were 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 was assessed as Negligible-Low, and Minimum Open-Water Season Discharge was assessed as High.

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

[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-Low at Goose Island Channel and Big Point Channel and Moderate at Embarras River and Fletcher Channel.

Note: Benthic invertebrate communities at the lower reach of the MacKay River were assessed as Moderate and benthic invertebrate communities at the middle reach was 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 3.2.4.4 for a detailed description of the classification methodology.

Note: Fish assemblages in the Muskeg River were assessed as Moderate at the lower and middles reaches and High at the upper reach.

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

[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 3.2.4.3 for a description of the classification methodology.

[7] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. LKTR – lake trout; LKWH – lake whitefish; NRPK – northern pike; WALL – walleye; Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.2.4.2).

[8] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2013 were more than twice the standard deviation from their long-term mean in each lake.

1.0 INTRODUCTION

This document is the 2013 Technical Report of the Regional Aquatics Monitoring Program (RAMP). RAMP is a science-based, multi-stakeholder 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.

In 2011, the governments of Canada and Alberta developed "A Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring" (Canada and Government of Alberta 2012), which was built using the foundation of existing monitoring programs, including RAMP. The intent of this plan was to enhance the current monitoring activities and work to integrate environmental monitoring across all components (i.e., air, water, land, and biodiversity). The implementation of the Joint Oil Sands Monitoring Plan (JOSMP) was planned over three years (2012 to 2015) to characterize the state of the environment in the oil sands region, understand the cumulative effects and changes, and develop recommendations for an integrated environmental monitoring program, with an adaptive management framework for implementation in the oil sands region.

Since 2012, the RAMP Technical Program Committee has been working closely with the governments of Alberta and Canada to align monitoring activities under RAMP with the JOSMP. The intent is to have a complete and comprehensive aquatics monitoring program. Accordingly, this technical report includes results from the RAMP activities within the JOSMP. In 2013, RAMP was still operating independently to the extent that the results from monitoring activities were completed to meet the requirements of approval conditions for industry members. The enhanced monitoring conducted under the JOSMP is in addition to monitoring requirements outlined in regulatory approvals (e.g., RAMP).

1.1 ATHABASCA OIL SANDS REGION BACKGROUND

With an estimated 293.1 billion m^3 (1.845 trillion barrels) of total reserves of bitumen (initial volume in place), 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 26.68 billion m^3 (167.9 billion barrels) of remaining established bitumen reserves[1] (ERCB 2013) being equivalent to 11% of the world's known reserves of conventional crude oil[2] (US Energy Information Administration 2013). 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 2013).

In 1967, Great Canadian Oil Sands Ltd. (now Suncor Energy Inc.) initiated the first commercially successful bitumen extraction and upgrading facility in the Athabasca oil sands region. Since that time, investment and development in the Athabasca oil sands region near Fort McMurray in the Regional Municipality of Wood Buffalo (RMWB) has increased substantially. Approximately 31.7% of the estimated established bitumen

---

[1] Established crude bitumen reserves were defined as mineable reserves that were anticipated to be recovered by surface mining operations and in situ reserves that were anticipated to be recovered through wellbores using in situ recovery methods (ERCB 2013). Remaining established bitumen reserves were established bitumen reserves less cumulative bitumen production.

[2] The world's known reserves of conventional crude oil were based on 2012 data as 2013 data were not available (US Energy Information Administration 2013).

reserves in the Athabasca oil sands region were under active development as of the end of 2012, and 4.5% of the estimated established bitumen reserves of the Athabasca oil sands region had been extracted by the end of 2012 (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 2012			46,280
	Mineable	44,544	
	in situ	1,737	
Cumulative Production as of 31 December 2012			6,516
	Mineable	5,491	
	in situ	1,025	
Remaining Established Reserves			139,421

Data from ERCB (2013); all figures are as of December 31, 2012.

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

The increasing development of the Athabasca oil sands resource has been accompanied by an increase in environmental monitoring and research conducted in the Athabasca oil sands region and increasing interest among stakeholders in ensuring that measures in place to monitor any potential effects on the environment are effective. 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 seventeen 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 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). In 2012, AESRD partnered with Environment Canada as the Co-Lead for the JOSMP;
    - 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 (PADEMP) is another Environment Canada initiative and falls under the jurisdiction of Parks Canada. In 2012, Environment Canada partnered with AESRD as a Co-Lead for the JOSMP.
- JOSMP – JOSMP was initially established in 2012 as a joint plan between the governments of Canada and Alberta to enhance existing monitoring activities within the oil sands region. JOSM is a three-year plan that will be fully implemented by 2015 and is committed to implementing a comprehensive, integrated, and transparent environmental monitoring plan for the oil sands region, with an open data management system (Canada and Government of Alberta 2012).
- Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA) – AEMERA is a new agency that is anticipated to be in place in early 2014 to coordinate and integrate environmental monitoring activities throughout Alberta. Once established, AEMERA will be responsible for the coordination and implementation of the JOSM plan in the oil sands region.
- Industry – individual oil sands companies, including both members and non-members of RAMP, undertake regular aquatic monitoring programs in lakes, 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.

- Canada's Oil Sands Innovation Alliance (COSIA) – established in 2012, COSIA is an alliance of oil sands producers focused on accelerating the pace of improvement in environmental performance in the Alberta oil sands region through collaborative action and innovation. COSIA collaborates with industry, government, academia, and the public to improve measurement, accountability and environmental performance in the oil sands in four Environmental Priority Areas (EPAs) of tailings, water, land, and greenhouse gases.
- 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).

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.

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.

---

[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 2013 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. Brion Energy Corp.[2] Canadian Natural Resources Ltd. Cenovus Energy Inc. Connacher Oil and Gas Ltd. ConocoPhillips Canada Devon Energy 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.[3] 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 Regional Municipality of Wood Buffalo

Finance Sub-Committee	Technical Program Committee	Communications Sub-Committee
All funding participants	Consultants, and representatives from industry, government, and Aboriginal Communities	Consultants, and representatives from industry, government, and Aboriginal Communities

Technical Program Implementation	Communication Plan Implementation
Preparation of technical program for review by Steering Committee; technical workshops.	Community activities; website; etc.

[1] Composition of Steering Committee as of December 2013.

[2] Formerly known as Dover Operating Corp.

[3] Formerly known as SilverBirch Energy Ltd.

In 2013, 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), Brion Energy Corp. (Brion), Japan Canada Oil Sands Ltd. (JACOS), Teck Resources Ltd. (Teck), Cenovus Energy Inc. (Cenovus), Connacher Oil and Gas Ltd. (Connacher), 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.

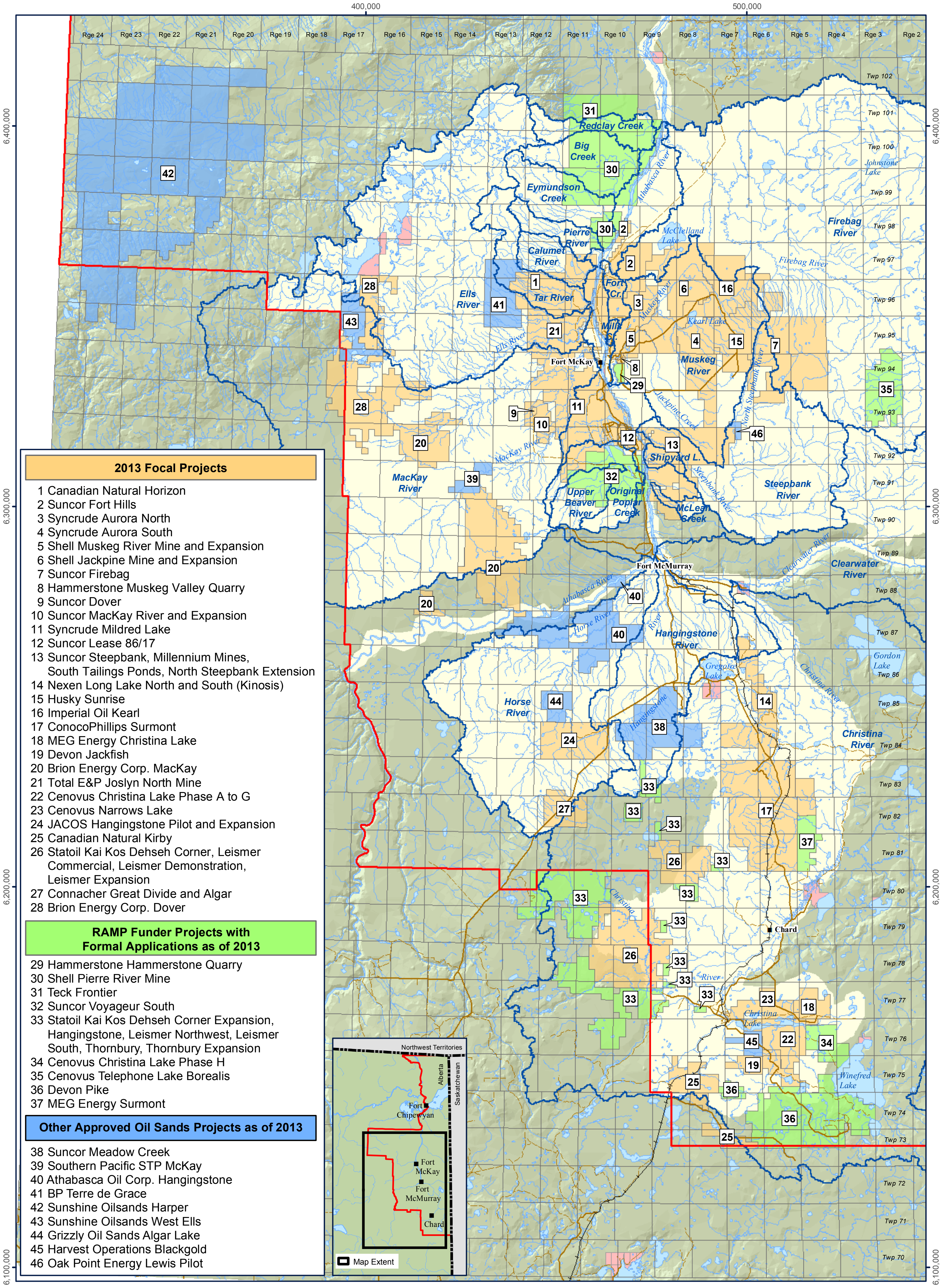
These objectives guide the scope, management, and implementation of the Program over time.

1.3 RAMP STUDY AREAS

The RMWB, prior to changes made in 2013, in northeastern Alberta defines the RAMP Regional Study Area (RSA, Figure 1.3-1). The RMWB, prior to 2013, 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 RAMP 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.



2013 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 and Expansion
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 Extension
14 Nexen Long Lake North and South (Kinosis)
15 Husky Sunrise
16 Imperial Oil Kearl
17 ConocoPhillips Surmont
18 MEG Energy Christina Lake
19 Devon Jackfish
20 Brion Energy Corp. MacKay
21 Total E&P Joslyn North Mine
22 Cenovus Christina Lake Phase A to G
23 Cenovus Narrows Lake
24 JACOS Hangingstone Pilot and Expansion
25 Canadian Natural Kirby
26 Statoil Kai Kos Dehseh Corner, Leismer Commercial, Leismer Demonstration, Leismer Expansion
27 Connacher Great Divide and Algar
28 Brion Energy Corp. Dover

RAMP Funder Projects with Formal Applications as of 2013

29 Hammerstone Hammerstone Quarry
30 Shell Pierre River Mine
31 Teck Frontier
32 Suncor Voyageur South
33 Statoil Kai Kos Dehseh Corner Expansion, Hangingstone, Leismer Northwest, Leismer South, Thornbury, Thornbury Expansion
34 Cenovus Christina Lake Phase H
35 Cenovus Telephone Lake Borealis
36 Devon Pike
37 MEG Energy Surmont

Other Approved Oil Sands Projects as of 2013

38 Suncor Meadow Creek
39 Southern Pacific STP McKay
40 Athabasca Oil Corp. Hangingstone
41 BP Terre de Grace
42 Sunshine Oilsands Harper
43 Sunshine Oilsands West Ells
44 Grizzly Oil Sands Algar Lake
45 Harvest Operations Blackgold
46 Oak Point Energy Lewis Pilot

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 Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
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\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_A_StudyArea_201401218_ss.mxd

In 2013, a review of the watershed boundaries that have been used by RAMP in previous years (e.g., CEMA), was conducted given that new, updated datasets were available from AESRD. The updated watershed boundaries were used for all maps and analyses for the RAMP 2013 Technical Report (see Appendix C for a complete description of how the new watershed boundaries were defined).

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 (AENV 2007a). AESRD has also conducted preliminary assessments 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). In 2012, AESRD developed the Lower Athabasca Regional Plan (LARP) that identifies and sets resource and environmental management outcomes for air, land, water and biodiversity, and will guide future resource decisions while considering social and economic impacts (Government of Alberta 2012). 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, Gregoire, and Horse rivers. The area is characterized by a predominantly sub-humid mid-boreal ecoclimate, closed stands of trembling aspen, balsam poplar with white spruce, black spruce, and balsam fir occurring in late successional stages, as well as cold and poorly-drained fens and bogs covered primarily with tamarack and black spruce. The western part of the southern portion of the 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 and a portion of the Connacher Great Divide and Algar projects;

- 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, a portion of the Suncor in situ Firebag Project, and a portion 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 and Expansion, Syncrude Aurora North and South mines, 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, and the Hammerstone Muskeg Valley Quarry;

- MacKay River – flows from the west and whose watershed includes the Suncor in situ MacKay River Project and Expansion and the Suncor Dover Project, Brion Energy MacKay Project, and portions of the Syncrude Mildred Lake Project area;

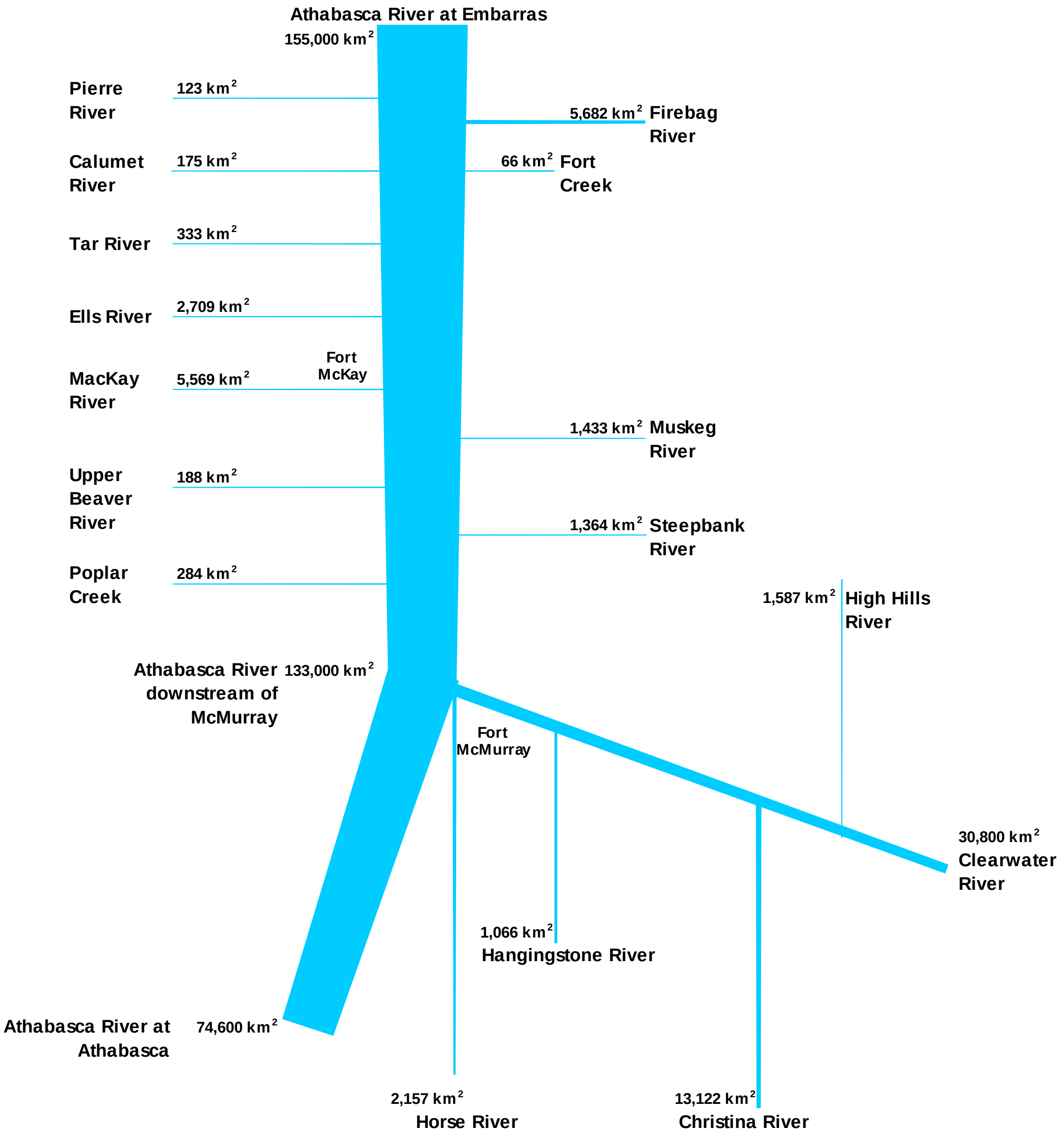
- Ells River – flows from the west and whose watershed includes the Total E&P Joslyn North Mine Project, and a small portion of the Canadian Natural Horizon Project, and the Brion Energy Dover Project; this river is also the drinking water source for the community of Fort McKay;

- Tar River – flows from the west and whose watershed contains most of the Canadian Natural Horizon 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, the Cenovus in situ Telephone Lake Project (in application), portions of the Husky in situ Sunrise Thermal Project, and the Imperial Oil Kearl Project.

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



Note: Drainage areas of Athabasca River tributaries derived from watershed boundaries provided by AESRD (see Appendix C).

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, Beaver River, and Fort Creek) that contain parts of a number of oil sands projects, including the Syncrude Mildred Lake development (Beaver River), Suncor Fort Hills Project (Fort Creek), Brion Energy 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.

1.4 GENERAL RAMP MONITORING AND ANALYTICAL APPROACH

1.4.1 Focal Projects

While most of the 2013 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 2013 Technical Report and is defined as those projects owned by 2013 industry members of RAMP (Section 1.2.1) that were under construction or operational in 2013 in the RAMP FSA. For 2013, 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.

2013 industry members of RAMP do have other projects in the RAMP FSA that were in the application stage as of 2013, or that received approval in 2013 or earlier, but had not yet started construction as of 2013. 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 2013 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** – monitors 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 2013) or were (prior to 2013) 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.

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 to identify potential chemical exposure pathways between the physical environment and biotic communities in the aquatic environment.

The objectives of the Water Quality component are to:

- 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, polycyclic aromatic hydrocarbons (PAHs), other organics, and total and dissolved metals.

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. In addition, as of 2013, a subset of water quality stations are monitored on a monthly basis in collaboration with the JOSMP to determine variability within a year.

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 equitability 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, 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 – historically, fish fence monitoring has been conducted on the Muskeg River and used to obtain information on the biology and use of habitat by spawning populations of large-bodied fish species that use the Muskeg River and its tributaries.

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

1.4.5.5 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 *a*.

The ASL component contains the following features:

1. The locations of the lakes are selected to represent a gradient in acid deposition from both current and anticipated developments in the 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 Overall Analytical Approach for 2013

The overall analytical approach for the 2013 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 2012 Technical Reports (RAMP 2005; RAMP 2006; RAMP 2007; RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012; and RAMP 2013).

Second, the analysis of RAMP results for 2013 compared to previous monitoring years is conducted for the Athabasca River and ARD, as well as at the watershed/river basin level to assess temporal trends.

Third, a set of criteria are used for determining whether or not there has been a change in the values of the measurement endpoints: (i) at *test* stations; and (ii) compared to *baseline* range of natural variability (Table 1.4-1).

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 2013.

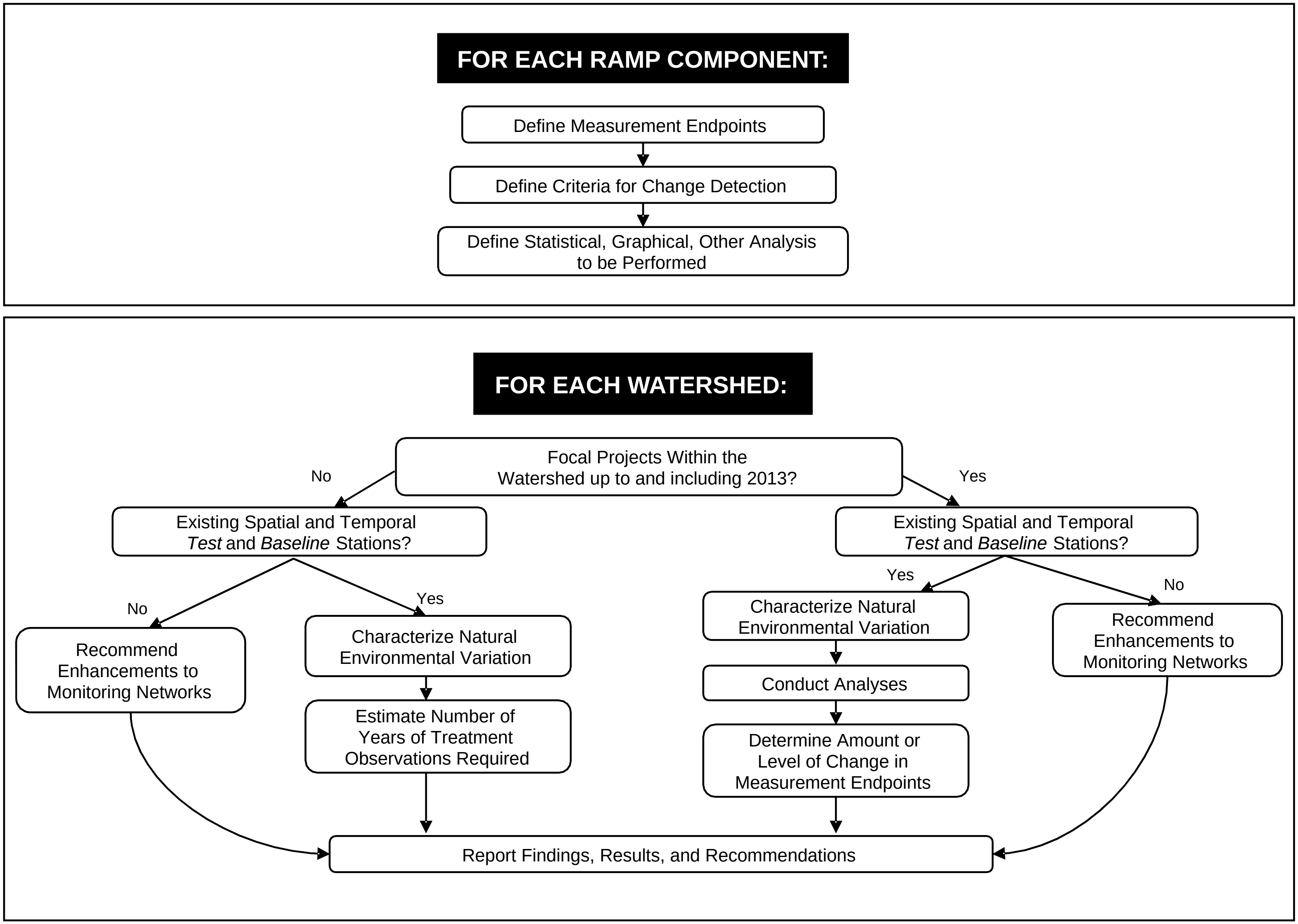


Table 1.4-1 Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2013 Technical Report.

RAMP Component	Measurement Endpoints Used in 2013 Technical Report[1]	Criteria for Determining Change Used in 2013 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) 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 or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches/lakes, with low “noise” in the statistical test. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years.
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 2013 Technical Report	Criteria for Determining Change Used in 2013 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 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 or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years. Statistical comparisons were only completed for reaches with three or more years of data. For all other reaches, assessments were conducted solely based on comparisons to the *baseline* range of variability.
Fish Populations: Fish Tissue	Mercury concentration in fish muscle tissue	Risk to Human Health Negligible-Low: Fish tissue concentrations for mercury below Health Canada criteria for recreational and subsistence fishers and the general consumer. High (subsistence): Fish tissue concentrations for mercury above Health Canada criteria for subsistence fishers, but below criteria for recreational fishers and general consumers. High (general consumer): Fish tissue concentrations for mercury above Health Canada criteria for general consumers, and recreational and subsistence fishers.
Fish Populations: Sentinel Species Monitoring	Age Growth Relative Gonad Weight Condition Factor Relative Liver Weight	Comparison to Environment Canada's Environmental Effects Monitoring (EEM) criteria (Environment Canada 2010) where an effect is determined by a difference of ± 10% in condition, ± 25% in age, growth, relative gonad weight, and relative liver weight of fish at the *test* site relative to fish condition at the *baseline* site. 1. Negligible-Low: no exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site. 2. Moderate: exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, but not in two consecutive years of sampling including the current year. 3. High: exceedance greater than ± 10% in condition ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, and exceedance observed in two consecutive years of sampling including the current year.
Acid-Sensitive Lakes	Critical Load of acidity pH Gran alkalinity Base cation concentrations Nitrate plus nitrite concentrations Dissolved Organic Carbon Aluminum	Exceedance of Critical Load of acidity of a particular lake by the measured or modeled value of the Potential Acid Input (PAI) to that lake. A statistically significant change in any of the measurement endpoints beyond natural variability, resulting in a reduction of lake pH, Gran alkalinity, Critical Load or base cation concentrations, or an increase in nitrates or aluminum concentrations. For each lake, mean and standard deviation calculated for each of seven measurement endpoints over all the monitoring years. The number of lakes in 2013 within each subregion with endpoint values greater than two standard deviations from the mean is calculated. 1. Negligible-Low: subregion has <2% of endpoint-lake combinations exceeding ± 2SD criterion. 2. Moderate: subregion has 2% to 10 % of endpoint-lake combinations exceeding ± 2SD criterion. 3. High: subregion has > 10% of endpoint-lake combinations exceeding ± 2SD criterion.

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

1.5 ORGANIZATION OF THE RAMP 2013 TECHNICAL REPORT

Together with this Introduction, the RAMP 2013 Technical Report contains nine sections within which the results of the 2013 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 2013 – This section contains:

- a description of the activities in 2013 for each of the focal projects;
- a list of projects owned by 2013 industry members of RAMP that were in the application stage as of 2013, or which received approval in 2013 (or earlier) but were not in the construction phase as of 2013;
- a list of active oil sands projects in the RAMP study areas owned or operated by companies that were not members of RAMP in 2013;
- a list of report focal project water withdrawal and discharge locations; and
- a summary of land change occurring up to 2013 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: 2013 RAMP Monitoring Activities – This section of the report contains concise descriptions of the RAMP monitoring program that was conducted in 2013 for each RAMP component, and includes:

- an overview of the 2013 program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, 2013 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 2012 field program;
- a description of the challenges and issues encountered during 2013 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 2013 – This section of the report describes the 2013 water year (WY) (November 1, 2012 to October 31,

2013) and how the 2013 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 2013 Results – This is the main results section of the RAMP 2013 Technical Report, consisting of three major parts:

- Section 5.1 is the report of 2013 findings for the mainstem Athabasca River and the Athabasca River Delta;
- Sections 5.2 to 5.13 are watershed-level reports of the 2013 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations; and
- Section 5.14 is the report of 2013 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 2013. The recommendations include proposed changes to the monitoring network for future years based on the results for 2013.

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 2013

This section provides information on oil sands and other developments in the Focus Study Area (FSA) of RAMP that was needed to support the assessment of the 2013 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 considered: development status of focal projects; development status of other oil sands projects in the RAMP FSA; summary of focal project activities in 2013; summary of focal project water withdrawals and discharges from surface water sources; and RAMP FSA land change analysis for 2013.

2.1 DEVELOPMENT STATUS OF FOCAL PROJECTS

The development status of all RAMP industry member projects, as of the end of 2013 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 2013 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 2013 whose operators were not members of RAMP in 2013 (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 the Benthic Invertebrate Communities component (Section 3.2.3.1).

2.3 SUMMARY OF FOCAL PROJECT ACTIVITIES IN 2013

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 was used to interpret the 2013 monitoring results for all RAMP components. Water discharge and withdrawal information provided in this section was used for the analysis, assessment, and reporting for the Climate and Hydrology component (Section 3.2.1.4). The information provided in this section reflects changes within the 2013 Water Year (i.e., November 1, 2012 to October 31, 2013) for consistency with analyses conducted for the Climate and Hydrology Component.

2.3.1 Brion Energy Corp.

In 2013, the Brion Energy 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 approved in 2013 (Table 2.3-1). Project activities included water releases of approximately 0.35 million m^3 from the borrow pits, storm water pond, and SAGD well pads to the surrounding watershed area.

Table 2.3-1 Status and activities of developments owned by 2013 industry members of RAMP in the RAMP Focus Study Area.

2013 RAMP Industry Member	Development	Focal Projects	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2013 Status
Brion Energy Corp.	MacKay River Phase 1	√	92, 93-12-W4M	in situ	35,000	2010	2015	Construction
	MacKay River Phase 2			in situ	40,000	2010	2018	Approved
	MacKay River Phase 3			in situ	40,000	2010	2020	Approved
	MacKay River Phase 4			in situ	35,000	2010	2022	Approved
	Dover North Phase 1		87,88,89,90,91-12-W4M	in situ	50,000	2010	2016	Approved
	Dover North Phase 2			in situ	50,000	2010	2018	Approved
	Dover North Phase 3			in situ	50,000	2010	2021	Approved
	Dover North Phase 4			in situ	50,000	2010	2023	Approved
	Dover South Phase 5			in situ	50,000	2010	2025	Approved
Canadian Natural	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	–	2016	Construction
	Horizon Phase 3	√		mine	80,000	–	2017	Construction
	Horizon Tranche 2	√		mine	5,000	–	2010	Construction
	Kirby North Phase 1		73,74,75-7,8,9-W4M	in situ	40,000	–	2016	Approved
	Kirby North Phase 2			in situ	60,000	–	2019	Application
	Kirby South Phase 1	√		in situ	40,000	–	2013	Operational
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	–	2011	Operational
	Christina Lake Phase D	√		in situ	40,000	–	2012	Operational
	Christina Lake Phase E	√		in situ	40,000	2009	2013	Operational
	Christina Lake Optimization (phases C,D,E)			in situ	21,200	–	2015	Application
	Christina Lake Phase F	√		in situ	50,000	–	2016	Construction
	Christina Lake Phase G			in situ	50,000	2009	2017	Approved
	Christina Lake Phase H			in situ	50,000	–	2019	Application
	Narrows Lake Phase A	√	76,77-6,7-W4M	in situ	45,000	2010	2017	Construction
	Narrows Lake Phase B and C			in situ	85,000	2010	–	Approved
Connacher Oil and Gas	Great Divide Pod One	√	82,83-11,12-W4M	in situ	10,000	–	2007	Operational
	Great Divide Algar	√		in situ	10,000	–	2010	Operational
	Great Divide Expansion 1A			in situ	12,000	–	–	Approved
	Great Divide Expansion 1B			in situ	12,000	–	–	Approved
ConocoPhillips	Surmont Phase 1	√	81,82,83-5,6,7-W4M	in situ	27,000	2001	2004	Operational
	Surmont Phase 2	√		in situ	109,000	–	2010	Construction
	Pilot	√		in situ	1,200	–	1997	Operational

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), ERCB (2013), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites. SAGD is steam-assisted gravity drainage.

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

Table 2.3-1 (Cont'd.)

2013 RAMP Industry Member	Development	Focal Projects	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2013 Status
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		73,74,75-4,5,6,7,8-W4M	in situ	35,000	–	2016	Application
	Pike 1B			in situ	35,000	–	2017	Application
	Pike 1C			in situ	35,000	–	2018	Application
Husky Energy	Sunrise Phase 1	√	94-97-6,7-W4M	in situ	60,000	–	2014	Construction
	Sunrise Phase 2A			in situ	70,000	–	2018	Approved
	Sunrise Phase 2B			in situ	70,000	–	2020	Approved
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
Imperial Oil Resources	Kearl Lake Phase 1	√	95,96,97-6,7,8-W4M	mine	110,000	2005	2009	Operational
	Kearl Lake Phase 2	√		mine	110,000	–	2015	Construction
	Kearl Lake Phase 3			mine	80,000	–	2020	Approved
	Kearl Lake Phase 4 Debottleneck			mine	45,000	–	–	Approved
JACOS	Hangingstone Pilot	√	84-10,11,12-W4M	in situ	11,000	–	1999	Operational
	Hangingstone Expansion	√		in situ	20,000	–	2014	Construction
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	Operational
	Christina Lake Phase 3A	√		in situ	50,000	2008	2016	Construction
	Christina Lake Phase 3B			in situ	50,000	2009	2018	Approved
	Christina Lake Phase 3C			in situ	50,000	2011	2020	Approved
	Surmont Phase 1-3		81,82-5-W4M	in situ	123,000	2012	–	Application
Nexen	Long Lake Phase 1	√	85-6-W4M	in situ	72,000	2000	2003	Operational
	Long Lake South (Kinosis) Phase 1A	√	84-7-W4M	in situ	40,000	2006	–	Construction
	Long Lake South (Kinosis) Phase 1B			in situ	40,000	2006	–	Approved
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	Approved
	Pierre River Mine Phase 1		97,98,99-10,11-W4M	mine	100,000	2007	2018	Application
	Pierre River Mine Phase 2			mine	100,000	–	–	Application

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), ERCB (2013), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites. SAGD is steam-assisted gravity drainage.

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

Table 2.3-1 (Cont'd.)

2013 RAMP Industry Member	Development	Focal Projects	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2013 Status
Statoil Canada Ltd.	Kai Kos Dehseh Corner		19 to 21, 26, 28, 29 to 33-78-9-W4M	in situ	40,000	–	2017	Approved
	Kai Kos Dehseh Corner Expansion			in situ	40,000	–	–	Application
	Kai Kos Dehseh Hangingstone			in situ	20,000	–	–	Application
	Kai Kos Dehseh Leismer Commercial			in situ	10,000	–	–	Approved
	Kai Kos Dehseh Leismer Demonstration	√	19 to 21, 26, 28, 29 to 33-78-9-W4M	in situ	10,000	–	2010	Operational
	Kai Kos Dehseh Leismer Expansion			in situ	20,000	–	–	Approved
	Kai Kos Dehseh Leismer Northwest			in situ	20,000	–	–	Application
	Kai Kos Dehseh Leismer South			in situ	20,000	–	–	Application
	Kai Kos Dehseh Thornbury			in situ	40,000	–	–	Application
	Kai Kos Dehseh Thornbury Expansion			in situ	20,000	–	–	Application
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	√		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	√	91,92-9-W4M	mine	23,000	–	2008	Operational
	Voyageur South Phase 1		91,92-10-W4M	mine	120,000	2007	–	Application
	Firebag (stages 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	–	2018	Approved
	Firebag Stage 6			in situ	62,500	–	2019	Approved
	Firebag Stages 3 to 6 Debottlenecking			in situ	23,000	–	–	Approved
	Fort Hills Phase 1	√	96-11-W4M, 97,98-10-W4M	mine	160,000	2001	2005	Construction
	Fort Hills Debottleneck			mine	20,000	–	–	Approved
	MacKay River Phase 1	√	92, 93-12-W4M	in situ	33,000	1998	2000	Operational
	MacKay River Expansion (MR2)			in situ	40,000	2005	2017	Approved
	Meadow Creek phases 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	2006	Operational
	Aurora South Train 1		94, 95-7,8-W4M	mine	100,000	–	2012	Approved
	Aurora South Train 2			mine	100,000	–	2012	Approved
Teck Resources Ltd.	Frontier Phase 1		99-11, 100,101-9,10,11-W4M	mine	74,600	2011	2021	Application
	Frontier Phase 2			mine	84,000	2011	2024	Application
	Frontier Phase 3			mine	79,300	2011	2027	Application
	Frontier Phase 4 Equinox			mine	39,400	2011	2030	Application
Total E&P Joslyn	Joslyn North Mine Project Phase 1		94,95,96-11-W4M, 94-12-W4M	mine	100,000	2006	2011	Approved

Notes: Information in this table obtained from GOA (2013a, b), OSDG (2013), ERCB (2013), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites. SAGD is steam-assisted gravity drainage.

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

Table 2.3-2 Approved oil sands projects within the RAMP FSA operated by non-RAMP members, as of 2013.

Operator	Project	Location (Township-Range-Meridian)	Type of Operation
Southern Pacific Resource Corp.	STP McKay Phase 1	91-14,15-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
Sunshine Oilsands Ltd.	Harper Carbonate Pilot	95,96,97,98,99,100,101,102 -20,21,22,23,24,25-W4M	in situ
	West Ells Phase 1 and 2	94,95,96-17,18-W4M	in situ
Oak Point Energy Ltd.	Lewis Pilot	93, 94-7-W4M	In situ
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 GOA (2013a, b), OSDG (2013), ERCB (2013), Energy Resources Conservation Board (ERCB) project approvals, project EIA documents, and company websites.

2.3.2 Canadian Natural Resources Ltd.

As of 2013, the Canadian Natural Horizon Phase 1 and the Kirby South Phase 1 projects were operational; the Horizon Phase 2A, 2B, 3, and Tranche 2 projects were in the construction stage; the Kirby North Phase 1 project was approved; and the Kirby North Phase 2 project was in the application stage (Table 2.3-1). Water use and discharge activities in 2013 included:

- Horizon Project – water withdrawals of 19.40 million m^3 from the Athabasca River;
- Horizon Project – water releases of 4.31 million m^3 to the Tar River watershed from surface runoff and dewatering activities; and
- Kirby Project – water withdrawals of approximately 0.031 million m^3 from the Christina River watershed for drilling, dust suppression, and other project activities.

2.3.3 Cenovus Energy Inc.

As of 2013, the Cenovus Energy Inc. Christina Lake Project phases 1A, 1B, C, D, and E were operational, Phase F was under construction, Phase G was approved, and Phase H and the Christina Lake Optimization (Phases C, D, E) project were in the application stage (Table 2.3-1). The Narrows Lake Project Phase A was under construction in 2013 and Phases B and C were approved. The Telephone Lake Borealis Project phases A and B were in the application stage. Water use and discharge activities in 2013 included water withdrawals of approximately 0.10 million m3 from surface water sources in the Christina River watershed for construction, dust suppression, and other project activities.

2.3.4 Connacher Oil and Gas Ltd.

Connacher Oil and Gas Limited (Connacher) became a new member of RAMP in 2013. The Great Divide Pod One and Algar projects were operational in 2013, and the Great Divide Expansion Project phases 1A and 1B were approved. In 2013, activities for the Connacher Great Divide Pod One and Algar projects included water releases of 0.02 million m^3 and 0.03 million m^3 respectively, from surface water discharge ponds to the watershed area.

2.3.5 ConocoPhillips Canada

The ConocoPhillips Surmont Pilot and Phase 1 projects were operational in 2013 (Table 2.3-1) and withdrew approximately 0.042 million m^3 from various surface water sources in the Christina River catchment for construction, dust suppression, and other project activities. The Surmont Phase 2 Project was under construction in 2013.

2.3.6 Devon Energy Canada

The Devon Canada Jackfish Phase 1 and Phase 2 projects were operational in 2013 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. The Pike Phase 1A, 1B, and 1C projects were in the application stage in 2013.

2.3.7 Hammerstone Corp.

The Hammerstone Muskeg Valley Quarry project was operational and the Hammerstone Quarry project was in the application phase in 2013 (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.

2.3.8 Husky Energy

The Husky Energy Sunrise project Phase 1 was under construction in 2013 and phases 2A and 2B were approved (Table 2.3-1). Project activities included water discharges of approximately 0.07 million m^3 from the wastewater treatment plant to the Muskeg River watershed; water releases of 1.07 million m^3 from a storm water pond, landfill, plant, and well pads for stormwater management; and water withdrawals of approximately 0.05 million m^3 from the perimeter ditch, Pit 1, and storm water pond.

2.3.9 Imperial Oil Resources

As of 2013, the Imperial Oil Resources Kearl Project Phase 1 was operational, the Kearl Project Phase 2 was under construction, and the Kearl Phase 3 and Kearl Phase 4 Debottleneck were approved (Table 2.3-1). Kearl project activities related to water use and discharge in 2013 included:

- water discharges of 0.52 million m^3 to the Athabasca River;
- water discharges of 4.11 million m^3 to the Muskeg River;
- water diversions of 0.40 million m^3 to Kearl Lake; and
- water withdrawals of 4.72 million m^3 from the Athabasca River.

2.3.10 Japan Canada Oil Sands Limited (JACOS)

The Japan Canada Oil Sands Limited (JACOS) Hangingstone Pilot Project was operational in 2013 and the Expansion project was in the construction phase (Table 2.3-1). In 2013, Hangingstone Pilot Project activities included water withdrawals of approximately 0.004 million m^3 from the Blueberry Pit and the Plant 2 Industrial Run-off Pond and water discharges of approximately 0.02 million m^3 from the project well pads and industrial run-off ponds to the Horse River watershed. Project activities for the Expansion project included water diversions of approximately 0.02 million m^3 to support construction and drilling activities.

2.3.11 MEG Energy Corp.

The MEG Energy Christina Lake Project Phase 1 Pilot, Phase 2A, and Phase 2B were operational in 2013; Phase 3A was under construction; phases 3B, and 3C were approved; and the Surmont Project phases 1 to 3 were in the application stage (Table 2.3-1). In 2013, water withdrawals included approximately 0.12 million m^3 from various sources within the Christina River watershed to support construction, drilling, and dust suppression activities.

2.3.12 Nexen Inc.

As of 2013, the Nexen Inc. Long Lake Project Phase 1 was operational, the Long Lake South (Kinosis) Project Phase 1A was in the construction stage, and the Kinosis Project Phase 1B was approved (Table 2.3-1). The Long Lake Phase 1 project activities in 2013 included water withdrawals of approximately 0.183 million m^3 from surface water sources in the Christina River watershed for dust suppression and other project activities.

2.3.13 Shell Canada Energy

Shell Canada Energy focal projects in 2013 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, the Jackpine Mine Phase 1B, and the Jackpine Mine Expansion (Table 2.3-1). The Pierre River Mine project is still in the application phase (Table 2.3-1). Shell Canada Energy focal project activities' use and discharge of water in 2013 included:

- Muskeg River Mine and Jackpine Mine - water withdrawals of 14.95 million m^3 from the Athabasca River;
- Jackpine Mine – water diversions of 1.48 million m^3 from collection ditches and discharges through sedimentation ponds to Khahago Creek, Jackpine Creek, and Shelley Creek;
- Jackpine Mine – water augmentation of 0.36 million m^3 from the Athabasca River to Jackpine Creek to maintain flow from October to April; and
- Muskeg River Mine – water diversions of 2.52 million m^3 from Muskeg River flooding, collection ditches, and discharges through sedimentation ponds to the Muskeg River, or into lakes and out through an unnamed watercourse to the Muskeg River.

2.3.14 Statoil Canada Ltd.

As of 2013, the Statoil Canada Limited (Statoil) Leismer Demonstration Project was operational; 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 diversions were approximately 0.04 million m^3 in 2013 for drilling, dust control, and other miscellaneous activities.

2.3.15 Suncor Energy Inc.

As of 2013, nine of Suncor's focal projects were operational: the Fort Hills Phase 1 project was in the construction stage; Firebag Phase 5 and 6, Fort Hills Debottleneck, Firebag Stages 3-6 Debottlenecking, MacKay River Expansion (MR2), and Meadow Creek Phase 1 and 2 projects were approved; and the Voyageur South Phase 1 project was in the application stage (Table 2.3-1). Suncor focal project activities and related use/discharge of water in 2013 included:

- Millennium and Voyageur Mines – discharge of approximately 1.7 million m^3 of water to the Athabasca River from holding ponds, and withdrawal of 23.9 million m^3 from the Athabasca River;
- Firebag In Situ Project – water discharges of 0.64 million m^3 to the Firebag River watershed for water management and dust suppression activities, and water diversions of 0.14 million m^3 from process water ponds;
- MacKay River and Dover projects – water discharges of 0.01 million m^3 to a wooded area of the MacKay River watershed and water diversions of 0.01 million m^3 for dust suppression activities; and
- Fort Hills Project– water releases of 5.44 million m^3 to the surrounding watershed area from muskeg dewatering or waterworks activities.

2.3.16 Syncrude Canada Ltd.

Syncrude's operational focal projects in 2013 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 2013 included:

- Mildred Lake Mine– water withdrawals of 43.8 million m^3 from the Athabasca River;
- Mildred Lake Mine– discharges of 1.35 million m^3 of groundwater, surface water, and treated domestic wastewater to the Athabasca River;
- Aurora North Mine – diversion of 5.03 million m^3 of water from surface runoff, muskeg dewatering, or basal water to the Muskeg River watershed; and
- water discharges of 51.27 million m^3 to Poplar Creek via the Poplar Creek Spillway.

2.3.17 Teck Resources Ltd.

The Teck Resources Ltd. Frontier Project phases 1 to 3 and Phase 4 Equinox were in the application phase in 2013.

2.3.18 Total E&P Canada Ltd.

As of 2013, the Total E&P Joslyn North Mine Project Phase 1 was approved (Table 2.3-1). Activities for the Joslyn North Mine project in 2013 included water diversions of approximately 1.09 million m^3 to support winter drilling and construction activities, for dust control during summer months, to make snow fills, or to control pond water levels.

2.4 WATER USE RELATED TO FOCAL PROJECT ACTIVITIES IN 2013

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 2013 RELATED TO DEVELOPMENT ACTIVITIES

Land change, as of 2013 related to development activities, was estimated with satellite imagery in conjunction with more detailed maps provided by a number of RAMP industry members. Twelve SPOT-5 10-m resolution images (five north of Fort McMurray and seven south of Fort McMurray) taken on August 1, August 2, August 10, August 23, September 1, September 5, and September 8, 2013 were obtained. A land change classification protocol was developed and applied to the imagery to identify and delineate two types of land change in 2013 from the projects listed in Table 2.3-1 and Table 2.3-2. Developed areas where there was no natural exchange of water with the rest of the watershed (e.g., tailings ponds) were designated as hydrologically closed-circuited. Developed areas where there was natural exchange of water with the rest of the watershed (e.g., cleared land) were designated as not hydrologically closed-circuited.

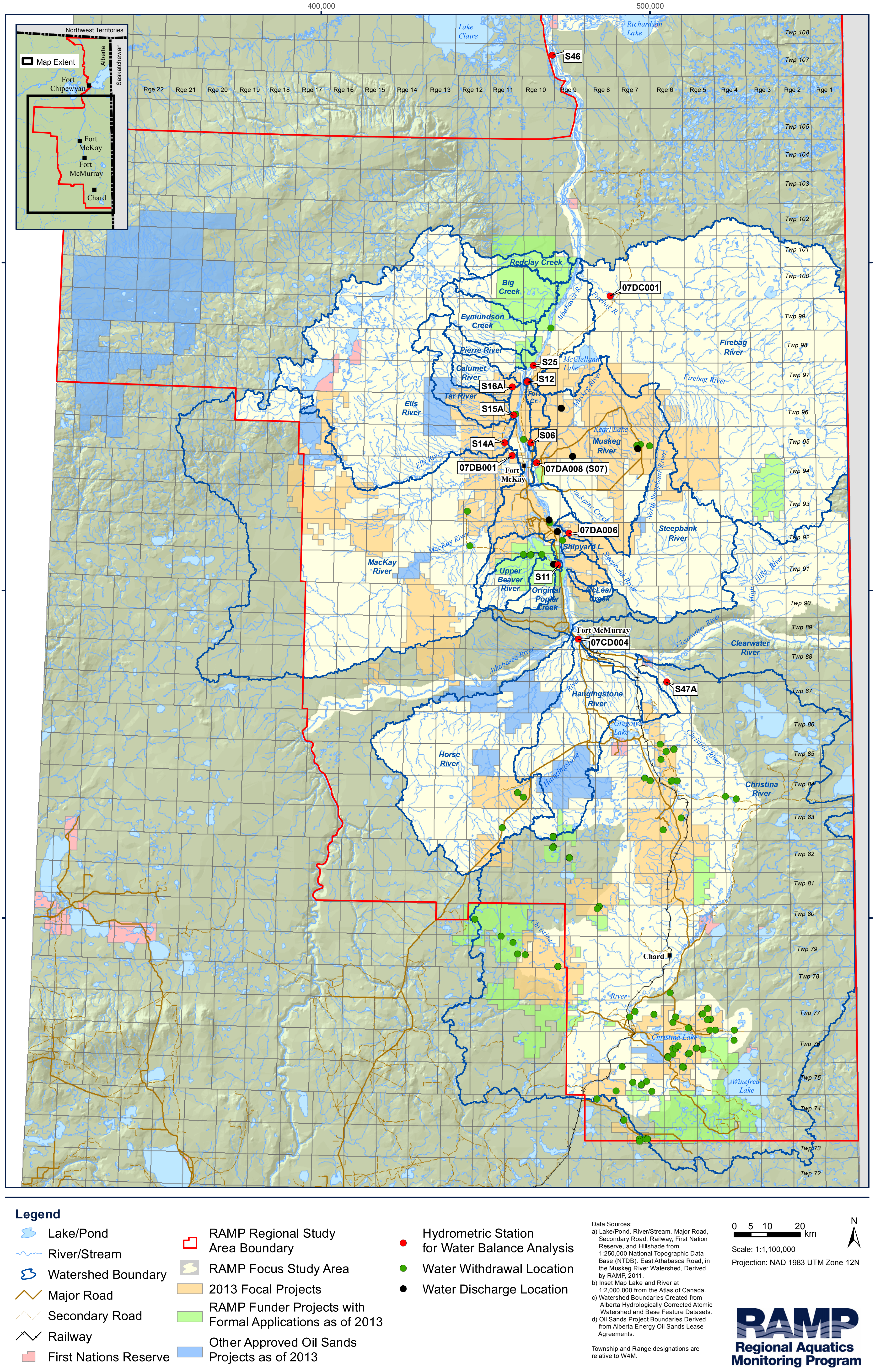
Because of the resolution of the satellite imagery, SAGD well pads were the smallest oil sands development entity delineated. Details of the land change estimation procedure are provided in Appendix A. Drafts of the land change maps were provided to RAMP members for review, and recommendations for revision of the maps were used to produce the final set of 2013 land change maps.

Land change area as of 2013 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 2013 within the RAMP FSA was estimated to be approximately 117,850 ha for focal projects and approximately 900 ha for oil sands projects operated by companies who were not members of RAMP in 2013, for a total of approximately 118,750 ha. The land change area for focal projects increased from 105,700 ha in 2012 and the land change area for oil sands projects operated by companies who were not RAMP members increased from 400 ha in 2012. The increase in land change area for focal projects reflected the addition of Connacher as a new member of RAMP in 2013; thereby adding the land change from Connacher's development to the total focal project land change area. The increase in land change area for oil sands projects operated by companies who were not RAMP members likely reflected the updated AESRD watershed boundaries, which resulted in a larger estimate for the MacKay River watershed, as well as a larger estimate for the total watershed area within the FSA. The total area of land change represented approximately 3.3% of the RAMP FSA. The percentage of the area of watersheds with land change as of 2013 varied from less than 1% for many watersheds (MacKay, Christina, Hangingstone, Horse, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, and Ells watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

Land change area within the city of Fort McMurray in 2013 was estimated at approximately 5,100 ha. More than half of this land change was in watersheds of smaller tributaries of the Athabasca River, with the other land change occurring in the Hangingstone and Horse River watersheds. The land change area within the city of Fort McMurray increased from approximately 4,700 ha in 2012.

Figure 2.5-1 Locations of surface water withdrawals and discharges from focal project activities used in the RAMP water balance calculations, 2013 Water Year.



Legend

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Oil Sands Project Boundaries Derived from Alberta Energy Oil Sands Lease Agreements.

Township and Range designations are relative to W4M.

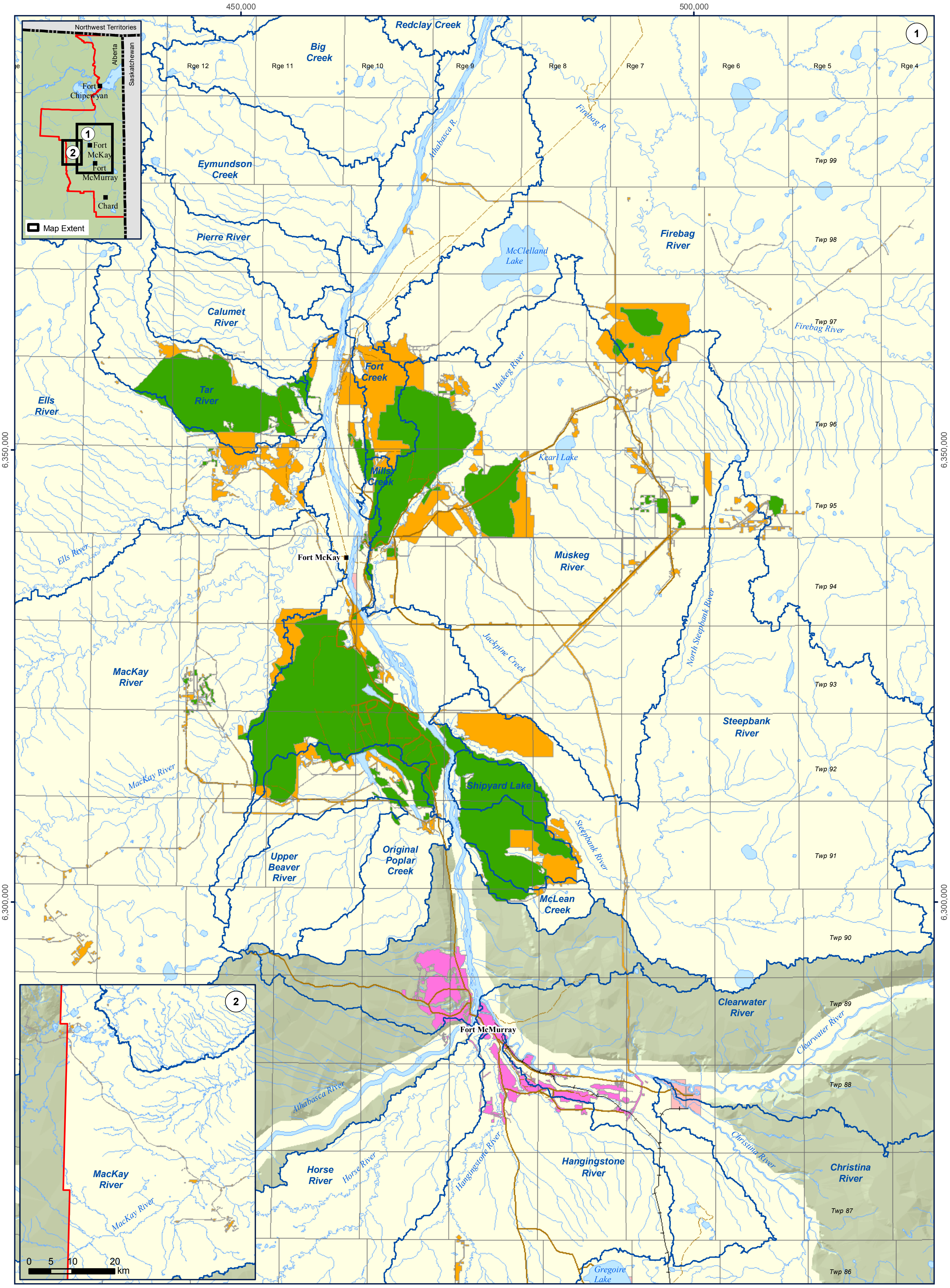
Scale: 1:1,100,000

Projection: NAD 1983 UTM Zone 12N

RAMP Regional Aquatics Monitoring Program

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_C_DischargeWithdrawal_20140307_ss.mxd

Figure 2.5-2 RAMP land change classes derived from SPOT-5 (August and September 2013) 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 2013[d]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

Township and Range designations are relative to W4M

0 2 4 8 km
N

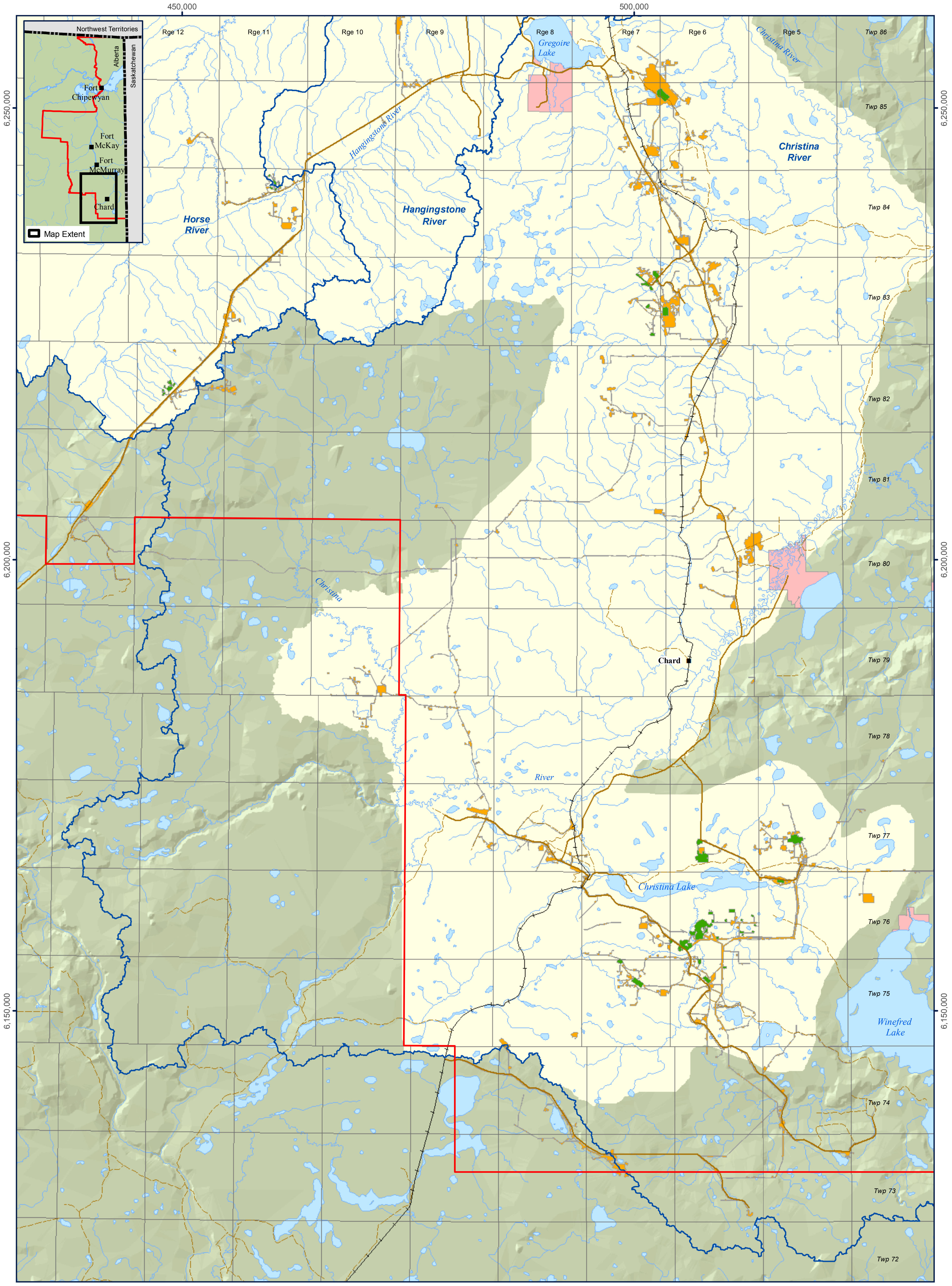
Scale: 1:425,000

Projection: NAD 1983 UTM Zone 12N

RAMP
Regional Aquatics Monitoring Program

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_B1_LCNorthVector_20140218_ss.mxd

Figure 2.5-3 RAMP land change classes derived from SPOT-5 (August and September 2013) satellite imagery, south 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

Land Change Area as of 2013[d]

- 🟧 Not Hydrologically Closed-Circuited
- 🟩 Hydrologically Closed-Circuited

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) 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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_B2_LCSouthVector_20140218_ss.mxd

Table 2.5-1 Area of watersheds within the RAMP Focal Study Area with land change in 2013.

Watershed	Total Watershed Area (ha)[4]	Watershed Area with Land Change (ha)							
		Focal Projects		Other Oil Sands Projects in RAMP FSA		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	143,304	9,995	12,835	-	-	9,995	12,835	22,830	15.93
Steepbank	136,395	4,882	538	-	-	4,882	538	5,420	3.97
MacKay[4]	556,871	3,431	711	445	-	3,876	711	4,587	0.82
Tar	33,264	1,306	9,836	13	-	1,319	9,836	11,155	33.53
Calumet	17,522	129	70	-	-	129	70	199	1.14
Firebag	568,190	5,366	1,358	-	-	5,366	1,358	6,724	1.18
Ells	270,944	3,022	355	17	-	3,039	355	3,394	1.25
Christina	1,312,160	10,568	1,343	358	-	10,926	1,343	12,269	0.93
Hangingstone	106,572	402	32	-	-	402	32	434	0.41
Mills Creek	1,424	244	664	-	-	244	664	908	63.74
Shipyard Lake	5,113	15	4,629	-	-	15	4,629	4,643	90.82
Fort Creek	6,640	3,671	1,792	-	-	3,671	1,792	5,463	82.28
Horse	215,740	1,273	97	67	-	1,340	97	1,437	0.67
McLean	4,643	192	1,071	-	-	192	1,071	1,262	27.19
Original Poplar[1]	28,388	1,567	3,790	-	-	1,567	3,790	5,357	18.87
Upper Beaver	18,796	39	80	-	-	39	80	119	0.63
Minor Athabasca River Tributaries[2]	135,132	5,727	26,822	-	-	5,727	26,822	32,549	24.09
Total	**3,561,097**	**51,827**	**66,021**	**899**	**0**	**52,727**	**66,021**	**118,748**	**3.33**
Lac La Biche[4]	863,473	521	-	-	-	521	0	521	0.06

[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 total watershed areas were updated using data from AESRD. The MacKay River watershed area is now larger compared to the old boundary, which makes the total watershed area of the FSA larger than previous years using older data sources. Other watersheds have slight differences in size compared to the old boundaries.

[4] The Lac La Biche watershed was added in 2011 given some of the Canadian Natural Kirby project is located within this watershed. The Lac La Biche watershed is not part of the RAMP FSA.

Table 2.5-2 Percent of total watershed areas within the RAMP Focal Study Area with land change in 2013.

Watershed	Total Watershed Area (ha)[3]	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	143,304	6.97	8.96	-	-	6.97	8.96	15.93
Steepbank	136,395	3.58	0.39	-	-	3.58	0.39	3.97
MacKay[3]	556,871	0.62	0.13	0.08	-	0.70	0.13	0.82
Tar	33,264	3.92	29.57	0.04	-	3.97	29.57	33.53
Calumet	17,522	0.74	0.40	-	-	0.74	0.40	1.14
Firebag	568,190	0.94	0.24	-	-	0.94	0.24	1.18
Ells	270,944	1.12	0.13	0.01	-	1.12	0.13	1.25
Christina	1,312,160	0.81	0.10	0.03	-	0.83	0.10	0.93
Hangingstone	106,572	0.38	0.03	-	-	0.38	0.03	0.41
Mills Creek	1,424	17.12	46.62	-	-	17.12	46.62	63.74
Shipyard Lake	5,113	0.29	90.53	-	-	0.29	90.53	90.82
Fort Creek	6,640	55.29	26.99	-	-	55.29	26.99	82.28
Horse	215,740	0.59	0.04	0.03	-	0.62	0.04	0.67
McLean	4,643	4.13	23.06	-	-	4.13	23.06	27.19
Original Poplar[1]	28,388	5.52	13.35	-	-	5.52	13.35	18.87
Upper Beaver[1]	18,796	0.21	0.42	-	-	0.21	0.42	0.63
Minor Athabasca River Tributaries[2]	135,132	4.24	19.85	-	-	4.24	19.85	24.09
Total	**3,561,097**	**1.46**	**1.85**			**1.48**	**1.85**	**3.33**
Lac La Biche[4]	863,473	0.06	-	-	-	0.06	-	0.06

[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 total watershed areas were updated using data from AESRD. The MacKay River watershed area is now larger compared to the old boundary, which makes the total watershed area of the FSA larger than previous years using older data sources. Other watersheds have slight differences in size compared to the old boundaries.

[4] The Lac La Biche watershed was added in 2011 given some of the Canadian Natural Kirby project is located within this watershed. The Lac La Biche watershed is not part of the RAMP FSA.

3.0 2013 RAMP MONITORING ACTIVITIES

This section contains a description of RAMP monitoring conducted in 2013 and includes the following for each RAMP component:

- Summary of 2013 monitoring activities and field methods;
- Description of any other information obtained (i.e., information from regulatory agencies, owners and operators of the 2013 focal projects, knowledge obtained from local communities, and other sources);
- Description of changes in the monitoring network from the 2012 program;
- Description of the challenges and issues encountered during 2013 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 2013 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 2013. Appendix B contains a detailed description of the QA/QC procedures used for RAMP monitoring in 2013.

All 2013 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 2013 RAMP Climate and Hydrology monitoring network included:

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

3.1.1.1 Overview of 2013 Monitoring Activities

Climate and Hydrology monitoring in 2013 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 four 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):
    - 29 year-round stations;
    - 17 open-water stations;
    - monitoring water temperature at 46 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 2013 program.

3.1.1.2 Field Methods

Field methods are described in this section and include 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 2013 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 field visits during the winter season to all year-round RAMP stations; three of the five winter visits included a regional snowcourse survey.

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

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;

Table 3.1-1 RAMP climate and hydrometric stations operating in 2013.

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	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	all year[1]	level, discharge, water temperature (C)
S9 Kearl Lake Outlet	483983, 6347020	all year	level, discharge, water temperature (C)
S10A Wapasu Creek near the mouth	488573, 6358554	all year	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)
S20A Muskeg River Upland	492230, 6354940	open-water	level, discharge, water temperature (C)
S22 Muskeg Creek near the mouth	480969, 6349071	all year	level, discharge, water temperature (C)
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	all year[1]	discharge

[1] WSC took over year-round monitoring on January 1, 2013.

[2] Station was installed in May 2013

[3] Station was installed in August 2013

[4] (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]
S27 Firebag River near the mouth (07DC001)	487914, 6389855	all year[1]	discharge
S29 Christina River near Chard (07CE002)	508211, 6187940	all year[1]	discharge
S31 Hangingstone Creek at North Star Road	469812, 6236089	all year	level, discharge, water temperature (C)
S32 Surmont Creek at Highway 881	490250, 6254524	all year	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	all year	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	all year[1]	discharge
S39 Beaver River above Syncrude (07DA018)	465560, 6311437	all year[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	all year[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)
S47A 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	level, discharge, water temperature (R-C)
S51 High Hills River near the mouth	532571, 6290998	all year	level, discharge, water temperature (G)
S53 Dover River near the mouth (07DB002)	451453, 6337017	all year	level, discharge, water temperature (R-C)
S54 Dunkirk River near Fort McKay (07DB003)	395815, 6302067	all year	level, discharge, water temperature (G)
S55 Gregoire River near the mouth	510185, 6259986	all year	level, discharge, water temperature (R-C)
S56 Jackfish River below Christina Lake (07CE005)	493753, 6169685	all year	level, discharge, water temperature (C)
S57 Sunday Creek above Christina Lake	506227, 6158403	all year	level, discharge, water temperature (C)
S58 Sawbones Creek above Christina Lake	511444, 6167182	open-water	level, discharge, water temperature (C)
S60 Unnamed Creek South of Christina Lake	511145, 6159877	open-water[2]	level, discharge, water temperature (C)
S61 Christina River above Statoil Leismer	466037, 6193791	all year[2]	level, discharge, water temperature (C)
S62 Birch Creek at Hwy 881	492232, 6163213	all year[2]	level, discharge, water temperature (C)
S63 Sunday Creek at Hwy 881	494283, 6157255	all year[2]	level, discharge, water temperature (C)
S64 Unnamed Creek East of Christina Lake	517384, 6163640	open-water[2]	level, discharge, water temperature (C)
S65 North Green Stockings Creek at East Athabasca Hwy	489845, 6333039	open-water[3]	level, discharge, water temperature (C)

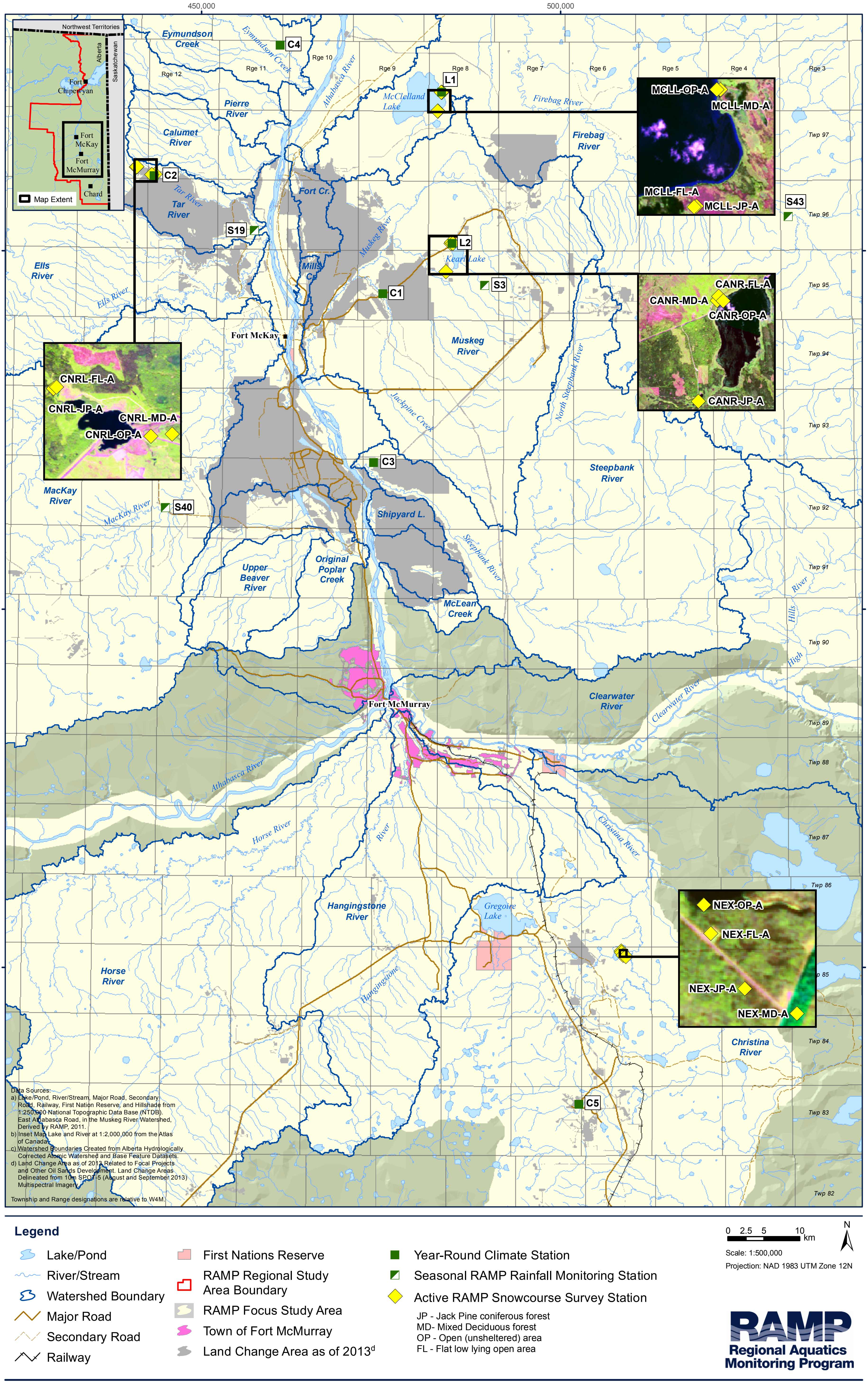
[1] WSC took over year-round monitoring on January 1, 2013.

[2] Station was installed in May 2013

[3] Station was installed in August 2013

[4] (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, 2013.

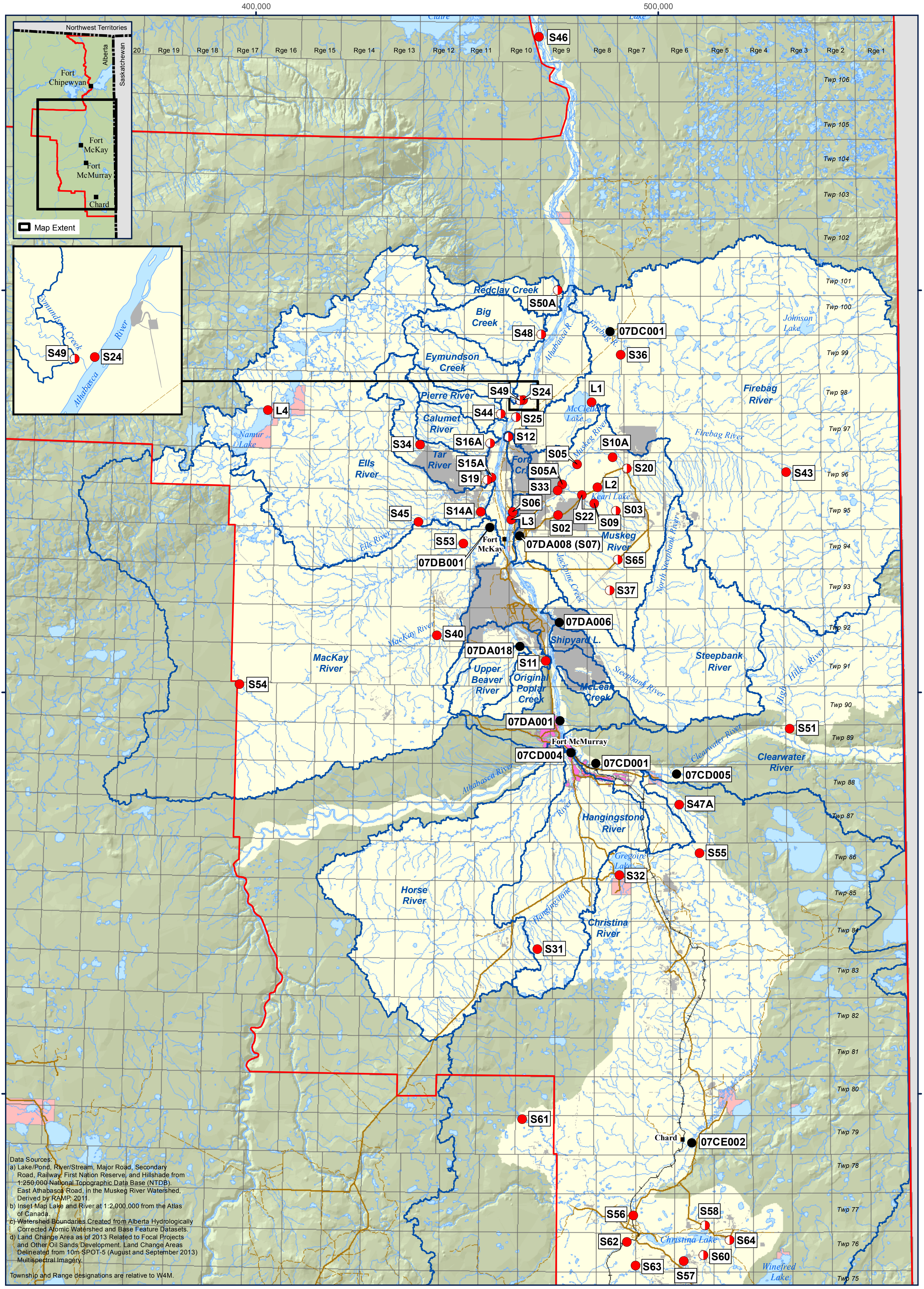


Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_D_Climate_20140218_ss.mxd

Figure 3.1-2 Locations of hydrometric stations operated by RAMP and Water Survey of Canada, 2013.



Data Sources:

a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.

b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.

c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.

d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) 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 2013[d]

Hydrometric Station

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

0 5 10 20 km

Scale: 1:950,000

Projection: NAD 1983 UTM Zone 12N

N

RAMP
Regional Aquatics Monitoring Program

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_E_Hydro_20140411_ss.mxd

    - 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 0.88 due to the addition of the ice as a confining layer, panels measured with two velocity measurements were not subject to any velocity correction; and
- Velocity averaging: at least 40-second averages for the Sontek FlowTracker ADV (Acoustic Doppler Velocimeter), OTT ADC (Acoustic Digital Current meter), and electromagnetic meters (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 (jack pine coniferous forest, mixed deciduous forest, open area, flat low-lying open area);
- Snow depth and the mass of a vertical profile of the snowpack were measured four times in each plot to calculate snow density;
- Forty snow water equivalent (SWE) values were calculated in each plot by multiplying individual snow depth values by mean snow density. A mean SWE value was calculated for each plot; and
- Station photos were taken to provide a visual record of ground snow conditions (e.g., patchiness) and any intercepted snow in treed stands.

3.1.1.3 Changes in Monitoring Network from 2012

Monitoring at the following stations was previously conducted by RAMP during the winter season and by Water Survey of Canada (WSC) in the open-water season:

S7/07DA008 Muskeg River near Fort McKay, S26/07DB001 MacKay River near Fort McKay, S27/07DC001 Firebag River near the mouth, S29/07CE002 Christina River near Chard, S38/07DA006 Steepbank River near Fort McMurray, S39/07DA018 Beaver River above Syncrude, and S42/07CD005 Clearwater River above Christina River. On January 1, 2013, WSC took over year-round operation of these stations; data were provided by WSC to RAMP for inclusion in the annual technical report.

New Monitoring Stations

- In order to characterize upstream hydrologic conditions of the Christina River, Station S61 was installed at a location 37 km northwest of Conklin, and upstream of the Statoil Leismer project. This station was installed and became operational in May 2013 for year-round monitoring of discharge, water level, and water temperature.
- To improve the characterization of hydrologic conditions in the Christina Lake drainage area, four stations were installed on tributaries to the lake. Station S62 Birch Creek at Hwy 881, and Station S63 Sunday Creek at Hwy 881, are operated year-round. Station S60 Unnamed Creek South of Christina Lake, and Station S64 Unnamed Creek East of Christina Lake, are operated during the open-water season only. These stations were installed and became operational in May 2013 for monitoring of discharge, water level, and water temperature.
- A monitoring station was installed on North Green Stockings Creek at the East Athabasca Hwy to characterize the hydrologic conditions of the area upstream of Khahago Creek. The station was installed and became operational in August 2013. A station on North Green Stockings Creek was selected in favor of Pemmican Creek at the East Athabasca Hwy (originally included in the JOSMP) because the channel characteristics in Pemmican Creek would yield poor results. Pemmican Creek and North Green Stockings Creek share similar basin size, similar terrain, and both drain into Khahago Creek, which drains into Muskeg Creek.

Modified Stations

The following modifications and field equipment upgrades were made in 2013 to support station function and reliability of data collection:

- Station S20 was relocated 800 m upstream, at the bridge of the main access road for the Imperial Kearl Project to avoid influence from beaver activity. The station was re-named as S20A.
- A new Pluvio2 precipitation gauge was installed at station L1 McClelland Lake, to replace the ageing Pluvio 1,000 gauge.
- A Sontek-SL Side-Looking Doppler Current Meter was installed at stations S58 Sawbones Creek and S36 McClelland Lake Outlet above Firebag River, to provide continuous discharge and velocity measurements, and assist with data analyses.
- Climate sensors were exchanged for calibration at the C2 Horizon, C4 Pierre, and C5 Surmont climate stations.
- Twelve 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 L1 McClelland Lake; L2 Kearl Lake; L3 Isadore’s Lake; S2 Jackpine Creek at Canterra Road; S5 Muskeg River above Stanley Creek; S14A Ells River at the CNRL bridge; S16A Calumet River near the mouth; S20A Muskeg River Upland; S33 Muskeg River at the Aurora North/Shell MRM Boundary; S40 MacKay River at the Petro-Canada bridge; S43 Firebag River above Suncor Firebag; and S45 Ells River above the Joslyn Creek Diversion.

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 2013:

- High water level in spring 2013 flooded the enclosure at Station S5 Muskeg River above Stanley Creek. The modem was damaged but the data logger remained functional, so no data loss occurred. Once water levels dropped, the data logger and modem were replaced, and the enclosure was relocated to higher ground.
- The pressure transducer at Station S11 Poplar Creek at Hwy 63, was dry from August 19 to September 22, 2013, caused by channel scour during the spring flooding that moved the channel. The monitoring station was relocated to the right bank, about 10 m downstream of the original monitoring location, and was re-instated on September 22, 2013.
- High water level during the spring flooded the enclosure at Station S32 Surmont Creek at Hwy 881. The modem and data logger were damaged, and the system stopped recording data on May 20, 2013. The modem and datalogger were replaced, and the enclosure was relocated to a higher position. The station was re-instated on June 25, 2013.
- The pressure transducer at Station S55 Gregoire River near the mouth, was pulled from the data logger on June 11, 2013, during a high-water event. Significant channel scour at this site resulted in approximately 10 m of the left bank being washed away, causing damage to three of four benchmarks. The station was re-instated on August 11, and two new benchmarks were installed on September 15, 2013.
- The pressure transducer at Station S56 Jackfish River below Christina Lake was pulled from the logger by debris in the river, during spring high water. The transducer was replaced on May 18, 2013 and the station was re-instated.
- An ice jam and subsequent ice break-up caused damage to Station S24 Athabasca River below Eymundson Creek, on May 2, 2013. The data logger and modem were replaced, two new benchmarks were installed, and the enclosure was mounted to a new mast to re-instate the station on May 13, 2013.
- An ice jam and subsequent ice break-up caused damage to S46 Athabasca River near Embarras Airport, on May 2, 2013. All benchmarks were damaged by ice, and the enclosure was flooded. The data logger and pressure transducer were replaced, three new benchmarks were installed, and the enclosure was mounted to a new mast to re-instate the station on May 23, 2013.
- Ice break-up caused the pressure transducer to be pulled from the data logger at Station S47A Christina River near the mouth, on May 2, 2013. The transducer was replaced and the station was re-instated on May 9, 2013.
- A power cable was severed by wildlife causing a disruption to monitoring at Station S36 McClelland Lake outlet above the Firebag River, on August 21, 2013. The power cables were repaired and the station was re-instated on September 15, 2013.
- A power cable was pulled from the monitoring equipment at Station S43 Firebag River above Suncor Firebag, causing a disruption to monitoring on July 17, 2013. The cable was repaired and the station was re-instated August 12, 2013.
- A power connector was severed at Station S50A Red Clay Creek, when wildlife pulled the enclosure from the tree it was mounted to, causing a disruption to

station monitoring on August 5, 2013. The station was repaired and re-instated during the next field visit on August 10, 2013.

- Wildlife caused the transducer cable to be disconnected at Station S61 Christina River above Statoil Leismer, causing a disruption to monitoring on September 12, 2013. The sensor was rewired and the station was re-instated on September 16. Wildlife caused damage to power cables and the transducer cable again on September 28, causing a disruption to monitoring. The station was repaired and re-instated during the next field visit on October 17, 2013.
- The tipping bucket and solar panel were vandalized at Station S31 Hangingstone Creek at North Star Road. The data logger remained online, so monitoring was not disrupted. The solar panel was replaced during the field visit on September 17, and a replacement tipping bucket will be installed in spring 2014.

Data Logger Malfunctions and Attrition

The following data logger malfunctions and equipment challenges were addressed by the RAMP Climate and Hydrology component in 2013:

- A faulty power connection at Station S5A Muskeg River above Muskeg Creek, caused monitoring to be intermittent from April 9 to May 8, 2013, when the connection was repaired.
- Water level recorded at S25 Susan Lake Outlet was erroneous from May 5 to July 11, 2013 due to a faulty pressure transducer. Given this data gap in the period of record for the 2013 WY, a hydrograph was not presented in Section 5.
- A faulty power connection caused a disruption to monitoring at Station S31 Hangingstone Creek at North Star Road, on February 25, 2013. The connection was repaired during the next field visit, and the station was re-instated on April 3, 2013.
- A faulty power connection at Station S53 Dover River near the mouth, caused a disruption to monitoring on June 8, 2013. The connection was repaired and the station was re-instated during the next field visit on June 15, 2013.
- A solar panel short at Station S51 High Hills River near the mouth, caused the data logger to malfunction on August 11, 2013. The solar panel was repaired and station function was re-instated on September 14, 2013.

3.1.1.5 Other Information Obtained

Streamflow data from WSC were obtained and incorporated into the RAMP database, for stations that were jointly operated by RAMP and WSC in previous years. 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 2013 technical 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 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 2013. (Page 1 of 2)

see symbol key at bottom

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

Legend

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

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

🟦 *Test* (downstream of focal projects)
🟩 *Baseline* (upstream of focal projects)

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

see symbol key at bottom

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

Legend

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

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

🟦 *Test* (downstream of focal projects)
🟩 *Baseline* (upstream of focal projects)

3.1.2 Water Quality Component

3.1.2.1 Overview of 2013 Monitoring Activities

Monitoring activities for the Water Quality component were conducted in twelve sampling campaigns in 2013: monthly sampling at five locations, and larger, seasonal campaigns in winter (March 14 and 15); spring (May 19 to 22); summer (July 11 to 16); and fall (September 3 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. Water quality was sampled at 63 RAMP stations in 2013. Figure 3.1-3 provides the locations of water quality sampling in 2013. Table 3.1-3 summarizes the location of 2013 water quality sampling stations, seasonal distribution of the sampling effort, and water quality variables measured at each station. Sampling intensity was greatest during the fall campaign, with samples collected from all 2013 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). In 2013, monthly water quality sampling was initiated at some locations, as part of the JOSM Plan to determine if any differences across months within a year exist.

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 were samples collected for total hydrocarbons (oil and grease) and BTEX analyses, which were taken from the surface of the water to ensure capture of any floating hydrocarbons, and to ensure that the pre-charged preservative stayed in the sample. The ultra-trace mercury bottle was triple-rinsed prior to the final sample collection, following guidance from the analytical laboratory.

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

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

All water samples were collected, preserved, and shipped according to protocols specified by consulting laboratories. 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 2013 were analyzed for the RAMP standard variables in all sampling seasons, which included the addition of CCME fractionated hydrocarbons and PAHs in 2011 (Table 3.1-4). All analyses were conducted by ALS Environmental Ltd. (Fort McMurray and Edmonton, Alberta), with the exception of total and dissolved metals (including ultra-trace mercury) and acid-extractable organics (naphthenic acids), which were analyzed by Alberta Innovates Technology Futures (AITF) in Vegreville, Alberta, and PAHs, which were analyzed by AXYS Analytical Services Ltd. in Sidney, BC. Samples collected from regional lakes were also analyzed for chlorophyll *a* by ALS.

Details of analytical chemistry methods and associated detection limits for the Water Quality component are provided in Table 3.1-4. 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

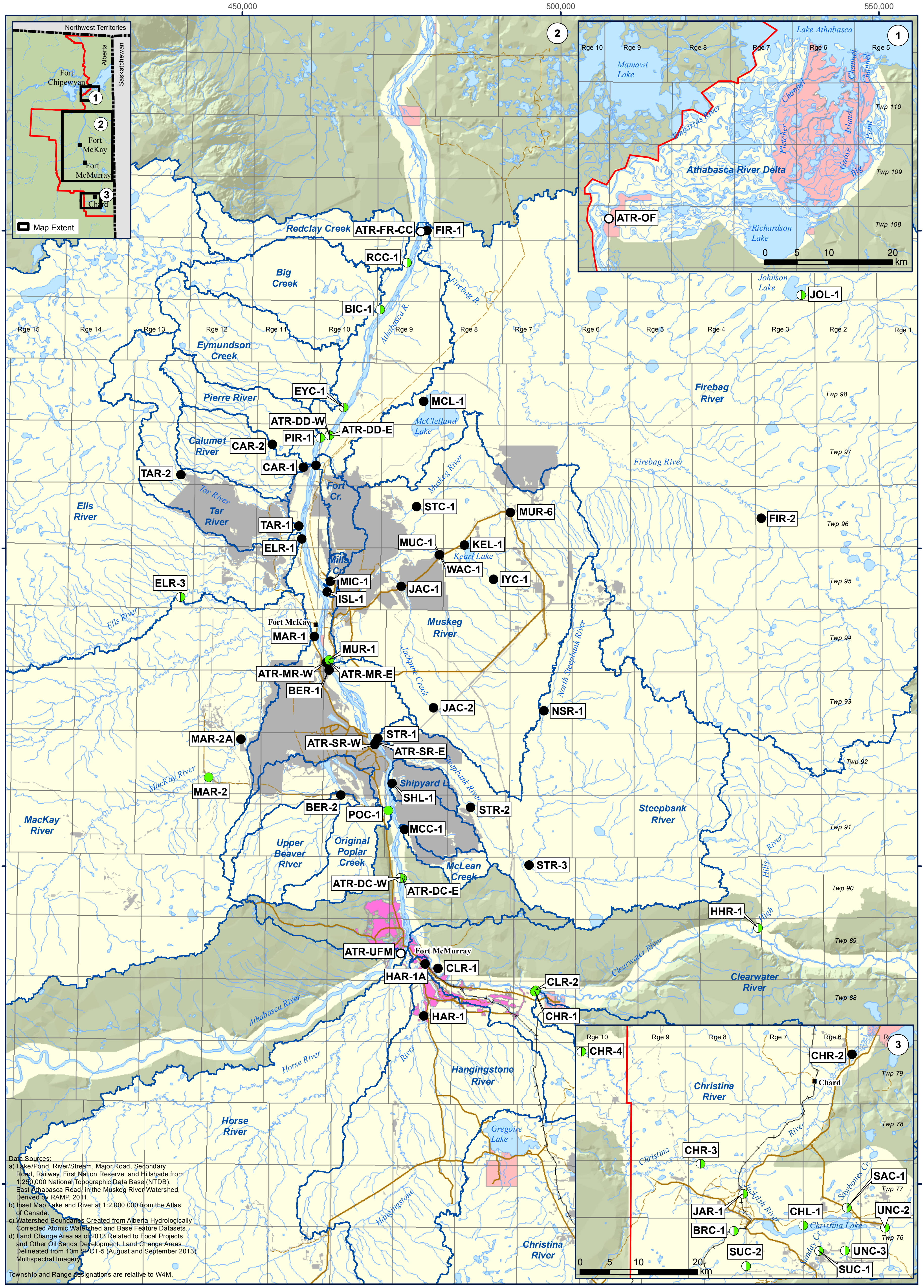
Ultra-trace analysis of PAHs in water was introduced to RAMP in the 2011 program, with analysis conducted by AXYS Analytical Ltd. (AXYS) using low-resolution mass spectrometry (LRMS). Results for 43 parent and alkylated PAH homologues were reported, with analytical reporting (detection) limits of approximately 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 2013. 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.

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).

Figure 3.1-3 Locations of water quality stations monitored by RAMP and AESRD, 2013.



Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) 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 2013[d]

Water Quality Station
● RAMP Monthly
◐ RAMP Seasonal
● RAMP Fall Only
○ AESRD Monthly

0 2.5 5 10 km

N

Scale: 1:600,000

Projection: NAD 1983 UTM Zone 12N

RAMP
Regional Aquatics Monitoring Program

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_F_Water_20140224_ss.mxd

Table 3.1-3 Summary of sampling for the RAMP 2013 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	1	1	1	1	East bank grab
ATR-DC-W	Athabasca River upstream of Donald Creek (west bank)	474797	6298209	1	1	1	1	West bank grab
ATR-DD-E	Athabasca River downstream of all development (east bank)	463709	6367828	1	1	1	1	East bank grab
ATR-DD-W	Athabasca River downstream of all development (west bank)	463709	6367819	1	1	1	1	West bank grab
ATR-MR-E	Athabasca River upstream of the Muskeg River (east bank)	463504	6332230	-	-	-	1	East bank grab
ATR-MR-W	Athabasca River upstream of the Muskeg River (west bank)	463195	6332090	-	-	-	1	West bank grab
ATR-SR-E	Athabasca River upstream of the Steepbank River (east bank)	470932	6319461	-	-	-	1	East bank grab
ATR-SR-W	Athabasca River upstream of the Steepbank River (west bank)	470785	6319199	-	-	-	1	West bank grab
Tributaries to the Athabasca River (Southern)								
Clearwater River and Tributaries								
CLR-1	Clearwater River upstream of Fort McMurray	480735	6283997	1	-	-	1	Mid-channel grab
CLR-2*	Clearwater River upstream of Christina River	496094	6280541	-	1	1	1	Mid-channel grab
HAR-1	Hangingstone River	478518	6276485	-	-	-	1	Mid-channel grab
HAR-1A	Hangingstone River near the mouth	478741	6284693	-	-	-	1	Mid-channel grab
Christina River and Tributaries								
CHR-1*	Christina River upstream of Fort McMurray	495968	6280327	1	1	1	1	Mid-channel grab
CHR-2	Christina River upstream of Janvier	511754	6192348	-	-	-	1	Mid-channel grab
CHR-3	Christina River upstream of Jackfish River	486512	6174647	1	1	1	1	Mid-channel grab
CHR-4	Christina River upstream of development	466231	6193833	1	-	-	1	Mid-channel grab
JAR-1	Jackfish River	493797	6169546	1	1	1	1	Mid-channel grab
SUC-1	Sunday Creek downstream	506716	6159804	1	1	1	1	Mid-channel grab
SUC-2	Sunday Creek upstream	494292	6157244	1	1	1	1	Mid-channel grab
SAC-1	Sawbones Creek	511453	6167195	1	1	1	1	Mid-channel grab
UNC-2	Unnamed Creek east of Christina Lake	517894	6163788	1	1	1	1	Mid-channel grab
UNC-3	Unnamed Creek south of Christina Lake	511129	6159870	1	1	1	1	Mid-channel grab
BRC-1	Birch Creek	492173	6163203	1	1	1	1	Mid-channel grab
High Hills River								
HHR-1	High Hills River (mouth)	529938	6289299	1	1	1	1	Mid-channel grab
Tributaries to the Athabasca River (Eastern)								
FOC-1	Fort Creek	461549	6363105	-	-	-	1	Mid-channel grab
MCC-1	McLean Creek (mouth)	474637	6306051	-	-	-	1	Mid-channel grab
Steepbank River								
NSR-1	North Steepbank River	497367	6324536	-	-	-	1	Mid-channel grab
STR-1	Steepbank River (mouth)	471320	6320145	-	-	-	1	Mid-channel grab
STR-2	Steepbank River upstream of Suncor Millennium	485845	6309326	-	-	-	1	Mid-channel grab
STR-3	Steepbank River upstream of North Steepbank River	495011	6300231	-	-	-	1	Mid-channel grab
Muskeg River and Muskeg River Tributaries								
MUR-1*	Muskeg River (mouth)	463643	6332490	1	1	1	1	Mid-channel grab
MUR-6A	Muskeg River upstream of Wapasu Creek	492093	6355679	-	-	-	1	Mid-channel grab
JAC-1	Jackpine Creek (mouth)	474982	6344048	-	-	-	1	Mid-channel grab
JAC-2	Jackpine Creek (upstream)	480050	6324945	-	-	-	1	Mid-channel grab
MUC-1	Muskeg Creek (mouth)	481032	6349025	-	-	-	1	Mid-channel grab
IYC-1	Iyinimin Creek	489421	6345190	-	-	-	1	Mid-channel grab
STC-1	Stanley Creek (mouth)	477402	6356617	-	-	-	1	Mid-channel grab
WAC-1	Wapasu Creek at Canterra Road crossing	480969	6349062	-	-	-	1	Mid-channel grab

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids) + PAHs
2 = standard water quality + chlorophyll-a + PAHs
3 = AESRD routine parameters (conventional parameters, major ions, nutrients and total metals)
4 = AESRD routine parameters + RAMP standard parameters
5 = AESRD routine parameters + PAHs
* = monthly sampling

Table 3.1-3 (Cont'd.)

Station Identifier and Location		UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	Winter	Spring	Summer	Fall	
Firebag River								
FIR-1	Firebag River (mouth)	479033	6400124	-	-	-	1	Mid-channel grab
FIR-2	Firebag River upstream of Suncor Firebag	530960	6355240	-	-	-	1	Mid-channel grab
Tributaries to the Athabasca River (Western)								
BER-1	Beaver River (mouth)	463640	6330910	-	-	-	1	Mid-channel grab
POC-1*	Poplar Creek (mouth)	472958	6308822	1	1	1	1	Mid-channel grab
BER-2	Beaver River (upper)	465489	6311275	-	-	-	1	Mid-channel grab
CAR-1	Calumet River (mouth)	460760	6363184	-	-	-	1	Mid-channel grab
CAR-2	Calumet River (upper river)	454085	6367008	-	-	-	1	Mid-channel grab
ELR-1	Ells River (mouth)	459304	6351517	-	-	-	1	Mid-channel grab
ELR-3	Ells River (upstream)	440306	6342418	1	1	1	1	Mid-channel grab
TAR-1	Tar River (mouth)	458854	6353551	-	-	-	1	Mid-channel grab
TAR-2	Tar River upstream of Canadian Natural Horizon	440357	6361662	-	-	-	1	Mid-channel grab
PIR-1	Pierre River (mouth)	462291	6367440	-	1	1	1	Mid-channel grab
EYC-1	Eymundson Creek (mouth)	465933	6372234	-	1	1	1	Mid-channel grab
BIC-1	Big Creek (mouth)	471687	6387679	1	1	1	1	Mid-channel grab
RCC-1	Red Clay Creek (mouth)	475878	6395027	-	1	1	1	Mid-channel grab
MacKay River								
MAR-1	MacKay River (mouth)	461314	6336214	-	-	-	1	Mid-channel grab
MAR-2*	MacKay River upstream of Suncor MacKay	444731	6314041	1	1	1	1	Mid-channel grab
MAR-2A	MacKay River upstream of Suncor Dover	449746	6320067	-	-	-	1	Mid-channel grab
Lakes and Wetlands								
ISL-1	Isadore's Lake	463356	6343198	-	-	-	2	Mid-lake grab
KEL-1	Kearl Lake	484850	6350577	-	-	-	2	Mid-lake grab
MCL-1	McClelland Lake	478523	6373163	-	-	-	2	Mid-lake grab
SHL-1	Shipyard Lake	473558	6313093	-	-	-	2	Mid-lake grab
JOL-1	Johnson Lake	537800	6389935	2	2	2	2	Mid-lake grab
CHL-1	Christina Lake	504047	6164156	2	2	2	2	Mid-lake grab
Tributaries to Lakes								
MIC-1	Mills Creek, tributary to Isadore's Lake	463842	6344880	-	-	-	1	Mid-channel grab
QA/QC[1]								
-				1	1	1	1	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	5	3	5	3	AESRD sampling
ATR-OF	Athabasca River at Old Fort (monthly)	470205	6474330	4	4	4	4	AESRD sampling
ATR-FR-CC	Athabasca River upstream of the Firebag River	478031	6377868	5	5	5	5	AESRD sampling

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard water quality + chlorophyll-a + PAHs
3 = AESRD routine parameters (conventional parameters, major ions, nutrients and total metals)
4 = AESRD routine parameters + RAMP standard parameters
5 = AESRD routine parameters + PAHs
* = monthly sampling

3.1.2.3 Changes in Monitoring Network from 2012

The 2013 monitoring network for the Water Quality component was the same as the 2012 monitoring network with the following exceptions:

- Four new *test* stations were established, including Christina River upstream of Jackfish River (CHR-3), Unnamed Creek east of Christina Lake (UNC-2), Unnamed Creek south of Christina Lake (UNC-3), and Hangingstone River at the mouth (HAR-1A);
- Four new *baseline* stations were established, including Christina River upstream of development (CHR-4), Ells River upstream of development (ELR-3), Sunday Creek upstream (SUC-2), and Birch Creek (BRC-1);
- Ells River stations, ELR-2 and ELR-2A, were removed from the sampling program as these stations are no longer *baseline* (ELR-3 now represents *baseline* conditions in the Ells River watershed);
- Muskeg River station, MUR-6, was moved upstream approximately 1 km to the location of the hydrology station S20A. The station was re-named MUR-6A; and
- Five stations were sampled monthly, including lower Muskeg River (MUR-1), Poplar Creek (POC-1), middle MacKay River (MAR-2), lower Christina River (CHR-1), and upper Clearwater River (CLR-2, although CLR-1 was sampled in January to April before moving the sampling to CLR-2).

3.1.2.4 Changes in Analytical Chemistry Methods from 2012

No changes were made in analytical chemistry methods from 2012 to 2013.

3.1.2.5 Challenges Encountered and Solutions Applied

During the summer sampling program, high rain events created flooding and 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.

Due to laboratory error, samples collected from *baseline* station TAR-2 for analysis of several conventional water quality variables (e.g., TSS, major ions, nutrients, and total hydrocarbons) were not analyzed.

3.1.2.6 Other Information Obtained

All sampling for the Water Quality component in 2013 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 for ATR-UFM and ATR-OF 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 differed 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 3.1-4 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	0.1300	0.9597	LR GC/MS	AXYS
	C1-Biphenyls	ng/L	0.1251	4.0686	LR GC/MS	AXYS
	C2-Biphenyls	ng/L	0.3759	20.7882	LR GC/MS	AXYS
	Naphthalene	ng/L	0.2065	15.1623	LR GC/MS	AXYS
	C1-Naphthalenes	ng/L	0.1680	8.4772	LR GC/MS	AXYS
	C2-Naphthalenes	ng/L	0.2989	4.2543	LR GC/MS	AXYS
	C3-Naphthalenes	ng/L	0.2495	3.1153	LR GC/MS	AXYS
	C4-Naphthalenes	ng/L	0.3243	5.0606	LR GC/MS	AXYS
	Acenaphthylene	ng/L	0.1963	0.2801	LR GC/MS	AXYS
	Acenaphthene	ng/L	0.1377	0.3696	LR GC/MS	AXYS
	C1-Acenaphthenes	ng/L	0.1635	0.6689	LR GC/MS	AXYS
	Fluorene	ng/L	0.1228	0.3371	LR GC/MS	AXYS
	C1-Fluorenes	ng/L	0.3125	5.1099	LR GC/MS	AXYS
	C2-Fluorenes	ng/L	0.2289	3.1208	LR GC/MS	AXYS
	C3-Fluorenes	ng/L	0.3746	3.8970	LR GC/MS	AXYS
	Phenanthrene	ng/L	0.2078	1.6890	LR GC/MS	AXYS
	Anthracene	ng/L	0.2174	0.3696	LR GC/MS	AXYS
	C1-Phenanthrenes/Anthracenes	ng/L	0.2337	0.9835	LR GC/MS	AXYS
	C2-Phenanthrenes/Anthracenes	ng/L	0.1702	2.6336	LR GC/MS	AXYS
	C3-Phenanthrenes/Anthracenes	ng/L	0.4689	1.5072	LR GC/MS	AXYS
	C4-Phenanthrenes/Anthracenes	ng/L	0.9271	2.9292	LR GC/MS	AXYS
	Retene	ng/L	0.9271	0.6694	LR GC/MS	AXYS
	Dibenzothiophene	ng/L	0.1649	0.4971	LR GC/MS	AXYS
	C1-Dibenzothiophenes	ng/L	0.3037	0.3095	LR GC/MS	AXYS
	C2-Dibenzothiophenes	ng/L	0.2067	1.4945	LR GC/MS	AXYS
	C3-Dibenzothiophenes	ng/L	0.2652	1.8484	LR GC/MS	AXYS
	C4-Dibenzothiophenes	ng/L	0.2415	2.5229	LR GC/MS	AXYS
	Fluoranthene	ng/L	0.1361	0.7358	LR GC/MS	AXYS
	Pyrene	ng/L	0.1352	0.5274	LR GC/MS	AXYS
	C1-Fluoranthenes/Pyrenes	ng/L	0.4282	1.4140	LR GC/MS	AXYS
	C2-Fluoranthenes/Pyrenes	ng/L	0.4185	1.6084	LR GC/MS	AXYS
	C3-Fluoranthenes/Pyrenes	ng/L	0.6609	0.9160	LR GC/MS	AXYS
	Benz[a]anthracene	ng/L	0.2414	0.1544	LR GC/MS	AXYS
	Chrysene	ng/L	0.2362	0.2952	LR GC/MS	AXYS
	C1-Benzo[a]anthracenes/Chrysenes	ng/L	0.1927	0.3240	LR GC/MS	AXYS
	C2-Benzo[a]anthracenes/Chrysenes	ng/L	0.2855	0.3707	LR GC/MS	AXYS
	Benzo[b,j,k]fluoranthene	ng/L	0.2747	0.2972	LR GC/MS	AXYS
	Benzo[a]pyrene	ng/L	0.4482	0.2511	LR GC/MS	AXYS
	C1-Benzofluoranthenes/Benzopyrenes	ng/L	0.3875	0.9115	LR GC/MS	AXYS
	C2-Benzofluoranthenes/Benzopyrenes	ng/L	0.3600	1.2177	LR GC/MS	AXYS
	Indeno[1,2,3-c,d]-pyrene	ng/L	0.2791	0.2865	LR GC/MS	AXYS
	Dibenz[a,h]anthracene	ng/L	0.3065	0.7801	LR GC/MS	AXYS
	Benzo[g,h,i]perylene	ng/L	0.2510	0.1665	LR GC/MS	AXYS

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				2013			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																																			
Upstream of Fort McMurray (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	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	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	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				3
(east bank)	ATR-SR-E																1				1				1				1				1				1				1				1				1				1				1				3				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				3
(east bank) [b c]	ATR-MR-E								1								1				1				1				1				1				1				1				1				1				1				1				3				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	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	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	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				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	3			3
(upstream of Project Millennium)	STR-2																					1			1				1				1				1				1				1				1				1				1				3				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				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				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				3
Muskeg River																																																																					
Mouth [f,i]	MUR-1			1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1				1				1				1				1				1				1				1				1				3				3	3	3	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				
(1000 m upstream of MUR-6)	MUR-6A																																																																			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				3
(upper)	JAC-2																																																1				1				2				3				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				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				3
Iyinimin Creek (mouth)	IYC-1																																											1	1				1								1				3				3				3
Wapasu Creek (Canterra Road Crossing)	WAC-1								11,2	1			11,1																				1				1				1				1				1				1				1				3				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
[i] Monthly sampling initiated in 2013.

🟦 *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				2013			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western)																																																																				
Poplar Creek (mouth)[i]	POC-1																1				1				1				1				1				1				1				1				1				1				1				3				3	3	3	3	3
Beaver River (mouth)	BER-1																											1	1			1	1			1	1				1				1	1			1				1				1				3				3				3
(upper)	BER-2																																														1	1	1	1	1	1	1	1	1	1	1				3				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				3
(mid-river, upstream of Suncor Dover)	MAR-2A																																																	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3				3
(upstream of Suncor MacKay)[i]	MAR-2																					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
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				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				
(upper)	ELR-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				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				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				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				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				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				3
Pierre River (mouth)	PIR-1																																																									1	3	3	3	3	3	3	3	3			3
Eymundson Creek (mouth)	EYC-1																																																									1	3	3	3	3	3	3	3	3			3
Big Creek (mouth)	BIC-1																																																									1	3	3	3	3	3	3	3	3	3	3	3
Red Clay Creek (mouth)	RCC-1																																																									1	3	3	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	3			3
(upstream of Christina River)[i]	CLR-2																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7		6	6	7		6		7				1				1				1				3				3		3	3	3
Christina River (upstream of Fort McMurray)[i]	CHR-1																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1				1				1				3				3	3	3	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				3
(mid)	CHR-2A																																									1			1																								
(upstream of Jackfish River)	CHR-3																																																																			3	3	3	3
(upstream of development)	CHR-4																																																																			3	3	3	3
Jackfish River (outlet of Christina Lake)	JAR-1																																																														3	3	3	3	3	3	3
Sunday Creek (inlet to Chistina Lake)	SUC-1																																																														3	3	3	3	3	3	3
Sunday Creek (upstream)	SUC-2																																																																	3	3	3	3
Sawbones Creek (inlet to Chistina Lake)	SAC-1																																																														3	3	3	3	3	3	3
Unnamed Creek (east of Christina Lake)	UNC-2																																																																	3	3	3	3
Unnamed Creek (south of Christina Lake)	UNC-3																																																																	3	3	3	3
Birch Creek	BRC-1																																																																	3	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																				3
Hangingstone River (mouth)	HAR-1A																																																																				3
Horse River (Fish program support)	HOR-1																																																				1																
High Hills River (mouth)	HHR-1																																																									1	3	3	3	3	3	3	3	3	3	3	3
Lake Tributaries																																																																				
Mills Creek	MIC-1																																																								1				3				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				17
Isadore's Lake	ISL-1							16									16			16	16											16	16			16	16			16	16			16	16			16	16				16				16				17				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				17
McClelland Lake	MCL-1																16			1	16				1				1												16				16				16				1				16				17				17				17
Johnson Lake	JOL-1																																																									16	17	17	17	17	17	17	17	17	17	17	17
Christina Lake	CHL-1																																																														17	17	17	17	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						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	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
[i] Monthly sampling initiated in 2013.

🟦 *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 2013 Monitoring Activities for the Benthic Invertebrate Communities Component

Benthic invertebrate communities were sampled from September 3 to 19, 2013. A total of 395 samples were collected from 33 river reaches, four delta channels, and six lakes (Table 3.1-7, Figure 3.1-4). As in previous years, sampled habitats were classified as either depositional (dominated by fine sediment deposits and low to no flow) or erosional (dominated by rocky substrates and frequent riffle areas). These habitat classes have not changed from year to year within a reach. Sampling methods are specific to the habitat class, as described below.

Field Methods

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

Ten replicate samples were collected from within pre-established river reaches that were typically 2 to 4 km long. Five replicate samples were collected from Athabasca River Delta (ARD) channels. Samples were selected from within each reach, based on habitat availability and approximately equal spacing. The same sampling locations were re-visited from year to year, when conditions permitted. Water level variations from year to year frequently required that sampling be undertaken at different locations than those sampled the previous year.

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

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

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

- Wetted and bankfull channel widths – visual estimate (for rivers/streams only);
- Field water quality measurements – dissolved oxygen, conductivity, temperature, and pH. The instrument (hand-held Hanna meter) used to measure conductivity and pH was calibrated according to manufacturer's instructions; dissolved oxygen was measured by field titrations (portable Winkler titration kit);
- Water velocity – determined by measuring the time for a semi-submerged object to travel a known distance (2 m);
- Water depth at the benthos sampling location – measured with a graduated device (pole or Hess cylinder);
- Amount of benthic algae at erosional stations (for chlorophyll *a* measurement) – obtained by scraping of a 1 cm x 1 cm square from three randomly-selected cobbles and combining these into one composite sample per station;

- Substrate particle size distribution (erosional stations only) – visual estimates of areal coverage by particles in standard size categories using the modified Wentworth classification system (Cummins 1962) and expressed as percentages;
- An additional Ekman grab sample collected at depositional stations for analysis of total organic carbon (TOC, as a dry weight percentage) and particle size (% sand, silt and clay, as dry weight);
- Geographical position – using a hand-held Magellan Global Positioning System (GPS) unit; and
- General station appearance.

Laboratory Methods

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

Dr. Jack Zloty in Summerland, BC performed sorting and taxonomic identifications, as in previous years. Samples were sieved in the laboratory using a 250-µm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by the sieve was elutriated using a flotation technique to separate organic material from sand and gravel, and invertebrates from organic material. Samples containing bitumen were treated with paint thinner to remove hydrocarbons prior to sorting. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. The remaining organic material was separated into coarse and fine size fractions using a 1-mm sieve. The fine size fraction of large samples was sub-sampled using a modification of the method described by Wrona et al. (1982) in which fine materials were scanned for invertebrates with the aid of a dissecting microscope at a magnification of 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 2012

The 2013 monitoring network for the Benthic Invertebrate Communities component was the same as the 2012 monitoring network, with the exceptions of the following additions and changes:

- A new upper *baseline* reach on the Ells River (ELR-E3) to account for expanding development in that watershed. ELR-E2 and ELR-E2A, were removed from the sampling program as these reaches will no longer be *baseline* reaches (ELR-E3 now represents *baseline* conditions in the Ells River watershed);
- Lower *baseline* reach of Pierre River (PIC-D1), in advance of development in the watershed;
- Lower *baseline* reach of Red Clay Creek (RCC-E1), in advance of development in the watershed;
- Lower *baseline* reach of Eymundson Creek (EYC-D1), in advance of development in the watershed;

Table 3.1-7 Summary of sampling locations for the RAMP 2013 Benthic Invertebrate Communities component.

Waterbody and Location	Habitat[1]	Reach or Station	UTM Coordinates (NAD 83, Zone 12) Downstream Limit of Reach Easting	Downstream Limit of Reach Northing	Upstream Limit of Reach Easting	Upstream Limit of Reach Northing
Athabasca River Delta						
Goose Island Channel	depositional	GIC-1	509595	6494210	509531	6494474
Big Point Channel	depositional	BPC-1	512031	6494304	511954	6494450
Fletcher Channel	depositional	FLC-1	496412	6491582	496484	6491706
Embarrass River	depositional	EMR-2	494653	6491912	494732	6492044
Steepbank River						
Lower Reach	erosional	STR-E1	471379	6320145	472477	6319985
Upper Reach	erosional	STR-E2	499875	6297297	500789	6297519
Muskeg River						
Lower Reach	erosional	MUR-E1	463642	6332488	464499	6332283
Middle Reach	depositional	MUR-D2	466296	6339484	466600	6340505
Upper Reach	depositional	MUR-D3	480068	6357932	482137	6359819
Jackpine Creek						
Lower Reach	depositional	JAC-D1	471855	6346416	473051	6346333
Upper Reach	depositional	JAC-D2	480037	6324995	480796	6324609
Beaver River						
Upper Reach	depositional	BER-D2	465481	6311288	465433	6311020
Poplar Creek						
Lower Reach	depositional	POC-D1	473043	6308838	472531	6308614
Pierre River						
Lower Reach	depositional	PIR-D1	462252	6367481	462076	6367819
Red Clay Creek						
Lower Reach	erosional	RCC-E1	475769	6395077	4755466	6395356
Big Creek						
Lower Reach	depositional	BIC-D1	471617	6387774	470920	6387768
Birch Creek						
Lower Reach	depositional	BRC-D1	492173	6163203	491339	6163021
Eymundson Creek						
Lower Reach	depositional	EYC-D1	465878	6372237	465490	6372711
Firebag River						
Lower Reach	depositional	FIR-D1	479340	6400652	479418	6398380
Middle Reach	erosional	FIR-E2	530960	6355044	531927	6355110

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

[2] UTM coordinates of first replicate station.

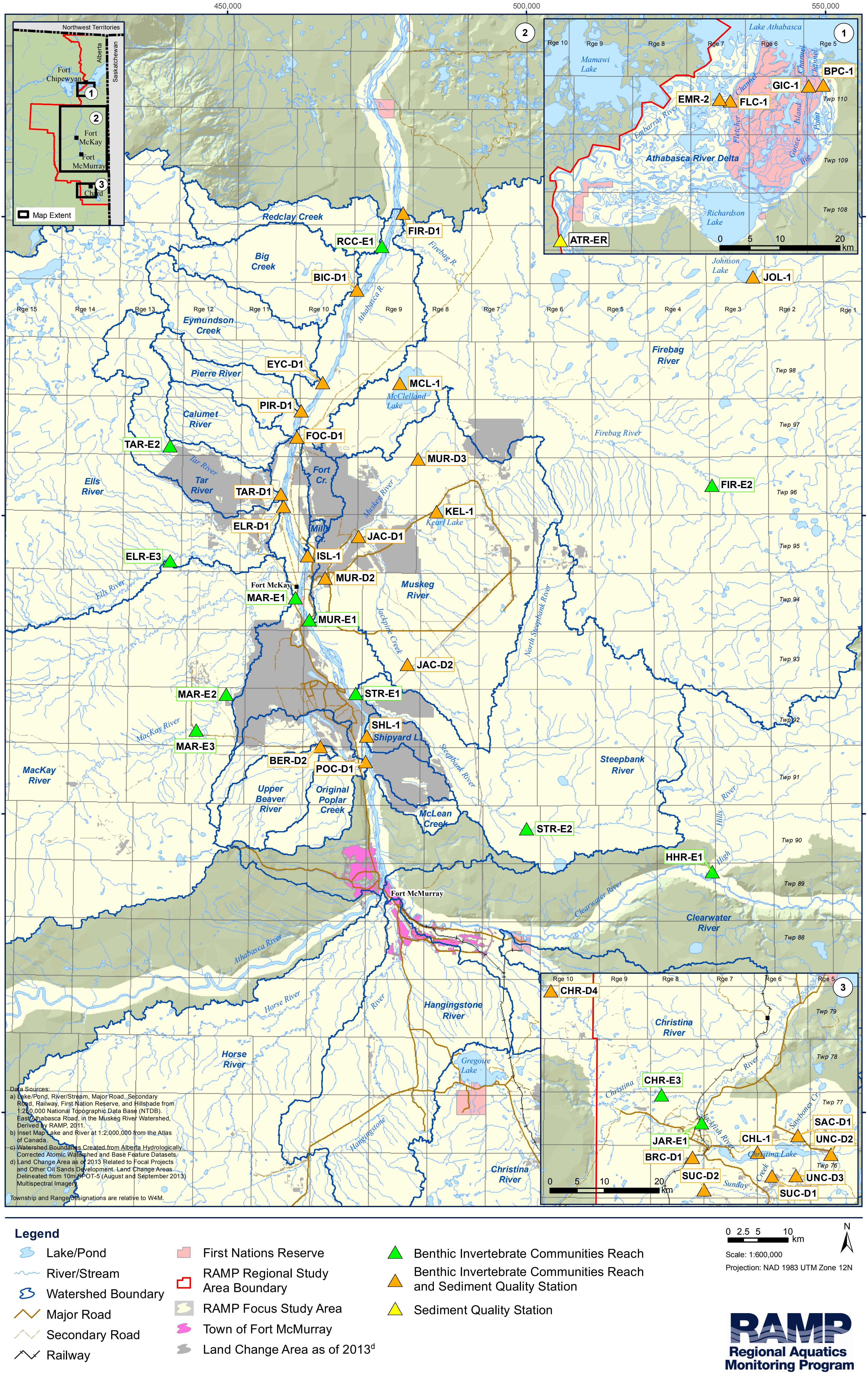
Table 3.1-7 (Cont'd.)

Waterbody and Location	Habitat[1]	Reach or Station	UTM Coordinates (NAD 83, Zone 12)			
			Downstream Limit of Reach		Upstream Limit of Reach	
			Easting	Northing	Easting	Northing
MacKay River						
Lower Reach	erosional	MAR-E1	461549	6336037	460689	6336712
Middle Reach	erosional	MAR-E2	449744	6320046	448661	6319314
Upper Reach	erosional	MAR-E3	444749	6314047	443986	6314120
Tar River						
Lower Reach	depositional	TAR-D1	458849	6353499	458566	6353566
Upper Reach	erosional	TAR-E2	440357	6361654	439874	6362088
Ells River						
Lower Reach	depositional	ELR-D1	459252	6351526	458592	6351534
Upper Reach	erosional	ELR-E3	440395	6342417	439342	6392681
Unnamed Creek (east of Christina Lake)						
Middle Reach	depositional	UNC-D2	517462	6163751	517894	6163738
Unnamed Creek (south of Christina Lake)						
Upper Reach	depositional	UNC-D3	511129	6159870	510932	6159494
High Hills River						
Lower Reach	erosional	HHR-E1	529937	6289298	530137	6289833
Fort Creek						
Lower Reach	depositional	FOC-D1	461543	6363105	461738	6363065
Jackfish River						
Lower Reach	erosional	JAR-E1	493856	6169498	494170	6168868
Christina River						
Middle Reach	erosional	CHR-E3	466231	6193835	465867	6193731
Upper Reach	depositional	CHR-D4	486512	6174647	486052	6175227
Sawbones Creek						
Lower Reach	depositional	SAC-D1	511437	6167216	511492	6167891
Sunday Creek						
Lower Reach	depositional	SUC-D1	506714	6159799	506267	6159659
Upper Reach	depositional	SUC-D2	494292	6157244	494016	6156719
Lakes[2]						
Kearl Lake	lake	KEL-1	484913	6351049	484917	6350770
McClelland Lake	lake	MCL-1	478523	6373163	478641	6372033
Shipyard Lake	lake	SHL-1	473471	6313094	473424	6313291
Christina Lake	lake	CHL-1	504047	6164156	502990	6164137
Johnson Lake	lake	JOL-1	537800	6389935	537913	6391670
Isadore's Lake	lake	ISL-1	463332	6343441	463544	6343119

[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, 2013.



Data Sources:

a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.

b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.

c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.

d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_G_BenthosSed_20140218_ss.mxd

- Lower *baseline* reach of Big Creek (BIC-D1), in advance of development in the watershed;
- Upper *baseline* reach of Sunday Creek (SUC-D2) to provide *baseline* data for the lower *test* reach (SUC-D1);
- Lower *baseline* reach of Birch Creek (BRC-D1) to provide regional *baseline* data for the Christina Lake area;
- Lower *test* reach of Unnamed Creek (UNC-D2), east of Christina Lake;
- Lower *test* reach of Unnamed Creek (UNC-D3), south of Christina Lake (locally known as Monday Creek);
- Middle *test* reach of Christina River (CHR-E3), to characterize the river upstream of the confluence with Jackfish River and the Christina Lake area;
- Upper *baseline* reach of the Christine River (CHR-D4) to provide *baseline* information for the watershed;
- The lower Christina River (*test* reach CHR-D1 and *test* reach CHR-D2) was not sampled in 2013, following the rotating panel design of the program;
- The Calumet River (*test* reach CAR-D1 and *baseline* reach CAR-D2) was not sampled in 2013, following the rotating panel design of the program; and
- The Firebag River (*test* reach FIR-D1 and *baseline* reach FIR-E2) was sampled in 2013, following the rotating panel design of the program.

Challenges Encountered and Solutions Applied

All planned sampling was undertaken without major issue or incident. Seven replicates were collected at the Pierre River (*baseline* reach PIR-D1) instead of ten because the length of the reach with habitat that was considered appropriate to sample, was shorter than anticipated.

Other Information Obtained

Concurrent benthic samples were collected at *test* reach STR-E1 and *baseline* reach STR-E2 of the Steepbank River; and *test* reach MAR-E1 and *baseline* reach MAR-E3 of the MacKay River at five of ten replicates using a Hess cylinder and a CABIN kick-net. The CABIN kick-net sampling was conducted by Environment Canada staff under the JOSMP. The CABIN kick net samples were retained by Environment Canada for an evaluation and comparison of the data from the two sampling methods.

Summary of Component Data Now Available

As of 2013, 3,519 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 2013 Monitoring Activities for the Sediment Quality Component

Sediment samples were collected from September 3 to 14, 2013 at the most downstream replicate sampling location in each depositional reach sampled for benthic invertebrate communities (total of 31 depositional reaches), one station on the Athabasca River downstream of the Embarras River, 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, boat, 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 2013 are provided in Table 3.1-10.

Changes in Monitoring Network from 2012

Given the three-year sampling rotation for some stations, *test* station FIR-D1 (lower reach on the Firebag River) was sampled in 2013, and not in 2012 or 2011. *Test* station CHR-D1 (lower reach on the Christina River), *test* station CHR-D2 (middle reach on the Christina River), *test* station CAR-D1 (lower reach on the Calumet River), and *baseline* reach CAR-D2 (upper reach on the Calumet River) were not sampled in 2013. There were eight new stations added to the sediment sampling network in 2013, including *baseline* stations CHR-D4 (upper Christina River), BRC-D1 (Birch Creek), SUC-D2 (upper Sunday Creek), EYC-D1 (Eymundson Creek), PIR-D1 (Pierre River), and BIC-D1 (Big Creek), and *test* stations UNC-D2 (Unnamed Creek east of Christina Lake), and UNC-D3 (Unnamed Creek south of Christina Lake).

Challenges Encountered and Solutions Applied

No challenges were encountered during the Sediment Quality component sampling program in fall 2013.

Other Information Obtained

No additional sediment quality information for 2013 was obtained.

Summary of Component Data Now Available

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

Table 3.1-8 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				2013			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Delta																																																																							
Athabasca River Delta	1	depositional	ATRFLC,GIC,BPC																								1				1				1				1								1				1				1				1				1				1				1
Embarras River	1	depositional	EMR-1																																																												1				1				1
Embarras River	1	depositional	EMR-2																																																								1												
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				
Upstream of Jackfish River	1	erosional	CHR-E3																																																																				1
Upstream of Dev elopment	1	depositional	CHR-D4																																																																				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				1
Middle Reach	1	erosional	ELR-E2																												1				1				1				1																								1				
Historical Upper Reach	1	erosional	ELR-E2A																																																								1				1				1				
Upper Reach	1	erosional	ELR-E3																																																																				1
Firebag River																																																																						
Lower Reach	1	depositional	FIR-D1																												1				1				1				1				1												1												1
Upper Reach	1	erosional	FIR-E2																												1				1				1				1				1												1												1
Fort Creek																																																																							
Lower Reach	1	depositional	FOC-D1												2								1				1				1								1				1				1				1								1				1				1				1
Hangingstone River																																																																							
Lower Reach	1	erosional	HAR-E1																																1				1				1				1				1																				
High Hills River																																																																							
Lower Reach	1	erosional	HHR-E1																																																												1				1				1
Jackpine Creek																																																																							
Lower Reach	1	depositional	JAC-D1																								1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	depositional	JAC-D2																												1				1				1				1				1				1				1				1				1				1				1
MacKay River																																																																							
Lower Reach	1	erosional	MAR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1
Middle Reach	1	erosional	MAR-E2																								1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	MAR-E3																																																							1				1				1				1
Muskeg River																																																																								
Lower Reach	1	erosional	MUR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1
Middle Reach	1	depositional	MUR-D2																1				1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	depositional	MUR-D3																								1				1				1				1				1				1				1				1				1				1				1				1
Big Creek																																																																							
Lower Reach	1	depositional	BIC-D1																																																																				1
Eymundson Creek																																																																								
Lower Reach	1	depositional	EYC-D1																																																																				1
Pierre River																																																																								
Lower Reach	1	depositional	PIR-D1																																																																					1
Red Clay Creek																																																																							
Lower Reach	1	erosional	RCC-E1																																																																				1
Steepbank River																																																																								
Lower Reach	1	erosional	STR-E1																1				1				1				1				1				1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	STR-E2																												1				1				1				1				1				1				1				1				1				1				1

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

🟦 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 = 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*)

[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				2013			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Tar River																																																																							
Lower Reach	1[1]	depositional	TAR-D1																				🟩 2				🟩 1				🟩 1				🟦 1				🟦 1				🟦 1												🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Historical Upper Reach	1	erosional	TAR-E1																												🟩 1				🟩 1				🟩 1				🟩 1																												
Upper Reach	1	erosional	TAR-E2																																																🟩 1				🟩 1				🟩 1				🟩 1				🟩 1
Beaver River																																																																							
Lower Reach	1	depositional	BER-D2																																												🟩 1				🟩 1				🟩 1				🟩 1				🟩 1				🟩 1
Poplar Creek																																																																							
Lower Reach	1	depositional	POC-D1																																												🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Jackfish River																																																																							
Lower Reach	1	erosional	JAR-E1																																																														🟦 1				🟦 1
Sawbones Creek																																																																							
Lower Reach	1	depositional	SAC-D1																																																														🟦 1				🟦 1
Sunday Creek																																																																							
Lower Reach	1	depositional	SUC-D1																																																														🟦 1				🟦 1
Upper Reach	1	depositional	SUC-D2																																																																		🟩 1
Birch Creek																																																																							
Lower Reach	1	depositional	BRC-D1																																																																		🟩 1
Unnamed Creek south of Christina Lake																																																																							
Lower Reach	1	depositional	UNC-D3																																																																		🟩 1
Unnamed Creek east of Christina Lake																																																																							
Lower Reach	1	depositional	UNC-D2																																																																		🟩 1
Wetlands and Lakes																																																																							
Isadore's Lake	1	lake	ISL-1																																								🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Johnson Lake	1	lake	JOL-1																																																										🟩 1				🟩 1				🟩 1
Kearl Lake	1	lake	KEL-1																				🟩 1				🟩 1				🟩 1				🟩 1				🟩 1				🟩 1				🟩 1				🟩 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
McClelland Lake	1	lake	MCL-1																								🟩 1				🟩 1												🟩 1				🟩 1				🟩 1				🟩 1				🟦 1				🟦 1				🟦 1				🟦 1
Shipyard Lake	1	lake	SHL-1																🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1				🟦 1
Christina Lake	1	lake	CHL-1																																																														🟦 1				🟦 1
Historical Data																																																																							
Historical Data Review																1	1	1	1					1	1	1	1																																										
5-Year Summary Report																																																																							
Summary Report																								1	1																																													
Locations No Longer in Sample Design																																																																							
Athabasca River																																																																							
Near Fort Creek (east bank)	1	depositional	ATR-B-A1 to A3				🟦 1																																																																
(west bank)	1	depositional	ATR-B-A4 to A6				🟦 1																																																																
Near Donald Creek (east bank)	1	depositional	ATR-B-B1 to B3				🟦 1																																																																
(west bank)	1	depositional	ATR-B-B4 to B6				🟦 1																																																																
Suncor near-field monitoring	2	depositional	-																				🟦 2																																													
MacKay River																																																																							
200 m upstream of mouth	1	erosional	MAR-1								🟩 1																																																										
500 m upstream of mouth	1	erosional	MAR-2								🟩 1																																																										
1.2 km upstream of mouth	1	erosional	MAR-3								🟩 1																																																										
Muskeg River																																																																							
50 m upstream of mouth	1	erosional	MUR-1								🟦 1																																																										
200 m upstream of mouth	1	erosional	MUR-2								🟦 1																																																										
450 m upstream of mouth	1	erosional	MUR-3								🟦 1																																																										
Steepbank River																																																																							
50 m upstream of mouth	1	erosional	STR-1								🟦 1																																																										
150 m upstream of mouth	1	erosional	STR-2								🟦 1																																																										
300 m upstream of mouth	1	erosional	STR-3								🟦 1																																																										

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 2013.

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
FIR-D1	Firebag River (lower reach)	479340	6400652	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
PIR-D1	Pierre Creek	462252	6367481	
EYC-D1	Eymundson Creek	465878	6372237	2
BIC-D1	Big Creek	471617	6387774	2
Tributaries to the Athabasca River (Southern)				
CHR-D4	Christina River (upstream of development)	466231	6193835	2
SUC-D1	Sunday Creek (lower reach)	506716	6159804	2
SUC-D2	Sunday Creek (upper reach)	494292	6157244	2
SAC-D1	Sawbones Creek (lower reach)	511453	6167195	2
BRC-D1	Birch Creek	492173	6163203	2
UNC-D2	Unnamed Creek (east of Christina Lake)	517462	6163751	2
UNC-D3	Unnamed Creek (south of Christina Lake)	511129	6159870	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*)

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 varied with moisture content in sediment.

Table 3.1-10 (Cont'd.)

Group	Analyte	Units	Detection Limit	Analytical Method (VMV code)	Lab
Total Metals (Cont'd.)	Manganese (Mn)	mg/kg	1	EPA 200.2/6020A	ALS
	Mercury (Hg)	mg/kg	0.05	EPA 200.2/245.1	ALS
	Molybdenum (Mo)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Nickel (Ni)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Phosphorus (P)	mg/kg	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 varied with moisture content in sediment.

Table 3.1-10 (Cont'd.)

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

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

* Detection limit varies with moisture content in sediment.

Table 3.1-11 Summary of 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				2013			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																																					
Upstream of Fort McMurray (cross channel)	ATR-UFM																								🟩 1				🟩 2				🟩 1																																		
Upstream of Donald Creek (west bank)[a]	ATR-DC-W				🟩 2				🟩 2								🟩 1				🟩 2				🟩 1				🟩 2				🟩 1																																		
(east bank)[a]	ATR-DC-E				🟩 2				🟩 2								🟩 1				🟩 2				🟩 1				🟩 2				🟩 1																																		
Upstream of Steepbank River (west bank)	ATR-SR-W																🟦 1				🟦 2				🟦 1				🟦 2				🟦 1																																		
(east bank)	ATR-SR-E																🟦 1				🟦 2				🟦 1				🟦 2				🟦 1																																		
Upstream of the Muskeg River (west bank)[a b]	ATR-MR-W								🟦 2								🟦 1				🟦 2				🟦 1				🟦 2				🟦 1																																		
(east bank)[a b]	ATR-MR-E								🟦 2								🟦 1				🟦 2				🟦 1				🟦 2				🟦 1																																		
Upstream of Fort Creek (west bank)[a b]	ATR-FC-W				🟦 2				🟦 2								🟦 1				🟦 2				🟦 1				🟦 2																																								
(east bank)[a b]	ATR-FC-E				🟦 2				🟦 2								🟦 1				🟦 2				🟦 1				🟦 2																																								
Testing inter-site variability (3 composite samples)	-																🟦 1								🟦 1																																												
Downstream of all development (west bank)	ATR-DD-W																								🟦 1				🟦 2				🟦 1																																		
(east bank)	ATR-DD-E																								🟦 1				🟦 2				🟦 1																																		
Upstream of mouth of Firebag River (west bank)	ATR-FR-W																								🟦 1				🟦 2				🟦 1																																		
(east bank)	ATR-FR-E																								🟦 1				🟦 2				🟦 1																																		
Upstream of the Embarras River	ATR-ER																🟦 3				🟦 1				🟦 1				🟦 2				🟦 1				🟦 1								🟦 1				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Athabasca Delta / Lake Athabasca																																																																						
Delta composite[c]	ARD-1												🟦 2																																																								
Big Point Channel	BPC-1												🟦 2				🟦 2				🟦 2				🟦 2				🟦 2								🟦 1								🟦 1				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Goose Island Channel	GIC-1																				🟦 2				🟦 2				🟦 2								🟦 1								🟦 1				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Fletcher Channel	FLC-1																				🟦 2				🟦 2				🟦 2								🟦 1								🟦 1				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Flour Bay	FLB-1																🟦 2																																																								
Extensive Survey (6 sites)	[d]																																				🟦 1																																		
Embarras River																																																																							
Embarras River	EMR-1																																				🟦 1																								🟦 2								
Embarras River	EMR-2																																				🟦 1																				🟦 2								🟦 2				🟦 2
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				
(upstream of development)	CHR-D4																																																																					🟩 2
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																🟩 2				🟩 2																																
Sunday Creek	SUC-D1																																																																🟦 2				🟦 2
Sunday Creek (upstream)	SUC-D2																																																																					🟩 2
Unnamed Creek 2 (east of Christina Lake)	UNC-D2																																																																					🟦 2
Unnamed Creek 3 (south of Christina Lake)	UNC-D3																																																																					🟦 2
Birch Creek	BRC-D1																																																																					🟩 2
Sawbones Creek	SAC-D1																																																															🟦 2				🟦 2
Athabasca River Tributaries (North of Fort McMurray)																																																																							
McLean Creek (mouth)	MCC-1												🟦 2				🟦 2				🟦 1				🟦 2												🟦 2																																
Beaver River	BER-D2																																																🟩 2				🟩 2				🟩 2				🟩 2				🟩 2				🟩 2
Poplar Creek (mouth)	POC-1/POC-D1				🟦 1																				🟦 2								🟦 2																🟦 2				🟦 2				🟦 2				🟦 2				🟦 2				🟦 2
Steepbank River (mouth)	STR-1				🟦 1				🟦 1																🟦 2												🟦 2																																
(upstream of Suncor Project Millennium)	STR-2																								🟩 2												🟩 2																																
(upstream of North Steepbank)	STR-3																																				🟩 2																																
North Steepbank River (upstream of Suncor Lewis)	NSR-1																								🟩 2				🟩 2				🟩 1				🟩 1																																
MacKay River (mouth)	MAR-1				🟩 1				🟩 1												🟩 2				🟦 2								🟦 2																																		
(upstream of Suncor MacKay)	MAR-2																				🟩 1												🟩 2																																		

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.

🟦 *Test* (downstream of focal projects)

🟩 *Baseline* (upstream of focal projects)

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

Table 3.1-11 (Cont'd.)

See symbol key below.

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

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.

🟦 *Test* (downstream of focal projects)

🟩 *Baseline* (upstream of focal projects)

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

3.1.4 Fish Populations Component

3.1.4.1 Overview of 2013 Monitoring Activities

The following monitoring activities were conducted in 2013 for the Fish Populations component:

- Spring, summer, and fall fish inventories on the Athabasca and Clearwater rivers;
- Fish assemblage monitoring (FAM) on tributaries to the Athabasca and Clearwater rivers, and channels of the Athabasca River Delta;
- Sentinel species monitoring (trout-perch) using lethal sampling methods at five sites on the Athabasca River; and
- Tissue analyses on target fish species in Namur Lake (lake whitefish and lake trout) and Christina Lake (lake whitefish, walleye, and northern pike).

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 2013 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 2013, 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, 2013, July 22 and July 31, 2013, and September 16 and September 25, 2013, respectively. Approximately four 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).

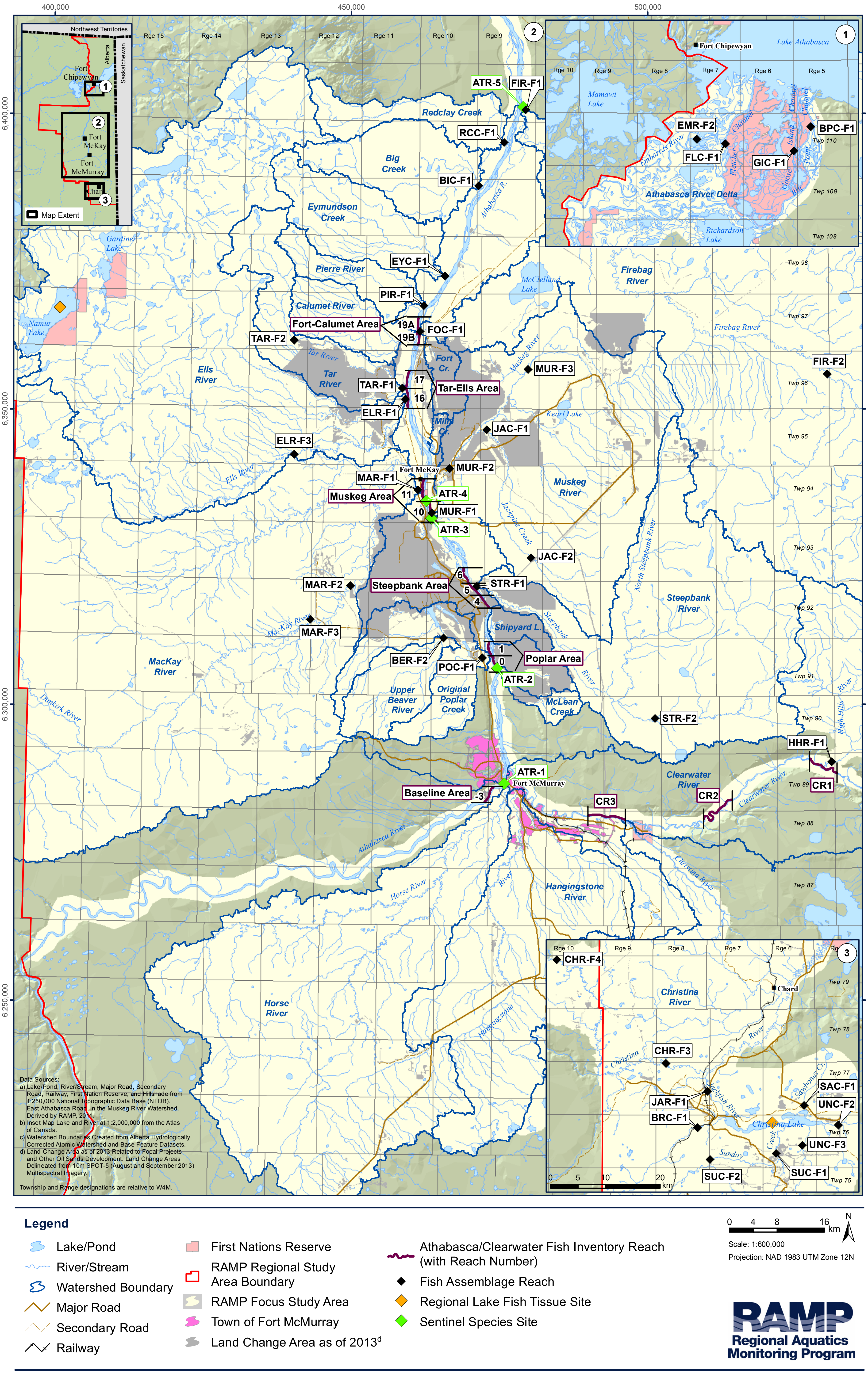
Sampling was conducted on both rivers in areas conducive to electrofishing, primarily in shallow-river margins deep enough to be accessible by boat.

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, 2013.



Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_H_Fish_20140218_ss.mxd

Table 3.1-12 Locations of fish inventory areas on the Athabasca and Clearwater rivers, 2013.

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

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

* Reaches were sampled in spring and fall 2013, based on a rotating panel design for the *baseline* reaches. The *test* reaches are sampled every season and year and all reaches are sampled in summer.

Fish Tag Return Assessment

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

Regional Lakes Fish Tissue

In 2013, tissue studies were performed on lake whitefish, walleye, and northern pike captured during AESRD's fall walleye index netting program (FWIN) on Christina Lake, south of Fort McMurray and lake whitefish and lake trout captured during AESRD's summer profundal index netting program (SPIN) on Namur Lake, northwest of Fort McMurray (Figure 3.1-5).

Sampling in Namur Lake took place between August 4 and August 8, 2013 and in Christina Lake on October 2, 2013 by AESRD. A target of 25 fish of each species 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 lengths 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 Namur Lake and Christina Lake for tissue analysis for mercury is provided in Table 3.1-13.

Table 3.1-13 Number of fish by species captured in each size class for fish tissue analyses of mercury, Namur Lake (August 2013) and Christina Lake (October 2013).

Waterbody	Species	Size Class (mm)						
		<200	201-300	301-400	401-500	501-600	601-700	>700
Namur Lake	Lake trout	0	0	0	2	11	7	0
	Lake whitefish	0	7	5	7	1	0	0
Christina Lake	Lake whitefish	1	5	3	1	0	0	0
	Walleye	1	5	8	3	2	1	0
	Northern pike	0	0	0	7	3	3	1

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 from Namur Lake 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.

Lethal Tributary Sentinel Species Monitoring

The objective of the sentinel species monitoring program in 2013 was to monitor potential changes in fish populations due to stressors resulting from focal project development by assessing growth, reproduction, and survival. Similar to 2002 and 2010, sentinel species monitoring in 2013 was carried out at five sites on the Athabasca River (Table 3.1-14 and Figure 3.1-5). A sentinel species program was also completed in 1999 at three of the five sites. Sites ATR-3, ATR-4, and ATR-5 were designated as *test,* while the remaining two sites, ATR-1 and ATR-2 were designated as *baseline*. Trout-perch (*Percopsis omiscomaycus*) was the target sentinel fish species with a target of 20 adult males and 20 adult females to be captured per site.

Table 3.1-14 Location and general description of each site sampled for sentinel fish species monitoring, 2013.

Site Code	Site Description	UTM Coordinates (NAD 83, Zone 12)[1]
ATR-1	*Baseline* reach upstream of Fort McMurray to provide a baseline population not exposed to Sewage Treatment Plant (STP) discharge or oil sands development.	D/S: 475650 E / 6286679 N U/S: 470302 E / 6283093 N
ATR-2	*Baseline* reach upstream of oil sands development but downstream of STP discharge.	D/S: 473534 E / 6303729 N U/S: 473477 E / 6303388 N
ATR-3	*Test* reach below the Beaver River confluence to provide exposure to both Suncor/Syncrude operations.	D/S: 463707 E / 6330992 N U/S: 463407 E / 6331547 N
ATR-4	*Test* reach downstream of the Muskeg River confluence and development in Muskeg River watershed.	D/S: 463263 E / 6332929 N U/S: 462534 E / 6334554 N
ATR-5	*Test* reach downstream of all tributary watersheds with oil sands developments (downstream of Firebag River confluence).	D/S: 478852 E / 6401786 N U/S: 478761 E / 6410216 N

[1] Reach lengths varied depending on capture efficiency.

Fish Sampling Fish sampling was conducted between September 30 and October 5, 2013, with assistance from Environment Canada personnel given that sentinel species monitoring was also a component of the JOSM Plan. Sampling on the Athabasca River was carried out by a four-person field crew using a Coffelt VVP-15 boat electrofisher, with backpack electrofishers used as a supporting method. Sampling efforts focused on river margins deep enough to be accessible by boat, but shallow enough to provide suitable habitat for trout-perch. The boat electrofisher was configured with two anode boom arrays and multiple dropper cables. The boat's hull acted as the cathode. Electrofishing was performed in a downstream direction, and current was applied in 4 to 5 second bursts at a high frequency (i.e., to catch small-bodied fish) within the designated size. Stunned trout-perch were captured downstream of the current using dip nets with a fine mesh net (6.35 mm mesh size) to ensure collection of all size classes.

All captured trout-perch were identified to species and brought back in aerated holding containers to a contained laboratory facility for dissecting. Each fish was measured for fork length (± 1.0 mm) and weighed (± 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 instream 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).

Fish Assemblage Monitoring Program

Fish assemblage monitoring (FAM) in tributaries to the Athabasca and Clearwater rivers was incorporated into RAMP in 2011; 2013 was the third year of monitoring on tributaries and the first year of monitoring in the ARD. The objective of this monitoring component was to evaluate fish assemblages in reaches where water quality, and benthic invertebrate communities and sediment quality were also assessed. Accordingly, fish assemblage monitoring was conducted at all benthic invertebrate sampling reaches on tributaries surveyed in fall 2013 (Table 3.1-15). The FAM program was conducted from August 20 to 22, 2013 in channels of the ARD and from September 4 to September 15, 2013 in tributary reaches 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 assemblage, water and sediment chemistry, and benthic invertebrate communities.

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

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

The reaches in the ARD were not divided into subreaches given the difficulty in dividing reaches when boat electrofishing.

Table 3.1-15 Locations of reaches surveyed for the fish assemblage monitoring program, August and September 2013.

Watershed	Reach	Habitat Type	Reach Designation	UTM Coordinates (NAD 83, Zone 12)	
				Downstream Boundary	Upstream Boundary
Athabasca River Delta	EMR-F2	depositional	*test*	494773 E 6492172 N	491031 E 6490864 N
	BPC-F1	depositional	*test*	511778 E 6497994 N	511793 E 6493173 N
	FLC-F1	depositional	*test*	497305 E 6494105 N	496174 E 6490046 N
	GIC-F1	depositional	*test*	509619 E 6494139 N	508737 E 6488742 N
Muskeg River	MUR-F1	erosional	*test*	463532 E 6332455 N	463809 E 6332444 N
	MUR-F2	depositional	*test*	466555 E 6340414 N	466526 E 6339977 N
	MUR-F3	depositional	*test*	479754 E 6356736 N	479700 E 6357074 N
Jackpine Creek	JAC-F1	depositional	*test*	472816 E 6346545 N	472908 E 6346535 N
	JAC-F2	depositional	*baseline*	480227 E 6324884 N	480374 E 6324778 N
Steepbank River	STR-F1	erosional	*test*	471169 E 6320049 N	471573 E 6320291 N
	STR-F2	erosional	*baseline*	501214 E 6297649 N	501117 E 6297858 N
Ells River	ELR-F1	depositional	*test*	459059 E 6351678 N	459110 E 6351966 N
	ELR-F3	erosional	*baseline*	440310 E 6342408 N	440271 E 6342486 N
MacKay River	MAR-F1	erosional	*test*	461178 E 6366373 N	460983 E 6336589 N
	MAR-F2	erosional	*test*	449754 E 6320173 N	449644 E 6319969 N
	MAR-F3	erosional	*baseline*	445021 E 6314476 N	444895 E 6314183 N
Tar River	TAR-F1	depositional	*test*	458562 E 6353565 N	458349 E 6353414 N
	TAR-F2	erosional	*baseline*	440304 E 6361713 N	440304 E 6361713 N
Firebag River	FIR-F1	depositional	*test*	479351 E 6400631 N	478955 E 6399981 N
	FIR-F2	erosional	*baseline*	530462 E 6355794 N	530300 E 6355956 N
High Hills River	HHR-F1	erosional	*baseline*	529950 E 6289363 N	529884 E 6289527 N
Christina River	CHR-F3	erosional	*test*	486185 E 6174902 N	486194 E 6175006 N
	CHR-F4	depositional	*baseline*	466226 E 6193833 N	466091 E 6193757 N
Birch Creek	BRC-F1	depositional	*baseline*	492141 E 6163198 N	492070 E 6163117 N
Jackfish River	JAR-F1	erosional	*test*	493851 E 6169758 N	493773 E 6169576 N
Sunday Creek	SUC-F1	erosional	*test*	506318 E 6158395 N	506388 E 6158207 N
	SUC-F2	depositional	*baseline*	494288 E 6157256 N	494158 E 6157167 N
Sawbones Creek	SAC-F1	depositional	*test*	511446 E 6167157 N	511587 E 6167510 N
Unnamed Creek (east of Christina Lake)	UNC-F2	depositional	*test*	517709 E 6163619 N	517810 E 6163711 N
Unnamed Creek (south of Christina Lake)	UNC-F3	depositional	*test*	511129 E 6159870 N	511051 E 6159665 N
Pierre River	PIR-F1	depositional	*baseline*	462211 E 6367493 N	462239 E 6367723 N
Eymundson Creek	EYC-F1	depositional	*baseline*	465766 E 6372528 N	465726 E 6372722 N
Red Clay Creek	RCC-F1	erosional	*baseline*	475771 E 6395076 N	492072 E 6396324 N
Big Creek	BIC-F1	depositional	*baseline*	471471 E 6387771 N	471319 E 6387783 N
Beaver River	BER-F2	depositional	*baseline*	465486 E 6311291 N	465469 E 6311129 N
Poplar Creek	POC-F1	depositional	*test*	472084 E 6307913 N	471819 E 6307778 N
Fort Creek	FOC-F1	depositional	*test*	461546 E 6363109 N	461730 E 6363057 N

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

- Habitat type (Table 3.1-16);
- 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 3.1-17);
- Substrate (dominant and subdominant particle size) (Table 3.1-18);
- Bank slope (degrees);
- Bank height (m); and
- Large and small woody debris (count of debris in length/size classes).

In situ water quality variables including temperature, 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 3.1-16 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 3.1-17 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 3.1-18 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 2012

The 2013 monitoring activities for the Fish Populations component differed from those carried out in 2012 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* and *baseline* reaches on tributaries to the south of Fort McMurray (i.e., Sunday Creek, Birch Creek, and two unnamed creeks), two new reaches on the Christina River (*test* reach CHR-F3 and *baseline* reach CHR-F4), two reaches on the Firebag River (*test* reach FIR-F1 and *baseline* reach FIR-F2), and *baseline* reaches on the Pierre River (PIR-F1), Eymundson Creek (EYC-F1), Red Clay Creek (RCC-F1), and Big Creek (BIC-F1);

- A new upper *baseline* reach on the Ells River (ELR-F3) to account for expanding development in that watershed. ELR-F2 and ELR-F2A, were removed from the sampling program as these reaches were no longer *baseline* (ELR-F3 now represents *baseline* conditions in the Ells River watershed);

- Given the three-year sampling rotation, fish assemblage monitoring was not conducted on the Calumet River (*test* reach CAR-F1 and *baseline* reach CAR-F2) or the Christina River (*test* reaches CHR-F1 and CHR-F2) in 2013;

- Given the three-year sampling rotation of the fish tissue sampling program, fish tissue sampling was not conducted on the Athabasca (last conducted in 2011) and Clearwater (last conducted in 2012) rivers;

- The regional lakes fish tissue program was conducted on Namur Lake in summer 2013 and Christina Lake in fall 2013. Namur Lake and Christina Lake were previously sampled in 2007 and 2003, respectively; and

- Given the three-year sampling rotation, a lethal sentinel species monitoring program for trout-perch was conducted in 2013. The program was last completed in 2010.

3.1.4.4 Challenges Encountered and Solutions Applied

There were no changes in sampling design or implementation of any Fish Populations component activities in 2013.

3.1.4.5 Other Information Obtained

There was no additional information obtained for the RAMP Fish Populations component in 2013.

3.1.4.6 Summary of Component Data Now Available

Fish Populations component data collected to date by RAMP are summarized in Table 3.1-19.

Table 3.1-19 Summary of RAMP data available for the Fish Populations component.

WATERBODY AND LOCATION	Site ID	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																																					
Upstream of Fort McMurray	-3																																																										1	1	1		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		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		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		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		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		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												3
Reference site between STP and Suncor	ATR-2												1,3												3				10															3	3												3												3
Downstream of Suncor's Discharge	ATR-3												1,3												10,3				10															3	3												3												3
Below Muskeg River	ATR-4												1,3												10,3				10															3	3												3												3
Downstream of Development (near Firebag River)	ATR-5																												10,6															3	3												3												3
Athabasca River Delta																																																																					
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																																																																	10				10
Embarras River	EMR-F2																																																																	10				10
Athabasca River Tributaries (northern)																																																																					
Fort Creek (mouth)	FOC-F1														1,8,5,9	1																																															10				10				10
Poplar Creek (mouth)	POC-F1																																																				10								10				10				10
Beaver River (upper)	BER-F2																																																				10								10				10				10
Pierre River (mouth)	PIR-F1														1,8,5,9	1																																																					10
Eymundson Creek (mouth)	EYC-F1																																																				10																10
Red Clay Creek (mouth)	RCC-F1																																																				10																10
Big Creek (mouth)	BIC-F1																																																				10																10
Athabasca River Tributaries (southern)																																																																					
High Hills River (mouth)	HH-R/HHR-F1																																																												10				3,10				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		1	1	1
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		1	1	1
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		1	1	1
Christina River (mouth)	CHR-F1																																																																10				
Christina River (upstream of Janvier)	CHR-F2																																1																																10				
Christina River (upstream of Jackfish River)	CHR-F3																																																																10				10
Christina River (upstream of development)	CHR-F4																																1																																10				10
Jackfish River	JAR-F1																																																																10				10
Unnamed Creek (east of Christina Lake)	UNC-F2																																																																				10
Unnamed Creek (south of Christina Lake)	UNC-F3																																																																				10
Sunday Creek (lower reach)	SUC-F1																																																																10				10
Sunday Creek (upper reach)	SUC-F2																																																																				10
Birch Creek	BRC-F1																																																																				10
Sawbones Creek	SAC-F1																																																																10				10
Ells River																																																																					
Upper Ells River (new baseline reach)	ELR-F3												1,3																		4		3		4		3							3	3												10				10				10				10
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				10
MacKay River																																																																					
Lower reach (mouth) (j)	MAR-F1		1																				1					10			4																						10								10				10				10
Mid-River (upstream of Suncor MacKay)	MAR-F2																																																												10				10				10
Upper MacKay River reach	MAR-F3																																																												10				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				10
Upper Tar River	TAR-F2												1,3																																																10				10				10
Calumet River																																																																					
Lower Calumet River	CAR-F1																																																																10				
Upper Calumet River	CAR-F2																																																																10				
Firebag River																																																																					
Lower Firebag River	FIR-F1																																																																				10
Upper Firebag River	FIR-F2																																																																				10
Muskeg River																																																																					
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1												1,3						4		3		4		4		4						3						4	3	3										4	3	3,10				10				10				3,10				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				10
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																						1,4		1,4																																				10				10				10
Muskeg River Tributaries																																																																					
Jackpine Creek (upper portion of the creek)	JAC-F2																																																				10				10				10				10				10
Jackpine Creek (accessable areas of lower creek)	JAC-F1														8					1				1								1																					10				10				10				10				10
Muskeg Creek (Canterra road crossing)(e)																							1,4		1,4																																												
Wapasu Creek (mouth or Canterra road)(e)																							1,4		1,4																																												
Steepbank River																																																																					
Steepbank Mine baseline fisheries reach (1995)(f)	AF014			1																																																																
Lower Steepbank River (current *test* site)	STR-F1/SR-E																																3							3	3											3	3,10				10				10				3,10				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				10
Regionally-Important Lakes																																																																					
Christina Lake	CHL-F1																																																																10				6
Various lakes in water/air emissions pathway																													6				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 2013 Monitoring Activities

The 2013 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 and September, 2013. The location of each lake is presented in Figure 3.1-6. 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 3.1-20. The unique identification number listed in Table 3.1-20 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 3.1-20.

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 monitoring region that are unaffected directly 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; however, 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 in late summer from August 27 to September 20, 2013, 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 alkalinity as the water melts and oxygen is re-introduced. Detecting a decrease in pH or decrease in Gran alkalinity in the spring during this recovery period was not possible in the CEMA/AESRD study. A more detailed study of the spring acid pulse phenomenon was initiated by RAMP in 2012 and the results were reported in the 2012 Technical Report (RAMP 2013).

Summary of Field Methods

AESRD provided the sampling equipment and logistical support for the lake sampling. A float plane was used to access the majority of study lakes while a helicopter with floats was used to reach the smaller lakes. AESRD water quality sampling protocols were used as the basis for the field methods (AENV 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 shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection, and analyzed for the water quality variables listed in Table 3.1-21. 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.

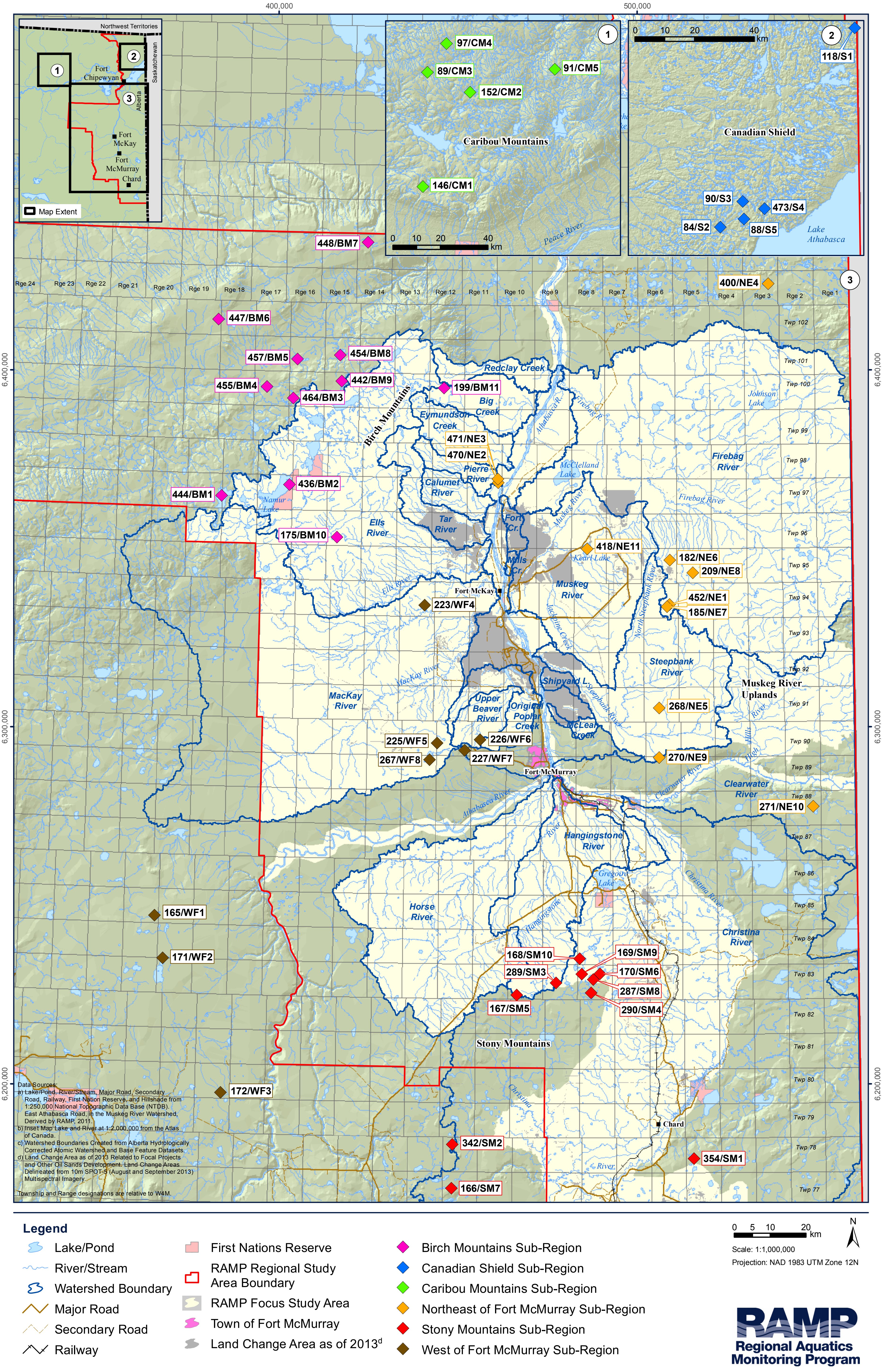
3.1.5.2 Changes in Monitoring Network from 2013

All 50 lakes were sampled in 2013. 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 2013.

Figure 3.1-6 Locations of Acid-Sensitive Lakes sampled in 2013.



Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed, Derived by RAMP, 2011.
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
d) Land Change Area as of 2013 Related to Focal Projects and Other Oil Sands Development. Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_J_ASL_20140218_ss.mxd

Table 3.1-20 Lakes sampled in 2013 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	SM10	1.38	483819	6235130	08/27/13
169	A24	SM9	1.45	484387	6230872	08/27/13
170	A26	SM6	0.71	489502	6230877	08/27/13
167	A29	SM5	1.05	466180	6224950	08/27/13
166	A86	SM7	1.44	448014	6170896	08/27/13
287	25	SM8	2.18	487594	6229281	08/27/13
289	27	SM3	1.83	477248	6228400	08/27/13
290	28	SM4	0.54	487068	6225576	08/27/13
342	82	SM2	1.97	448271	6183205	08/27/13
354	94	SM1	2.50	515689	6179207	08/27/13
Birch Mountains Sub-Region						
436	L18/Namur	BM2	43.39	402704	6368016	08/26/13
442	L23/Otasan	BM9	3.44	417321	6396959	08/26/13
444	L25/Legend	BM1	16.80	383849	6364923	08/26/13
447	L28	BM6	1.30	382996	6414339	08/26/13
448	L29/Clayton	BM7	0.65	424694	6435790	08/26/13
454	L46/Bayard	BM8	1.20	416941	6404239	08/26/13
455	L47	BM4	4.37	396500	6395456	08/26/13
457	L49	BM5	2.61	404995	6403111	08/26/13
464	L60	BM3	0.91	403796	6392247	08/26/13
175	P13	BM10	0.38	416003	6353212	08/25/13
199	P49	BM11	2.61	446002	6394961	09/20/13
Northeast of Fort McMurray Sub-Region						
452	L4 (A-170)	NE1	0.61	508990	6334305	08/28/13
470	L7	NE2	0.33	515029	6327465	08/28/13
471	L8	NE3	0.56	524390	6322556	08/28/13
400	L39/E9/A-150	NE4	1.12	536495	6424234	08/28/13
268	E15	NE5	1.87	506092	6305335	09/04/13
182	P23	NE6	0.28	509000	6346712	09/20/13
185	P27	NE7	0.09	508300	6333712	08/25/13
209	P7	NE8	0.15	515399	6343212	08/25/13
270	4	NE9	3.44	506113	6291421	09/04/13
271	6	NE10	4.31	549064	6277789	09/04/13
418	Kearl	NE11	5.34	485939	6349881	08/28/13
West of Fort McMurray Sub-Region						
165	A42	WF1	3.20	365015	6247322	08/27/13
171	A47	WF2	0.47	367321	6235430	08/27/13
172	A59	WF3	2.06	383467	6197733	08/27/13
223	P94	WF4	0.03	440557	6334112	08/25/13
225	P96	WF5	0.21	444002	6295513	08/25/13
226	P97	WF6	0.16	456002	6296463	08/25/13
227	P98	WF7	0.08	451762	6293513	08/25/13
267	1	WF8	2.22	441917	6290884	08/27/13
Caribou Mountains Sub-Region						
146	E52/ Fleming	CM1	1.60	243692	6522556	08/29/13
91	O-1/E55	CM5	2.70	298955	6571856	08/29/13
97	O-2/E67	CM4	0.56	253582	6582654	08/29/13
152	E59/Rocky I.	CM2	9.53	263546	6562225	08/29/13
89	E68 Whitesand	CM3	2.46	245596	6570610	08/29/13
Canadian Shield Sub-Region						
473	A301	S4	1.40	525150	6559733	09/05/13
118	L107/Weekes	S1	3.73	555469	6620456	09/05/13
84	L109/Fletcher	S2	1.29	510321	6553552	09/05/13
88	O-10	S5	0.70	518279	6556260	09/05/13
90	R1	S3	0.55	517889	6562197	09/05/13

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

Table 3.1-21 Water quality variables analyzed in 2013 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*

3.1.5.4 Other Information Obtained

AESRD collected additional water samples for metals analyses from each lake surveyed during the 2013 field season (Table 3.1-20). These water samples were sent to Alberta Innovates Technology Futures (AITF), Vegreville, Alberta for analysis of the total and dissolved fractions of the metals listed in Table 3.1-22. The results of the metals analyses are reported in Appendix F. As in 2012, the mercury concentrations were subjected to low-level (ng/L) analysis. For the first time, in 2013, samples for low-level methyl mercury were also collected and reported.

Table 3.1-22 Metals analyzed in 2013 in lake water sampled for the Acid-Sensitive Lakes component.

silver
aluminum
antimony
arsenic
barium
beryllium
bismuth
cadmium
cobalt
chromium
copper
iron
mercury
methyl 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 fifteen years of the ASL component is summarized in Table 3.1-23.

Table 3.1-23 Summary of lakes sampled for the Acid-Sensitive Lakes component, 1999 to 2013.

NO_xSO_x GIS No.	Original RAMP Designation	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
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 2013 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, 2013 to October 31, 2013) discharge;
- Mean winter (November 1, 2012 to March 31, 2013) discharge;
- Annual maximum daily (November 1, 2012 to October 31, 2013) discharge; and
- Open-water season minimum daily discharge.

These measurement endpoints are used in various oil sands project EIAs (RAMP 2009b) that can be calculated from one year of data, and were selected for the analysis of the 2013 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 2013 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. A detailed description and analysis of the flood events that occurred in June 2013 is provided in Section 6 of this report.

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 2013 WY observations and calculated *baseline* conditions using the EDA approach.

3.2.1.3 Comparison to *Baseline* Conditions

The 2013 hydrologic data were analyzed using a water balance approach consistent with previous analytical methods from 2004 to 2012. 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 2013 hydrograph. Additional details regarding this analytical approach are found in RAMP (2008) and Appendix C of this report.

The RAMP 2013 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 2013 *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 2013 Baseline Hydrograph

The 2013 WY *baseline* hydrographs were defined for this analysis as the hydrographs that would have been observed in the 2013 WY had there been no focal projects in the watershed. Additional influences may be incorporated in the 2013 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 2013 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 2013 WY;
- Q_{obs} is the *test* hydrograph which was observed in the 2013 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 2013 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 four 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 were cleared and contributing was relatively small compared to the overall land-cover of the watershed such that this assumption (whether it be from 15 to 25%) would have a minor impact on the overall calculation results when considering the drainage basin as a whole.

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 2013 WY flow records and associated land use and industrial flow data. The water balance approach thereby provides a consistent approach for the 2013 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 2013 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 2013 concentrations of water quality measurement endpoints to historical concentrations of each endpoint at each station, water quality regional *baseline* conditions, and selected criteria for determining change in water quality.

3.2.2.1 Review and Selection of Water Quality Measurement Endpoints

The selection of water quality measurement endpoints was guided by:

- water quality measurement endpoints used in the EIAs of oil sands projects (RAMP 2009b);
- a draft list of water quality variables of concern in the lower Athabasca region developed by CEMA (2004a);
- water quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the RAMP 1997 to 2007 water quality dataset indicating significant inter-correlation of various water quality variables, particularly metals (RAMP 2008); and
- 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 2003)	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 2013 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 2003). Dissolved aluminum more accurately represents biologically available forms of aluminum that may be toxic to aquatic organisms (Butcher 2001);
- *Total boron, total molybdenum, total strontium* - three metals found in predominantly-dissolved form in waters of the RAMP FSA (RAMP 2004), and may be indicators of groundwater influence in surface waters;
- *Total arsenic* and *total mercury (ultra-trace)* - metals of potential importance to the health of aquatic life and human health;
- *Naphthenic acids* - relatively-labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern;
- *Total hydrocarbons (CCME fractions + BTEX)* - indicators of the total hydrocarbon content in water, including indicators (fractions) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene, and xylene (collectively called BTEX), based on methods presented by CCME (2001) (added 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 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 discharge-averaged before trend analysis.

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

Trend analysis was conducted on specific water quality measurement endpoints including total suspended solids, total dissolved solids, dissolved phosphorus, total nitrogen, total boron, total strontium, calcium, chloride, magnesium, potassium, sodium, sulphate and total arsenic from the period of RAMP sampling (1997 to 2013), to assess trends potentially related to development between the two stations during this time period.

Ion Balance

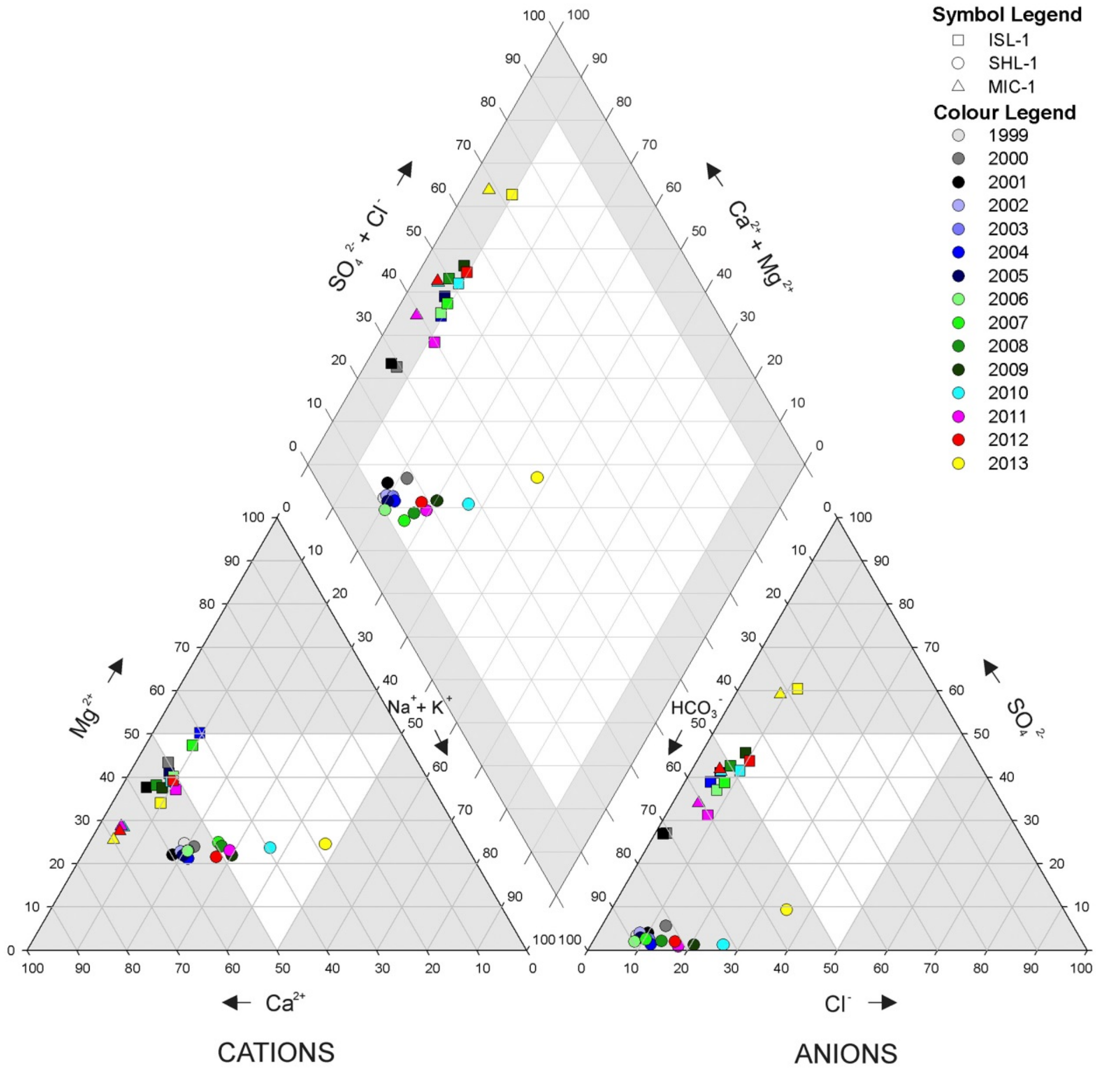
Piper diagrams were used to examine the ion balance at each station or at multiple stations within a watershed, to assess temporal or spatial differences in the ionic composition of water. Piper diagrams display the relative concentrations of major cations and anions on two separate ternary (triangular)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

Comparison to Water Quality Guidelines and Historical Data

The 2013 value (fall, seasonal, or monthly) of each water quality measurement endpoint was tabulated for each station sampled. Historical variability was presented for each water quality measurement endpoint, represented by minimum, maximum, and median values observed, as well as the number of observations, at each station from 1997 to 2013 (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 2013.

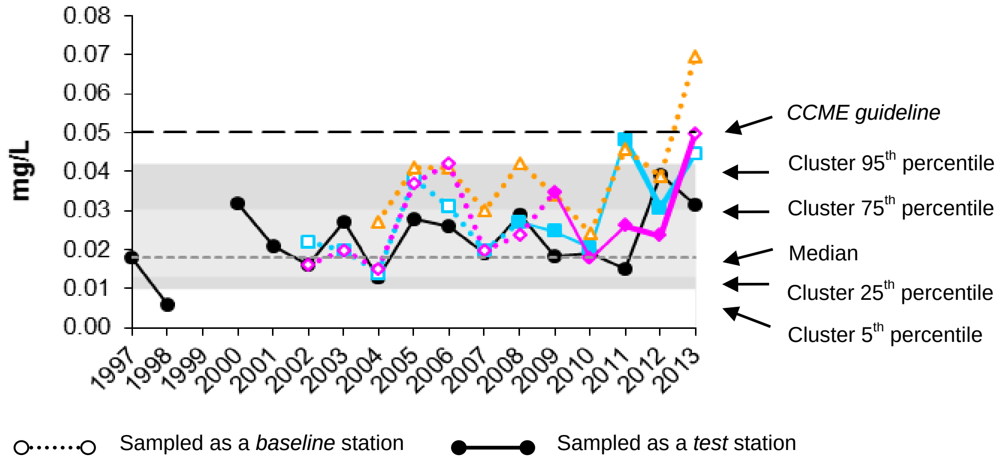


Comparison to Regional Baseline Concentrations

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 2013 (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 2013, 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.



For stations with monthly data collected in 2013, monthly results were presented against the fall range of *baseline* concentrations appropriate for that station. It should be noted that the fall range of *baseline* water quality is not necessarily representative of water quality for samples collected outside of fall. To address this discrepancy, monthly data outside of fall (September/October) were only screened informally against these regional *baseline* fall concentrations (i.e., comments are made in relevant sections of Section 5 regarding how monthly data compared to fall *baseline* ranges, but non-fall data were not used to determine potential effects within the analytical framework of this report).

Development of Regional *Baseline* Concentrations Descriptions of regional *baseline* water quality conditions were developed from existing data collected 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 2013, 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 90th 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 2013, a cluster analysis confirmed overall patterns previously seen in the data: stations generally group together based on geographical location rather than sampling year. The overall cluster groupings also resembled clusters produced in the RAMP 2010 cluster analysis. Rank and scale transformations of the data produced similar cluster memberships for most of the stations, suggesting that clustering based on water quality data in 2013 was based on strong relationships. To preserve clustering of station-data combinations located within specific watersheds, multivariate analysis was not used exclusively to determine cluster membership. For determination of regional ranges of natural variability, stations were grouped together based on cluster analysis and geographical location. This method incorporated both overall patterns determined from cluster analysis with ecological knowledge of the area. Four "clusters" were determined: 1. Athabasca River; 2. Southern Tributaries and the Firebag River; 3. Western Tributaries and McLean Creek; and 4. Eastern Tributaries, Steepbank River, and Muskeg River. Stations included in each group of *baseline* data, and those compared against these groups are provided in Table 3.2-2. Ranges of regional *baseline* values calculated for each group of stations and used for comparisons are provided in Table 3.2-3 to Table 3.2-5.

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

Regional *Baseline* Grouping (Cluster)	*Baseline* Stations Used in Creating Regional Comparison[1]	Stations (2013) Compared Against Regional *Baseline* Range
1. Athabasca River	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. Eastern and Southern tributaries, and Ells River	BRC-1, CHR-4, CLR-1, CLR-2, ELR-1, ELR-2, ELR-2A, ELR-3, FIR-2, HHR-1, HOR-1, SUC-2	CLR-1, CLR-2, HHR-1, CHR-1, CHR-2, CHR-3, CHR-4, JAR-1, SAC-1, SUC-1, SUC-2, UNC-2, UNC-3, BRC-1, ELR-1, ELR-3, HAR-1, HAR-1A, FIR-1, FIR-2
3. Western tributaries	BER-2, BIC-1, CAR-1, CAR-2, DUR-1, EYC-1, MAR-1, MAR-2, PIR-1, RCC-1, SHC-1, TAR-1, TAR-2	BER-1, BER-2, BIC-1, CAR-1, CAR-2, EYC-1, MAR-1, MAR-2, MAR-2A, MCC-1, PIR-1, POC-1, RCC-1, TAR-1, TAR-2
4. Muskeg River, Steepbank River, Fort Creek, and Mills Creek	FOC-1, IYC-1, JAC-1, JAC-2., MUC-1, MUR-6, NSR-1, STC-1, STR-2, STR-3, WAC-1	FOC-1, IYC-1, JAC-1, JAC-2, 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* from 1997 to 2013, 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 upstream of the station in a watershed.

Table 3.2-3 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2013, Group 1 Athabasca River.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	38	7.70	7.84	8.05	8.19	8.21	8.31	8.40
Total suspended solids	38	3	3	10	16	23	91	136
Conductivity	38	202	203	233	269	291	318	366
Nutrients								
Total dissolved phosphorus	38	0.003	0.005	0.007	0.011	0.018	0.028	0.030
Total nitrogen	38	0.250	0.293	0.456	0.514	0.698	0.805	0.901
Nitrate+nitrite	38	0.050	0.050	0.071	0.100	0.100	0.124	0.290
Dissolved organic carbon	38	1.5	2.9	6.0	7.0	9.9	14.3	17.1
Ions								
Sodium	38	8.0	8.5	10.0	11.6	17.0	21.2	28.0
Calcium	38	17.7	18.8	23.2	31.5	33.8	39.4	43.6
Magnesium	38	5.49	5.73	6.88	8.53	9.56	11.17	12.30
Chloride	38	1.86	2.00	3.00	6.00	17.95	25.06	36.00
Sulphate	38	5.67	6.49	11.30	24.10	28.68	36.53	50.20
Potassium	38	0.75	0.80	0.86	1.00	1.19	1.40	1.60
Total dissolved solids	38	40.0	88.5	154.5	168.0	179.5	240.0	282.0
Total alkalinity	38	62.9	68.6	84.0	99.5	110.8	122.9	145.0
Selected metals								
Total aluminum	38	0.030	0.139	0.444	0.594	1.088	2.253	3.760
Dissolved aluminum	38	0.006	0.007	0.010	0.012	0.025	0.122	1.100
Total arsenic	38	0.0005	0.0005	0.0006	0.0008	0.0010	0.0013	0.0017
Total boron	38	0.0143	0.0168	0.0213	0.0252	0.0317	0.0398	0.0450
Total molybdenum	38	0.0002	0.0002	0.0003	0.0006	0.0007	0.0009	0.0011
Total mercury (ultra-trace)	27	0.60	1.20	1.20	1.20	2.05	5.58	12.90
Total strontium	38	0.0897	0.0980	0.1335	0.2010	0.2488	0.2873	0.2950

Table 3.2-4 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2013, Group 2 eastern/southern tributaries.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	45	7.20	7.44	7.90	8.00	8.15	8.37	8.48
Total suspended solids	45	3	3	3	6	12	36	174
Conductivity	45	80	141	164	191	216	261	341
Nutrients								
Total dissolved phosphorus	45	0.004	0.008	0.014	0.021	0.056	0.094	0.118
Total nitrogen	44	0.300	0.312	0.488	0.606	0.804	1.604	2.311
Nitrate+nitrite	45	0.050	0.071	0.071	0.071	0.100	0.100	0.100
Dissolved organic carbon	45	6.0	7.0	9.0	13.1	15.4	25.7	44.8
Ions								
Sodium	45	2.0	3.0	4.0	10.2	13.7	25.0	29.0
Calcium	45	10.0	10.9	13.8	22.2	25.0	34.1	45.9
Magnesium	45	2.86	3.74	4.46	6.44	7.30	9.81	12.60
Chloride	45	0.5	0.5	0.6	2.0	16.2	35.6	43.0
Sulphate	45	0.50	0.59	2.20	4.95	10.80	17.52	22.60
Potassium	45	0.5	0.5	0.7	0.9	1.1	1.3	1.4
Total dissolved solids	45	40	110	117	138	158	189	197
Total alkalinity	45	29.8	40.7	51.0	84.9	96.0	128.2	184.0
Selected metals								
Total aluminum	45	0.015	0.024	0.060	0.140	0.460	2.286	5.000
Dissolved aluminum	45	0.001	0.0031	0.0051	0.0080	0.0138	0.0541	0.1850
Total arsenic	45	0.0001	0.0004	0.0005	0.0006	0.0010	0.0014	0.0025
Total boron	45	0.0083	0.0122	0.0156	0.0282	0.0494	0.0654	0.0836
Total molybdenum	45	0.0000	0.0001	0.0001	0.0002	0.0006	0.0008	0.0010
Total mercury (ultra-trace)	40	0.60	0.80	1.20	1.20	1.85	4.23	13.70
Total strontium	45	0.0284	0.0462	0.0575	0.0838	0.1060	0.1280	0.1400

Table 3.2-5 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2013, Group 3 western tributaries.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	56	7.16	7.78	8.07	8.2	8.3	8.4	8.52
Total suspended solids	56	2	3	3	7	24	106	208
Conductivity	56	164	197	280	403	527	736	1,172
Nutrients								
Total dissolved phosphorus	56	0.004	0.009	0.024	0.039	0.065	0.137	0.305
Total nitrogen	56	0.400	0.498	0.763	1.101	1.813	3.125	5.541
Nitrate+nitrite	56	0.05	0.066	0.071	0.071	0.1	0.1	0.1
Dissolved organic carbon	56	8.00	11.75	15.78	26.80	34.00	48.00	54.40
Ions								
Sodium	56	6.00	9.13	12.75	19.50	53.80	71.85	96.20
Calcium	56	17.80	22.29	31.35	44.00	53.15	72.13	83.50
Magnesium	56	6.61	7.38	10.25	13.30	17.40	22.38	26.60
Chloride	56	0.50	0.50	1.20	2.00	9.60	31.00	80.20
Sulphate	56	6.8	8.2	14.3	23.3	42.8	101.5	137.0
Potassium	56	0.50	0.88	1.18	1.70	3.05	4.44	5.33
Total dissolved solids	56	160.0	170.0	209.8	290.0	372.5	508.8	547.0
Total alkalinity	56	74.6	87.3	121.0	182.5	227.3	315.3	354.0
Selected metals								
Total aluminum	56	0.020	0.031	0.112	0.243	0.504	2.653	5.130
Dissolved aluminum	56	0.0010	0.0023	0.0076	0.0169	0.0248	0.0386	0.0821
Total arsenic	56	0.0002	0.0005	0.0010	0.0012	0.0020	0.0035	0.0050
Total boron	56	0.035	0.045	0.060	0.083	0.113	0.230	0.424
Total molybdenum	56	0.0001	0.0001	0.0003	0.0005	0.0012	0.0018	0.0025
Total mercury (ultra-trace)	48	0.60	0.84	1.20	1.40	2.95	10.11	21.00
Total strontium	56	0.101	0.114	0.147	0.182	0.255	0.335	0.435

Table 3.2-6 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2013, Group 4 Muskeg River, Steepbank River and miscellaneous watersheds.

Measurement Endpoint	n	Percentiles						
		Min	5th	25th	Median	75th	95th	Max
Physical variables								
pH	69	7.2	7.4	7.8	8.0	8.2	8.3	8.5
Total suspended solids	69	3	3	3	4	8	22	243
Conductivity	69	110	139	195	244	326	522	671
Nutrients								
Total dissolved phosphorus	70	0.006	0.011	0.014	0.018	0.027	0.042	0.070
Total nitrogen	70	0.30	0.45	0.70	0.80	1.00	1.63	2.63
Nitrate+nitrite	70	0.05	0.05	0.10	0.10	0.10	0.10	0.10
Dissolved organic carbon	69	6.0	11.8	17.0	21.0	25.0	29.2	33.0
Ions								
Sodium	69	2.0	3.0	5.0	9.0	13.9	22.1	64.0
Calcium	69	16.5	18.3	23.2	32.7	45.4	71.5	82.2
Magnesium	69	4.90	5.51	7.20	10.30	14.60	18.94	25.10
Chloride	69	0.5	0.5	1.0	2.0	2.0	3.6	36.0
Sulphate	69	0.5	0.9	2.0	3.1	4.6	7.1	11.2
Potassium	69	0.30	0.50	0.51	0.80	1.00	1.66	2.10
Total dissolved solids	69	109	132	160	200	240	326	378
Total alkalinity	69	55	69	100	127	186	287	313
Selected metals								
Total aluminum	70	0.007	0.014	0.029	0.050	0.108	0.569	2.840
Dissolved aluminum	70	0.0015	0.0024	0.0055	0.0100	0.0148	0.0473	0.1700
Total arsenic	70	0.0002	0.0003	0.0005	0.0007	0.0010	0.0010	0.0016
Total boron	70	0.0060	0.0105	0.0185	0.0428	0.0584	0.1212	0.1500
Total molybdenum	70	0.00003	0.0000	0.0001	0.0001	0.0002	0.0003	0.0064
Total mercury (ultra-trace)	46	0.6	1.2	1.2	1.2	1.2	2.8	8.8
Total strontium	70	0.0494	0.0576	0.0754	0.0967	0.1430	0.1970	0.2960

3.2.2.3 Classification of Results

The following criteria were used for assessing water quality results:

- **Trend Analysis** - Any significant (α=0.05) trends over time in water quality measurement endpoints.
- **Comparison to Historical Concentrations** - Fall 2013 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 2013 in any season or month 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 3.2-7). All values that exceeded these guidelines were reported explicitly in Section 5.

- **Comparison to Regional *Baseline* Conditions** - 2013 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 2013 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=589) yielded index values ranging from 39.7 to 100.0. It should be noted that historical index values calculated for specific observations may change annually, given that 95th percentile values for individual variables included in the index may change with addition of new *baseline* data to the 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

Table 3.2-7 Water quality guidelines used to screen data collected by the RAMP Water Quality Component, 2013.

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	-	-	5,800	6,000
Anthracene	ng/L	-	-	12	4,000
Benzo(a)anthracene	ng/L	-	-	18	100
Benzo(a)pyrene	ng/L	-	-	15	10
Fluoranthene	ng/L	-	-	40	4,000
Fluorene	ng/L	-	-	3,000	12,000
Naphthalene	ng/L	-	-	1,100	1,000
Phenanthrene	ng/L	-	-	400	300
Pyrene	ng/L	-	-	25	-

a: CCME (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.

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, Christina, and Johnson lakes), because of concerns raised by the RAMP Peer Review (AITF 2011) regarding combining lakes and streams in regional *baseline* ranges.

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;
  - control charts to indicate when a reach was shifting from *baseline* conditions; and
- developing criteria to be used in detecting changes in benthic invertebrate community measurement endpoints.

Selection of Benthic Invertebrate Community Measurement Endpoints

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

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

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

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 E for a full description of the method). Separate ordinations were carried out for benthos from the Athabasca River Delta, lakes, erosional river reaches, and depositional river reaches, because these four classes of habitat can be anticipated to produce unique fauna, and on the basis of previous analyses, had demonstrated differences in composition among those four habitat types.

All measurement endpoints for benthic invertebrate communities were calculated for each sample and then averaged for each reach or lake for the purpose of illustrating time trends. The measurement endpoints were 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. Variation in measurement endpoints were adjusted to account for the influence of water velocity (river samples) and water depth (lake samples), based on relationships observed for *baseline* samples. One-way ANOVAs were conducted for each adjusted benthic invertebrate community measurement endpoint with each reach-year (or lake-year, as appropriate) combination as the factorial variable. Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to identify differences between *baseline* and *test* reaches (or lakes), between *baseline* and *test* periods, and differences in time trends between lower *test* reaches and upper *baseline* reaches (or lakes, as appropriate). In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

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

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

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

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

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

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

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

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

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

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

Comparison to Published Literature

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

Determination of Normal Ranges

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

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

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

Where,

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

Normal ranges for the assessment of *test* reaches in 2013 were calculated as: (i) the within-reach normal range using data from all previous years for a *test* reach (or lake or delta channel), where more than eight years of data exists or within a lake where a regional assessment was not possible (Figure 3.2-3); and (ii) the among-*baseline*-reach normal range using all available data from *baseline* reaches, grouped by erosional or depositional habitat, up to and including 2012. The within-reach (or lake or channel) normal range was considered first. An exceedance of limits of the within-reach normal range was followed up with a comparison to regional normal ranges.

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

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

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

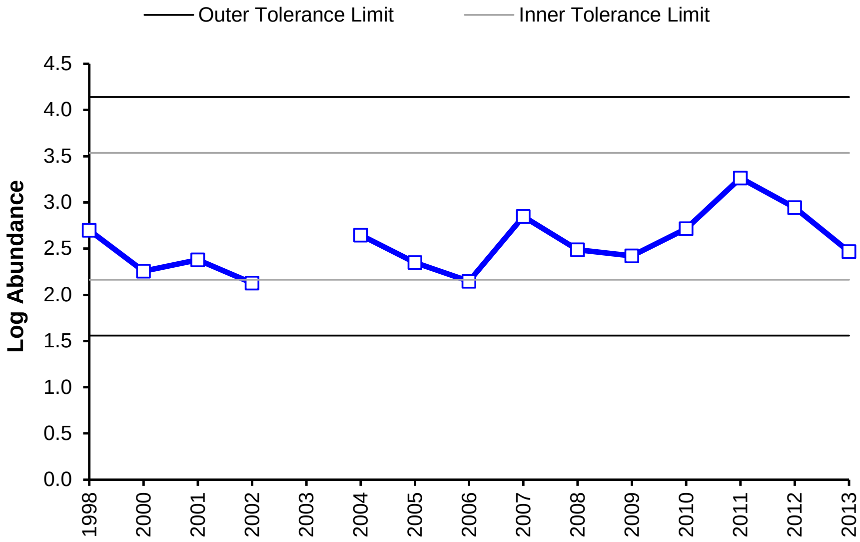
Where,

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

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

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

Figure 3.2-3 Example time trend chart for benthic invertebrate community log of total abundance in relation to the within-reach range of variability, in this case, for the lower Steepbank River.



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

Environmental Variables

A number of environmental variables, including physical substrate condition and water temperature, chemistry, and flow velocities were measured at each reach. These environmental variables were measured because they influence the kinds of benthic invertebrate fauna found at a reach or in a lake. Where benthic invertebrate communities are shown to vary over time in a manner consistent with the development of 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 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). Upper and lower tolerance limits of the normal range of chlorophyll *a* values from reaches designated as *baseline* were determined (Appendix D) and provided in figures that illustrate trends over time in chlorophyll *a* values.

Classification of Results

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

Measured changes were classified as Negligible-Low, Moderate, or High on the basis of the strength of the statistical signal from a reach/lake for changes in core measurement endpoints for benthic invertebrate communities (Table 3.2-8). Strong statistical signals are considered to be differences that are statistically significant ($p < 0.05$) and that are as strong as, or stronger, than the background "noise" in reach-year variations. For the purpose of this report, a change was additionally considered "strong" (i.e., interpretable) if the change explained > 20% of the variation in annual means, or if the mean in 2013 fell between the inner and outer the outer tolerance limits for the 5th or 95th percentiles or was outside the outer tolerance limits. There are four core measurement endpoints for benthic invertebrate communities assessed (abundance, taxa richness, equitability, and percent EPT), and two more if the multivariate ordination axes are considered. If any one of those measurement endpoints produced a strong signal of a change, then the conclusion will be that a 'Moderate' change has been detected. If any three of the key measurement endpoints produces a strong statistical signal, then the conclusion will be that a 'High' change had been detected. If no key measurement endpoints produces a strong statistical signal, or if all of the signals indicate a benthic community that is in good condition, then the conclusion will be that a "Negligible-Low" change has been detected.

Table 3.2-8 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 the key measurement endpoints in 2013, with difference from *baseline* implying a negative change.
Exceed *baseline* range of variation	No	No	Yes	Strong signal in three key measurement endpoints in 2013, with the difference from *baseline* implying a negative change.

3.2.3.2 Sediment Quality Component

The analytical approach undertaken for the Sediment Quality component in 2013 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 2013 results, comparing 2013 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 2013 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 3.2-9) was guided by:

- sediment quality measurement endpoints listed in the EIAs of oil sands projects as being potentially affected by oil sands development activities (RAMP 2009b);
- sediment quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the RAMP 1997 to 2004 sediment quality dataset indicating significant inter-correlation of various sediment quality variables; and
- 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 3.2-9 Potential sediment quality measurement endpoints.

Variable Group	EIA Review: Variables Listed in EIAs	RAMP 5-Year Report (Golder 2003)	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 sum of total metals, only metals in sediment that exceeded CCME Interim Sediment Quality Guideline (ISQG) values (CCME 2002) were presented, as metals in sediments are not listed in oil sands EIAs as being potentially affected by development (RAMP 2009b); and
- *Sublethal toxicity* - sublethal toxic effects of whole sediment samples on the survival and growth of the amphipod (seed-shrimp) *Hyalella azteca* (14-day test) and the midge *Chironomus tentans* (10-day test).

Tabular and Graphical Presentation of 2013 Sediment Quality Results

The 2013 sediment quality data for each sediment quality measurement endpoint were tabulated for each station sampled. Historical variability also was presented for each measurement endpoint, represented by minimum, maximum, and median values observed (as well as number of observations) from 1997 to 2013. Concentrations of any sediment quality measurement endpoint and any metal that exceeded relevant guidelines were also reported.

Data for the selected sediment quality measurement were presented graphically in the context of relevant regional variability 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 2013 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 3.2.2.2), also yielding a single index value ranging from 0 to 100.

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

Index calculations for 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 2013 (n=357), sediment quality index values of 33.7 to 100.0 were calculated.

Sediment quality index scores were classified using the following scheme:

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

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

3.2.4 Fish Populations Component

The analytical approach used in 2013 for the Fish Populations component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2009b) and consisted of:

- selecting fish population measurement endpoints;
- conducting analysis of covariance (ANCOVA), analysis of variance (ANOVA), or Mann-Kendall trend analysis on fish population measurement endpoints to test for differences in time trends, and/or differences between *baseline* and *test* reaches;

- presenting results in tabular and graphical format comparing 2013 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 of 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. Relative age-frequency distributions were displayed graphically for each year (all seasons combined) in order to evaluate trends in dominant age classes over time and survival of fish to older age classes. Analysis of covariance (ANCOVA) followed by Tukey post-hoc tests were used to compare differences across years for length-at-age of each fish species, where length was the dependent variable, year was the independent variable, and age was the covariate. If the ANCOVA showed a statistically significant difference among years, the direction and magnitude of the change was calculated. Magnitude was defined as the percentage change in the adjusted means of length at age from an earlier year to a later year; magnitude values greater than 25% were considered to be a significant change (Environment Canada 2010).

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

- Fish condition (or "how fat a fish is") was compared between *baseline* years (1987 to 1996) and 2013 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 captured from 1987 to 1996, period prior to major oil sands development) estimated as the 5th and 9th percentiles, which is a surrogate for $\bar{x} \pm 2SD$.

In order to be consistent with past analyses, the 2013 analyses of condition were restricted to fish of the following species-specific minimum lengths: walleye >400 mm; lake whitefish >350 mm; northern pike >400 mm; goldeye >300 mm; longnose sucker >350 mm; white sucker >350 mm; and trout-perch >50 mm.

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

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

- Percent of fish in each season with fin erosion and body wounds; and

- Percent of fish with external pathology, including parasites, growths/lesions, and body deformities.

A seasonal Mann-Kendall trend analysis (i.e., addresses variability due to seasonality and allows evaluation of overall trends in the time series) was conducted on the percent of parasites, growth/lesions, and body deformities for all species combined, across years, with a level of significance of α=0.05 (Nielsen 2005).

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 2013.

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 Regional Lakes Fish Tissue Program

Selection of Measurement Endpoints

Measurement endpoints used to analyze fish tissue results from Christina and Namur lakes included whole-organism metrics (fork length, body weight, and age), and mercury concentrations burden (both concentration and concentration standardized to fish length).

Temporal Trends and Spatial Comparisons

Whole-organism Metrics Whole-organism metrics (i.e., fork length, body weight, age) were reported with gender and stage of maturity for fish collected during the tissue program on Christina and Namur lakes.

Mercury Mercury results were reported for fish collected from Christina and Namur lakes. Scatterplots were then used to initially assess relationships between mercury concentrations and whole-organism metrics for each species and sex combination. Mercury concentrations among years (2002 and 2013 for Christina Lake and 2000, 2007, and 2013 for Namur Lake) for each species 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 ($p>0.01$), and the second step was to compare the intercepts of the regressions (the p-value for the intercept was provided in the results).

Comparison to Published Guidelines

Mercury measured in fish collected from Christina and Namur lakes 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 3.2-10);
- Health Canada Guidelines for general fish consumption (0.50 mg/kg) (Health Canada 2007, last updated July 2007) and subsistence level fish consumption (0.2 mg/kg) (Health and Welfare Canada 1979, INAC 2003, updated June 2006); and

- Region III USEPA risk-based criteria for consumption of fish tissue for recreational (0.4 mg/kg) and subsistence fishers (0.049 mg/kg) (USEPA 2000, updated October 2007).

Table 3.2-10 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 2013. There have been no consumption limits established for Namur Lake.

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 Christina Lake.

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).

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.

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 3.2-11 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 3.2-11 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 Sentinel Species Monitoring

Selection of Measurement Endpoints

Measurement endpoints selected for sentinel species monitoring on the Athabasca River are summarized in Table 3.2-14. 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 3.2-12 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	gonad weight	Body weight
Energy Storage	Liver size	Liver weight	Body weight
	Condition	Body weight	Fork length

Temporal Trends and Spatial Comparisons

Possible spatial and temporal differences in measurement endpoints of trout-perch were assessed by comparing each *test* site (ATR-3, ATR-4, ATR-5) against the *baseline* sites (ATR-1, ATR-2). The following comparisons were evaluated for 2013 and compared to the same comparisons made in 2002 and 2010:

- Between *baseline* sites (to determine variability across *baseline* sites) - if no differences were observed, the *baseline* sites were pooled to perform statistical comparisons against *test* sites; if baseline sites are different, comparisons between ATR-2 and test sites were used to determine response patterns in trout-perch (by using ATR-2, the variability associated with the STP was removed);
- *Test s*ite ATR-3 versus *baseline* sites ATR-1 and ATR-2 (or combined);
- *Test s*ite ATR-4 versus *baseline* sites ATR-1 and ATR-2 (or combined); and
- *Test s*ite ATR-4 versus *baseline* sites ATR-1 and ATR-2 (or combined).

For testing for possible differences in age of trout-perch 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 trout-perch 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 trout-perch 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 trout-perch 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.

The first step in the analysis was to compare slopes of regressions from different populations to ensure they were equal ($p>0.01$), and the second step was to compare the intercepts of the regressions (the p-value for the intercept was provided in the results).

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 trout-perch.

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; Tetreault et al. 2003; Gibbons and Munkittrick 1994), to provide context for the results from the 2013 trout-perch 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 gonad size in fish collected at a *test* site from gonad size of fish collected at a *baseline* site;
- ± 25% difference in live size in fish collected at a *test* site from liver size 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 3.2-13):

- An exceedance of the effects criteria on any one of the three responses (age, energy use [weight-at-age, gonad size], energy storage [liver size, body weight at length]) 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 3.2-13 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 five 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 five responses in two consecutive sampling cycles.

3.2.4.4 Fish Assemblage Monitoring Program

Selection of Measurement Endpoints

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

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

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

  Where,

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

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

- Assemblage Tolerance Index (ATI) - The ATI was developed by Whittier et al. (2007) for stream and river fish assemblages in the western United States to quantify a species' tolerance to an overall human disturbance gradient (Table 3.2-14). 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. With this index, lower tolerance values imply a species that is more sensitive to disturbance.

Table 3.2-14 Tolerance values for fish collected during the 2013 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]
cisco	CISC	2.5[1]
emerald shiner	EMSH	6.9
finescale dace*	FNDC	7.0
fathead minnow*	FTMN	8.3
goldeye	GOLD	9.3
lake chub*	LKCH	5.5
lake whitefish*	LKWH	2.5[1]
longnose dace*	LNDC	6.2
longnose sucker*	LNSC	4.6
northern redbelly dace*	NRDC	7.0[1]
northern pike	NRPK	7.8
pearl dace*	PRDC	6.7
slimy sculpin*	SLSC	3.0[1]
spoonhead sculpin	SPSC	3.0[1]
spottail shiner*	SPSH	7.7
trout-perch*	TRPR	8.4
walleye	WALL	8.7
white sucker*	WHSC	7.6
yellow perch	YLPR	7.4

* Commonly caught fish species of Athabasca River tributaries in the Alberta oil sands region.

[1] Judgment-based score from values for similar species.

Temporal Trends and Spatial Comparisons

Possible changes in fish assemblages were evaluated by comparing measurement endpoints in reaches designated as *test* to upstream *baseline* reaches and regional *baseline* reaches and/or across years within a reach. When necessary, the measurement endpoints were $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances. For reaches where there were three years of data, one-way ANOVAs were conducted for each fish assemblage measurement endpoint with each reach-year combination as the factorial variable. The ANOVA used variations within reaches to judge the significance of linear time trends. Linear contrasts were used to carry out the analysis of variance and to test the specific hypothesis. Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to identify differences in time trends between lower *test* reaches and upper *baseline* reaches. In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

The nature of statistically significant differences was examined to determine if the difference was consistent with a negative change in the fish assemblage. A decrease in taxa richness and an increase in ATI would each be considered a negative change or difference. An decrease in diversity would be considered a negative change. Similar to statistical analyses conducted for the Benthic Invertebrate Communities component, changes are more easily interpreted when the change accounts for at least 20% of the variation in the annual means, so that additional criterion is used this year to identify interpretable effects. An effect that explains 20% of the noise is equivalent to an effect size of 1 standard deviation; i.e., means differ by 1 SD.

In cases where there is an upstream *baseline* reach, the testable hypothesis was:

- H_{O1}: No difference in time trends in mean values of measurement endpoints between *test* and *baseline* reaches.

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

- H_{O2}: No trend over time in mean values of measurement endpoints.

Comparison to Published Literature

There are no conventional "guidelines" *per se* against which to judge observed differences in measurement endpoints of fish assemblages given *baseline* ranges of variation tend to depend on local or regional climatic, hydrological, and geological conditions. Consequently, 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 Normal Ranges

The normal range for *baseline* reaches were calculated similarly to the ranges for benthic invertebrate communities (see Section 3.2.3.1) (within-reach ranges were not calculated given the small sample size of data available for each reach). The first step was to determine which fish assemblage reaches were similar in habitat conditions in order to group *baseline* reaches according to their similarities. A principal components analysis of the physical and chemical habitat data for each of the 34 *baseline* reach x year combinations was conducted in order to determine how the various habitat attributes covaried, and to select a sub-set of variables that would be used to explore causes of variation in measurement endpoints of fish assemblage composition. The PCA was conducted using the following suite of variables: mean 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 sampling, instream cover as algae, instream cover as macrophytes, instream cover as large woody debris (LWD), instream cover as small woody debris (SWD), instream cover as trees, instream cover as over-hanging 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 were carried forward for further interpretation (Jackson 1993). Pearson correlations (i.e., Pearson *r*-values) between individual variables and the "significant" PCA axes that were $>|0.6|$ were considered strongly associated with an axis. Variables that strongly correlated with an axis were considered at least somewhat redundant.

Based on the results of the PCA, variables that explained some variability across *baseline* reaches included (see Appendix E for the complete analysis):

- Substrate class (i.e., erosional or depositional);
- Canopy cover as trees;

- Upstream catchment area;
- Instream cover as boulders;
- Mean bankfull and wetted width; and
- Mid-channel water flow.

Using these habitat variables that were significantly correlated with PCA axes, a cluster analysis was performed to group reaches of similar habitat variables. Two main groupings of *baseline* reaches were observed based on substrate texture (erosional and depositional); therefore, normal ranges of *baseline* variation were calculated separately for depositional and erosional reaches.

The normal range for the assessment of *test* reaches in 2013 was calculated as the among-*baseline*-reach range using all available data from *baseline* reaches, grouped by erosional or depositional habitat, up to and including the current year (i.e., 2013).

Similar to the analysis for the Benthic Invertebrate Communities component, tolerance limits were then calculated for the 5th and 95th percentiles for among-*baseline*-reach normal ranges (as per Hunt et al. 2001; Smith 2002; Krishnamoorthy and Mathew 2009).

The tolerance limit for the p^{th} percentile (5th or 95th percentile) is:

$$\overline{x} \pm k \bullet sd$$

Where,

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

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

Classification of Results

The criteria used for classifying results of fish assemblages focused on whether or not the measurement endpoints for the fish assemblage at a *test* reach either exceeded normal ranges of *baseline* variability, had significantly changed across years, or was significantly different from the upstream *baseline* reach (if applicable).

Measured changes were classified as Negligible-Low, Moderate, and High on the basis of the strength of the statistical signal from a reach for changes in measurement endpoints for fish assemblages, and for exceedances from the normal *baseline* range of variability (Table 3.2-15). There are five measurement endpoints assessed for fish assemblages (abundance, CPUE, richness, Simpson's Diversity, and the assemblage tolerance index). If any one of those measurement endpoints produced a significant change in 2013 compared to previous years ($p<0.05$) and/or if the mean in 2013 fell between the inner and outer tolerance limits or outside the outer tolerance limits for the 5th or 95th percentile for the normal range of *baseline* variability, then the 'Moderate' criterion was considered to have been met. This criterion was particularly relevant for the assessment of reaches for which there was at least a three-year data record. Allowing any one of the five measurement endpoints to trigger this criterion assumed that each measurement endpoint represented an attribute of the assemblage that was important. If any three of the key measurement endpoints produces a strong statistical signal, then the conclusion will be that a 'High' level of change had been detected. The second criterion was considered to be met (producing a "yes" in Table 3.2-15) if any three measurement endpoint values had fallen outside of the normal range of *baseline* variability within the current year or if a measurement endpoint was outside the normal range of *baseline* variability for three consecutive years.

Table 3.2-15 Classification of results for the fish assemblage monitoring program.

Criterion	Classification			"Yes"
	Negligible-Low	Moderate	High	
Statistical significance	No	Yes	Yes	Strong statistical signal on any one of five measurement endpoints (Mod), with a difference implying a negative change and statistical signal in four of the five endpoints (High).
Exceed *baseline* range of variation	No	No	Yes	Any three of the five measurement endpoints outside the inner tolerance limits of the 5th and 95th percentiles or three consecutive years of a measurement endpoint outside of the normal *baseline* range of variability.

3.2.5 Acid-Sensitive Lakes Component

The analytical approach used in 2013 for the ASL component followed the 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 the 2013 results.

Minor changes and additions to the analyses described in the RAMP Technical Design and Rationale document are presented in the sections below.

3.2.5.1 Selection of Measurement Endpoints

The measurement endpoints for the ASL component in 2013 were as follows:

- pH;
- Gran alkalinity;
- Base cation concentrations;
- Nitrate plus nitrite;
- Sulphate;
- Dissolved organic carbon; and
- Dissolved aluminum.

Gran alkalinity and pH are considered the principal ASL measurement endpoints. Sulphate is included in the list of measurement endpoints but, unlike many lakes in eastern North America, sulphate and acidity (H^+) in Alberta lakes are poorly correlated because of the abundance of neutral sulphate compounds in wet and dry deposition (AEP 1990; Lau 1982; Legge 1988; RAMP 2004). Concentrations of sulphate in the ASL component lakes were typically low and, despite high rates of deposition in the past, were found to be sequestered and immobilized within the individual catchment basins (Whitfield et al. 2010).

3.2.5.2 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 using an ANOVA

A one-way Analysis of Variance (ANOVA) was conducted to determine whether there have been any significant changes in mean concentrations of each ASL measurement endpoint in the 50 RAMP lakes during the twelve years of monitoring when all 50 lakes were sampled (2002 to 2013). An ANOVA was run after testing for the homogeneity of the variance of each variable between years. When the variance of a variable was found to be non-homogeneous, a non-parametric test (Kruskal-Wallis one-way ANOVA) was applied to detect changes in the median concentrations. Tukey's post-hoc test was used to examine individual differences in mean values among years when the ANOVA indicated significant differences. Any observed changes were discussed in relation to acidification, natural variability and other possible causes unrelated to emissions of acidifying substances (e.g., hydrologic events).

Among-Year Comparisons of Measurement Endpoints using the General Linear Model

An ANOVA using the General Linear Model (GLM) was applied to examine trends in measurement endpoints over time in the study lakes. The model regresses the concentration of a measurement endpoint against time in each individual lake and determines the overall significance of the regressions over the 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 across lakes. The GLM was applied to the population of 50 lakes as well as subsets of the 50 lakes that included both *baseline* and *test* lakes (e.g., within physiographic regions as for lakes determined as most likely to undergo acidification).

Mann–Kendall Trend Analysis on Measurement Endpoints in Individual Lakes

Potential trends in measurement endpoints were examined in all 50 lakes using a Mann-Kendall trend analysis. Significant trends were examined and discussed in relation to previous hydrologic events and the logical consistencies (or inconsistencies) of these observed trends. The program used for the analysis (MAKESENS) calculated the Mann-Kendall statistic S on lakes having fewer than ten years of data. For lakes having at least ten years of data, a normal approximation test was applied to calculate the Z test statistic. To assist in interpreting the results of the trend analyses, control charts were provided of measurement endpoints in those lakes where significant changes occurred in a direction indicative of acidification.

Control Charting of Measurement Endpoints in 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 Potential Acid Input to Critical Load (PAI to CL). The higher the ratio in a given lake, the greater the risk for acidification of this lake. The control plots followed standard analytical control chart theory where control limits representing two and three standard deviations were plotted on the graphs with the points and the mean value (Gilbert 1987; Systat 2004). The two and three standard deviations were calculated using all historical data for a lake (1999 to 2012). A trend in the value of a measurement endpoint was determined on the basis of the criteria described below. Given the low probability (1% or less) that these criteria would be violated in a truly random population of a measurement endpoint, there was a high probability of detecting a true trend in a measurement endpoint over time. The visual presentation of the data in control charts permitted the detection of trends before significant changes actually occur.

The following criteria were used to identify a trend or potential risk for acidification using Shewhart control plots (from Systat 2004):

- One year where a measurement endpoint was beyond three standard deviations (on either side).
- Nine consecutive years where a measurement endpoint was on one side of central line (mean value).
- Six consecutive years where a measurement endpoint was steadily increasing or decreasing.
- Two out of three consecutive years where a measurement endpoint was outside the two standard deviations limit (on one side). This is a modified version of the first test. This gives an early warning that the measurement endpoints might be going “out-of-control”.
- 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 of acidity (CL), in units of keq H+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology; and represents a measure of a lake’s sensitivity to acidification. CLs for the RAMP lakes in 2013 were calculated using the Henriksen steady state water chemistry model modified for the effects of organic acids on buffering and acid sensitivity. Details of the model and its assumptions are described below.

The Modified Henriksen Model

The original Henriksen model was modified to account for both the buffering of weak organic anions and the lowering of acid neutralizing capacity (ANC) attributable to strong organic acids. The modified model assumed that DOC, with its associated buffering from weak organic acids (ANC_{org}) and reduction of ANC from strong organic acids (A^-_{SA}), was exported from the catchment basin to each lake in the same way that we assume the export of base cations (carbonate alkalinity) to each lake. The modified Henriksen model is:

$$CL= ([BC]^*_0 + ANC_{org} - A^-_{SA} - ANC_{lim}) .Q$$

Where,

- $[BC]^*_0$ is the original base cation concentration before acidification;
- ANC_{lim} is the limiting acid-neutralizing capacity of the lake required to maintain a healthy and functional aquatic ecosystem;
- $ANC_{org} = 0.00680^* DOC^{(0.8833^*pH)}$;
- $A^-_{SA} = 6.05 ^*DOC +21.04$; and
- Q is the runoff to each lake from the catchment and lake area.

The modifications of the Henriksen model for organic acids and the empirical relationships for developed for ANC_{org} and A_{-SA} are described in WRS (2006) and RAMP (2009b).

Calculation of Runoff (Q)

The runoff (Q) to each lake, was calculated from the analysis of heavy isotopes of oxygen (^{18}O) and (^2H) in each lake conducted, and provided by John Gibson (University of Victoria). With this technique, the natural evaporative enrichment of ^{18}O and ^2H 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 previous years of applying the Henriksen model (2002 to 2012), 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 the differences between the current and calculated original base cation concentrations in all 50 lakes were insignificant.
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.

Despite indications that base cations have not increased in the ASL component lakes in 2013, $[BC_o]$ was calculated for each lake by applying a modified Brakke et al. (1990)

equation. This process was followed in order to be consistent with international methodologies. The calculation of BC_0 followed the equations published in the "Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads" (CLRTAP 2004; Henriksen et al. 2002). $[BC_0]$ was calculated as:

$$[BC_{o\}} = [BC_T]–F(SO_{4,T} - SO_{4,o} + NO_{3,T} - NO_{3,o})$$

Where,

- $[BC_T]$ is the current base cation concentration;
- F is the "F factor" describing the ratio of the change in base cations to the additions of strong acids to each lake from acid deposition;
- $SO_{4,T}$ and $SO_{4,o}$ are the current and original sulphate concentrations in each lake, respectively; and
- $NO_{3,T}$ and $NO_{3,o}$ are the current and original nitrate concentrations in each lake, respectively.

The F factor is defined as:

$$F = \sin(\Pi/2 \cdot Q \cdot [BC_T]/S)$$

Where,

- S is the base cation flux when all acid deposition is neutralized in the catchment (F=1); and
- Q and $[BC_T]$ are defined above.

Following Henriksen et al. (2002) and CLRTAP (2004), S was assumed to be 400 meq/m²/y. Further details on these calculations of CL are presented in Section 5.14 and Appendix F.

Choice of ANC_{lim}

The critical load concept as expressed in the Henriksen model assumes a dose-response relationship between a water quality variable and an aquatic indicator organism. In this case, the water quality variable is the acid-neutralizing capacity (alkalinity) required to maintain a healthy fish population. In applying the Henriksen model in Europe, a critical threshold ANC_{lim} of 20 µeq/L was set to protect brown trout, the most common European salmonid, and to ensure that no toxic acidic episodes occur to this species during the year.

In North America, the effects of acidification on biota have been historically related to pH rather than alkalinity or acid-neutralizing capacity. Research on pH tolerance of a wide range of aquatic organisms has shown that a pH>6 is required to maintain aquatic ecosystem functioning and protect both fish and other organisms (RMCC 1990; Environment Canada 1997; Jeffries and Lam 1993). Within a given region, lake pH has been empirically and theoretically related to alkalinity as an inverse hyberbolic sine function (Small and Sutton 1986) and this relationship has been used to equate the two variables for the purpose of critical load modeling (e.g., Jeffries and Lam 1993). The relationship between pH and alkalinity for the Athabasca oil sands region was derived from a water quality survey conducted on lakes in the ALPAC forest management area (WRS 2001, see Appendix F). Across these lakes, a pH of 6 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 2013 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 individual lakes.

Update of the ASL Database, Summary Statistics and Comparisons of RAMP ASL Chemistry to Regional Lake Chemistry

The water chemistry data from 2013 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 2013 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 12 years of monitoring by AESRD (2001, 2003 to 2013) 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 2013, additional analyses were conducted to detect potential changes in metals concentrations attributable to acidification. These analyses included:

- a comparison of selected metals between physiographic regions using an Analysis of Variance (ANOVA);
- a comparison of metal concentrations between *baseline* and *test* lakes using an ANOVA; and
- a Mann Kendall trend analysis on selected metals for all 50 lakes from 2003 to 2013. The metals showing significant increases in individual lakes were plotted in control charts and interpreted as described in Section 3.2.5.2.

3.2.5.5 Classification of Results

A summary of the state of the ASL component lakes in 2013 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of the measurement endpoints for each lake within each subregion. The measurement endpoint and the relevant trend that is indicative of acidification are as follows: Gran alkalinity (downwards); pH (downwards); sum base cations (upwards); nitrates (upwards); dissolved organic carbon (downwards); sulphate (upwards); and aluminum (upwards).

For each lake, the mean and standard deviation were calculated for each measurement endpoint across all monitoring years. The number of lakes in 2013 within each subregion having measurement endpoint values greater than two standard deviations (SD) (above or below the mean as indicated above) was calculated. The number of exceedances of measurement endpoints greater than 2SDs was expressed as a percentage of the total number of lake-measurement endpoint combinations for each subregion. The results were classified as follows:

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

4.0 CLIMATE AND HYDROLOGIC CHARACTERIZATION OF THE ATHABASCA OIL SANDS REGION IN 2013

4.1 INTRODUCTION

The following characterization of the 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 2013 Regional Aquatics Monitoring Program (RAMP). 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 2013 water year (WY), from November 1, 2012 to October 31, 2013.

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 69 years (1945 to 2013). 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 2013. This data series will be referred hereafter as the Fort McMurray data set. A summary of the details for each Fort McMurray 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 2013 WY was 410.1 mm (Figure 4.2-1), which was approximately 6% lower than the long-term annual mean of 434.5 mm for Fort McMurray (calculated from the 1945 WY to the 2012 WY). Monthly total precipitation values were below average in ten of 12 months in the 2013 WY (November to May and August to October) (Figure 4.2-2). The wettest months in the 2013 WY were June and July, with total precipitation amounting to 191.6 mm and 87.1 mm, respectively, representing an increase from the historical mean by 192% and 87%, respectively. The monthly total precipitation recorded in June 2013 was the highest monthly total precipitation recorded since 1945, and accounted for 47% of the 2013 WY annual total precipitation. A more detailed description and analysis of the flooding events that occurred in June 2013 are provided in Section 6 of this report.

Precipitation falling as snow, from November 1, 2012 to March 31, 2013, was 49.4 mm and approximately 90% lower than the historical mean for this period. Conversely, precipitation (assumed to be rainfall) from April 1 to October 31, was 360.7 mm and approximately 6% higher than the historical mean value for the same period.

Figure 4.2-1 Historical annual precipitation at Fort McMurray, 1945 WY to 2013 WY.

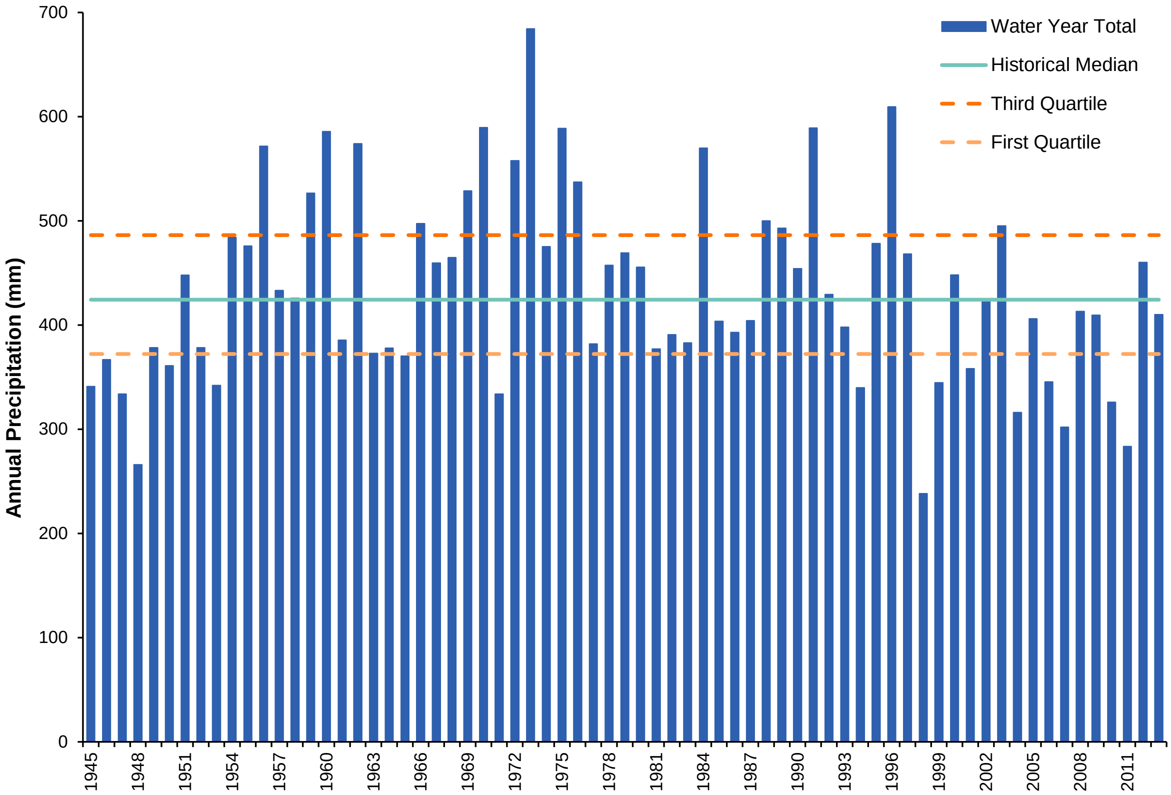
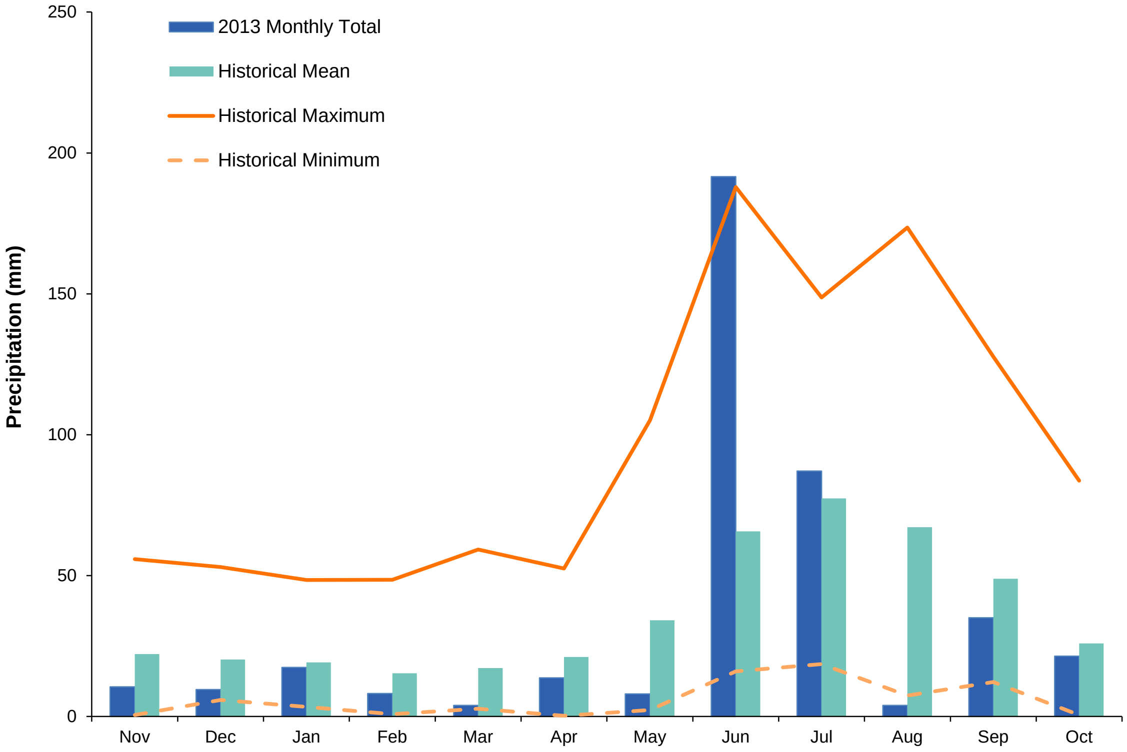


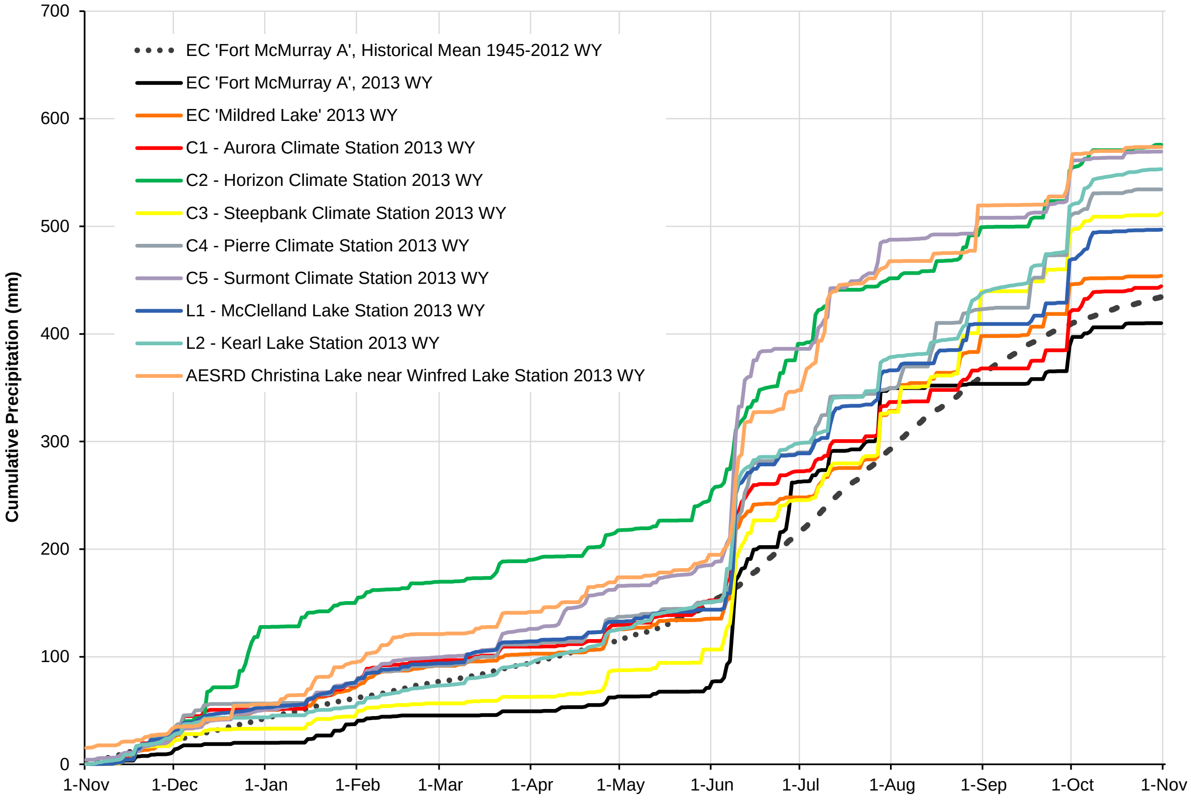
Figure 4.2-2 Monthly precipitation at Fort McMurray in 2013.



Precipitation records for EC Mildred Lake station (ID# 3064528), Alberta Environment and Sustainable Resource Development (AESRD) Christina Lake near Winefred Lake station (ID# 3061580), and RAMP stations C1–Aurora, C2–Horizon, C4-Pierre, C3-Steepbank, C5-Surmont, L1–McClelland Lake, and L2–Kearl Lake provided additional information to characterize climatic conditions throughout the region in 2013 (Figure 4.2-3). The 2013 WY cumulative precipitation recorded at these stations was above the historical mean of 434.5 mm for Fort McMurray.

For all regional stations, with the exception of C3-Steepbank and L2–Kearl Lake, the cumulative precipitation from November 1, 2012 to March 31, 2013 was above the historical cumulative precipitation at Fort McMurray observed during the same period. The precipitation during this time period at C3-Steepbank and L2–Kearl Lake accounted for 12% and 17% of the annual total precipitation, respectively, compared to the winter precipitation from other stations that accounted for approximately 21 to 25% of the annual total precipitation.

Figure 4.2-3 Cumulative total precipitation at climate stations in the Athabasca oil sands region in 2013.



Note: information on the RAMP climate stations are provided in Table 3.1-1.

4.2.2 Snowpack

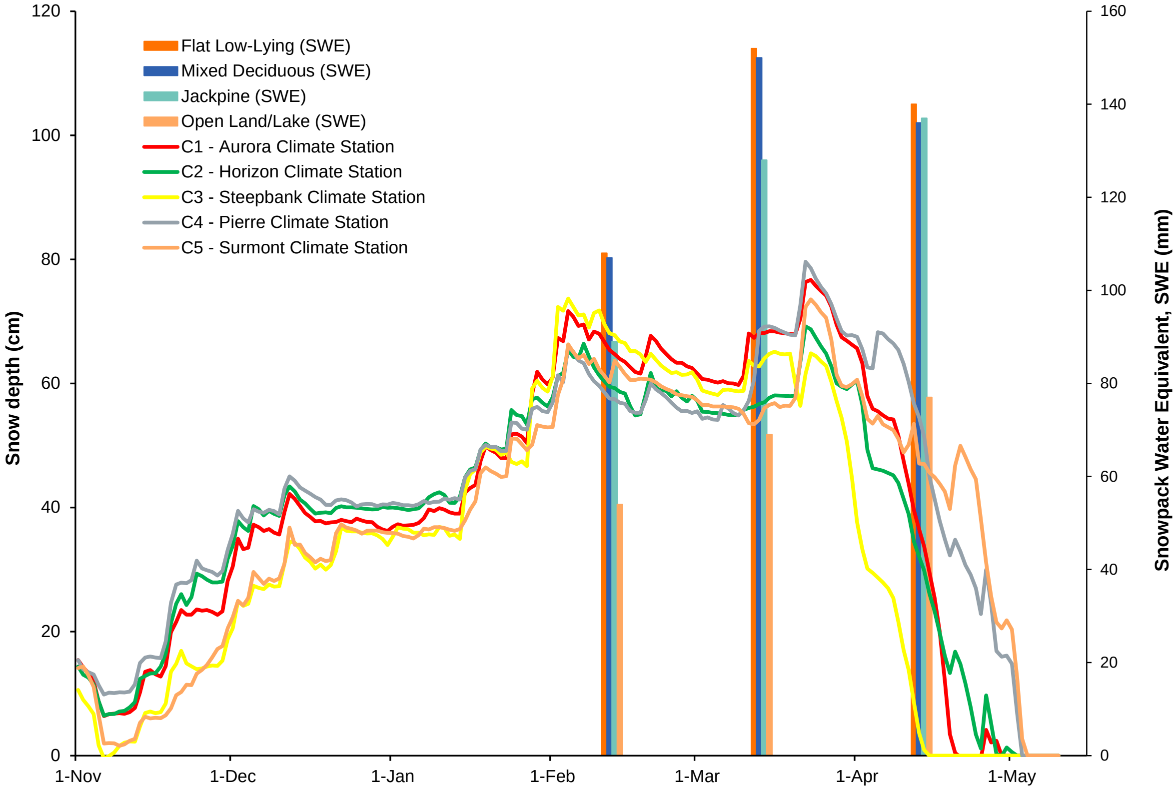
Snowpack amounts (in terms of mm snow water equivalent or SWE) were measured at 16 locations during the period of February 1 to 6, February 25 to 27, and March 25 to 29, 2013, in each of four land category types (i.e., flat low-lying, mixed deciduous, jackpine, and open land/lake). The maximum mean SWE value recorded for each land category is presented in Figure 4.2-4. Historical maximum mean SWE values for the period of 2004 to 2012 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 terrains. Flat low-lying, mixed deciduous, and jackpine terrains recorded the highest SWE values on record, while open land/lake measurements were only slightly above the nine-year mean maximum 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 2013 WY. The snowpack started melting in late March and melted completely from mid-April to early May (Figure 4.2-5). Detailed information for the 2013 snow surveys conducted at each station is provided in Appendix C.

Figure 4.2-4 Maximum measured snowpack amounts in the Athabasca oil sands region, 2004 to 2013.

Note: Data from RAMP regional snowcourse surveys. Four snowcourses were sampled in each of four land categories (Figure 3.1-1), in February and March 2013. Mean snow water equivalent (SWE) values shown here represented the maximum monthly mean values recorded for each land category and year.

Figure 4.2-5 Comparison of snowpack depth (cm) observed at RAMP climate stations and snow water equivalent (SWE, mm) measured in each land category in 2013.



4.2.3 Air Temperature

Daily mean air temperatures measured at Fort McMurray for the 2013 WY were generally between historical minimum and historical maximum values (Figure 4.2-6). Winter air temperatures, from November to March, were more variable than the remainder of the year and followed the general historical annual trend.

Approximately 15% of the daily mean air temperature from November 2012 to January 2013 was missing from the EC database, which consequently, affected the comparison of the monthly mean temperatures with the corresponding historical values. Monthly mean air temperatures in the 2013 WY generally varied between the historical minimum and historical maximum monthly mean air temperatures (Figure 4.2-7). In addition, the monthly mean air temperatures during late spring, summer, and early fall months of the 2013 WY were generally warmer than the historical mean monthly air temperatures. The mean air temperature in April 2013 was below zero (-1.0°C) compared to the historical mean temperature in April of 2.4°C.

Figure 4.2-6 **2013 WY daily mean air temperature at Fort McMurray compared to historical values (1945 to 2012).**

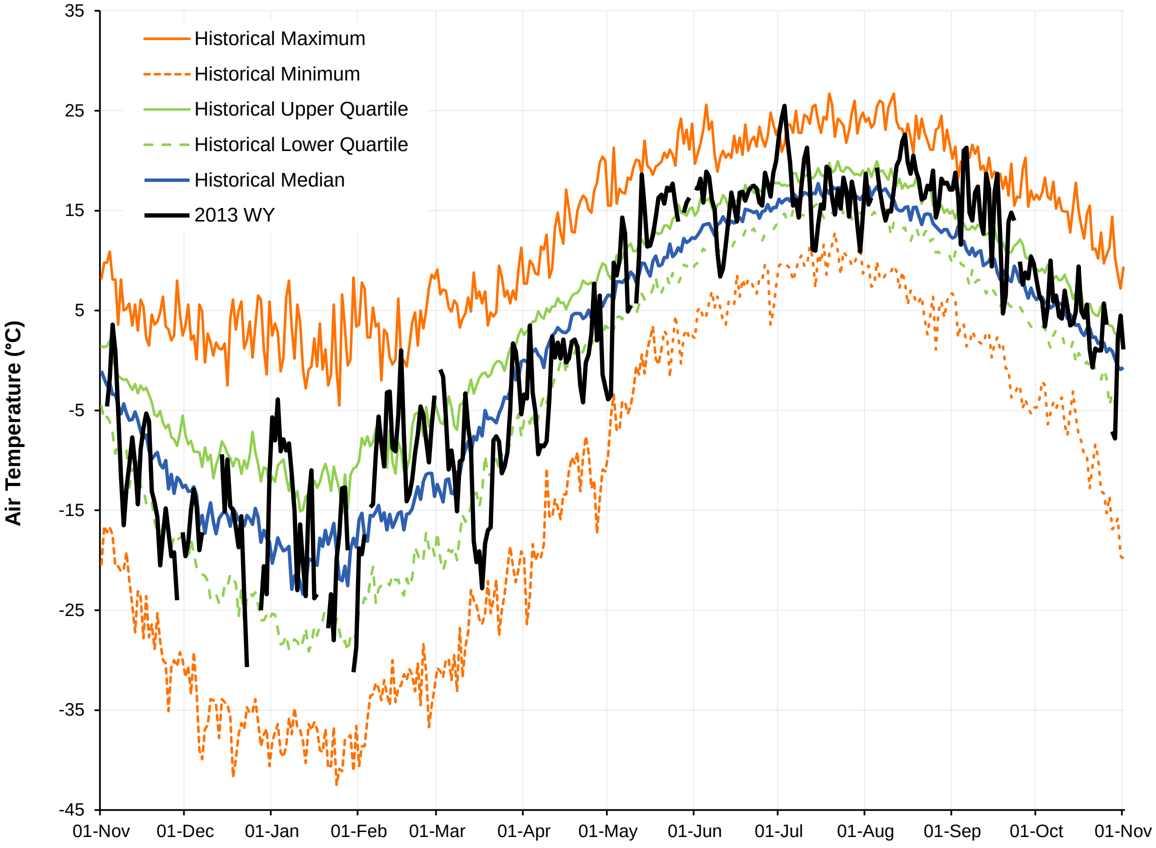
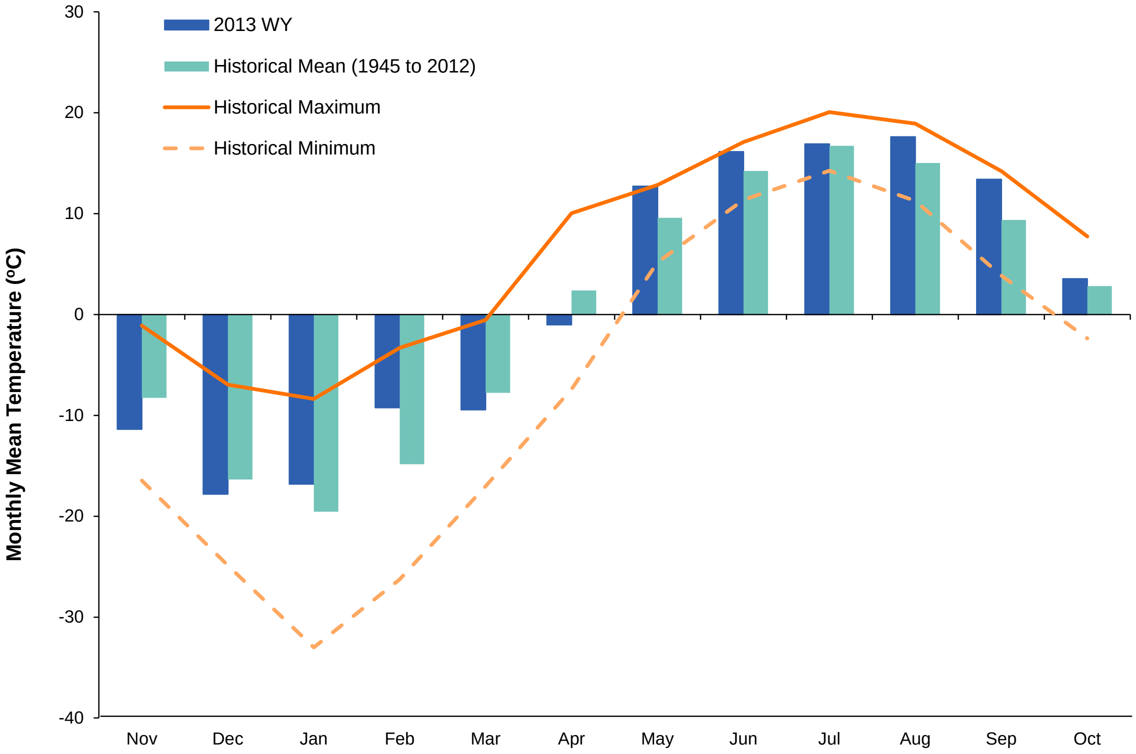


Figure 4.2-7 Comparison of historical (1945 to 2012) and 2013 WY monthly mean air temperatures at Fort McMurray.



Note: Daily mean air temperatures for Fort McMurray were averaged for each month for the period from 1945 to 2012. These values were compared to monthly means for the 2013 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 2013 WY provisional data. The four stations are located on the Athabasca, Muskeg, MacKay, and Christina rivers. Each station represents a primary area 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 2013
Muskeg River near Fort McKay	07DA008	Eastern tributary of the Athabasca River	1,457	1974 to 2013
MacKay River near Fort McKay	07DB001	Western tributary of the Athabasca River	5,569	1972 to 2013
Christina River near Chard	07CE002	South of Fort McMurray	4,863	1982 to 2013

4.3.1 Athabasca River

The total annual flow volume for the Athabasca River measured at WSC Station 07DA001, Athabasca River below McMurray, was 22,098 million m^3 for the 2013 WY (Table 4.3-2). This was 13% greater than the historical mean flow volume of 19,495 million m^3 over the station's 54-year period of record (1958 to 2012). The 2013 WY was the sixth year since 1991 to have exceeded the historical mean WY runoff volume; the other years were 1996, 1997, 2005, 2011, and 2012 (Figure 4.3-1).

Flows generally decreased from November 2012 to early April 2013 with flows from December 2012 to March 2013 remaining similar to historical median values. Flows increased during freshet in early May to a peak of 2,150 m^3/s on May 11 (Table 4.3-2). Flows also increased in response to rainfall events in early to mid-June, and exceeded historical maximum flows from June 12 to June 15, 2013. The maximum recorded daily flow of 3,040 m^3/s, occurred on June 26, and was 20% higher than the mean historical maximum daily flow of 2,536 m^3/s. Flows from early July to October were between the historical lower and upper quartile values. The minimum flow for the 2013 open-water period (May to October) was 347 m^3/s recorded on October 29, and was approximately 18% lower than the mean historical minimum daily flow of 425 m^3/s (Table 4.3-2).

Figure 4.3-1 Historical annual runoff volume in the Athabasca River basin, 1958 to 2013.

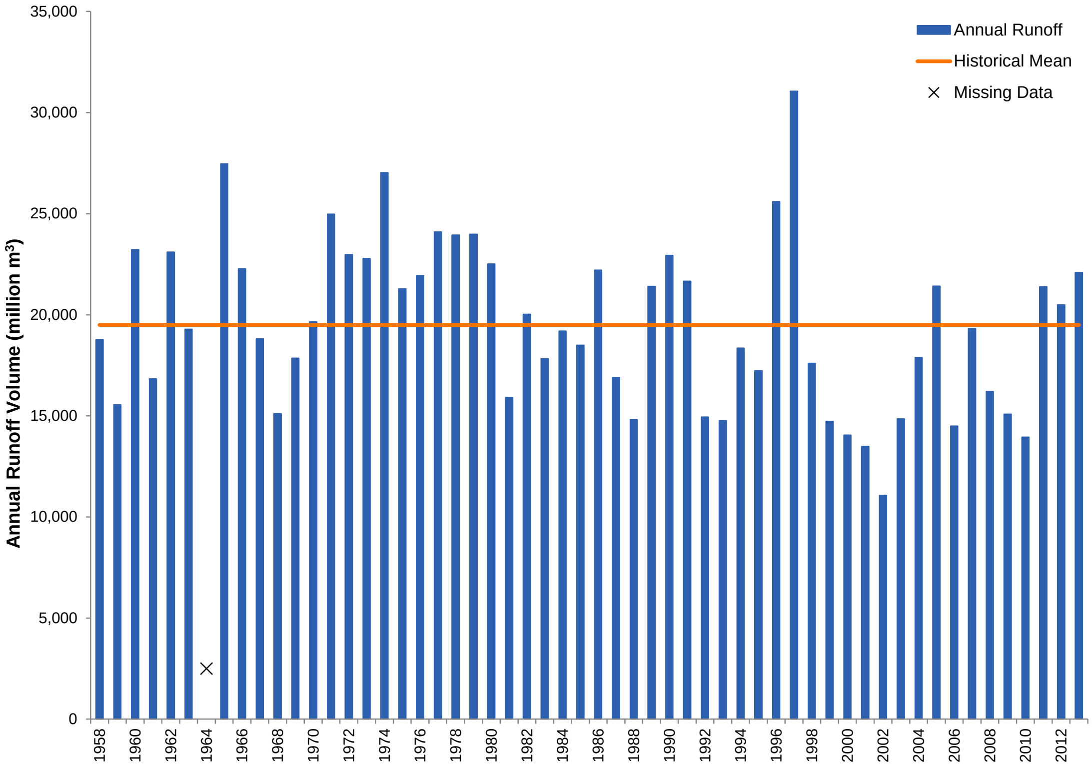


Figure 4.3-2 **The 2013 WY Athabasca River hydrograph compared to historical values.**

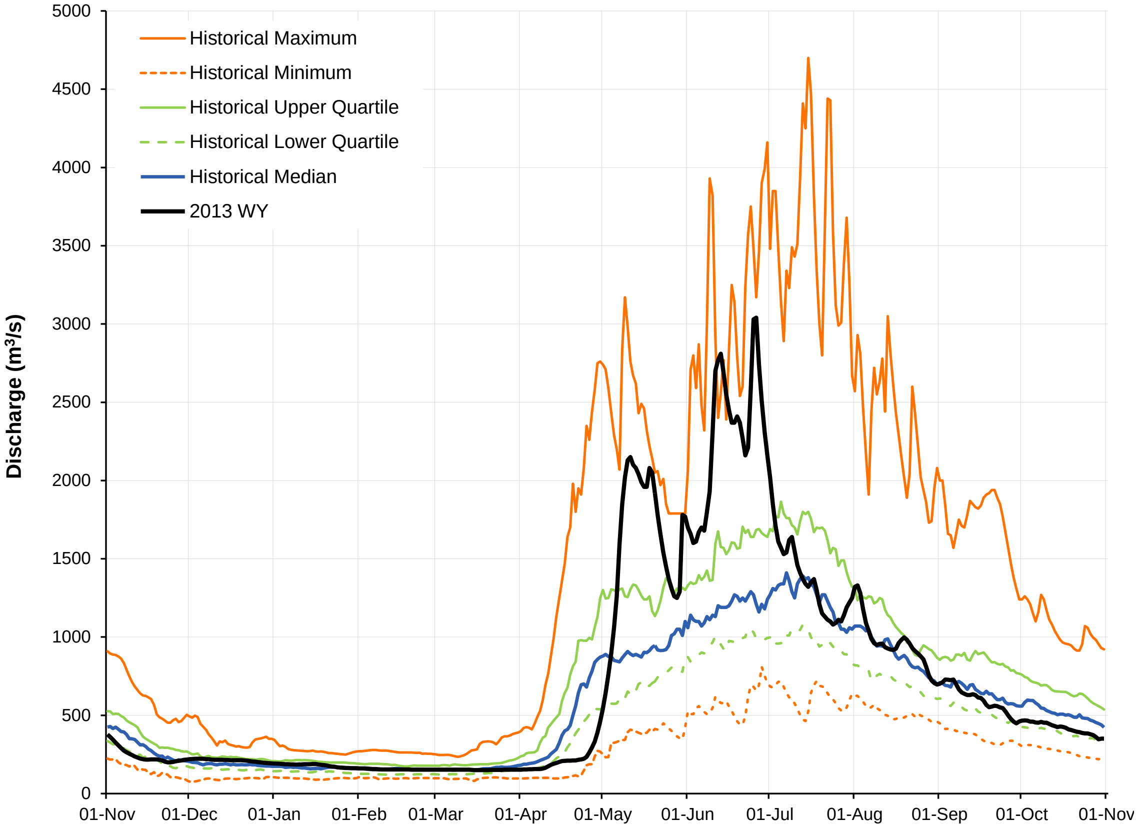


Table 4.3-2 Summary of 2013 hydrologic variables compared to historical values measured in the Athabasca oil sands region.

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 2013	1974 to 2013	1973 to 2013	1983 to 2013
Runoff Volume[1]				
Historical[2] mean (million m^3)	19,495	115	418	429
2013 (million m^3)	22,098	241.8	778.8	1,108[4]
Maximum Daily Discharge[1]				
Historical mean (m^3/s)	2,536	25.3	111.2	82.5
2013 (m^3/s)	3,040	80.6	187.0	-
Minimum Daily Discharge[3]				
Historical mean (m^3/s)	424.9	1.0	3.7	6.7
2013 (m^3/s)	347.0	1.2	1.9	0.9

[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 runoff volume and maximum daily flow were provided for the period of March to October for the other three stations; data from November to February for these three stations were not published by WSC.

[2] The historical mean included all data up to the end of the 2012 WY.

[3] Open-water season was based on values from May to October for all stations.

[4] The 2013 runoff volume for the period of March to October included estimated flows for the missing data from May 9 to 13, June 12 to 21, and June 26 to 27, 2013. Also, the maximum daily discharge at Christina for the 2013 WY was not provided due to these missing flow data during the peak flow seasons.

4.3.2 Muskeg River

The 2013 runoff volume for the period of March to October for the Muskeg River watershed recorded at WSC Station 07DA008, Muskeg River near Fort McKay, was 242 million m^3 (Table 4.3-2). This was approximately 111% higher than the long-term mean runoff volume (March to October) 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 2013 WY was dominated by the spring freshet as well as rainfall events that occurred in early to mid-June (Figure 4.3-4).

Winter flows in 2013 WY generally remained above the upper quartile values until mid-March, and then increased in April and early May due to snowmelt, to a peak of 52.8 m^3/s on May 11, 2013 (Figure 4.3-4). Flows recorded from May to June 2013 were above the historical upper quartile range and exceeded the historical maximum values from May 12 to May 21 and June 11 to June 26. The peak flow for the 2013 WY was 80.6 m^3/s on June 15, 2013. Flows in late July and early October 2013 also responded to precipitation events during the same period as shown by the corresponding relationship between daily precipitation measured at the RAMP C1-Aurora climate station and flow recorded for the Muskeg River (Figure 4.3-4). The 2013 open-water season (May to October) minimum daily flow of 1.15 m^3/s recorded on September 16 was 10% higher than the historical mean minimum daily flow of 1.05 m^3/s (Table 4.3-2).

Figure 4.3-3 Historical runoff volume (March to October) in the Muskeg River basin, 1974 to 2013.

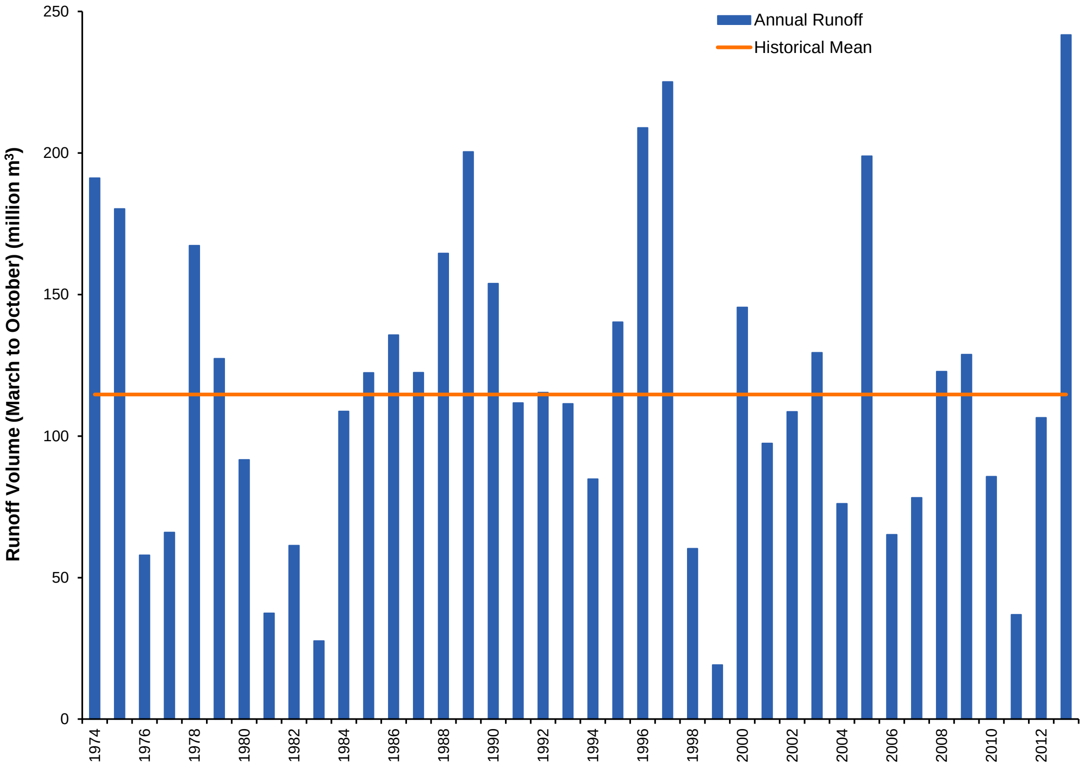
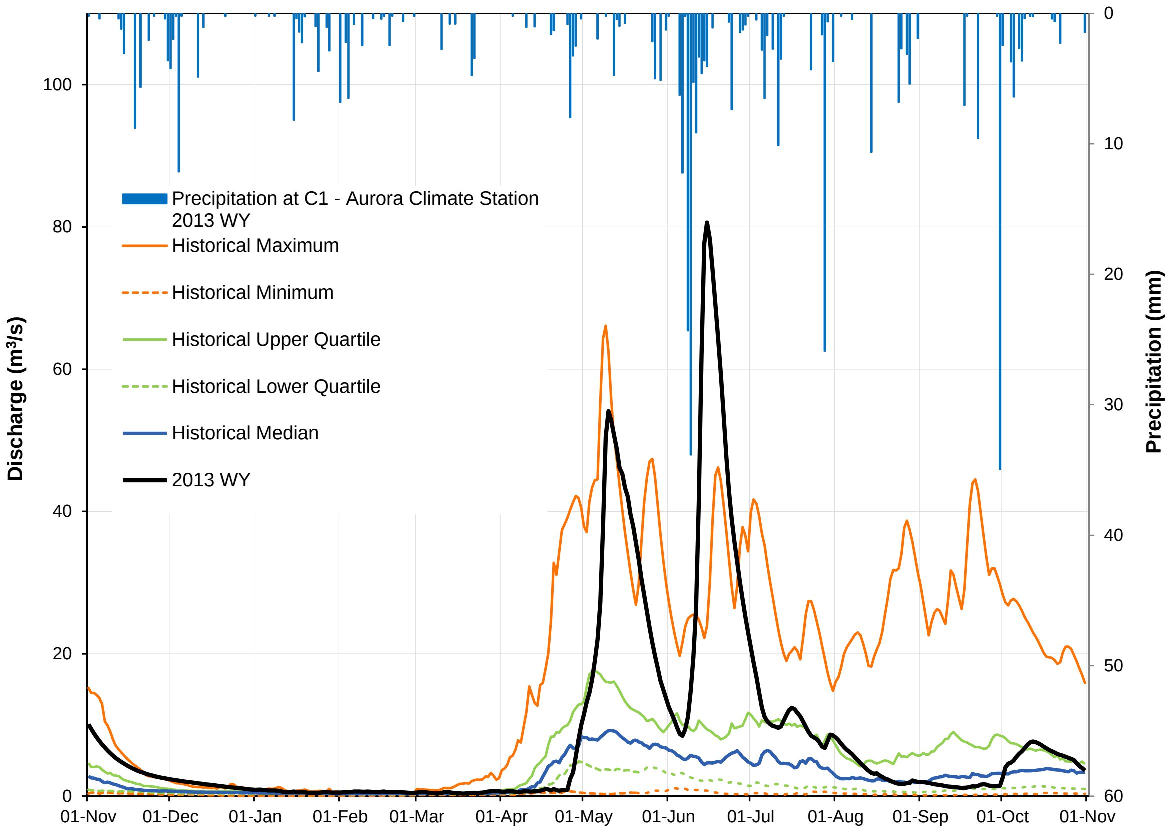


Figure 4.3-4 **The 2013 WY Muskeg River hydrograph compared to historical values and 2013 daily precipitation data at the C1 Aurora climate station.**



4.3.3 MacKay River

The 2013 runoff volume for the period of March to October for the MacKay River watershed recorded at WSC Station 07DB001, MacKay River near Fort McKay, was 778.8 million m^3 (Table 4.3-2). This was approximately 86% higher than the long-term mean runoff volume (March to October) of 418.4 million m^3 (Figure 4.3-5, Table 4.3-2), based on a 40-year period of record.

Winter flows in the 2013 WY generally remained within the inter-quartile range until mid-April, and then increased due to snowmelt to a peak of 155 m^3/s on May 8, 2013. Flows also increased in response to rainfall events in early June, reaching a maximum annual daily flow of 187 m^3/s on June 13, 2013. Increases in flow during the months of July and October were a result of precipitation in the region as shown by the corresponding relationship between daily precipitation measured at the EC Mildred Lake station and flow recorded for the MacKay River (Figure 4.3-6). The 2013 open-water season (May to October) minimum daily flow of 1.9 m^3/s occurred on September 24, and was approximately 48% lower than the mean historical minimum daily flow of 3.7 m^3/s.

Figure 4.3-5 Historical runoff volume (March to October) in the MacKay River basin, 1973 to 2013.

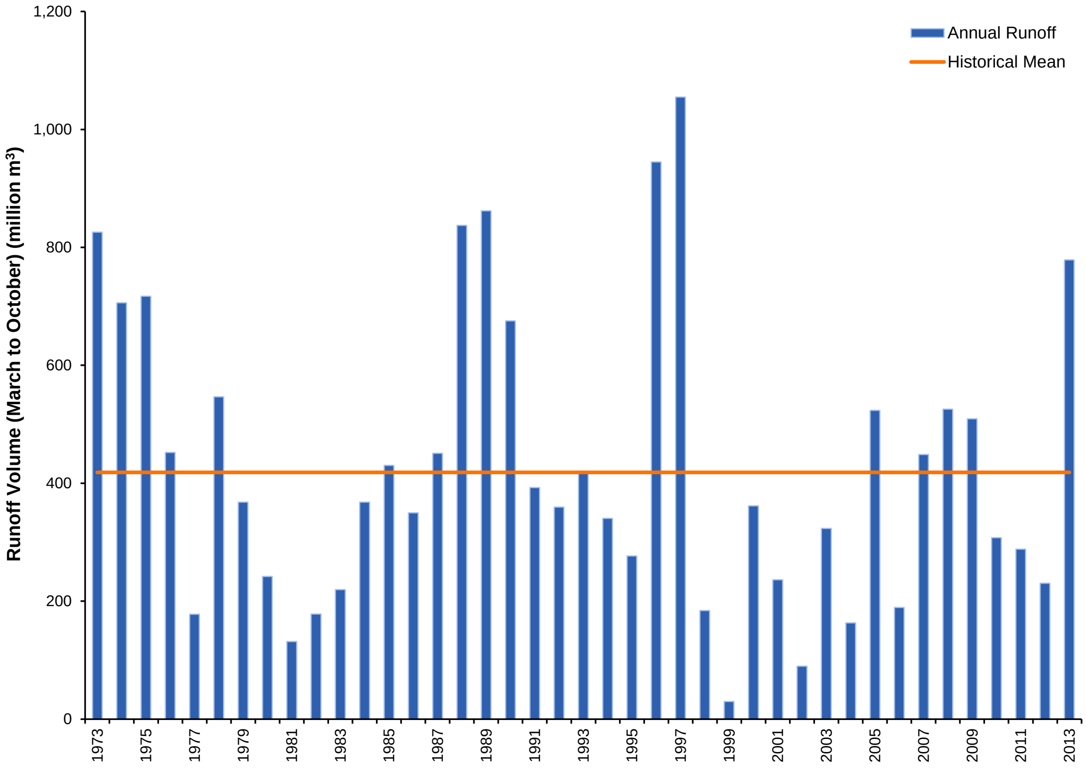
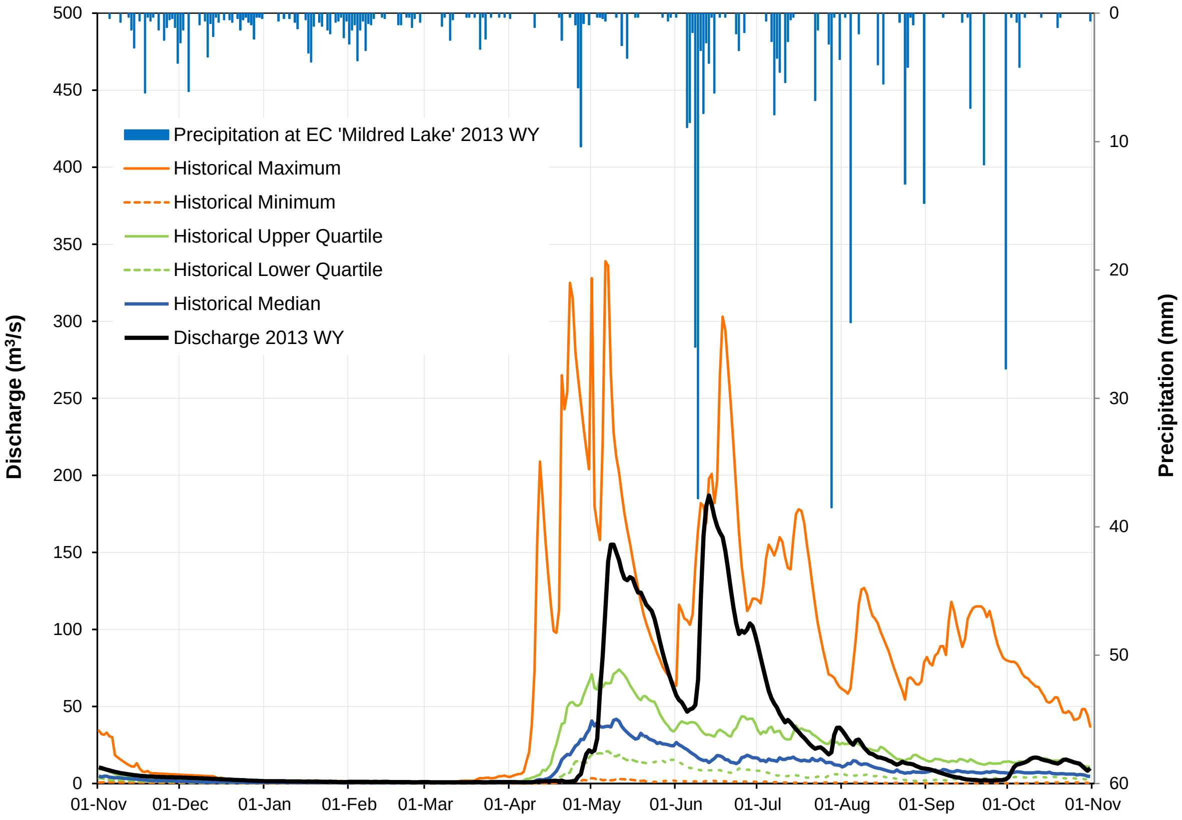


Figure 4.3-6 **The 2013 WY MacKay River hydrograph compared to historical values and 2013 daily precipitation data at the EC Mildred Lake climate station.**

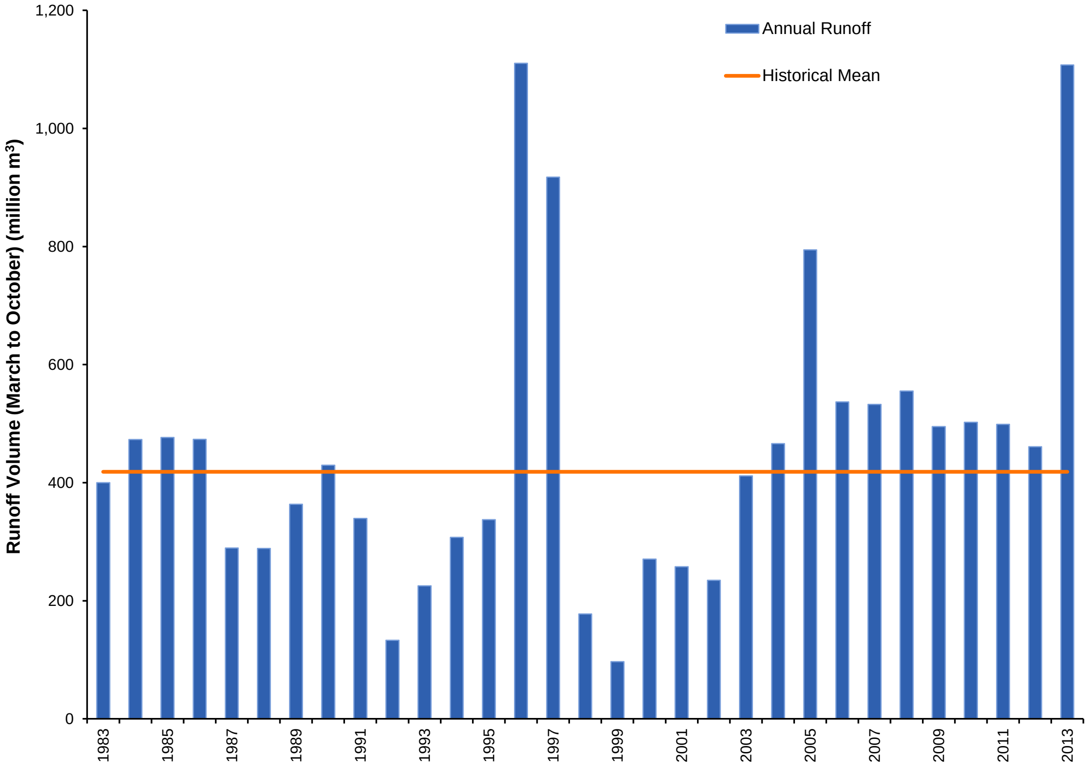


4.3.4 Christina River

The WSC station 07CE002, Christina River near Chard, data record was provided with data gaps from May 9 to 13 and June 12 to 21, 2013; therefore, for the purpose of estimating volumes, these data were interpolated; however, no data are presented or included in the statistics other than the annual total volume. The 2013 runoff volume for the period of March to October for the Christina River watershed recorded at WSC station 07CE002, Christina River near Chard, was estimated at 1,100 million m^3 (Table 4.3-2). This was approximately 158% higher than the long-term mean runoff volume (March to October) of 429 million m^3 over the 30-year period of record. The 2013 WY was the tenth consecutive year where flow volumes for the period of March to October were above the mean recorded at this station (Figure 4.3-7).

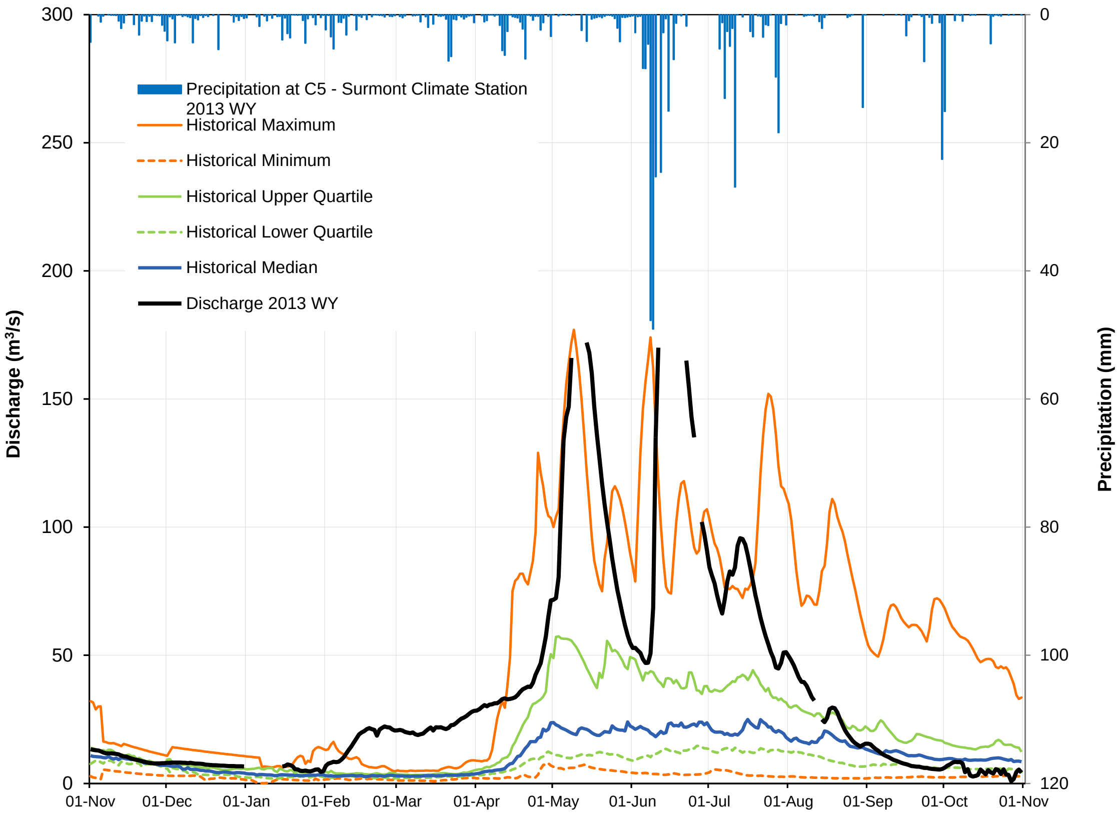
Winter flows generally remained around historical upper quartile values from November 2012 to January 2013, before increasing and exceeding the historical maximum values from February to early April. Flows increased above historical maximum values in early May due to snowmelt, but the freshet peak was not captured (gap in data). Flows also increased in response to rainfall events in early June, exceeding the historical maximum flows from June 11 to 28, 2013. In addition to the high flows in June, flows in mid-July and early October 2013 also increased in response to rainfall events during the same period as shown by the corresponding relationship between daily precipitation measured at the RAMP C5-Surmont climate station and flows recorded for the Christina River (Figure 4.3-8). The daily minimum discharge in the 2013 WY of 0.87 m^3/s occurred on October 27, and was approximately 51% lower than the historical minimum daily flow of 1.77 m^3/s (Table 4.3-2).

Figure 4.3-7 Historical runoff volume (March to October) in the Christina River basin, 1983 to 2013.



Note: The 2013 WY runoff volume (March to October) included estimated flows for missing data from January 1 to 4, May 9 to 13, June 12 to 21, and June 26 to 27, 2013.

Figure 4.3-8 **The 2013 WY Christina River hydrograph compared to historical values and 2013 daily precipitation data at the C5 Surmont climate station.**



4.4 SUMMARY

In summary, climate and hydrology in the RAMP FSA in the 2013 WY was characterized by the following conditions:

1. Annual precipitation measured at Fort McMurray was 6% lower than the historical mean, with monthly total precipitation below the long-term mean in ten of 12 months. The monthly total precipitation recorded in June 2013 was the highest monthly total precipitation recorded since 1945, and accounted for 47% of the 2013 WY annual total precipitation. The 2013 WY cumulative precipitation recorded at Fort McMurray was lower than the corresponding cumulative precipitation recorded at the regional climate stations.

2. Mean daily air temperatures in the 2013 WY were generally between historical minimum and historical maximum values. The monthly mean air temperatures during late spring, summer, and early fall months of the 2013 WY were generally warmer than the historical mean monthly air temperatures. The April mean air temperature in 2013 WY was below zero (-1.0ºC) compared to the historical mean temperature in April of 2.4ºC, consequently resulting in a later than average spring freshet.

3. The runoff volume measured at the WSC Station 07DA001, Athabasca River below Fort McMurray, was above the historical mean for the sixth year in the last two decades. In the 2013 WY, the annual flow volume of 22,098 million m^3 was 13% higher than the historical mean for this station.

4. Runoff volumes for the period of March to October, were approximately 111%, 86%, and 158% higher than historical mean values for the Muskeg, MacKay, and Christina rivers, respectively.

5. Annual maximum daily flows in the 2013 WY were largely influenced by rainfall events that occurred in early to mid-June in the Muskeg, MacKay, and Christina rivers, as shown by the strong relationship between flows recorded at these stations and daily precipitation measured at nearby climate stations.

5.0 2013 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 2013 results for the Athabasca River and the Athabasca River Delta (ARD); Sections 5.2 to 5.12 present 2013 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 2013. 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	5-116	5-209	5-241	5-276	5-319	5-334	5-387	5-432	5-486	5-602	5-617	5-648	-
Water Quality	5-9	5-117	5-210	5-242	5-277	5-320	5-335	5-388	5-432	5-489	5-603	5-618	5-648	-
Benthic Invertebrate Communities	5-12	5-121	5-212	5-243	5-280	-	5-337	5-390	5-435	5-493	-	5-620	5-648	-
Sediment Quality	5-15	5-127	5-214	5-245	5-283	-	5-341	5-392	5-436	5-500	-	5-622	5-648	-
Fish Populations	5-18	5-130	5-214	5-247	5-283	-	5-343	5-393	5-436	5-502	-	5-623	5-648	-

Definitions for Monitoring Status

The RAMP 2013 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 2013) or were (prior to 2013) 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 2013 Conditions**												
	Athabasca River								***Athabasca 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									n/a	n/a	n/a	n/a	n/a
Fish Populations													
Criteria	**ATR-1** Upstream of Fort McMurray	**ATR-2** Upstream of Development, Downstream of STP			**ATR-3** Upstream of Muskeg River	**ATR-4** Downstream of Muskeg River		**ATR-5** Downstream of Firebag River	**FLC-F1** Fletcher Channel	**GIC-F1** Goose Island Channel	**BPC-F1** Big Point Channel	no station sampled	**EMR-F2** Embarras River
Sentinel Species	n/a	n/a			🟡	🟡		🟡	ns	ns	ns	ns	ns
Fish Assemblages	ns	ns			ns	ns		ns	n/a	n/a	n/a	n/a	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.

ns – not sampled

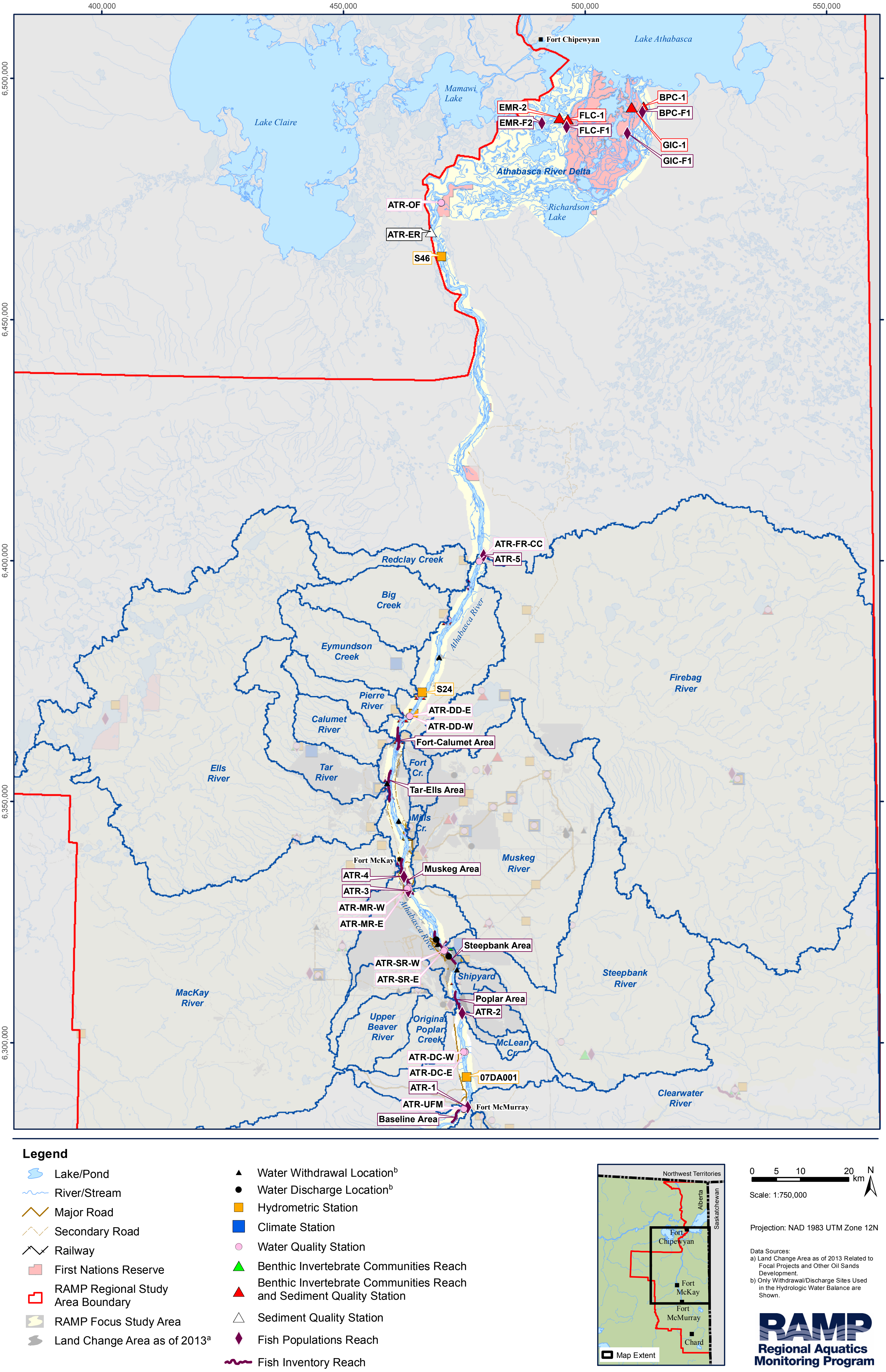
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional baselines; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (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 5.1-1 Athabasca River and Athabasca River Delta.



Data Sources:
a) Land Change Area as of 2013 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\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K01_Mainstem_20140224_ss.mxd

Figure 5.1-2 Representative monitoring stations of the Athabasca River and Athabasca River Delta, fall 2013.

Hydrology Station S24: Athabasca River below Eymundson Creek

Hydrology Station S46: Athabasca River near Embarras Airport

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

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

Water Quality Station ATR-DD-W: Athabasca River downstream of development

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

Benthic and Sediment Quality Station EMR-2: Athabasca River Delta – Embarras River

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

5.1.1 Summary of 2013 Conditions

As of 2013, approximately 3.3% (118,748 ha) of the RAMP FSA had undergone land change from focal projects and other oil sands developments (Table 2.5-2). Approximately 24.1% (35,549 ha) of the minor Athabasca River tributary watersheds had undergone land change as of 2013 from focal projects and other oil sands developments (Table 2.5-2). For 2013, 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 2013 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 2013. Figure 5.1-2 contains fall 2013 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%, 1.7%, 0.6% and 1.1% lower, respectively, than in 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 2013 at all stations in the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at upstream *baseline* stations (ATR-DC-E and ATR-DC-W) and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded the guideline at all stations in fall 2013 and total boron continued to show 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 at *test* reach BPC-1 were classified as **Negligible-Low** because although there was a significant change in CA Axis 2 scores between 2013 and previous sampling years, the change did not indicate degradation of the benthic invertebrate community. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variability for reaches of the ARD.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **Moderate** because of the significant increase in equitability, exceeding the historical range of variability, and a decrease in richness over time. However, the benthic invertebrate community contained EPT taxa in relatively high abundances (3%), which was higher than 2012.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach GIC-1 were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa and decrease of CA Axis 1 and 2 scores were not indicative of a negative change. In addition, all measurement endpoints were within the inner tolerance limits of the normal range of variability for reaches in the ARD.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were classified as **Moderate** because of the significant decreases in abundance, richness, and CA Axis 1 scores over time. However, there were some EPT taxa present and all measurement endpoints were within the normal range of variation for annual means from previous years, which indicated that conditions of this river have not significantly degraded.

In 2013, stations were predominantly comprised of sand, with the exception of *test* stations EMR-2 and FLC-1 where silt substrate was dominant. Concentrations of sediment quality measurement endpoints at all five stations in the ARD showed concentrations that were similar to previously-measured concentrations, with the exception of PAHs, which were generally higher in 2013 at *test* stations EMR-2 and FLC-1. The concentration of PAHs at all stations in fall 2013 were dominated by alkylated species, indicating a petrogenic origin of these compounds. From 1999 to 2010, an increase in the concentration of total PAHs was observed at *test* station BPC-1, although this trend was not evident in concentration of total PAHs normalized to TOC. In fall 2013, the concentration of total PAHs at *test* station BPC-1 was below previously-measured concentrations. The PAH Hazard Index at all stations exceeded the potential chronic toxicity threshold value of 1.0. Chronic toxicity data for sediments exceeded the maximum ten-day growth for the midge *Chironomus* at all stations in 2013. Generally survival of *Chironomus* and *Hyalella,* and fourteen-day growth of *Hyalella* were within previously-measured values in fall 2013. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

Fish Populations (fish inventory) The objective of the fish inventory program is to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individuals within these populations.

As of 2013, 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. Goldeye and lake whitefish were among the large-bodied KIR species that have exhibited the greatest increase in abundance over time. Significant increases were observed in total catch and CPUE of goldeye in the last three years (i.e., 2011 to 2013), potentially due to warm, calm, spring seasons over the last three years, which can provide favourable conditions for goldeye recruitment. Similarly, CPUE of lake whitefish in fall 2013 was higher than previous years. Both goldeye and lake whitefish have shown significant increases at the majority of *test* reaches in fall since 1997. Furthermore, shifts toward older dominant age classes and significant increases in mean condition were observed in both species.

The fish health assessment indicated that abnormalities observed among all species in 2013 were within the historical range and consistent with studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

Fish Populations (sentinel species) The effects criteria for age, weight-at-age, relative gonad weight, and relative liver weight defined by Environment Canada (2010) is a ± 25% difference between a *test* site and *baseline* site ATR-2 and a ± 10% difference for condition (body weight at length). Differences greater than the effects criteria between *baseline* and *test* sites suggested an ecologically relevant change in the trout-perch population at the *test* site.

A difference in measurement endpoints that exceeded the Environment Canada effects criteria was observed for age of female trout-perch and gonad weight of male trout-perch at *test* site ATR-5. The age of female trout-perch at ATR-5 was 25.2% younger than for trout-perch *baseline* site ATR-2, which was also observed in female trout-perch at *test* site

ATR-5 in 2010. The gonad weight of male trout-perch at *test* site ATR-5 was 25.3% greater than trout-perch at *baseline* site ATR-2, which had also been observed in 2002, but the opposite pattern was observed in 2010. With no other exceedances in response patterns; and given that the 25% criteria were only marginally exceeded, these results suggested very little variability in trout-perch populations among *test* sites and *baseline* site ATR-2 in 2013.

Based on the results of the 2013, which provided a fairly consistent response patterns in energy use and energy storage (growth, gonad weight, and liver size) in female and male trout-perch at *test* sites, differences from the *baseline* site ATR-2 were classified as **Negligible-Low**.

Fish Populations (fish assemblages) Results of the fish assemblage monitoring in the ARD indicated high species richness and abundance across all channels, with this highest catch observed in Big Point Channel and the Embarras River. The dominant species included small-bodied fish species (emerald shiner and lake chub) as well as northern pike as the dominant large-bodied species. Measurement endpoints were fairly consistent across channels, with high ATI values reflecting the tolerant nature of fish species in the delta. The fish species composition of the channels of the ARD was consistent with the species composition in the Athabasca River, as documented during the RAMP fish inventory surveys.

5.1.2 Hydrologic Conditions: 2013 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. Prior to the 2012 WY, RAMP Station S24, Athabasca River below Eymundson Creek, was used for the water balance analysis. 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 RAMP Station S24 can be found in Appendix C.

Continuous hydrometric data have been collected for Station S46 since August 2011. Historical continuous annual data were available for 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 2013 WY, continuous data were collected at S46 from November 1, 2012 to October 31, 2013, with data missing from May 4 to May 22. The open-water runoff volume in 2013 WY was 20,001 million m^3. This value was 7% higher than the historical mean open-water runoff volume of 18,681 million m^3 based on the 1971 to 1984 and 2012 flow record. Flows decreased from November 2012 to mid-January 2013, and the discharge remained below the historical median for this period (Figure 5.1-3). Flows increased in April and early May in response to the spring freshet until monitoring temporarily ceased on May 4. When monitoring resumed on May 22, flows were slightly below the historical maximum value and decreased until the end of May. Flows increased in mid-June exceeding the historical maximum values from June 13 to June 30 due to rainfall events. The annual maximum daily flow of 3,689 m^3/s recorded on June 16 was 32% higher than the historical mean maximum daily flow. Flows generally decreased from late June until the end of the 2013 WY, with values from mid-July to September varying within the historical inter-quartile range.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at Station S46 in the 2013 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 2013 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 (Table 5.1-2):

1. The closed-circuited land area from focal projects as of 2013 in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River, and Upper Beaver River was estimated to be 361.7 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 55.8 million m^3.

2. As of 2013, 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 86.2 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 2.66 million m^3.

3. Water withdrawals directly from the Athabasca River by focal projects in the 2013 WY were 102.5 million m^3.

4. Water discharges directly to the Athabasca River by focal projects in the 2013 WY were 1.82 million m^3.

5. The 2013 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 23.8 million m^3 less than the discharge would have been in the absence of focal projects in those watersheds.

The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 177.52 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%, 1.7%, 0.6% and 1.1% lower, respectively, than from the estimated *baseline* hydrograph (Table 5.1-3). These differences were classified as **Negligible-Low** (Table 5.1-1).

In the second case, inputs from both focal projects and other oil sands developments were considered. The non-focal oil sands developments considered occurred within the Horse River, MacKay River, and Christina River watersheds (Table 2.5-1). The estimated cumulative effect of focal plus non-focal oil sands developments was a loss of flow of 177.33 million m^3 at Station S46 from the estimated *baseline* flow that would have occurred in the absence of these focal projects and other oil sands developments (Table 5.1-2). This value was 0.194 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 2013, water quality samples were taken from 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 2013);
- *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 2013);
- *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 2013); 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 2013).

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 trends ($\alpha=0.05$) in fall concentrations of water quality measurement endpoints at RAMP stations were detected:

- Increasing concentrations of total suspended solids and total nitrogen, and a decreasing concentration of sulphate at *baseline* station ATR-DC-E;
- An increasing concentration of total suspended solids at *test* station ATR-SR-E;
- Increasing concentrations of total boron and total nitrogen, and a decreasing concentration of chloride at *test* station ATR-MR-E;
- An increasing concentration of total boron at *test* station ATR-MR-W; and
- An increasing concentration of total boron at *test* station ATR-DD-W.

No significant trends from 1998 to 2013 were observed at *baseline* station ATR-DC-W and *test* stations ATR-DD-E and ATR-SR-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 at stations upstream (-DC) and downstream (-SR, -MR, -DD) of watersheds with oil sands development (i.e., McLean and Poplar creeks and Steepbank, Muskeg, MacKay, Tar rivers).

Water quality data were collected monthly by AESRD at stations upstream of Fort McMurray (ATR-UFM) and downstream near the Athabasca Delta at Old Fort (ATR-OF). These data were assessed for seasonal trends from 1997 to 2013. The following significant trends ($\alpha=0.05$) in concentrations of water quality measurement endpoints were detected from monthly AESRD 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 concentrations of dissolved phosphorus, 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).

2013 Results Relative to Historical Concentrations Relative to previous years, water quality in the Athabasca River in September 2013 remained generally consistent. Concentrations of most water quality measurement endpoints in fall 2013 were within the range of previously-measured concentrations at the Athabasca River stations, with the exception of the following (Table 5.1-4):

- total aluminum, with a concentration that exceeded the previously-measured maximum concentration at *test* station ATR-SR-E (i.e., 3.19 mg/L versus previous maximum of 2.97 mg/L in 2008);
- dissolved phosphorus, with a concentration that exceeded the previously-measured maximum concentration at *test* station ATR-MR-W (i.e., 0.023 versus 0.019 mg/L);
- calcium, with a concentration that exceeded the previously-measured maximum concentration (33.1 mg/L versus 32.1 mg/L) and total nitrogen, with a concentration below the previously-measured minimum concentration (0.431 mg/L versus 0.461 mg/L) at *test* station ATR-DD-E; and
- total suspended solids (12 mg/L versus 14 mg/L), total nitrogen (0.401 mg/L versus 0.451 mg/L), and total arsenic (0.000642 mg/L versus 0.000676 mg/L), with concentrations below previously-measured minimum concentrations at *test* station ATR-DD-W.

All water quality measurements at *baseline* stations ATR-DC-E and ATR-DC-W and *test* stations ATR-SR-W and ATR-MR-E were within the range of previously-measured concentrations in fall 2013.

Ion Balance The ionic composition in fall 2013 at all Athabasca River stations was consistent with the ionic composition at these stations since 1997, and was 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 (Figure 5.1-4) and likely relates 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 2013, with the exception of total aluminum at all stations in the Athabasca River mainstem (Table 5.1-4).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Athabasca River mainstem in fall 2013 (Table 5.1-5):

- Total iron at all stations;
- Total silver and dissolved iron at *baseline* station ATR-DC-E;
- Total phosphorus at *baseline* station ATR-DC-E and *test* station ATR-SR-E;
- Total chromium and sulphide at *test* station ATR-SR-E; and
- Total phenols at *test* stations ATR-MR-E, ATR-DD-W, ATR-SR-E, and 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.

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of the following water quality measurement endpoints exceeded the 95th percentile of regional *baseline* concentrations in fall 2013 (Figure 5.1-7 to Figure 5.1-10):

- Potassium and chloride at *baseline* station ATR-DC-E; and
- total suspended solids at *test* station ATR-SR-E.

There were no concentrations of water quality measurement endpoints that were below the 5th percentile of regional *baseline* concentrations in fall 2013 (Figure 5.1-7 to Figure 5.1-10).

Water Quality Index The WQI values at all stations in the Athabasca River mainstem in fall 2013 indicated **Negligible-Low** differences from regional *baseline* water quality conditions, with WQI values ranging from 97.4 to 100 (Table 5.1-6).

Classification of Results Differences in water quality in fall 2013 at all stations in the Athabasca River were classified as **Negligible-Low** compared to regional *baseline* conditions. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at upstream *baseline* stations (ATR-DC-E and ATR-DC-W) and consistent with regional *baseline* conditions. Concentrations of total aluminum exceeded the guideline at all stations in fall 2013 and total boron continued to show 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 Athabasca River Delta (ARD) in fall 2013:

- Depositional *test* reach BPC-1 in Big Point Channel, sampled from 2002 to 2005 and 2007 to 2013;
- Depositional *test* reach FLC-1 in Fletcher Channel, sampled from 2002 to 2005 and 2007 to 2013;
- Depositional *test* reach GIC-1 in Goose Island Channel, sampled from 2002 to 2005 and 2007 to 2013; and
- Depositional *test* reach EMR-2 in the Embarras River, sampled in 2010 to 2013.

2013 Habitat Conditions Samples from *test* reaches BPC-1, GIC-1, FLC-1, and EMR-2 were collected at water depths ranging from 1.9 and 3.7 m. Water at these reaches was neutral/basic with moderate dissolved oxygen (>6.0 mg/L), moderate conductivity

(~250 µS/cm) and temperatures between 18°C and 20°C (Table 5.1-7). The substrate in Goose Island, Big Point, and Fletcher channels was comprised of fines and typically dominated by sand and silt (Table 5.1-7). The substrate in the Embarras River was primarily silt, with smaller amounts of clay and sand (Table 5.1-7). Organic carbon content of sediment was low in all reaches (<3% TOC) (Table 5.1-7).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach BPC-1 in fall 2013 was dominated by Chironomidae (64%) and tubificid worms (29%) (Table 5.1-8). Chironomids at *test* reach BPC-1 were primarily of the genera *Procladius*, *Polypedilum*, and *Paracladopelma*. Mayflies (Ephemeroptera: *Ametropus neavei*) were found in low relative abundances at *test* reach BPC-1.

The benthic invertebrate community at *test* reach FLC-1 in fall 2013 was dominated by chironomids (68%) and tubificid worms (19%), with subdominant taxa consisting of Ceratopogonidae (6%) and Trichoptera (3%) (Table 5.1-9). Chironomids at *test* reach FLC-1 consisted of seven taxa and were primarily of the genera *Probezzia*, *Procladius*, and *Paracladopelma*. Trichoptera (*Hydropsyche* and *Neuroclipsis*), Odonata (*Ophiogomphus*), and a single *Sphaerium* bivalve were present at *test* reach FLC-1.

The benthic invertebrate community at *test* reach GIC-1 was dominated by chironomids (66%) and tubificid worms (13%), with subdominant taxa consisting of naidid worms (8%) (Table 5.1-10). Chironomids at *test* reach GIC-1 were primarily of the forms *Polypedilum* and *Procladius.* Mayflies (*Ametropus neavei*) were present in low relative abundances in some replicate samples at *test* reach GIC-1 (Table 5.1-10). *Isoperla* stoneflies and gomphid dragonflies were found in one replicate sample at *test* reach GIC-1. *Pisidium/Sphaerium* bivalves were present in low relative abundances.

The benthic invertebrate community at *test* reach EMR-2 was dominated by chironomids (31%), tubificid worms (21%), and Ceratopogonidae (20%), with subdominant taxa consisting of Gastropoda (11%), Nematoda (7%), and naidid worms (7%) (Table 5.1-10). Chironomids were primarily from the genera *Probezzia*, *Procladius*, *Chironomus*, and *Tanytarsus*. Mayflies (*Hexagenia limbata*) were found in one replicate. Bivalves (*Pisidium/Sphaerium*) were present and gastropods were principally *Probythinella*.

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 channels of the ARD.

Temporal comparisons for each reach included testing for:

- Changes over time in values of measurement endpoints (Hypothesis 7, Section 3.2.3.1); and
- Changes between 2013 and all previous years of sampling.

Big Point Channel

Temporal Comparison Results CA Axis 2 scores were significantly higher in 2013 than the mean of previous sampling years at *test* reach BPC-F1, accounting for 59% of the variance in annual means (Table 5.1-11). The higher CA Axis 2 scores in 2013 were possibly due to a decrease in the relative abundances of caddisflies and bivalves (Figure 5.1-12).

Comparison to Published Literature The relative abundance of tubificid worms (29%) at *test* reach BPC-1 was lower than in previous years indicating fair conditions (Griffiths

1998) and EPT taxa were present in very low relative abundances. The composition of the benthic invertebrate community in 2013 was about what would be expected in a shifting-sand environment (Barton and Smith 1984).

2013 Results Relative to Historical Conditions All measurement endpoints of benthic invertebrate communities at *test* reach BPC-1 in fall 2013 were within the inner tolerance limits for the means of all previous sampling years in channels of the ARD (Figure 5.1-11, Figure 5.1-12).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach BPC-1 were classified as **Negligible-Low** because although there was a significant change in CA Axis 2 scores between 2013 and previous sampling years, the change did not indicate degradation of the benthic invertebrate community. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variability for reaches of the ARD (Figure 5.1-12).

Fletcher Channel

Temporal Comparison Results There was a significant decrease in richness over time at *test* reach FLC-1, accounting for 40% of the variance in annual means (Table 5.1-12). There was a significant increase in equitability over time and it was higher in 2013 than the mean of all previous years, explaining 27% and 20% of the variance in annual means, respectively (Table 5.1-12).

Comparison to Published Literature The benthic invertebrate community at *test* reach FLC-1 in fall 2013 was typical of a shifting-sand riverine environment (Barton and Smith 1984), which typically support chironomids, worms, and ceratopogonids, which were found at this reach. EPT taxa, which were present at *test* reach FLC-1, are often difficult to find in shifting-sand environments (Barton and Smith 1984).

2013 Results Relative to Historical Conditions All measurement endpoints of benthic invertebrate communities at *test* reach FLC-1 were within the tolerance limits of the normal range of variation for annual means from all previous sampling years in the ARD, with the exception of equitability, which exceeded the inner tolerance limit for the 95th percentile (Figure 5.1-11, Figure 5.1-12). All measurement endpoints were slightly higher than 2012, with the exception of equitability, which decreased from 2012 (Figure 5.1-12).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **Moderate** because of the significant increase in equitability, exceeding the historical range of variability, and a decrease in richness over time. However, the benthic invertebrate community contained EPT taxa in relatively high abundances (3%), which was higher than 2012.

Goose Island Channel

Temporal Comparison Results The percentage of the fauna as EPT taxa significantly increased over time and was higher in 2013 than the mean of previous years, accounting for 58% and 24% of the variation in annual means, respectively (Table 5.1-13). There was a significant decrease over time in CA Axis 1 and 2 scores, explaining 27% and 20% of the variance in annual means, respectively (Table 5.1-13, Figure 5.1-12). The shift in scores could be due to an overall decrease in the relative abundance of caddisflies and an increase in the relative abundance of chironomids over time (Figure 5.1-11).

Comparison to Published Literature The benthic invertebrate community at *test* reach GIC-1 in fall 2013 was typical of a shifting-sand riverine environment (Barton and Smith 1984), which typically support chironomids, worms, and ceratopogonids, which were present at this reach. Mayflies such as *A. neavei*, which was present at *test* reach GIC-1 in fall 2013, can be difficult to find, with reported numbers often not reflecting their true abundance (Barton 1979).

2013 Results Relative to Historical Conditions All measurement endpoints of benthic invertebrate communities at *test* reach GIC-1 in fall 2013 were within the inner tolerance limits for the means of all previous sampling years in channels of the ARD (Figure 5.1-11, Figure 5.1-12).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach GIC-1 were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa and decrease of CA Axis 1 and 2 scores were not indicative of a negative change. In addition, all measurement endpoints were within the inner tolerance limits of the normal range of variability from previous sampling years in the ARD.

Embarras River

Temporal Comparison Results Abundance significantly decreased over time and was lower in 2013 than the mean of previous sampling years at *test* reach EMR-2 (Table 5.1-14). These changes accounted for 87% and 74% of the variance in annual means, respectively.

Taxa richness and CA Axis 1 scores significantly decreased over time and CA Axis 1 scores were lower in 2013 than the mean of previous years (Table 5.1-14). These changes accounted for 33%, 75%, and 95% of the variance in annual means, respectively. The lower CA Axis 1 scores could be due to fewer bivalves present in recent years and an increase in ceratopogonids over time (Figure 5.1-11).

Comparison to Published Literature The benthic invertebrate community at *test* reach EMR-2 was typical of a shifting-sand environment. The relative abundance of tubificid worms (21%) was higher than previous years (<4% from 2010 to 2012). Chironomids, ceratopogonids, and gastropods were also abundant. Bivalves (*Pisidium/Sphaerium*) and mayflies (*Hexagenia limbata)* were present indicating good water quality conditions in this channel (Hynes 1960; Griffiths 1998).

2013 Results Relative to Historical Conditions Measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were within the inner tolerance limits for the normal range of variation for means of previous sampling years in the ARD (Figure 5.1-11, Figure 5.1-12).

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were classified as **Moderate** because of the significant decreases in abundance, richness, and CA Axis 1 scores over time. However, there were some EPT taxa present and all measurement endpoints were within the normal range of variation for annual means from previous years, which indicated that conditions of this river have not significantly degraded.

5.1.4.2 Sediment Quality

In fall 2013, 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 2013;
- *test* station FLC-1 in Fletcher Channel, sampled from 2001 to 2003, 2005 and 2007 to 2013;
- *test* station GIC-1 in Goose Island Channel, sampled from 2001 to 2003, 2005 and 2007 to 2013;
- *test* station EMR-2 in the Embarras River, sampled in 2005, 2010, 2012, and 2013; and
- *test* station ATR-ER, on the Athabasca River mainstem immediately upstream of the Embarras River, sampled from 2000 to 2005 and 2007 to 2013.

Temporal Trends The following significant ($\alpha=0.05$) trends over time in concentrations of sediment quality measurement endpoints were detected:

- A decreasing concentration of F1 hydrocarbons at *test* station BPC-1; and
- Decreasing concentrations of total metals, total arsenic, total parent PAHs, and total C1 hydrocarbons at *test* station ATR-ER.

No significant trends in sediment quality measurement endpoints were observed at *test* stations FLC-1 and GIC-1. Trend analysis could not be conducted for *test* station EMR-2 because of limited available data (n=4).

2013 Results Relative to Historical Concentrations Concentrations of sediment quality measurement endpoints at all five stations in fall 2013 were within previously-measured concentrations, with the exception of the following:

- Sediment at *test* station BPC-1 in fall 2013 was dominated by sand, with concentrations in 2013 below previously-measured minimum concentrations for CCME F3 and F4 hydrocarbons, naphthalene, retene, total PAHs, total parent PAHs, and total alkylated PAHs (Table 5.1-15). Direct toxicity measurements indicated high survival rate (80%) of the amphipod *Hyalella* but a lower survival of the midge *Chironomus* (56%). All toxicity measurements in fall 2013 were within the range of previously-measured results, with the exception of the ten-day growth of the midge *Chironomus*, which exceeded the previously-measured maximum value (Table 5.1-15). The concentration of total metals was lower in 2013 than the previously-measured minimum concentration, except when normalized to 1% total organic carbon where the concentration of total metals was within the previously-measured range (Table 5.1-15, Figure 5.1-13).

- Sediment at *test* station FLC-1 was dominated by silt, with concentrations of CCME F2 hydrocarbons, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs that exceeded the previously-measured maximum concentrations in fall 2013 (Table 5.1-16). Although the concentration of total PAHs exceeded the previously-measured maximum concentration, when normalized to 1% total organic carbon, total PAHs were within the range of previously-measured concentrations at this station (Figure 5.1-14). Results of sediment toxicity tests indicated high survival of the amphipod *Hyalella* (90%), and lower survival of the midge *Chironomus* (68%) (Table 5.1-16).

- Sediment at *test* station GIC-1 was dominated by sand, with smaller amounts of silt (Table 5.1-17). Concentrations of sediment quality measurement endpoints were generally within previously-measured concentrations, with the exception of predicted PAH toxicity, which reached a maximum value in fall 2013 (Table 5.1-17 and Figure 5.1-15). Total PAHs were within the range of previously-measured concentrations, except when normalized to 1% total organic carbon, when the concentration exceeded the previously-measured maximum concentration (Figure 5.1-15). Sediment toxicity tests indicated a high survival of the amphipod *Hyalalla* (98%) and a lower survival of the midge *Chironomus* (62%), both within previously-measured values. In fall 2013, the midge *Chironomus* had a higher ten-day growth than previously measured (Table 5.1-17).

- Sediment at *test* station EMR-2 was dominated by silt, with a lower percentage of silt and clay and a slightly higher percentage of sand in 2013 compared to previously-measured values (Table 5.1-18). The concentration of F2 hydrocarbons, total dibenzothiophenes, total PAHs, and total alkylated PAHs exceeded previously-measured maximum concentrations, while total parent PAHs were below the previously-measured minimum concentration (Table 5.1-18 and Figure 5.1-16). The concentration of total metals was below the previously-measured minimum concentration in 2013, but when normalized to percent fines, was within the range of previously-measured concentrations (Figure 5.1-16). Direct measurements of sediment toxicity varied from previously-measured results, where both the midge *Chironomus* and the amphipod *Hyalella* had lower survival in 2013 than in previous years (62% and 42%, respectively). The ten-day growth rate for the midge *Chironomus* was higher and the fourteen-day growth of the amphipod *Hyalella* was lower in 2013, relative to previously-measured values (Table 5.1-18).

- Sediment at *test* station ATR-ER was dominated by sand, with all sediment quality measurement variables within previously-measured concentrations (Table 5.1-19 and Figure 5.1-17). Sediment toxicity tests showed survival below 80% for the midge *Chironomus* (56%), while the amphipod *Hyalella* had a 93% survival. Survival and growth for both the midge *Chironomus* and amphipod *Hyalella* were within previously-measured values, with the exception of ten-day growth of the midge *Chironomus*, which exceeded the previously-measured maximum value (Table 5.1-19).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment or soil quality guidelines were exceeded in fall 2013, with the exception of total arsenic at *test* station EMR-2, CCME F3 hydrocarbons at *test* station FLC-1, and potential chronic toxicity of PAHs at all stations, which exceeded the potential chronic toxicity threshold value of 1.0.

2013 Results Relative to *Baseline* Concentrations There was no *baseline* sediment quality data for the ARD; therefore, results were not compared to *baseline* ranges of variability.

Sediment Quality Index The SQI values for stations of the ARD were not calculated for fall 2013 given the absence of *baseline* data for this region.

Summary In 2013, stations were predominantly comprised of sand, with the exception of *test* stations EMR-2 and FLC-1 where silt substrate 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, with the exception of PAHs, which were generally higher in 2013 at *test* stations EMR-2 and FLC-1. The concentration of PAHs at all stations in fall 2013 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 PAH concentrations that were carbon-normalized. In fall 2013, the concentration of total PAHs at *test* station BPC-1 was below previously-measured concentrations. The PAH Hazard Index at all stations exceeded the potential chronic toxicity threshold value of 1.0. Chronic toxicity data for sediments exceeded the maximum ten-day growth for the midge *Chironomus* at all stations in 2013. Generally, survival of *Chironomus* and *Hyalella* and the fourteen-day growth of *Hyalella* were within previously-measured values in fall 2013. Because no *baseline* data were available for the ARD, no SQI or relative *baseline* comparisons were conducted.

5.1.5 Fish Populations

Fish population monitoring in 2013 consisted of a spring, summer, and fall fish inventory, a fish tag return assessment, and sentinel species monitoring on the Athabasca River mainstem as well as fish assemblage monitoring in four channels of the Athabasca River Delta.

5.1.5.1 Athabasca River Fish Inventory

The fish inventory program on the Athabasca River in 2013 consisted of a spring, summer, and fall fish survey; and a fish tag return assessment. The *test* areas (Poplar, Steepbank, Muskeg, Tar-Ells, and Fort-Calumet) of the river, located downstream of oil sands development have been continually sampled by RAMP since 1997. From 1987 to 1996, these areas were sampled by Syncrude and have been designated as *baseline* years given that sampling was conducted prior to major oil sands development. A *baseline* reach (-03B), located upstream of Fort McMurray has been sampled continually since 2011.

Temporal and Spatial Comparisons

Temporal and spatial comparisons were carried out to assess changes in each area of the river, by season, 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 4,775 fish were captured in 14 standardized reaches within six areas of the Athabasca River during the spring, summer, and fall fish inventories (Table 5.1-20, Figure 5.1-18), of which:

- 1,275 fish representing 13 species were caught in spring;
- 1,067 fish representing 17 species were caught in summer; and
- 2,433 fish representing 15 species were caught in fall.

Comparisons of total catch and species richness in 2013 by area and season are provided in Table 5.1-21 and Figure 5.1-19.

Total species richness remained relatively stable over the past four years; a total of 19 species were captured in 2013 and 2012 while 20 species were recorded in 2011 and 2010. The lowest and highest species richness to date were documented in 2009 (16 species) and 1997 (22 species). Compared to 2012, total catch in 2013 was substantially lower in fall (-793) but only slightly lower in spring (-264); total catch in summer was slightly higher (+217). The decrease in fall catch from 2012 to 2013 was potentially due to lower water levels and less available fish habitat or the timing of lake whitefish spawning migration relative to the sampling period. Fall 2013 was much warmer than fall 2012, which likely resulted in later migration of lake whitefish in 2013.

Species Composition Compared to recent years, key findings with regards to species composition in 2013 are as follows:

1. The most abundant large-bodied fish species was white sucker and goldeye in spring; goldeye and walleye in summer; and goldeye and lake whitefish in fall. In spring 2013, white sucker became the most abundant large-bodied fish, following a higher abundance of walleye in spring 2012. Similarly, walleye was slightly less abundant than lake whitefish in fall 2013, whereas in fall 2012, the abundance of walleye and lake whitefish was fairly consistent (Figure 5.1-19, Figure 5.1-20).

2. Flathead chub was the most abundant small-bodied fish species in spring and summer, while spottail shiner was the most abundant in fall (Table 5.1-20). In 2012, trout-perch, emerald shiner, and flathead chub were the most abundant small-bodied species in spring, summer, and fall, respectively (Figure 5.1-19).

3. In spring 2013, the percentage of goldeye captured was the highest observed since fishing effort was standardized in 2005. The abundance of goldeye remained consistent between summer 2012 and 2013 while the goldeye catch in fall showed a decrease to within the historical range following a peak in 2011 and 2012 (Figure 5.1-20).

Catch Per Unit Effort In order 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 six areas of the Athabasca River). Historically, other reaches in the Athabasca River have been sampled; however, these data were not included for comparisons of CPUE. Comparisons of CPUE over time has focused on KIR fish species (i.e. goldeye, lake whitefish, longnose sucker, northern pike, trout-perch, walleye, and white sucker) given their importance to stakeholders and their suitability for assessing localized conditions of the river (e.g., white sucker and longnose sucker are bottom feeders; trout-perch is a non-migratory sentinel species; and walleye and lake whitefish are highly migratory throughout the system).

Total CPUE for each species by area and season in 2013 is provided in Figure 5.1-21. Mean CPUE for each KIR fish species in 2013 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 2013, designated as “RAMP post-reach standardization” (Figure 5.1-22 to Figure 5.1-28). Since the initiation of standardized reaches in 2005, an effort has been made to target the whole fish community and ensure consistent sampling methodology across reaches; consequently, total CPUE has generally been higher in the last eight years of the program.

Spatial and temporal comparisons were conducted to assess changes in CPUE of KIR fish species over time between each area of the Athabasca River. Comparisons involved a trend analysis ($p<0.05$) on KIR fish species for each area from 1997 to 2013 (Table 5.1-22). Species-specific results are as follows:

- With the exception of the Tar-Ells area in spring, CPUE of goldeye was higher at all *test* areas compared to the *baseline* area in spring and fall. In summer, goldeye CPUE at *test* areas remained consistent to the *baseline* reach (Figure 5.1-22). Goldeye CPUE exhibited an increasing trend in 2013 at all *test* areas in fall, with the exception of the Muskeg area ($p<0.05$).

- Lake whitefish were only considered in fall when the adult spawning population was in the Athabasca River; CPUE was higher at all *test* areas compared to the *baseline* area (Figure 5.1-23). Lake whitefish exhibited a significant increase in CPUE at all *test* areas in fall, with the exception of the Fort Calumet area ($p<0.05$).

- CPUE of longnose sucker was lower at all *test* areas in spring and fall; only the Poplar *test* area had a greater CPUE than the *baseline* area in summer. Significant increases in CPUE were only observed at the Poplar *test* area ($p=0.01$) (Figure 5.1-23).

- In spring, CPUE of northern pike was lower across all *test* areas with the exception of the Poplar area (Figure 5.1-24). Summer CPUE values were only slightly lower across all *test* areas, while fall CPUE was relatively consistent with the exception of seemingly lower values observed at the Steepbank and Tar-Ells *test* areas. Significant increases in CPUE were observed only at the Fort Calumet *test* area ($p=0.04$).

- There were no trout-perch captured in the *baseline* area in spring 2013. CPUE of trout-perch was slightly higher at all *test* areas compared to the *baseline* area in summer (Figure 5.1-26), whereas only the Muskeg area had higher CPUE than the *baseline* area in fall. CPUE of trout-perch significantly increased in spring and fall at all areas, with the exception of Fort-Calumet ($p<0.05$).

- In spring, CPUE of walleye was substantially higher in the *baseline* area compared to all *test* areas (Figure 5.1-26). This observation was likely due to preferred spawning habitat in the *baseline* area (i.e. hard substrate, fast-flowing water [Scott and Crossman 1973]). Similarly, fall CPUE values were noticeably higher in the *baseline* area compared to the *test* areas. Results were relatively consistent across both the *baseline* and *test* areas in summer. Walleye CPUE exhibited a significant increasing trend at the Steepbank and Poplar *test* areas in fall over time ($p<0.002$).

White sucker were only caught in the *baseline* area during the summer inventory; CPUE of white sucker was higher in the *baseline* area than all *test* areas (Figure 5.1-28). Following a decrease in 2012, white sucker CPUE in spring 2013 increased above the historical range, particularly in the Muskeg area, likely due to white sucker spawning in the Muskeg River. The reason for low 2012 CPUE values is uncertain but be related to the timing of the inventory relative to the timing of the spawning migration into the Muskeg River. White sucker CPUE exhibited a significant increasing trend in spring across years at the Steepbank and Tar-Ells areas ($p<0.002$; Table 5.1-22).

Age-Frequency Distributions Relative age-frequency distributions and size-at-age relationships for large-bodied KIR fish species across all seasons are presented in Figure 5.1-29 to Figure 5.1-34. The average relative age-frequency distributions for all large-bodied KIR species were grouped from: 1997 to 2004 (RAMP prior to enhanced standardization of reaches and fishing methods); 2005 to 2011 (RAMP post-standardization of reaches and fishing methods); 2012; and 2013. Only large-bodied KIR fish species with adequate samples sizes ($n \geq 20$ and equal regression slopes [$p>0.01$]) were included and only significant differences were reported. The species-specific results are as follows:

1. The dominant age class of goldeye in 2013 was six years, which was slightly older than the dominant age classes in 2011 and 2012 of four and five years, respectively. Furthermore, the dominant age class of goldeye from 1997 to 2004 was three years, indicating a continuous shift to older age classes.
2. The dominant age class of lake whitefish in 2013 was ten years; age classes in 2011 and 2012 was eight years while six years was the dominant class from 1997 to 2004. This marked shift to an older dominant age class could indicate poor recruitment of young individuals to the population. Significant differences in size-at-age were observed between 2012 and 2011 ($p<0.001$) and 2012 and 2013 ($p<0.001$). Both test results indicate larger lake whitefish at age in 2012.
3. The co-dominant age classes of longnose sucker in 2013 were ten and twelve years; a further increase from co-dominant classes of six and seven years in 2012; and three years from 1997 to 2004.
4. Dominant age classes of northern pike continued to display variability with regards to historical trends. Age classes were distributed relatively evenly from three to six years in 2013 while 1997 to 2004 and 2012 data showed a dominant class of five years. Significant differences in size-at-age were observed between 2012 and 2013 ($p=0.01$); indicating larger northern pike at a given age in 2012.
5. There were no defined dominant age classes for walleye in 2013; the majority were found to be between the ages of four and eight. This shift marked a further increase in age from the co-dominant age classes of three and six years in 2012.
6. The dominant age class of white sucker was ten years in 2013, whereas dominance among age classes in 2012 ranged from four to ten years. This continued shift toward an older population has been observed since co-dominant age classes of five and eight years were recorded from 1997 to 2004.

Condition Factor Mean condition factor for KIR fish species captured in the Athabasca River were compared to mean condition from recent years as well as historical *baseline* means from 1987 to 1996 (Figure 5.1-35 to Figure 5.1-41). Fish captured in spring were not considered as most species are spring spawners. As such, condition would be strongly influenced by advanced gonadal development of pre-spawning fish or reduced gonad size of spent fish. Similar reasoning was applied to lake whitefish in fall during their spawning period. The species-specific results for summer and fall are as follows:

1. Mean condition of goldeye in summer and fall 2013 was noticeably higher than 2012 and above the *baseline* means (1987 to 1996).
2. Mean condition of lake whitefish in fall 2013 was slightly greater than 2012 and remained above the mean from 1987 to 1996.
3. With the exception of 2005, mean condition of longnose sucker in fall 2013 was lower across all years and below the mean from 1987 to 1996.
4. Mean condition of northern pike in summer 2013 was lower than 2012 but greater than the *baseline* mean (1987 to 1996). Mean condition in fall 2013

remained approximately the same compared to the three previous years (2010 to 2012); mean condition throughout these years were all below the *baseline* mean (1987 to 1996).

5. Mean condition of walleye in summer and fall 2013 exhibited a considerable increase from 2010 to 2012; 2013 marked the first time since 2009 where both summer and fall mean condition were above the means from 1987 to 1996.
6. Mean condition of white sucker was similar between 2013 and 2012 following a slight decrease from 2011. Summer and fall mean condition remained below and above the mean from 1987 to 1996, respectively.

Statistical differences between 2013 and historical *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 ($n \geq 20$ and equal slopes between length and weight [$p > 0.01$]) were included and only significant differences were reported. Significant differences were observed among goldeye, lake whitefish, and walleye in fall 2013 ($p < 0.01$). Percent differences in adjusted mean condition (i.e., effect size) were 14.4%, 6.9%, and 5.0% greater than the historical *baseline* mean for goldeye, lake whitefish, and walleye, respectively.

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 2013, 3.2%, 0.6%, and 0.2% of fish were found to have some type of external abnormality in spring, summer, and fall, respectively. Incidences of external abnormalities in 2013 were lower than 2012 across all seasons.

Of the 4,775 fish captured in the 2013 Athabasca River inventory, 155 (1.1%) exhibited some form of external pathological abnormality such as parasites, growths, lesions (open sores), or body deformities. The percentage of fish exhibiting some form of pathology by year for all seasons combined is summarized in Table 5.1-23. For each type of external pathology, there has been no increasing trend observed over time ($p > 0.05$; Figure 5.1-42). External pathology was primarily observed in white sucker (15.3%) and northern pike (6.7%); however, the percent of external pathology was within the historical range documented for both species (white sucker: 1.7% to 26.4% and northern pike: 0% to 11.9%). Other species for which pathological abnormalities were recorded, mostly due to their higher capture frequency compared to other species in the river, included burbot, emerald shiner, flathead chub, goldeye, lake whitefish, longnose sucker, 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 conducted on the Wapiti, Smoky, and Peace rivers documented abnormalities among 33% of burbot (Hvenegaard and Boag 1993). In the Peace-Athabasca Delta, a study in 1993 documented 0.95% of lake whitefish captured with some type of external abnormality (Balagus et al. 1993). Other studies have documented no external abnormalities in any fish in the upper portion of the Athabasca River (R.L. & L. 1994), while other studies in the upper portion of the Athabasca River have documented a range between 0% and 15.7% of the total number of fish captured with some type of external abnormality (Mill et al. 1996).

Summary Assessment for the Fish Inventory

The objective of the fish inventory program is to assess general trends in population variables such as abundance and richness as well as to determine age, size, and health of individuals within these populations.

As of 2013, 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. Goldeye and lake whitefish were among the large-bodied KIR species that have exhibited the greatest increase in abundance over time. Significant increases were observed in total catch and CPUE of goldeye in the last three years (i.e., 2011 to 2013), potentially due to warm, calm, spring seasons over the last three years, which can provide favourable conditions for goldeye recruitment (Paul 2013). Similarly, CPUE of lake whitefish in fall 2013 was higher than previous years. Both goldeye and lake whitefish have shown significant increases at the majority of *test* reaches in fall since 1997. Furthermore, shifts toward older dominant age classes and significant increases in mean condition were observed in both species.

The fish health assessment indicated that abnormalities observed among all species in 2013 were within the historical range and consistent with studies published prior to major oil sands development in the upper Athabasca River, the Athabasca River Delta, and the Peace/Slave rivers.

5.1.5.2 Fish Tag Return Assessment

Angler Returns

A total of four RAMP Floy tags from walleye were submitted by anglers in 2013 to Alberta Environment and Sustainable Resource Development (AESRD). All tag returns recorded during the 2013 RAMP fish inventory program and from anglers is provided in Table 5.1-24, with a cumulative summary of RAMP tag returns to date provided in Table 5.1-25. Figure 5.1-43 shows the location of first capture and tagging by RAMP and the location of the recapture by the angler. Given that the location of initial capture and tag return are not always on the same river, tag returns for both the Athabasca and Clearwater inventories are provided in this section.

Fish Inventory Returns

In 2013, a total of two walleye were recaptured during the Athabasca River inventories:

- One walleye was recaptured with a tag in May 2013 in reach 5B of the Steepbank area, following the original capture, just upstream in reach 4B in May 2012.
- One walleye was recaptured in September 2013 in the same reach (19B of the Fort-Calumet area) as the original capture location in May 2012.

During the 2013 Clearwater River fish inventory, only, one northern pike was recaptured in September 2013 in the exact reach (CR2B) that it was initially captured in October 2008.

5.1.5.3 Athabasca River Sentinel Species Monitoring

Sentinel species monitoring, using trout-perch (*Percopsis omiscomaycus*), was conducted at five sites on the Athabasca River in October 2013. A lethal trout-perch sentinel species program was also conducted in 1999, 2002, and 2010. Based on their location with respect to the location of focal project activities in 2013, sites ATR-3, ATR- 4, and ATR-5 were designated as *test* and compared to *baseline* sites ATR-1 and ATR-2, which were located upstream of any influence of oil sands development (Figure 5.1-1).

2013 Habitat Conditions Water quality at all sites indicated suitable conditions for trout-perch, with dissolved oxygen ranging from 9.8 to 10.6 mg/L; conductivity ranging from 205 to 278 µS/cm; and pH ranging from 8.40 and 8.58 (Table 5.1-26). The maximum sampling depth ranged from 0.50 m (*baseline* site ATR-1) to 5.2 m (*test* site ATR-4). Velocities varied between sites ranging from 0.02 m/s (*baseline* site ATR-2) to 0.25 m/s (*test* site ATR-4), with the majority of the sites being classified as run habitat. The slow velocity at *baseline* site ATR-2 was due to backwater areas where most trout-perch were captured. The dominant substrate at most sites was cobble or a mixture of cobble and sand; with the exception of *test* site ATR-3, which was dominantly sand (Table 5.1-26).

Spatial and Temporal Comparisons

A summary of morphometric data for male and female trout-perch by site is provided in Table 5.1-27. Target numbers of trout-perch (20 adult fish of each sex) were collected at all sites, with the exception of females at *baseline* site ATR-1 (n=18) and *test* site ATR-5 (n=19) (Table 5.1-27).

Comparisons were done between the *baseline* sites (ATR-1 and ATR-2) to determine whether measurement endpoints of trout-perch were similar and could be pooled and compared to *test* sites. ANCOVA/ANOVA results indicated that these sites showed significant differences between trout-perch populations (Table 5.1-28). Therefore, statistical analyses were done separately for each *baseline* site to each *test* site. To interpret the response patterns; however, results from comparisons with *baseline* site ATR-2 were used given these comparisons accounted for variability associated with the upstream sewage treat plant at Fort McMurray.

Age In 2013, the mean age of adult female and adult male trout-perch ranged from three years (*test* site ATR-5) to five years (*baseline* site ATR-1) (Table 5.1-27). The mean age across sampling years (1999, 2002, 2010, and 2013) was generally consistent (Figure 5.1-44), with slightly older male and female populations in 2013 at all sites, with the exception of *test* site ATR-3, which had a higher mean age of trout-perch in 2010 than 2013 (5 and 4 years, respectively).

In 2013, the proportion of trout-perch in younger age classes was low, with the highest proportion of trout-perch between three and six years, with the exception of ATR-5, which showed a higher proportion of individuals in the one and two year age classes. The dominant age class of trout-perch was five years and four years at *baseline* sites ATR-1 and ATR-2, respectively. The dominant age class at *test* sites were four years at ATR-3 and ATR-4 and three years at ATR-5 (Figure 5.1-45). The relative age-frequency distributions of trout-perch captured in 1999 showed age classes ranging from one to six years for *baseline* site ATR-2, two to four years at *test* site ATR-3, and one to four years at *test* site ATR-4 (Figure 5.1-45). Dominant age classes were two and three years at all sites in 1999. In 2002, dominant age classes remained at two and three years but the population showed more individuals in older age classes at all sites (Figure 5.1-45). A new *baseline* site (ATR-1) and *test* site (ATR-5) were added to the program in 2002 and showed age classes ranging from one to six years and one to four years, respectively. The dominant age class in 2010 was two years at *baseline* site ATR-1 and four years at *baseline* site ATR-2. At the *test* sites, the dominant age class in 2010 was five years at ATR-3, four years at ATR-4, and two years at ATR-5 (Figure 5.1-45).

An ANOVA was used to compare age of male and female trout-perch between *baseline* sites (ATR-1 and ATR-2) and *test* sites (ATR-3, ATR-4, and ATR-5) in 2013 (Table 5.1-28). Female trout-perch at all *test* sites were younger than trout-perch at *baseline* site ATR-1; however; only *test* site ATR-5 showed a significantly younger female population than *baseline* site ATR-2 (p=0.001). Generally, there were no significant differences in the mean age between *baseline* sites and *test* sites in 2013 for male trout-perch, with the exception of *test* site ATR-5 (p=<0.001), where trout-perch were significantly younger than at *baseline* ATR-1 (Table 5.1-28).

An exceedance of the effects criterion (±25% from the *baseline* mean age) was observed at *test* site ATR-5, where female and male trout-perch were 38% and 26% younger, respectively, than trout-perch at *baseline* site ATR-1 and female trout-perch being 25% younger than female trout-perch at *baseline* ATR-2 (Table 5.1-29). Younger female trout-perch were also observed at *test* site 5 compared to *baseline* site 2 in 2010 (Table 5.1-29).

Growth (Weight-at-Age) An ANCOVA was used to compare the relationship between body weight and age of male and female trout-perch between *baseline* and *test* sites in the Athabasca River in 2013. The first step in the ANCOVA was to compare slopes of regressions from different populations to ensure they were equal (p>0.01), and the second step was to compare the intercepts of the regressions (the p-value for the intercept was provided in the results). Female trout-perch showed a significant difference in growth at *test* site ATR-4 compared to *baseline* site ATR-2 (p=0.026) (Table 5.1-28). Male trout-perch showed a significant difference in growth at *test* site ATR-5 compared to *baseline* sites (p=0.003 and p=0.050, respectively). Male and female trout-perch at *test* sites were heavier at any given age, indicating greater growth compared to trout-perch at the *baseline* sites (Figure 5.1-46). There were an exceedance of the effects criteria (i.e., ±25% from the *baseline* mean) in male trout-perch at *test* site ATR-5 (38.4%) and female trout-perch at *test* site ATR-4 (28.0%) compared to *test* site ATR-1 in 2013 (Table 5.1-29). Exceedances of the effects criterion for growth was observed in trout-perch at *test* sites ATR-4 and ATR-5 in 2010 compared to *baseline* sites (ATR-1 and ATR-2); however, the exceedances were not consistent between years (Table 5.1-29).

In 1999 and 2002, growth of male trout-perch at *test* sites was lower than at *baseline* sites and female trout-perch generally had greater growth at *test* sites than *baseline* sites (Figure 5.1-46). In 2010; however, female trout-perch generally had lower growth compared to the *baseline* sites and male trout-perch at ATR-4 exhibited greater growth compared to *baseline* site ATR-2.

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 for a fish. In 2013, the mean GSI of adult female trout-perch ranged from 5.23 (*test* site ATR-5) to 5.90 (*test* site ATR-4) and the mean GSI of male adult trout-perch ranged from 1.87 (*baseline* site ATR-2) to 3.27 (*baseline* site ATR-1) (Table 5.1-28, Figure 5.1-47).

An ANCOVA was used to compare the relationship between gonad weight and body weight of male and female trout-perch between *baseline* and *test* sites in the Athabasca River in 2013. Gonad size was relatively similar for both male and female trout-perch in 2013, with the exception of lower gonad weight in female trout-perch at *test* site ATR-4 compared to *baseline* site ATR-1 (p=0.007) and a higher gonad weight in male trout-perch at *test* site ATR-5 compared to *baseline* site ATR-2 (p=0.013) (Table 5.1-28).

Exceedances of the effects criterion (±25% of the *baseline* mean) were observed in male trout-perch at *test* sites ATR-3 (29.0%) for gonad size compared to *baseline* site ATR-1; and male trout-perch at *test* site 5 (25.3%) compared to *baseline* site ATR-2 (Table 5.1-29). Exceedances of the effects criterion for gonad size was observed in trout-perch at *test* sites ATR-4 and ATR-5 in 2002 and 2010 compared to *baseline* sites (ATR-1 and ATR-2); however, the exceedances were not consistent between years (Table 5.1-29).

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 2013, the mean LSI of adult female trout-perch ranged from 1.71 (*test* site ATR-5) to 2.00 (*baseline* site ATR-2), and from 1.35 (*test* site ATR-5) to 1.56 (*test* site ATR-4) for male trout-perch (Table 5.1-27, Figure 5.1-49).

An ANCOVA was used to compare the relationship between liver weight and body weight of male and female trout-perch between *baseline* and *test* sites in the Athabasca River in 2013. There was a significant decrease (p=0.027) in liver weight relative to body weight in female trout-perch at *test* site ATR-5 compared to *baseline* site ATR-2 with no other *test* sites showing significant differences from either of the *baseline* sites (Table 5.1-28).

The effects criterion for liver weight (±25% of the *baseline* mean) was not exceeded in trout-perch at *test* sites compared to the *baseline* sites in 2013 (Table 5.1-29). Historically, the effects criterion for liver weight was not exceeded in trout-perch at *test* sites (ATR-3, ATR-4, and ATR-5) when compared to the *baseline* sites (ATR-1 and ATR-2) (Table 5.1-29, Figure 5.1-50).

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 2013, the mean condition of female and male trout-perch was similar ranging from 1.11 and 1.05 (*baseline* site ATR-1) for females and males, respectively, to 1.11 (*test* site ATR-3) for both female and male trout-perch (Table 5.1-27, Figure 5.1-51).

An ANCOVA was used to compare condition of male and female adult trout-perch between *baseline* and *test* sites in the Athabasca River in 2013. The condition of male and female trout-perch was relatively similar between sites, with the exception of male trout-perch at *test* site ATR-3 where condition was significantly higher (p=0.002) compared to trout-perch from the *baseline* site ATR-1, (Table 5.1-28). Condition of trout-perch in previous sampling years, including 2007 when non-lethal sampling was conducted, was relatively consistent across sites (Figure 5.1-52).

The effects criterion for condition (±10% from the *baseline* mean) was not exceeded in trout-perch at *test* sites when compared to either of the *baseline* sites in 2013 (Table 5.1-29). Exceedances of the effects criterion for condition were observed in trout-perch at *test* site ATR-4 in 2002 when compared to *baseline* sites ATR-1 and ATR-2 (Table 5.1-29).

Power Analyses 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 (0.70 to 1.00), with the exception of GSI for male trout-perch ($P<0.5$) (Table 5.1-30). There were 19 comparisons that did not achieve the desired level of Power (>0.9) recommended by 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 5.1-30). However, it should be noted that many of these comparisons achieved a power near 0.8, with the exception of GSI, and some studies have suggested that a power of 0.8 is adequate (Cohen 1988). Power was adequate for all pairwise comparisons of condition in trout-perch.

Summary of Results As outlined in RAMP (2009b), the trout-perch sentinel species program was developed to evaluate spatial and temporal differences in measurement endpoints between *test* and *baseline* sites. There were few significant differences observed between trout-perch from *test* sites on the Athabasca River and trout-perch from individual *baseline* sites. However, the majority of differences that were observed were between *test* sites and *baseline* site ATR-1 (Table 5.1-28). These results suggested that the differences were likely related to the variability associated with differences in habitat conditions found upstream of the sewage treat plant at Fort McMurray relative to ATR-2 and the *test* sites.

The majority of significant differences observed between trout-perch from the *test* sites and *baseline* site ATR-2 were observed for *test* site ATR-5, the furthest downstream site on the Athabasca River. Results from this comparison indicated that trout-perch at *test* site ATR-5 exhibited greater growth and gonadal development in males and lower liver growth and age in females compared to *baseline* site ATR-2. These same patterns were observed in 2010, with the exception that gonadal development was lower in male trout-perch in 2010 (Table 5.1-29).

Classification of Results The effects criteria for age, weight-at-age, relative gonad weight, and relative liver weight defined by Environment Canada (2010) is a ± 25% difference between a *test* site and *baseline* site ATR-2, and a ± 10% difference for condition (body weight at length). Differences greater than the effects criteria (identified as "+" and "-"responses in Table 5.1-29) between *baseline* and *test* sites suggested an ecologically relevant change in the trout-perch population at the *test* site.

A difference in measurement endpoints that exceeded the Environment Canada effects criteria (Environment Canada 2010) was observed for age of female trout-perch and gonad weight of male trout-perch at *test* site ATR-5. The age of female trout-perch at ATR-5 was 25.2% younger than for trout-perch *baseline* site ATR-2, which was also observed in female trout-perch at *test* site ATR-5 in 2010 (Table 5.1-29, Table 5.1-29). The gonad weight of male trout-perch at *test* site ATR-5 was 25.3% greater than trout-perch at *baseline* site ATR-2, which had also been observed in 2002, but the opposite pattern was observed in 2010 (Table 5.1-29). With no other exceedances in response patterns; and given that the 25% criteria were only marginally exceeded, these results suggested very little variability in trout-perch populations among *test* sites and *baseline* site ATR-2 in 2013.

Based on the results of the 2013, which provided a fairly consistent response patterns in energy use and energy storage (growth, gonad weight, and liver size) in female and male trout-perch at *test* sites, differences from the *baseline* site ATR-2 were classified as **Negligible-Low**.

5.1.5.4 Athabasca River Delta Fish Assemblage Monitoring

A pilot study on fish assemblage monitoring was conducted in channels of the Athabasca River Delta (ARD) in 2012 using a variety of gears. The results of the pilot study showed that hoopnets, seining, and minnow traps did not provide adequate effort or spatial coverage to define fish assemblages in these channels. In 2013, given the higher water levels, it was possible to conduct fish assemblage monitoring by boat electrofishing. Fish assemblages were sampled in August 2013 at:

- depositional *test* reach EMR-F2 in the Embarras River (this reach is at the same location as the benthic invertebrate community *test* reach EMR-2);
- depositional *test* reach FLC-F1 in Fletcher Channel (this reach is at the same location as the benthic invertebrate community *test* reach FLC-1);
- depositional *test* reach BPC-F1 in Big Point Channel (this reach is at the same location as the benthic invertebrate community *test* reach BPC-1); and
- depositional *test* reach GIC-F1 in Goose Island Channel (this reach is at the same location as the benthic invertebrate community *test* reach GIC-1).

2013 Habitat Conditions *Test* reach BPC-F1 was comprised entirely of deep run habitat, with a wetted and bankfull width of 115 m (Table 5.1-32). The substrate was dominated by silt and sand. Water at *test* reach BPC-F1 had a maximum depth of 5.4 m and negligible velocity, was basic (pH: 8.2), with high conductivity (307 µS/cm), moderate dissolved oxygen (7.8 mg/L), and a temperature of 20.4˚C. Instream cover consisted primarily of filamentous algae, large woody debris, macrophytes, 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 with a wetted of 60 m and bankfull width of 62 m (Table 5.1-32). Water at *test* reach FLC-F1 had a maximum depth of 5 m and negligible velocity, was basic (pH: 8.3), with high conductivity (301 µS/cm), moderate dissolved oxygen (7.8 mg/L), and a temperature of 19.8˚C. Instream cover consisted of small woody debris, with overhanging vegetation along undercut banks.

Test reach GIC-F1 was comprised entirely of deep run habitat, with a wetted width and bankfull width of 110 m (Table 5.1-32). The substrate was dominated entirely by silt and sand. Water at *test* reach GIC-F1 had a maximum depth of 9 m and negligible velocity, was basic (pH: 8.3), with moderate conductivity (293 µS/cm), moderate dissolved oxygen (7.2 mg/L), and a temperature of 19.6˚C. Instream cover consisted of filamentous algae, macrophytes, large woody debris, and small amounts of small woody debris, with overhanging vegetation along undercut banks.

Test reach EMR-F2 was comprised entirely of deep run habitat, with a wetted width and bankfull width of 90 m (Table 5.1-32). The substrate was dominated by silt and sand. Water at *test* reach EMR-F2 had a maximum depth of 10 m and negligible velocity, was basic (pH: 8.2), with high conductivity (307 µS/cm), moderate dissolved oxygen (6.8 mg/L), and a temperature of 19.5˚C. Instream cover consisted of small amounts of small woody debris with overhanging vegetation along the banks.

Relative Abundance of Fish Species The dominant species captured was emerald shiner at *test* reaches BPC-F1 (38.9%) and EMR-F2 (54.4%) and lake chub at *test* reaches FLC-F1 (65.5%) and GIC-F1 (41.2%) (Table 5.1-33). The dominant large-bodied fish species captured was northern pike, and primarily at *test* reach BPC-F1, likely due to the preferred habitat for this species in these channels, including slow moving water and instream vegetation (Table 5.1-33).

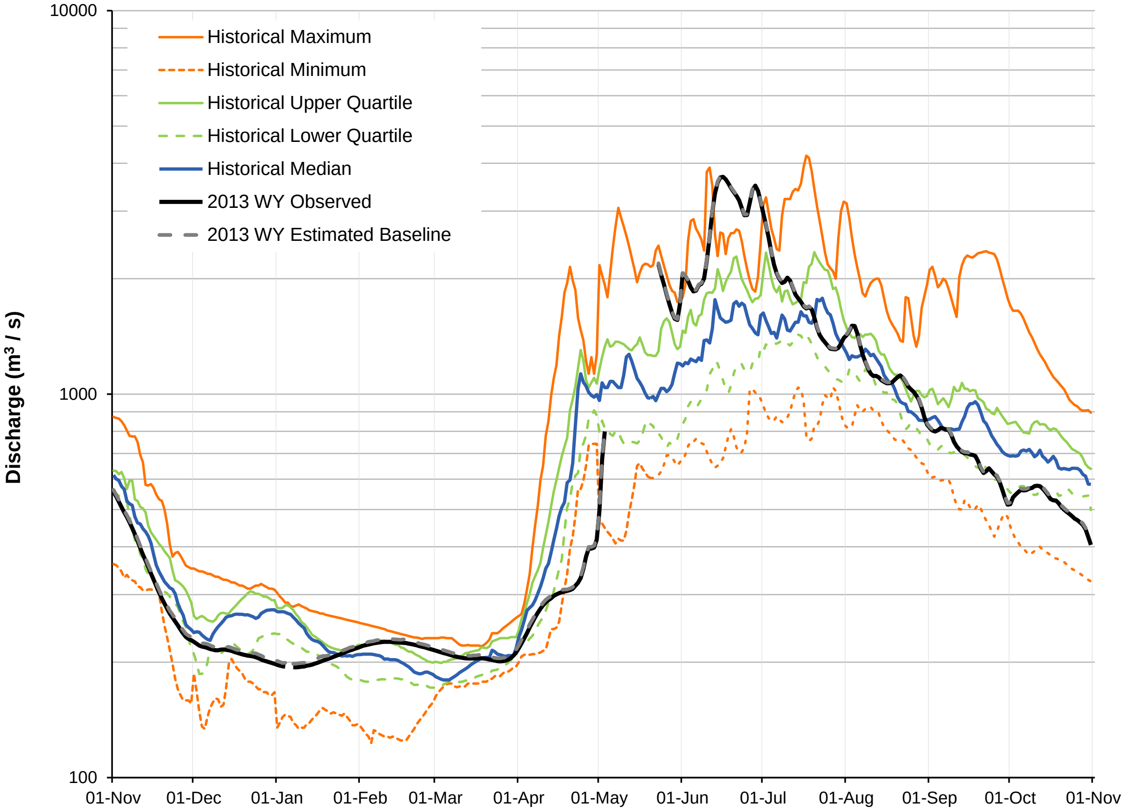
Spatial Comparisons Species richness, abundance, and CPUE were highest at *test* reaches EMR-F2 and BPC-F1 and lowest at *test* reach GIC-F1 (Table 5.1-34, Figure 5.1-53). In addition, most large-bodied and sportfish species were captured at *test* reaches EMR-F1 and BPC-F1, suggesting that these channels (Embarras and Big Point) are migratory routes for fish that move between Lake Athabasca and the Athabasca River. The ATI value was similar at all reaches, ranging from 7.27 (*test* reach EMR-F2) to 8.71 (*test* reach FLC-F1) (Table 5.1-34); the higher ATI values were related to the high proportion of shiner species found at all reaches, which are tolerant fish species.

Comparison to Published Literature 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 late summer 2013. A study, using seining, angling, and gill netting, was completed in the 1970s by the Alberta Oil Sands Environmental Research Program (AOSERP) that documented 18 species in the Athabasca River Delta (Bond 1980), which included all of the species captured by RAMP in August 2013. Additional species historically documented in the delta included mountain whitefish, longnose dace, and ninespine stickleback. Similar fish species are regularly captured by RAMP during the Athabasca River fish inventory program. In 2012, RAMP conducted a pilot fish monitoring program in the delta using hoopnets, seining, and minnow trapping (RAMP 2013). The limitations in spatial coverage of these fishing methods limited the range of species in the fish assemblage that were captured. In 2013, with the use of boat electrofishing, it is likely that the full fish assemblage of these channels was captured given the species composition was similar to what is observed in the fish inventory survey on the Athabasca River (Table 5.1-21).

2013 Results Relative to Historical or *Baseline* Conditions Given the different habitat conditions between the ARD and tributaries to the Athabasca River where fish assemblage monitoring was conducted, the measurements for *test* reaches of the ARD were not compared to regional *baseline* conditions. In future years of monitoring in ARD, comparisons will be made to historical data for these reaches.

Summary of Results Results of the fish assemblage monitoring in the ARD indicated high species richness and abundance across all channels, with this highest catch observed in Big Point Channel and the Embarras River. The dominant species included small-bodied fish species (emerald shiner and lake chub) as well as northern pike as the dominant large-bodied species. Measurement endpoints were fairly consistent across channels, with high ATI values reflecting the tolerant nature of species in the delta (Whittier et al. 2007) The fish species composition of the channels of the ARD was consistent with the species composition in the Athabasca River, as documented during the RAMP fish inventory surveys (see Section 5.1.5.1).

Figure 5.1-3 The observed (test) hydrograph and estimated *baseline* hydrograph for the Athabasca River near Embarras Airport in the 2013 WY, compared to historical values.



Note: Based on 2013 WY provisional data from Athabasca River near Embarras Airport, Station S46. The upstream drainage area is 156,000 km^2. Historical values were calculated for the period 1971 to 1984 and 2012 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 was only shown here; differences between this and the estimated *baseline* hydrograph resulting from other oil sands developments in the Athabasca River watershed were negligible and not detectable on this graph.

.

Table 5.1-2 Estimated water balance at Station S46, Athabasca River near Embarras Airport, 2013 WY.

Component	Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus Other Oil Sands Developments	
Observed *test* hydrograph (total discharge)	**23,878.143**		**Sum of observed daily discharges obtained from Athabasca River near Embarras Airport, RAMP Station S46**
Closed-circuited area water loss from the observed hydrograph	-55.781	-55.781	361.5 km^2 of land estimated to have been closed-circuited as of 2013 (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)	+2.658	+2.679	86.9 km^2 (86.2 km^2 focal projects only) of land estimated to have undergone land change as of 2013 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	-22.830		Withdrawals by Suncor (daily values provided).
	-41.395		Withdrawals by Syncrude (daily values provided).
	-14.346		Withdrawals by Shell (daily values provided).
	-19.254		Withdrawals by Canadian Natural (daily values provided).
	-4.630		Withdrawals by Imperial (daily values provided).
Water releases in the Athabasca River watershed from focal projects	+1.570		Releases by Suncor (daily values provided).
	+0.251		Releases by Syncrude (daily values provided).
The difference between *test* and *baseline* hydrographs on tributary streams	-23.763	-23.590	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)	**24,055.663**	**24,055.468**	**Estimated *baseline* discharge at Athabasca River near Embarras Airport, RAMP Station S46.**
Incremental flow (change in total discharge)	-177.520	-177.326	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-0.738%**	**-0.737%**	**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 2013 WY data for Station S46, Athabasca River near Embarras Airport.

[1] It is assumed that discharges entering the Athabasca River mainstem from the Upper Beaver watershed via the Poplar Creek spillway would have entered the Athabasca River mainstem via the Original Beaver River watershed; therefore, the incremental changes of the Beaver Creek diversion on the Athabasca River mainstem flows were assumed to be zero.

[2] The Horse, MacKay, and Christina River watersheds were the only watersheds considered in the RAMP FSA that contained other oil sands developments under construction or operation as of 2013 (Table 2.5-1).

Table 5.1-3 Calculated change in hydrologic measurement endpoints for the Athabasca River in the 2013 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)		Relative Change	
		Focal Projects	Focal Projects Plus Other Oil Sands Developments	Focal Projects	Focal Projects Plus Other Oil Sands Developments
Mean open-water season discharge	1402.978	1410.962	1410.950	-0.566%	-0.565%
Mean winter discharge	240.016	244.176	244.175	-1.704%	-1.703%
Annual maximum daily discharge	3689.609	3710.380	3710.334	-0.560%	-0.559%
Open-water season minimum daily discharge	404.542	408.923	408.920	-1.071%	-1.071%

Note: Based on the provisional 2013 WY data for Athabasca River near Embarras Airport, Station S46.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to 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 5.1-4 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2013.

Measurement Endpoint	Units	Guideline[a]	Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)[d]		Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)[d]		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)[d]		Downstream of Development (ATR-DD-E, ATR-DD-W)[e]	
			East	West	East	West	East	West	East	West
Physical variables										
pH	pH units	6.5-9.0	7.9	8.2	8.1	8.2	8.2	8.1	8.2	8.2
Total suspended solids	mg/L	-	23.0	7.0	123	20.0	11.0	16.0	14.0	12.0
Conductivity	µS/cm	-	252	297	262	269	270	271	278	280
Nutrients										
Total dissolved phosphorus	mg/L	0.05	0.017	0.016	0.022	0.009	0.008	0.023	0.012	0.016
Total nitrogen	mg/L	1.0	0.57	0.53	0.35	0.33	0.55	0.44	0.43	0.40
Nitrate+nitrite	mg/L	3	<0.071	<0.258	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	10.2	6.3	7.2	5.6	7.9	7.2	7.7	7.5
Ions										
Sodium	mg/L	-	20.8	11.1	14.4	9.9	12.0	10.6	12.1	12.4
Calcium	mg/L	-	22.8	34	31.1	36.3	29.7	32	33.1	33.2
Magnesium	mg/L	-	6.7	9.9	8.3	9.4	8.1	9.0	8.8	8.9
Chloride	mg/L	120	25.4	5.9	11.9	4.5	8.1	6.0	8.3	8.3
Sulphate	mg/L	270	10.4	27.1	18.7	24.5	21	23	22.6	22.9
Total dissolved solids	mg/L	-	154	183	174	164	162	170	155	157
Total alkalinity	mg/L	-	81	115	95.4	108	104	106	107	107
Selected metals										
Total aluminum	mg/L	0.1	**1.05**	**1.00**	**3.19**	**1.00**	**0.92**	**1.05**	**1.09**	**0.84**
Total arsenic	mg/L	0.005	0.0008	0.0008	0.0011	0.0006	0.0007	0.0008	0.0008	0.0006
Dissolved aluminum	mg/L	0.1	0.0124	0.0118	0.0126	0.0138	0.0085	0.0121	0.0108	0.0133
Total boron	mg/L	1.2	0.036	0.025	0.030	0.024	0.027	0.025	0.026	0.030
Total molybdenum	mg/L	0.073	0.00031	0.00066	0.00047	0.00078	0.00060	0.00069	0.00065	0.00076
Total mercury (ultra-trace)	ng/L	5, 13	2.1	1.7	2.6	1.4	1.5	1.7	1.5	1.2

Values in **bold** are above the guideline; underlined values are outside historical range of fall observations for station (single line = historical high; double underline = historical low).

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

[c] Non-detectable values treated in summary calculations as 1 x calculated Method Detection Limit.

[d] Historical comparison to 14 years of fall data (1998 to 2012).

[e] Historical comparison to eight years of fall data (2005 to 2012).

Table 5.1-4 (Cont'd.)

Measurement Endpoint	Units	Guideline[a]	Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)[d]		Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)[d]		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)[d]		Downstream of Development (ATR-DD-E, ATR-DD-W)[e]	
			East	West	East	West	East	West	East	West
Selected metals (Cont'd.)										
Total strontium	mg/L	-	0.133	0.217	0.187	0.228	0.210	0.227	0.216	0.250
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	-	<0.1	<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	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.25	0.13	0.24	0.13	0.14	0.14	0.21	0.21
Oilsands extractable	mg/L	-	0.29	0.21	0.29	0.22	0.22	0.23	0.22	0.22
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	ng/L	-	<15.16	<15.16	<15.16	<15.16	<15.16	<15.16	<15.16	<15.16
Retene	ng/L	-	1.80	0.92	4.67	1.15	1.39	1.15	1.66	1.80
Total dibenzothiophenes	ng/L	-	30.9	8.9	36.5	17.0	17.4	13.3	20.7	19.2
Total PAHs[c]	ng/L	-	185.5	112.6	243.6	141.0	148.7	132.9	158.5	153.4
Total Parent PAHs[c]	ng/L	-	25.2	23.3	30.5	23.4	23.7	23.6	24.8	24.5
Total Alkylated PAHs[c]	ng/L	-	160.3	89.3	213.1	117.6	125.0	109.3	133.7	128.9
Other variables that exceeded CCME/AESRD guidelines in 2013										
Dissolved iron	mg/L	0.3	**0.331**	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	-	-	**0.0036**	-	-	-	-	-
Total chromium	mg/L	0.001	-	-	**0.0022**	-	-	-	-	-
Total iron	mg/L	0.3	**1.33**	**0.738**	**2.03**	**0.634**	**0.683**	**0.736**	**0.752**	**0.447**
Total phenols	mg/L	0.004	-	-	**0.0046**	**0.0042**	**0.0120**	-	-	**0.0051**
Total phosphorus	mg/L	0.05	**0.061**	-	**0.097**	-	-	-	-	-
Total silver	mg/L	0.0001	**0.00012**	-	-	-	-	-	-	-

Values in **bold** are above the guideline; underlined values are outside historical range of fall observations for station (single line = historical high; double underline = historical low).

[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

[c] Non-detectable values treated in summary calculations as 1 x calculated Method Detection Limit.

[d] Historical comparison to 14 years of fall data (1998 to 2012).

[e] Historical comparison to eight years of fall data (2005 to 2012).

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 2013.

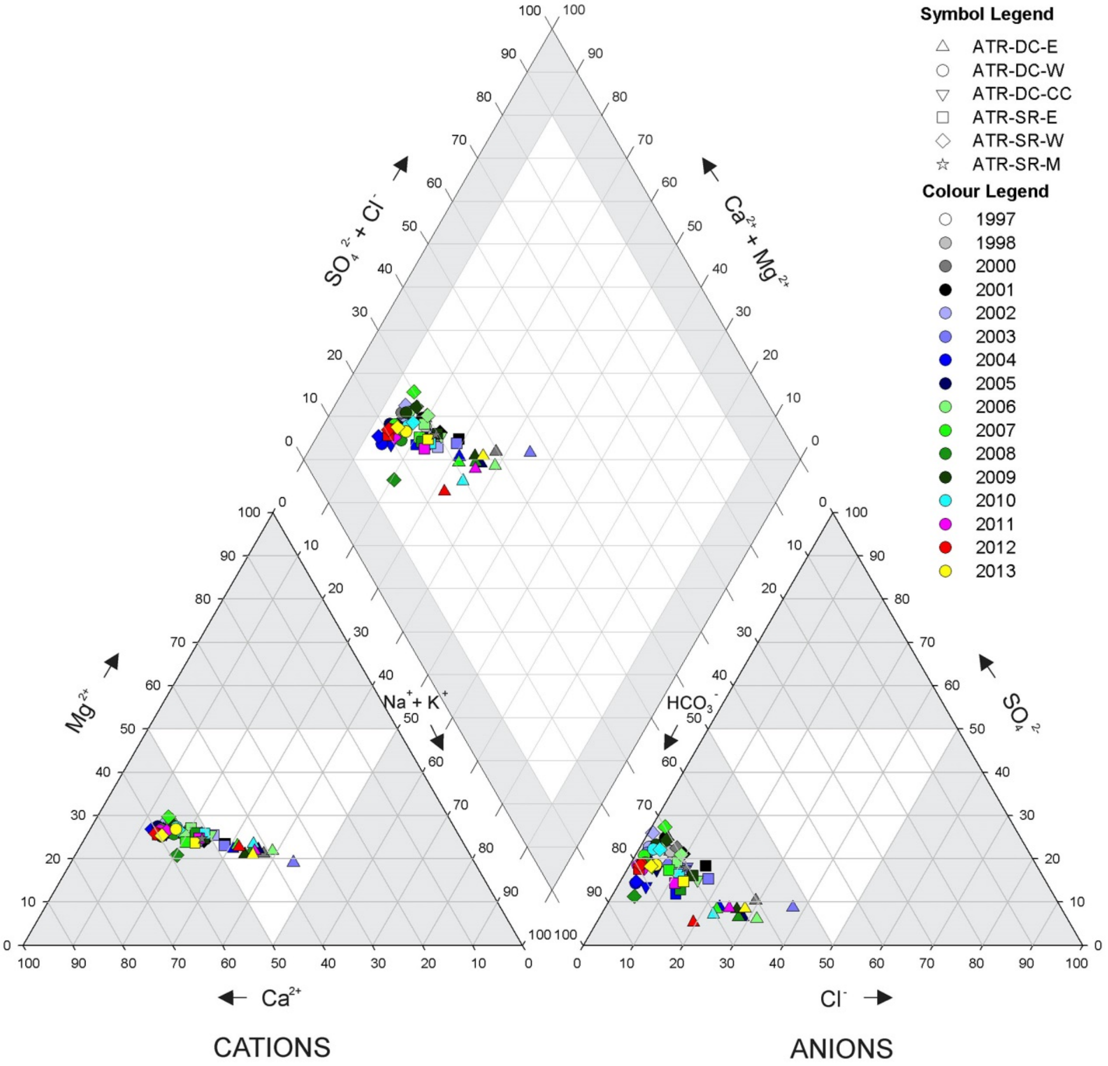


Figure 5.1-5 Piper diagram of ion concentrations in Athabasca River mainstem (*test* stations ATR-MR versus *baseline* stations ATR-DC), fall 1997 to 2013.

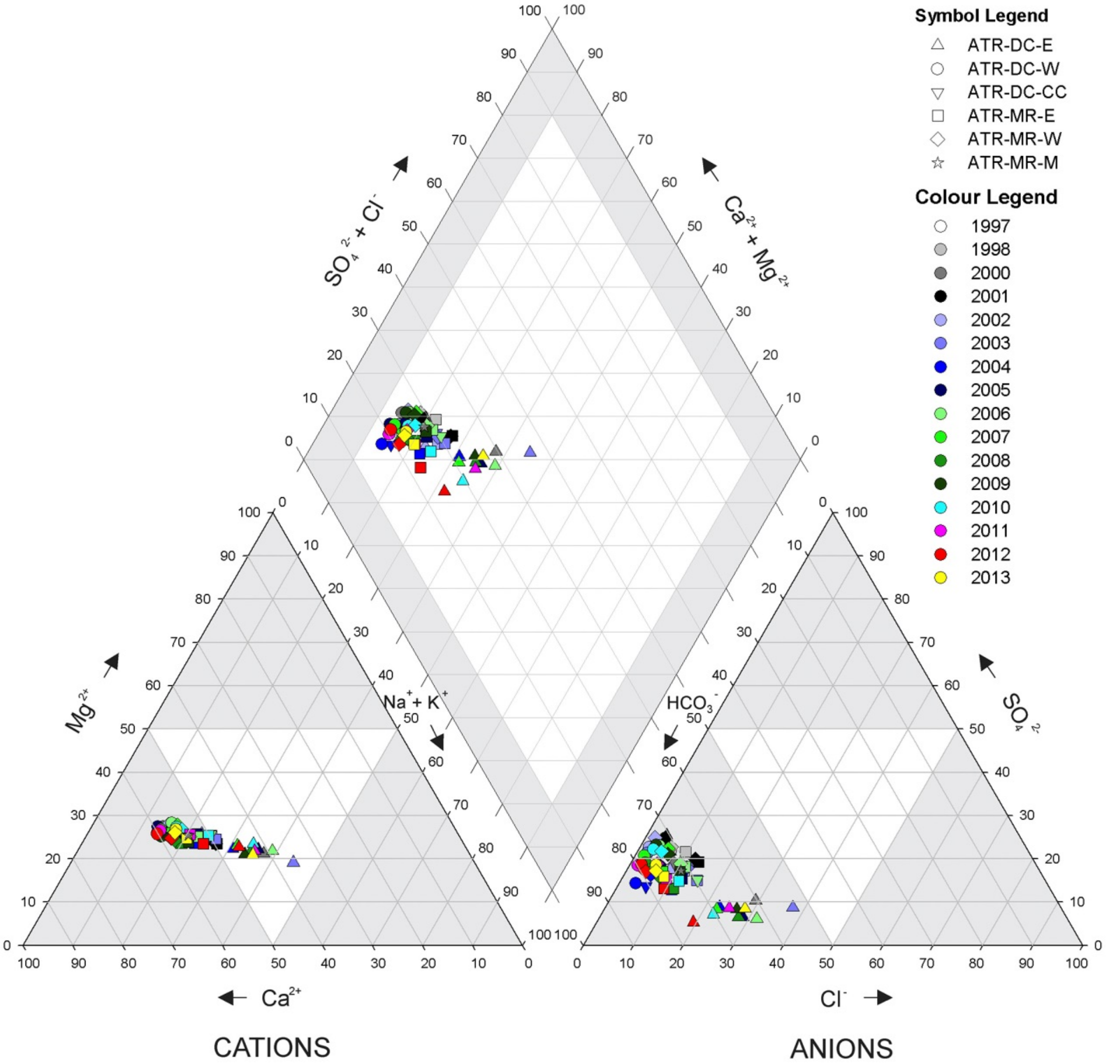


Figure 5.1-6 Piper diagram of ion concentrations in Athabasca River mainstem *test* stations ATR-DD versus *baseline* stations ATR-DC), fall 1997 to 2013.

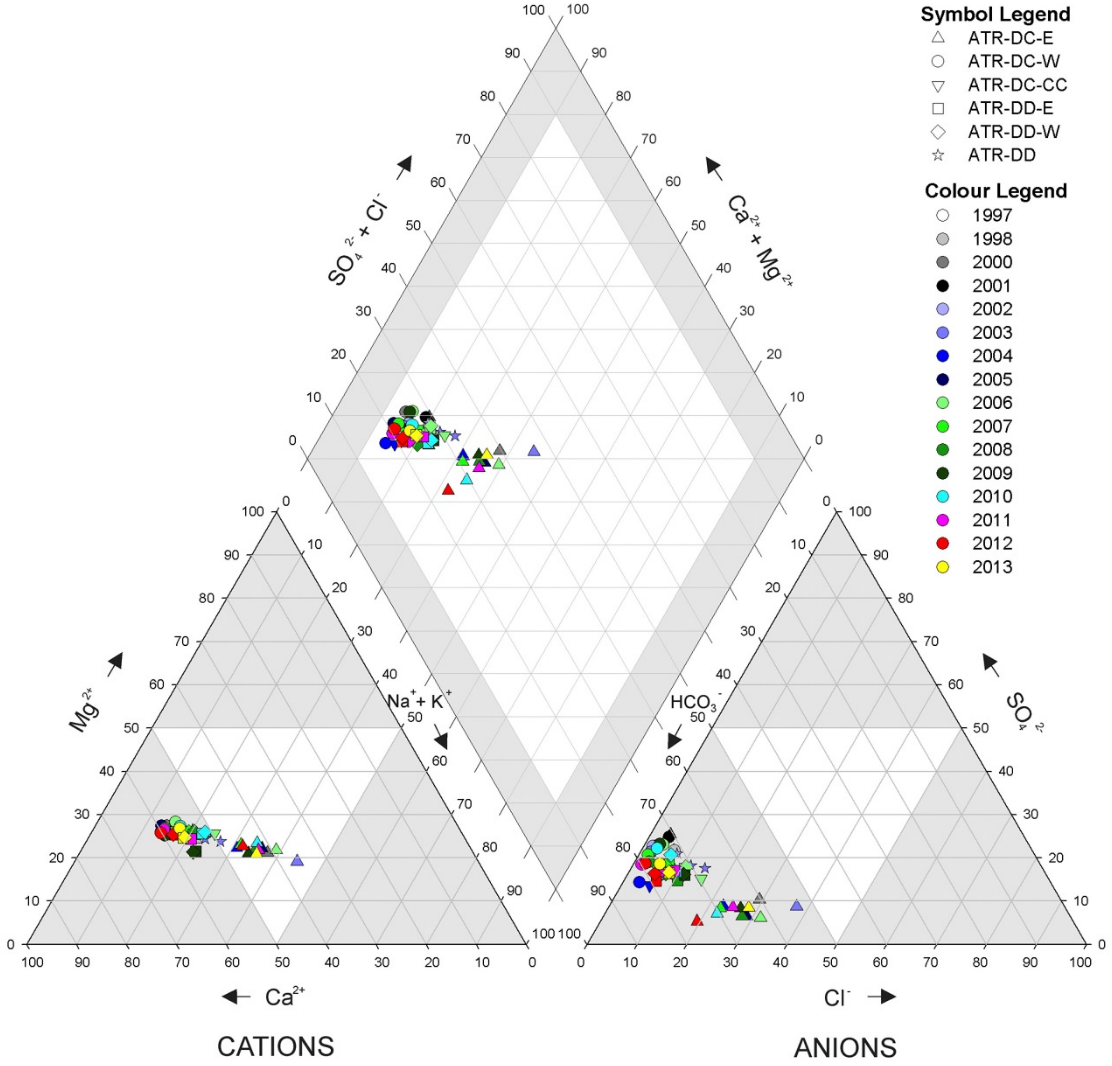


Table 5.1-5 Water quality guideline exceedances in the Athabasca River mainstem, 2013.

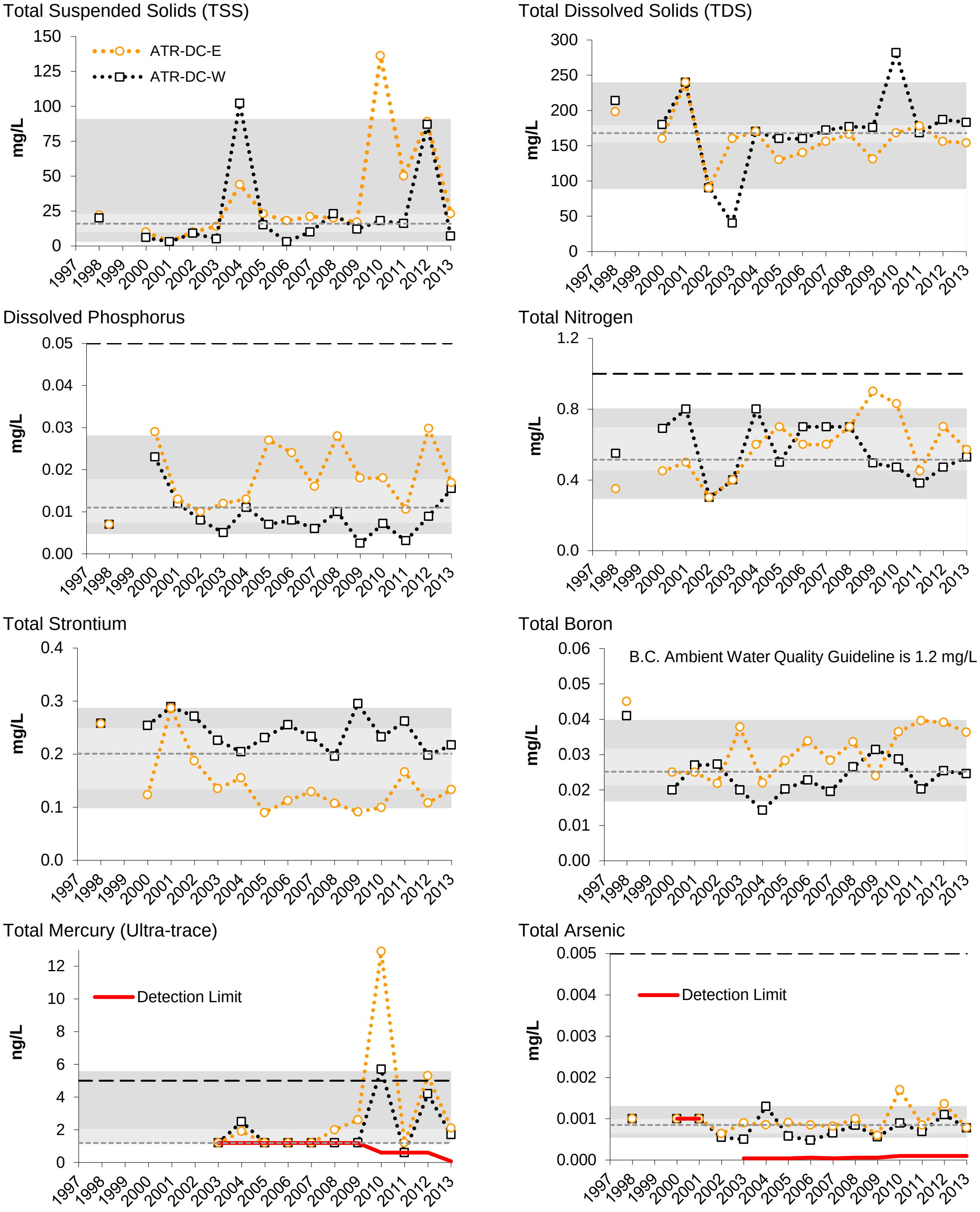
Parameter	Units	Guideline[a]	Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)		Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)		Downstream of Development (ATR-DD-E, ATR-DD-W)	
			East[1]	West	East	West	East	West	East	West
Winter										
Dissolved Iron	mg/L	0.3	0.400	-	ns	ns	ns	ns	0.350	-
Total aluminum	mg/L	0.1	0.111	-	ns	ns	ns	ns	0.156	0.146
Total iron	mg/L	0.3	0.747	-	ns	ns	ns	ns	0.551	0.484
Total phenols	mg/L	0.004	0.0046	0.0044	ns	ns	ns	ns	-	-
Spring										
Dissolved aluminum	mg/L	0.1	0.105	-	ns	ns	ns	ns	-	-
Dissolved copper	mg/L	0.002[b]	-	0.0022	ns	ns	ns	ns	-	0.0022
Dissolved iron	mg/L	0.3	0.412	-	ns	ns	ns	ns	0.342	0.306
Sulphide	mg/L	0.002	0.0156	0.0210	ns	ns	ns	ns	0.0204	0.0193
Total aluminum	mg/L	0.1	11.7	12.3	ns	ns	ns	ns	13.9	16.5
Total cadmium	mg/L	0.00009-0.00014[b]	0.00012	0.00021	ns	ns	ns	ns	0.00021	0.00036
Total chromium	mg/L	0.001	0.00995	0.01070	ns	ns	ns	ns	0.0155	0.0179
Total copper	mg/L	0.002[b]	0.0071	0.0092	ns	ns	ns	ns	0.0106	0.0128
Total iron	mg/L	0.3	10.8	11.5	ns	ns	ns	ns	13.7	16.9
Total lead	mg/L	0.00155[b]	0.0062	0.0084	ns	ns	ns	ns	0.0105	0.0149
Total mercury (ultra-trace)	mg/L	5, 13	7.60	12.8	ns	ns	ns	ns	-	-
Total nitrogen	mg/L	1	1.41	1.34	ns	ns	ns	ns	1.62	1.95
Total phenols	mg/L	0.004	0.0055	0.0054	ns	ns	ns	ns	0.0060	0.0067
Total phosphorus	mg/L	0.05	0.3630	0.3890	ns	ns	ns	ns	0.5340	0.5880
Total silver	mg/L	0.0001	0.00011	0.00017	ns	ns	ns	ns	0.00014	0.00019
Total zinc	mg/L	0.03	-	0.032	ns	ns	ns	ns	0.035	0.045
Summer										
Dissolved Iron	mg/L	0.3	0.967	-	ns	ns	ns	ns	0.398	0.363
Sulphide	mg/L	0.002	0.009	0.003	ns	ns	ns	ns	0.008	0.009
Total aluminum	mg/L	0.1	5.77	7.04	ns	ns	ns	ns	7.93	7.68
Total chromium	mg/L	0.001	0.0042	0.0051	ns	ns	ns	ns	0.0053	0.0051
Total copper	mg/L	0.002[b]	0.0030	0.0042	ns	ns	ns	ns	0.0035	0.0035
Total iron	mg/L	0.3	6.93	6.31	ns	ns	ns	ns	3.75	3.56
Total lead	mg/L	0.0019[b]	0.0020	-	ns	ns	ns	ns	-	-
Total mercury (ultra-trace)	mg/L	5, 13	7.6	9.4	ns	ns	ns	ns	8.7	6.7
Total nitrogen	mg/L	1	1.08	-	ns	ns	ns	ns	-	-
Total phenols	mg/L	0.004	0.006	-	ns	ns	ns	ns	-	-
Total phosphorus	mg/L	0.05	0.187	0.165	ns	ns	ns	ns	0.137	0.135
Fall										
Dissolved iron	mg/L	0.3	0.331	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	-	-	0.0036	-	-	-	-	-
Total chromium	mg/L	0.001	-	-	0.0022	-	-	-	-	-
Total iron	mg/L	0.3	1.33	0.738	2.03	0.634	0.683	0.736	0.752	0.447
Total phenols	mg/L	0.004	-	-	0.005	0.004	0.012	-	-	0.005
Total phosphorus	mg/L	0.05	0.061	-	0.097	-	-	-	-	-
Total silver	mg/L	0.0001	0.00012	-	-	-	-	-	-	-

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.

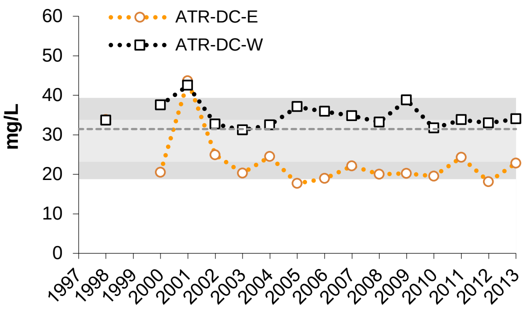
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

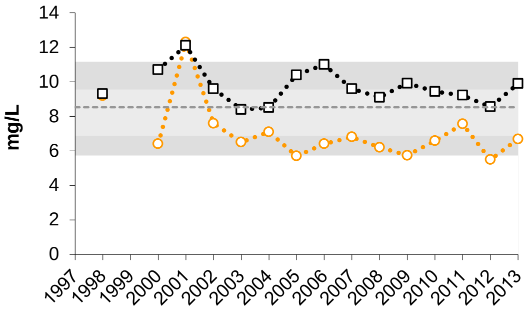
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.1-7 (Cont'd.)

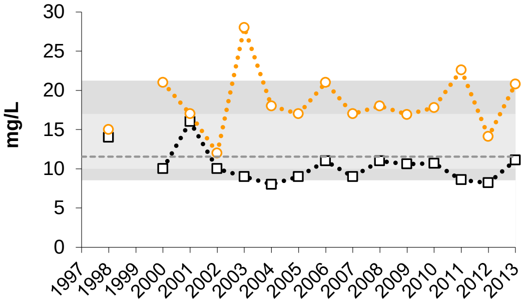
Calcium



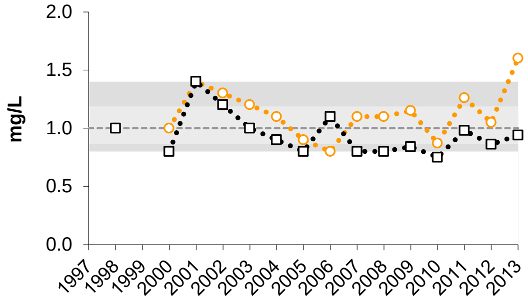
Magnesium



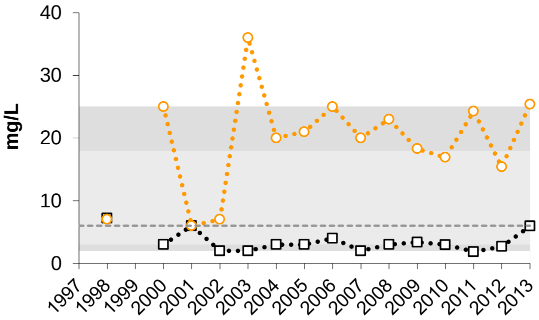
Sodium



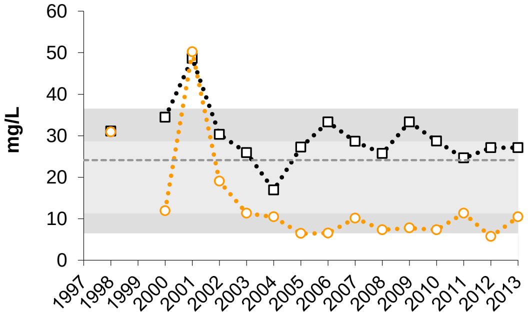
Potassium



Chloride



Sulphate



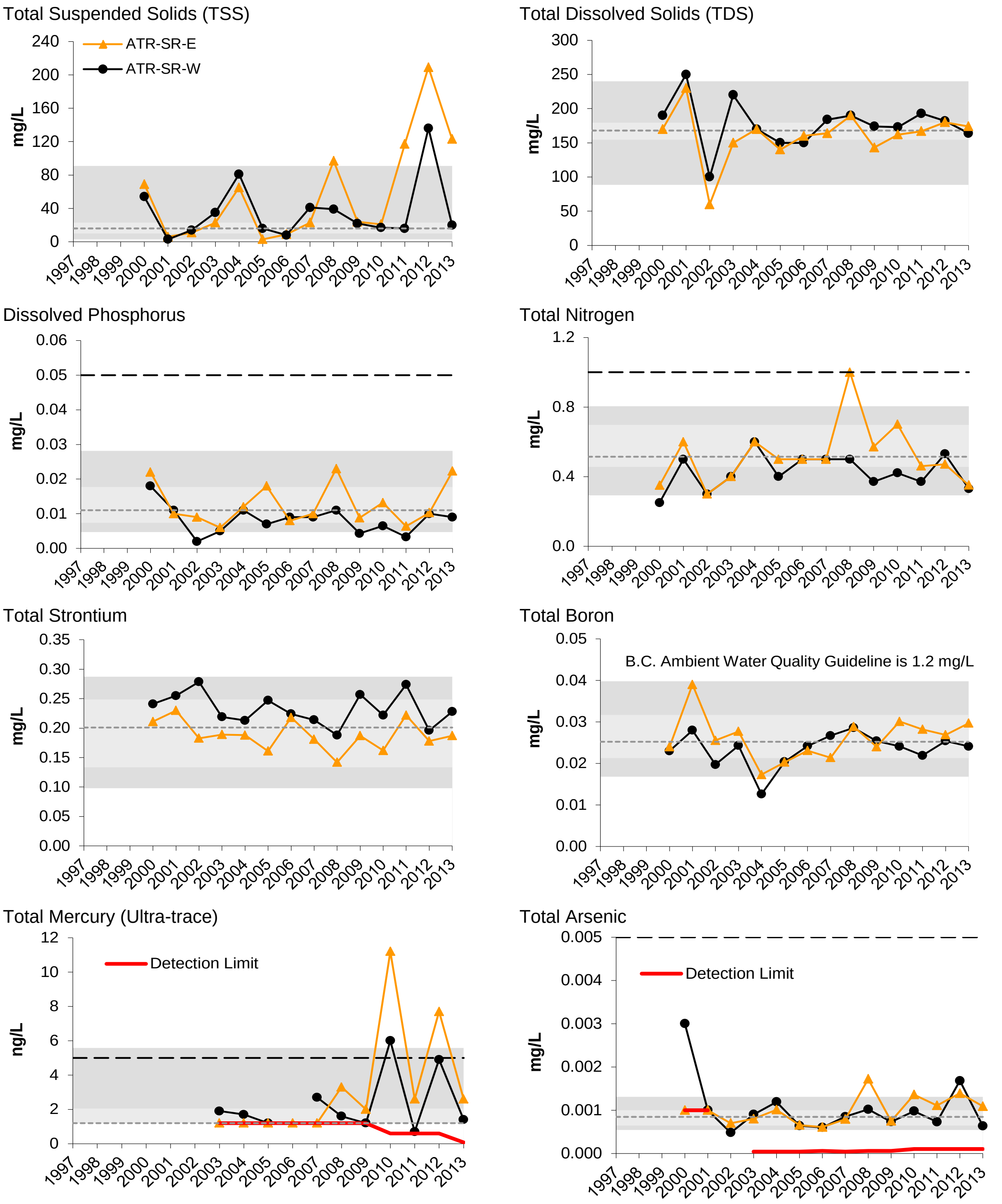
Non-detectable values are shown at the detection limit.

- - - - - 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 3.2.2.2 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).**



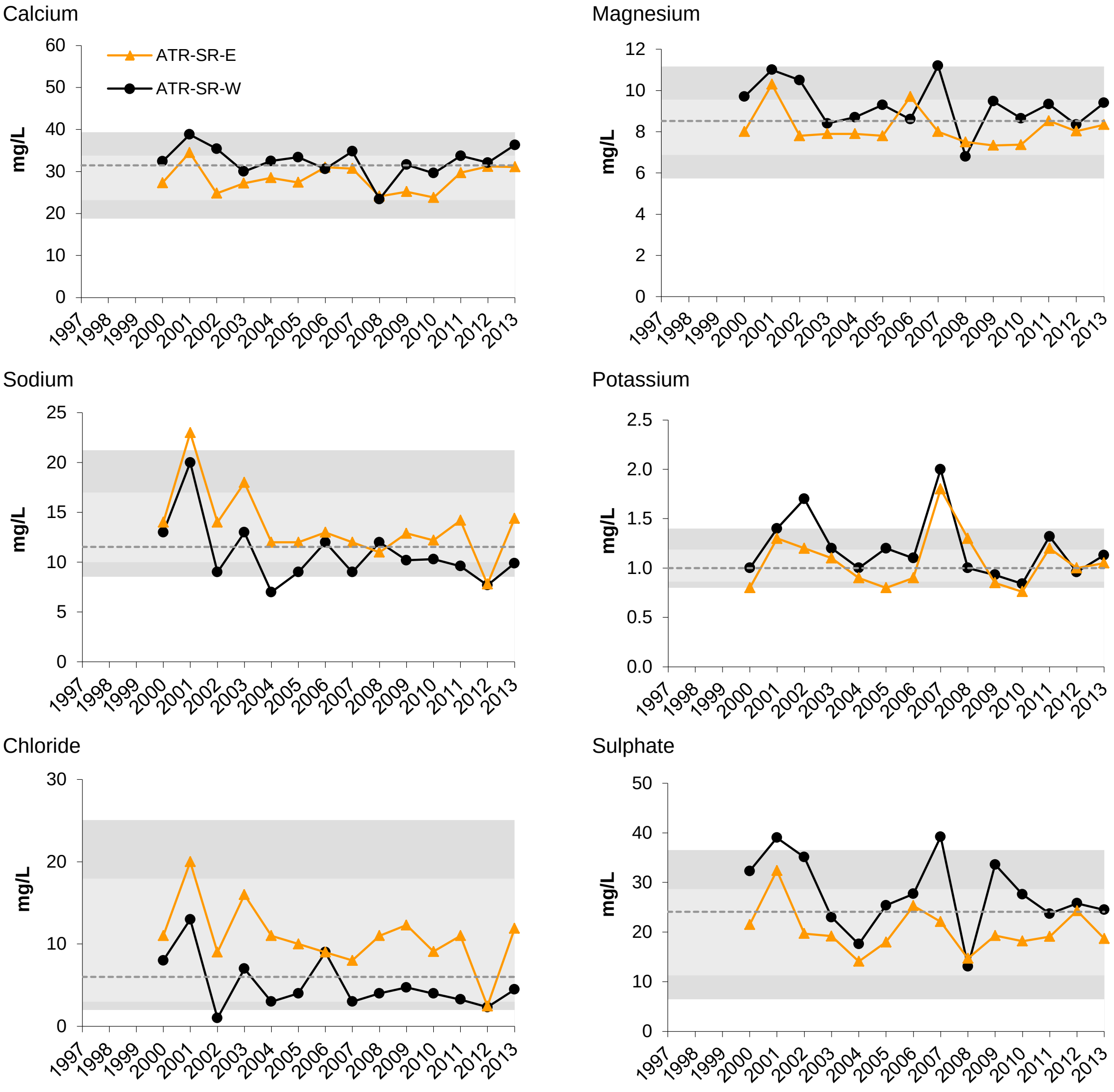
Non-detectable values are shown at the detection limit.

- - - - - 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 3.2.2.2 for a discussion of this approach.

Figure 5.1-8 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

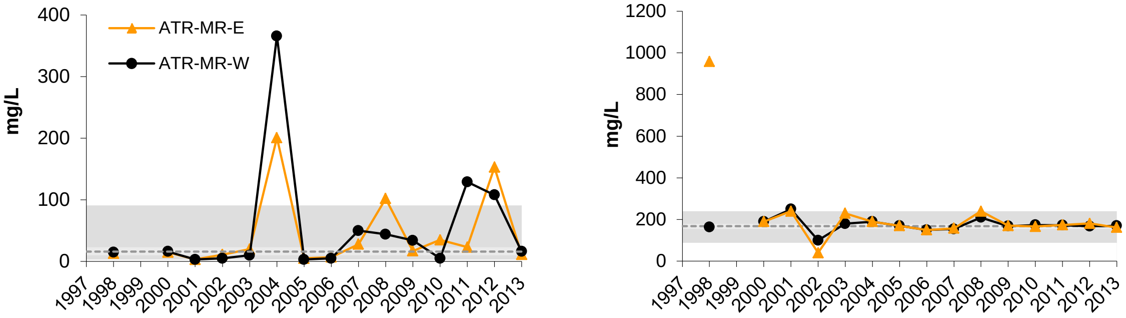
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 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).**

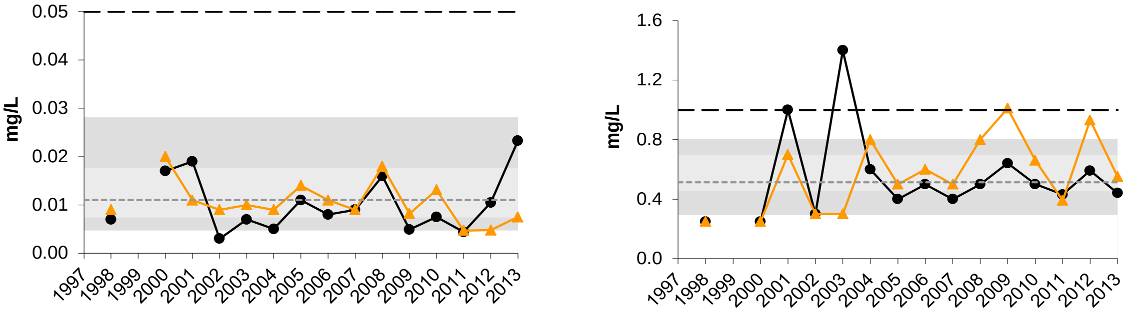
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



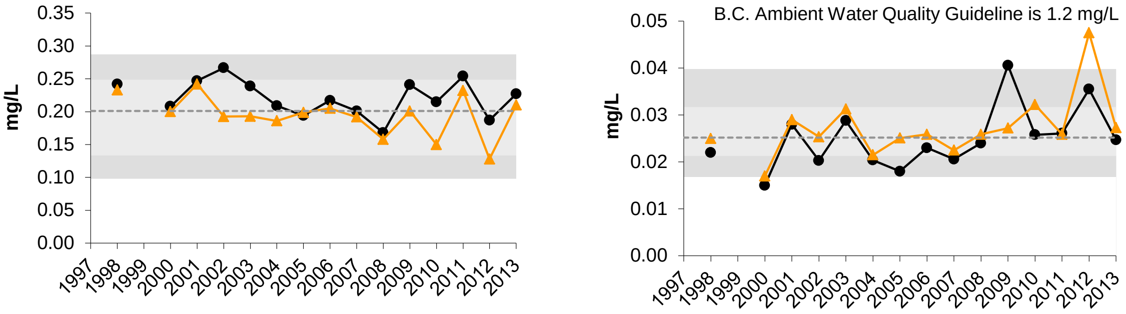
Dissolved Phosphorus

Total Nitrogen



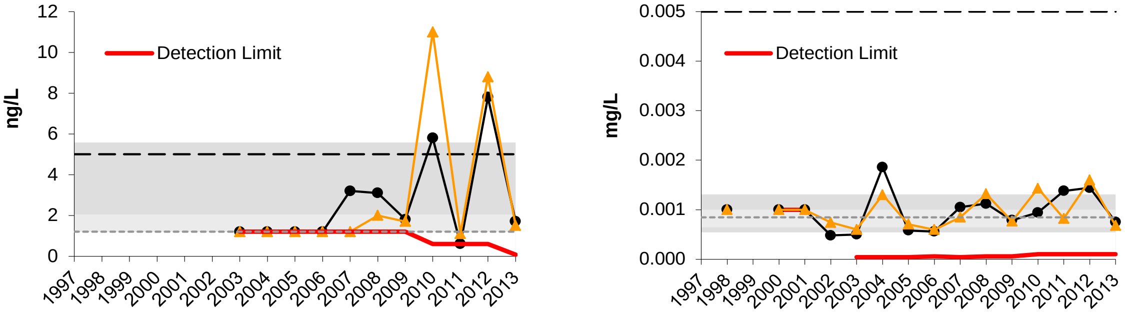
Total Strontium

Total Boron



Total Mercury (Ultra-trace)

Total Arsenic



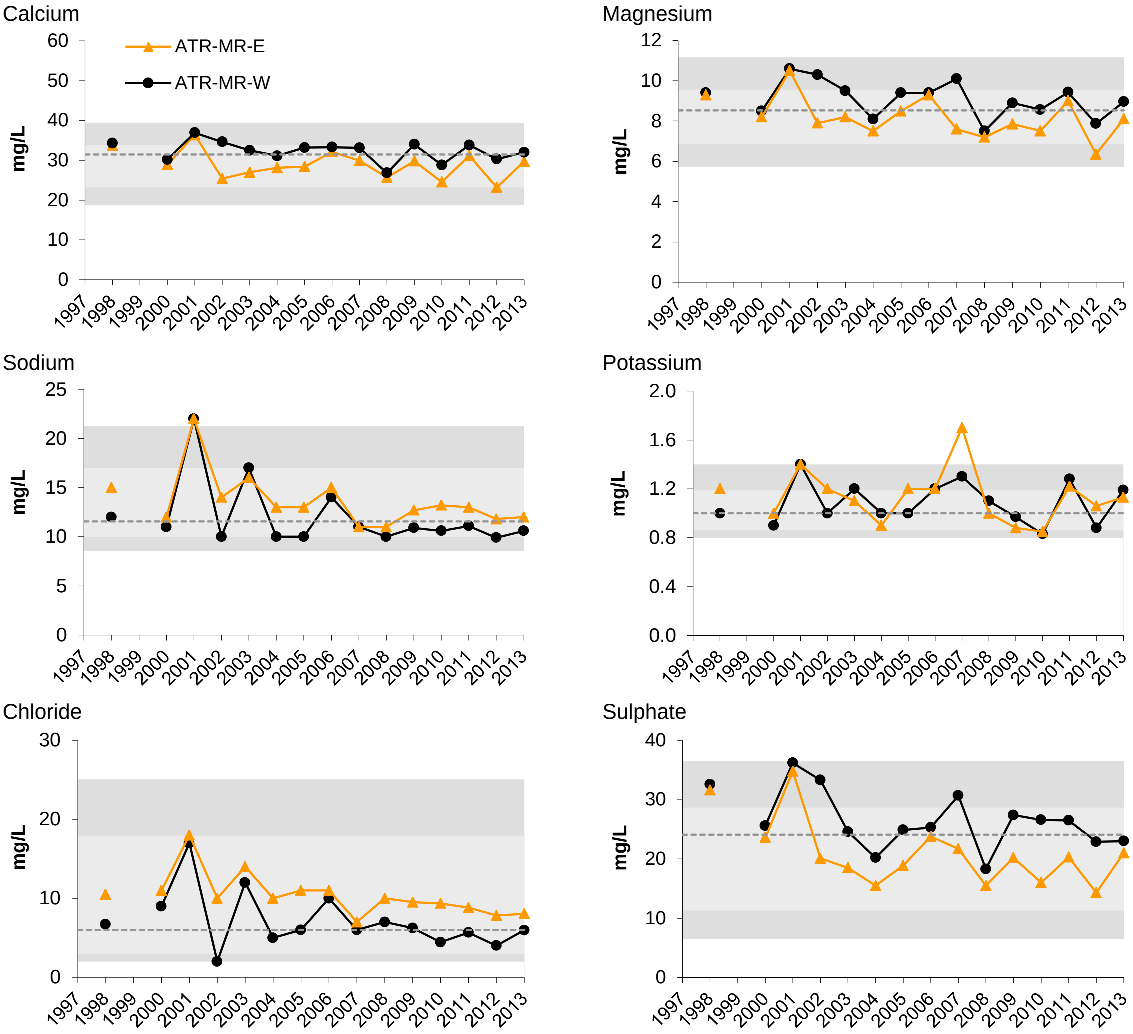
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.1-9 (Cont'd.)



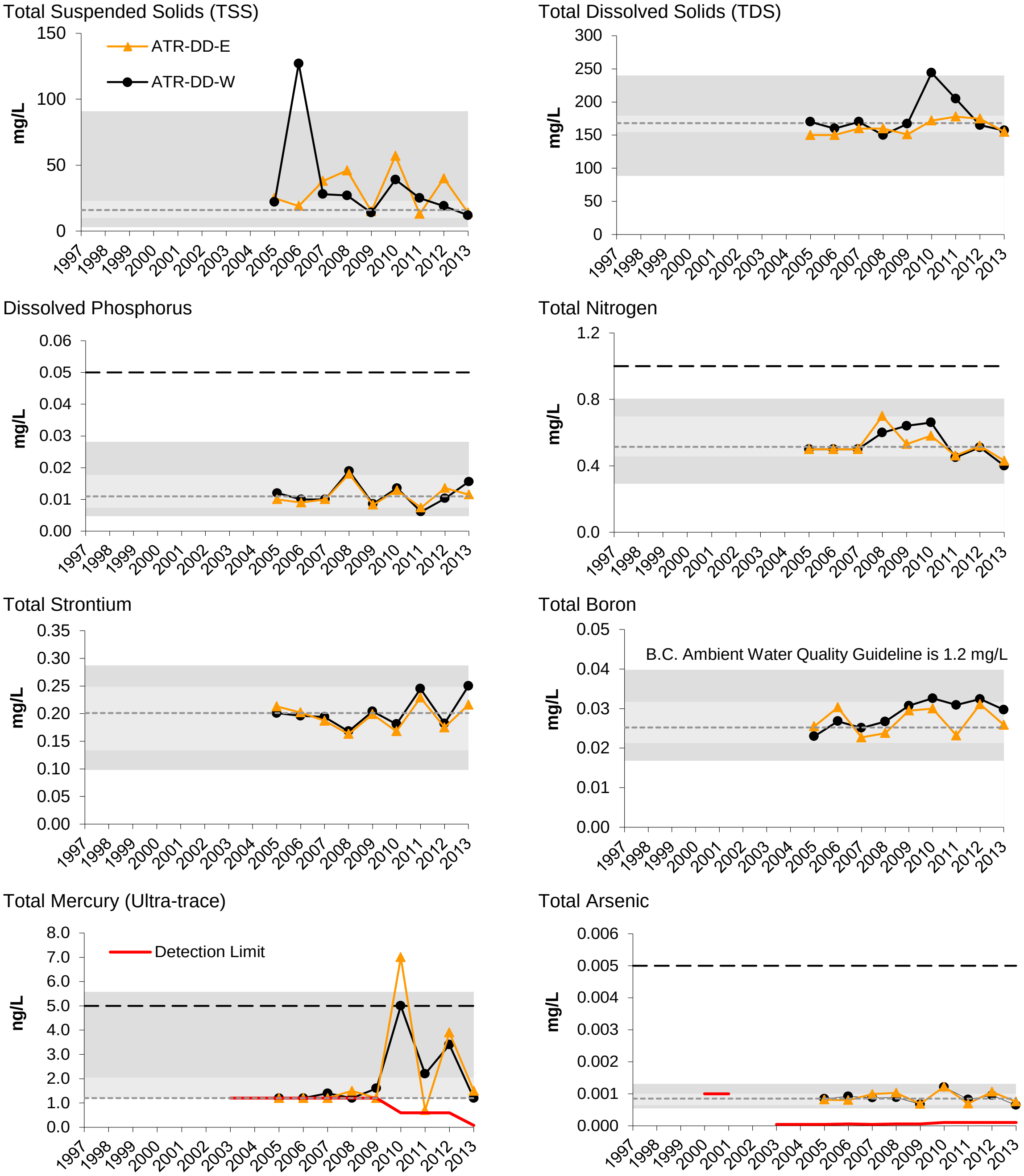
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.1-10 Concentrations of selected water quality measurement endpoints (fall data) relative to historical concentrations and regional *baseline* fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD).



Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

Total Arsenic

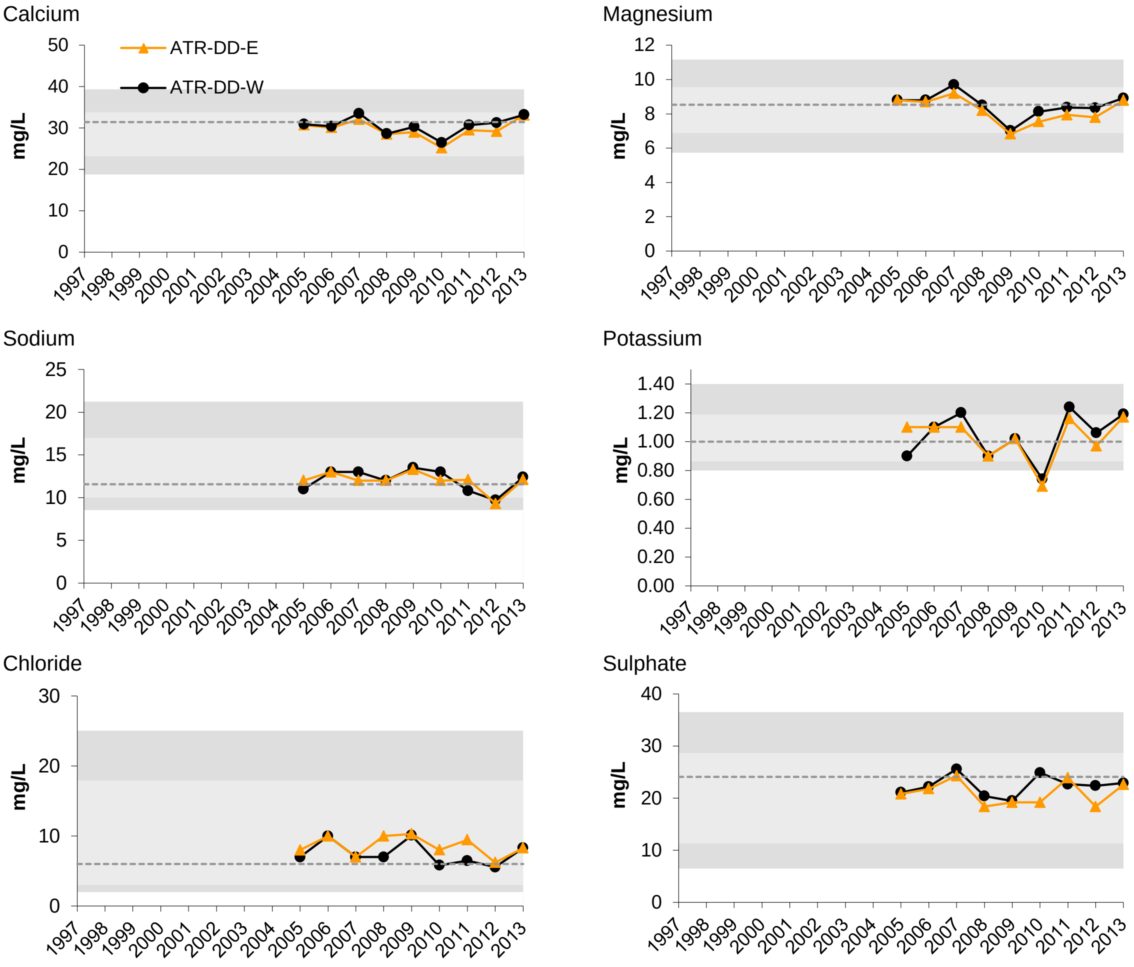
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.1-10 (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 3.2.2.2 for a discussion of this approach.

Table 5.1-6 Water quality index (fall 2013) for Athabasca River mainstem stations.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
ATR-DC-E	Upstream of Donald Creek, East Bank	*baseline*	98.7	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*	97.4	Negligible-Low
ATR-SR-W	Upstream of the Steepbank River, West Bank	*test*	100.0	Negligible-Low
ATR-MR-E	Upstream of the Muskeg River, East Bank	*test*	98.7	Negligible-Low
ATR-MR-W	Upstream of the Muskeg River, West Bank	*test*	100.0	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 2013.

Variable	Units	BPC-1 Big Point Channel	FLC-1 Fletcher Channel	GIC-1 Goose Island Channel	EMR-2 Embarras River
Sample date	-	Sept 7, 2013	Sept 7, 2013	Sept 7, 2013	Sept 7, 2013
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	3.7	1.9	2.7	2.4
Current velocity	m/s	0.41	0.21	0.36	0.20
Field Water Quality					
Dissolved oxygen	mg/L	6.2	8.9	7.2	-
Conductivity	µS/cm	247	254	293	258
pH	pH units	7.8	7.9	7.5	8.0
Water temperature	°C	18.4	19.8	18.5	19.4
Sediment Composition					
Sand	%	87	58	49	13
Silt	%	9	33	38	57
Clay	%	4	9	13	30
Total Organic Carbon	%	0.44	1.18	2.17	2.91

Table 5.1-8 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Big Point Channel of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach BPC-1		
	2003	2004 to 2012	2013
Nematoda	<1	<1 to 7	<1
Erpobdellidae		0 to <1	
Naididae	1	0 to 7	4
Tubificidae	75	46 to 75	29
Hydracarina	<1	0 to <1	
Amphipoda		0 to 2	
Gastropoda	4	0 to 12	
Bivalvia	10	<1 to 37	
Ceratopogonidae	1	<1 to 7	2
Chironomidae	6	3 to 63	64
Diptera (misc)	0 to <1	0 to 4	<1
Ephemeroptera	<1	0 to 2	<1
Anisoptera	<1	0 to <1	
Plecoptera		0 to <1	
Trichoptera	1	0 to 4	
Heteroptera	<1	0 to <1	
Megaloptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	267	107 to 2,359	36
Richness	11	7 to 15	6
Equitability	0.17	0.15 to 0.60	0.74
% EPT	1	0 to 19	<1

Table 5.1-9 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Fletcher Channel of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach FLC-1		
	2002	2003 to 2012	2013
Nematoda	5	0 to 22	2
Naididae	<1	0 to 15	1
Tubificidae	2	10 to 81	19
Hydracarina		0 to <1	
Macrothricidae	<1	0 to <1	
Gastropoda	1	0 to 14	
Bivalvia	1	<1 to 13	1
Ceratopogonidae	2	<1 to 10	6
Chironomidae	86	4 to 79	68
Diptera (misc)	0 to <1	0 to <1	<1
Ephemeroptera	<1	0 to 2	
Odonata		0 to <1	<1
Plecoptera		0 to 1	
Trichoptera		0 to 2	3
Heteroptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	1,034	6 to 2,639	75
Richness	12	4 to 12	6
Equitability	0.20	0.13 to 0.89	0.66
% EPT	1	0 to 6	3

Table 5.1-10 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Goose Island Channel and the Embarras River of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach GIC-1			*Test* Reach EMR-2		
	2002	2003 to 2012	2013	2010	2011 to 2012	2013
Nematoda	5	0 to 2	1	1	6 to 12	7
Hydra			2			
Erpobdellidae					<1	
Glossiphoniidae					1	
Oligochaeta					<1	
Naididae		0 to 7	8	<1	<1	7
Tubificidae	<1	23 to 62	13	1	<1 to 4	21
Lumbriculidae		0 to <1				
Hydracarina	<1	0 to <1	<1	<1		<1
Amphipoda		0 to <1				
Cladocera			<1			
Macrothricidae	<1	0 to 2				
Gastropoda	5	0 to 24		<1	<1	11
Bivalvia	13	<1 to 4	2	29	7	2
Ceratopogonidae	1	1 to 17	1	4	16	20
Chironomidae	74	13 to 64	66	41	29 to 81	31
Diptera (misc.)		0 to <1	1			
Tipulidae		0 to <1				
Ephemeroptera		0 to 1	1	<1	10	<1
Odonata	<1	0 to <1	1			
Trichoptera	<1	0 to 2		3	<1	<1
Heteroptera		0 to <1				
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	781	41 to 806	97	1,022	27 to 241	360
Richness	14	8 to 12	9	23	5 to 13	13
Equitability	0.18	0.24 to 0.52	0.44	0.33	0.35 to 0.56	0.24
% EPT	<1	0 to 2	3	3	<1 to 10	<1

Table 5.1-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Big Point Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs, Previous Years	
Log of Abundance	**0.027**	0.083	12	7	Decreasing over time.
Log of Richness	0.134	0.558	21	3	No change.
Equitability	0.060	**0.044**	14	17	Higher in 2013 than mean of previous years.
Log of EPT	0.719	0.206	1	13	No change.
CA Axis 1	**0.002**	**0.020**	13	7	Decreasing over time; lower in 2013 than mean of previous years.
CA Axis 2	0.056	**<0.001**	9	59	Higher in 2013 than mean of previous years.

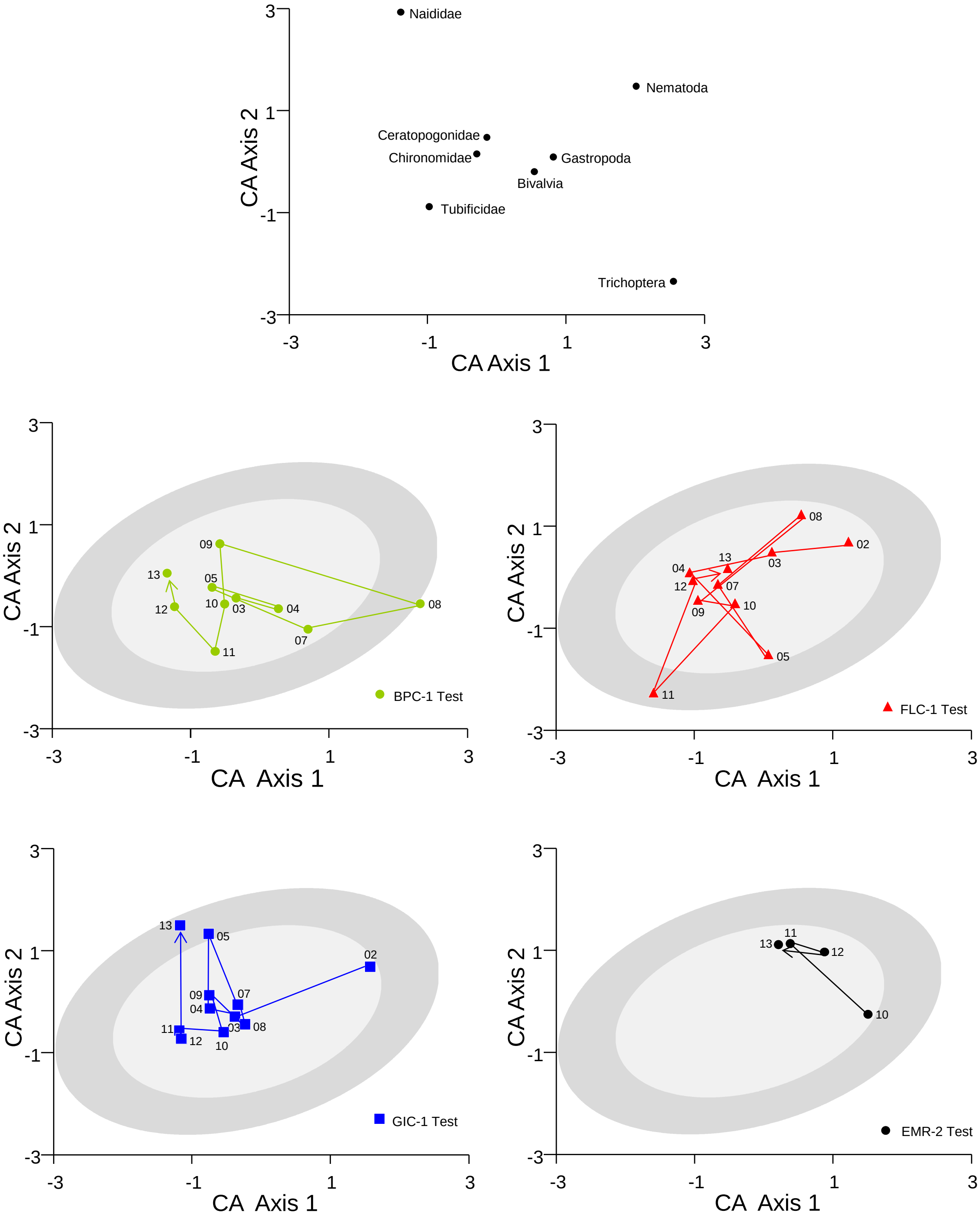
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

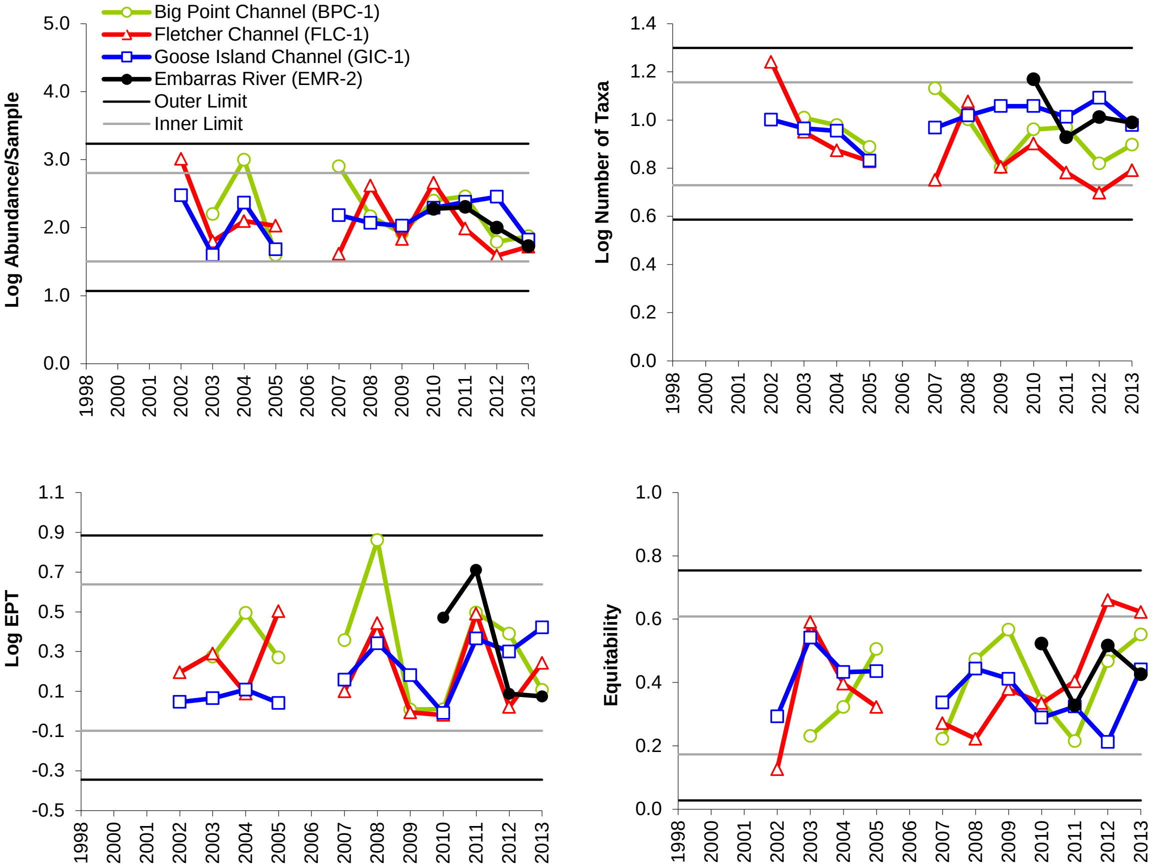
Note: Data for abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.1-11 Ordination (Correspondence Analysis) of benthic invertebrate communities of channels of the ARD.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile all ARD reaches for years up to and including 2012.

Figure 5.1-12 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta, 2002 to 2013.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all ARD reaches for years up to and including 2012.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.1-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Fletcher Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs. Previous Years	
Log of Abundance	**0.045**	0.186	15	7	Decreasing over time.
Log of Richness	0.006	0.394	40	4	Decreasing over time.
Equitability	**<0.001**	**<0.001**	27	20	Increasing over time; higher in 2013 than mean of previous years.
Log of EPT	0.895	0.690	0	1	No change.
CA Axis 1	**<0.001**	**0.028**	14	6	Increasing over time; lower in 2013 than mean of previous years.
CA Axis 2	0.129	**<0.001**	3	14	Higher in 2013 than mean of previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.1-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Goose Island Channel of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs. Previous Years	
Log of Abundance	0.398	**0.032**	2	10	Lower in 2013 than mean of previous years.
Log of Richness	0.069	0.778	23	1	No change.
Equitability	0.067	0.252	13	5	No change.
Log of EPT	**0.002**	**0.015**	58	34	Increasing over time; higher in 2013 than mean of previous years.
CA Axis 1	**<0.001**	0.870	27	0	Decreasing over time.
CA Axis 2	**0.010**	0.465	20	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).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.1-14 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Embarras River of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs. Previous Years	
Log of Abundance	**0.007**	**0.011**	87	74	Decreasing over time; lower in 2013 than mean of previous years.
Log of Richness	**0.010**	0.259	33	5	Decreasing over time.
Equitability	0.785	0.758	2	2	No change.
Log of EPT	0.216	0.184	22	25	No change.
CA Axis 1	**<0.001**	**<0.001**	75	95	Decreasing over time; lower in 2013 than mean of previous years.
CA Axis 2	0.645	0.180	2	17	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}$ (x+1) transformed.

Table 5.1-15 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC-1).

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.1	11	3.4	17.0	32.0
Silt	%	-	9.6	11	5.0	45.0	58.0
Sand	%	-	86.3	11	10.0	38.0	91.7
Total organic carbon	%	-	0.51	11	<0.10	1.20	2.24
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<10	<21
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<10	<21
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	7	<5	<20	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	27	7	110	178	**307**
Fraction 4 (C34-C50)	mg/kg	2800[1]	29	7	33	102	199
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0022	11	0.0030	0.0089	0.0240
Retene	mg/kg	-	0.016	11	0.024	0.051	0.096
Total dibenzothiophenes	mg/kg	-	0.108	11	0.104	0.236	0.358
Total PAHs	mg/kg	-	0.571	11	0.718	1.358	2.028
Total Parent PAHs	mg/kg	-	0.037	11	0.050	0.106	0.209
Total Alkylated PAHs	mg/kg	-	0.534	11	0.668	1.250	1.879
Predicted PAH toxicity[3]	H.I.	1.0	**2.05**	11	0.83	**1.16**	**2.59**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	5.6	10	3.2	7.3	9.0
Chironomus growth - 10d	mg/organism	-	4.11	10	0.89	1.84	3.60
Hyalella survival - 14d	# surviving	-	8.0	10	6.6	8.1	10.0
Hyalella growth - 14d	mg/organism	-	0.11	10	0.05	0.15	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

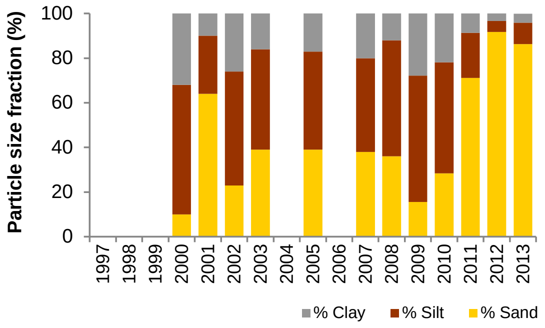
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

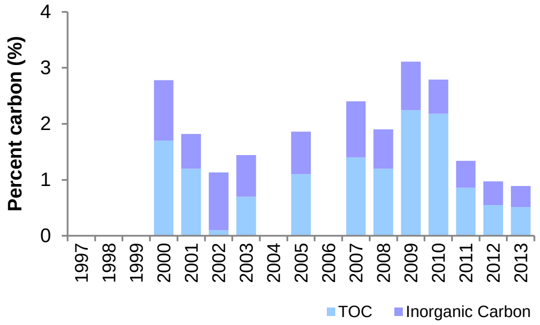
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-13 Characteristics of sediment collected in Big Point Channel (BPC-1), 1999 to 2013 (fall data only).

Particle size distribution



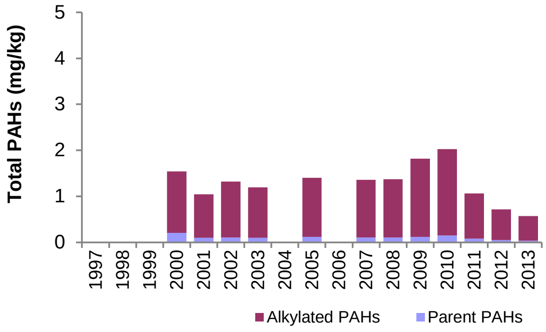
Carbon Content



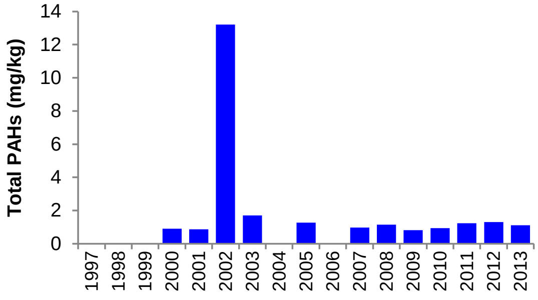
Total Metals[1]

Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)

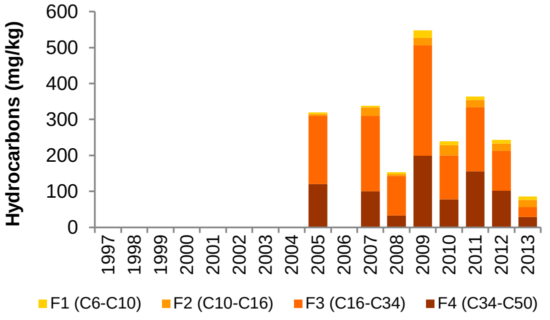
Total PAHs



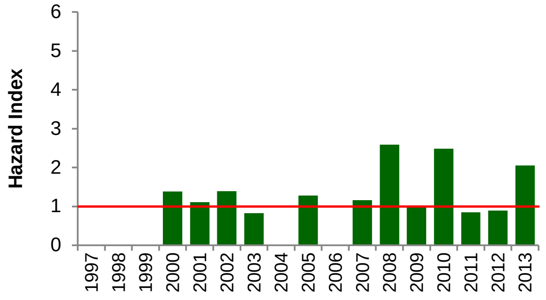
Total PAHs normalized to 1% TOC



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 5.1-16 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC-1).

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	15.6	10	3.6	13.0	22.8
Silt	%	-	57.4	10	3.4	36.5	72.0
Sand	%	-	27.0	10	11.0	48.8	93.0
Total organic carbon	%	-	2.21	10	0.58	1.15	2.22
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	10	30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	10	30
Fraction 2 (C10-C16)	mg/kg	150[1]	37	7	<5	21	30
Fraction 3 (C16-C34)	mg/kg	300[1]	**369**	7	68	208	**430**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	243	7	49	170	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0106	9	0.0021	0.0070	0.0156
Retene	mg/kg	-	0.157	10	0.020	0.041	0.105
Total dibenzothiophenes	mg/kg	-	0.686	10	0.089	0.178	0.591
Total PAHs	mg/kg	-	3.206	10	0.586	1.116	2.745
Total Parent PAHs	mg/kg	-	0.141	10	0.041	0.095	0.160
Total Alkylated PAHs	mg/kg	-	3.065	10	0.545	1.022	2.615
Predicted PAH toxicity[3]	H.I.	1.0	**1.42**	10	0.40	0.84	**5.36**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.8	8	3.4	6.4	9.4
Chironomus growth - 10d	mg/organism	-	4.26	8	1.08	2.16	3.60
Hyalella survival - 14d	# surviving	-	9.0	8	8.0	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.29	7	0.10	0.19	0.34

Values in **bold** indicate concentrations exceeding guidelines.

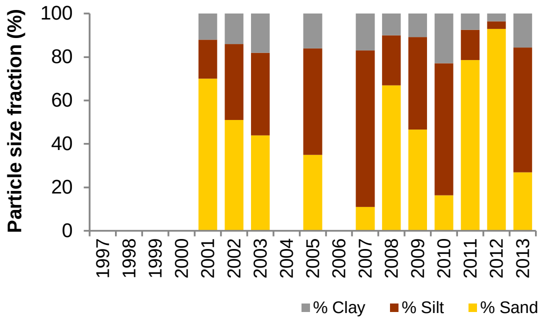
Values underlined indicate concentrations outside the range of historic observations.

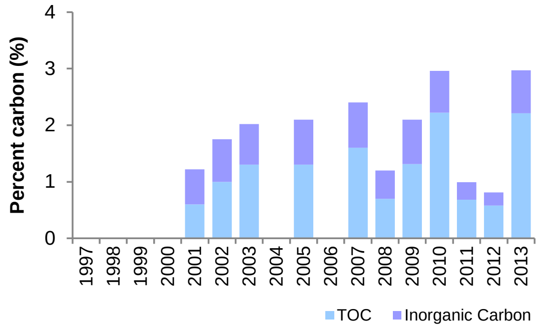
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

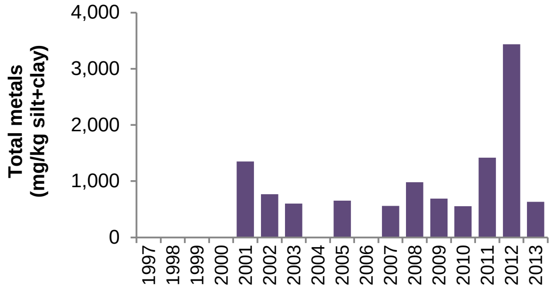
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

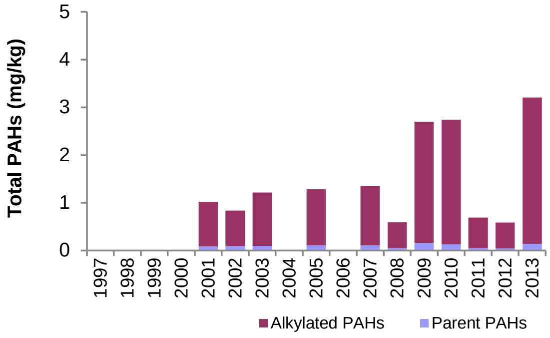
Figure 5.1-14 Characteristics of sediment collected in Fletcher Channel (FLC-1), 2001 to 2013 (fall data only).

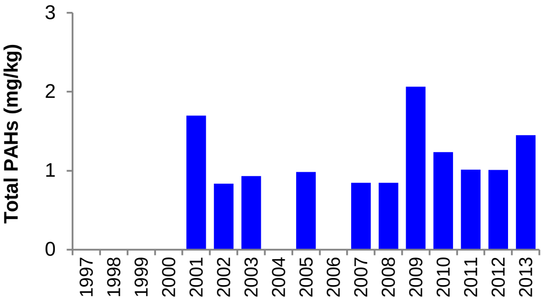

Particle size distribution

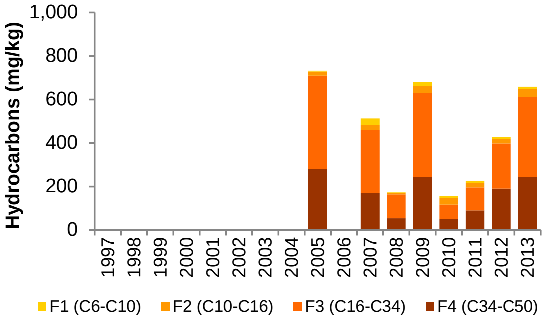

Carbon Content

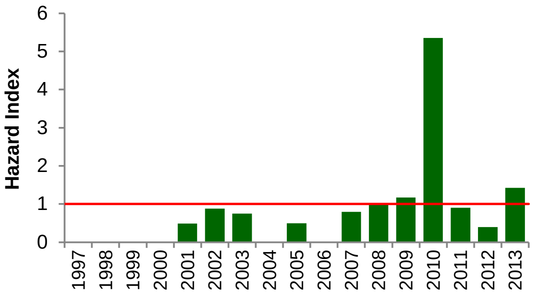

Total Metals[1]


Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)


Total PAHs


Total PAHs normalized to 1% TOC


CCME Hydrocarbon Fractions


PAH Hazard Index[2]

[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-17 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC-1).

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7.9	10	2.2	14.6	28.0
Silt	%	-	21.0	10	8.8	46.7	58.0
Sand	%	-	71.1	10	17.0	35.3	89.0
Total organic carbon	%	-	0.90	10	0.47	1.44	2.40
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	7	<5	20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	130	7	39	180	**360**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	116	7	46	110	200
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0069	10	0.0028	0.0068	0.0146
Retene	mg/kg	-	0.048	10	0.006	0.039	0.078
Total dibenzothiophenes	mg/kg	-	0.326	10	0.043	0.221	0.412
Total PAHs	mg/kg	-	1.764	10	0.294	1.238	2.161
Total Parent PAHs	mg/kg	-	0.099	10	0.021	0.110	0.177
Total Alkylated PAHs	mg/kg	-	1.665	10	0.273	1.122	1.984
Predicted PAH toxicity[3]	H.I.	1.0	**1.88**	10	0.64	**1.03**	**1.58**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.2	8	4.0	7.4	8.4
Chironomus growth - 10d	mg/organism	-	4.22	8	1.34	2.08	4.20
Hyalella survival - 14d	# surviving	-	9.8	8	7.0	8.9	10.0
Hyalella growth - 14d	mg/organism	-	0.18	8	0.10	0.19	0.30

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).

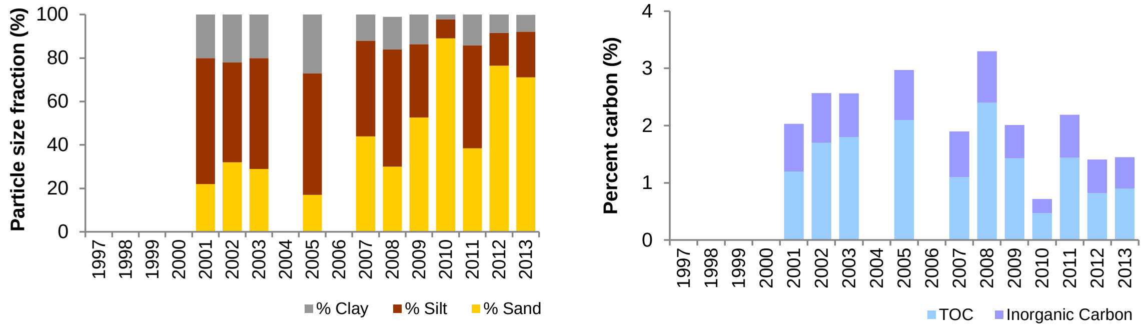
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.1-15 Characteristics of sediment collected in Goose Island Channel (GIC-1), 2001 to 2013 (fall data only).

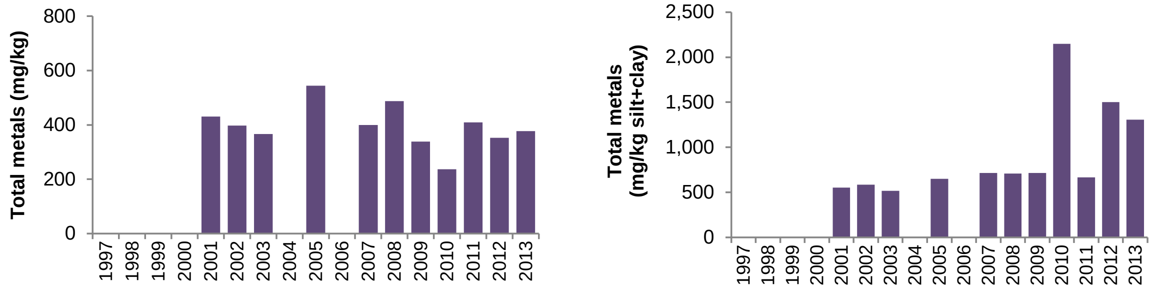
Particle size distribution

Carbon Content



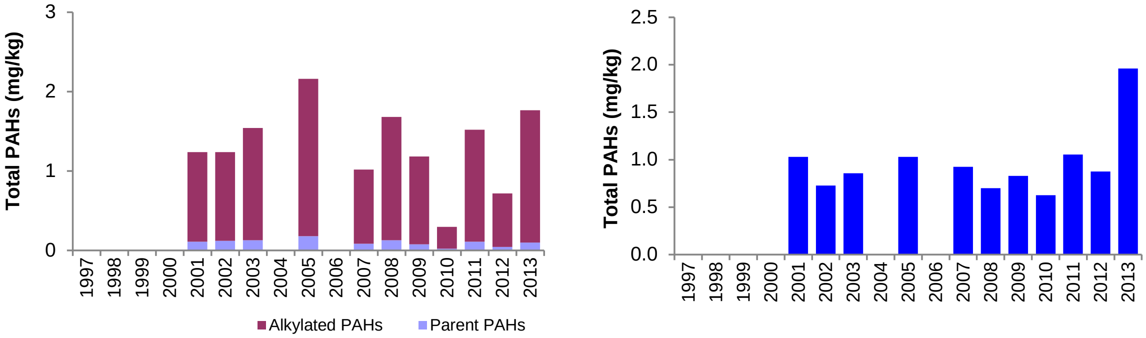
Total Metals[1]

Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



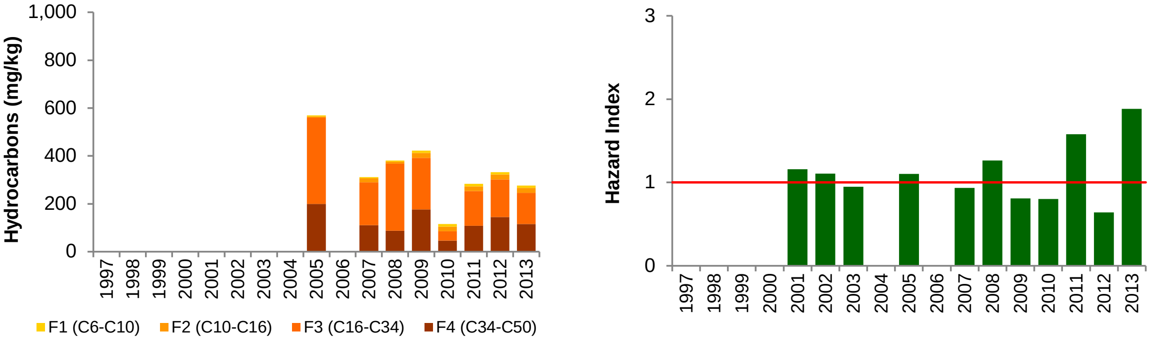
Total PAHs

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 5.1-18 Concentrations of sediment quality measurement endpoints, Embarras River (EMR-2).

Variables	Units	Guideline	September 2013	2005-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay[4]	%	-	27.5	3	32.4	37.7	43.0
Silt[4]	%	-	46.8	3	53	55	57
Sand[4]	%	-	25.7	3	4	9	10
Total organic carbon	%	-	2.68	3	2.41	2.58	2.60
Total hydrocarbons							
BTEX	mg/kg	-	<20	3	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	3	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	54	3	<5	<32	<33
Fraction 3 (C16-C34)	mg/kg	300[1]	279	3	54	222	**390**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	174	3	36	164	190
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0126	3	0.0113	0.0177	0.0245
Retene	mg/kg	-	0.094	3	0.072	0.116	0.130
Total dibenzothiophenes	mg/kg	-	0.507	3	0.278	0.483	0.492
Total PAHs	mg/kg	-	2.69	3	2.09	2.62	2.63
Total Parent PAHs	mg/kg	-	0.163	3	0.167	0.174	0.204
Total Alkylated PAHs	mg/kg	-	2.53	3	1.92	2.42	2.45
Predicted PAH toxicity[3]	H.I.	1.0	**1.50**	3	**1.29**	**1.34**	**5.96**
Metals that exceeded CCME guidelines in 2013							
Total Arsenic	mg/kg	5.9	**7.6**	3	**7.0**	**8.1**	**8.2**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.2	2	6.8	7.1	7.4
Chironomus growth - 10d	mg/organism	-	2.45	2	1.62	1.83	2.04
Hyalella survival - 14d	# surviving	-	4.2	2	8.8	9.1	9.4
Hyalella growth - 14d	mg/organism	-	0.10	2	0.20	0.21	0.21

Values in **bold** indicate concentrations exceeding guidelines.

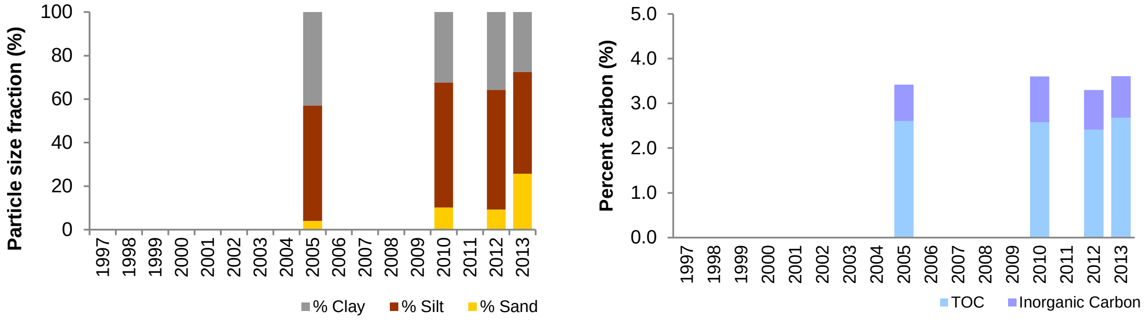
Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

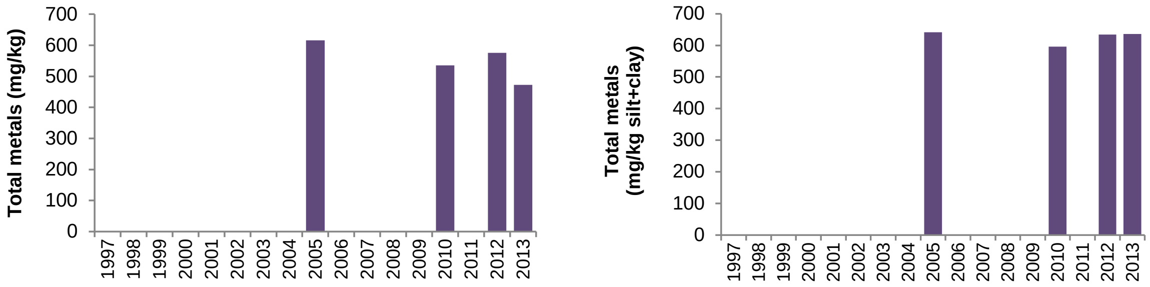
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-16 Characteristics of sediment collected in the Embarras River (EMR-2), 2005, 2010, and 2012 to 2013 (fall data only).



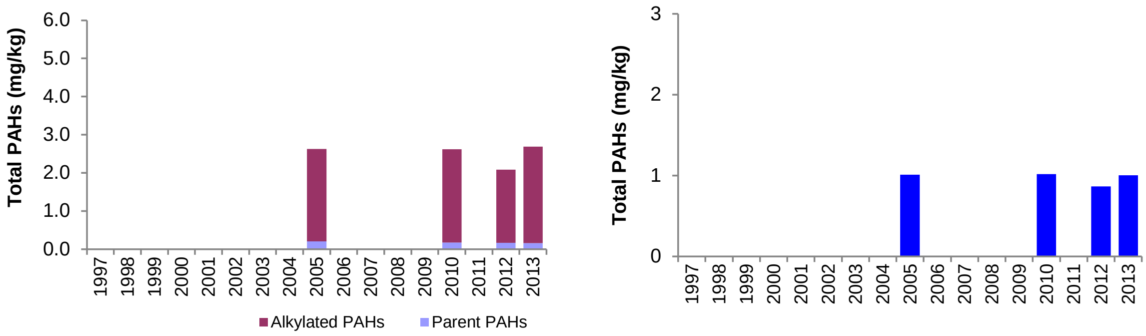
Particle size distribution

Carbon Content



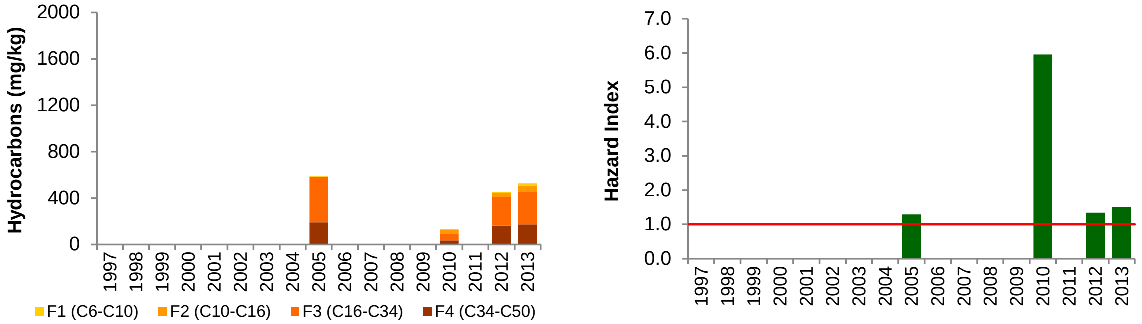
Total Metals[1]

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 5.1-19 Concentrations of sediment quality measurement endpoints, Athabasca River mainstem upstream of Embarras River (ATR-ER).

Variables	Units	Guideline	September 2013	2000-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.2	12	0.5	11.5	22.0
Silt	%	-	6.5	12	0.5	31.0	42.0
Sand	%	-	90.3	12	36	57.0	99.0
Total organic carbon	%	-	0.34	12	0.10	1.02	1.70
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	8	11	20	39
Fraction 3 (C16-C34)	mg/kg	300[1]	21	8	<20	191	**570**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	27	8	24	161	340
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0022	12	0.0005	0.0073	**0.0370**
Retene	mg/kg	-	0.006	12	0.002	0.037	0.081
Total dibenzothiophenes	mg/kg	-	0.044	12	0.012	0.208	0.749
Total PAHs	mg/kg	-	0.324	12	0.075	1.015	2.482
Total Parent PAHs	mg/kg	-	0.022	12	0.005	0.089	0.156
Total Alkylated PAHs	mg/kg	-	0.302	12	0.070	0.926	2.355
Predicted PAH toxicity[3]	H.I.	1.00	**1.32**	12	0.34	0.89	1.50
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	5.6	8	3.4	7.7	9
Chironomus growth - 10d	mg/organism	-	6.85	8	1.15	2.02	3.5
Hyalella survival - 14d	# surviving	-	9.3	8	6.8	9.1	10
Hyalella growth - 14d	mg/organism	-	0.20	8	0.05	0.22	0.29

Values in **bold** indicate concentrations exceeding guidelines.

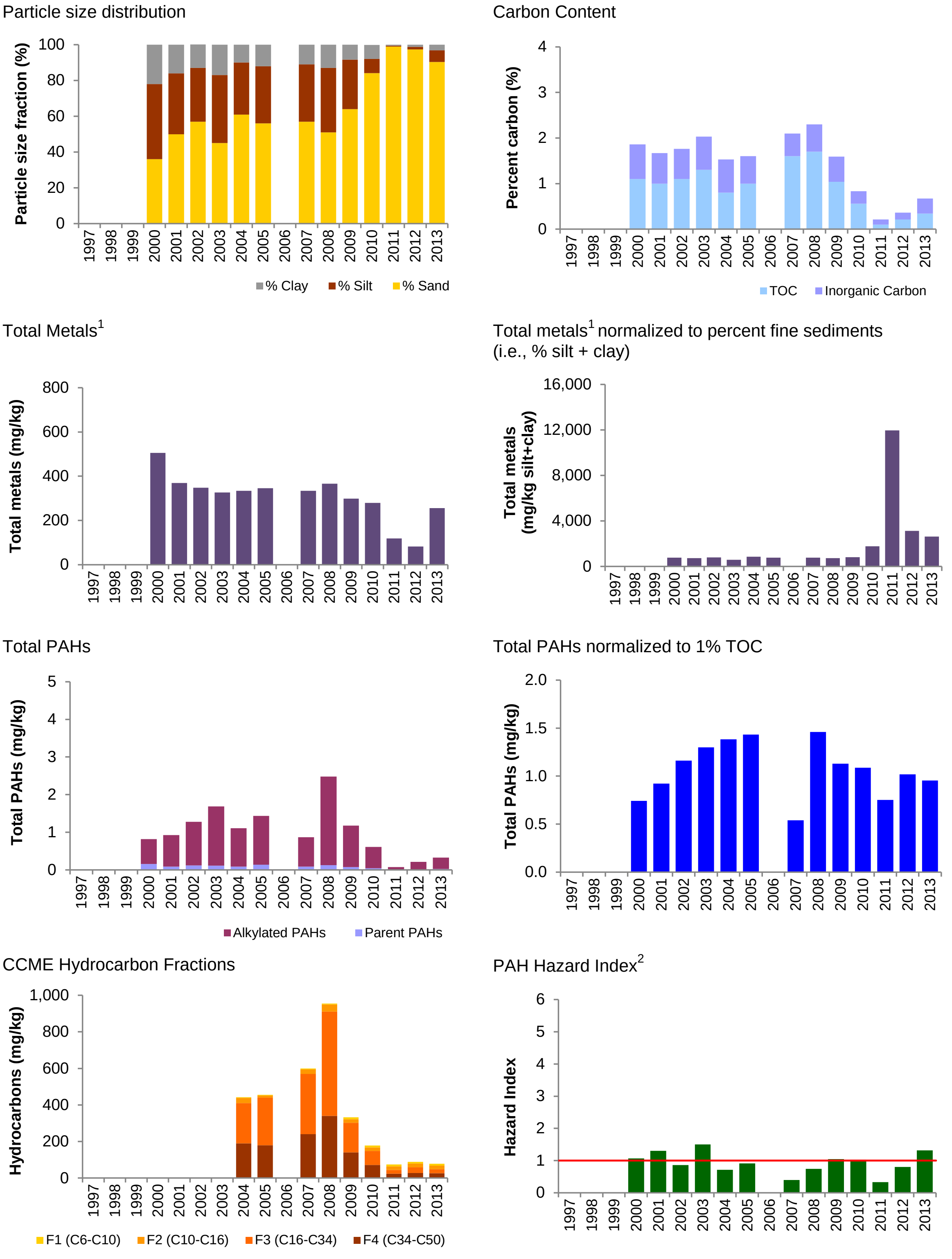
Values underlined indicate concentrations outside the range of historical observations.

[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 5.1-17 Characteristics of sediment collected in the Athabasca River upstream of Embarras River (ATR-ER), 2000 to 2013 (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 fish species in the Athabasca River captured during the spring, summer, and fall fish inventories, 2013.

Species	Spring		Summer		Fall	
	No.	%	No.	%	No.	%
Arctic grayling	1	0.1	-	-	-	-
burbot	13	1.0	12	1.1	4	0.2
emerald shiner	3	0.2	80	7.5	845	34.7
flathead chub	75	5.9	218	20.4	159	6.5
finescale dace	3	0.2	7	0.7	-	-
goldeye*	359	28.2	306	28.7	426	17.5
lake chub	1	0.1	33	3.1	21	0.9
lake whitefish*	1	0.1	4	0.4	246	10.1
longnose sucker*	146	11.5	26	2.4	101	4.2
mountain whitefish	-	-	-	-	1	0.0
northern pike*	25	2.0	34	3.2	30	1.2
northern redbelly dace	-	-	2	0.2	-	-
pearl dace	-	-	5	0.5	-	-
slimy sculpin	-	-	2	0.2	3	0.1
spottail shiner	-	-	85	8.0	322	13.2
trout-perch*	42	3.3	119	11.2	89	3.7
walleye*	173	13.6	112	10.5	127	5.2
white sucker*	433	34.0	15	1.4	43	1.8
yellow perch	-	-	7	0.7	16	0.7
Total	**1,275**	**100**	**1,067**	**100**	**2,433**	**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 2013.

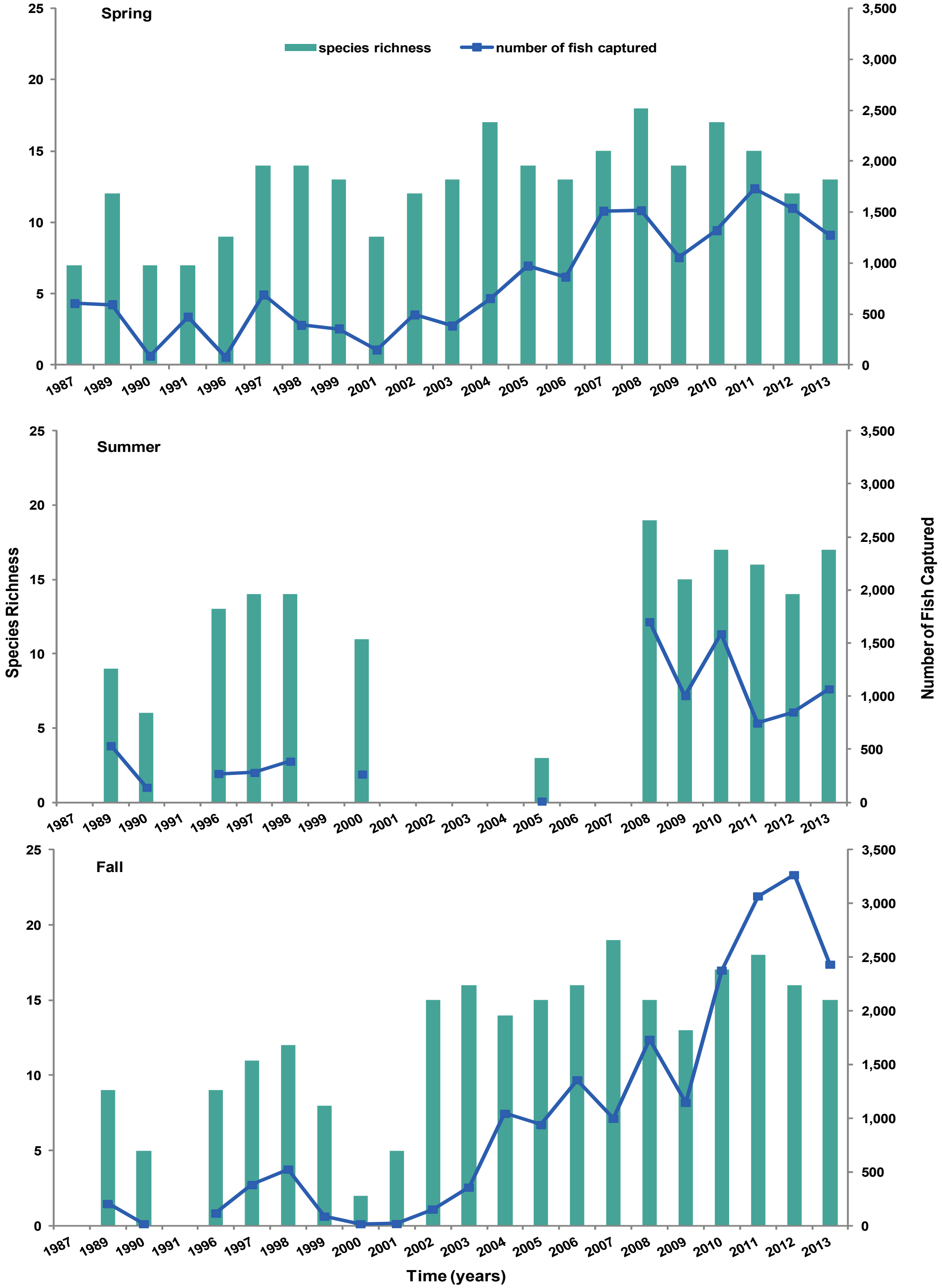


Table 5.1-21 Percent composition of species in the Athabasca River captured in each area during the spring, summer, and fall fish inventories, 2013.

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**
Arctic grayling	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
burbot	1.9	1.5	1.2	-	1.5	1.1	8.3	1.8	0.4	0.6	-	0.5	-	-	0.3	-	0.2	0.4
emerald shiner	-	0.5	0.4	0.3	-	-	-	3.0	9.2	8.3	12.0	6.5	2.7	36.8	38.4	34.6	38.6	36.2
finescale dace	-	1.0	-	-	0.5	-	-	0.6	-	-	3.1	-	-	-	-	-	-	-
flathead chub	18.7	8.0	6.8	1.5	6.2	2.8	30.6	31.5	10.6	24.4	14.7	24.1	26.7	2.6	6.8	6.2	2.6	6.9
goldeye	9.4	37.3	42.6	29.7	10.8	24.9	30.6	13.3	35.6	22.4	27.8	36.7	37.0	11.0	6.3	16.8	30.3	12.4
lake chub	-	-	-	0.3	-	-	1.4	3.0	1.4	5.1	4.7	3.0	-	0.7	0.8	1.1	0.8	1.1
lake whitefish	-	-	-	0.3	-	-	-	-	0.4	1.3	0.5	-	4.1	15.1	11.0	10.6	8.9	9.2
mountain whitefish	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-
longnose sucker	22.4	11.4	19.5	3.5	8.7	11.6	2.9	8.5	2.5	-	-	1.5	8.9	10.3	5.5	3.7	1.6	1.8
slimy sculpin	-	-	-	-	-	-	1.4	-	0.4	-	-	-	-	-	0.8	-	-	-
pearl dace	-	-	-	-	-	-	1.4	1.2	0.4	0.6	-	-	-	-		-	-	-
northern pike	1.9	8.5	1.2	0.3	0.5	0.6	4.2	4.2	3.9	3.9	1.6	2.0	1.4	1.8	0.8	1.8	0.4	1.4
northern redbelly dace	-	-	-	-	-	-	-	-	-	0.6	0.5	-	-	-	-	-	-	-
spottail shiner	-	-	-	-	-	-	1.4	4.2	13.4	8.3	7.9	5.5	1.4	10.3	13.3	12.6	8.9	22.2
trout perch	-	5.0	2.0	0.3	12.8	0.6	4.2	5.5	13.0	9.0	17.8	11.1	4.1	3.7	1.8	6.0	2.6	3.4
walleye	45.8	18.9	14.3	5.0	9.7	7.7	11.1	20.0	6.7	12.2	8.4	8.5	13.7	3.3	8.1	5.3	3.6	3.4
white sucker	-	8.0	11.6	58.8	49.2	50.8	2.8	0.6	2.5	1.9	0.5	0.5	-	4.0	3.1	1.1	1.2	1.4
yellow perch	-	-	-	-	-	-	-	2.4	-	1.3	0.5	-	-	-	3.1	0.2	0.4	0.2
Total # of species	**6**	**10**	**10**	**10**	**9**	**8**	**12**	**14**	**14**	**14**	**13**	**11**	**9**	**12**	**14**	**12**	**13**	**13**
Total Count	**107**	**201**	**251**	**340**	**195**	**181**	**72**	**165**	**284**	**156**	**191**	**199**	**146**	**272**	**383**	**564**	**505**	**563**

* 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, 2010 to 2013.

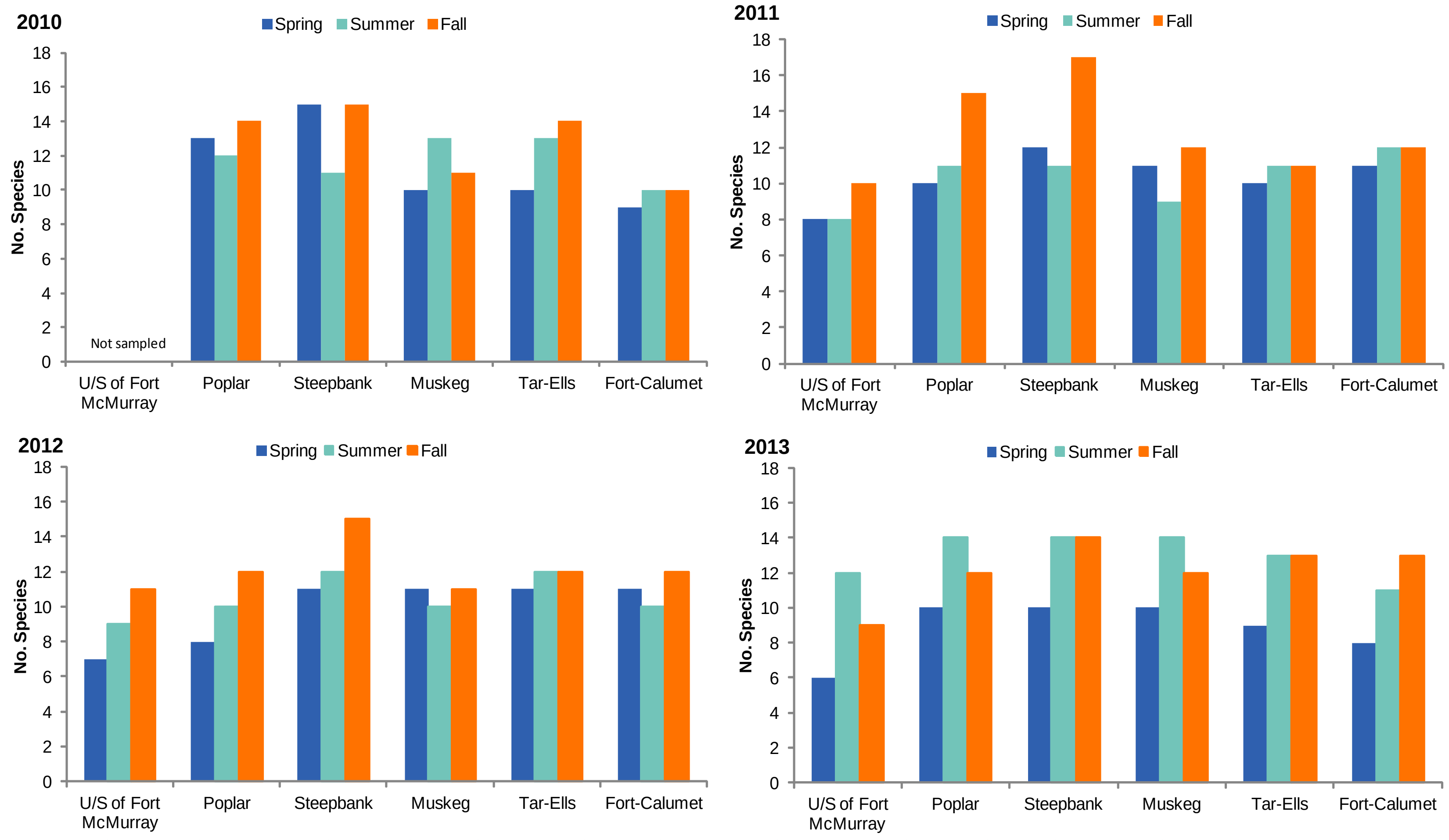


Figure 5.1-20 Percent composition of large-bodied KIR species caught during the Athabasca River spring, summer and fall fish inventories, 1987 to 2013.

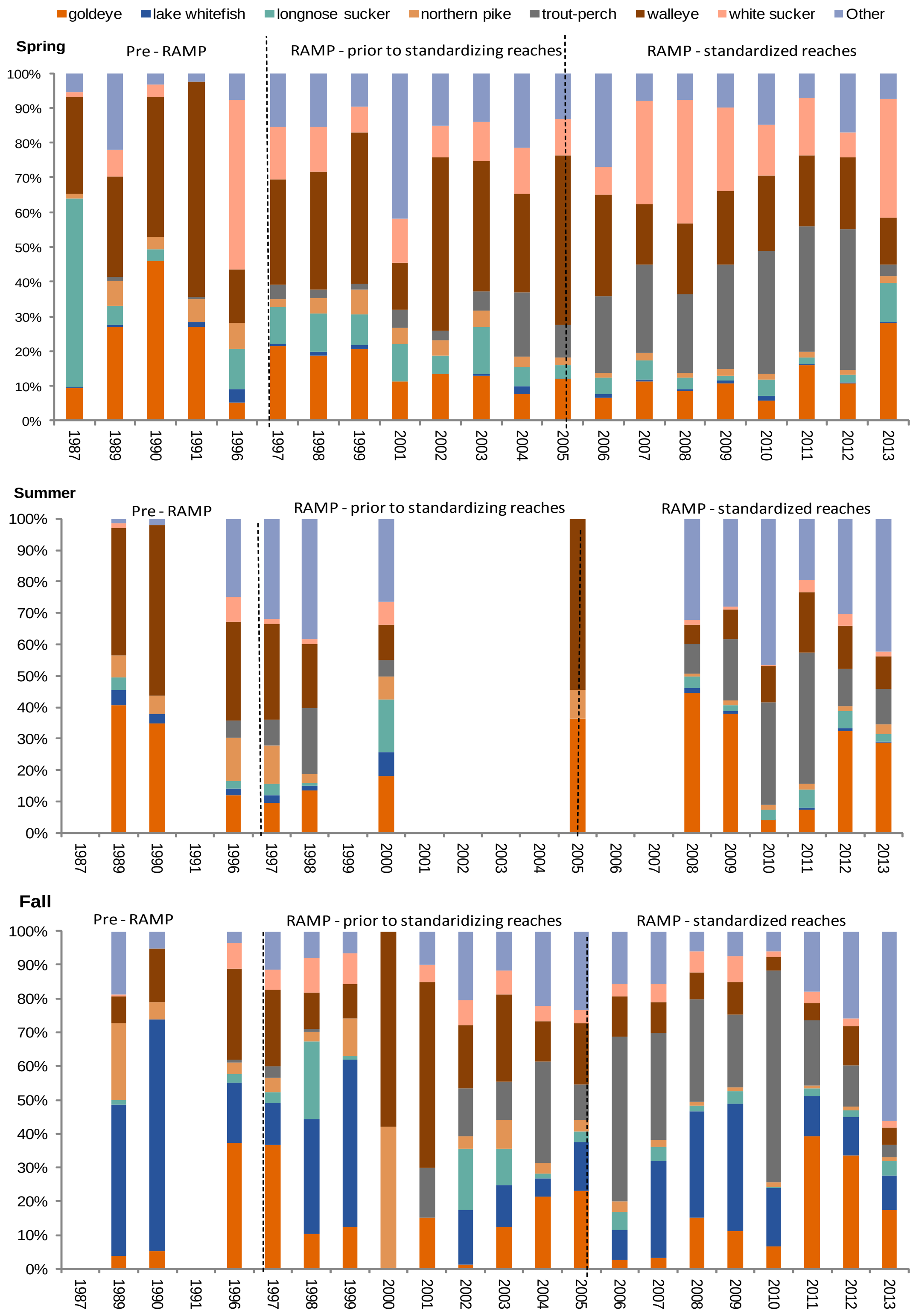


Table 5.1-22 Results of temporal trend analyses in CPUE for KIR fish species in the Athabasca River by area, 1997 to 2013.

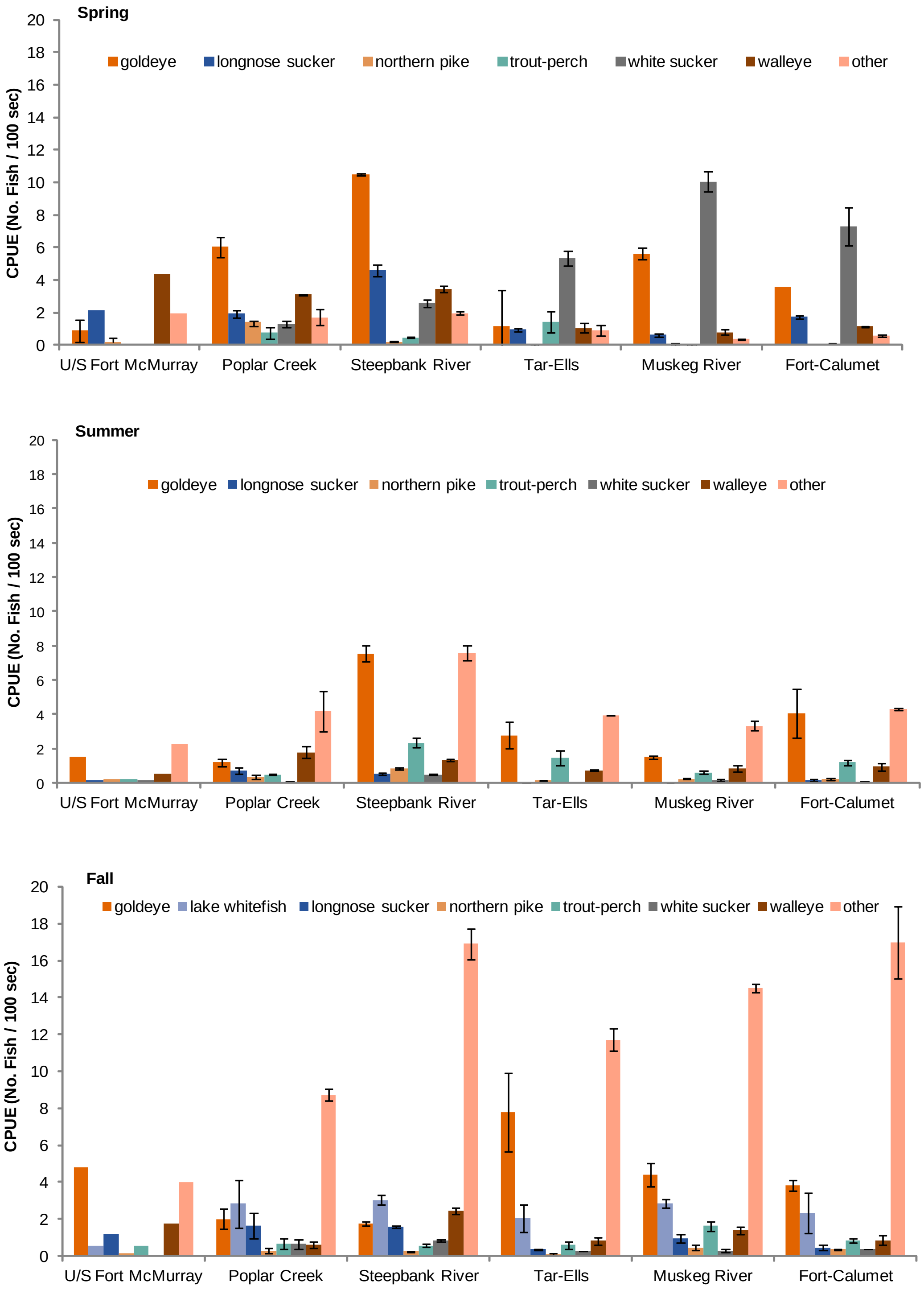
Area	Goldeye			Lake whitefish			Longnose sucker			Northern pike			Trout-perch			Walleye			White sucker		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Poplar	0.495	0.680	**0.021**	0.407	0.347	**0.025**	0.120	0.099	**0.015**	0.733	0.891	0.677	**<0.001**	0.268	**0.001**	**0.019**	0.373	0.081	0.081	0.890	**<0.001**
Muskeg	**0.008**	0.328	0.091	0.668	0.721	**0.003**	0.880	0.903	0.099	0.705	0.669	0.564	**<0.001**	0.222	**0.001**	0.289	0.760	**0.017**	**<0.001**	0.902	0.149
Steepbank	0.576	0.436	**0.011**	0.055	0.530	**0.011**	0.019	0.755	0.184	0.108	0.276	0.762	**0.002**	0.062	**0.001**	0.944	0.119	**0.001**	0.054	0.138	**0.037**
Tar-Ells	0.705	0.436	**0.018**	0.593	0.853	**0.021**	0.622	0.058	0.784	1.000	0.640	0.125	**<0.001**	**0.012**	**0.025**	0.325	0.276	0.155	**0.001**	0.110	0.743
Fort-Calumet	0.107	1.000	**0.029**	0.584	0.096	0.754	0.721	0.452	0.917	0.371	1.000	**0.048**	0.283	1.000	0.466	1.000	0.452	1.000	0.107	1.000	0.754

Bolded values denotes significant trend ($p<0.05$).

Note: All significant trends were assessed to be increasing.

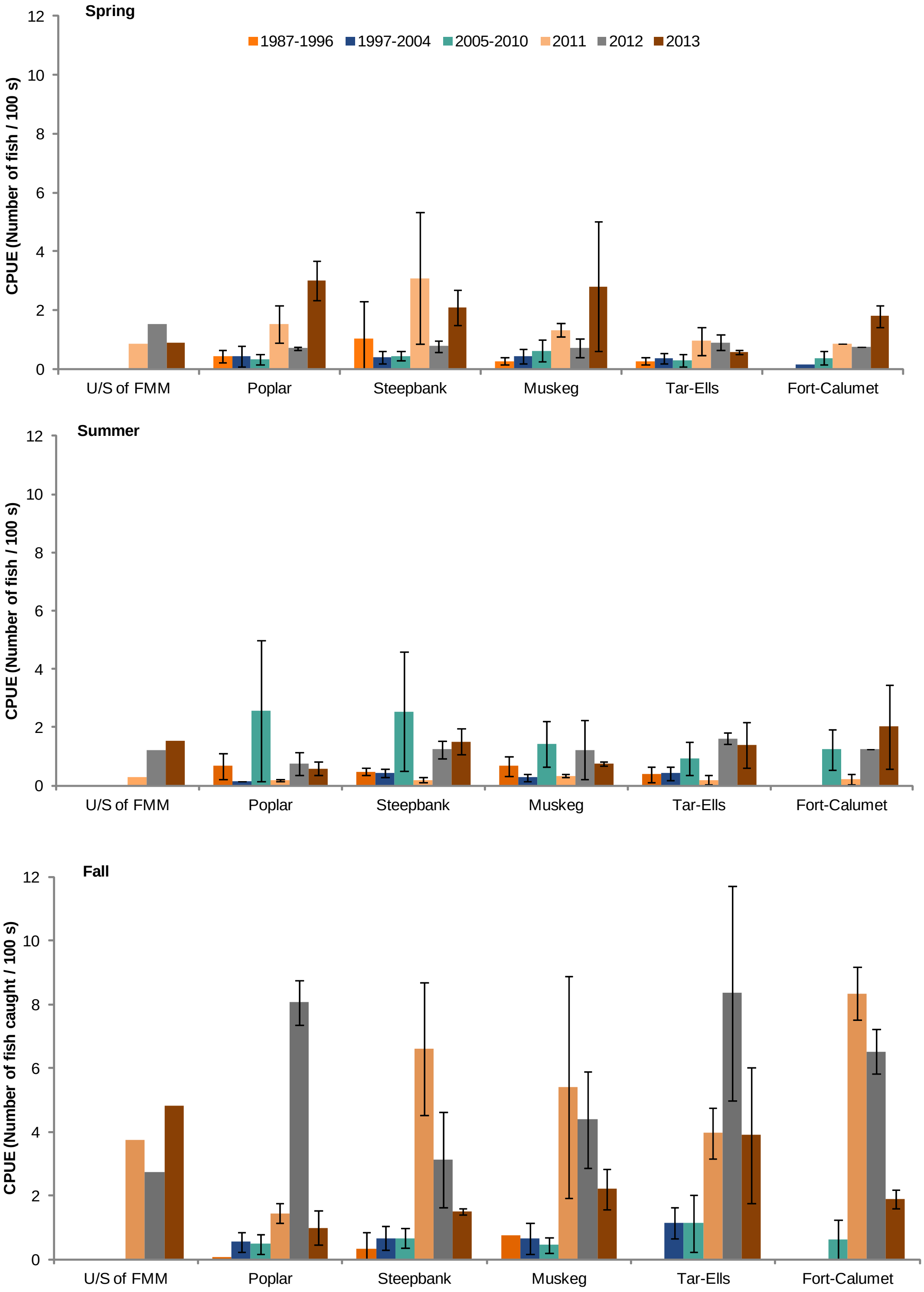
Trend analysis could not be completed for the *baseline* area due to insufficient number of sampling years.

Figure 5.1-21 Total CPUE (±1SD) for KIR fish species in the Athabasca River during spring, summer, and fall fish inventories in 2013.



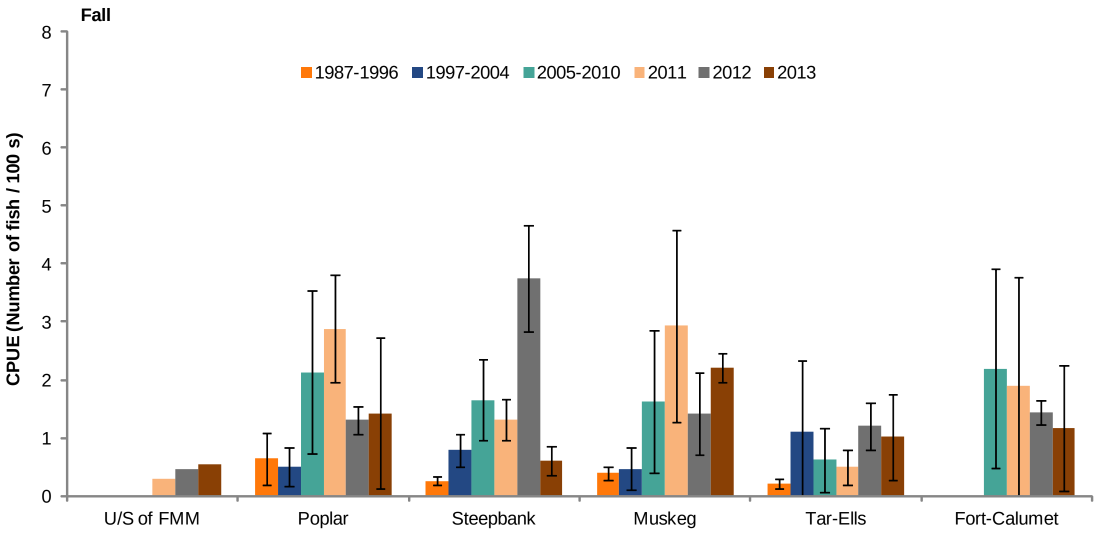
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-22 CPUE (±1SD) for goldeye from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

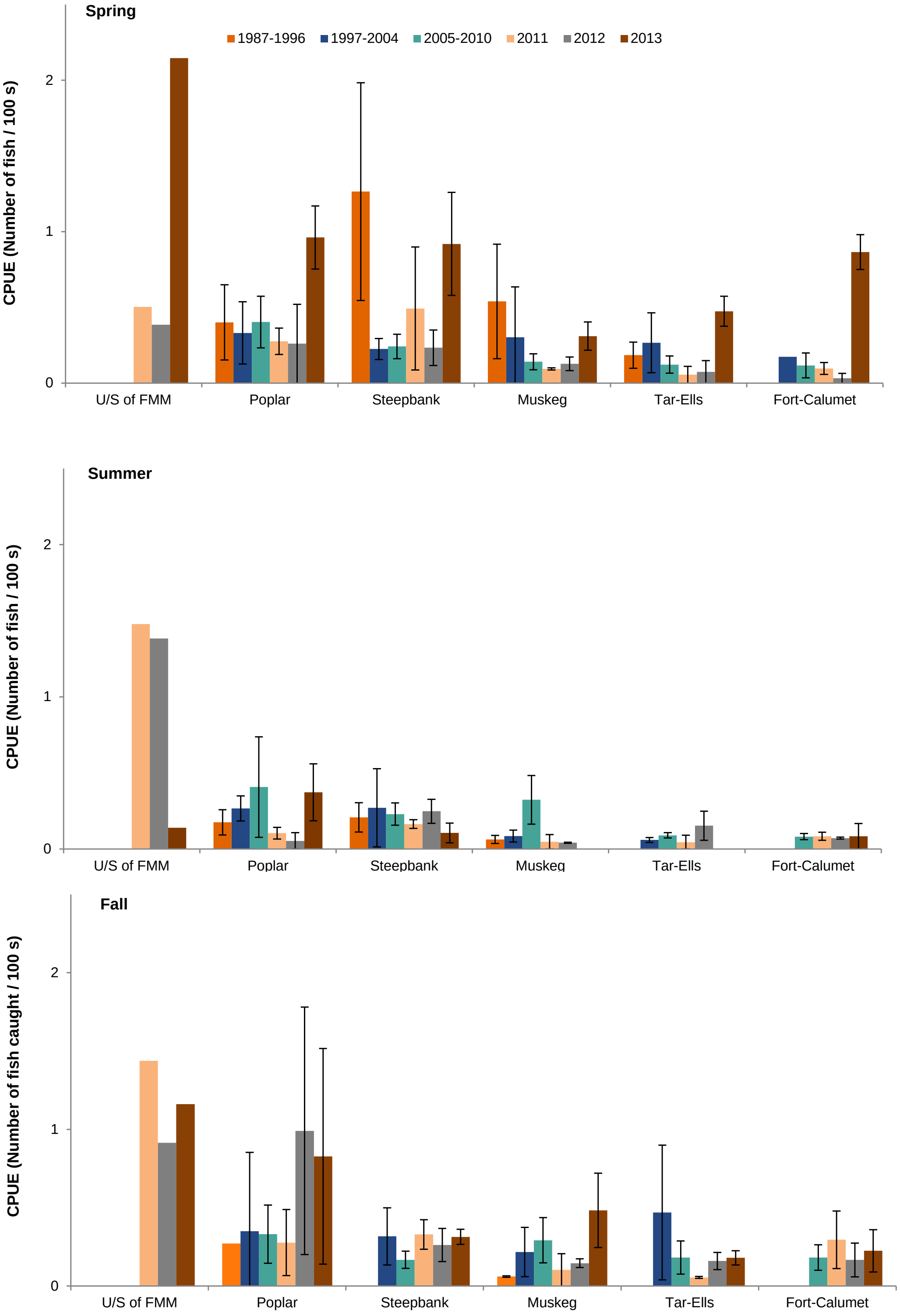
Figure 5.1-23 **CPUE (±1SD) for lake whitefish from 1987 to 2013 during the fall fish inventory on the Athabasca River.**



Note: Lake whitefish were not captured in spring or summer.

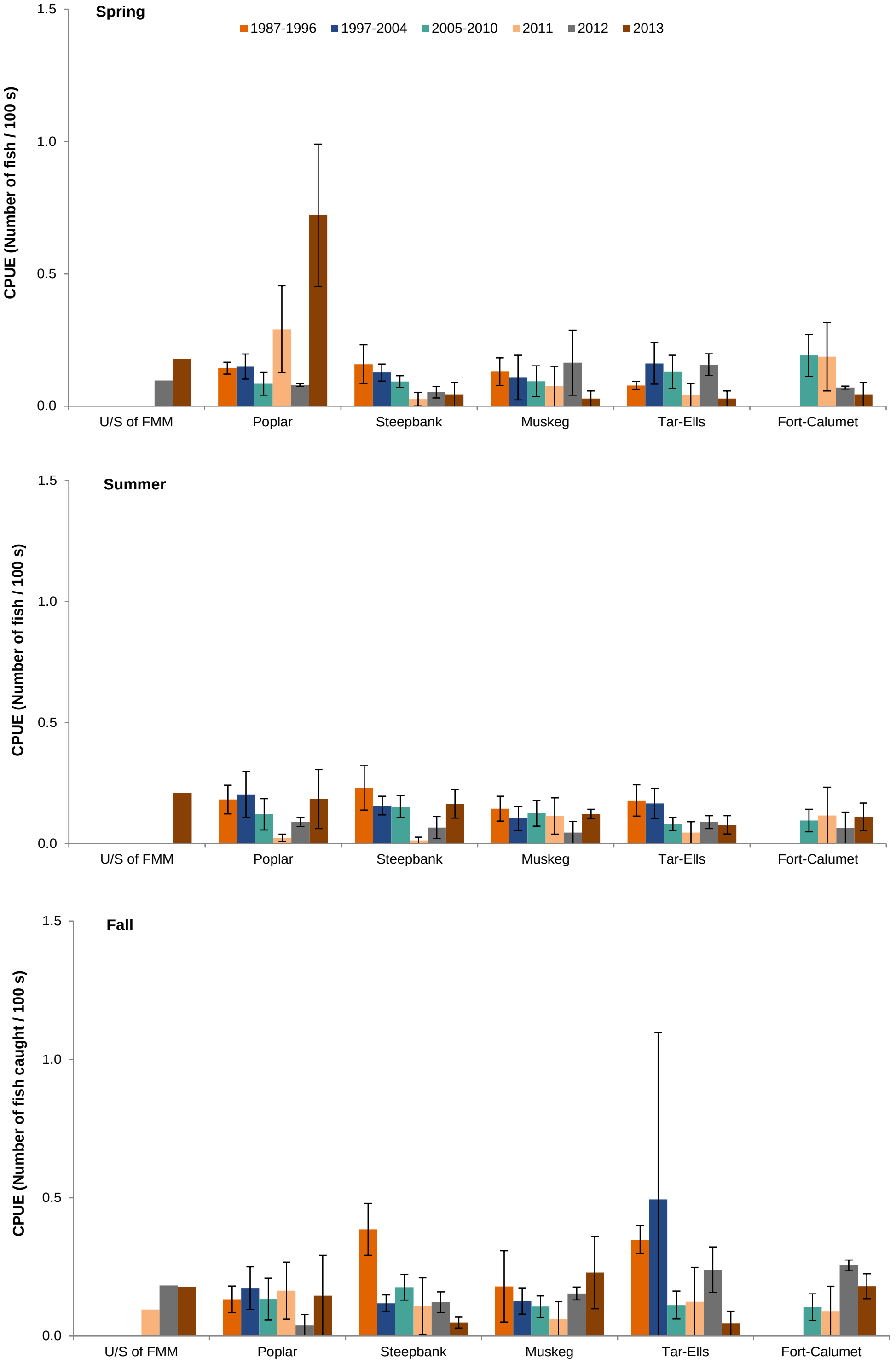
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-24 CPUE (±1SD) for longnose sucker from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



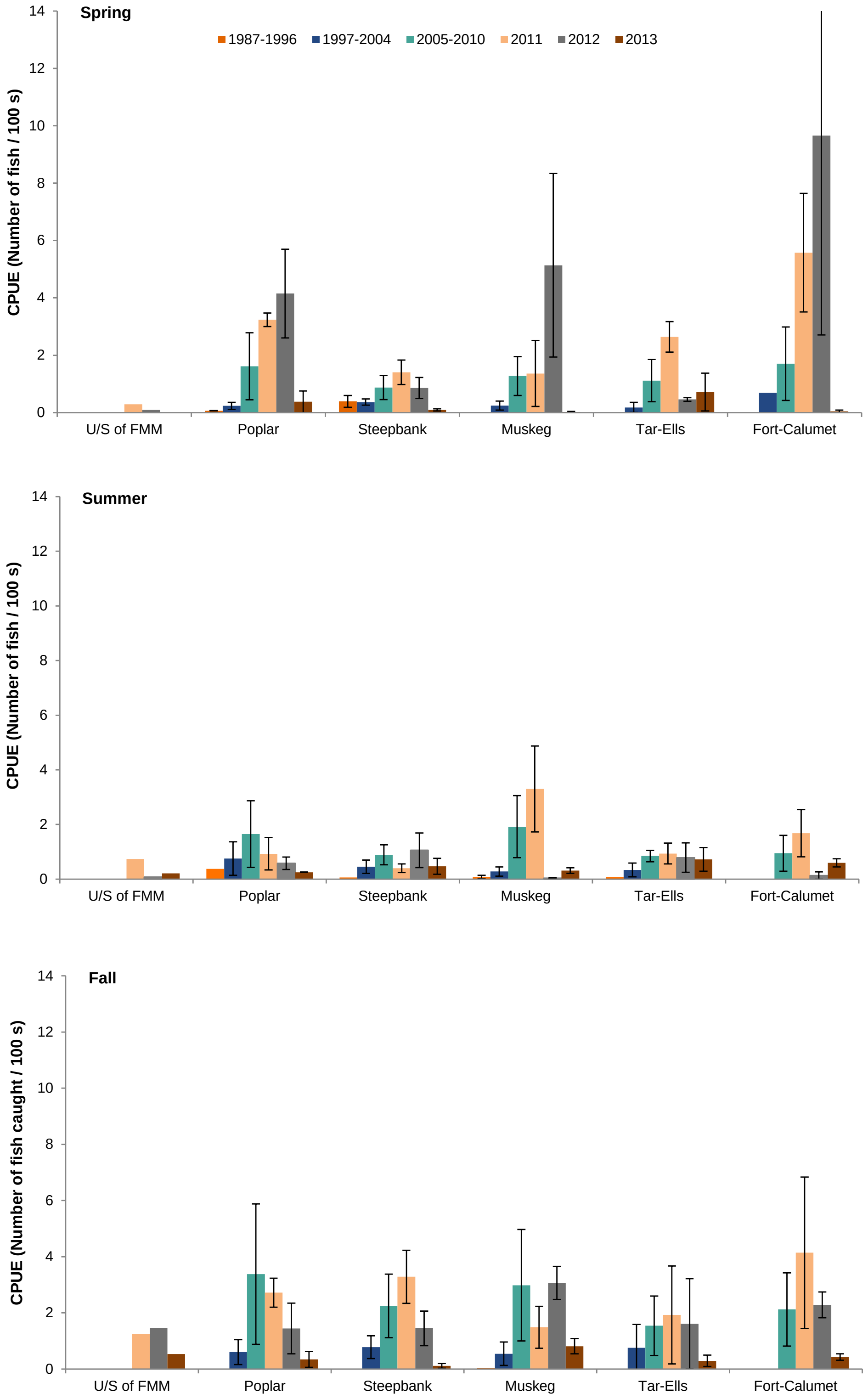
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-25 CPUE (±1SD) for northern pike from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



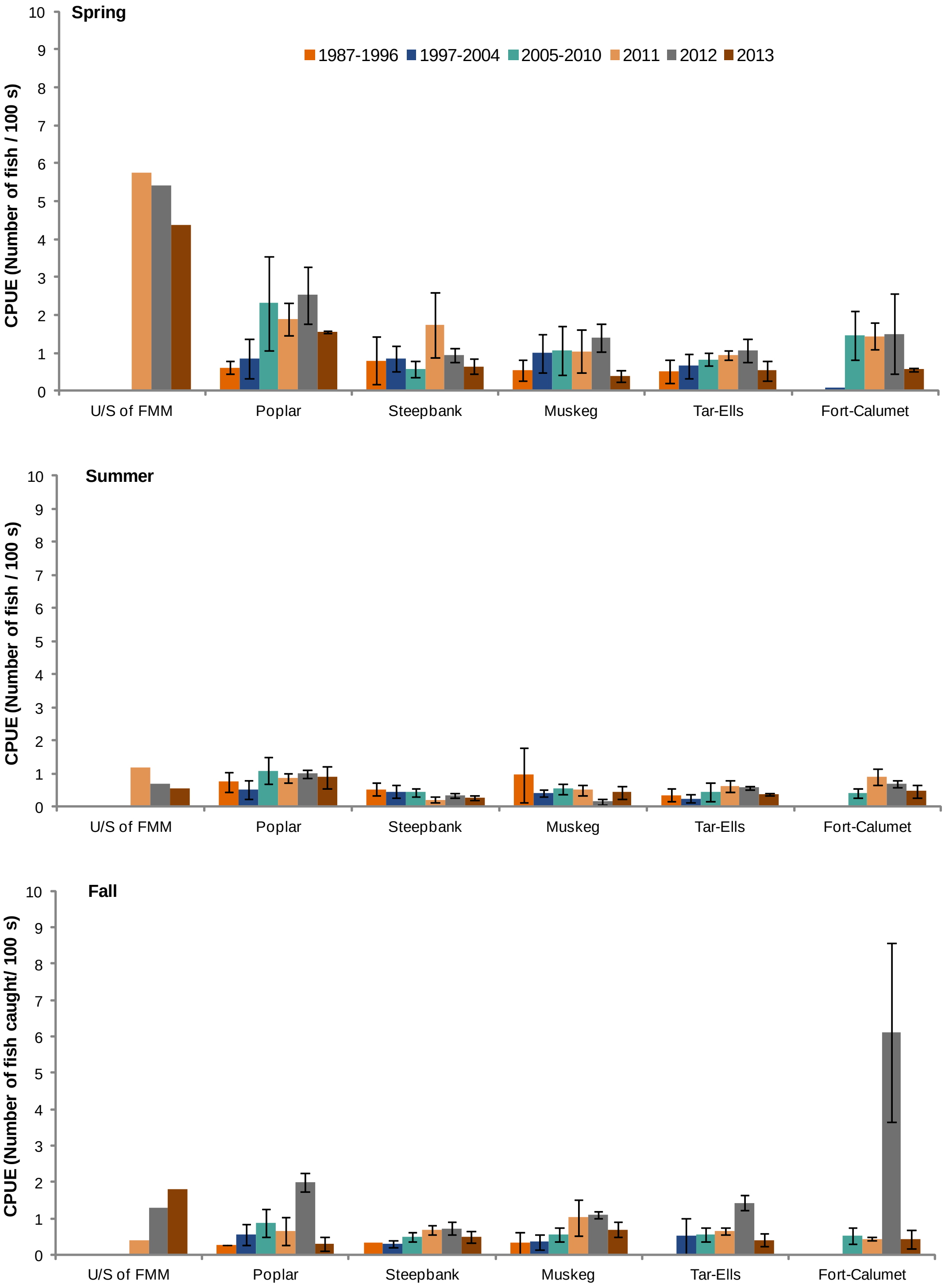
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-26 CPUE (±1SD) for trout-perch from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



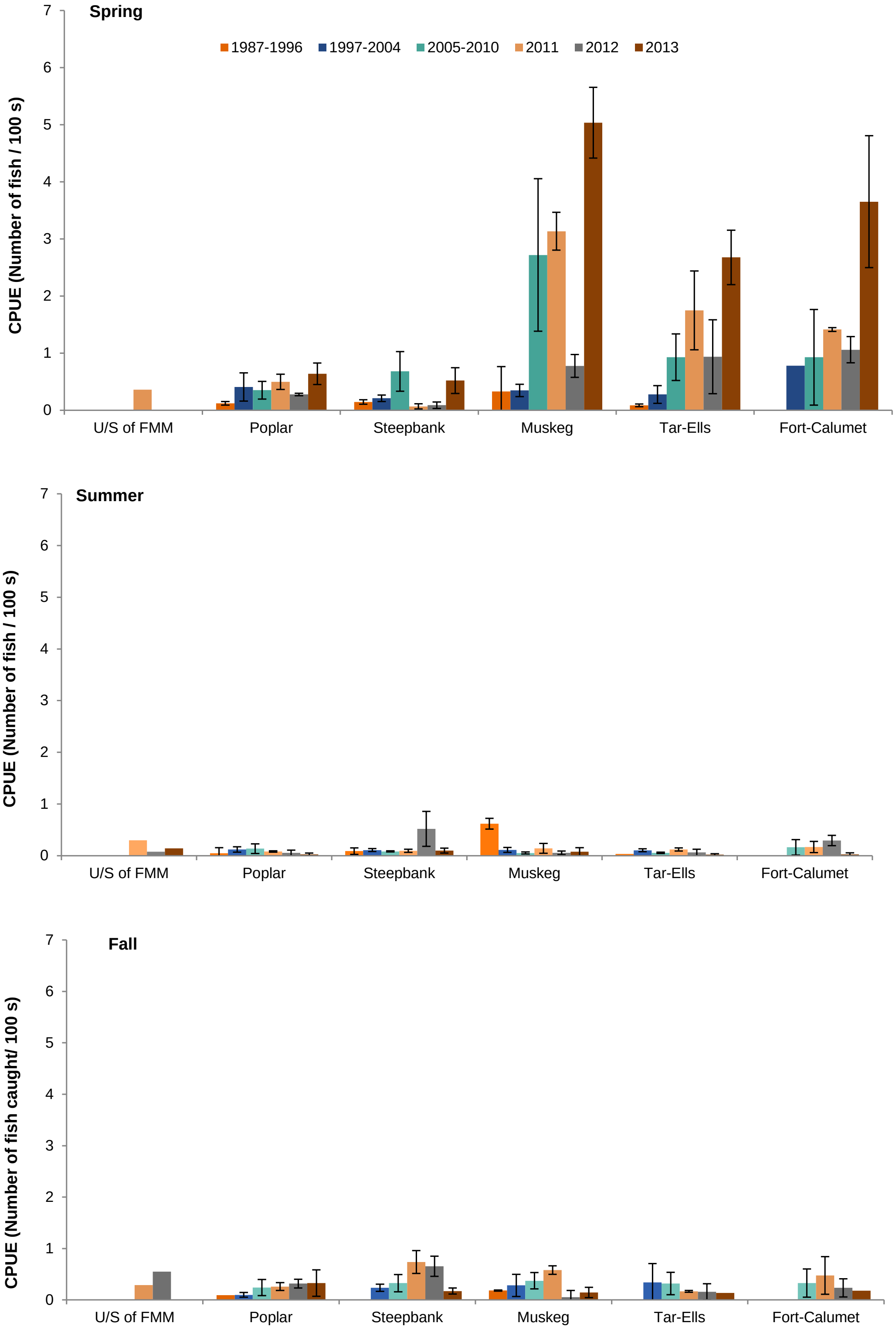
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-27 CPUE (±1SD) for walleye from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



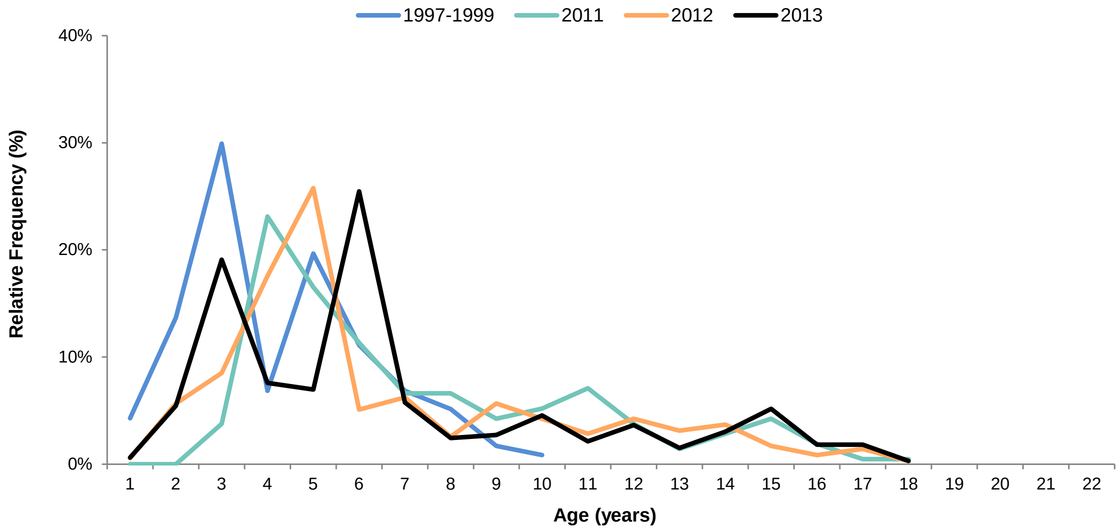
Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-28 CPUE (±1SD) for white sucker from 1987 to 2013 during spring, summer, and fall fish inventories on the Athabasca River.



Note: Standard deviations denote the variability across reaches within an area of the river. There was only one reach in the U/S of Fort McMurray area; therefore, standard deviations could not be calculated.

Figure 5.1-29 Relative age-frequency distributions and size-at-age relationship for goldeye captured in the Athabasca River from 1997 to 2013.



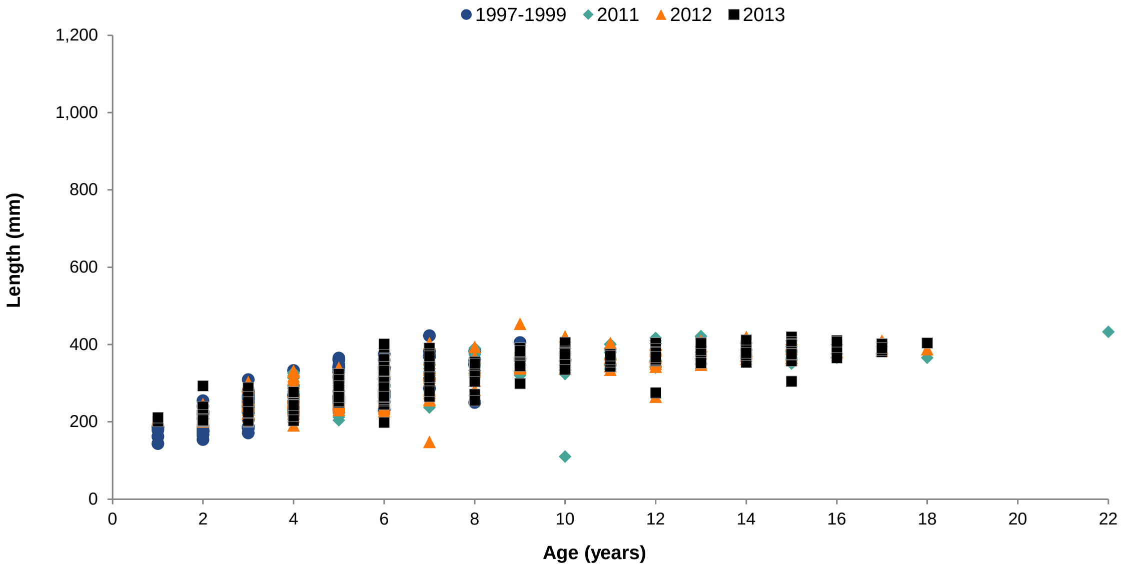


Figure 5.1-30 Relative age-frequency distributions and size-at-age relationship for lake whitefish captured in the Athabasca River from 1997 to 2013.

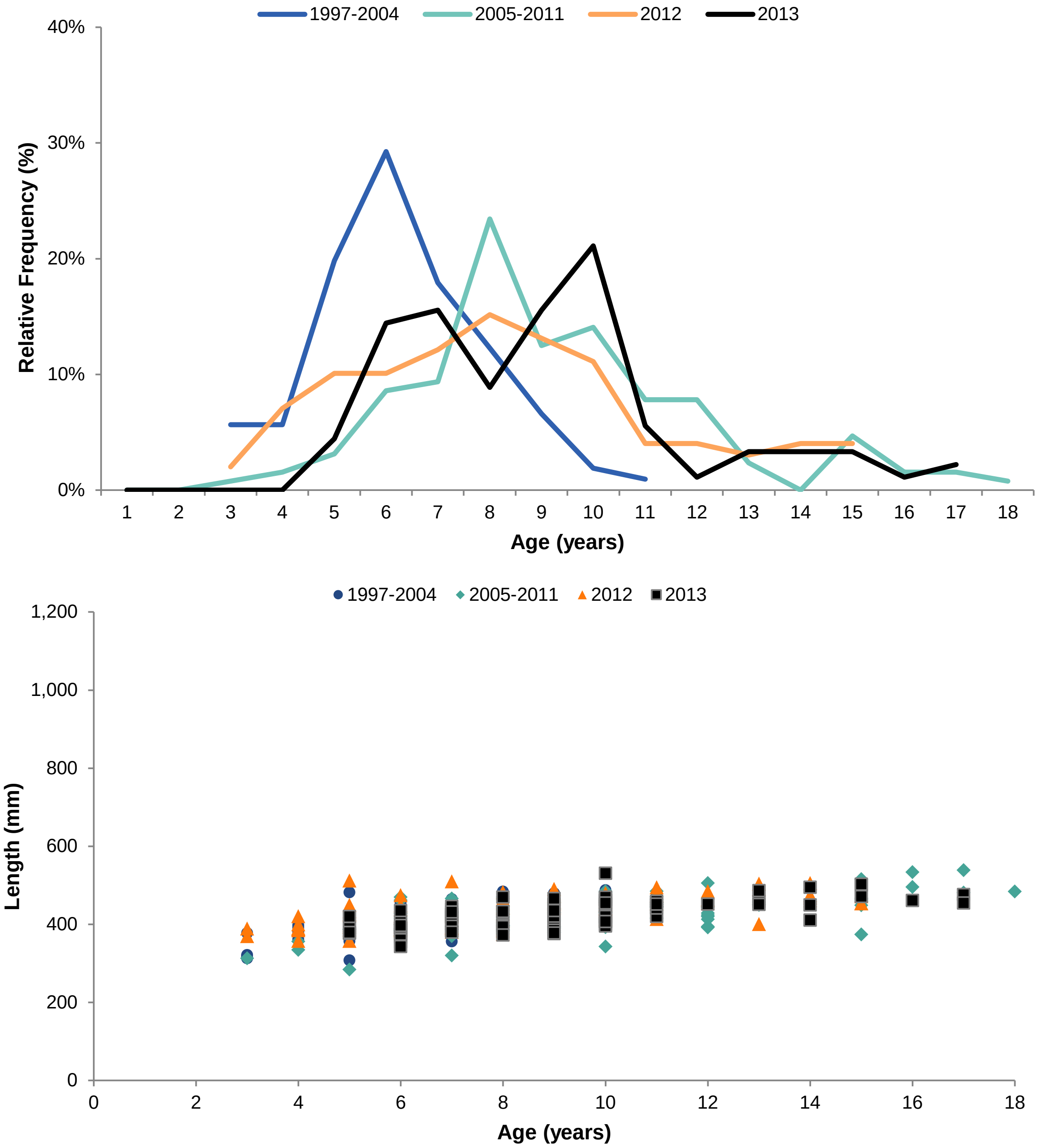
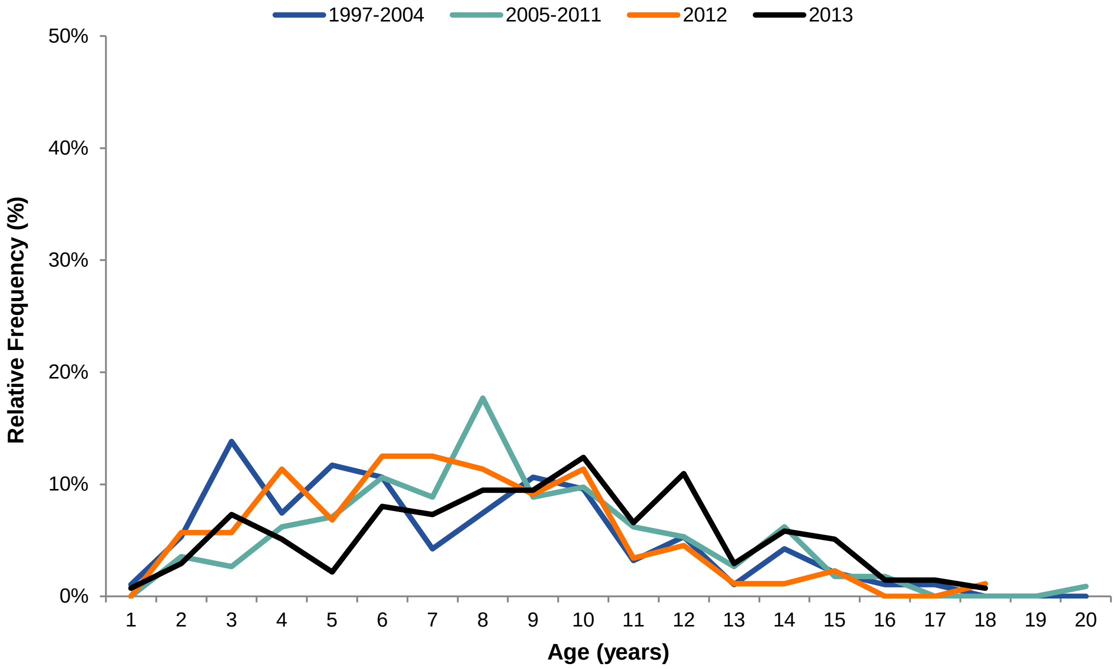


Figure 5.1-31 Relative age-frequency distributions and size-at-age relationship for longnose sucker captured in the Athabasca River from 1997 to 2013.



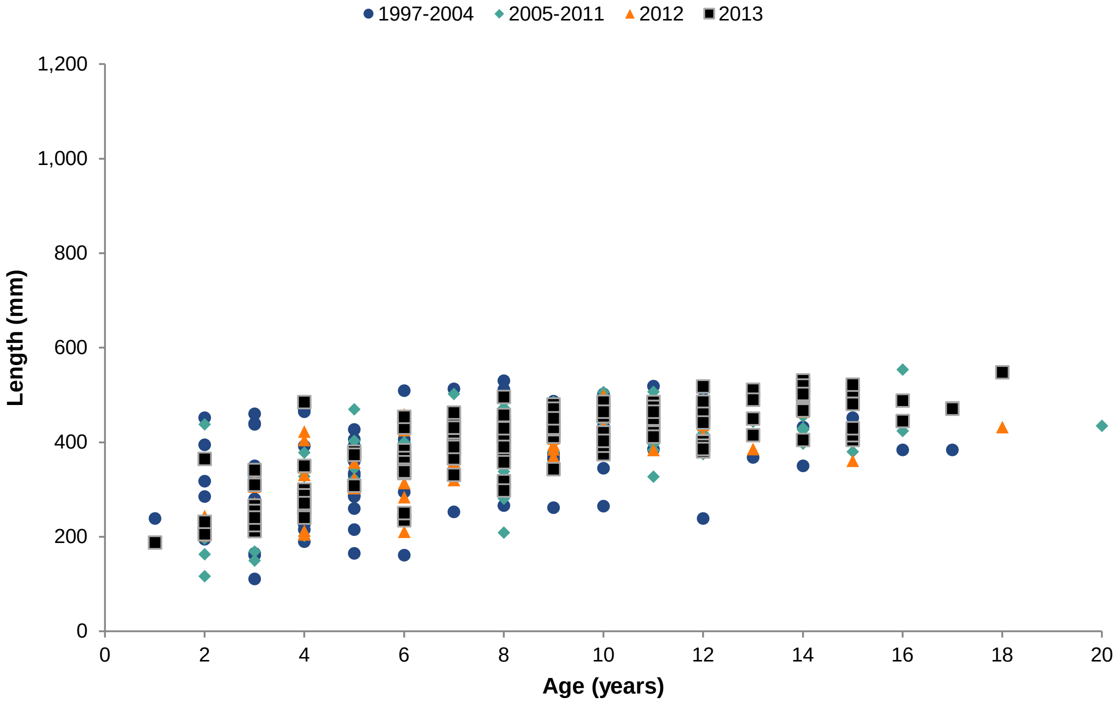
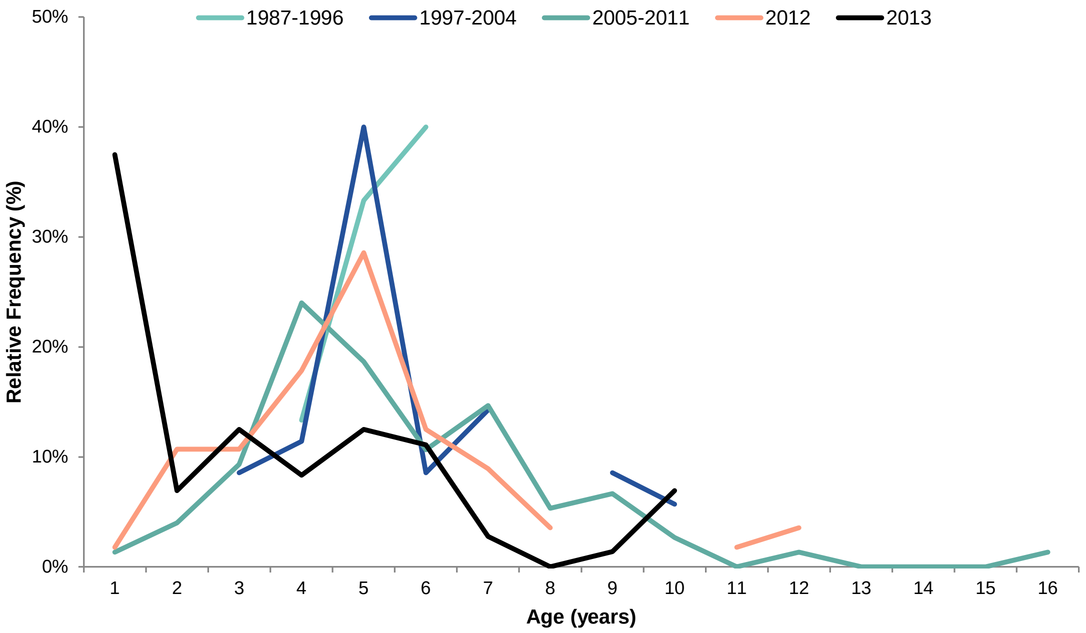


Figure 5.1-32 Relative age-frequency distributions and size-at-age relationship for northern pike captured in the Athabasca River from 1987 to 2013.



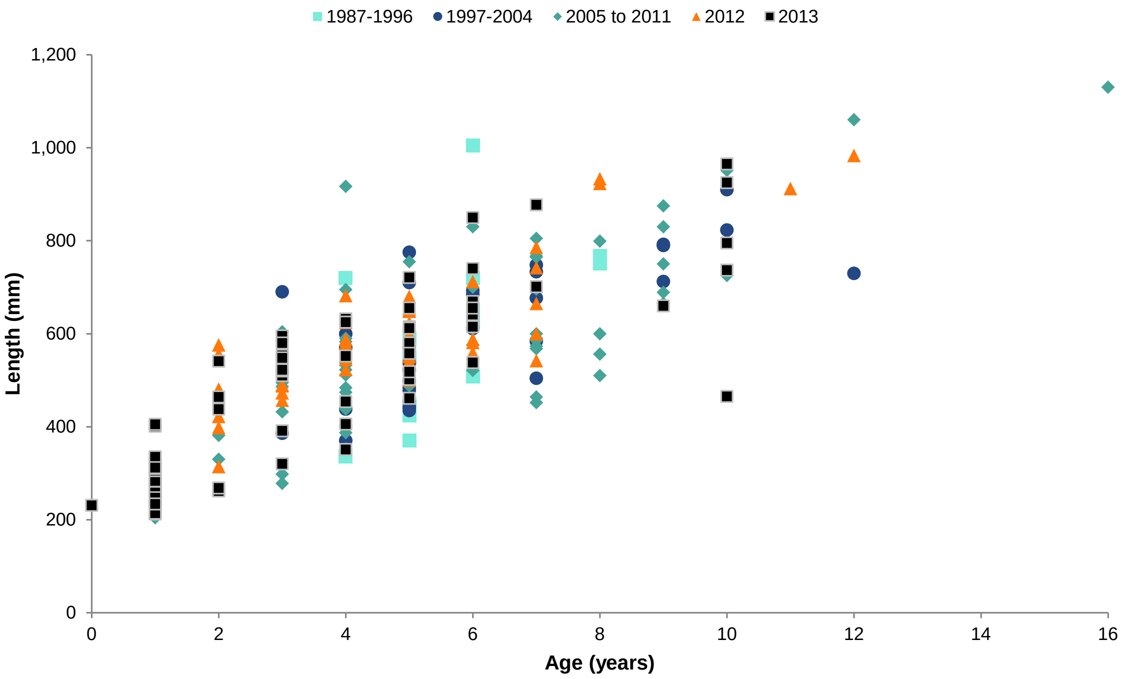
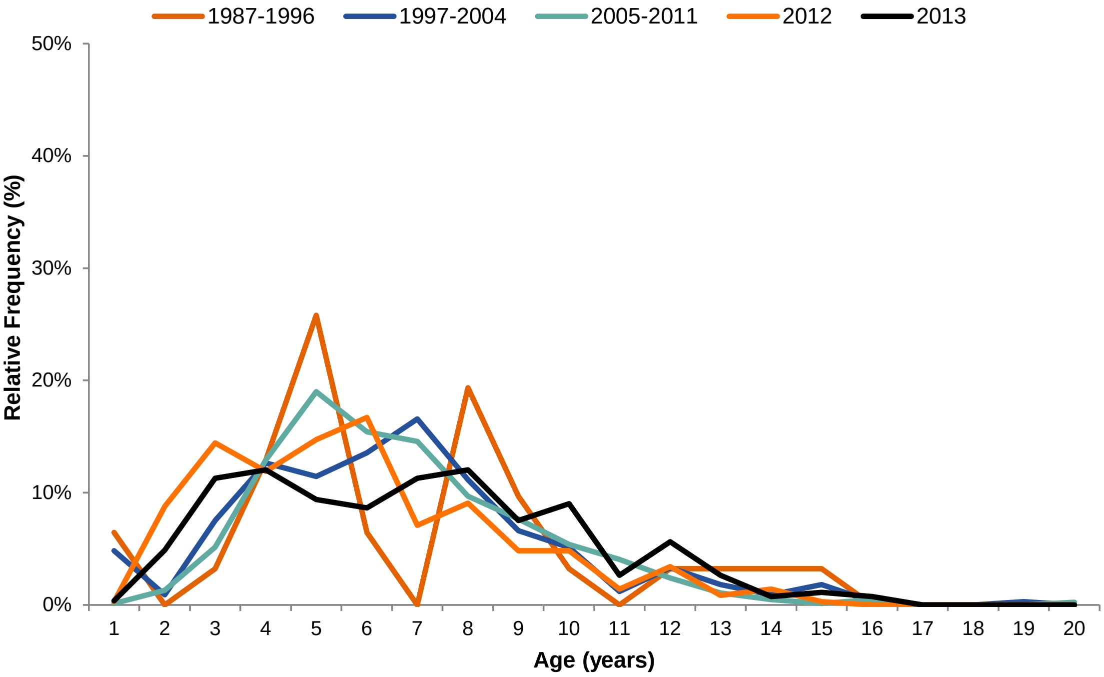


Figure 5.1-33 Relative age-frequency distributions and size-at-age relationship for walleye captured in the Athabasca River from 1987 to 2013.



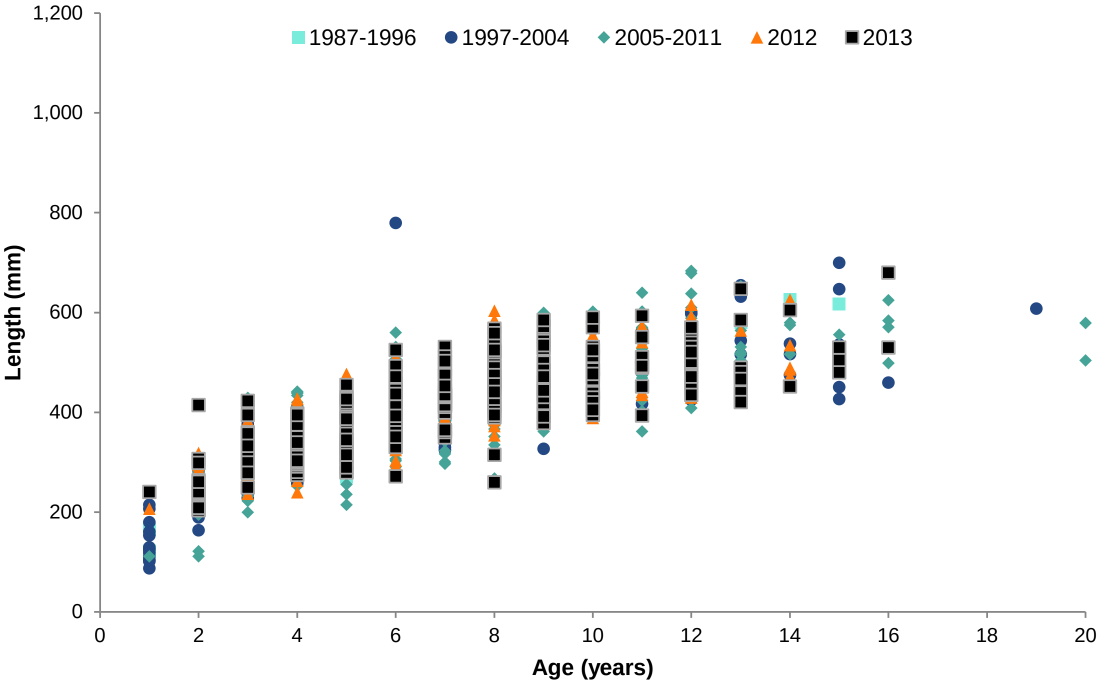
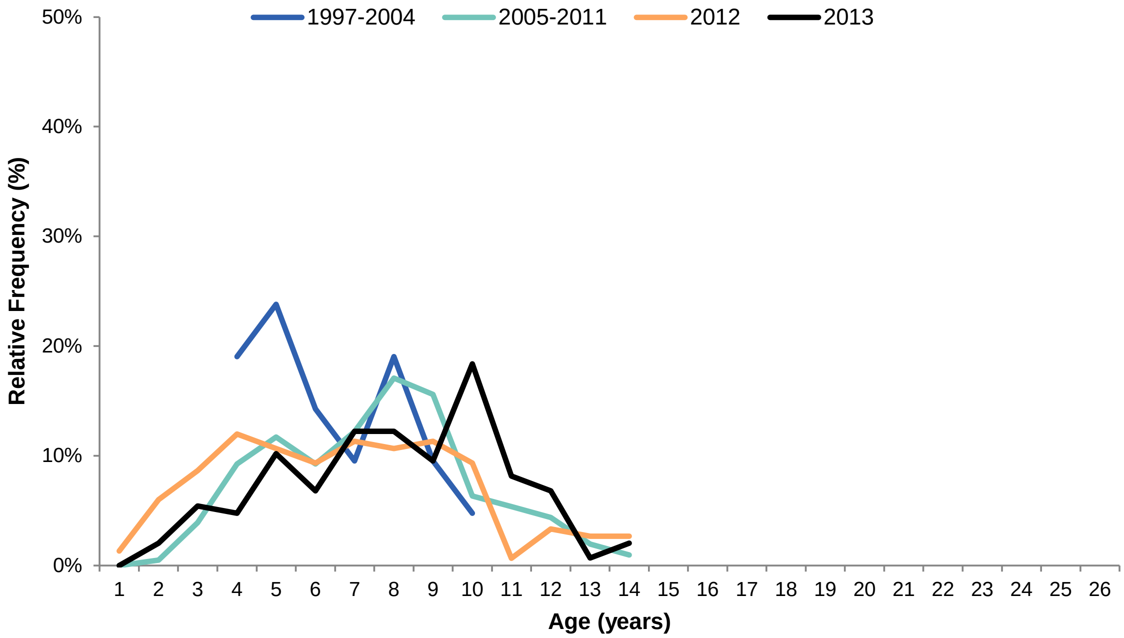


Figure 5.1-34 Relative age-frequency distributions and size-at-age relationship for white sucker captured in the Athabasca River from 1997 to 2013.



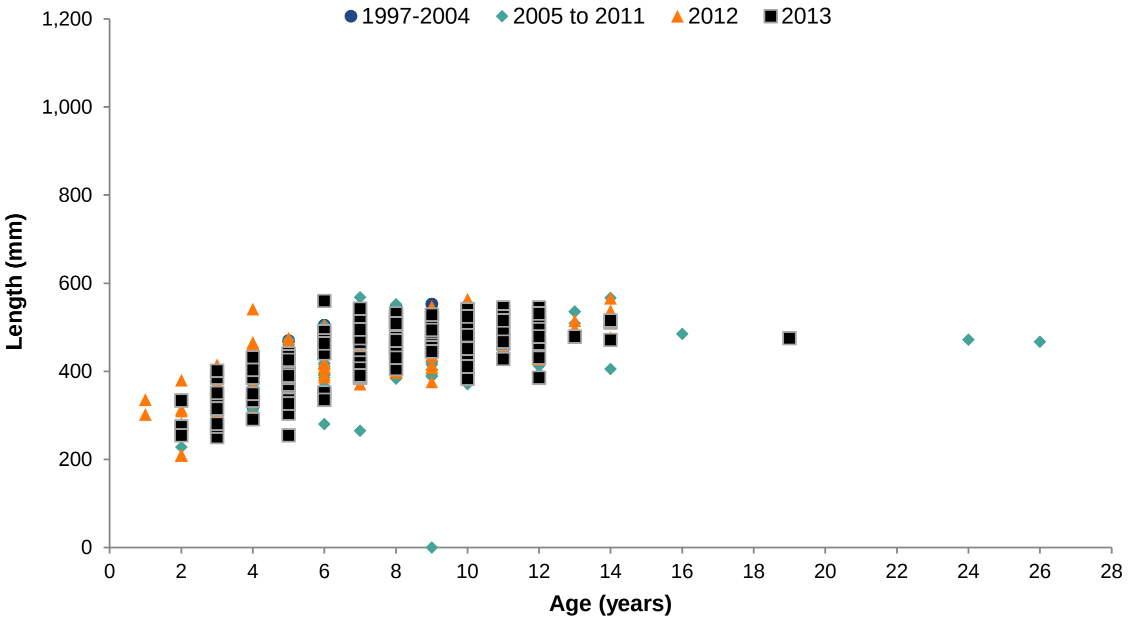


Figure 5.1-35 Mean condition (±2SD) of goldeye captured in summer and fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

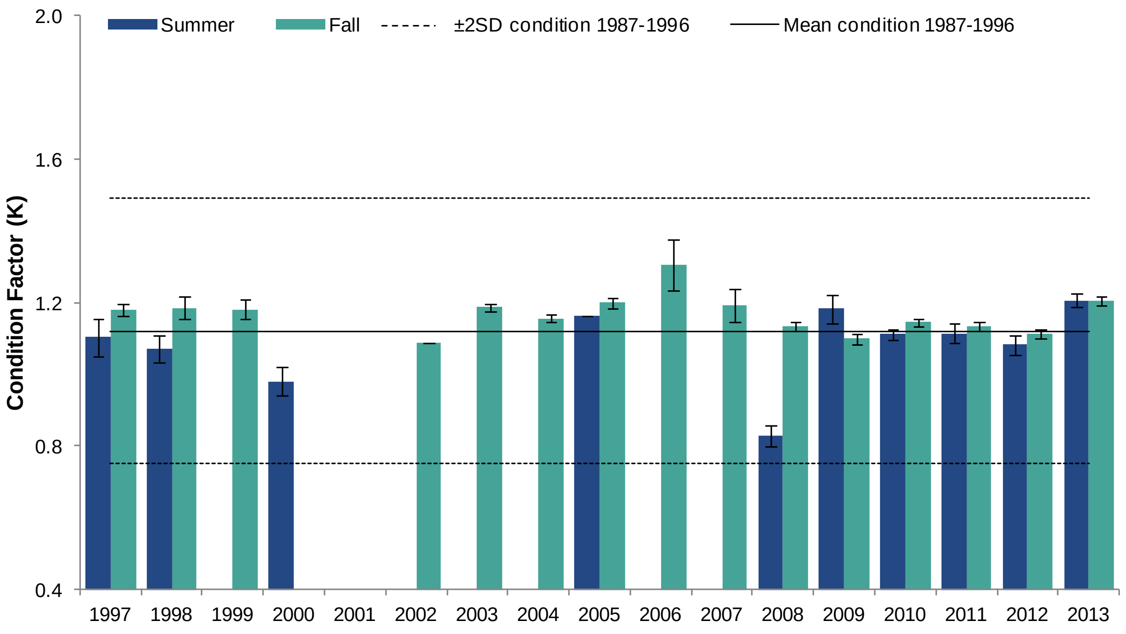


Figure 5.1-36 Mean condition (±2SD) of lake whitefish captured in fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

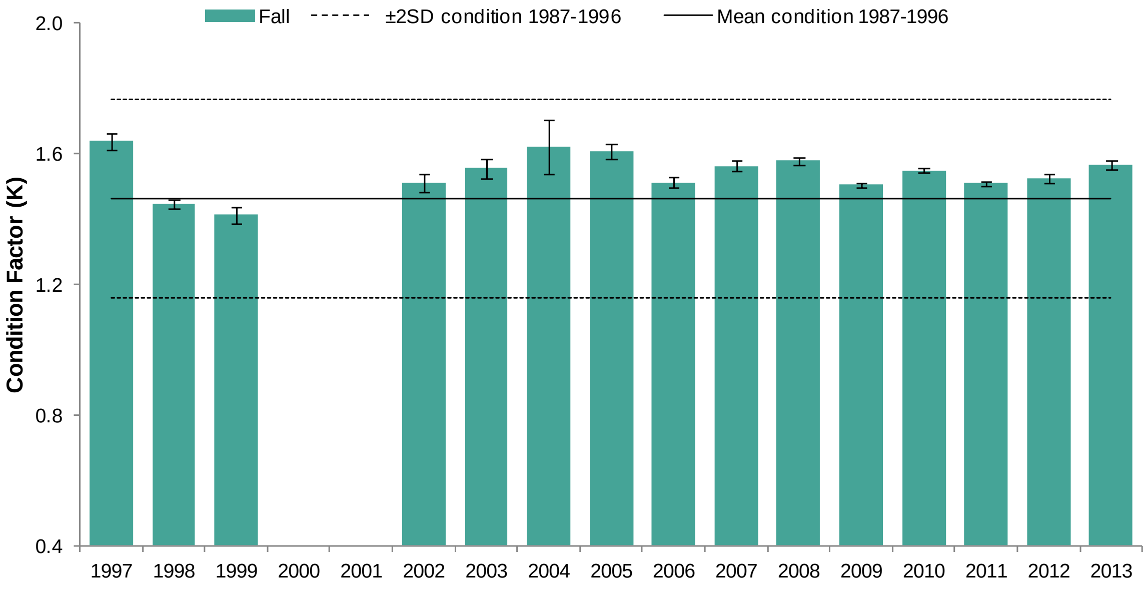


Figure 5.1-37 Mean condition (±2SD) of longnose sucker captured in summer and fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

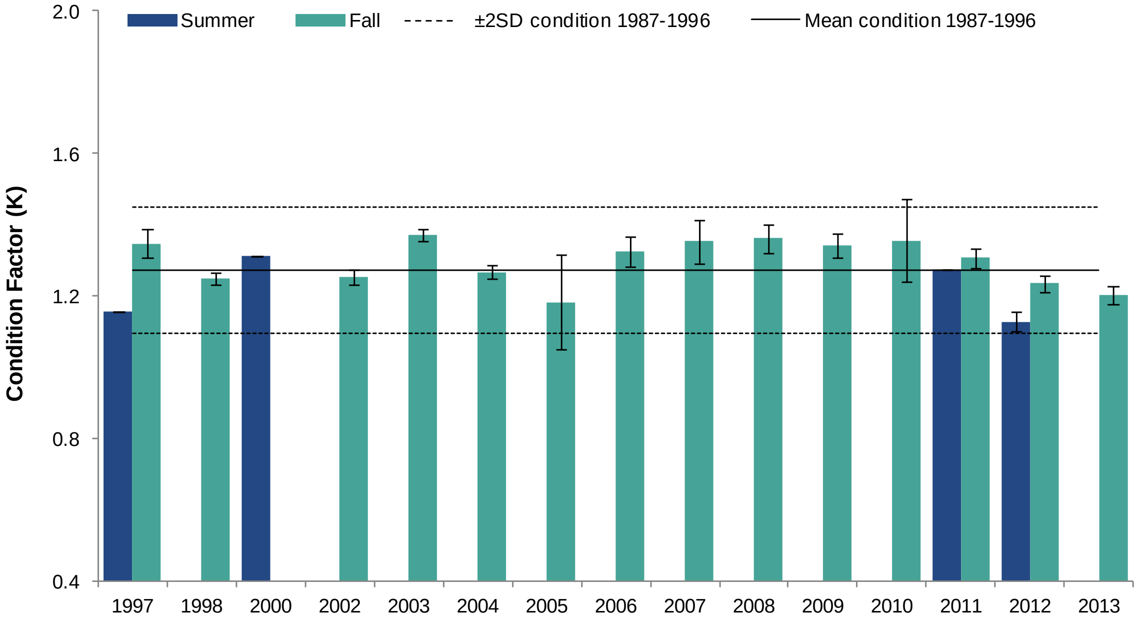


Figure 5.1-38 Mean condition (±2SD) of northern pike captured in summer and fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

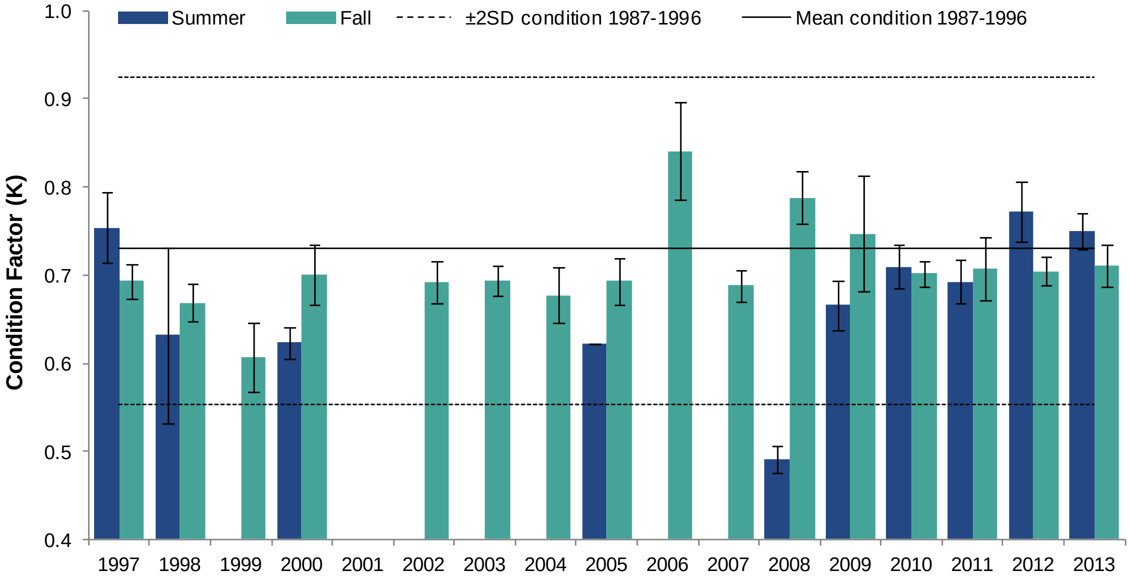
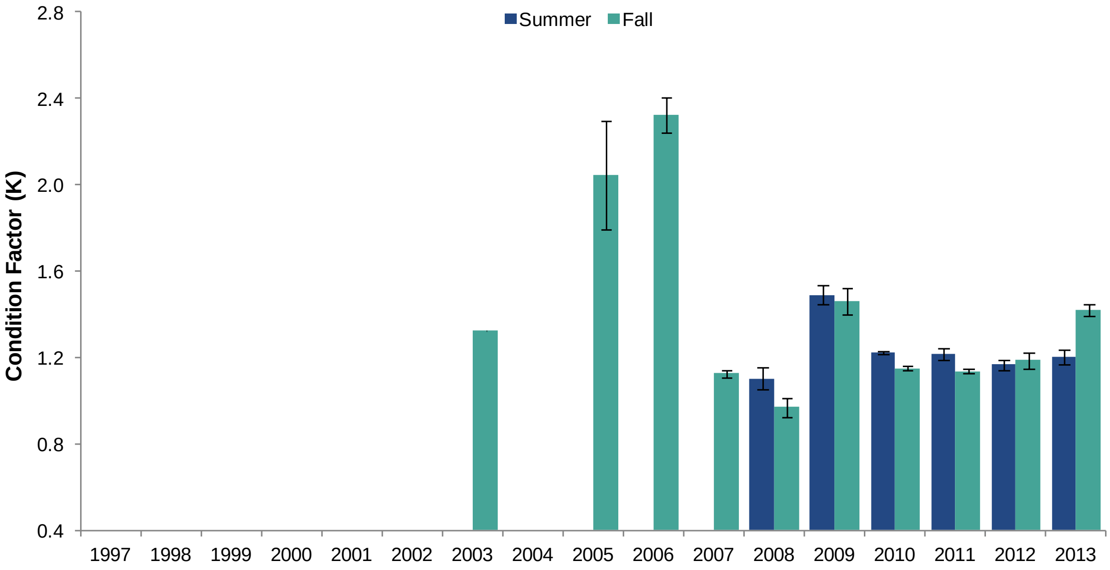


Figure 5.1-39 Mean condition (±2SD) of trout-perch captured in summer and fall from 1997 to 2013 in the Athabasca River.



Note: Trout-perch were not collected during fish inventories from 1987 to 1996; therefore a baseline range could not be calculated.

Figure 5.1-40 Mean condition (±2SD) of walleye captured in summer and fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).

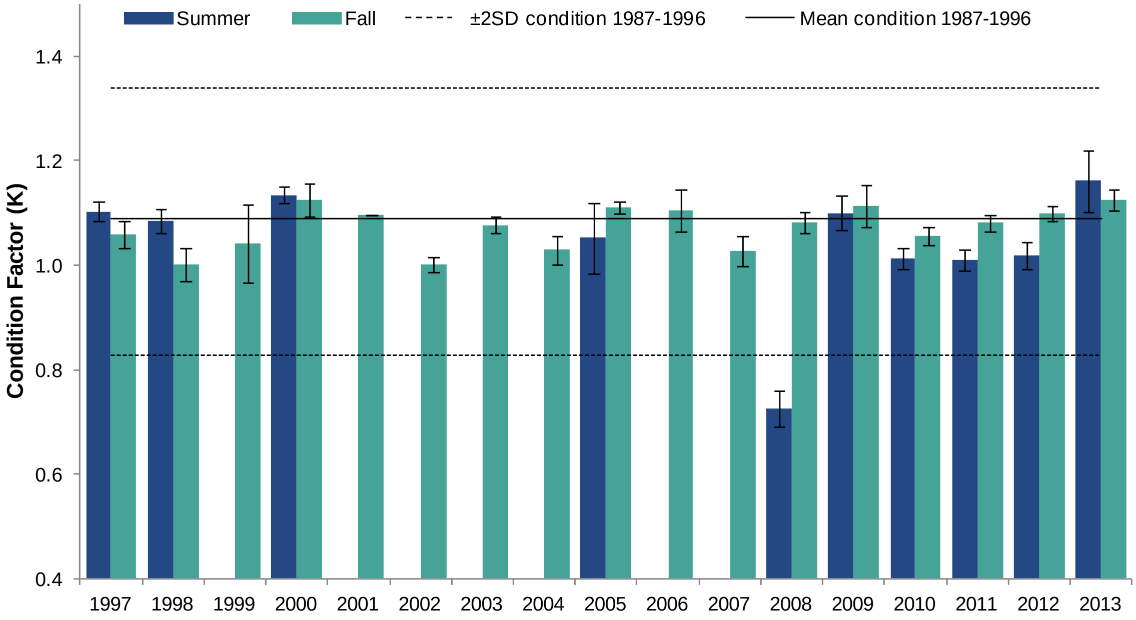


Figure 5.1-41 **Mean condition (±2SD) of white sucker captured in summer and fall from 1997 to 2013 in the Athabasca River, relative to pre-RAMP values (1987 to 1996).**

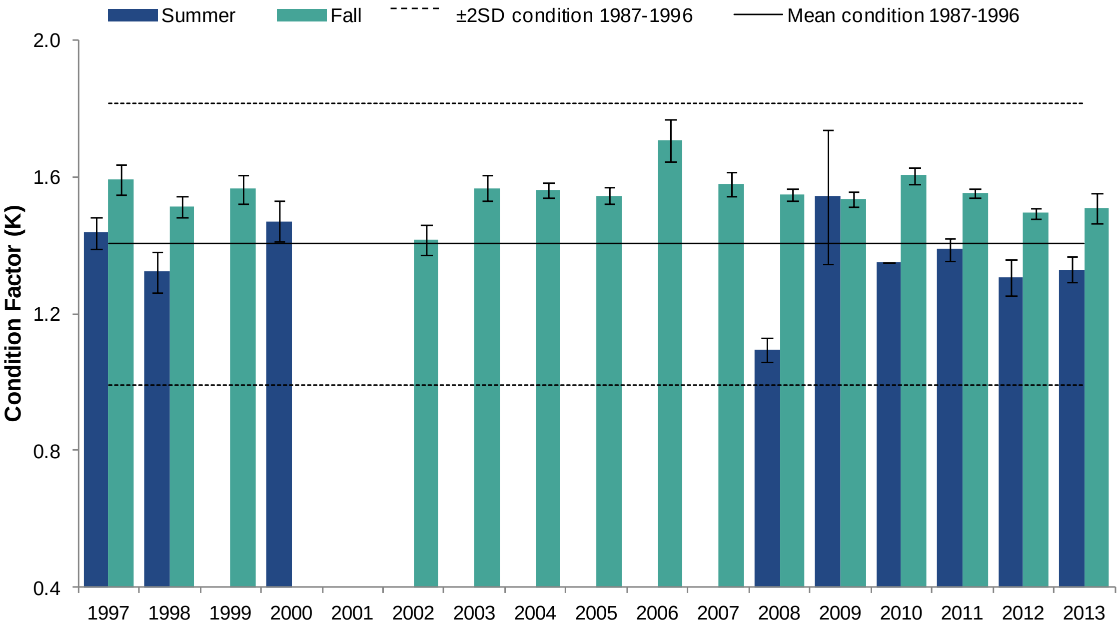


Table 5.1-23 Percent of total fish captured in the Athabasca River with external pathology (growth/lesion, deformity, parasites), 1987 to 2013.

Year	% Growth/Lesion	% Deformity (body/fins)	% Parasites	% Total	Total # Fish
1987	0.33	0.00	0.00	0.33	1,823
1989	1.09	0.42	0.71	2.22	4,237
1990	0.65	0.43	0.22	1.30	921
1991	1.74	0.00	0.83	2.57	1,322
1996	2.65	1.58	2.29	6.51	1,965
1997	2.38	1.14	0.96	4.48	2,187
1998	1.39	0.67	0.88	2.94	2,381
1999	2.01	1.68	1.84	5.53	597
2000	2.43	0.41	0.81	3.65	493
2001	1.24	0.00	0.00	1.24	403
2002	0.45	0.17	0.22	0.84	1,793
2003	0.65	0.18	0.30	1.13	1,680
2004	0.37	0.05	0.69	1.12	1,883
2005	0.88	0.20	0.00	1.08	2,042
2006	0.63	0.05	0.27	0.95	2,222
2007	1.15	0.32	0.12	1.59	2,511
2008	1.43	0.42	0.32	2.18	4,951
2009	0.94	0.59	0.87	2.40	3,207
2010	0.53	0.21	0.64	1.39	5,284
2011	0.34	0.16	0.49	0.99	5,466
2012	0.30	0.21	0.11	0.62	5,656
2013	0.69	0.15	0.27	1.11	4,775

Figure 5.1-42 Percent of total fish captured in the Athabasca River with some type of external pathology, 1987 to 2013.

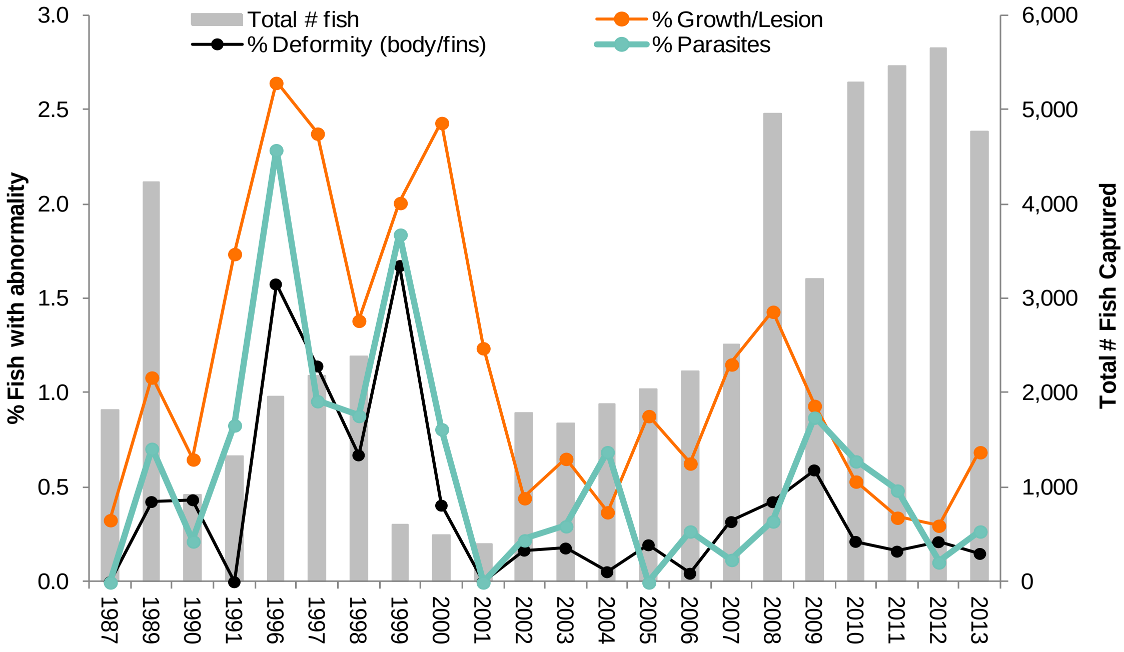


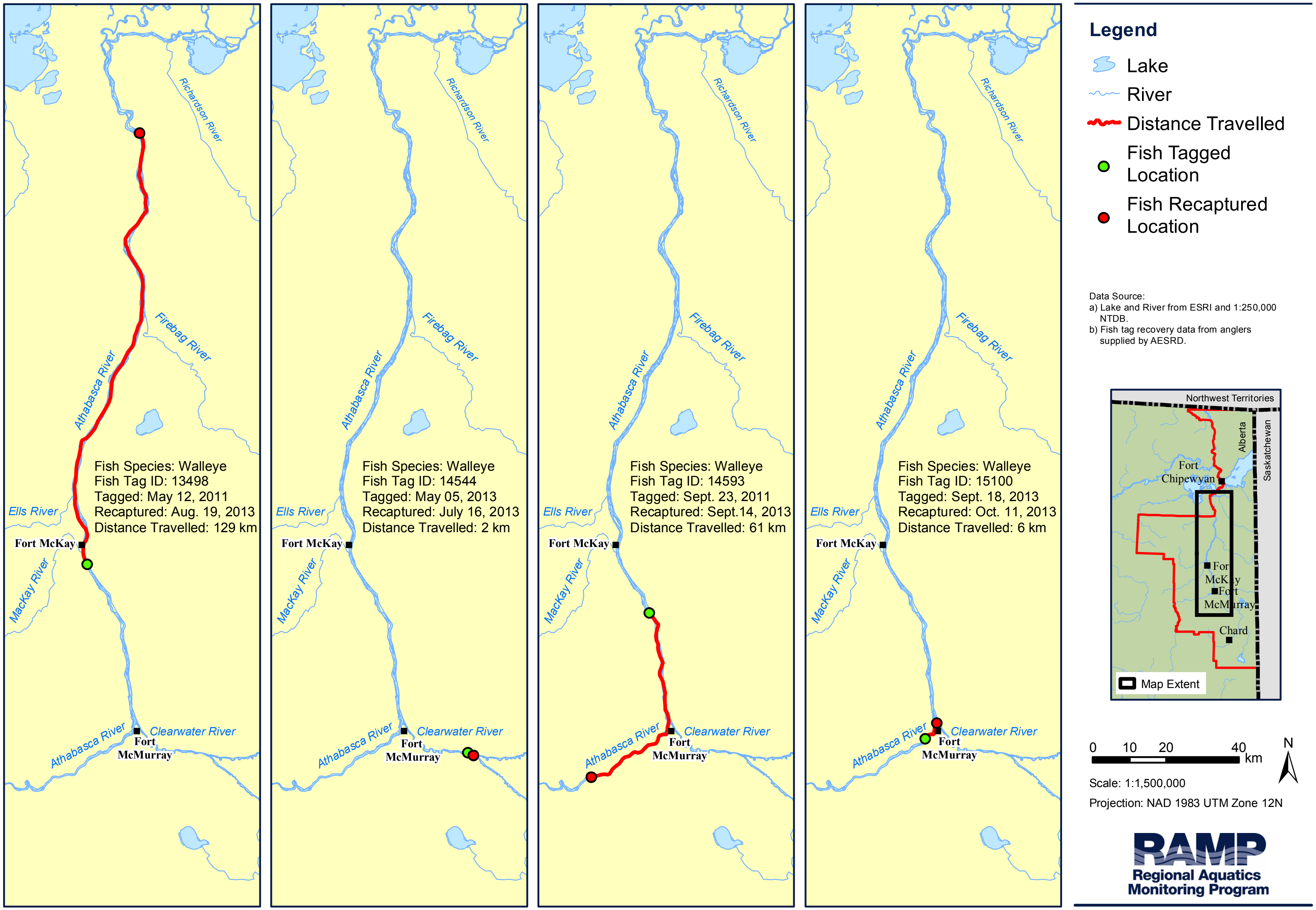
Table 5.1-24 Results of RAMP fish tag returns by anglers and during the Athabasca River and Clearwater River fish inventories, 2013.

Variable	Walleye	Northern Pike
No. of Fish Captured	6	8
Minimum Distance Travelled (km)	≥2	≥1
Maximum Distance Travelled (km)	129	≥1

Table 5.1-25 Results of RAMP fish tag returns by anglers, Athabasca and Clearwater rivers, 1999 to 2013.

Variable	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Captured	1	4	53	102	10
Minimum Distance Travelled (km)	271	5	≥1	≥1	≥1
Maximum Distance Travelled (km)	271	236	57	715	241

Figure 5.1-43 Location where tagged fish were recaptured by anglers in 2013.



Fish Species: Walleye
Fish Tag ID: 13498
Tagged: May 12, 2011
Recaptured: Aug. 19, 2013
Distance Travelled: 129 km

Fish Species: Walleye
Fish Tag ID: 14544
Tagged: May 05, 2013
Recaptured: July 16, 2013
Distance Travelled: 2 km

Fish Species: Walleye
Fish Tag ID: 14593
Tagged: Sept. 23, 2011
Recaptured: Sept.14, 2013
Distance Travelled: 61 km

Fish Species: Walleye
Fish Tag ID: 15100
Tagged: Sept. 18, 2013
Recaptured: Oct. 11, 2013
Distance Travelled: 6 km

Legend

- Lake
- River
- Distance Travelled
- ● Fish Tagged Location
- ● Fish Recaptured Location

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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_L_FishTag_20140312_ss.mxd

Table 5.1-26 Average habitat characteristics of sentinel species monitoring sites on the Athabasca River, fall 2013.

Variable	Units	Site				
		ATR-1	ATR-2	ATR-3	ATR-4	ATR-5
Sample date	-	Oct 1, 2013	Oct 1, 2013	Sept 30, 2013	Sept 30, 2013	Oct 2, 2013
Fishing effort	secs	11,788	4,943	3,950	2,207	6,480
Dissolved Oxygen	mg/L	10.4	10.6	9.8	10	10
Conductivity	µS/cm	273	278	256	255	205
pH	pH units	8.40	8.41	8.46	8.58	8.29
Temperature	ºC	9.7	9.7	10.7	10.7	8.0
Habitat Type	-	riffle	run	run	run	run
Maximum Depth	m	0.5	0.8	0.7	5.2	0.52
Average Flow	m/s	0.20	0.02		0.25	0.07
Bankfull Width	m	350	> 200	> 200	110	> 200
Wetted width	m	300	> 200	200	100	> 200
Dominant substrate	-	cobble	cobble/sand	sand	cobble	cobble/sand
Instream Cover	-	boulders	boulders	none	LWD, SWD	LWD, SWD, boulders
Riparian Cover	-	none	none	SWD	none	LWD, SWD

SWD = small woody debris; LWD = large woody debris

Note: Velocity was not measured at *test* site ATR-3.

Table 5.1-27 Summary of morphometric data (mean ± SE) for trout-perch in the Athabasca River, fall 2013.

Site	N	Sex	Age (yrs)	Length (mm)	Weight (g)	K	GSI	LSI
ATR-1	16	female	5±0.28	73.3±1.8	4.90±0.31	1.12±0.03	6.35±0.36	1.90±0.11
	40	male	5±0.20	72.4±1.4	4.14±0.20	1.05±0.01	3.27±0.61	1.52±0.16
ATR-2	22	female	4±0.26	74.1±1.4	4.54±0.23	1.09±0.01	5.61±0.31	2.00±0.08
	21	male	3±0.24	69.2±1.5	3.78±0.25	1.10±0.01	1.87±0.13	1.47±0.05
ATR-3	20	female	4±0.20	75.3±1.2	4.80±0.23	1.10±0.01	5.76±0.19	1.90±0.06
	20	male	4±0.26	71.7±1.3	4.15±0.20	1.11±0.02	2.10±0.14	1.36±0.05
ATR-4	20	female	4±0.23	77.6±1.1	5.21±0.21	1.11±0.01	5.90±0.17	1.92±0.07
	20	male	4±0.21	73.3±0.9	4.19±0.12	1.07±0.02	2.13±0.07	1.56±0.07
ATR-5	19	female	3±0.24	71.2±1.6	5.05±0.26	1.09±0.02	5.23±0.42	1.71±0.11
	25	male	3±0.17	69.0±1.5	3.64±0.20	1.07±0.01	2.43±0.11	1.35±0.05

Condition factor (K) = (weight)/length^3) * 10^5

GSI = (gonad weight)/body weight) * 100

LSI = (liver weight)/body weight) * 100

Figure 5.1-44 Mean age (± 2SD) of male and female trout-perch at *baseline* (ATR-1 and ATR-2) and *test* sites (ATR-3, ATR-4, and ATR-5) of the Athabasca River, 1999, 2002, 2010, and 2013.

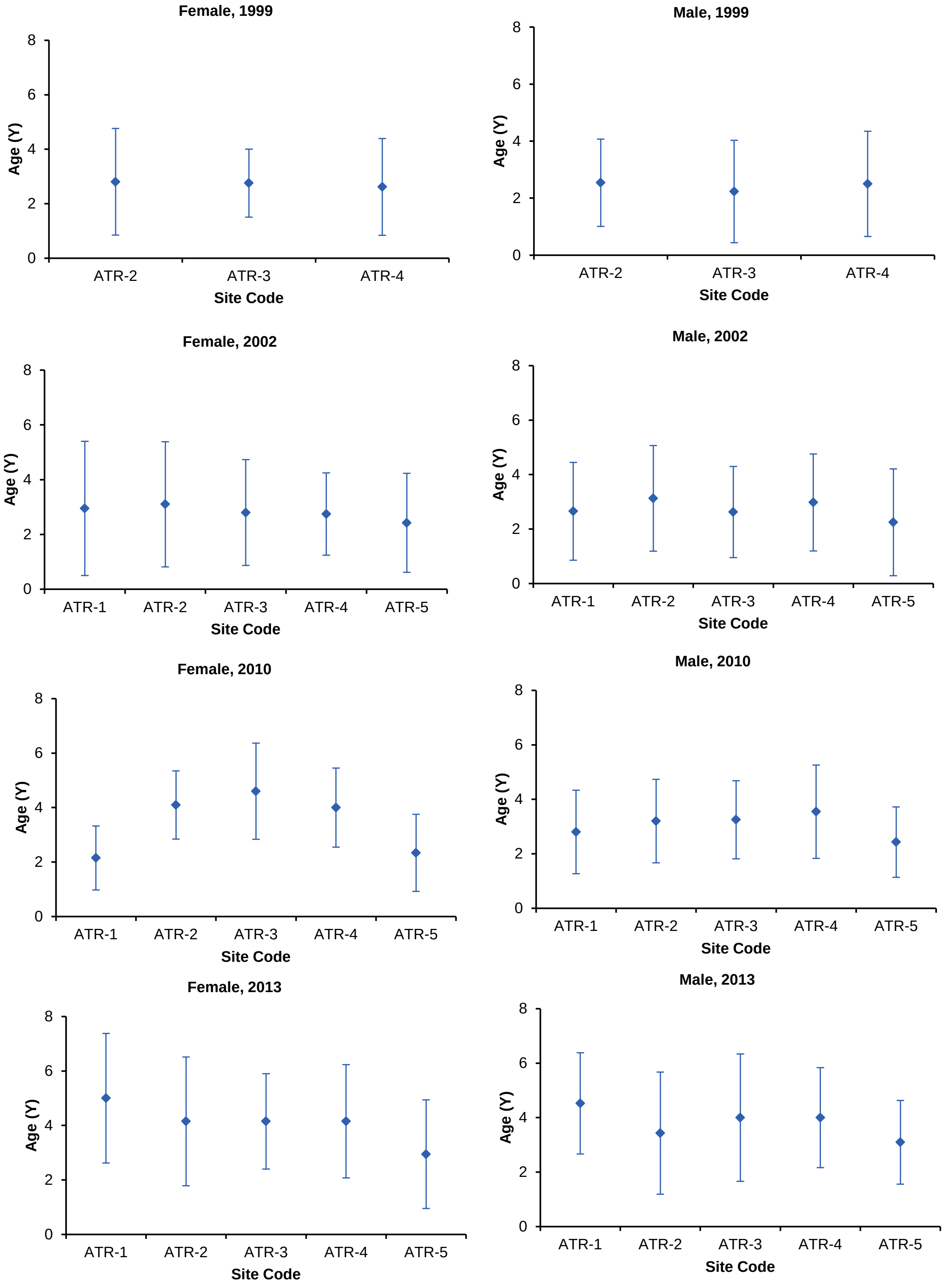


Figure 5.1-45 Relative age-frequency distribution for trout-perch across sites, 1999, 2002, 2010, and 2013.

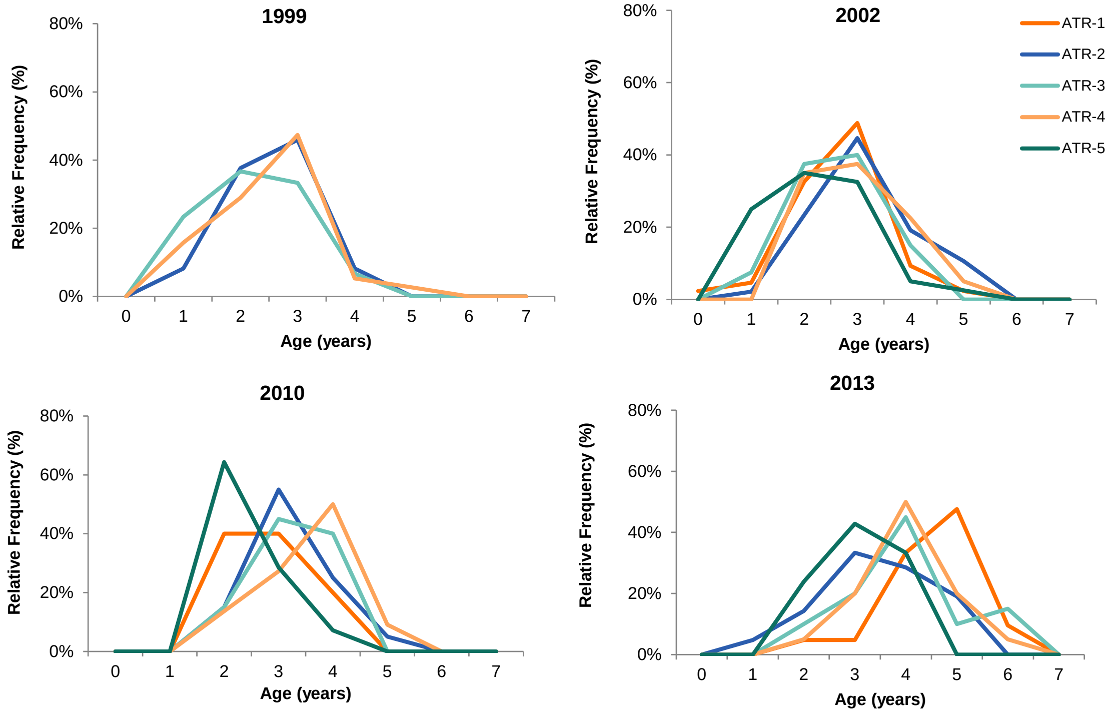


Table 5.1-28 Summary of ANOVA and ANCOVA results for each measurement endpoint of trout-perch from *baseline* sites ATR-1 and ATR-2 compared to *test* sites ATR-3, ATR-4 and ATR-5, September 2013.

Sex	Comparison	Age	Weight at Age	Relative Liver Weight	Relative Gonad Weight	Body Weight at Length
Female	ATR-1 vs. ATR-2	**0.011**	0.055	0.491	0.285	0.818
	ATR-1 vs. ATR-3	**0.004**	0.060	0.862	0.065	0.684
	ATR-1 vs. ATR-4	**0.006**	nc	0.970	**0.007**	0.825
	ATR-1 vs. ATR-5	**<0.001**	0.067	0.369	0.839	0.377
	ATR-2 vs. ATR-3	0.854	0.437	0.248	0.841	0.442
	ATR-2 vs. ATR-4	0.913	**0.026**	0.303	0.568	0.344
	ATR-2 vs. ATR-5	**0.001**	0.417	**0.027**	0.541	0.903
Male	ATR-1 vs. ATR-2	**0.002**	**0.029**	0.704	0.235	0.**011**
	ATR-1 vs. ATR-3	0.110	0.062	0.652	0.059	**0.002**
	ATR-1 vs. ATR-4	0.099	nc	0.318	0.066	0.343
	ATR-1 vs. ATR-5	**<0.001**	nc	0.572	0.437	0.185
	ATR-2 vs. ATR-3	0.124	0.797	0.136	0.962	0.807
	ATR-2 vs. ATR-4	0.073	0.361	0.343	0.423	nc
	ATR-2 vs. ATR-5	0.420	**0.050**	0.090	**0.013**	0.140

Bolded values denote a significant difference ($p<0.05$); nc = not completed given slopes of the regression lines were unequal ($p<0.01$).

Table 5.1-29 Summary of effects criterion for measurement endpoints for male and female trout-perch from *baseline* sites (ATR-1 and ATR-2) compared to *test* sites (ATR-3, ATR-4, ATR-5), 1999, 2002, 2010, and 2013.

Site		**Age**				**Body Weight at Age**				**Relative Gonad Weight**				**Relative Liver Weight**				**Body Weight at Length**			
		% Change				**% Change**				**% Change**				**% Change**				**% Change**			
Baseline	***Test***	**1999**	**2002**	**2010**	**2013**	**1999**	**2002**	**2010**	**2013**	**1999**	**2002**	**2010**	**2013**	**1999**	**2002**	**2010**	**2013**	**1999**	**2002**	**2010**	**2013**
ATR-1	ATR-3		-5.0	78.6	-16.5		4.3	1.6	17.5		2.8	10.7	-10.4		1.1	0.8	1.0		3.7	0.6	-1.0
	ATR-4		-5.8	59.9	-16.9		-6.4	4.4	28.0		6.7	-9.4	-13.4		-8.6	-7.2	-0.3		**-10.3**	2.3	-0.6
	ATR-5		-14.3	5.9	**-38.3**		4.4	**-30.7**	24.1		18.1	**-27.1**	-1.2		19.8	-10.5	-8.4		-2.0	-8.2	-2.3
ATR-2	ATR-3	0.5	-7.0	9.4	1.2	4.4	1.3	-19.2	5.9	-3.7	-3.2	1.6	1.4	5.9	-7.7	-16.1	-5.6	1.0	1.4	2.8	1.2
	ATR-4	-5.0	-7.8	-2.0	0.7	-2.8	-8.8	-11.1	16.3	8.6	-4.7	-5.4	-3.6	-3.2	-17.5	-15.7	-6.0	-5.6	**-12.2**	1.0	1.7
	ATR-5		-16.1	**-35.1**	**-25.2**		1.7	**-28.6**	7.7		8.6	**-36.6**	-10.9		8.2	-19.8	-16.8		-4.2	-2.8	-0.2
ATR-1	ATR-3		-2.8	12.4	-10.5		-0.9	-19.9	18.8		16.4	2.8	**-29.0**		9.3	-7.0	-4.1		6.8	-0.2	5.3
	ATR-4		7.0	19.7	-9.6		-13.0	-2.3	19.5		22.1	-11.1	-22.9		-0.8	6.6	9.9		-1.7	1.0	1.5
	ATR-5		-15.4	-9.4	**-26.0**		-4.3	-34.5	**38.4**		**51.4**	**-42.3**	-10.3		17.1	-11.8	-4.9		0.1	-2.9	1.8
ATR-2	ATR-3	-10.0	-12.2	1.3	13.8	-2.8	-2.8	5.2	1.9	4.0	**30.3**	19.4	-0.7	-0.1	2.9	-21.1	-7.5	0.2	-1.3	-2.5	0.5
	ATR-4	7.8	-3.3	7.9	15.0	-2.8	-14.1	**28.5**	6.5	13.5	**36.5**	-2.3	6.7	-5.0	13.1	-13.2	5.6	-5.2	-9.3	-1.6	-3.6
	ATR-5		-23.6	-18.3	-5.9		-10.1	-19.1	13.8		**68.3**	**-32.4**	**25.3**		-5.2	-19.5	-8.3		-7.8	-3.7	-2.3

Effect size (%) = antilog(LSM_B/LSM_T), where LSM = least squared mean; T = *test* site; and B = *baseline* site.

Bolded values exceeded the effect size criterion.

Underlined values were significantly different from the *baseline* site (p<0.05).

Figure 5.1-46 Relationship between body weight (g) and age (years) of male and female trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.

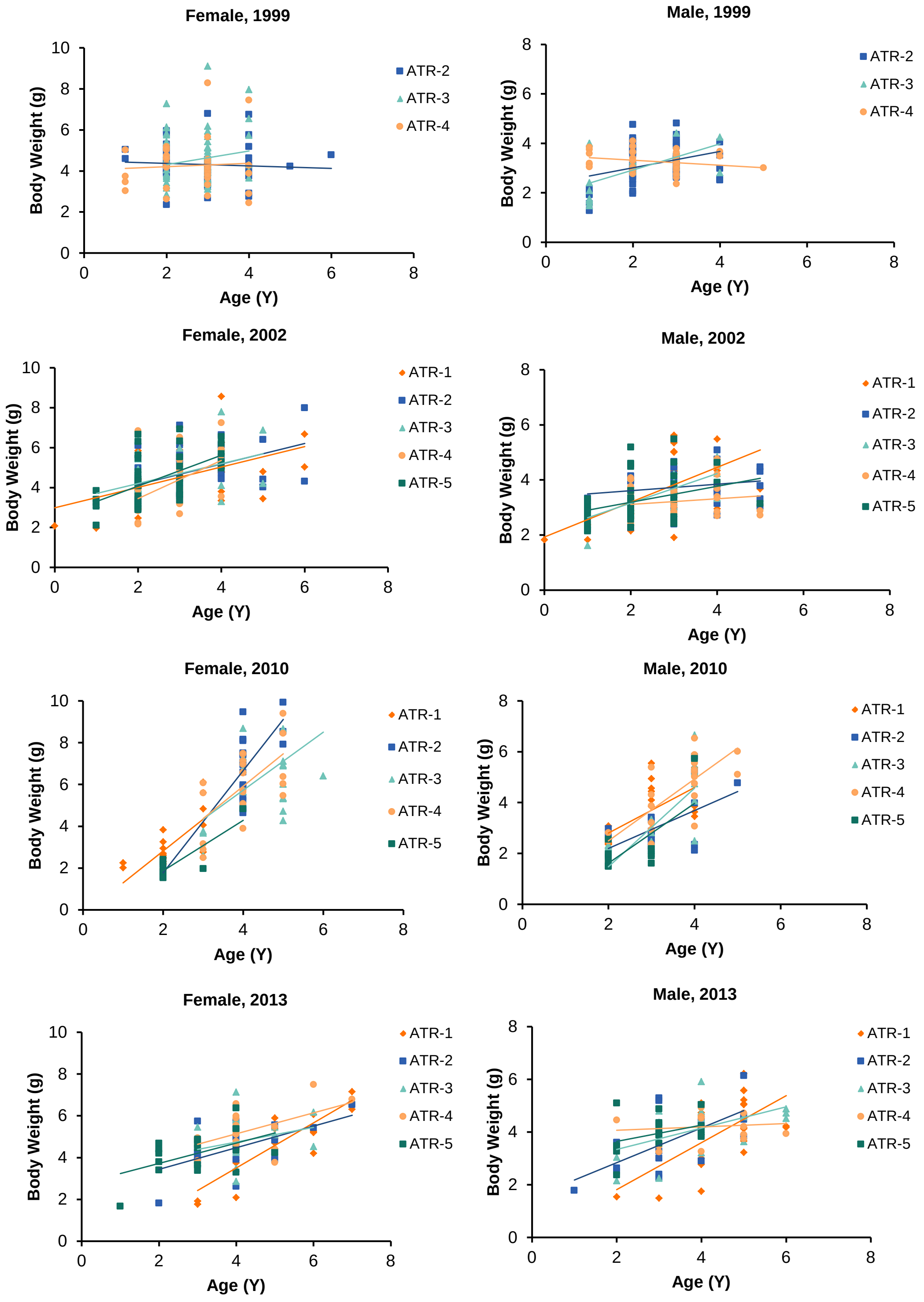


Figure 5.1-47 Mean gonadosomatic index (GSI) (± 2SD) of female and male trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.

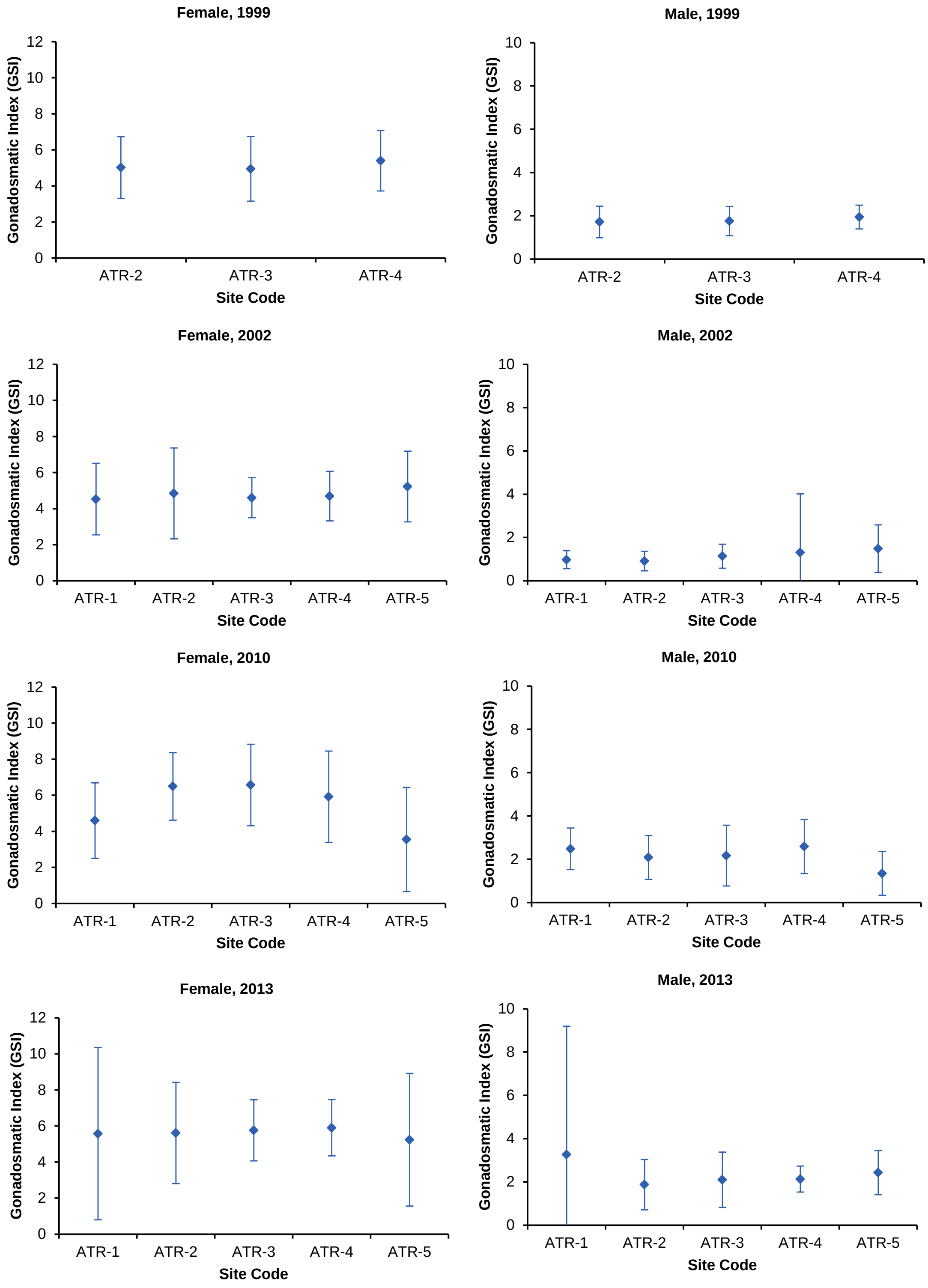


Figure 5.1-48 Relationship between gonad weight (g) and body weight (g) of male and female trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.

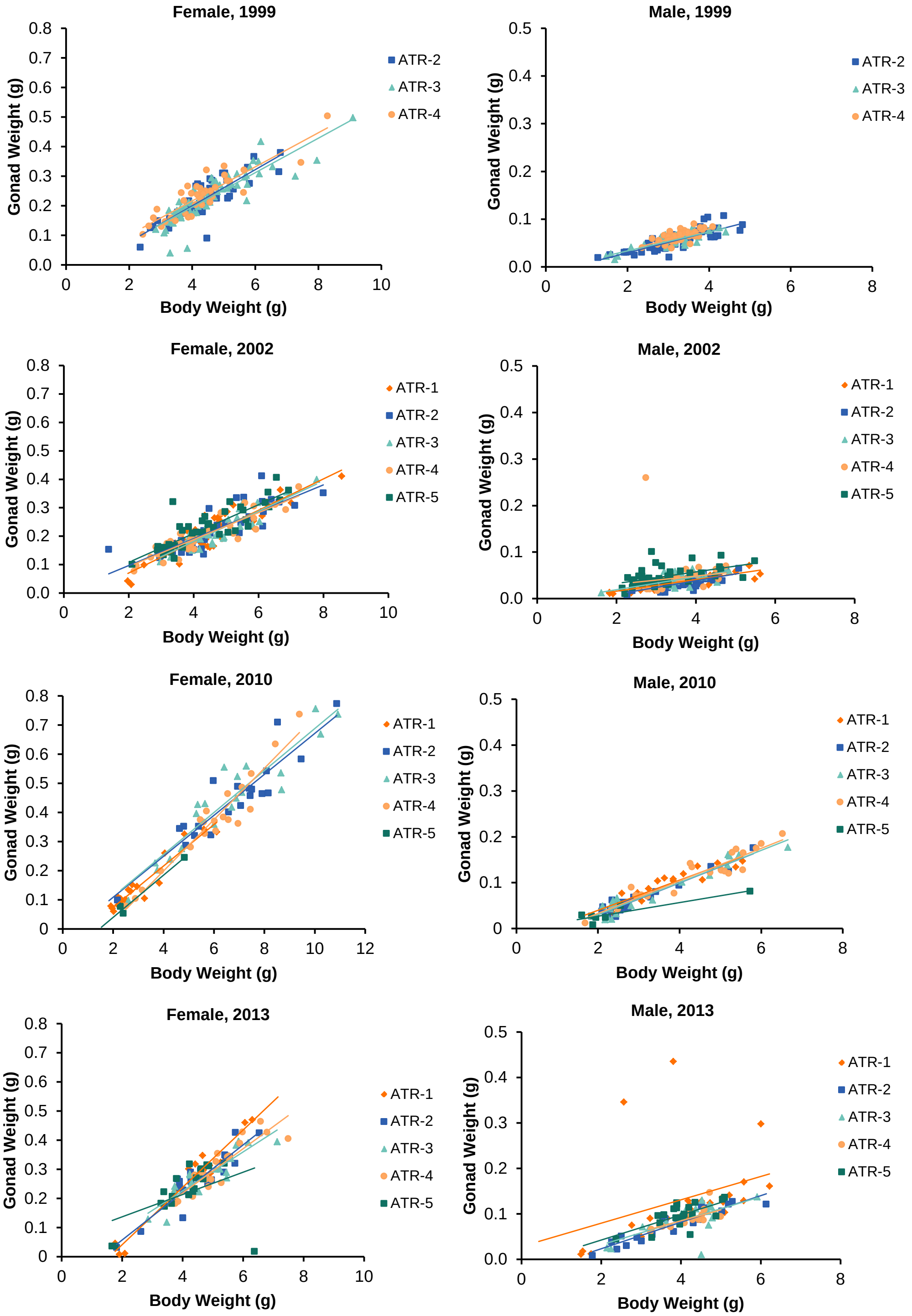


Figure 5.1-49 Mean liversomatic index (LSI) (± 2SD) of female and male trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.

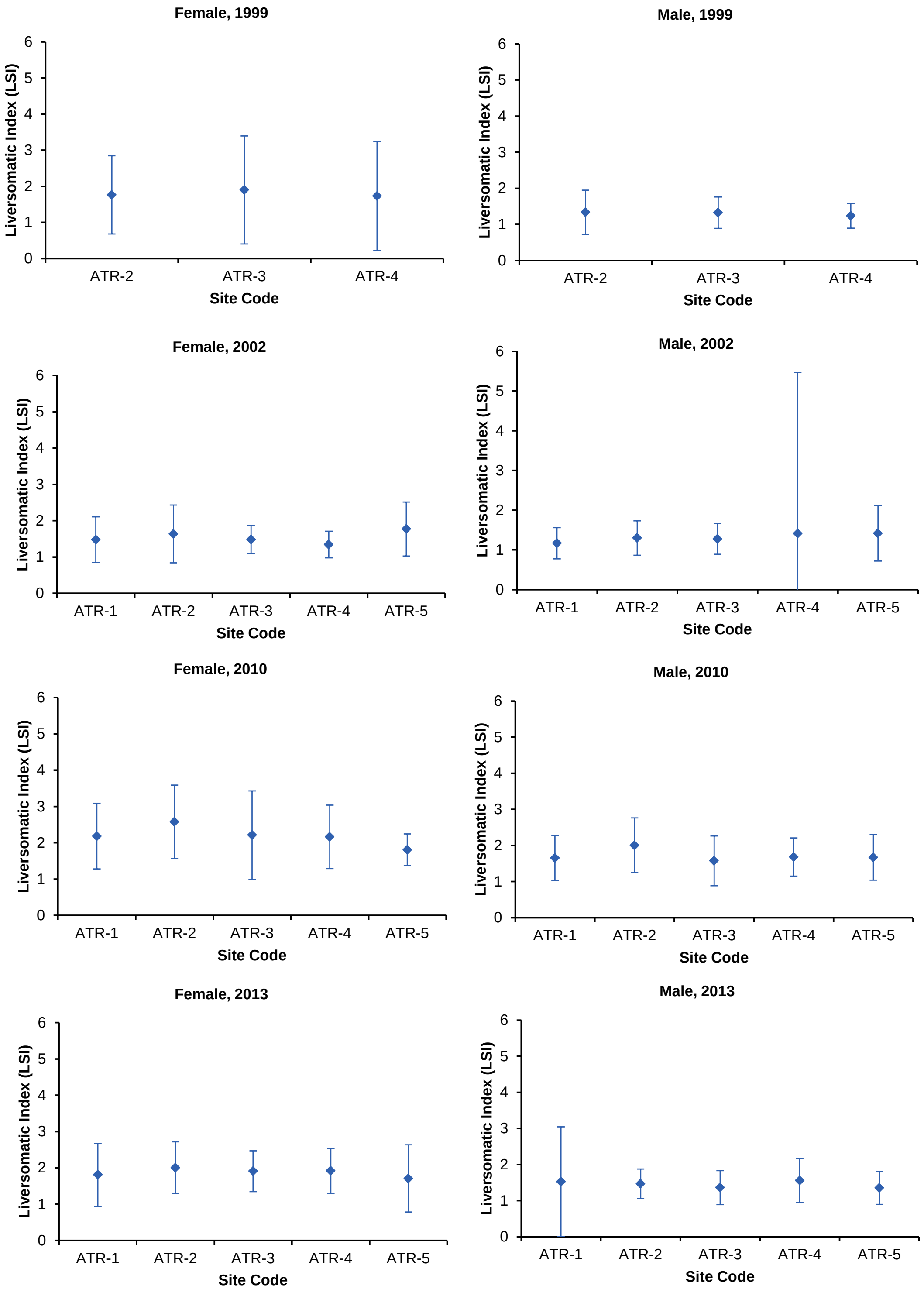


Figure 5.1-50 Relationship between liver weight (g) and body weight (g) of male and female trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.

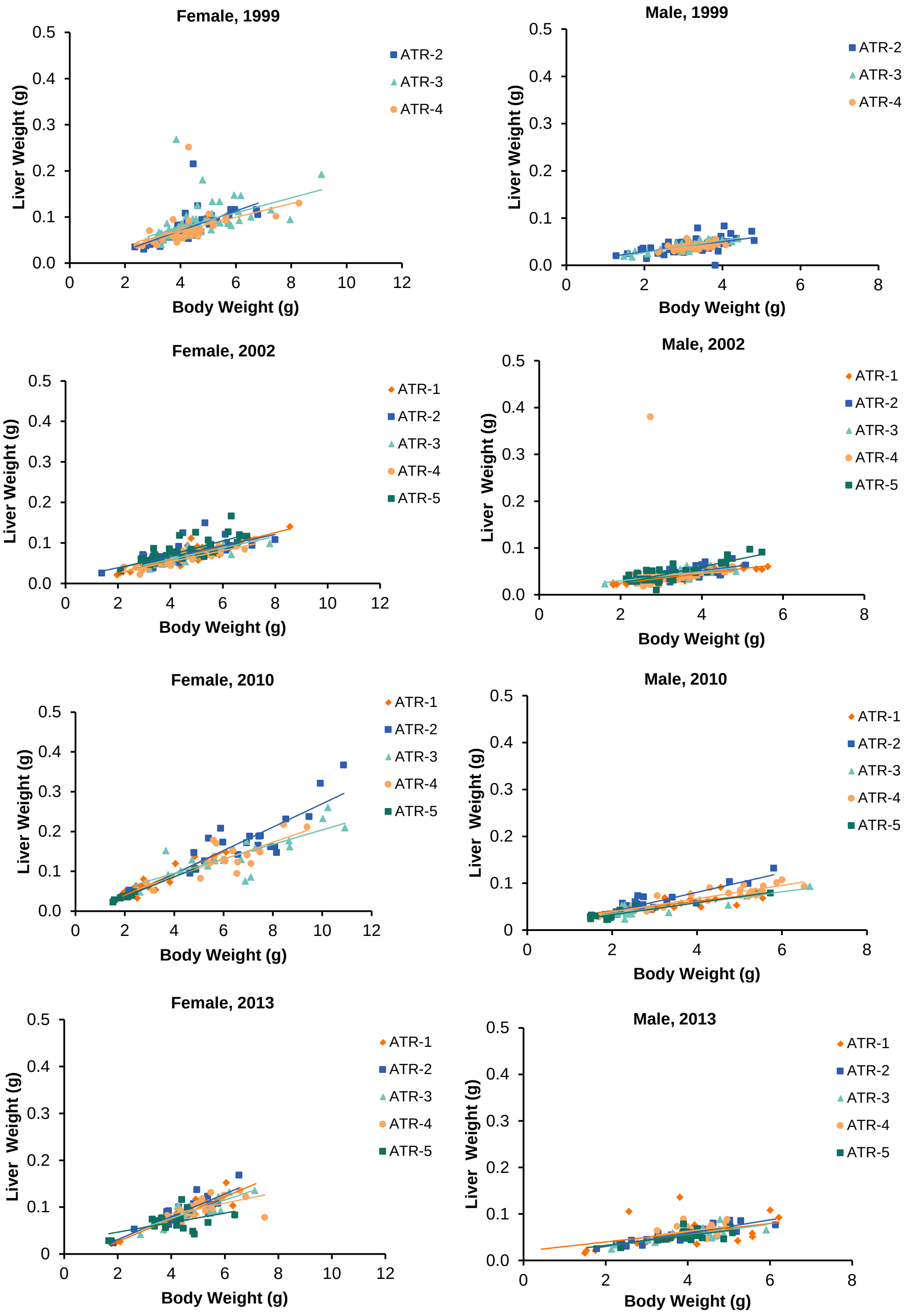


Figure 5.1-51 **Mean condition factor (± 2SD) of female and male trout-perch at *baseline* (ATR-1 and ATR-2) and *test* (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2010, and 2013.**

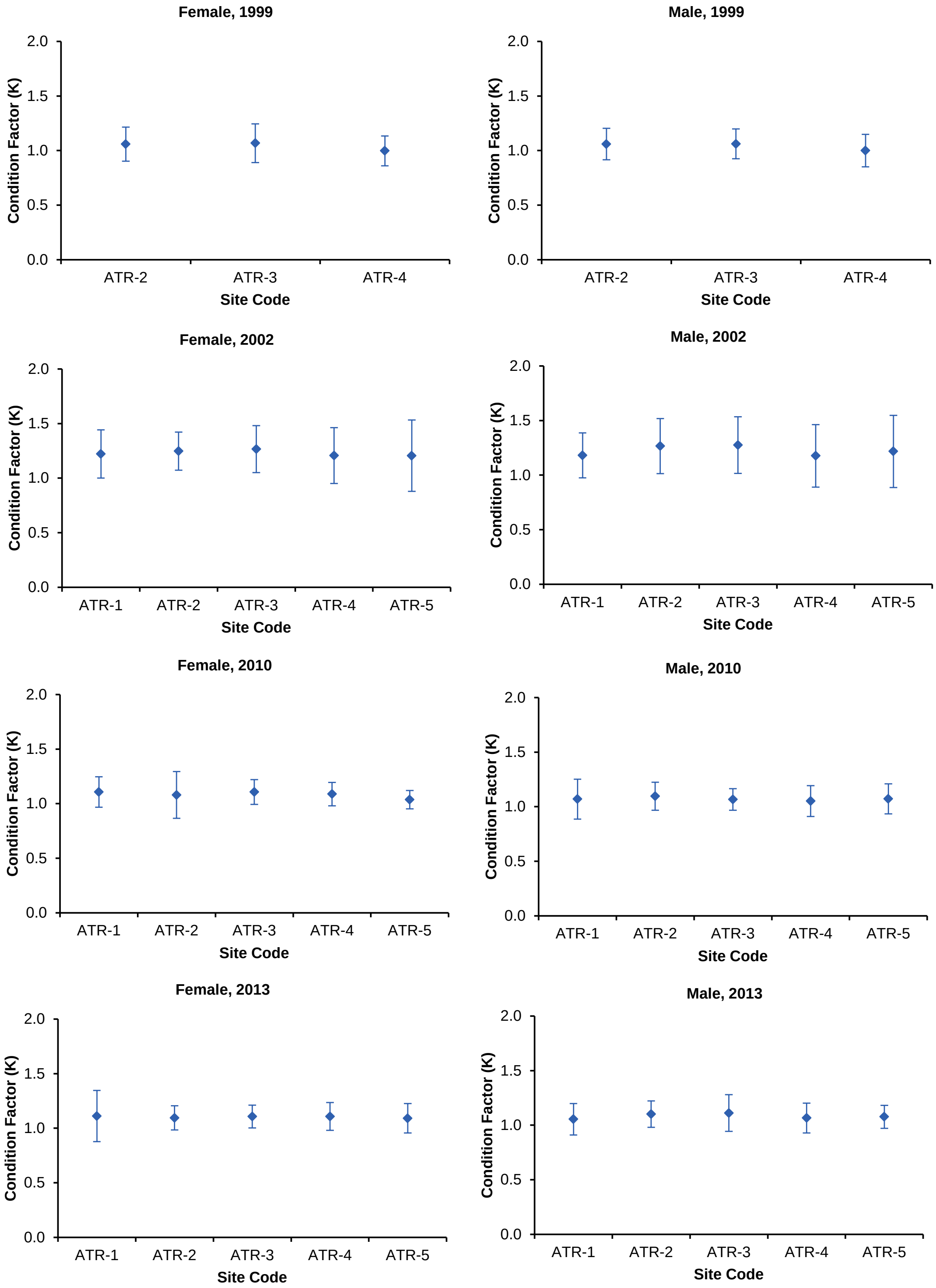
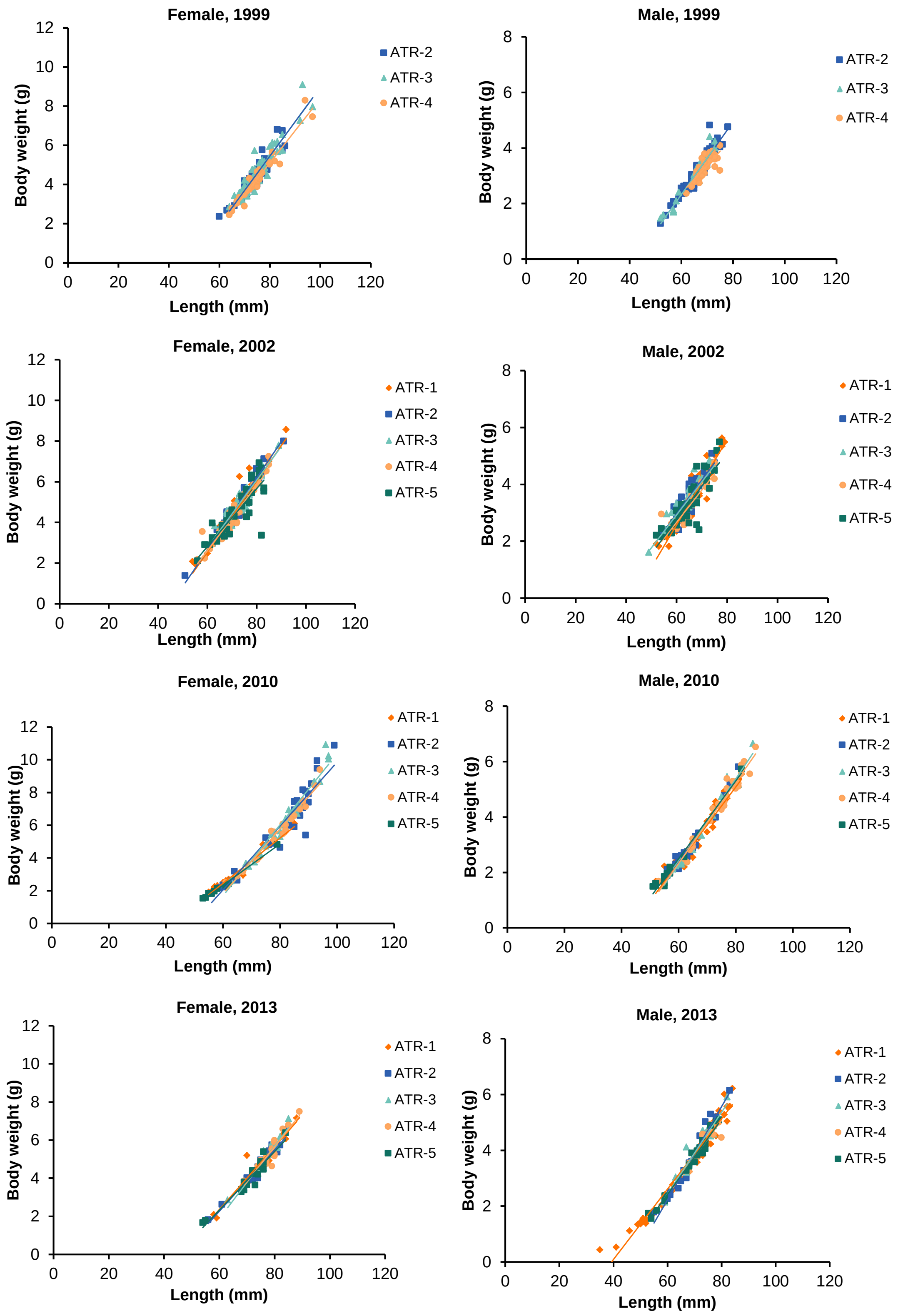


Figure 5.1-52 Relationship between body weight (g) and total length (mm) of trout-perch at *baseline* (ATR-1 and ATR-2) and test (ATR-3, ATR-4 and ATR-5) sites of the Athabasca River, 1999, 2002, 2007, 2010, and 2013.


Female, 1999

Male, 1999

Female, 2002

Male, 2002

Female, 2010

Male, 2010

Female, 2013

Male, 2013

Table 5.1-30 Post-hoc power analyses of pairwise comparisons of *test* sites ATR-3, ATR-4, and ATR-5 to each *baseline* site (ATR-1 and ATR-2), that were not statistically significant.

Variable/Sex	Effect Size	Comparison	Effect size (log)	MSE (ANCOVA)	Actual Sample Size	Post Hoc Power (calculated)
Age						
female	25% effect	ATR-2 vs. ATR-3	0.09691	0.0076	40	0.965
	25% effect	ATR-2 vs. ATR-5	0.09691	0.0084	40	0.950
male	25% effect	ATR-1 vs. ATR-3	0.09691	0.0145	41	0.812
	25% effect	ATR-1 vs. ATR-4	0.09691	0.0141	41	0.822
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0131	41	0.847
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0111	41	0.894
	25% effect	ATR-2 vs. ATR-5	0.09691	0.0111	42	0.829
Weight-At-Age						
female	25% effect	ATR-1 vs. ATR-3	0.09691	0.0089	36	0.915
	25% effect	ATR-1 vs. ATR-5	0.09691	0.0093	33	0.880
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0101	40	0.912
	25% effect	ATR-2 vs. ATR-5	0.09691	0.0104	37	0.883
male	25% effect	ATR-1 vs. ATR-3	0.09691	0.0145	41	0.812
	25% effect	ATR-1 vs. ATR-4	0.09691	0.0141	41	0.821
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0094	41	0.932
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0082	41	0.960
Gonad Weight vs. Body Weight						
female	25% effect	ATR-1 vs. ATR-3	0.09691	0.0049	33	0.986
	25% effect	ATR-1 vs. ATR-5	0.09691	0.0049	31	0.982
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0080	40	0.957
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0060	40	0.987
	25% effect	ATR-2 vs. ATR-5	0.09691	0.0610	39	0.331
male	25% effect	ATR-1 vs. ATR-3	0.09691	0.0636	44	0.349
	25% effect	ATR-1 vs. ATR-4	0.09691	0.0382	44	0.489
	25% effect	ATR-1 vs. ATR-5	0.09691	0.0407	45	0.476
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0390	40	0.452
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0110	40	0.889
Liver Weight vs. Body Weight						
female	25% effect	ATR-1 vs. ATR-3	0.09691	0.0053	34	0.984
	25% effect	ATR-1 vs. ATR-4	0.09691	0.0074	34	0.941
	25% effect	ATR-1 vs. ATR-5	0.09691	0.0140	33	0.743
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0050	40	0.995
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0060	40	0.987
male	25% effect	ATR-1 vs. ATR-3	0.09691	0.0170	44	0.783
	25% effect	ATR-1 vs. ATR-4	0.09691	0.0176	44	0.769
	25% effect	ATR-1 vs. ATR-5	0.09691	0.0165	45	0.800
	25% effect	ATR-2 vs. ATR-3	0.09691	0.0048	40	0.997
	25% effect	ATR-2 vs. ATR-4	0.09691	0.0056	40	0.991
	25% effect	ATR-2 vs. ATR-5	0.09691	0.0047	41	0.998
Condition						
female	10% effect	ATR-1 vs. ATR-3	0.04139	0.0009	37	0.991
	10% effect	ATR-1 vs. ATR-4	0.04139	0.0011	37	0.983
	10% effect	ATR-1 vs. ATR-5	0.04139	0.0011	36	0.976
	10% effect	ATR-2 vs. ATR-3	0.04139	0.0005	42	0.999
	10% effect	ATR-2 vs. ATR-4	0.04139	0.0006	42	0.999
	10% effect	ATR-2 vs. ATR-5	0.04139	0.0006	41	0.999
male	10% effect	ATR-1 vs. ATR-4	0.04139	0.0006	60	0.999
	10% effect	ATR-1 vs. ATR-5	0.04139	0.0005	65	1.000
	10% effect	ATR-2 vs. ATR-3	0.04139	0.0008	41	0.998
	10% effect	ATR-2 vs. ATR-4	0.04139	0.0007	41	0.999
	10% effect	ATR-2 vs. ATR-5	0.04139	0.0005	46	0.999

Underline values denote comparisons where there was not adequate power and sample size was too low (P<0.90).

Table 5.1-31 Summary of effects criterion for each measurement endpoint from *baseline* site (ATR-2) compared to each *test* site (ATR-3, ATR-4, and ATR-5), fall 2013.

Sex	Site	Age (% change)	Energy Use (% change)		Energy Storage (% change)		Significant Difference from *Baseline*					Response Pattern Based on Effects Criteria				
								Energy Use		Energy Storage			Energy Use		Energy Storage	
			Weight-at-age	Relative Gonad Weight	Relative Liver Weight	Body Weight at Length	Age	Weight-at-age	Relative Gonad Weight	Relative Liver Weight	Body Weight at Length	Age	Weight-at-age	Relative Gonad Weight	Relative Liver Weight	Body Weight at Length
Female	ATR-3	1.2	5.9	1.4	-5.6	1.2	0	0	0	0	0	0	0	0	0	0
	ATR-4	0.7	16.3	-3.6	-6.0	1.7	0	+	0	0	0	0	0	0	0	0
	ATR-5	**-25.2**	7.7	-10.9	-16.8	-0.2	-	0	0	-	0	-	0	0	0	0
Male	ATR-3	13.8	1.9	-0.7	-7.5	0.5	0	0	0	0	0	0	0	0	0	0
	ATR-4	15.0	6.5	6.7	5.6	-3.6	0	0	0	0	0	0	0	0	0	0
	ATR-5	-5.9	13.8	**25.3**	-8.3	-2.3	0	+	+	0	0	0	0	+	0	0

Bolded values exceeded the effect size criterion.

Note: + = *test* site is higher; - = *test* site is lower; 0 = no change from *baseline* site.

Table 5.1-32 Average habitat characteristics of fish assemblage monitoring reaches of the Athabasca River Delta, August 2013.

Variable	**Units**	**BPC-F1 *Test* Reach of Big Point Channel**	**GIC-F1 *Test* Reach of Goose Island Channel**	**FLC-F1 *Test* Reach of Fletcher Channel**	**EMR-F2 *Test* Reach of the Embarras River**
Sample date	-	Aug 22, 2013	Aug 22, 2013	Aug 21, 2013	Aug 22, 2013
Habitat type	-	run	run	run	run
Reach length	m	5,783	5,613	4,433	4,291
Maximum depth	m	5.4	9.0	5.0	10.0
Bankfull channel width	m	115	110	62	90
Wetted channel width	m	115	110	60	90
Substrate					
Dominant	-	fines	fines	fines	fines
Subdominant	-	sand	sand	sand	sand
Instream cover					
Dominant	-	filamentous algae, macrophytes, large woody debris, small woody debris, live trees/roots, overhanging vegetation	filamentous algae, macrophytes, large woody debris, small woody debris, live trees/roots, overhanging vegetation, undercut banks	small woody debris, overhanging vegetation, undercut banks	small woody debris
Subdominant	-	-	-	-	macrophytes, live trees/roots, overhanging vegetation
Field water quality					
Dissolved oxygen	mg/L	7.8	7.2	7.8	6.8
Conductivity	µS/cm	307	293	301	313
pH	pH units	8.22	8.29	8.26	8.24
Water temperature	^{0}C	20.4	19.6	19.8	19.5
Riparian cover – understory (<5 m)					
Dominant	-	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging Vegetation	overhanging Vegetation	-	overhanging Vegetation

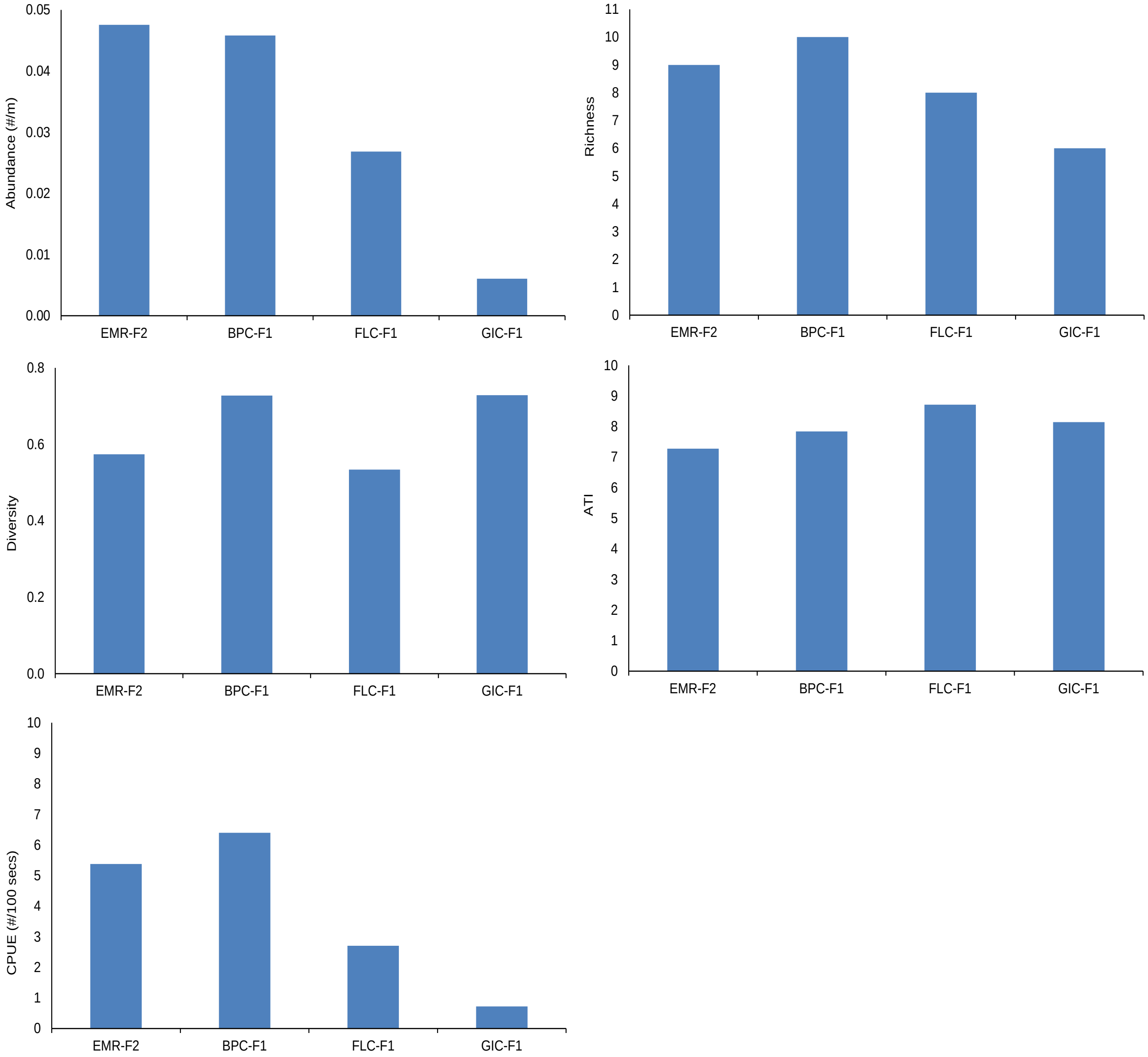
Table 5.1-33 Total number and percent composition of fish species captured in channels of the Athabasca River Delta, August 2013.

Common Name	Code	Total Species				Percent of Total Catch			
		EMR-F2	BPC-F1	FLC-F1	GIC-F1	EMR-F2	BPC-F1	FLC-F1	GIC-F1
burbot	BURB	-	1	-	1	0.0	0.4	0.0	2.9
cisco	CISC	-	1	-	-	0.0	0.4	0.0	0.0
emerald shiner	EMSH	111	103	11	4	54.4	38.9	9.2	11.8
lake chub	LKCH	7	73	78	14	3.4	27.5	65.5	41.2
lake whitefish	LKWH	2	-	-	-	1.0	0.0	0.0	0.0
longnose sucker	LNSC	-	1	-	-	0.0	0.4	0.0	0.0
northern pike	NRPK	5	15	4	6	2.5	5.7	3.4	17.6
spottail shiner	SPSH	73	53	19	8	35.8	20.0	16.0	23.5
trout-perch	TRPR	1	6	1	-	0.5	2.3	0.8	0.0
walleye	WALL	1	11	4	1	0.5	4.2	3.4	2.9
white sucker	WHSC	1	1	1	-	0.5	0.4	0.8	0.0
yellow perch	YLPR	3	-	1	-	1.5	0.0	0.8	0.0
Total Count		204	265	119	34	100	100	100	100
Total Species Richness		9	10	8	6	-	-	-	-
Electrofishing Effort (secs)		3,811	4,140	4,399	4,698	-	-	-	-

Table 5.1-34 Summary of fish assemblage measurement endpoints for reaches of the Athabasca River Delta, 2013.

Reach	Abundance (#/m)	Richness	Diversity	ATI	CPUE (#/100 secs)
EMR-F2	0.048	9	0.57	7.27	5.38
BPC-F1	0.046	10	0.73	7.84	6.40
FLC-F1	0.027	8	0.53	8.71	2.71
GIC-F1	0.006	6	0.73	8.14	0.72

Figure 5.1-53 Variations in fish assemblage measurement endpoints for *test* reaches of the Athabasca River Delta, 2013.



5.2 MUSKEG RIVER WATERSHED

Table 5.2-1 Summary of results for the Muskeg River watershed.

Muskeg River Watershed	**Summary of 2013 Conditions**										
	Muskeg River			***Jackpine Creek***		***Other Creeks***				***Lakes***	
Climate and Hydrology											
Criteria	**07DA008** near Fort McKay		**S5, S5A, S20A, S33***	**S2** at Canterra Road	**S37** east Jackpine Creek near the 1,300 ft. contour	**S22** Muskeg Creek near the mouth	**S65** North Greenstock-ings Creek Tributary	**S10A** Wapasu Creek near the mouth	**S3** Iyinimin Creek above Kearl Lake	**L2** Kearl Lake	**S9** Kearl Lake Outlet
Mean open-water season discharge	🟠		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Mean winter discharge	🟡		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Annual maximum daily discharge	🟠		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Minimum open-water season discharge	🟤		not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured	not measured
Water Quality											
Criteria	**MUR-1** at the mouth	no station sampled	**MUR-6A** upstream of Wapasu Creek	**JAC-1** at the mouth	**JAC-2** upper station	**MUC-1** Muskeg Creek at the mouth	**STC-1** Stanley Creek at the mouth	**WAC-1** Wapasu Creek at Canterra Road	**IYC-1** Iyinimin Creek	**KEL-1** Kearl Lake	no station 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-F1** lower reach	**MUR-F2** middle reach	**MUR-F3** upper reach	**JAC-F1** lower reach	**JAC-F2** upper reach	no reach sampled	no reach sampled	no reach sampled	no reach sampled	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 were designated based on comparisons with *baseline* reaches.

*Station S5 located on Muskeg River above Stanley Creek, S5A located on Muskeg River above Muskeg Creek, S20A located on Muskeg River Upland, and S33 located on Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary.

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.

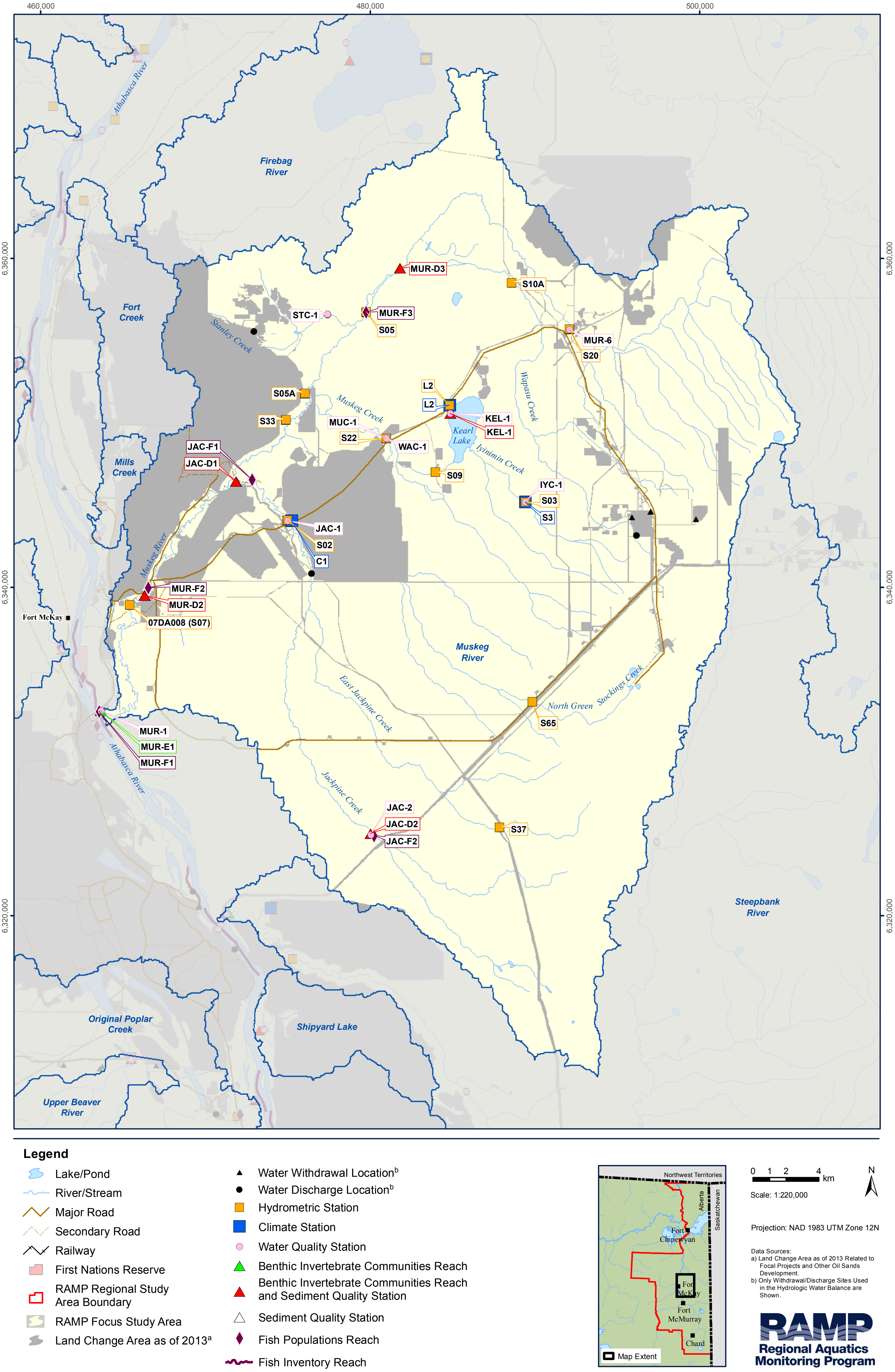
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.2.3.1 for a detailed description of the classification methodology.

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 3.2.4.4 for a description of the classification methodology.

Figure 5.2-1 Muskeg River watershed.



K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K02_Muskeg_20140224_ss.mxd

Figure 5.2-2 Representative monitoring stations of the Muskeg River watershed, 2013.

Benthic Invertebrate Reach MUR-E1 (Muskeg River): facing downstream

Water Quality Station MUC-1 (Muskeg Creek): facing upstream

Benthic and Sediment Quality Reach MUR-D2 (Muskeg River): facing downstream

Benthic and Sediment Quality Reach JAC-D2 (Jackpine Creek): facing downstream

Benthic and Sediment Quality Reach JAC-D1 (Jackpine Creek): facing upstream

Water Quality Station WAC-1 (Wapasu Creek)

Hydrology Station S5 (Muskeg River)

Water Quality Station KEL-1: Kearl Lake

5.2.1 Summary of 2013 Conditions

As of 2013, approximately 16% (22,830 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 Expansion, and Shell Jackpine Mine and Expansion leases are designated as *test*.
2. The remainder of the watershed, including the upper portion of Jackpine Creek, is designated as *baseline*.

Monitoring programs were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components of RAMP in the Muskeg River watershed in 2013. Table 5.2-1 is a summary of the 2013 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 2013 in the Muskeg River watershed. Figure 5.2-2 contains fall 2013 photos of representative monitoring stations in the watershed.

Hydrology The calculated mean open-water discharge and the annual maximum daily discharge were 6.12% and 7.40% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **Moderate**. The mean winter discharge was 0.25% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low.** The open-water period minimum daily discharge was 15.32% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **High**. In the 2013 WY, the water level in Kearl Lake steadily decreased from November 2012 to mid-February 2013, and then fluctuated between historical minimum and historical lower quartile values until the beginning of the freshet in mid-April. Lake water levels exceeded the historical maximum values from June 11 to June 26 in response to rainfall events in early to mid-June. Rainfall events in early October also increased the lake level to above the historical median level until the end of the 2013 WY.

Water Quality In fall 2013, concentrations of most water quality measurement endpoints were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2013 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were **Negligible-Low**.

Monthly concentrations of most water quality measurement endpoints at *test* station MUR-1 were within the range of the regional *baseline* fall concentrations, with some monthly variability generally showing higher concentrations for ions and metals in winter when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at *test* station MUR-1 remained consistent.

Benthic Invertebrate Communities and Sediment Quality Differences in values of measurement endpoints at *test* reach MUR-E1 were classified as **Negligible-Low** because the significant increase in total abundance over time and the high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies were indicative of good water and habitat conditions. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. Equitability was lower than the inner tolerance limit for the 5th percentile, indicating that diversity in the reach was increasing, which was considered a positive change.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa was indicative of a positive change and all measurement endpoints were within the inner tolerance limits of the historical range of variability for this reach.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because the significant increase over time in EPT taxa and the higher percentage of EPT taxa in 2013 compared to the mean of *baseline* years or the mean all years combined were indicative of a positive change in the benthic invertebrate community. Three key measurement endpoints were outside of the tolerance limits for the historical range of variation, but were also indicative of greater diversity, richness, and abundance of EPT taxa. The relative abundance of tubificid worms was high in 2013, but consistent with previous years.

Differences in measurement endpoints for benthic invertebrate communities at *test* reach JAC-D1 were classified as **Negligible-Low** because although there were significant increases in abundance and richness and a decrease in equitability over time during the period that this reach was designated as *test*, these changes were not indicative of degrading conditions.

Differences in values of measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Negligible-Low.** There were no statistically large changes (i.e., accounting for greater than 20% in the variance of annual means) for any measurement endpoint. Additionally, the benthic invertebrate community of Kearl Lake included diverse fauna, with several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves). All measurement endpoints for benthic invertebrate communities in Kearl Lake were within the inner tolerance limits for the historical range of variation in Kearl Lake.

Concentrations of sediment quality measurement endpoints at all Muskeg River watershed stations sampled in fall 2013 were similar or lower than measured in previous years and within the range of regional *baseline* conditions. Differences in sediment quality in fall 2013 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 of the fish assemblage at *test* reach MUR-F1 were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there was a decrease in abundance and CPUE over time, which are indicative of a potential negative change in the fish assemblage. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and regional *baseline* conditions were classified as **Moderate** because CPUE and abundance were lower than the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F3 and regional *baseline* conditions were classified as **High** given that only one fish was captured at this reach in 2013, and CPUE, abundance, diversity, and richness were at the outer tolerance limit for the 5th percentile in 2012 and 2013. The low capture success was likely due to greater water depths in the last two years, which decreased capture efficiency.

Differences in measurement endpoints of the fish assemblage at *test* reach JAC-F1 were classified as **High** because richness and CPUE were at the inner tolerance limit for the lower 5th percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints over time, which are indicative of a potential negative change in the fish assemblage.

5.2.2 Hydrologic Conditions: 2013 Water Year

Muskeg River

Hydrometric monitoring for the Muskeg River watershed was conducted at 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, S10A Wapasu Creek near the mouth, S20A Muskeg River Upland, S22 Muskeg Creek near the mouth, S33 Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary, S37 East Jackpine Creek near the 1,300 ft. contour, and S65 North Greenstockings Creek tributary at the East Athabasca Hwy. Details for each of these stations can be found in Appendix C.

Continuous annual hydrometric data have been collected at WSC Station 07DA008 (RAMP Station S7) from 1974 to 1986 and from 1999 to 2013. Seasonal data from March to October have been collected every year since 1974. The 2013 WY annual and open-water runoff volumes were 262 million m^3 and 236 million m^3, respectively. The annual runoff volume was 142% higher than the historical mean annual runoff and the open-water runoff volume was 132% higher than the historical mean open-water runoff. Flows decreased steadily from November 2012 to mid-March 2013, and generally remained above the historical upper quartile values (Figure 5.2-3). Flows increased in April and early May during freshet to a peak of 54.1 m^3/s on May 10. Following the freshet, flows generally decreased and remained near the historical upper quartile values until early June. Flows then increased in response to rainfall events in mid-June, reaching a maximum open-water daily flow of 80.6 m^3/s on June 15. This value was 227% higher than the historical mean open-water maximum daily flow of 24.7 m^3/s (Figure 5.2-3). Flows decreased through July and August until the lowest open-water flow of 1.15 m^3/s on September 16, which was 10% higher than the historical mean open-water minimum daily flow. Large rainfall events in early October increased flows in early to mid-October to above historical maximum values and then decreased to historical median values by the end of the 2013 WY.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at WSC Station 07DA008 (RAMP Station S7) for the 2013 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 2013 was estimated to be 128 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 24.4 million m^3.

2. As of 2013, the area of land change in the Muskeg River watershed from focal projects that was not closed-circuited was estimated to be 99.9 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 3.80 million m^3.

3. Syncrude discharged 5.03 million m³ of water into Stanley Creek via the Aurora Clean Water Diversion (CWD). As in previous water balance calculations involving the CWD (e.g., RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012; RAMP 2013), the assumption was made that none of the water released from the CWD would have reached the Muskeg River through other sources. Given that some of the CWD flows were diverted surface water, some proportion of this water likely would have contributed to the Muskeg River naturally; however, this was undefined.
4. Shell withdrew 0.362 million m³ from the Athabasca River and released into Jackpine Creek to augment or maintain flows from October to April.
5. Husky withdrew 0.046 million m³ of water for earthworks and dust suppression activities and released 0.068 million m³ of water from its Sunshine project treatment plant to the Muskeg River watershed.

The estimated cumulative effect of land change, water withdrawals, and water releases was a decrease in flow of 15.2 million m³ 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 6.12% and 7.40% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively (Table 5.2-3). These differences were classified as **Moderate** (Table 5.2-1). The mean winter discharge was 0.25% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low.** The open-water period minimum daily discharge was 15.32% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.2-3). This difference was 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 2013 WY, lake levels steadily decreased from November 2012 to mid-February 2013, and then fluctuated between historical minimum and historical lower quartile values until the beginning of the freshet in mid-April (Figure 5.2-4). Lake water levels increased during spring freshet to a peak of 332.151 masl on May 19. Lake water levels exceeded the historical maximum values from June 11 to June 26 in response to rainfall events in early to mid-June. The peak lake level of 332.391 m on June 15 was the maximum recorded lake level for the 2013 WY and was 0.293 m above the historical maximum lake level. Following this peak, lake levels decreased steadily to below the historical lower quartile value in mid-September. Rainfall events in early October increased the lake levels to above the historical median level until the end of the 2013 WY.

5.2.3 Water Quality

In fall 2013, water quality samples were taken from:

- the Muskeg River near its mouth (*test* station MUR-1), sampled from 1997 to 2013 in fall and on a monthly basis starting in 2013;
- the Muskeg River upstream of Wapasu Creek (*test* station MUR-6A), initiated in 2013 when access issues required moving station MUR-6 further upstream (less than a kilometer) and renamed as MUR-6A. MUR-6 was 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 2013;
- upper Jackpine Creek (*baseline* station JAC-2), sampled from 2008 to 2013;
- 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 2013;
- Stanley Creek near its mouth (*test* station STC-1), designated as *baseline* from 2001 to 2002 and *test* from 2003 to 2013;
- Iyinimin Creek near its mouth (*test* station IYC-1), sampled in 2007, 2008, 2010 to 2013, designated as *baseline* from 2007 to 2008 and *test* from 2010 to 2013;
- Wapasu Creek near its mouth (*test* station WAC-1), sampled intermittently from 1998 to 2013, designated as *baseline* from 1998 to 2006 and *test* from 2007 to 2013; and
- Kearl Lake (*test* station KEL-1), designated as *baseline* from 1998 to 2008 and *test* from 2009 to 2013.

Temporal Trends The following trends (α=0.05) in fall concentrations of water quality measurement endpoints were detected over the period of monitoring for each station:

- an increasing concentration of arsenic at *test* station MUR-1;
- an increasing concentration of total boron, and decreasing concentrations of chloride and sulphate at *test* station MUR-6A (using data from *test* station MUR-6 for previous years);
- decreasing concentrations of chloride and sulphate at *test* station MUC-1;
- increasing concentrations of total boron and total arsenic at *test* station JAC-1;
- increasing concentrations of total boron and dissolved phosphorus, and a decreasing concentration of sulphate at *test* station STC-1;
- a decreasing concentration of sulphate and an increasing concentration of arsenic at *test* station WAC-1; and
- a decreasing concentration of sulphate at *test* station KEL-1.

Trend analyses were not completed for *baseline* station JAC-2 or *test* station IYC-1 due to an insufficient number of sampling years.

2013 Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2013 had concentrations within the range of previously-measured concentrations at each station, with the following exceptions (Table 5.2-4 to Table 5.2-12):

- at *test* station MUR-6A, total dissolved phosphorus exceeded the previously-measured maximum concentration and sulphate was lower than the previously-measured minimum concentration;
- at *test* station MUC-1, chloride and sulphate were lower than previously-measured minimum concentrations;
- at *test* station JAC-1, dissolved phosphorus exceeded the previously-measured maximum concentration;

- at *baseline* station JAC-2, calcium and pH exceeded previously-measured maximum concentrations and total nitrogen was lower than the previously-measured minimum concentration;
- at *test* station STC-1, dissolved phosphorus and pH exceeded previously-measured maximum concentrations;
- at *test* station WAC-1, dissolved phosphorus exceeded the previously-measured maximum concentration; and
- at *test* station IYC-1, pH and dissolved phosphorus exceeded previously-measured maximum concentrations.

All water quality measurement endpoints for *test* stations MUR-1 and KEL-1 were within the range of previously-measured concentrations.

Ion balance The ionic composition of water at stations in the Muskeg River watershed was similar to previous years and dominated by calcium-bicarbonate (Figure 5.2-5 and 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 five years; however, the ionic balance at *test* station STC-1 has been consistently dominated by calcium and bicarbonate, with low concentrations of sulphate and chloride.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines In fall 2013, concentrations of water quality measurement endpoints at stations in the Muskeg River watershed were below water quality guidelines with the exception of:

- total aluminum at *baseline* station JAC-2 and *test* station IYC-1; and
- total nitrogen at *test* stations MUC-1 and KEL-1.

Other Fall Water Quality Guideline Exceedances The following other water quality variables exceeded water quality guidelines in the Muskeg River watershed in fall 2013 (Table 5.2-13):

- sulphide at *test* stations MUR-1, MUR-6A, WAC-1, JAC-1, IYC-1, KEL-1, and MUC-1, and *baseline* station JAC-2;
- total iron at *test* stations MUR-1, MUR-6A, JAC-1, IYC-1, WAC-1, and MUC-1, and *baseline* station JAC-2;
- dissolved iron at *test* stations MUR-1, MUR-6A, MUC-1, JAC-1, WAC-1, and IYC-1, and *baseline* station JAC-2;
- total phenols at *test* stations MUR-1, MUR-6A, WAC-1, JAC-1, IYC-1, KEL-1, and MUC-1, and *baseline* station JAC-2; and
- total phosphorus at *test* station IYC-1.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of water quality measurement endpoints 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 and Figure 5.2-8):

- chloride, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station MUR-1;

- total mercury, with concentrations that were below the 5th percentile of regional *baseline* concentrations at *test* stations MUR-6A, MUR-1, JAC-1, STC-1, and WAC-1;
- magnesium, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station MUR-6A;
- sulphate, with concentrations that were below the 5th percentile of regional *baseline* concentrations at *test* stations MUR-6A, STC-1, and WAC-1, and with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations IYC-1 and MUR-1; and
- total arsenic, with a concentration that was below the 5th percentile of regional *baseline* concentrations at *test* station STC-1 and that exceeded the 95th percentile of regional *baseline* concentrations at *test* station IYC-1.

Concentrations of water quality measurement endpoints in Kearl Lake (*test* station KEL-1) (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 sampled by RAMP due to the limited *baseline* data available.

Water Quality Index WQI values for all Muskeg watershed stations in fall 2013 indicated **Negligible-Low** differences from regional *baseline* water quality conditions. WQI Values ranged from 85.0 at *test* station IYC-1 to 100 at *test* station WAC-1 (Table 5.2-14).

Monthly Water Quality Results Water quality samples were collected monthly at *test* station MUR-1 in 2013 (Table 5.2-15).

Monthly Water Quality Guideline Exceedances Water quality variables that exceeded guidelines at *test* station MUR-1 in 2013 included (Table 5.2-16):

- sulphide and total iron in all months in 2013;
- total phenols in all months, with the exception of June and December;
- total phosphorus in July;
- total nitrogen in May, June, and July;
- total aluminum in January, May, June, July, and October;
- dissolved iron in all months, with the exception of June; and
- total chromium in January.

2013 Monthly Results Relative to Regional Fall *Baseline* Concentrations In 2013, most monthly data collected at *test* station MUR-1 fell within fall regional *baseline* concentrations (Figure 5.2-10), with the exception of:

- dissolved phosphorus, with concentrations below the 5th percentile of regional *baseline* fall concentrations in February (annual minimum), March, April, and November;
- total mercury (ultra-trace), with concentrations below the 5th percentile of regional *baseline* fall concentrations in January, February (annual minimum), and September to December;

- chloride and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, September, November, and December; and
- pH, with a value that exceeded the 95th percentile of regional *baseline* fall concentrations in September (annual maximum).

Monthly Ionic Balance In 2013, the ionic composition at *test* station MUR-1 was dominated by bicarbonate and calcium ions and remained consistent throughout the year (Figure 5.2-11).

Classification of Fall Results In fall 2013, concentrations of most water quality measurement endpoints were within the range of historical concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2013 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints at *test* station MUR-1 were within the range of the regional *baseline* fall concentrations, with some monthly variability generally showing higher concentrations for ions and metals in winter when water levels were low. Despite some variability across months, the ionic composition of water collected throughout the year at *test* station MUR-1 remained consistent.

5.2.4 Benthic Invertebrate Communities and Sediment Quality

5.2.4.1 Benthic Invertebrate Communities

Muskeg River Mainstem

Benthic invertebrate communities were sampled in fall 2013 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 2013.

2013 Habitat Conditions Water at *test* reach MUR-E1 in fall 2013 was shallow (0.2 m in sampled locations), fast flowing (1.65 m/s), alkaline (pH: 8.4), with high conductivity (376 µS/cm) (Table 5.2-17). The substrate was dominated by small cobble (32%) and gravel (small, 16 and large, 28%). Periphyton biomass averaged 47.9 mg/m^2, which was within the inner tolerance limits for regional *baseline* reaches (Figure 5.2-12).

Water at *test* reach MUR-D2 in fall 2013 was deep (1.3 m), weakly alkaline (pH: 7.4), with high conductivity (343 µS/cm), and high dissolved oxygen (7.3 mg/L) (Table 5.2-17). The substrate was dominated almost completely by sand (95%).

Water at *test* reach MUR-D3 in fall 2013 was shallow (0.5 m), slow moving, weakly alkaline (pH: 7.4), with high conductivity (356 µS/cm) (Table 5.2-17). The substrate was primarily comprised of sand (44%) and silt (51%), with a small amount of clay (5%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach MUR-E1 in fall 2013 was dominated by Ephemeroptera (46%), and chironomids (31%), with subdominant taxa consisting of naidid worms (6%) and Hydracarina (5%) (Table 5.2-18). Chironomids were diverse, consisting of many common forms (Wiederholm 1983) including *Lopescladius, Polypedilum,* and many taxa from the Tanytarsini tribe (i.e., *Micropsectra/Tanytarsus, Rheotanytarsus, and Stempellinella).* Mayflies were represented by the genera *Acerpenna pygmaea, Baetis,* and *Heptagenia* among others. Other flying insects such as stoneflies (*Chloroperlidae, Isoperla,* and *Acroneuria abnormis*), caddisflies (*Hydropsyche),* and damselflies (*Ophiogomphus*) were found in low relative abundances. Fingernail and pea clams (*Pisidium* and *Sphaerium*) and the gastropod, *Gyraulus*, were also present.

The benthic invertebrate community of *test* reach MUR-D3 was dominated by chironomids (67%), with subdominant taxa consisting of ceratopogonids (6%) and naidid worms (4%) (Table 5.2-18). Chironomids were primarily of the common forms *Polypedilum*, *Cladotanytarsus*, *Micropsectra/Tanytarsus*, and *Stempellinella.* Seven kinds of Ephemeroptera were found, the most common being from the genera *Caenis* and *Leptophlebia.* Bivalves *(Pisidium/Sphaerium)* and gastropods *(Lymnaea, Gyraulus)* were present in low relative abundances. (Table 5.2-18).

The benthic invertebrate community of *test* reach MUR-D3 was dominated by chironomids (30%), tubificid worms (19%), and bivalve clams (17%), with subdominant taxa consisting of Ephemeroptera (9%) (Table 5.2-18). Dominant chironomids included the common forms *Procladius* and *Polypedilum*. One kind of mayfly (Ephemeroptera; *Leptophlebiidae)* and stonefly (Plecoptera; Chloroperlidae) were noted at the upper *test* reach in fall 2013. Caddisflies (*Mystacides* and *Oecetis*) were found in low relative abundances. Permanent aquatic forms such as bivalves (*Pisidium/Sphaerium*), gastropods (*Menetus cooperi, Lymnaea, Valvata sincera*), and amphipods (*Gammarus lacustris* and *Hyallela Azteca*) were found at *test* reach MUR-D3.

Temporal Comparisons Below are the temporal and spatial comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for reaches of the Muskeg River.

Temporal comparisons for *test* reach MUR-E1 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2013 values and all previous years of sampling.

Temporal comparisons for *test* reach MUR-D2 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2013 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 1, Section 3.2.3.1);
- changes over time during the *test* period (Hypothesis 7, Section 3.2.3.1);
- changes between 2013 values and the mean of all *baseline* years; and
- changes between 2013 values and the mean of all previous years of sampling.

CA Axis 2 scores decreased over time at *test* reach MUR-E1 and were lower in 2013 than the mean of previous sampling years (Table 5.2-19). A shift in composition of the benthic invertebrate community to fewer bivalves and more tubificids at *test* reach MUR-E1 accounted for a large portion of the variance in annual means (Figure 5.2-13).

The percentage of the fauna as EPT taxa significantly increased over time at middle *test* reach MUR-D2 (Table 5.2-20). This change accounted for 24% of the variance in annual means.

The percentage of the fauna as EPT taxa was significantly higher in 2013 than either the mean of *baseline* years (2002 to 2007) or the mean of all previous years of sampling (2002 to 2012) at this reach, accounting for 29% and 38% of the variance in annual means, respectively (Table 5.2-21).

Comparison to Published Literature The benthic invertebrate community at *test* reach MUR-E1 was diverse, with a mean of 29 taxa per replicate sample and contained a number of taxa that are considered sensitive including the mayfly *Acerpenna pygmaea*, caddisfly *Hydropsyche*, and the stonefly *Isoperla* (Hynes 1960; Mandeville 2001; Griffiths 1998). Tubificidae, which is generally considered a group of tolerant worms (Mandeville 2001), were present in very low relative abundances (<1%) in fall 2013.

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 flying insects (mayflies: *Caenis* and *Acerpenna*) and permanent aquatic forms (bivalves: *Pisidium/ Sphaerium* and gastropods: *Gyraulus* and *Lymaea*). The percentage of the fauna as worms was low (<1%; Table 5.2-18), indicating good overall water quality (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at *test* reach MUR-D3 reflected typical depositional habitat conditions. The community was dominated numerically by chironomids (30%) and tubificid worms (19%) but also contained a high relative abundance of fingernail clams (*Pisidium/Sphaerium*, 17%), and other sensitive forms such as the mayfly *Leptophlebia* and the stonefly Chloroperlidae (Mandeville 2001) (Table 5.2-18).

2013 Results Relative to Historical or *Baseline* Conditions *Test* reaches of the Muskeg River have more than eight years of data; therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for each reach. If there were exceedances of the tolerance limits for a reach, in a direction of a negative change, comparisons to the tolerance limits for regional *baseline* variability (depositional or erosional) were evaluated.

Mean values of all measurement endpoints in fall 2013 at *test* reach MUR-E1 were within the inner tolerance limits of the historical range of variation for MUR-E1; however, equitability and richness were near the inner tolerance limit of the 5th percentile (Figure 5.2-13, Figure 5.2-14). The decrease in equitability was not a cause for concern as it indicated an increase in diversity at this reach. The percentage of fauna as EPT taxa was near the inner tolerance limit for the 95th percentile in 2013, but was not indicative of a negative change. CA Axis 1 and 2 scores were outside of the inner tolerance limits of the historical range of variation for the lower *test* reach (Figure 5.2-13).

Mean values of all measurement endpoints at *test* reach MUR-D2 were within the inner tolerance limits of the historical range of variation for this reach (Figure 5.2-15, Figure 5.2-16).

Abundance and CA Axis 1 and 2 scores at upper *test* reach MUR-D3 of the Muskeg River were within the inner tolerance limits of the historical range of variation (Figure 5.2-16, Figure 5.2-17). Richness was slightly higher than the inner tolerance limit, but not yet approaching the outer limit. Equitability was below the inner tolerance limit and approaching the outer tolerance limit of the 5th percentile. The percent EPT was near the outer tolerance limit of the 95th percentile. Although three measurement endpoints were outside the range of historical variation, the changes were indicative of improving water quality and benthic community health. When compared to the range of variability from regional *baseline* depositional reaches, abundance and equitability were within the inner tolerance limits; however, the percentage of EPT taxa was still outside the inner tolerance limit for the 95th percentile, indicating a greater percentage of sensitive EPT taxa compared to *baseline* reaches.

Classification of Results Differences in values of measurement endpoints at *test* reach MUR-E1 were classified as **Negligible-Low** because the significant increase in total abundance over time and the high relative abundances of chironomids and mayflies and the presence of caddisflies and stoneflies were indicative of good water and habitat conditions. The percentage of the fauna as worms (tubificids and naidids) was low indicating no significant change in the quality of the habitat. Equitability was lower than the inner tolerance limit for the 5th percentile, indicating that diversity in the reach was increasing, which is considered a positive change.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D2 were classified as **Negligible-Low** because the significant increase in the percentage of EPT taxa was indicative of a positive change and all measurement endpoints were within the inner tolerance limits of the historical range of variation for this reach.

Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach MUR-D3 were classified as **Negligible-Low** because the significant increase over time in EPT taxa and the higher percentage of EPT taxa in 2013 compared to the mean of *baseline* years or the mean all years combined were indicative of a positive change in the benthic invertebrate community. Three key measurement endpoints were outside of the tolerance limits for the historical range of variation, but were also indicative of greater diversity, richness, and abundance of EPT taxa. The relative abundance of tubificid worms was high in 2013, but consistent with previous years.

Jackpine Creek

Benthic invertebrate communities were sampled in fall 2013 at:

- depositional *test* reach JAC-D1 sampled since 2002 and designated as *test* since 2006; and
- depositional *baseline* reach JAC-D2 sampled since 2003.

2013 Habitat Conditions Water at *test* reach JAC-D1 in fall 2013 was moderately deep (0.40 m), with slow velocity (0.2 m/s), was weakly alkaline (pH: 7.9), with moderate conductivity (288 µS/cm), and high dissolved oxygen (Table 5.2-22).

Water at *baseline* reach JAC-D2 was slightly deeper than the lower reach (0.5 m), alkaline (pH: 8.1), with moderate conductivity (231 µS/cm). Similar to the lower *test* reach, the substrate at *baseline* reach JAC-D2 was dominated by sand (96%) (Table 5.2-22).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach JAC-D1 in fall 2013 was dominated by chironomids (65%), with subdominant taxa consisting of Hydracarina (3%), Plecoptera (2%), and nematodes (2%) (Table 5.2-23). The most common chironomid taxa at *test* reach JAC-D1 included genera such as *Polypedilum*, *Saetheria*, *Parakiefferiella*, and *Micropsectra/Tanytarsus*. Mayflies (*Baetis*, *Acerpenna*, *Baetisca*), stoneflies, and caddisflies (Ceraclea and Mystacides) were found in low relative abundances (Table 5.2-23). Gyraulus snails were also present.

The benthic invertebrate community at *baseline* reach JAC-D2 in fall 2013 was dominated by chironomids (82%), with subdominant taxa consisting of miscellaneous Diptera (6%) and Ceratopogonidae (2%) (Table 5.2-24). Chironomid taxa was dominated by *Micropsectra/Tanytarsus*, *Heterotrissocladius*, *Lopescladius/Rheosmittia*, and *Paracladopelma*. Miscellaneous Diptera included Empididae and Tipulidae. Mayflies, including *Caenis* and Leptophlebiidae were present in low abundances. Only a few individual stoneflies were found at *baseline* reach JAC-D2 in 2013 (Table 5.2-24). Caddisflies primarily consisted of Lepidostoma.

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 2013 values and the mean of all available *baseline* data for Jackpine Creek; and
- changes between 2013 values and the mean of all previous years of sampling (2002 to 2012).

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 1, 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, richness, and CA Axis 2 scores were significantly higher during the *test* period compared to the *baseline* period at *test* reach JAC-D1, and abundance and richness have significantly increased over time during the *test* period (Table 5.2-25). CA Axis 1 scores and equitability were significantly lower during the *test* period and equitability has significantly decreased over time during the *test* period at *test* reach JAC-D1. All of these changes explained a relatively large amount of variation in the annual means (>20%) (Table 5.2-25). Changes in abundance, richness, and equitability at *test* reach JAC-D1 have been similar to what has been observed at *baseline* reach JAC-D2 (Figure 5.2-18). Changes in CA Axis scores were due to a shift in taxa composition towards increased relative abundances of bivalves, amphipods, gastropods, and Coleoptera during the *test* period at *test* reach JAC-D1 (Figure 5.2-19).

Comparison to Published Literature The benthic invertebrate community at *test* reach JAC-D1 in fall 2013 was typical of what would be expected in depositional habitat. The benthic invertebrate community was dominated by chironomids and a low percentage of worms (<10%) (Table 5.2-23). Representative taxa of Ephemeroptera, Plecoptera, and Trichoptera were all present in 2013 indicating stable, cold-water habitat conditions (Hynes 1960; Griffiths 1998).

The upper reach of Jackpine Creek (*baseline* reach JAC-D2) was similar to the lower reach and supported a benthic invertebrate community reflecting a typical depositional river. Similar to *test* reach JAC-D1, the upper reach supported a benthic invertebrate community with a high richness in chironomids and a low percentage of EPT taxa and worms (Figure 5.2-20).

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach JAC-D1 has more than eight years of data (1998 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for *baseline* reach JAC-D2 were evaluated. All measurement endpoints for *test* reach JAC-D1, with the exception of equitability, were within the inner tolerance limits of the normal range of variation for means from this reach in previous years (Figure 5.2-18). A decrease in equitability was consistent with improving conditions. The percentage of EPT taxa was approaching the upper inner tolerance limit; which was also consistent with improving conditions. (Figure 5.2-18). When compared to regional *baseline* data, equitability was within the tolerance limits set by regional *baseline* depositional reaches.

Classification of Results Differences in measurement endpoints for benthic invertebrate communities at *test* reach JAC-D1 were classified as **Negligible-Low** because although there were significant increases in abundance and richness and a decrease in equitability over time during the period that this reach was designated as *test*, these changes were not indicative of degrading conditions.

Kearl Lake

2013 Habitat Conditions Water in Kearl Lake in fall 2013 was alkaline (pH: 7.9), with moderate conductivity (152 µS/cm) (Table 5.2-26). The substrate of Kearl Lake was primarily comprised of silt (80%), with smaller amounts of sand (9%) and clay (11%), and highly organic (37% TOC) (Table 5.2-26).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Kearl Lake in fall 2013 were dominated by chironomidae (35%), Bivalvia (31%), and Amphipoda (21%) (Table 5.2-27). Trichoptera (*Mayatrichia*), Ephemeroptera (*Caenis*), and Odonata (*Aeshna*) were present in low relative abundances (~1% each). Dominant chironomids included *Procladius, Cladopelma, Tanytarsus,* and *Paratanytarsus*, which are commonly distributed in Holarctic lakes. Bivalves were abundant and mainly from the two genera *Pisidium*/*Sphaerium*. Amphipods were of the species *Hyalella azteca* and *Gammarus lacustris*.

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 Kearl Lake.

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

- changes between *baseline* (2001 to 2008) and *test* (2009 to present) periods (Hypothesis 5, Section 3.2.3.1);

- changes over time in the *test* period (i.e., since 2009) (Hypothesis 6, Section 3.2.3.1);
- changes between 2013 values and the mean of all *baseline* years; and
- changes between 2013 values and the mean of all previous sampling years.

There was a significant increase in richness over time during the *test* period and richness was significantly higher in 2013 than the mean of *baseline* years and the mean of all previous years (2001 to 2012); however, these changes explained less than 20% of the variance in annual means (Table 5.2-28) and were not indicative of a negative change in the benthic invertebrate community.

Comparison to Published Literature The benthic invertebrate community of Kearl Lake was considered relatively typical of benthos in a shallow lake. The percentage of the fauna as worms was low (<10%) indicating generally good water and sediment quality (O'Toole et al. 2008). Chironomids accounted for 35% of the total benthic fauna and species present tended to be a combination of sensitive and tolerant taxa (Broderson and Lindegaard 1999). The benthic invertebrate community also contained a combination of permanent aquatic forms including amphipods and bivalves, as well as flying insects (chironomids, Ephemeroptera, Trichoptera), which indicated favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990).

2013 Results Relative to Historical Conditions Mean values of all measurement endpoints for benthic invertebrate communities in fall 2013 were within the inner tolerance limits of the historical range of variation for Kearl Lake (Figure 5.2-21, Figure 5.2-22).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Negligible-Low.** There were no statistically large changes (i.e., accounting for greater than 20% in the variance of annual means) for any measurement endpoint. Additionally, the benthic invertebrate community of Kearl Lake included diverse fauna, with several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and bivalves). All measurement endpoints for benthic invertebrate communities in Kearl Lake were within the inner tolerance limits for the historical range of variation in Kearl Lake.

5.2.4.2 Sediment Quality

Sediment quality was sampled in depositional reaches and lakes of the Muskeg River watershed in the same locations as benthic invertebrate community sampling in fall 2013:

- *test* station MUR-D2 of the Muskeg River (sampled in 2000, and 2003 to 2013);
- *test* station MUR-D3 of the Muskeg River (designated as *baseline* from 2002 to 2007 and *test* from 2008 to 2013);
- *test* station JAC-D1 of Jackpine Creek near its mouth (designated as *baseline* in 1997 and *test* from 2006 to 2013);
- *baseline* station JAC-D2 of Jackpine Creek (sampled from 2006 to 2013); and
- *test* station KEL-1 in Kearl Lake (designated as *baseline* from 2001 to 2008 and as *test* from 2009 to 2013).

Temporal Trends The following significant (α=0.05) trends in concentrations of sediment quality measurement endpoints were detected:

- decreasing concentrations of total arsenic and F1 hydrocarbons at *test* station KEL-1; and
- decreasing concentrations of total PAHs, total parent PAHs, total alkylated PAHs, and F1, F2, and F3 hydrocarbons at *test* station MUR-D2.

No significant trends were observed in sediment quality at *test* stations MUR-D3 and JAC-D1 and *baseline* station JAC-D2.

2013 Results Relative to Historical Concentrations Sediments sampled in 2013 from all stations in the Muskeg River watershed were taken from the same locations as those reaches sampled from 2006 to 2012. 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 2006 (Table 5.2-29 to Table 5.2-33).

All stations were dominated by sand, with the exception of *test* station KEL-1, which was dominated by silt in fall 2013. Concentrations of sediment quality measurement endpoints were similar to previously-measured concentrations at each station (Table 5.2-29 to Table 5.2-33).

Concentrations of volatile, low-molecular-weight hydrocarbons (i.e., CCME F1, F2, and BTEX – benzene, toluene, ethylbenzene, and xylene) were below detection limits at all stations in fall 2013. Concentrations of heavier hydrocarbon fractions in fall 2013 were within previously-measured concentrations for all stations, with the exception of *test* stations MUR-D2 and MUR-D3. *Test* stations MUR-D2 and MUR-D3 both had lower concentrations than previously measured for CCME F4 hydrocarbons and *test* station MUR-D2 had a lower concentration of CCME F3 hydrocarbons in fall 2013. The concentration of total PAHs (carbon-normalized) was higher than previously-measured concentrations, while the concentration of total metals (normalized to percent fines) was lower than previously-measured concentrations at *test* station JAC-D1. Concentrations of naphthalene, total dibenzothiophenes, and total parent PAHs were below previously-measured minimum concentrations at *test* stations MUR-D2 and MUR-D3 (Table 5.2-29 and Table 5.2-30). Additionally at *test* station MUR-D2, concentrations of retene, total PAHs, and total alkylated PAHs were below previously-measured minimum concentrations. The concentration of total dibenzothiophenes exceeded the previously-measured maximum concentration at *test* station KEL-1 in fall 2013.

The predicted PAH toxicity in sediments in fall 2013 was higher than previously-calculated maximum values for *test* stations JAC-D1 and MUR-D3. The ten-day growth of the midge *Chironomus* exceeded the previously-measured maximum result at *test* stations MUR-D2, MUR-D3, and KEL-1, and *baseline* station JAC-D2. *Chironomus* survival was lower in 2013 at *test* station KEL-1, while survival of the amphipod *Hyalella* was higher than previously-measured maximum values at *test* stations JAC-D1 and MUR-D2. The 14-day growth of *Hyalella* was higher in 2013 than the previously-measured result at *test* station MUR-D2.

Spatial comparisons The following comparisons of sediment quality measurement endpoints among stations in the Muskeg River watershed in fall 2013 were noted:

- percent sand was lower at *test* station MUR-D3 (83.0%) than *test* station MUR-D2 98.6%), which was consistent with 2012 results. Percent sand was similar between *test* station JAC-D1 (99.3%) and *baseline* station JAC-D2 (99.0%);
- total organic carbon was higher at *test* station MUR-D3 (3.13%) than *test* station MUR-D2 (0.13%);
- concentrations of hydrocarbons (including PAHs) were higher at the lower *test* station (MUR-D2) than the upper *test* station (MUR-D3) of the Muskeg River, while *baseline* station JAC-D2 exhibited the lowest hydrocarbon concentrations across sampling stations in the watershed; and
- survival of *Chironomus*, and survival and growth of *Hyalella* were similar between *test* station JAC-D1 and *baseline* station JAC-D2; *Chironomus* growth was higher at *baseline* station JAC-D2 (4.17 mg/organism) than *test* station JAC-D1 (2.50 mg/organism).

2013 Results Relative to Regional *Baseline* Conditions In fall 2013, concentrations of all sediment quality measurement endpoints at *test* stations MUR-D2 and MUR-D3, and *baseline* station JAC-D2 were within the range of regional *baseline* concentrations (Figure 5.2-23 to Figure 5.2-25). All concentrations of sediment quality measurement endpoints at *test* station JAC-D1 were within the range of the regional *baseline* concentrations, with the exception of total metals (normalized to percent fines), which was below the 5th percentile of regional *baseline* concentrations in fall 2013 (Figure 5.2-26).

Concentrations of sediment quality measurement endpoints at Kearl Lake (Figure 5.2-27) were not compared to regional *baseline* concentrations because lakes were not included in the calculation of the *baseline* concentrations given the ecological differences between lakes and rivers.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of CCME F3 hydrocarbons exceeded relevant CCME soil-quality guidelines at *test* station KEL-1. The concentration of F1 hydrocarbons at *test* station KEL-1 was not detectable, but had a detection limit that exceeded the CCME guideline. The predicted PAH toxicity exceeded the potential chronic toxicity threshold value of 1.0 at *test* stations JAC-D1 and MUR-D3 in fall 2013.

Sediment Quality Index The SQI values for all stations in the Muskeg River watershed in fall 2013 indicated **Negligible-Low** differences in sediment quality conditions from regional *baseline* conditions (Table 5.2-34). A SQI was not calculated for *test* station KEL-1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Classification of Results Concentrations of sediment quality measurement endpoints at all Muskeg River watershed stations sampled in fall 2013 were similar or lower than measured in previous years and within the range of regional *baseline* conditions. Differences in sediment quality in fall 2013 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 2013 at:

- erosional *test* reach MUR-F1, near the mouth of the Muskeg River, previously sampled from 2009 to 2012 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-E1);
- depositional *test* reach MUR-F2, sampled in 2011 and 2012 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D2); and
- depositional *test* reach MUR-F3, sampled in 2011 and 2012 (this reach is at the same location as the benthic invertebrate community *test* reach MUR-D2).

2013 Habitat Conditions *Test* reach MUR-F1 was comprised of run and shallow riffle habitat with a wetted width of 16.1 m and a bankfull width of 26.6 m (Table 5.2-35). The substrate was dominated by coarse gravel with smaller amounts of cobble. Water at *test* reach MUR-F1 in fall 2013 had a mean depth of 0.61 m and a slow velocity (0.22 m/s), was alkaline (pH: 8.38), with high conductivity (325 µS/cm), high dissolved oxygen (9.2 mg/L), and a temperature of 12.5˚C. Instream cover was comprised primarily of boulders and filamentous algae, with small amounts of small woody debris.

Test reach MUR-F2 was comprised entirely of deep run habitat with a wetted width of 13.1 m and a bankfull width of 16.8 m (Table 5.2-35). The substrate was entirely sand. Water at *test* reach MUR-F2 had a mean depth of 1.2 m and a slow velocity (0.09 m/s), was alkaline (pH: 8.11), with high conductivity (331 µS/cm), moderately low dissolved oxygen (5.2 mg/L), and a temperature of 17.9˚C. Instream cover was comprised primarily of macrophytes, filamentous algae, overhanging vegetation, and small woody debris, with smaller proportions of undercut banks.

Test reach MUR-F3 was comprised entirely of deep run habitat with a wetted width of 8.8 m and a bankfull width of 9.6 m (Table 5.2-35). Water at *test* reach MUR-F3 was deep (mean depth: 0.93 m), with negligible velocity, and substrate comprised of sand and fine material. Water at *test* reach MUR-F3 was slightly alkaline (pH: 7.76), with moderate conductivity (376 µs/cm), moderately low dissolved oxygen (5.4 mg/L), and a temperature of 13.4˚C. Instream cover was comprised primarily of small woody debris with smaller amounts of overhanging vegetation and undercut banks.

Relative Abundance of Fish Species The abundance of fish species at *test* reach MUR-F1 was substantially higher than in 2012, but still lower compared to previous sampling years (i.e., 2009 to 2011). Similar to the mouth of other tributaries to the Athabasca River, burbot accounted for a large (30%) proportion of the total catch, with slimy sculpin comprising 25% of the total catch (Table 5.2-36). Despite the low abundance, species composition was consistent to previous sampling years (Table 5.2-36).

The fish abundance at *test* reach MUR-F2 was higher than previous years; however, given the historically low catch in 2012, the abundance in 2013 was still relatively low compared to other rivers (Table 5.2-36).

With only a single fish captured in 2013, the abundance at *test* reach MUR-F3 was comparable to 2012, but much lower than 2011 (Table 5.2-36). The low capture success was likely due to greater water depths, which decreased capture efficiency.

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 2013. Temporal comparisons for *test* reach MUR-F1 included testing for changes over time (Hypothesis 1, Section 3.2.4.4). Spatial comparisons were not conducted for *test* reach MUR-F1 because there was no upstream *baseline* erosional reach on the Muskeg River.

There were significant decreases in CPUE and abundance (p=0.003 for both endpoints) over time at *test* reach MUR-F1, explaining greater than 32% of the variance in the annual means (Table 5.2-37, Table 5.2-38). There were no other significant trends over time (Table 5.2-37 and Figure 5.2-28). As was the case with many of the reaches in proximity to the Athabasca River, the high proportion of burbot, which is considered a sensitive species, resulted in a decrease, although not significant, in the assemblage tolerance index (ATI) at *test* reach MUR-F1 (Table 5.2-37, Figure 5.2-28).

Test reaches MUR-F2 and MUR-F3 were first sampled in 2011; therefore, temporal comparisons were conducted from 2011 to 2013. Given the low catch; however, statistical tests were not conducted. Spatial comparisons for *test* reaches MUR-F2 and MUR-F3 were not conducted because there was no upstream *baseline* depositional reach on the Muskeg River.

There was an increase in all measurement endpoints at *test* reach MUR-F2 in 2013 compared to all other years (Table 5.2-37 and Figure 5.2-29). It is important to note that this was based on only ten fish captured in 2013 compared to no fish captured in 2012; therefore, the strength of the comparison was limited. Only one fish was captured at *test* reach MUR-F3 compared to one fish in 2012 and 39 fish in 2011. Given that it was a white sucker that was captured in 2013, which are less tolerant than brook stickleback that have been captured in previous sampling years, there was a decrease in the ATI value at *test* reach MUR-F3 (Figure 5.2-29 and Table 5.2-37).

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 previous studies, 21 species have been documented in the Muskeg River; whereas RAMP has found only fourteen fish species from 2009 to 2013, 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) documented fish inventory studies throughout the entire Muskeg River, whereas smaller, defined reach lengths were sampled by RAMP.

Golder (2004) has documented similar habitat conditions in the portion of the Muskeg River where *test* reach MUR-F1 was located, consisting of slow riffle habitat, and infrequent pools dominated by cobble and gravel substrate with some boulder and fine sediment. Golder (2004) reported that this area of the river had low spawning potential, but provided excellent rearing habitat for young fish moving down from upstream spawning areas, as well as excellent resting areas for migratory fish coming from the Athabasca River (Bond and Machniak 1979). The low species richness observed at *test* reaches MUR-F2 and MUR-F3 could be attributed to the habitat conditions in these portions of the Muskeg River. Golder (2004) documented similar habitat conditions consisting of deep slow pools and runs, with substrate of primarily fines with very small amounts of gravel, cobble and boulders. This portion of the river has low habitat diversity and limited spawning habitat and food supply for most fish species (Golder 2004).

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *test* reach MUR-F1 were within the inner tolerance limits for the normal range of erosional *baseline* conditions (Figure 5.2-28). Mean values of CPUE and abundance at *test* reach MUR-F2 were between the inner and outer tolerance limits of the 5th percentile for the normal range of depositional *baseline* conditions (Figure 5.2-29). Mean values of CPUE, abundance, diversity, and richness at *test* reach MUR-F3 were at the outer tolerance limit of the 5th percentile of regional *baseline* depositional conditions, but only one fish was captured in 2013.

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach MUR-F1 were classified as **Moderate** because although values of all measurement endpoints were within the range of regional *baseline* variability, there was a decrease in abundance and CPUE over time, which are indicative of a potential negative change in the fish assemblage. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F2 and regional *baseline* conditions were classified as **Moderate** because CPUE and abundance were lower than the range of variation for *baseline* depositional reaches. Differences in measurement endpoints for fish assemblages between *test* reach MUR-F3 and regional *baseline* conditions were classified as **High** given that only one fish was captured at this reach in 2013, and CPUE, abundance, diversity, and richness were at the outer tolerance limit for the 5th percentile in 2012 and 2013. The low capture success was likely due to greater water depths in the last two years, which decreased capture efficiency.

Jackpine Creek

Fish assemblages were sampled in fall 2013 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).

2013 Habitat Conditions *Test* reach JAC-F1 was comprised of run habitat with backwater pools and a wetted width of 8.6 m and bankfull width of 9.9 m (Table 5.2-39). The substrate was dominated by sand. Water at *test* reach JAC-F1 in fall 2013 was moderately deep (mean depth: 0.49 m), with a slow velocity (0.09 m/s), alkaline (pH: 8.0), with moderate conductivity (260 µS/cm), high dissolved oxygen (8.0 mg/L), and a temperature of 14.1°C. Instream cover was comprised primarily of small woody debris and overhanging vegetation, with smaller proportions of live tree roots and undercut banks.

Baseline reach JAC-F2 was comprised of run habitat and a wetted width of 3.6 m and a bankfull width of 5.5 m (Table 5.2-39). The substrate was dominated by sand with some coarse gravel. Water at *baseline* reach JAC-F2 in fall 2013 had a mean depth of 0.58 m, with a slow velocity (0.05 m/s), was alkaline (pH: 8.6), with moderate conductivity (250 µS/cm), high dissolved oxygen (8.6 mg/L), and a temperature of 12.3°C. Instream cover was comprised primarily of small woody debris, with some overhanging vegetation.

Relative Abundance of Fish Species The abundance of fish species in 2013 at *test* reach JAC-F1 was higher than 2012, but lower than previous years (2010 and 2011). Only two species were captured in fall 2013, the majority of which were slimy sculpin (Table 5.2-40). Species richness was consistent to 2012, but lower than in 2011 and 2010 (Table 5.2-37). Fish abundance was higher at *baseline* reach JAC-F2 compared to 2012, but also lower than 2010 and 2011. The species composition in 2013 at *baseline* reach JAC-F2 was comparable to previous sampling years (Table 5.2-40).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach JAC-F1 included testing for changes over time in measurement endpoints (2009 to 2013, Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach JAC-F1 included testing for differences from *baseline* reach JAC-F2 in measurement endpoints over time (Hypothesis 2, Section 3.2.4.4).

Values of all measurement endpoints at *test* reach JAC-F1 were higher in 2013 compared to 2012, but lower than 2009 to 2011 (Table 5.2-37). There were significant decreases in abundance ($p=0.013$), richness ($p=0.003$), diversity ($p=0.003$), and ATI ($p<0.001$) over time at *test* reach JAC-F1, explaining greater than 20% of the variance in the annual means (Table 5.2-41). The significant decrease in CPUE ($p=0.04$) explained less than 20% of the variability in the annual means (Table 5.2-41).

There were no significant differences in measurement endpoints between *test* reach JAC-F1 and *baseline* reach JAC-F2 over time ($p>0.05$) (Table 5.2-41).

All measurement endpoints were higher at *baseline* reach JAC-F2 in 2013 compared to 2012 (Table 5.2-37 and Figure 5.2-30). ATI at *baseline* reach JAC-F2 in 2013 was the highest recorded across sampling years, likely related to the relatively high proportion of tolerant lake chub and brook stickleback in 2013 at *baseline* reach JAC-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 15 fish species were recorded in Jackpine Creek; whereas RAMP found only 11 species from 2009 to 2013, with the exception of Arctic grayling, fathead minnow, flathead chub, and spoonhead sculpin that have been previously documented. Two additional fish species were observed by RAMP from 2009 to 2013, including finescale dace and trout-perch (Table 5.2-40). 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).

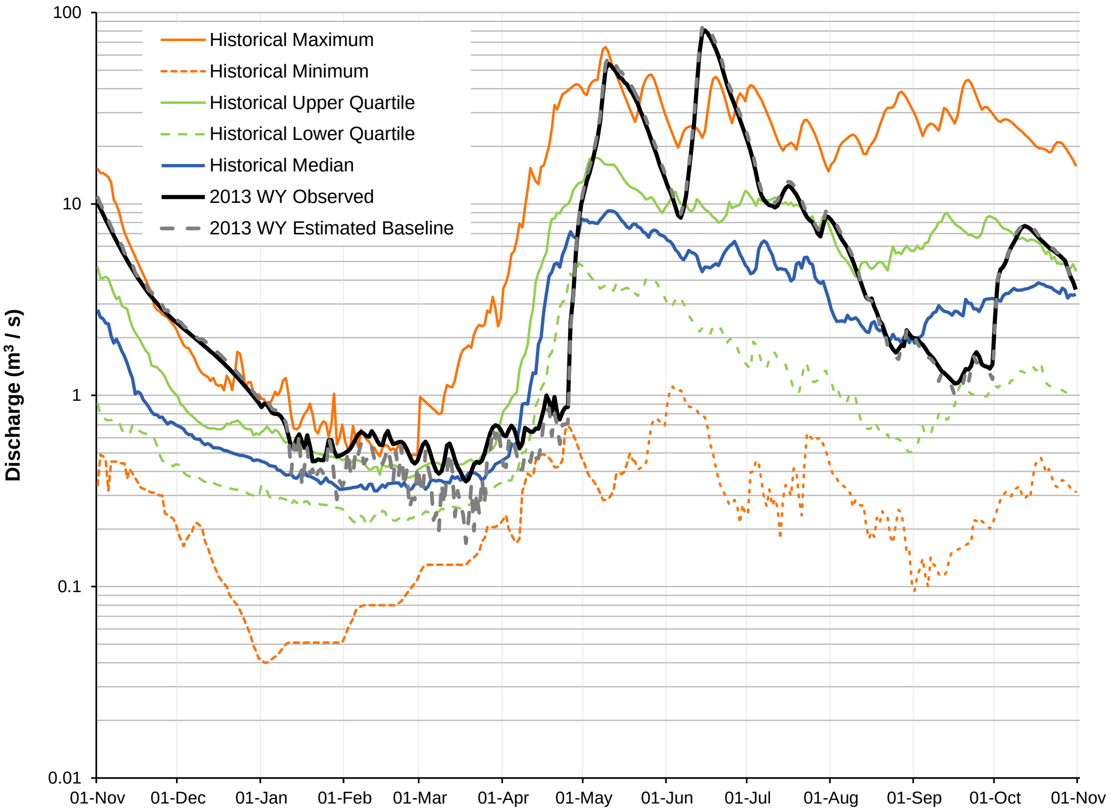
Golder (2004) documented similar habitat conditions to what have been observed by RAMP, consisting of runs and small pools with sand/fine substrate and slow flowing water. This habitat is likely not suitable for most fish species in the region that require harder substrate and faster flowing water for spawning and rearing (e.g., sculpin sp., Arctic grayling, and sucker sp.) (Bond and Machniak 1977).

2013 Results Relative to Regional *Baseline* Conditions Mean values of CPUE and richness were at the inner tolerance limit for the 5th percentile of the range of variability for depositional *baseline* conditions. The ATI value at *test* reach JAC-D1 was below the outer tolerance limit for the 5th percentile of regional *baseline* variability; however, a lower ATI value is indicative of a greater proportion of sensitive species in the assemblage.

Mean values of all measurement endpoints in fall 2013 at *baseline* reach JAC-F2 were within the normal range of variability for depositional *baseline* conditions (Figure 5.2-30).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach JAC-F1 were classified as **High** because richness and CPUE were at the inner tolerance limit for the lower 5th percentile of regional *baseline* variability and there were significant decreases in all measurement endpoints over time, which are indicative of a potential negative change in the fish assemblage.

Figure 5.2-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Muskeg River in the 2013 WY, compared to historical values.



Note: Based on provisional 2013 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7). The upstream drainage area is 1,457 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1974 to 2012, and historical daily values from November 1 to February 28 calculated from data collected from 1974 to 1986 and from 1999 to 2012.

Table 5.2-2 Estimated water balance at WSC Station 07DA008 (RAMP Station S7), Muskeg River near Fort McKay, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**261.775**	**Observed discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7)**
Closed-circuited area water loss from the observed *test* hydrograph	-24.397	Estimated 128 km^2 of the Muskeg River watershed was closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+3.800	Estimated 99.9 km^2 of the Muskeg River watershed with land change from focal projects as of 2013 that was not closed-circuited (Table 2.5-1)
Water withdrawals from the Muskeg River watershed from focal projects	-0.046	Water withdrawn by Husky (all values provided daily)
Water releases into the Muskeg River watershed from focal projects	0.068	Water released by Husky (all values provided daily)
Diversions into or out of the watershed	5.391	Syncrude Aurora Clean Water Diversion discharges to Stanley Creek, and Shell Jackpine Mine diversion for Jackpine creek augmentation
The difference between *test* and *baseline* hydrographs on tributary streams	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**276.960**	**Estimated *baseline* discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7)**
Incremental flow (change in total discharge)	-15.185	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-5.48%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on provisional 2013 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7).

Note: *Baseline* values shown in the table were likely underestimated, because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Table 5.2-3 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	15.837	14.868	-6.12%
Mean winter discharge	1.637	1.633	-0.25%
Annual maximum daily discharge	87.041	80.600	-7.40%
Open-water season minimum daily discharge	0.997	1.150	+15.32%

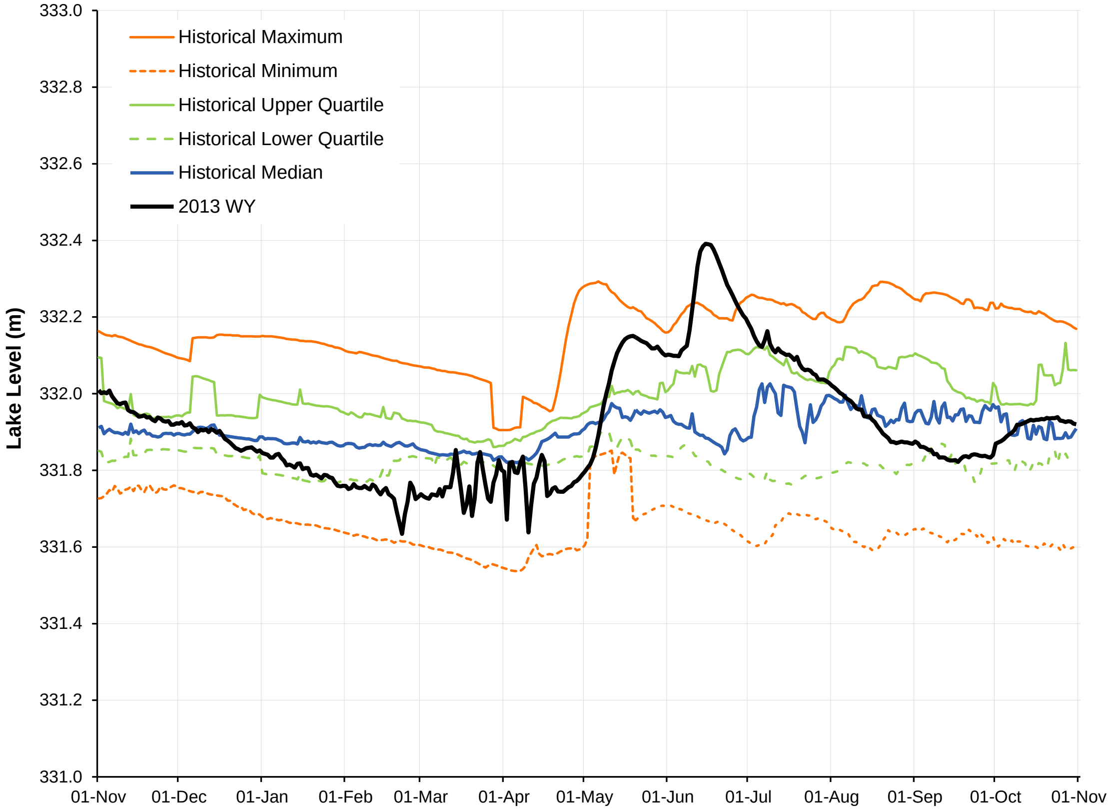
Note: Based on provisional 2013 WY data from Muskeg River near Fort McKay, WSC Station 07DA008 (RAMP Station S7).

Note: *Baseline* values shown in the table were likely underestimated, because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and two decimal places, respectively.

Note: 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 2013 WY, compared to historical values.



Note: Observed 2013 WY lake levels based on the 2013 WY provisional data for Kearl Lake, RAMP Station L2. Historical values calculated from 1999 to October 2012, 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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.41	16	7.40	8.24	8.61
Total suspended solids	mg/L	-	<3.0	16	<3.0	3.0	70
Conductivity	µS/cm	-	375	16	220	334	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.018	16	0.004	0.013	0.030
Total nitrogen	mg/L	1	0.831	16	0.400	0.900	1.62
Nitrate+nitrite	mg/L	3	<0.071	16	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	28.7	16	15.0	23.0	29.0
Ions							
Sodium	mg/L	-	15.5	16	8.0	12.6	64.0
Calcium	mg/L	-	52.8	16	28.8	46.5	108.0
Magnesium	mg/L	-	12.5	16	7.1	12.2	18.9
Chloride	mg/L	120	5.0	16	1.0	3.0	36.0
Sulphate	mg/L	410	7.96	16	0.60	5.02	91.00
Total dissolved solids	mg/L	-	293	16	170	272	405
Total alkalinity	mg/L	-	192	16	105	172	313
Selected metals							
Total aluminum	mg/L	0.1	0.056	16	0.026	0.077	**1.200**
Dissolved aluminum	mg/L	0.1	0.0043	16	0.0016	0.0038	0.0300
Total arsenic	mg/L	0.005	0.0005	16	0.0003	0.0004	0.0010
Total boron	mg/L	1.2	0.050	16	0.032	0.046	0.150
Total molybdenum	mg/L	0.073	0.00011	16	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	1.00	10	0.60	1.20	3.00
Total strontium	mg/L	-	0.151	16	0.086	0.125	0.296
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.430	2	0.210	0.545	0.880
Oilsands Extractable	mg/L	-	0.880	2	0.480	1.235	1.990
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	15.16	2	8.76	11.44	14.13
Retene	ng/L	-	1.13	2	0.89	1.52	2.15
Total dibenzothiophenes	ng/L	-	22.39	2	10.17	25.16	40.16
Total PAHs	ng/L	-	150.4	2	181.5	210.4	239.3
Total Parent PAHs	ng/L	-	23.74	2	17.18	18.93	20.69
Total Alkylated PAHs	ng/L	-	126.6	2	160.8	191.5	222.2
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.521**	16	<0.004	0.346	1.020
Total iron	mg/L	0.3	**0.63**	16	0.29	**0.65**	**1.81**
Total phenols	mg/L	0.004	**0.010**	16	<0.001	0.004	**0.011**
Sulphide	mg/L	0.002	**0.0021**	16	<0.0020	**0.0045**	**0.0220**

[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 5.2-5 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (*test* station MUR-6A), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)[b]			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.11	15	7.20	8.10	8.40
Total suspended solids	mg/L	-	<3.0	15	<3.0	<3.0	25.0
Conductivity	µS/cm	-	374	15	225	303	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05	<u>0.031</u>	15	0.011	0.014	0.029
Total nitrogen	mg/L	1	0.871	15	0.300	0.900	**1.931**
Nitrate+nitrite	mg/L	3	<0.071	15	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	26.6	15	13.0	19.0	36.3
Ions							
Sodium	mg/L	-	3.40	15	2.90	3.40	7.00
Calcium	mg/L	-	60.1	15	28.1	43.5	67.4
Magnesium	mg/L	-	19.1	15	10.0	15.8	24.0
Chloride	mg/L	120	<0.50	15	<0.50	1.00	3.00
Sulphate	mg/L	410	<u>0.52</u>	15	1.50	3.00	6.30
Total dissolved solids	mg/L	-	282	15	180	225	320
Total alkalinity	mg/L	-	205	15	99	166	292
Selected metals							
Total aluminum	mg/L	0.1	0.027	15	<0.003	0.020	**0.110**
Dissolved aluminum	mg/L	0.1	0.0058	15	0.0015	0.0051	<0.0100
Total arsenic	mg/L	0.005	0.0007	15	0.0003	0.0004	<0.0010
Total boron	mg/L	1.2	0.017	15	0.006	0.012	0.025
Total molybdenum	mg/L	0.073	0.00013	15	0.00007	0.00010	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	0.84	10	0.60	1.20	1.80
Total strontium	mg/L	-	0.111	15	0.053	0.084	0.164
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.26	2	0.20	0.31	0.42
Oilsands Extractable	mg/L	-	0.75	2	0.73	1.12	1.50
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.260	2	0.692	1.381	<2.071
Total dibenzothiophenes	ng/L	-	6.67	2	7.09	21.20	35.30
Total PAHs	ng/L	-	102.5	2	154.9	179.3	203.7
Total Parent PAHs	ng/L	-	22.44	2	16.48	18.16	19.84
Total Alkylated PAHs	ng/L	-	80.0	2	135.0	161.1	187.2
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved Iron	mg/L	0.3	<u>**0.982**</u>	15	<0.004	0.147	**0.890**
Sulphide	mg/L	0.002	**0.008**	15	<0.002	**0.006**	**0.014**
Total phenolics	mg/L	0.004	**0.008**	15	<0.001	**0.005**	**0.031**
Total iron	mg/L	0.3	**1.380**	15	0.070	0.256	**13.9**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Table 5.2-6 Concentrations of selected water quality measurement endpoints, Muskeg Creek (*test* station MUC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.08	13	7.40	8.00	8.34
Total suspended solids	mg/L	-	<3.0	13	<3.0	3.0	9.0
Conductivity	µS/cm	-	311	13	184	274	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.034	13	0.012	0.014	0.034
Total nitrogen	mg/L	1	**1.04**	13	0.40	**1.00**	**1.20**
Nitrate+nitrite	mg/L	3	<0.071	13	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	31.9	13	12.0	24.0	31.9
Ions							
Sodium	mg/L	-	14.8	13	7.0	17.0	64.0
Calcium	mg/L	-	43.4	13	20.8	29.7	71.1
Magnesium	mg/L	-	12.9	13	6.5	9.7	17.3
Chloride	mg/L	120	0.59	13	1.00	2.00	36.00
Sulphate	mg/L	270	1.18	13	2.00	3.40	8.00
Total dissolved solids	mg/L	-	255	13	140	212	378
Total alkalinity	mg/L	-	166	13	93.0	139	313
Selected metals							
Total aluminum	mg/L	0.1	0.052	13	0.021	0.050	**0.142**
Dissolved aluminum	mg/L	0.1	0.008	13	0.003	0.008	0.030
Total arsenic	mg/L	0.005	0.0009	13	0.0002	0.0005	0.0010
Total boron	mg/L	1.2	0.053	13	0.024	0.057	0.150
Total molybdenum	mg/L	0.073	<0.00010	13	0.00004	0.00010	0.00640
Total mercury (ultra-trace)	ng/L	5, 13	1.30	8	0.60	1.20	2.30
Total strontium	mg/L	-	0.140	13	0.069	0.098	0.296
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.30	2	0.03	0.29	0.54
Oilsands Extractable	mg/L	-	0.94	2	0.24	0.91	1.58
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	<0.669	2	0.789	1.430	<2.071
Total dibenzothiophenes	ng/L	-	14.00	2	9.61	23.27	36.93
Total PAHs	ng/L	-	122.4	2	160.3	185.5	210.7
Total Parent PAHs	ng/L	-	23.44	2	16.73	18.03	19.32
Total Alkylated PAHs	ng/L	-	98.9	2	141.0	167.5	194.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.780**	13	0.183	0.266	**1.020**
Sulphide	mg/L	0.002	**0.015**	13	0.002	**0.008**	**0.068**
Total iron	mg/L	0.3	**1.04**	13	0.29	**0.63**	**1.81**
Total phenols	mg/L	0.004	**0.006**	13	<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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.29	14	7.80	8.06	8.32
Total suspended solids	mg/L	-	9.0	14	<3.0	3.0	50.0
Conductivity	µS/cm	-	297	14	183	237	483
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.030	14	0.006	0.014	0.026
Total nitrogen	mg/L	1	0.881	14	0.700	0.900	**1.621**
Nitrate+nitrite	mg/L	3	<0.071	14	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	31.8	14	18.6	23.9	31.8
Ions							
Sodium	mg/L	-	13.7	14	10.0	12.0	18.8
Calcium	mg/L	-	38.2	14	20.0	29.1	65.6
Magnesium	mg/L	-	10.8	14	6.1	8.2	16.3
Chloride	mg/L	120	2.66	14	0.89	2.00	5.60
Sulphate	mg/L	270	1.27	14	0.50	2.80	9.76
Total dissolved solids	mg/L	-	236	14	110	199	322
Total alkalinity	mg/L	-	153	14	89	120	249
Selected metals							
Total aluminum	mg/L	0.1	0.048	14	0.016	0.068	**0.658**
Dissolved aluminum	mg/L	0.1	0.013	14	0.002	0.008	**0.170**
Total arsenic	mg/L	0.005	0.0008	14	0.0003	0.0005	0.0010
Total boron	mg/L	1.2	0.053	14	0.033	0.046	0.071
Total molybdenum	mg/L	0.073	0.00010	14	0.00007	0.00010	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	0.930	10	0.600	1.20	2.90
Total strontium	mg/L	-	0.152	14	0.077	0.105	0.212
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.31	2	0.08	0.25	0.41
Oilsands Extractable	mg/L	-	1.84	2	0.38	1.64	2.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	3.070	2	3.380	8.590	13.800
Total dibenzothiophenes	ng/L	-	48.25	2	15.26	75.69	136.11
Total PAHs	ng/L	-	228.7	2	180.1	388.2	596.2
Total Parent PAHs	ng/L	-	24.59	2	20.37	22.19	24.02
Total Alkylated PAHs	ng/L	-	204.1	2	159.8	366.0	572.2
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**1.10**	14	**0.38**	**0.59**	**1.57**
Total phenols	mg/L	0.004	**0.008**	14	0.001	**0.007**	**0.019**
Dissolved iron	mg/L	0.3	**0.832**	14	0.136	**0.301**	**0.699**
Sulphide	mg/L	0.002	**0.009**	14	0.002	**0.008**	**0.103**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2008-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.30	5	7.98	8.00	8.25
Total suspended solids	mg/L	-	<3.0	5	<3.0	13.0	243.0
Conductivity	µS/cm	-	283	5	202	216	346
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.021	5	0.007	0.014	0.023
Total nitrogen	mg/L	1	0.721	5	0.861	**1.061**	**2.631**
Nitrate+nitrite	mg/L	3	<0.071	5	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	27.3	5	22.6	27.3	29.1
Ions							
Sodium	mg/L	-	13.9	5	10.0	11.0	25.5
Calcium	mg/L	-	36.9	5	22.1	26.9	36.8
Magnesium	mg/L	-	11.3	5	7.2	8.6	11.5
Chloride	mg/L	120	1.18	5	<0.50	1.00	1.63
Sulphate	mg/L	270	1.60	5	0.67	1.95	4.33
Total dissolved solids	mg/L	-	207	5	150	173	264
Total alkalinity	mg/L	-	149	5	103	110	187
Selected metals							
Total aluminum	mg/L	0.1	**0.383**	5	**0.142**	**0.595**	**2.840**
Dissolved aluminum	mg/L	0.1	0.018	5	0.006	0.010	0.029
Total arsenic	mg/L	0.005	0.0010	5	0.0007	0.0008	0.0016
Total boron	mg/L	1.2	0.086	5	0.045	0.061	0.137
Total molybdenum	mg/L	0.073	0.00019	5	0.00011	0.00014	0.00024
Total mercury (ultra-trace)	ng/L	5, 13	1.20	5	1.00	1.20	**8.80**
Total strontium	mg/L	-	0.148	5	0.096	0.104	0.201
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.31	2	0.05	0.05	0.05
Oilsands Extractable	mg/L	-	0.43	2	0.42	0.75	1.08
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.220	2	<2.071	6.585	11.100
Total dibenzothiophenes	ng/L	-	7.446	2	7.091	26.267	45.444
Total PAHs	ng/L	-	104.5	2	154.1	226.6	299.1
Total Parent PAHs	ng/L	-	22.44	2	19.55	19.78	20.00
Total Alkylated PAHs	ng/L	-	82.0	2	134.5	206.8	279.1
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.709**	5	0.238	**0.448**	**0.503**
Sulphide	mg/L	0.002	**0.005**	5	**0.005**	**0.006**	**0.008**
Total iron	mg/L	0.3	**1.070**	5	**0.689**	**0.816**	**4.360**
Total phenols	mg/L	0.004	**0.005**	5	**0.006**	**0.009**	**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.

Table 5.2-9 Concentrations of selected water quality measurement endpoints, Stanley Creek (*test* station STC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.46	12	7.60	8.00	8.28
Total suspended solids	mg/L	-	<3.0	12	<3.0	<3.0	6.0
Conductivity	µS/cm	-	374	12	271	392	760
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.039	13	0.010	0.020	0.036
Total nitrogen	mg/L	1	0.501	13	0.300	0.400	**2.100**
Nitrate+nitrite	mg/L	3	<0.071	13	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	9.20	12	6.00	9.00	13.10
Ions							
Sodium	mg/L	-	3.3	12	2.0	5.5	26.0
Calcium	mg/L	-	64.2	12	45.4	60.0	112.0
Magnesium	mg/L	-	13.1	12	11.1	12.7	20.5
Chloride	mg/L	120	<0.50	12	<0.50	1.68	14.00
Sulphate	mg/L	410	<0.50	12	<0.50	3.75	126.00
Total dissolved solids	mg/L	-	228	12	200	254	480
Total alkalinity	mg/L	-	204	12	157	208	260
Selected metals							
Total aluminum	mg/L	0.1	0.015	13	<0.002	0.007	0.020
Dissolved aluminum	mg/L	0.1	0.003	13	<0.001	0.001	0.020
Total arsenic	mg/L	0.005	<0.00010	13	<0.00010	0.00014	<0.00100
Total boron	mg/L	1.2	0.034	13	0.018	0.025	0.087
Total molybdenum	mg/L	0.073	<0.000100	13	0.000008	0.000100	0.000200
Total mercury (ultra-trace)	ng/L	5, 13	1.1	10	<0.6	<1.2	<1.4
Total strontium	mg/L	-	0.111	13	0.075	0.139	0.248
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.51	2	0.54	0.77	1.00
Oilsands Extractable	mg/L	-	0.91	2	1.29	1.39	1.48
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	2.760	2	0.554	1.312	<2.071
Total dibenzothiophenes	ng/L	-	8.61	2	8.25	21.98	35.72
Total PAHs	ng/L	-	113.1	2	173.6	190.2	206.9
Total Parent PAHs	ng/L	-	22.55	2	16.52	18.07	19.62
Total Alkylated PAHs	ng/L	-	90.53	2	153.98	172.16	190.34

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

Table 5.2-10 Concentrations of selected water quality measurement endpoints, Wapasu Creek (*test* station WAC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.98	11	7.40	7.99	8.22
Total suspended solids	mg/L	-	<3.0	11	<3.0	<3.0	23.0
Conductivity	µS/cm	-	377	11	207	247	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.027	11	0.009	0.014	0.023
Total nitrogen	mg/L	1	0.97	11	0.50	1.00	**1.84**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	27.3	11	5.7	18.0	33.2
Ions							
Sodium	mg/L	-	8.00	11	6.00	7.10	9.00
Calcium	mg/L	-	60.3	11	26.7	33.1	71.7
Magnesium	mg/L	-	17.5	11	8.6	11.1	25.1
Chloride	mg/L	120	3.39	11	0.79	2.00	4.00
Sulphate	mg/L	270	0.61	11	<0.50	2.15	7.60
Total dissolved solids	mg/L	-	288	11	160	206	312
Total alkalinity	mg/L	-	200	11	99.1	124	292
Selected metals							
Total aluminum	mg/L	0.1	0.025	11	0.014	0.018	0.074
Dissolved aluminum	mg/L	0.1	0.0071	11	0.0025	0.0062	0.0500
Total arsenic	mg/L	0.005	0.0005	11	0.0002	0.0004	<0.0010
Total boron	mg/L	1.2	0.026	11	0.014	0.023	0.081
Total molybdenum	mg/L	0.073	0.00010	11	0.00003	0.00005	0.00040
Total mercury (ultra-trace)	ng/L	5, 13	0.95	9	<0.60	<1.2	3.3
Total strontium	mg/L	-	0.126	11	0.063	0.082	0.149
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.41	2	0.14	0.25	0.35
Oilsands Extractable	mg/L	-	1.34	2	0.13	0.78	1.42
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.780	2	<0.509	<1.290	<2.071
Total dibenzothiophenes	ng/L	-	6.67	2	20.36	27.86	35.35
Total PAHs	ng/L	-	105.1	2	207.9	218.4	228.9
Total Parent PAHs	ng/L	-	22.91	2	16.64	18.52	20.39
Total Alkylated PAHs	ng/L	-	82.2	2	191.2	199.9	208.5
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.683**	11	0.109	0.242	**1.130**
Total iron	mg/L	0.3	**0.979**	11	0.177	**0.450**	**2.070**
Total phenols	mg/L	0.004	**0.008**	11	0.002	**0.008**	**0.016**
Sulphide	mg/L	0.002	**0.010**	11	<0.002	**0.006**	**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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.48	5	7.94	8.00	8.47
Total suspended solids	mg/L	-	7.0	5	<3.0	17.0	122.0
Conductivity	µS/cm	-	364	5	134	191	535
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.034	5	0.017	0.018	0.031
Total nitrogen	mg/L	1	0.671	5	0.581	0.900	**1.931**
Nitrate+nitrite	mg/L	3	<0.071	5	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	24.6	5	24.6	30.3	33.9
Ions							
Sodium	mg/L	-	20.2	5	4.9	7.0	40.1
Calcium	mg/L	-	46.2	5	18.0	21.8	51.0
Magnesium	mg/L	-	14.3	5	6.2	7.6	18.0
Chloride	mg/L	120	1.30	5	<0.50	1.50	3.33
Sulphate	mg/L	270	7.38	5	2.24	2.70	12.30
Total dissolved solids	mg/L	-	245	5	134	167	359
Total alkalinity	mg/L	-	190	5	64.4	88.8	284
Selected metals							
Total aluminum	mg/L	0.1	**1.070**	5	0.055	**0.889**	**1.930**
Dissolved aluminum	mg/L	0.1	0.024	5	0.008	0.035	0.051
Total arsenic	mg/L	0.005	0.0012	5	0.0007	0.0008	0.0013
Total boron	mg/L	1.2	0.090	5	0.025	0.037	0.228
Total molybdenum	mg/L	0.073	0.00043	5	0.00011	0.00016	0.00047
Total mercury (ultra-trace)	ng/L	5, 13	2.30	5	<0.60	2.40	8.10
Total strontium	mg/L	-	0.121	5	0.046	0.068	0.193
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.27	2	0.02	0.20	0.37
Oilsands Extractable	mg/L	-	0.20	2	0.79	0.94	1.08
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.58	2	<2.14	10.87	19.60
Total dibenzothiophenes	ng/L	-	6.67	2	27.29	31.50	35.72
Total PAHs	ng/L	-	104.0	2	221.2	228.0	234.7
Total Parent PAHs	ng/L	-	22.44	2	17.00	19.94	22.87
Total Alkylated PAHs	ng/L	-	81.6	2	198.3	208.0	217.7
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.883**	5	0.280	**0.371**	**0.714**
Total iron	mg/L	0.3	**1.46**	5	**0.84**	**1.05**	**3.06**
Total phenols	mg/L	0.004	**0.005**	5	**0.005**	**0.009**	**0.016**
Sulphide	mg/L	0.002	**0.005**	5	<0.002	**0.007**	**0.013**
Total phosphorus	mg/L	0.05	**0.051**	5	0.032	0.042	**0.123**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.07	14	7.60	8.03	8.30
Total suspended solids	mg/L	-	3.0	14	<3.0	4.5	19.0
Conductivity	µS/cm	-	176	14	133	175	207
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.008	14	0.002	0.007	0.013
Total nitrogen	mg/L	1	**1.00**	14	0.45	**1.36**	**1.92**
Nitrate+nitrite	mg/L	3	<0.071	14	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	28.2	14	9.8	21.5	28.2
Ions							
Sodium	mg/L	-	10.6	14	8.0	10.0	11.3
Calcium	mg/L	-	20.2	14	16.5	19.5	20.6
Magnesium	mg/L	-	7.12	14	5.70	6.85	7.60
Chloride	mg/L	120	0.53	14	<0.50	<1.00	3.00
Sulphate	mg/L	270	3.09	14	1.38	4.45	5.70
Total dissolved solids	mg/L	-	156	14	94	155	220
Total alkalinity	mg/L	-	87	14	72	88	105
Selected metals							
Total aluminum	mg/L	0.1	0.010	14	0.007	0.019	**0.130**
Dissolved aluminum	mg/L	0.1	0.005	14	<0.001	0.001	0.030
Total arsenic	mg/L	0.005	0.00034	14	0.00029	0.00036	<0.00100
Total boron	mg/L	1.2	0.050	14	0.012	0.047	0.052
Total molybdenum	mg/L	0.073	<0.00010	14	0.00003	0.00010	0.00090
Total mercury (ultra-trace)	ng/L	5, 13	0.880	10	<0.600	<1.200	<1.300
Total strontium	mg/L	-	0.065	14	0.056	0.067	0.215
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.43	2	0.19	0.34	0.49
Oilsands Extractable	mg/L	-	1.08	2	0.42	0.84	1.25
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	10.90	12.52	<14.13
Retene	ng/L	-	<0.669	2	<0.509	<1.290	<2.071
Total dibenzothiophenes	ng/L	-	7.68	2	7.03	21.19	35.35
Total PAHs	ng/L	-	104.5	2	161.2	184.1	206.9
Total Parent PAHs	ng/L	-	22.57	2	18.81	19.77	20.73
Total Alkylated PAHs	ng/L	-	81.9	2	140.5	164.3	188.1
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.008**	14	<0.002	**0.004**	**0.010**
Total phenols	mg/L	0.004	**0.009**	14	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.

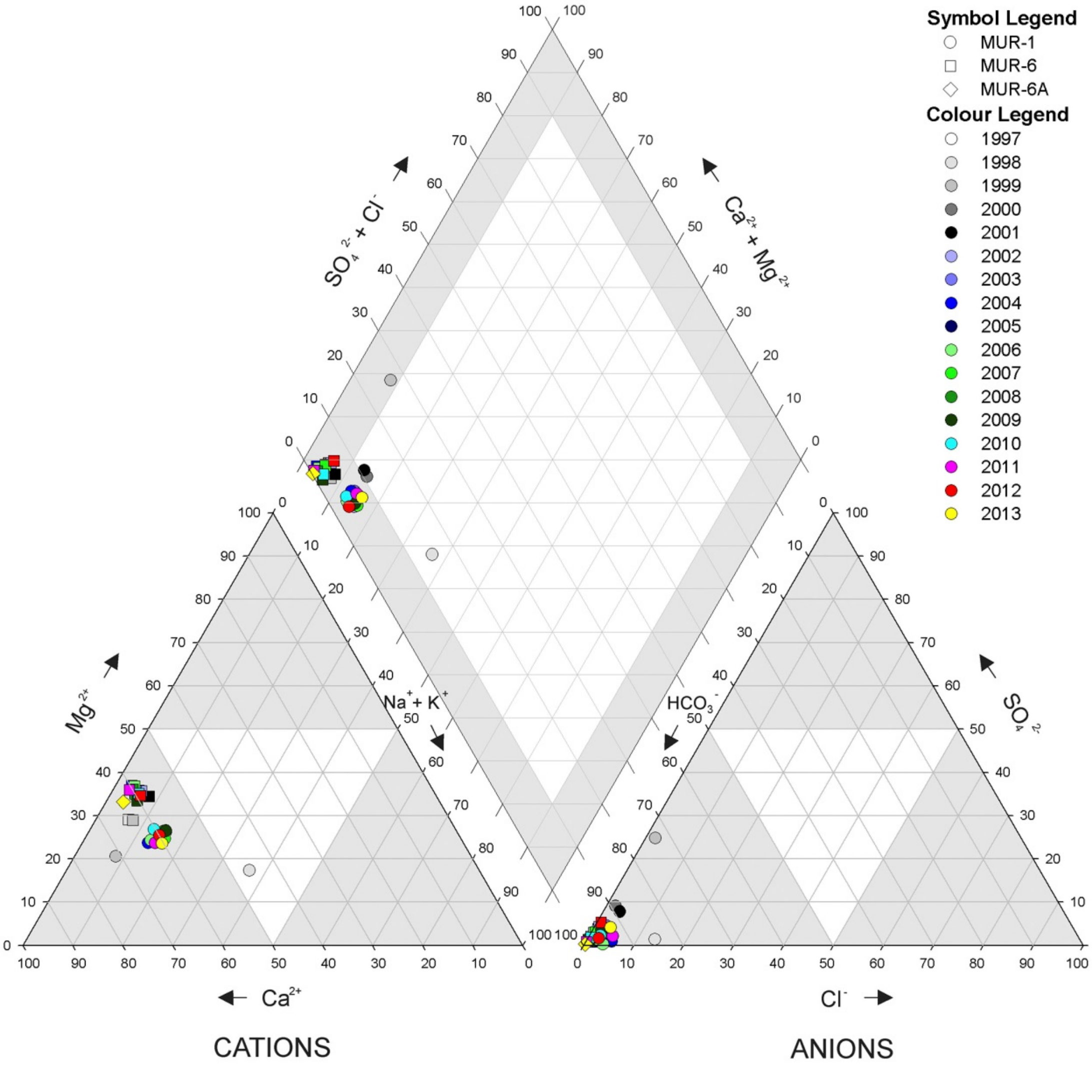


Figure 5.2-6 Piper diagram of fall ion concentrations in tributaries to the Muskeg River and Kearl Lake.

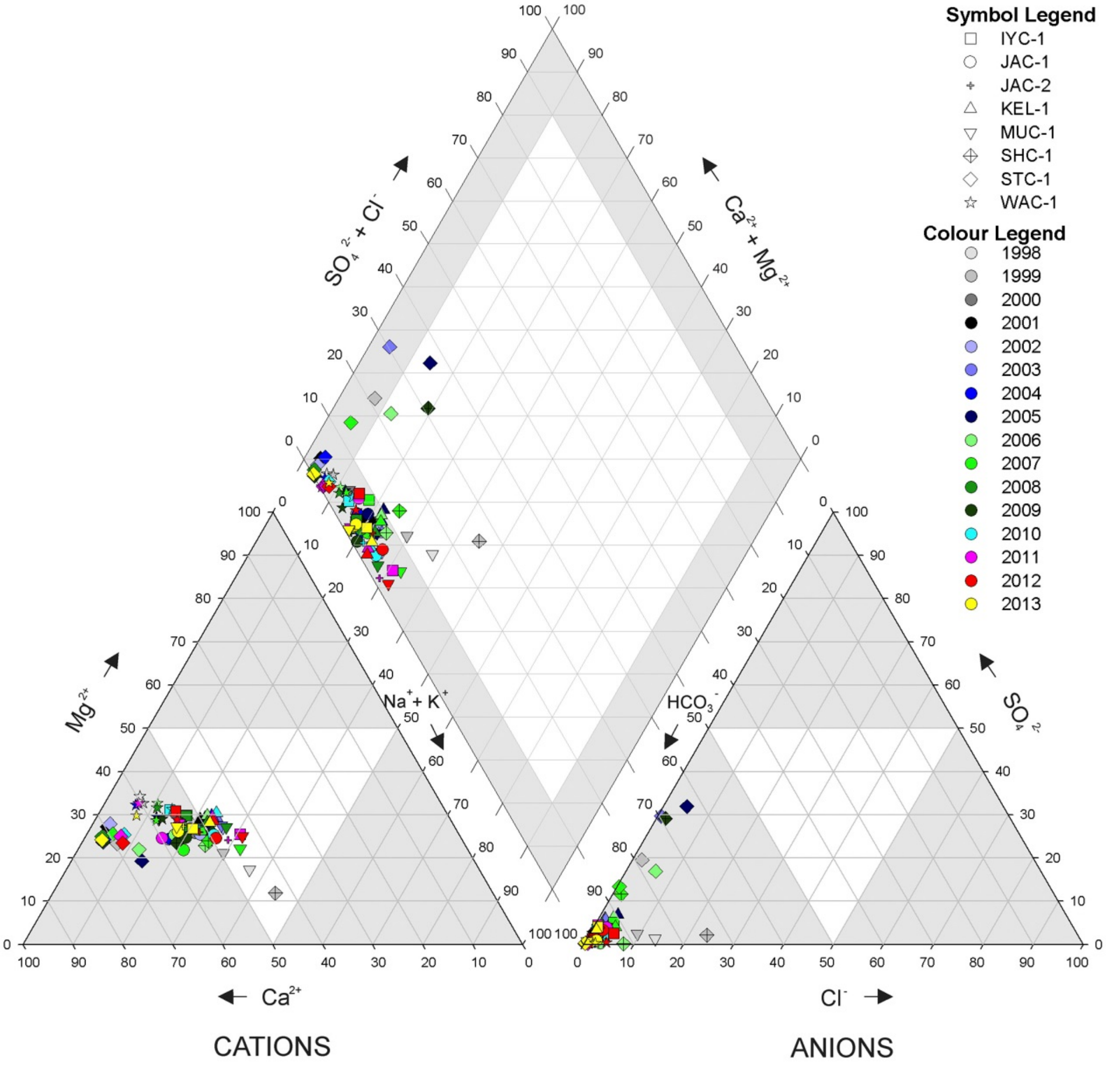


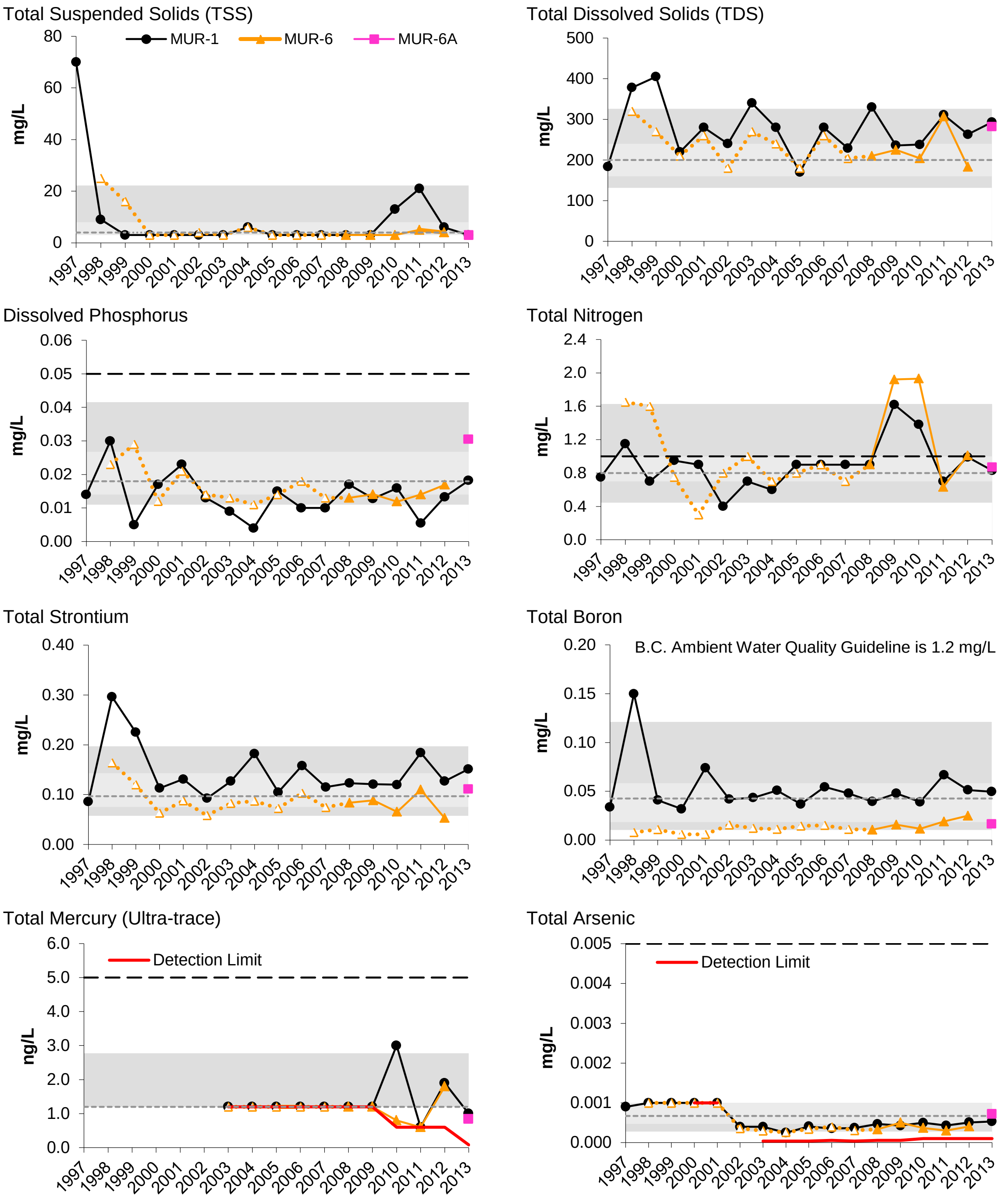
Table 5.2-13 Water quality guideline exceedances, Muskeg River watershed, fall 2013.

Variable	Units	Guideline[a]	MUR-1	MUR-6A	MUC-1	JAC-1	JAC-2	STC-1	WAC-1	IYC-1	KEL-1
Dissolved iron	mg/L	0.3	0.521	0.982	0.780	0.832	0.709	-	0.683	0.883	-
Sulphide	mg/L	0.002	0.0021	0.0082	0.0154	0.0085	0.0051	-	0.0102	0.0051	0.0075
Total aluminum	mg/L	0.1	-	-	-	-	0.38	-	-	1.07	-
Total iron	mg/L	0.3	0.632	1.380	1.040	1.100	1.070	-	0.979	1.460	-
Total nitrogen	mg/L	1	-	-	1.041	-	-	-	-	-	1.001
Total phenols	mg/L	0.004	0.0096	0.0077	0.0063	0.0079	0.0046	-	0.0084	0.0047	0.0093
Total phosphorus	mg/L	0.05	-	-	-	-	-	-	-	0.051	-

[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-6A) (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

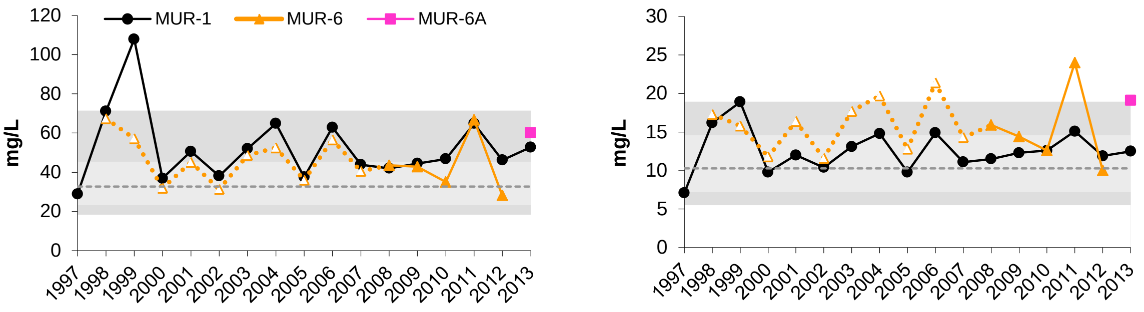
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Note: Historical *test* station MUR-6 was moved approximately one kilometer upstream due to station access issues and renamed as *test* station MUR-6A.

Figure 5.2-7 (Cont'd.)

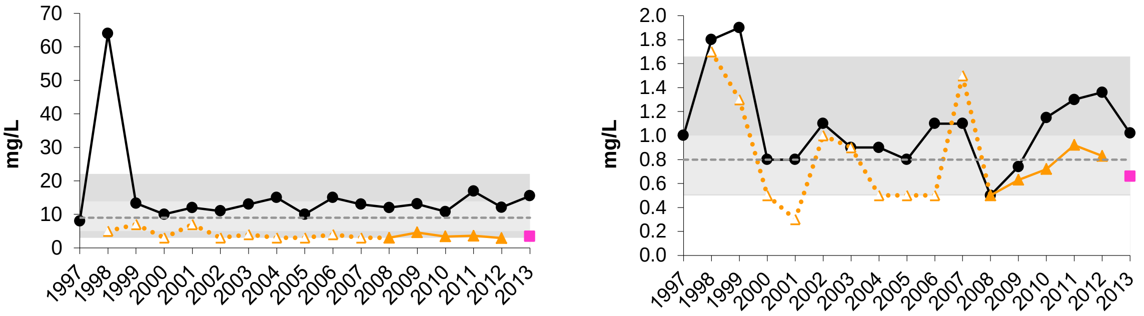
Calcium

Magnesium



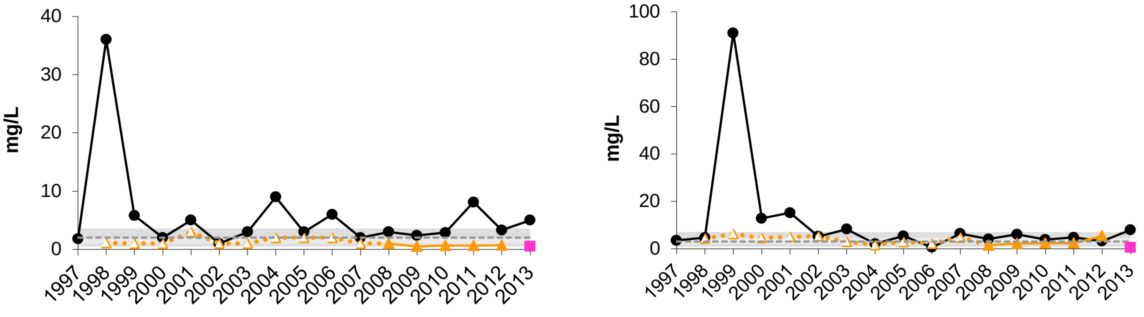
Sodium

Potassium



Chloride

Sulphate



Non-detectable values are shown at the detection limit.

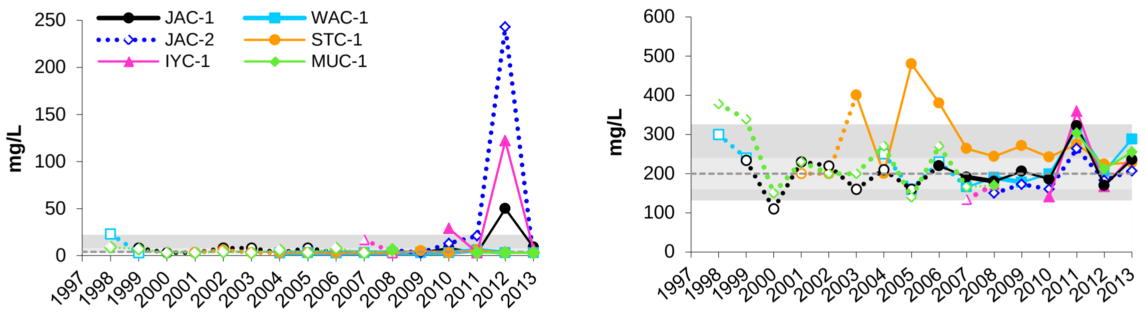
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

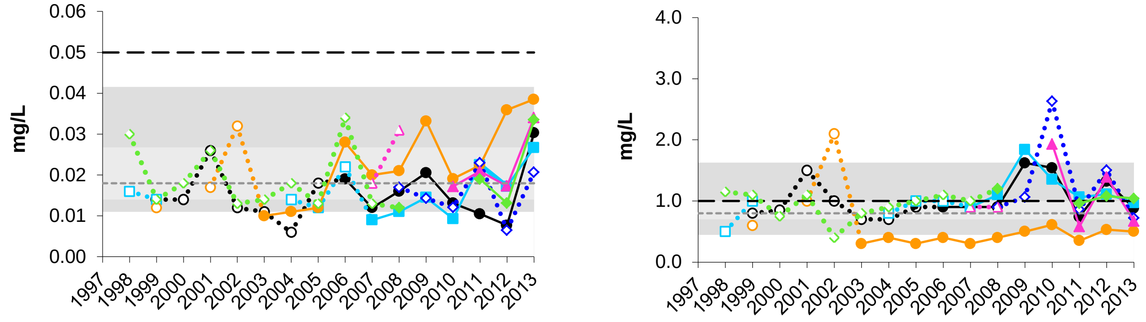
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Note: Historical *test* station MUR-6 was moved approximately one kilometer upstream due to station access issues and renamed as *test* station MUR-6A.

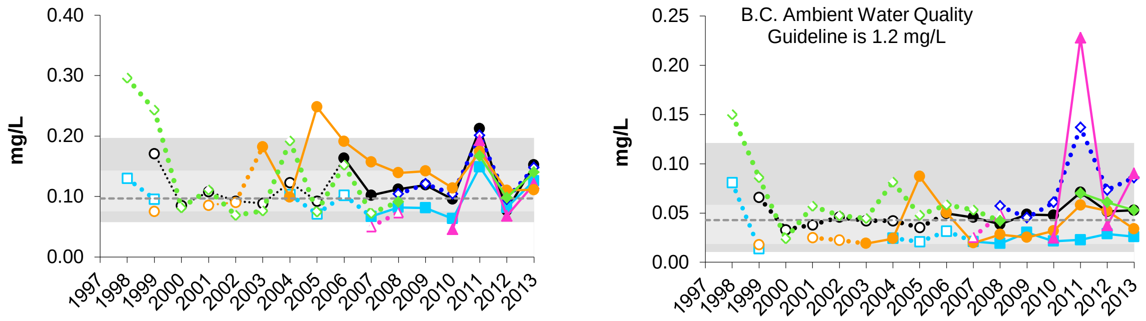
Figure 5.2-8 Selected water quality measurement endpoints in Muskeg River tributaries (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

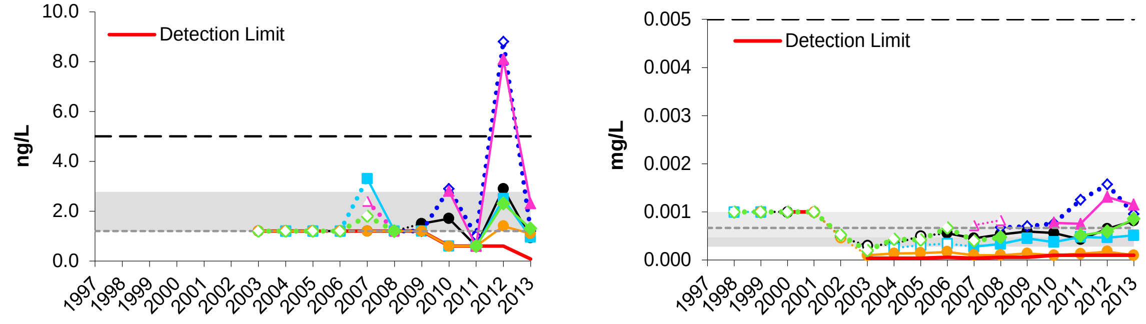
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

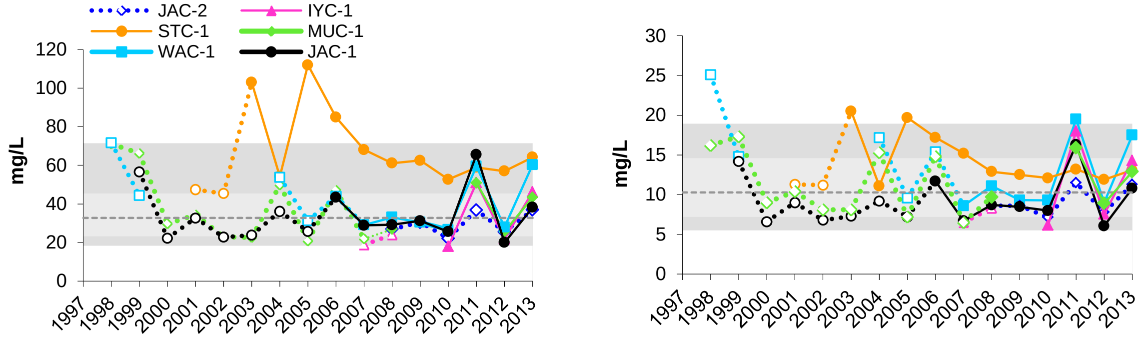
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

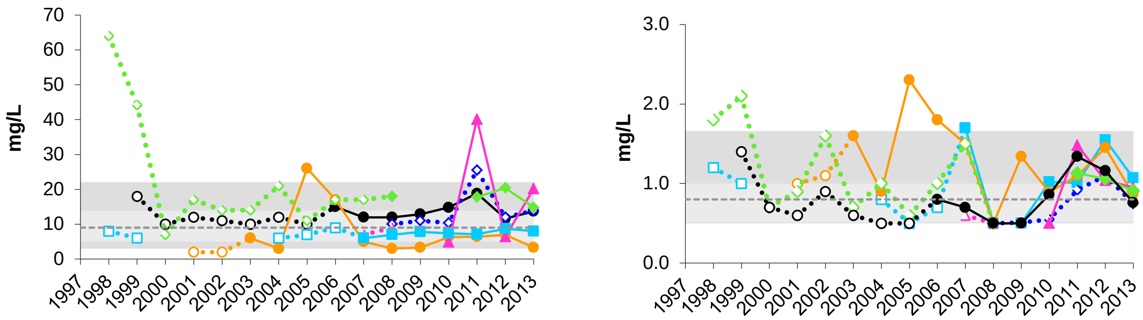
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.2-8 (Cont'd.)



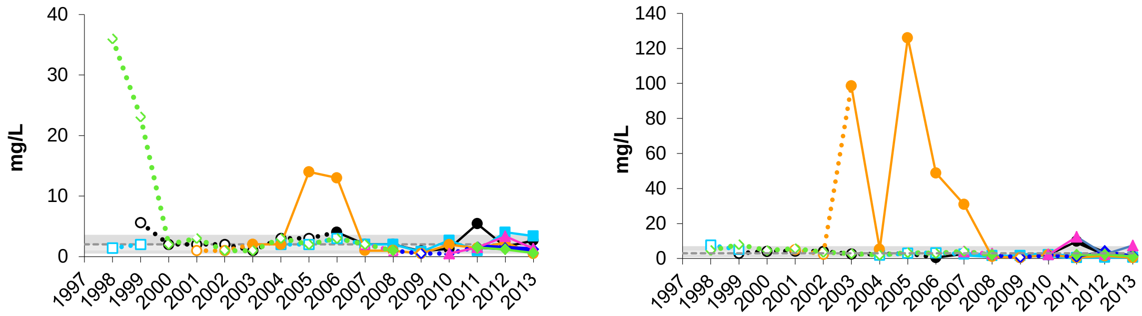
Calcium

Magnesium



Sodium

Potassium



Chloride

Sulphate

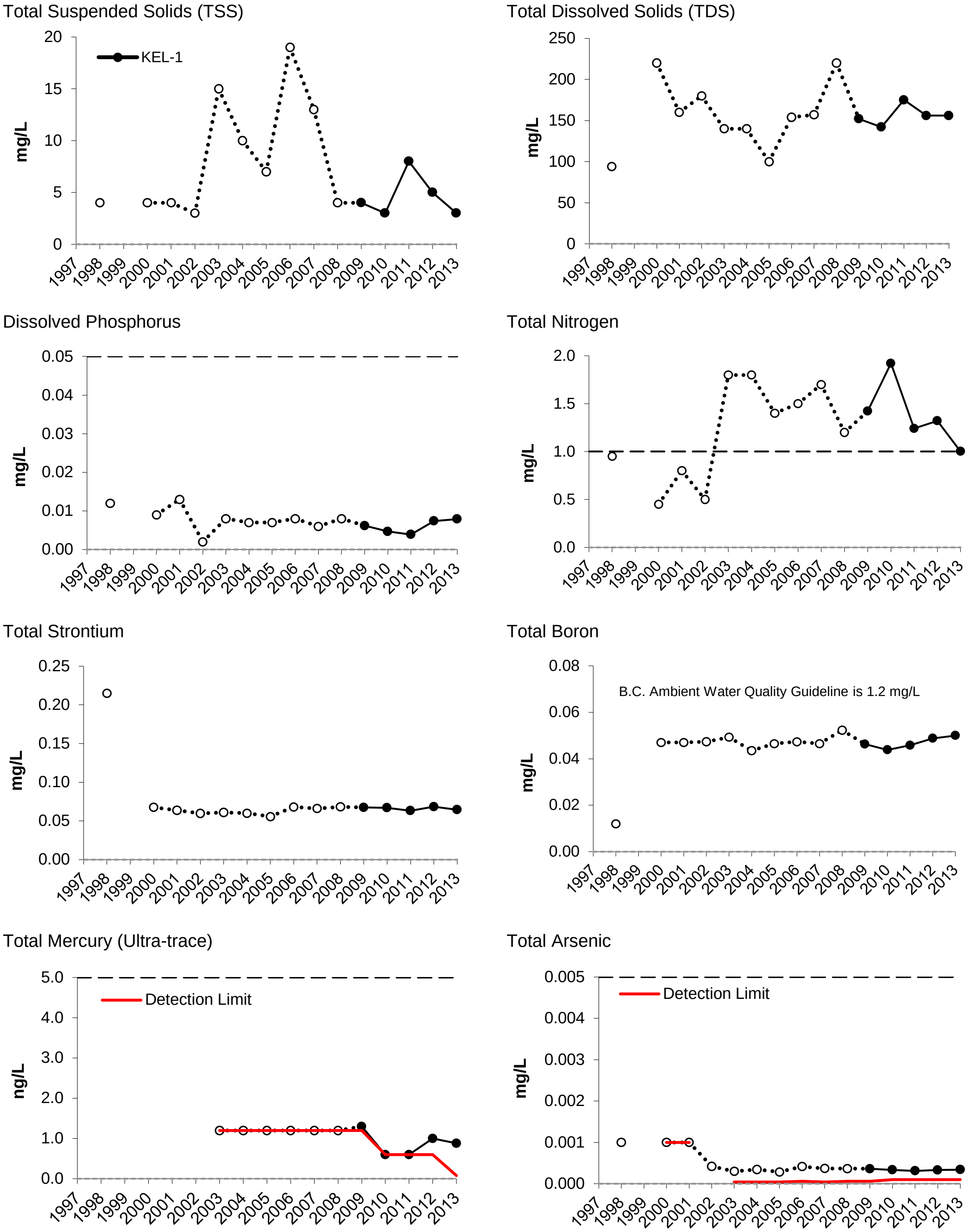
Non-detectable values are shown at the detection limit.

- - - - - 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 3.2.2.2 for a discussion of this approach.

Figure 5.2-9 Selected water quality measurement endpoints in Kearl Lake (fall data) relative to historical concentrations.



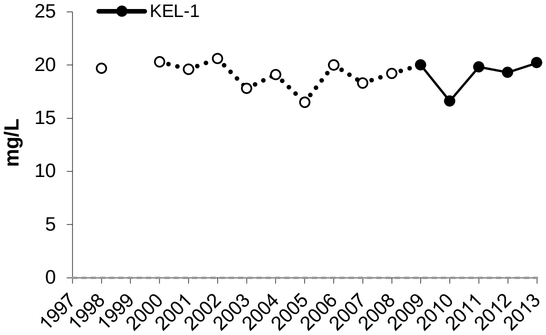
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

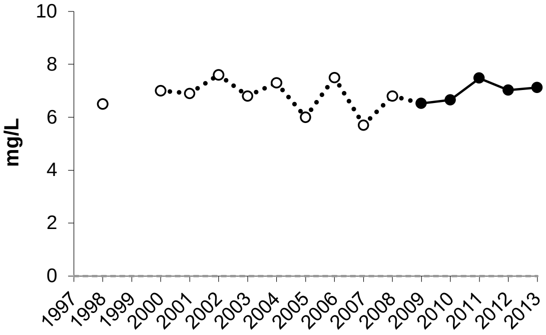
○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.2-9 (Cont'd.)

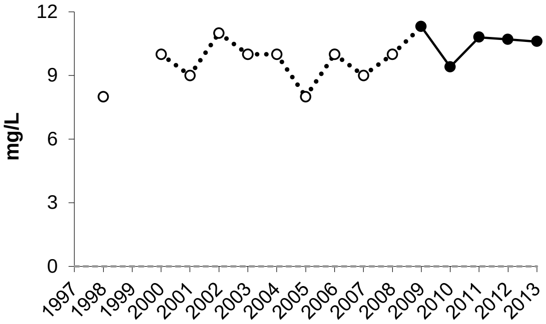
Calcium



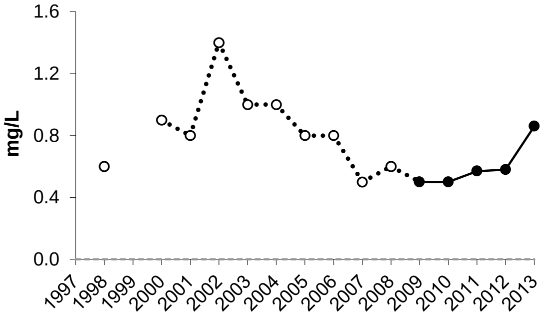
Magnesium



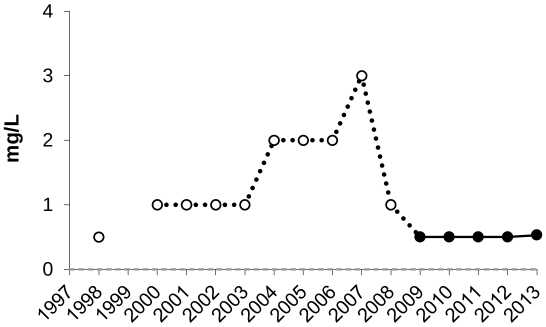
Sodium



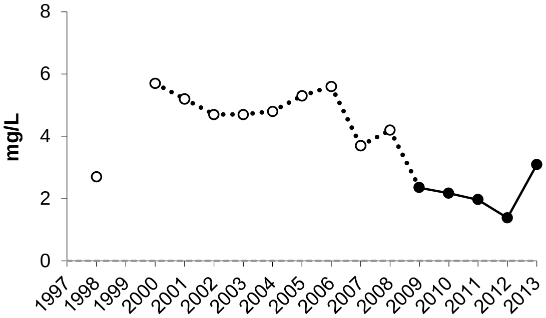
Potassium



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 2013) for Muskeg River watershed stations.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
MUR-1	lower Muskeg River	*test*	96.2	Negligible-Low
MUR-6A	upstream of Wapasu Creek	*test*	97.5	Negligible-Low
MUC-1	near mouth of Muskeg Creek	*test*	96.2	Negligible-Low
JAC-1	near mouth of Jackpine Creek	*test*	96.2	Negligible-Low
JAC-2	upper Jackpine Creek	*baseline*	98.7	Negligible-Low
STC-1	near mouth of Stanley Creek	*test*	97.5	Negligible-Low
IYC-1	near mouth of Iyinimin Creek	*test*	85.0	Negligible-Low
WAC-1	near mouth of Wapasu Creek	*test*	100.0	Negligible-Low

Table 5.2-15 Monthly water quality measurement endpoints at the mouth of the Muskeg River (*test* station MUR-1), January to December 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	12	7.61	(May)	8.00	8.41	(September)
Total suspended solids	mg/L	-	12	<3	-	3	17	(May)
Conductivity	µS/cm	-	12	207	(May)	343	480	(February)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	12	0.004	(February)	0.012	0.020	(June)
Total nitrogen	mg/L	1.0	12	0.691	(October)	0.898	**1.341**	(July)
Nitrate+nitrite	mg/L	3	12	<0.070	-	<0.071	0.185	(April)
Dissolved organic carbon	mg/L	-	12	20.9	(December)	24.3	31.2	(July)
Ions								
Sodium	mg/L	-	12	7.6	(May)	13.0	16.9	(April)
Calcium	mg/L	-	12	32.6	(May)	49.5	66.0	(April)
Magnesium	mg/L	-	12	8.3	(May)	11.9	17.0	(March)
Chloride	mg/L	120	12	1.57	(June)	4.73	7.10	(April)
Sulphate	mg/L	410	12	2.9	(June)	8.2	15.4	(December)
Total dissolved solids	mg/L	-	12	184.0	(May)	284.5	317.0	(February)
Total alkalinity	mg/L	-	12	102	(May)	188.5	252	(March)
Selected metals								
Total aluminum	mg/L	0.1	12	0.027	(November)	0.070	**1.350**	(January)
Dissolved aluminum	mg/L	0.1	12	0.004	(April)	0.007	0.015	(June)
Total arsenic	mg/L	0.005	12	0.0003	(February)	0.0005	0.0008	(July)
Total boron	mg/L	1.2	12	0.034	(November)	0.046	0.053	(April)
Total molybdenum	mg/L	0.073	12	<0.00010	-	0.00011	0.00022	(July)
Total mercury (ultra-trace)	ng/L	5, 13	12	0.70	(February)	1.15	2.20	(May)
Total strontium	mg/L	-	12	0.083	(May)	0.132	0.169	(April)
Total hydrocarbons								
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	12	0.22	(November)	0.45	0.75	(April)
Oilsands Extractable	mg/L	-	12	0.35	(November)	0.56	1.10	(October)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	12	<15.16	-	<15.16	68.30	(January)
Retene	ng/L	-	12	<0.669	-	1.175	8.920	(May)
Total dibenzothiophenes	ng/L	-	12	12.64	(February)	32.43	305.99	(July)
Total PAHs	ng/L	-	12	133.4	(March)	202.7	986.2	(July)
Total Parent PAHs	ng/L	-	12	22.78	(March)	30.01	96.19	(January)
Total Alkylated PAHs	ng/L	-	12	107.4	(February)	167.0	949.5	(July)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	10	0.003	(December)	**0.005**	**0.009**	(September)
Sulphide	mg/L	0.002	12	<0.003	(March)	**0.007**	**0.012**	(July)
Total phosphorus	mg/L	0.05	1	0.020	(March)	0.025	**0.062**	(July)
Total Kjeldahl nitrogen	mg/L	1.0	2	0.62	(October)	0.77	**1.27**	(July)
Total iron	mg/L	0.3	12	**0.740**	(November)	**0.959**	**3.990**	(January)
Dissolved iron	mg/L	0.3	11	0.269	(May)	**0.528**	**1.290**	(July)
Total chromium	mg/L	0.001	1	<0.00030	-	0.00049	**0.00166**	(January)

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

[1] n refers to number of exceedances in 2013.

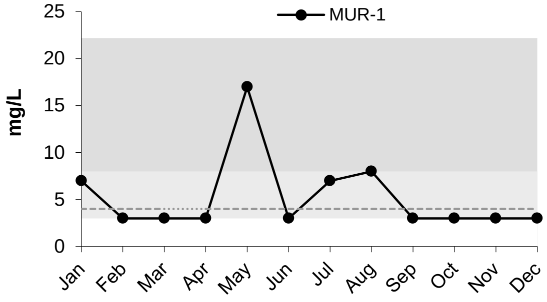
Table 5.2-16 Monthly water quality guideline exceedances at the mouth of the Muskeg River (*test* station MUR-1), January to December 2013.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0052	0.0049	0.0051	0.0057	0.0078	-	0.0093	0.0048	0.0090	0.0047	0.0051	-
Sulphide	mg/L	0.002	0.0031	0.0068	0.0032	0.0109	0.0100	0.0100	0.0122	0.0066	0.0052	0.0045	0.0066	0.0066
Total phosphorus	mg/L	0.05	-	-	-	-	-	-	0.062	-	-	-	-	-
Total nitrogen	mg/L	1.0	-	-	-	-	1.250	1.070	1.341	-	-	-	-	-
Total aluminum	mg/L	0.1	1.350	-	-	-	0.576	0.122	0.397	-	-	0.261	-	-
Total iron	mg/L	0.3	3.99	1.02	0.90	0.88	0.75	1.08	1.81	1.06	0.87	0.75	0.74	1.22
Dissolved iron	mg/L	0.3000	0.69	0.53	0.45	0.32	-	0.72	1.29	0.65	0.52	0.32	0.46	0.63
Total chromium	mg/L	0.001	0.002	-	-	-	-	-	-	-	-	-	-	-

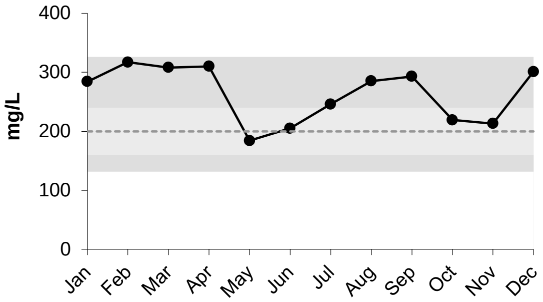
[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.2-10 Concentrations of selected water quality measurement endpoints in the Muskeg River (monthly data) relative to regional *baseline* fall concentrations.

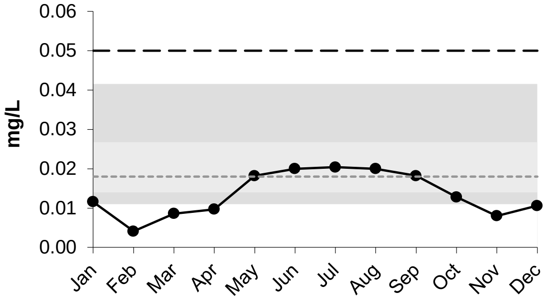
Total Suspended Solids (TSS)



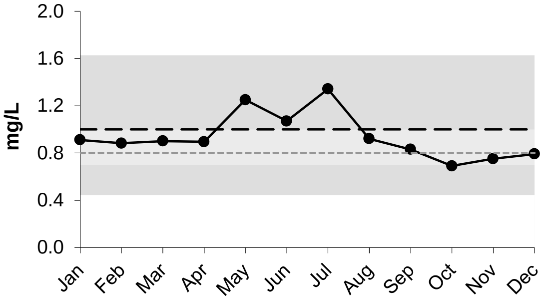
Total Dissolved Solids (TDS)



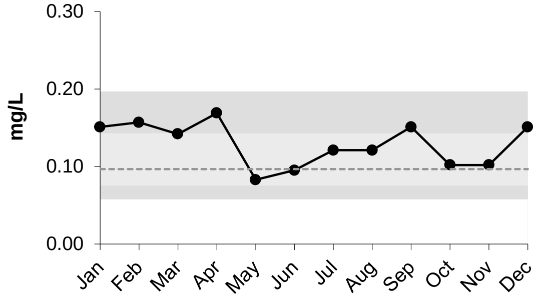
Dissolved Phosphorus



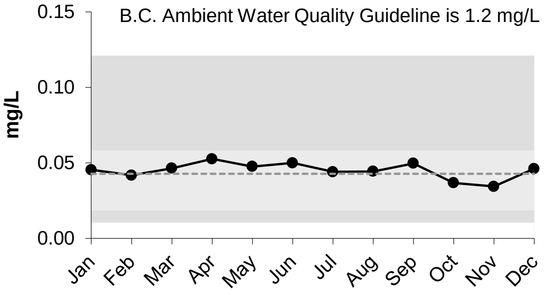
Total Nitrogen



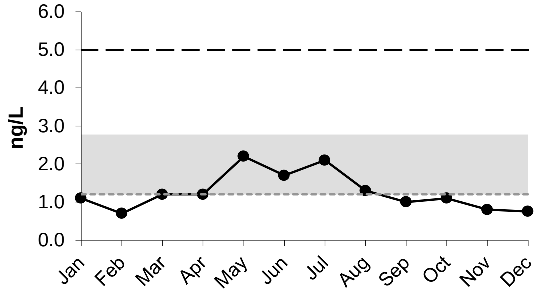
Total Strontium



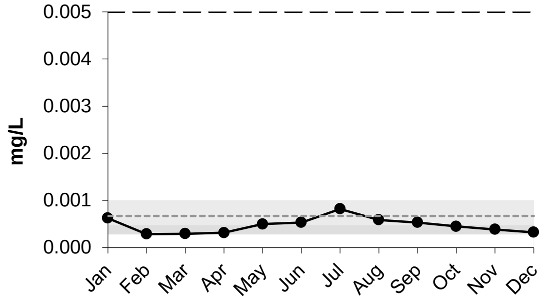
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic

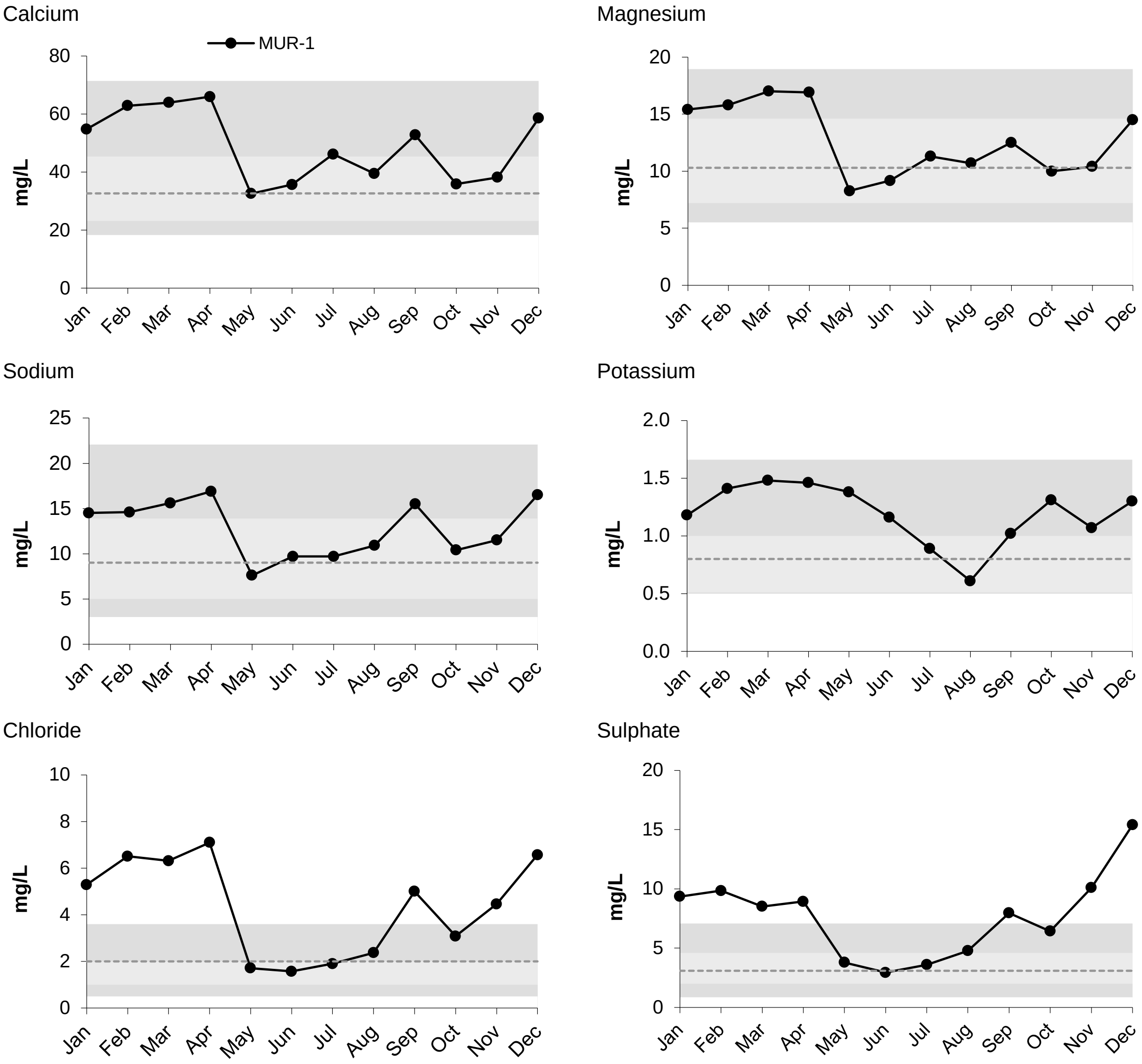


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.2-10 (Cont'd.)

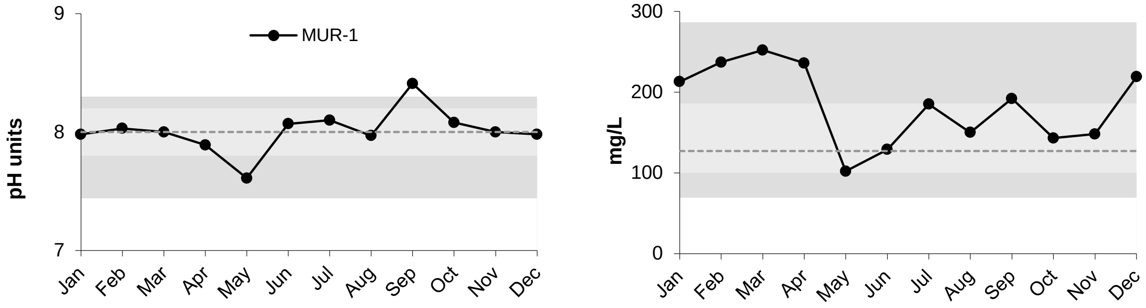


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

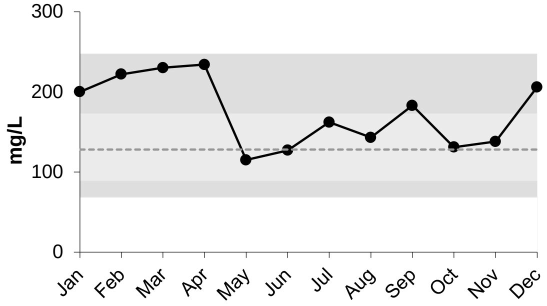
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.2-10 (Cotn'd.)


pH

Total Alkalinity

Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region in fall, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.2-11 Piper diagram of monthly ion concentrations in the lower Muskeg River (*test* station MUR-1).

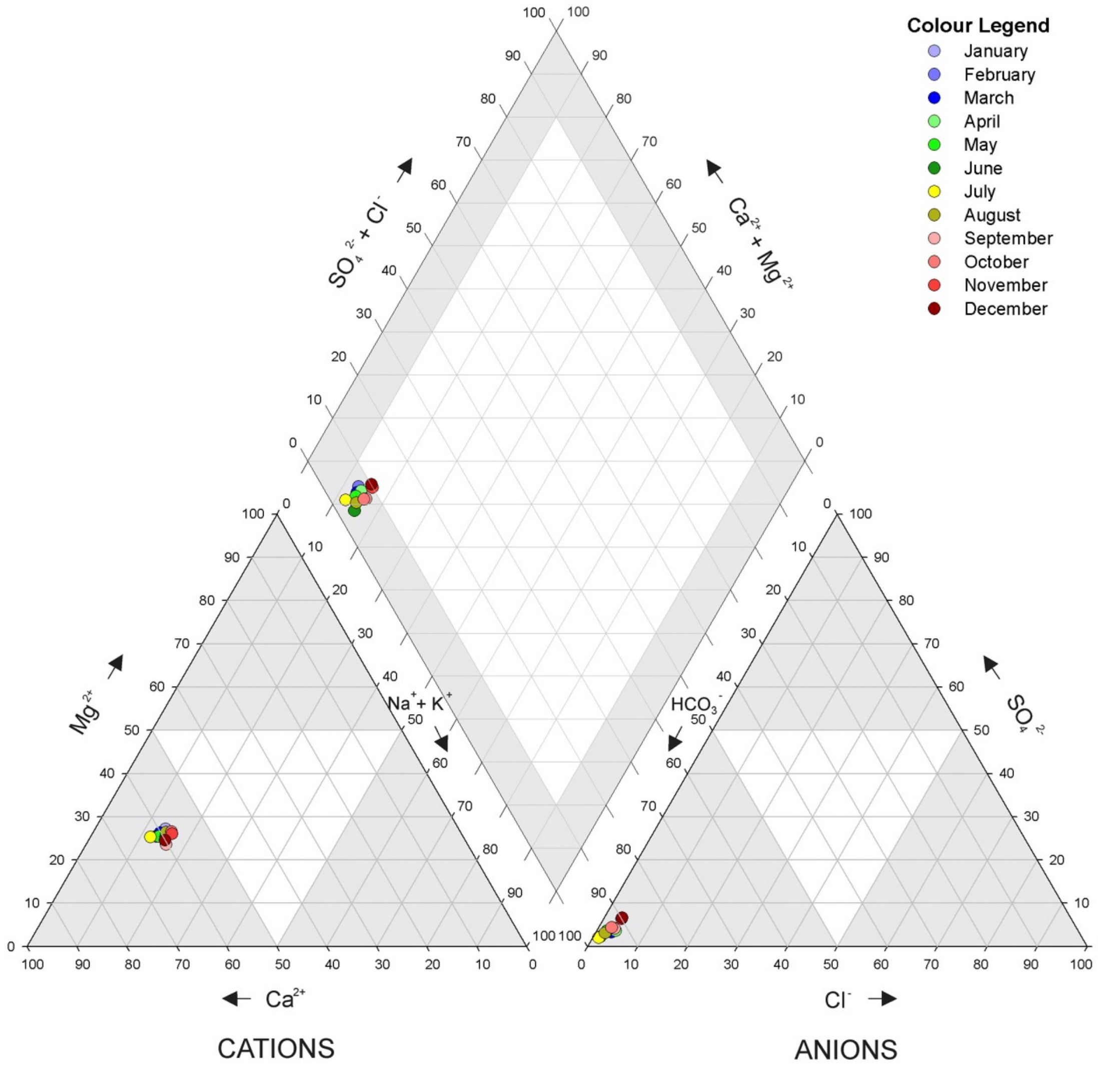
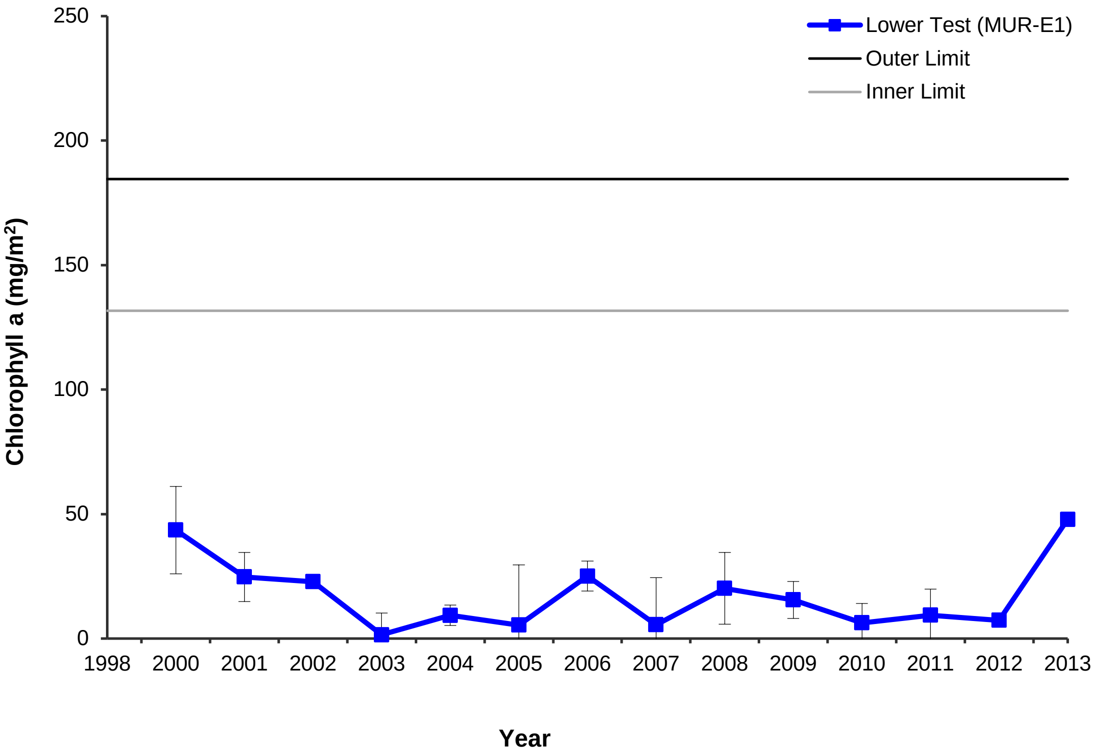


Table 5.2-17 Average habitat characteristics of benthic invertebrate sampling locations of the Muskeg River, fall 2013.

Variable	**Units**	**MUR-E1** **Lower *Test* Reach of the Muskeg River**	**MUR-D2** **Middle *Test* Reach of the Muskeg River**	**MUR-D3** **Upper *Test* Reach of the Muskeg River**
Sample date	-	Sept 9, 2013	Sept 6, 2013	Sept 4, 2013
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	1.3	0.5
Current velocity	m/s	1.65	0.23	Negligible
Field Water Quality				
Dissolved oxygen	mg/L	9.5	7.3	6.2
Conductivity	µS/cm	376	343	356
pH	pH units	8.4	7.4	7.4
Water temperature	°C	15.6	16.7	16.0
Sediment Composition				
sand	%	-	95	44
silt	%	-	4	51
clay	%	-	1	5
sand/silt/clay		12	-	-
small gravel	%	16	-	-
large gravel	%	28	-	-
small cobble	%	32	-	-
large cobble	%	12	-	-
boulder	%	0	-	-
Total Organic Carbon	%	-	0.82	18.5

Figure 5.2-12 Periphyton chlorophyll *a* biomass at *test* reach MUR-E1 of the Muskeg River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for all years up to and including 2012.

Table 5.2-18 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in the Muskeg River.

Taxon	Percent Major Taxa Enumerated in Each Year								
	***Test* Reach MUR-E1**			***Test* Reach MUR-D2**			***Test* Reach MUR-D3**		
	1998	**2000 to 2012**	**2013**	**2000**	**2001 to 2012**	**2013**	**2002**	**2003 to 2012**	**2013**
Hydra	-	0 to <1	<1	<1	0 to 4	<1	-	0 to 1	-
Nematoda	2	<1 to 5	1	2	1 to 6	1	1	0 to 6	2
Naididae	5	1 to 30	6	2	<1 to 11	4	<1	<1 to 7	<1
Tubificidae	5	0 to 26	<1	10	<1 to 31	<1	<1	2 to 26	19
Enchytraeidae	<1	0 to 1	<1	<1	0 to 6	<1	-	0 to 1	<1
Lumbriculidae	-	0 to <1	<1	1	0 to 7	<1	-	0 to 2	<1
Erpobdellidae	-	0 to <1	-	<1	0 to <1	-	<1	0 to <1	-
Hirudinea	-	0 to <1	-	<1	0 to 1	<1	<1	0 to 3	<1
Hydracarina	14	0 to 17	5	1	<1 to 3	2	<1	0 to 17	-
Amphipoda	-	0 to <1	-	-	0 to 2	0	<1	<1 to 5	<1
Gastropoda	3	0 to 7	<1	<1	0 to 4	<1	<1	0 to 2	1
Bivalvia	6	0 to 9	<1	4	0 to 5	<1	28	0 to 18	17
Ceratopogonidae	1	0 to 26	<1	1	1 to 28	6	<1	0 to 2	<1
Chironomidae	32	15 to 58	31	75	32 to 84	67	66	27 to 79	30
Dolichopodidae	-	<1	-	-	-	-	-	-	-
Diptera (misc.)	4	<1 to 22	2	<1	0 to 4	<1	<1	0 to 2	<1
Ephydridae	-	<1	-	-	-	-	-	-	-
Coleoptera	5	<1 to 10	<1	<1	0 to 1	0	-	0 to 1	<1
Ephemeroptera	12	5 to 50	46	<1	<1 to 6	4	-	<1 to 7	9
Odonata	<1	<1 to 2	2	<1	0 to <1	<1	-	0 to <1	-
Plecoptera	4	<1 to 8	2	<1	0 to <1	0	-	0 to 1	<1
Trichoptera	2	1 to16	1	<1	0 to <1	0	<1	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints									
Total Abundance (mean of replicate samples)	1,487	258 to 3,183	1,566	1321	137 to 1,300	518	218	133 to 351	389
Richness	60	29 to 43	29	26	10 to 32	22	12	9 to 17	16
Equitability	0.25	0.13 to 0.38	0.17	0.2	0.18 to 0.42	0.29	0.26	0.39 to 0.52	0.28
% EPT	18	14 to 57	52	<1	<1 to 6	4.25	<1	<1 to 5	12

Table 5.2-19 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River, *test* reach MUR-E1.

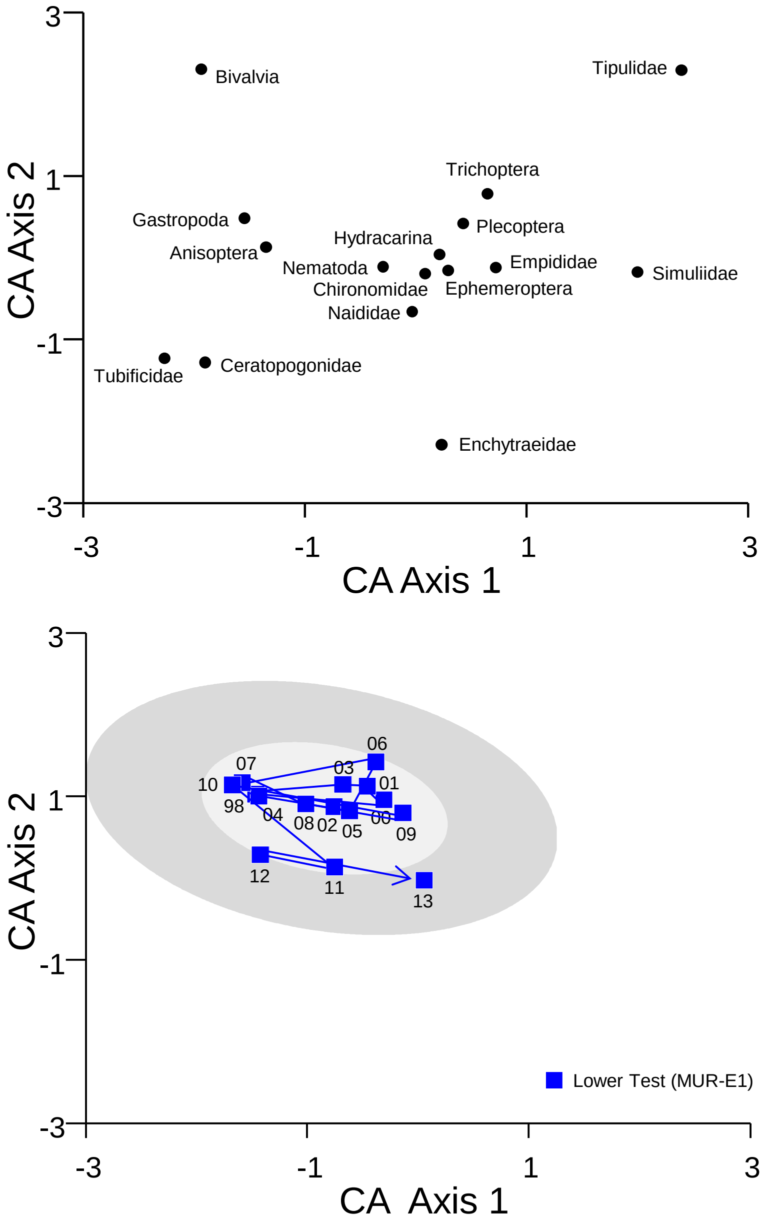
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time trend (*test* period)	**2013 vs. Previous Years**	**Time trend (*test* period)**	**2013 vs. Previous Years**	
Log Abundance	**<0.001**	0.110	11	2	Increasing over time.
Log Richness	0.496	**0.024**	1	8	Lower in 2013 than mean of previous years.
Equitability	**0.002**	**0.008**	12	9	Decreasing over time; lower in 2013 than mean of previous years.
Log EPT	0.163	<0.001	1	10	Higher in 2013 than mean of previous years.
CA Axis 1	0.873	<0.001	0	19	Higher in 2013 than mean of previous years.
CA Axis 2	**<0.001**	**<0.001**	▨ 30	▨ 33	Decreasing over time; lower in 2013 than mean of previous years.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-13 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the lower reach of the Muskeg River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-E1 (1998 to 2012).

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)	2013 vs. Previous Years	Time trend (*test* period)	2013 vs. Previous Years	
Log Abundance	0.214	0.800	1	0	No change.
Log Richness	**0.050**	0.842	5	1	Increasing over time.
Equitability	0.752	0.208	0	0	No change.
Log EPT	**0.002**	0.912	24	3	Increasing over time.
CA Axis 1	0.347	0.218	2	3	No change.
CA Axis 2	**<0.001**	0.112	18	2	Increasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.2-21 Results of analysis of variance (ANOVA) testing differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D3).

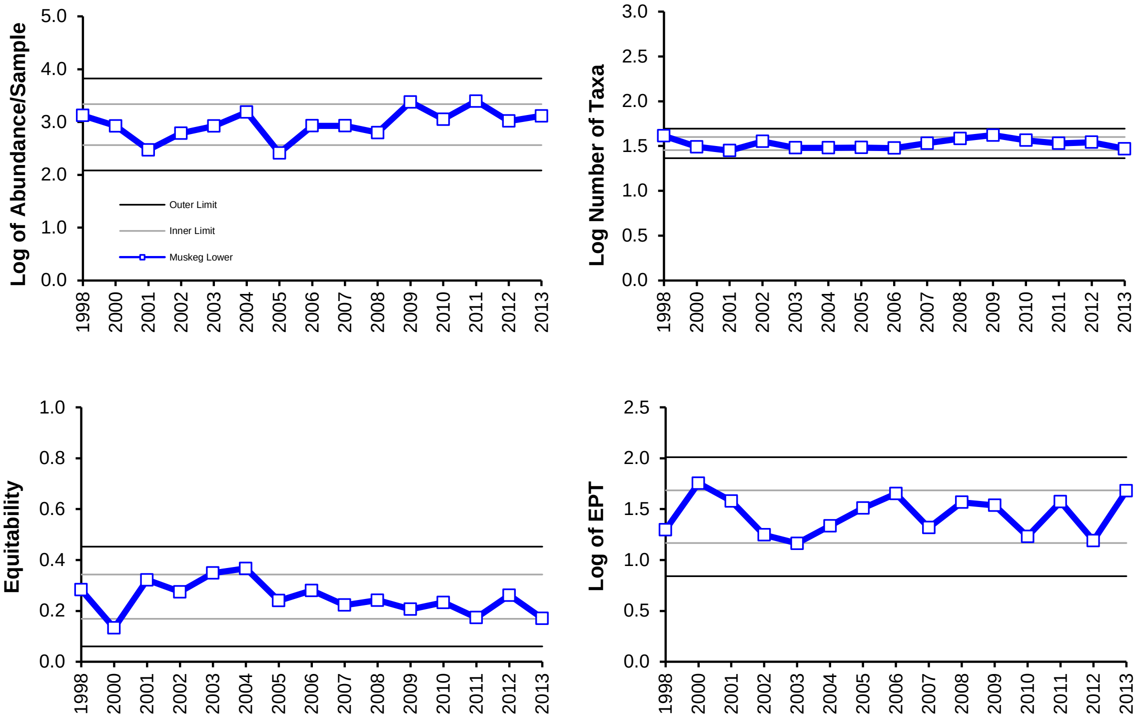
Variable	P-value				Variance Explained (%)				Nature of Change(s)
	Baseline **Period vs.** ***Test*** **Period**	**Time trend (*test* period)**	**2013 vs.** ***Baseline*** **Years**	**2013 vs. Previous Years**	***Baseline*** **Period vs.** ***Test*** **Period**	**Time trend (*test* period)**	**2013 vs.** ***Baseline*** **Years**	**2013 vs. Previous Years**	
Log Abundance	0.842	0.072	0.051	**0.033**	1	15	11	11	Higher in 2013 than mean of previous years.
Log Richness	0.103	0.220	0.373	0.148	1	21	11	17	No change.
Equitability	0.447	0.447	0.500	0.319	1	8	22	25	No change.
Log EPT	**0.027**	**0.012**	**0.022**	**0.035**	0	5	29	38	Increasing during *test* period; higher in *test* period.
CA Axis 1	0.323	0.607	0.721	0.911	3	1	0	0	No change.
CA Axis 2	0.506	0.717	0.157	0.165	1	0	5	4	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

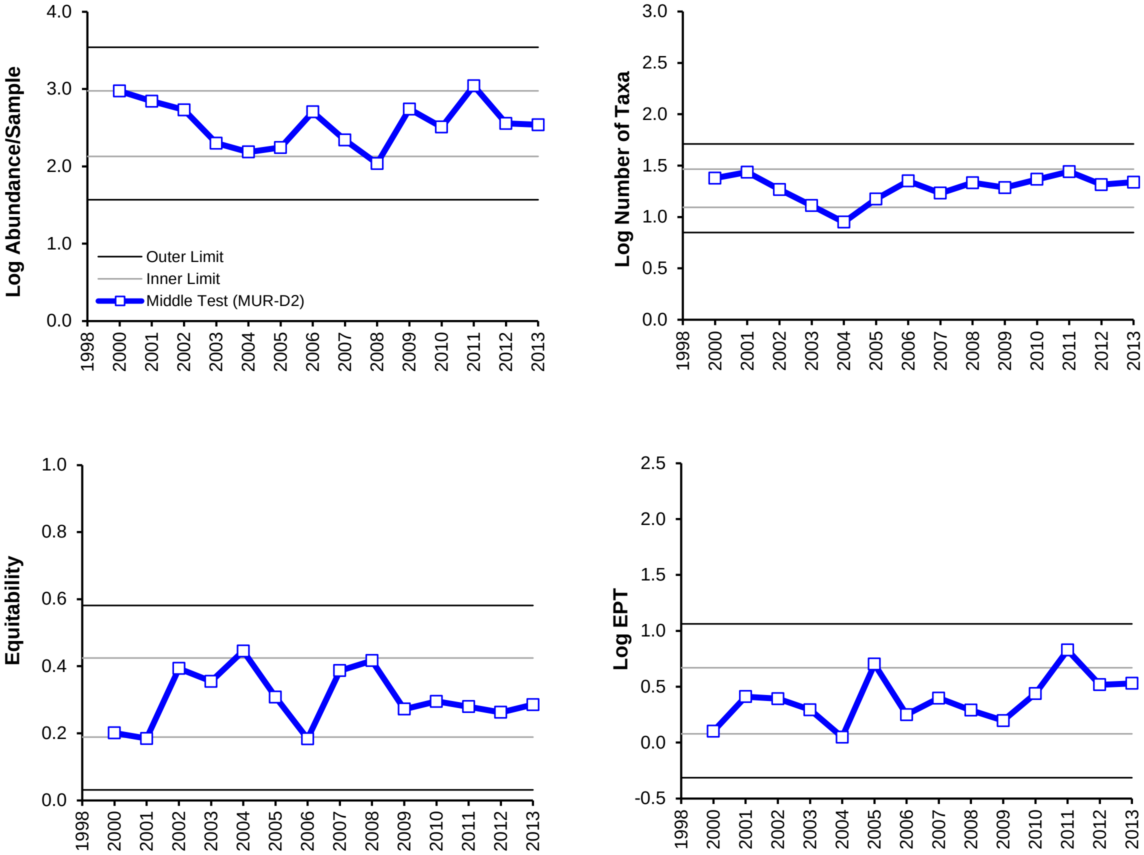
Figure 5.2-14 Variation in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-E1).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-E1 (1998 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

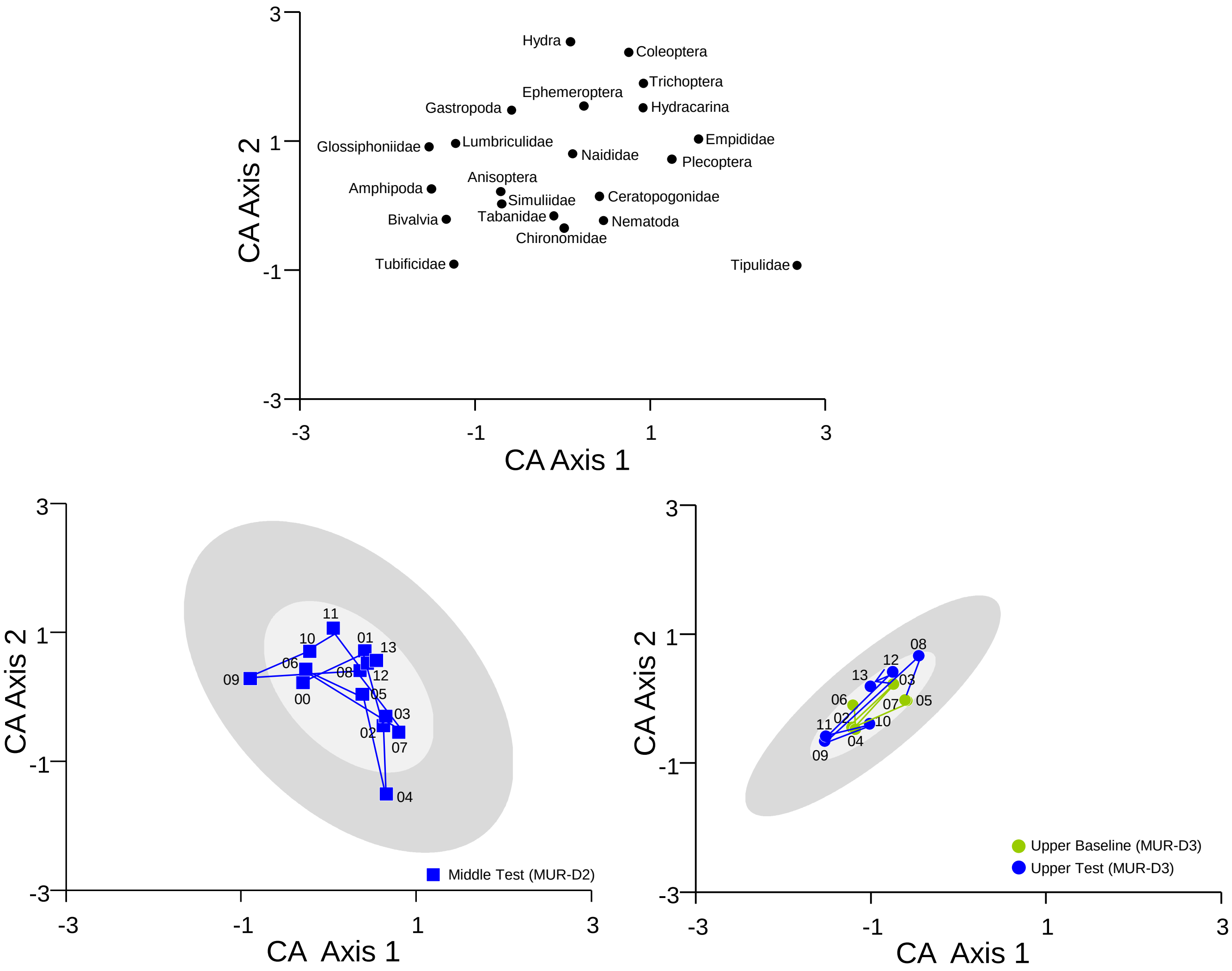
Figure 5.2-15 Variation in benthic invertebrate community measurement endpoints in the middle *test* reach of the Muskeg River (MUR-D2).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-D2 (2000 to 2012).

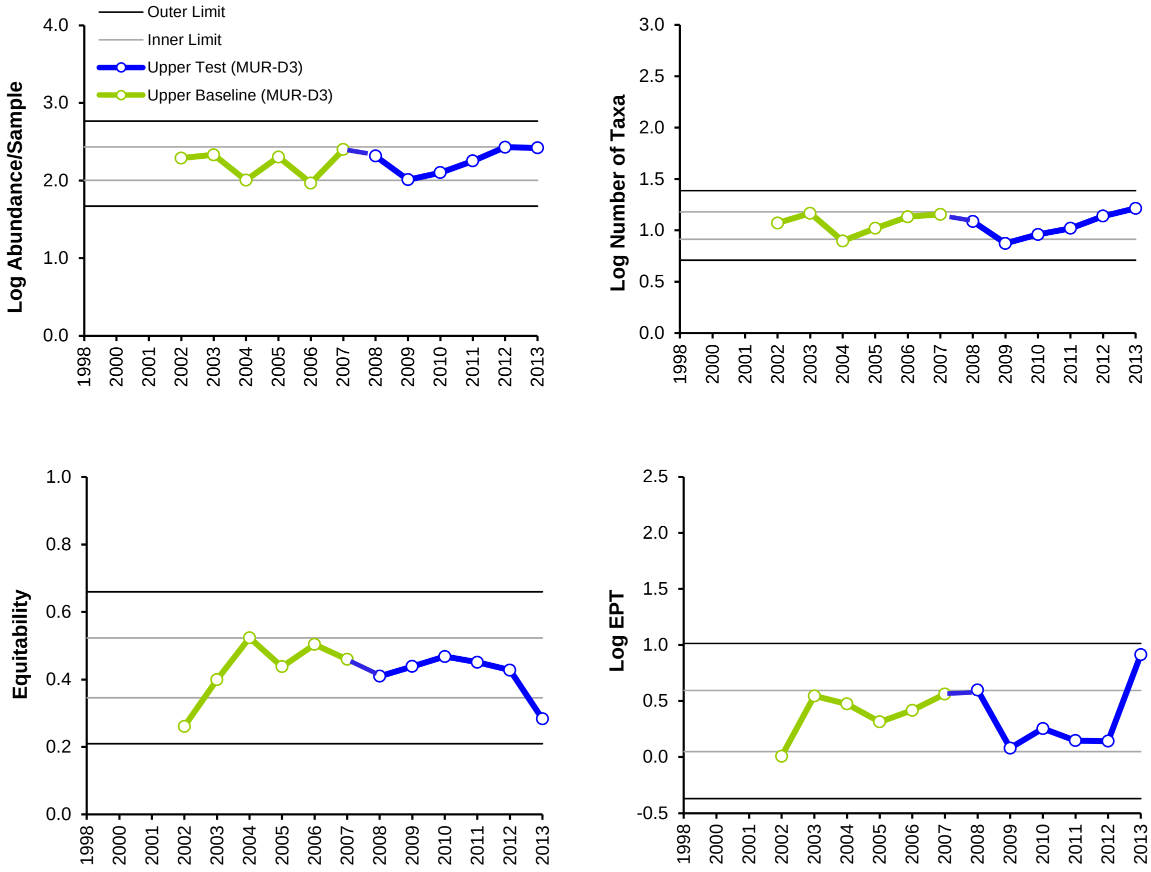
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-16 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the middle and upper reaches of the Muskeg River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at each reach.

Figure 5.2-17 Variation in benthic invertebrate community measurement endpoints at the upper *test* reach of the Muskeg River (MUR-D3).



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at MUR-D3 (2002 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.2-22 Average habitat characteristics of benthic invertebrate sampling locations in Jackpine Creek, fall 2013.

Variable	**Units**	**JAC-D1** **Lower *Test* Reach of Jackpine Creek**	**JAC-D2** **Upper *Baseline* Reach of Jackpine Creek**
Sample date	-	Sept 10, 2013	Sept 7, 2013
Habitat	-	Depositional	Depositional
Water depth	m	0.4	0.5
Current velocity	m/s	0.24	-
Field Water Quality			
Dissolved oxygen	mg/L	8.5	7.7
Conductivity	µS/cm	288	231
pH	pH units	7.9	8.1
Water temperature	°C	14.4	14.0
Sediment Composition			
Sand	%	96	96
Silt	%	3	2
Clay	%	1	2
Total Organic Carbon	%	0.80	0.27

Table 5.2-23 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in lower Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach JAC-D1		
	2002	2003 to 2012	2013
Hydra		0 to 1	
Nematoda	5	1 to 11	2
Naididae	<1	0 to 8	<1
Tubificidae	<1	<1 to 17	<1
Enchytraeidae	<1	0 to 18	<1
Lumbriculidae		<1	<1
Hirudinea		0 to <1	
Hydracarina	1	1 to 8	3
Amphipoda		0 to <1	
Gastropoda	<1	0 to 4	<1
Bivalvia	1	0 to 3	
Ceratopogonidae	2	0 to 16	<1
Chironomidae	88	38 to 86	65
Dolichopodidae		<1	
Diptera (misc.)	<1	<1 to 4	<1
Coleoptera		0 to <1	<1
Ephemeroptera	<1	0 to 7	<1
Odonata	<1	0 to <1	<1
Plecoptera		0 to 1	2
Trichoptera	<1	<1 to 3	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	619	79 to 2,053	467
Richness	15	7 to 31	21
Equitability	0.38	0.34 t 0.56	0.23
% EPT	<1	<1 to 3	4

Table 5.2-24 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in upper Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach JAC-D2		
	2003	2004 to 2012	2013
Hydra		0 to <1	
Nematoda	6	<1 to 5	1
Oligochaeta		<1	
Naididae	3	0 to 9	<1
Tubificidae	2	1 to 13	<1
Enchytraeidae	1	<1 to 5	<1
Lumbricidae		<1	
Lumbriculidae		<1	
Erpobdellidae		<1	
Hirudinea		0 to <1	
Hydracarina	<1	0 to 18	2
Amphipoda		<1	
Gastropoda		0 to 1	<1
Bivalvia	<1	0 to 13	
Ceratopogonidae	1	2 to 31	3
Chironomidae	67	3 to 69	82
Dolichopodidae		<1	
Diptera (misc.)	1	0 to 13	6
Coleoptera	6	1 to 7	2
Ephemeroptera	<1	1 to 19	1
Odonata		0 to <1	<1
Plecoptera	<1	0 to <1	<1
Trichoptera	<1	1 to 7	2
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	105	61 to 521	287
Richness	12	10 to 25	24
Equitability	0.59	0.42 to 0.61	0.28
% EPT	2	<1 to 21	3

Table 5.2-25 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints between *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.

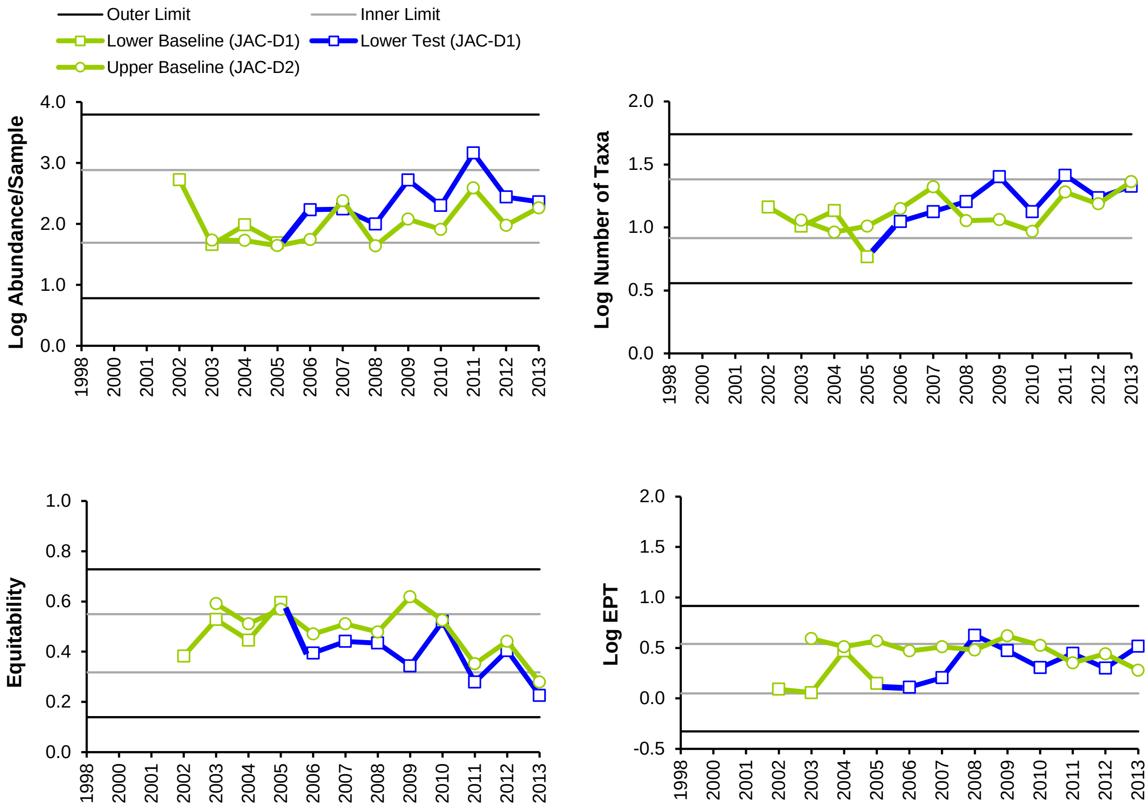
Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Differences Between *Baseline* and *Test* Reaches from Before to After Lower Reach Was Designated as *Test***	**Time Trend (*Test* Period)**	**Difference in Time Trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Test* Reach vs. *Baseline* Reach**	***Test* Period vs. *Baseline* Period**	**Differences Between *Baseline* and *Test* Reaches from Before to After Lower Reach Was Designated as *Test***	**Time Trend (*Test* Period)**	**Difference in Time Trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log of Abundance	**<0.001**	**<0.001**	0.047	**<0.001**	0.373	**0.022**	0.660	11	33	2	17	0	3	0	Higher at *test* reach; higher during *test* period; increasing over time in *test* period; higher in 2013 than the mean of all years at *baseline* reach.
Log of Richness	0.255	**<0.001**	0.105	**<0.001**	**0.014**	**0.009**	0.017	1	41	2	31	5	6	5	Higher in *test* period; increasing over time in *test* period and at a greater rate than *baseline* reach; higher in 2013 than mean of all years at *baseline* reach and mean of all previous years at *test* reach.
Equitability	**0.006**	**<0.001**	0.383	**<0.001**	0.792	0.100	0.641	10	28	1	32	0	23	15	Higher at *baseline* reach; higher in *baseline* period at *test* reach; decreasing over time at *test* reach.
Log of EPT	**<0.001**	**0.002**	0.656	0.128	0.106	0.937	0.094	12	9	0	2	2	0	3	Higher at *baseline* reach; higher in *test* period at *test* reach.
CA Axis 1	0.053	**<0.001**	**0.047**	0.118	0.017	0.981	0.364	4	29	4	2	6	0	1	Higher during *baseline* period; decreasing at a greater rate at *baseline* reach.
CA Axis 2	**0.013**	**<0.001**	0.360	0.119	0.159	0.330	**0.030**	4	33	1	2	1	1	3	Higher at *baseline* reach; higher during *test* period; higher in 2013 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 to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-18 Variations in benthic invertebrate community measurement endpoints in *test* reach JAC-D1 and *baseline* reach JAC-D2 of Jackpine Creek.

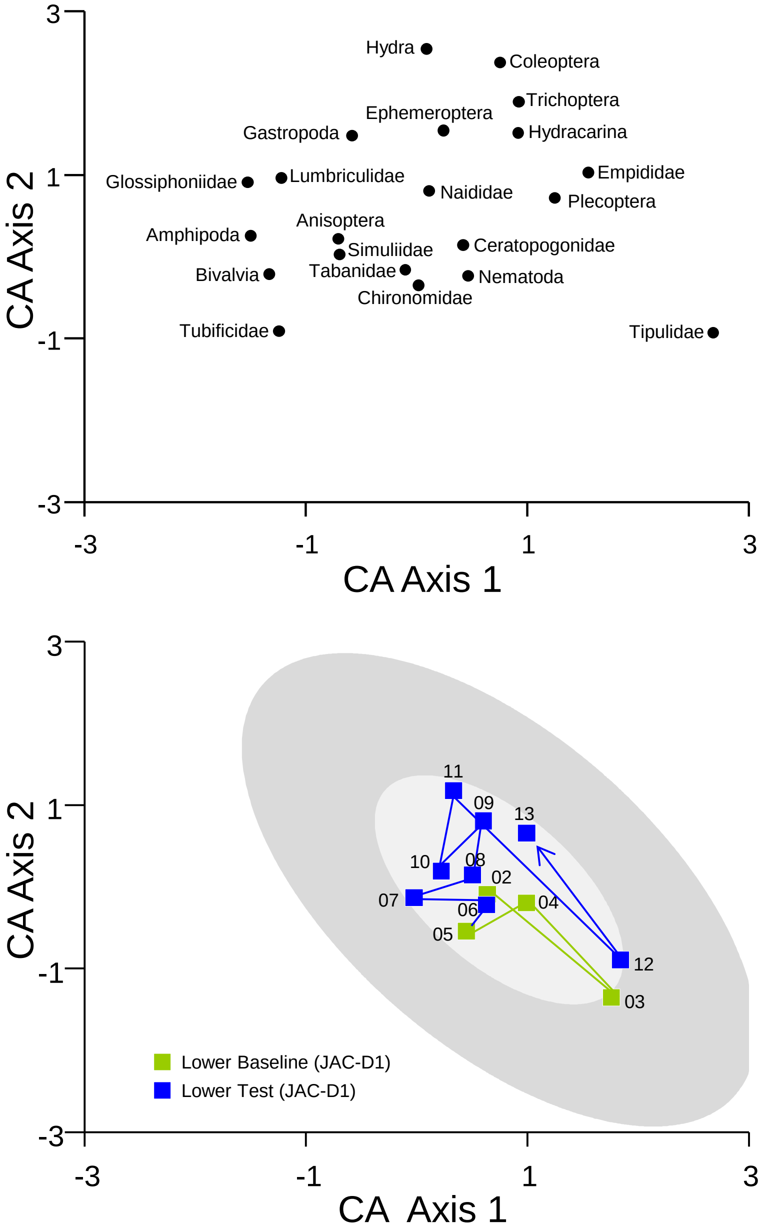


Note: *Test* reach JAC-D1 was designated as *baseline* from 2002 to 2005.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at JAC-D1 (2002 to 2012).

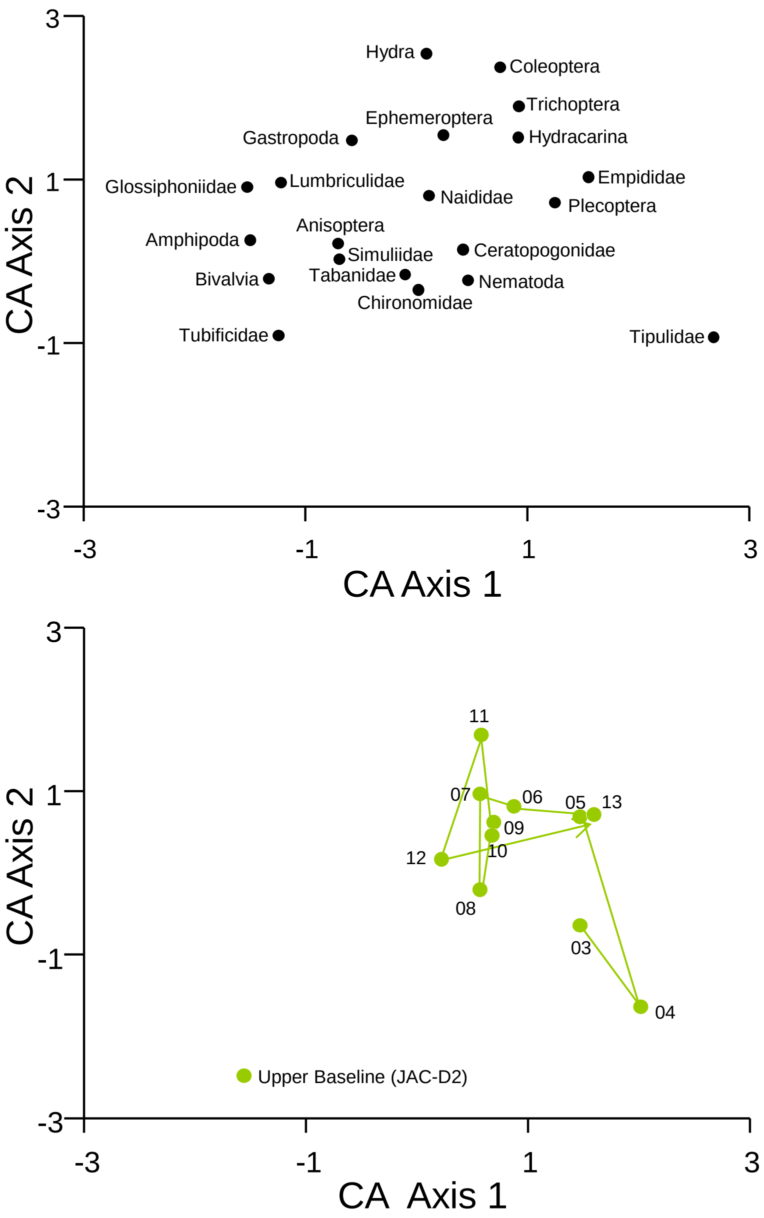
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-19 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Jackpine Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.2-20 **Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the upper reach of Jackpine Creek.**



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.2-26 Average habitat characteristics of benthic invertebrate community sampling locations in Kearl Lake, fall 2013.

Variable	Units	Kearl Lake
Sample date	-	Sept 7, 2013
Habitat	-	Depositional
Water depth	m	1.4
Field Water Quality		
Dissolved oxygen	mg/L	7.3
Conductivity	µS/cm	152
pH	pH units	7.9
Water temperature	°C	17.9
Sediment Composition		
Sand	%	9
Silt	%	80
Clay	%	11
Total Organic Carbon	%	37.5

Table 5.2-27 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Kearl Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Station KEL-1		
	2001	2002 to 2011	2013
Nematoda		0 to 5	2
Hirudinea	0 to <1	0 to <1	<1
Naididae		<1 to 20	6
Tubificidae		0 to 2	2
Emchytraeidae			<1
Lumbriculidae		0 to <1	
Hydracarina	<1	0 to 16	1
Amphipoda	13	2 to 58	21
Gastropoda	1	0 to 1	<1
Bivalvia	4	4 to 23	31
Ceratopogonidae		0 to 1	
Diptera (misc)	1	0 to <1	<1
Chironomidae	6	13 to 46	35
Ephemeroptera	<1	0 to 2	<1
Odonata		0 to <1	<1
Trichoptera	2	0 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean of replicate samples)	18	41 to 401	83
Richness	7	7 to 17	13
Equitability	0.92	0.29 to 0.77	0.53
% EPT	3	<1 to 2	0.4

Table 5.2-28 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Kearl Lake.

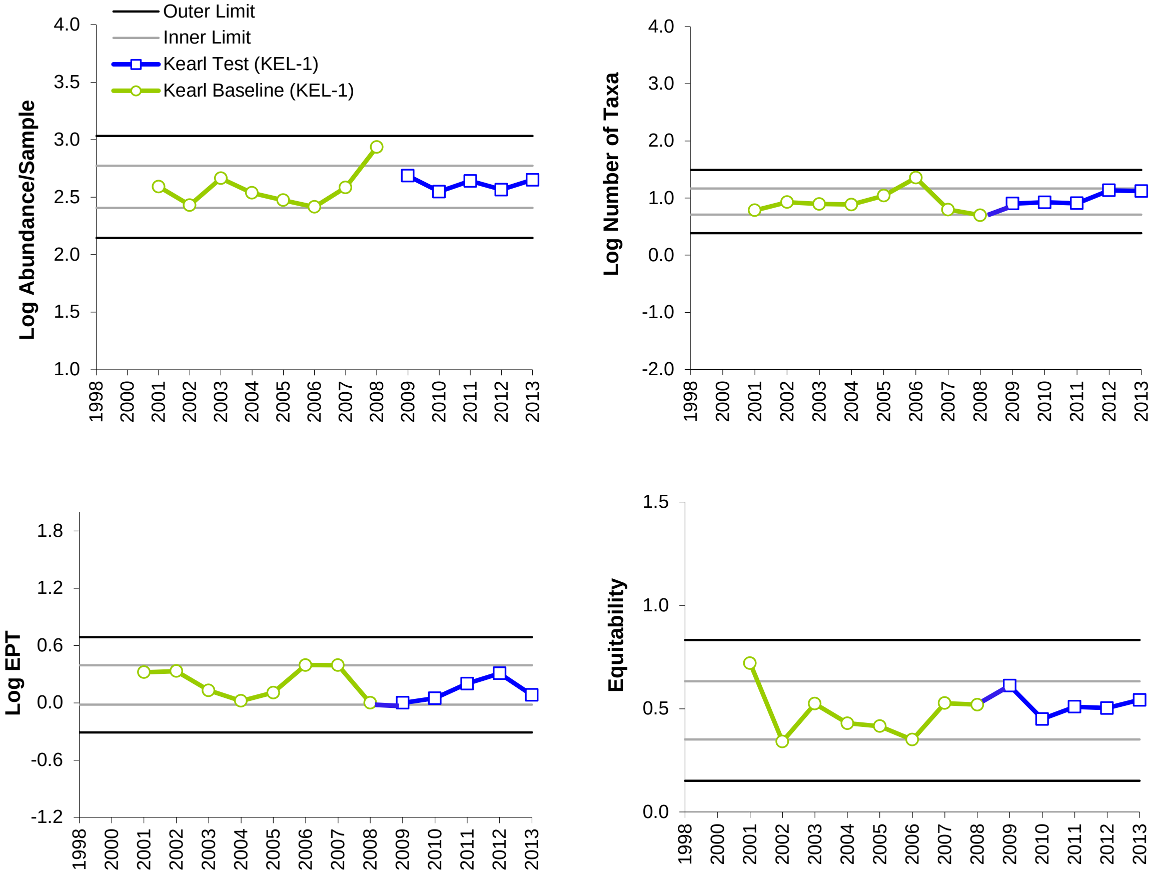
Variable	P-value				Variance Explained (%)				Nature of Change(s)
	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log Abundance	0.893	0.747	0.525	0.491	0	0	1	1	No change.
Log Richness	0.129	**0.005**	**0.015**	**0.017**	4	15	11	10	Increasing in *test* period; higher in 2013 than mean of *baseline* years and mean of all previous years.
Equitability	0.232	0.624	0.289	0.375	4	1	3	2	No change.
Log EPT	0.204	0.167	0.229	0.304	6	7	6	4	No change.
CA Axis 1	0.545	0.958	0.490	0.533	0	0	1	0	No change.
CA Axis 2	0.761	0.678	0.937	0.864	0	0	0	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 comparisons to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-21 Variations in benthic invertebrate community measurement endpoints in Kearl Lake (KEL-1).

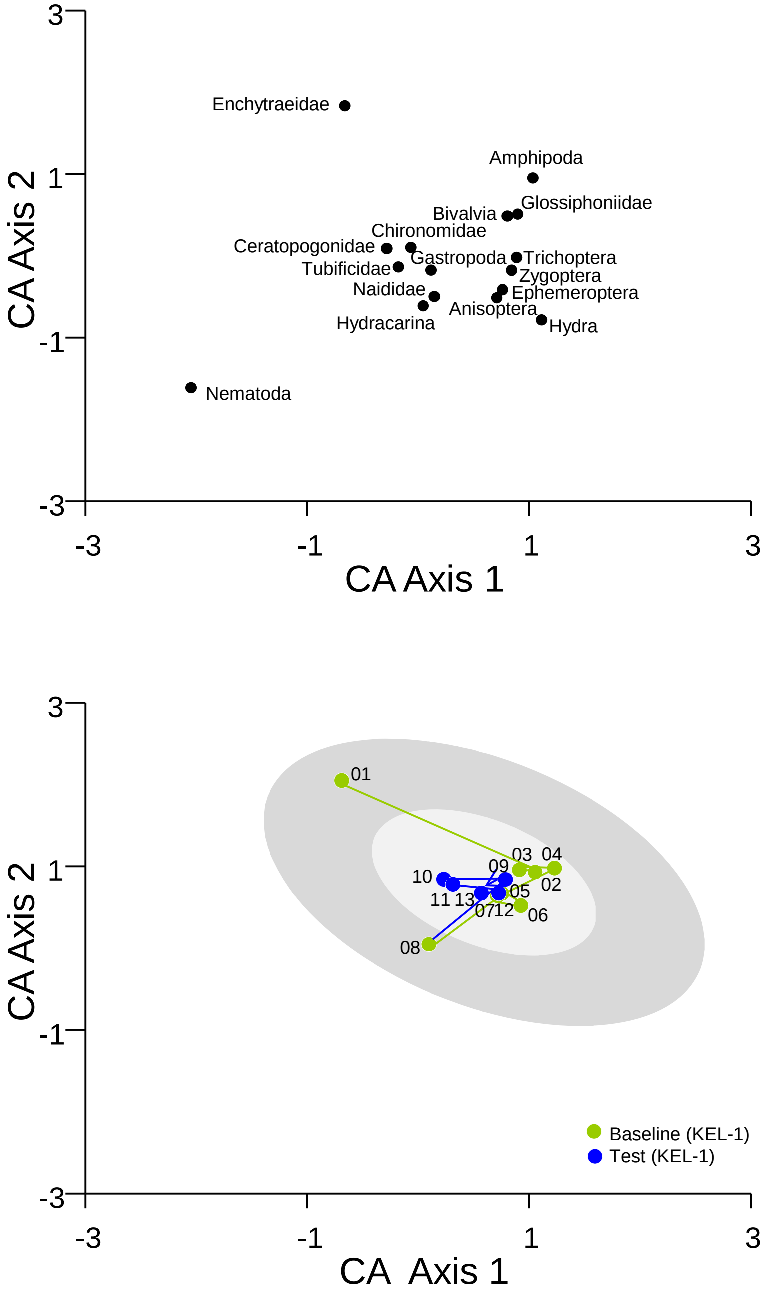


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2001 to 2012.

Note: Values have been adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-22 Ordination (Correspondence Analysis) of benthic invertebrate communities of RAMP lakes, showing Kearl Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.2-29 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D2), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**	**2001-2012 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1.0	9	1.0	6.1	12.0
Silt	%	-	<1.0	9	8.0	19.0	32.0
Sand	%	-	98.6	9	60.0	74.0	88.0
Total organic carbon	%	-	0.13	10	1.12	3.06	29.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	9	<5	68	**180**
Fraction 3 (C16-C34)	mg/kg	300[1]	50	9	110	**1080**	**2900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	43	9	62	1100	2100
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	11	0.0010	0.0023	0.0200
Retene	mg/kg	-	0.002	11	0.012	0.146	0.314
Total dibenzothiophenes	mg/kg	-	0.053	11	0.287	3.281	11.040
Total PAHs	mg/kg	-	0.404	11	0.904	14.270	30.440
Total Parent PAHs	mg/kg	-	0.014	11	0.029	0.313	0.676
Total Alkylated PAHs	mg/kg	-	0.389	11	0.875	13.863	29.764
Predicted PAH toxicity[3]	H.I.	1.0	1.00	11	0.73	**1.41**	**4.00**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	5.2	7	2.6	7.0	8.6
Chironomus growth - 10d	mg/organism	-	4.28	7	0.68	2.11	2.50
Hyalella survival - 14d	# surviving	-	10.0	7	8.0	8.0	9.2
Hyalella growth - 14d	mg/organism	-	0.37	7	0.11	0.25	0.35

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 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6.0	9	4.5	6.6	47.0
Silt	%	-	11.0	9	6.0	14.0	29.0
Sand	%	-	83.0	9	26.0	79.0	85.1
Total organic carbon	%	-	3.13	10	1.70	23.1	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<5	<80
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<5	<80
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	9	<5	47	130
Fraction 3 (C16-C34)	mg/kg	300[1]	67	9	52	**740**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	56	9	71	326	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0008	10	0.0030	0.0070	0.0145
Retene	mg/kg	-	0.295	10	0.016	0.374	2.330
Total dibenzothiophenes	mg/kg	-	0.042	10	0.048	0.128	0.190
Total PAHs	mg/kg	-	0.570	10	0.379	1.190	3.106
Total Parent PAHs	mg/kg	-	0.018	10	0.030	0.050	0.340
Total Alkylated PAHs	mg/kg	-	0.552	10	0.349	1.022	3.054
Predicted PAH toxicity[3]	H.I.	1.0	**1.22**	10	0.03	0.29	0.79
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.4	6	3.0	6.5	8.8
Chironomus growth - 10d	mg/organism	-	2.95	6	1.28	1.62	2.20
Hyalella survival - 14d	# surviving	-	8.2	6	7.0	8.2	9.2
Hyalella growth - 14d	mg/organism	-	0.21	6	0.11	0.24	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 5.2-31 Concentrations of selected sediment quality measurement endpoints in Jackpine Creek (*test* station JAC-D1), fall 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.1	9	0.7	4.0	18.7
Silt	%	-	0.6	9	0.3	11.0	19.9
Sand	%	-	99.3	9	74.5	84.0	99.0
Total organic carbon	%	-	0.36	9	0.20	1.10	3.57
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	8	13	20	71
Fraction 3 (C16-C34)	mg/kg	300[1]	115	8	101	**480**	**790**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	162	8	137	632	820
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0003	9	0.0003	0.0014	0.0030
Retene	mg/kg	-	0.020	8	0.007	0.031	0.951
Total dibenzothiophenes	mg/kg	-	0.452	9	0.105	0.444	1.639
Total PAHs	mg/kg	-	1.648	9	0.413	1.350	4.492
Total Parent PAHs	mg/kg	-	0.037	9	0.015	0.047	0.136
Total Alkylated PAHs	mg/kg	-	1.611	9	0.391	1.306	4.375
Predicted PAH toxicity[3]	H.I.	1.0	**1.60**	9	0.21	0.33	**1.33**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.8	7	5.6	7.8	9.6
Chironomus growth - 10d	mg/organism	-	2.50	7	1.15	2.43	3.40
Hyalella survival - 14d	# surviving	-	10.0	7	7.0	9.4	9.8
Hyalella growth - 14d	mg/organism	-	0.21	7	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 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1.0	6	1.0	7.4	13.0
Silt	%	-	<1.0	6	<1.0	17.5	23.1
Sand	%	-	<u>99.0</u>	6	66.0	74.1	98.0
Total organic carbon	%	-	0.40	7	0.10	1.40	2.06
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	7	<5	20	<27
Fraction 3 (C16-C34)	mg/kg	300[1]	20	7	10	58	190
Fraction 4 (C34-C50)	mg/kg	2,800[1]	20	7	<5	53	160
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0007	6	0.0005	0.0010	0.0041
Retene	mg/kg	-	0.003	6	0.001	0.015	0.033
Total dibenzothiophenes	mg/kg	-	0.006	6	0.002	0.010	0.016
Total PAHs	mg/kg	-	0.048	6	0.014	0.109	0.200
Total Parent PAHs	mg/kg	-	0.004	6	0.004	0.012	0.020
Total Alkylated PAHs	mg/kg	-	0.044	6	0.011	0.095	0.180
Predicted PAH toxicity[3]	H.I.	1.0	0.22	6	0.14	0.27	0.36
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.0	6	4.6	8.5	9.6
Chironomus growth - 10d	mg/organism	-	<u>4.17</u>	6	0.80	2.19	3.05
Hyalella survival - 14d	# surviving	-	9.4	6	8.0	9.0	9.8
Hyalella growth - 14d	mg/organism	-	0.27	6	0.25	0.32	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 2013.

Variables	**Units**	**Guideline**	**September 2013**	**2001-2012 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	10.3	7	1.0	14.2	58.0
Silt	%	-	66.6	7	4.0	33.0	69.9
Sand	%	-	23.0	7	9.0	53.0	93.0
Total organic carbon	%	-	35.0	9	5.04	33.5	38.1
Total hydrocarbons							
BTEX	mg/kg	-	<1000	8	<5	<45	<220
Fraction 1 (C6-C10)	mg/kg	30[1]	<1000	8	<5	<45	<220
Fraction 2 (C10-C16)	mg/kg	150[1]	<146	8	<5	122	**530**
Fraction 3 (C16-C34)	mg/kg	300[1]	**387**	8	230	**601**	**3,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	192	8	81	388	2,500
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0141	5	0.0083	0.0194	**0.0361**
Retene	mg/kg	-	0.041	9	0.016	0.049	0.113
Total dibenzothiophenes	mg/kg	-	<u>0.087</u>	9	0.028	0.044	0.084
Total PAHs	mg/kg	-	0.756	9	0.723	0.917	1.460
Total Parent PAHs	mg/kg	-	0.117	9	0.078	0.125	0.345
Total Alkylated PAHs	mg/kg	-	0.639	9	0.634	0.724	1.344
Predicted PAH toxicity[3]	H.I.	1.0	0.29	9	0.03	0.24	0.92
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>7.0</u>	5	8.4	8.8	9.0
Chironomus growth - 10d	mg/organism	-	<u>2.33</u>	5	1.16	1.29	1.50
Hyalella survival - 14d	# surviving	-	9.2	5	7.6	9.0	9.6
Hyalella growth - 14d	mg/organism	-	0.25	5	0.12	0.22	0.31

Values in **bold** indicate concentrations exceeding guidelines.

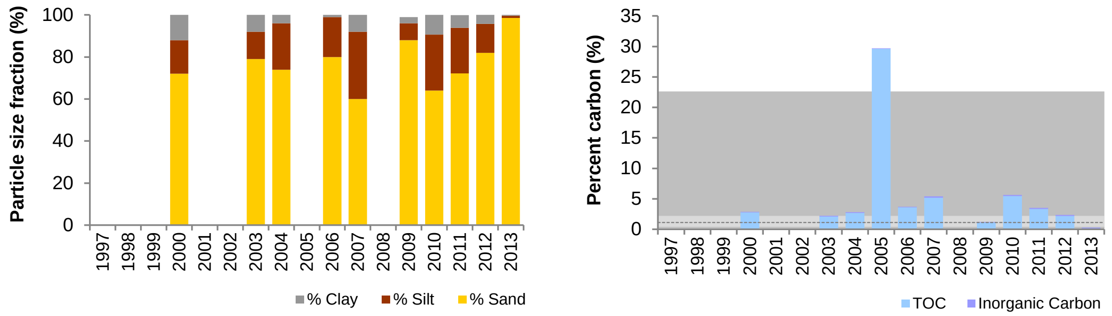
Values <u>underlined</u> indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

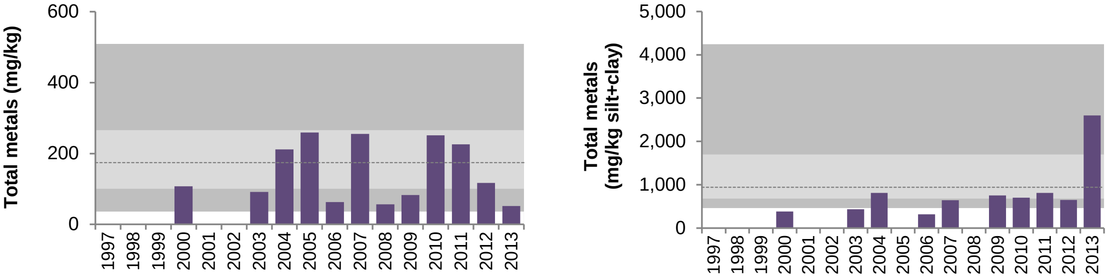
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

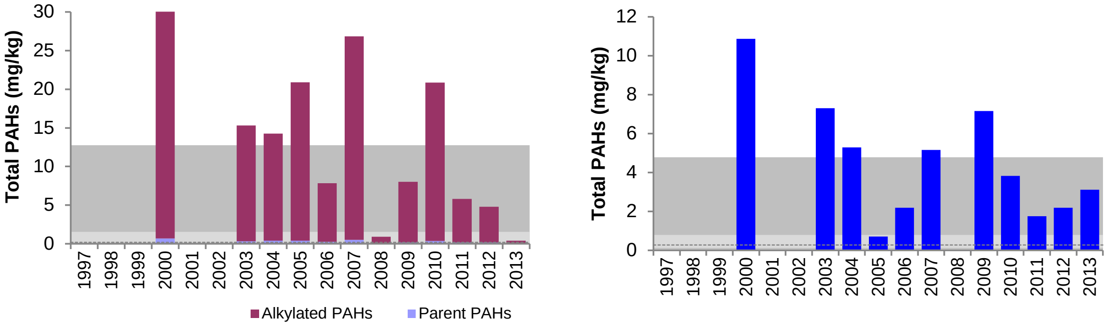
Figure 5.2-23 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D2.


Particle size distribution

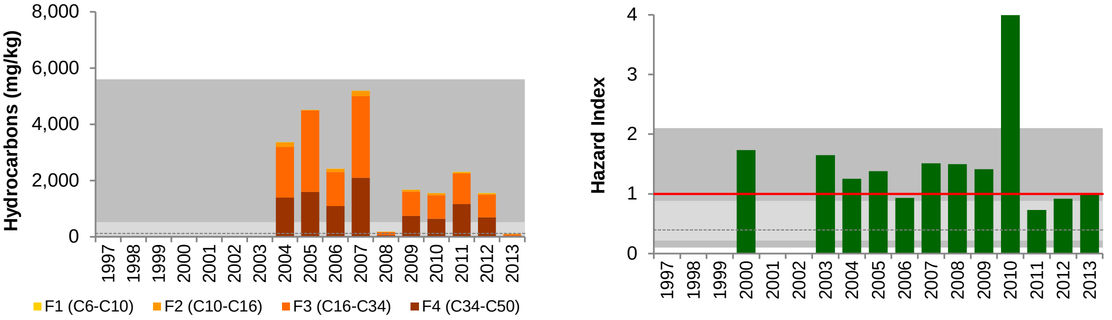
Carbon Content[1]


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 (1997-2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

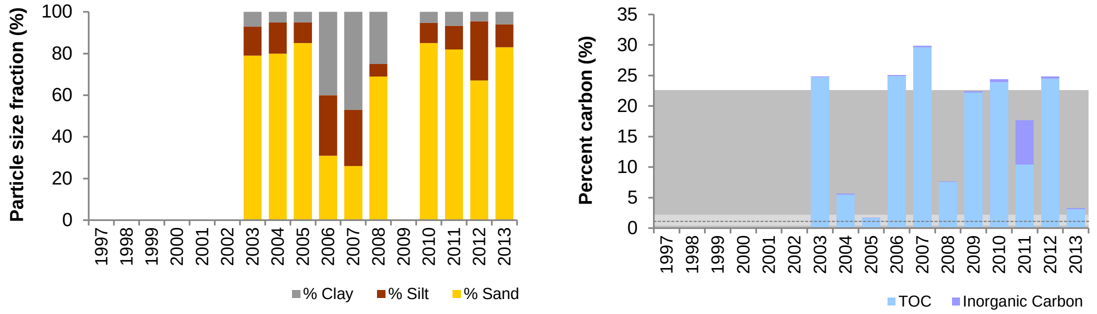
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-24 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D3.

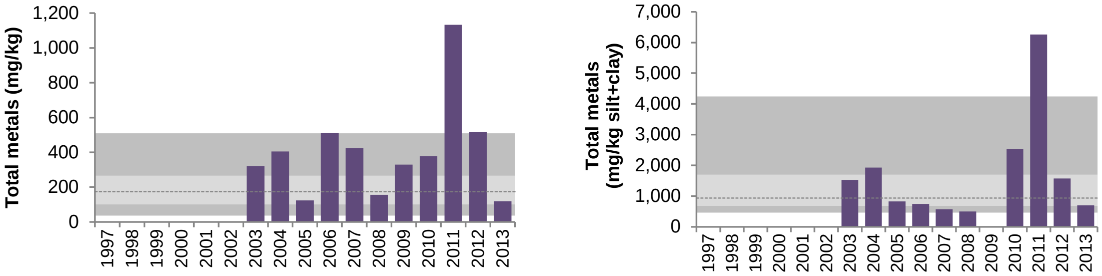
Particle size distribution

Carbon Content[1]



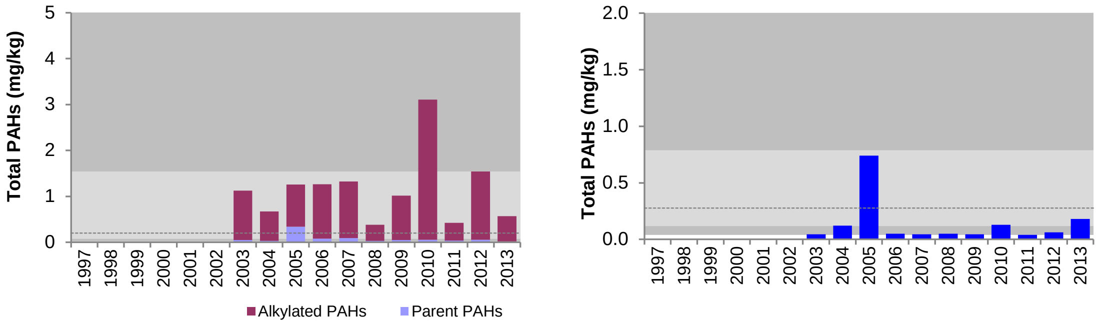
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



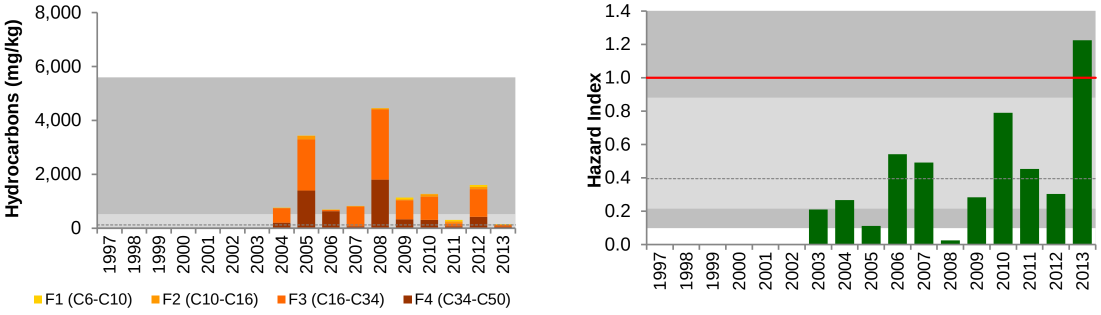
Total PAHs

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 (1997-2013).

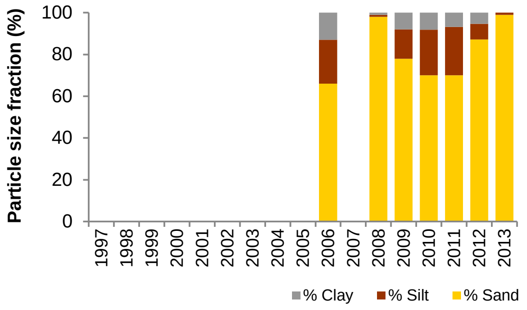
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

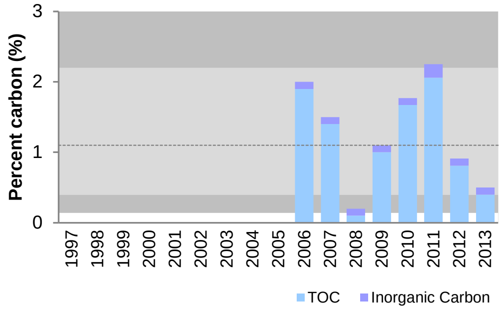
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-25 Variation in sediment quality measurement endpoints in Jackpine Creek, *baseline* station JAC-D2.

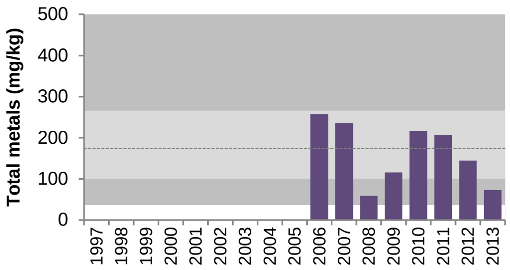
Particle size distribution



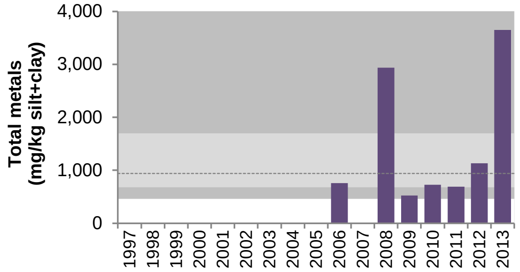
Carbon Content[1]



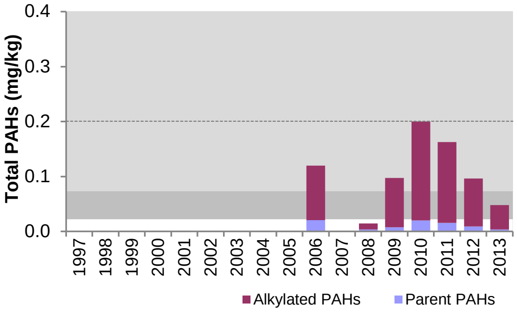
Total Metals[2]



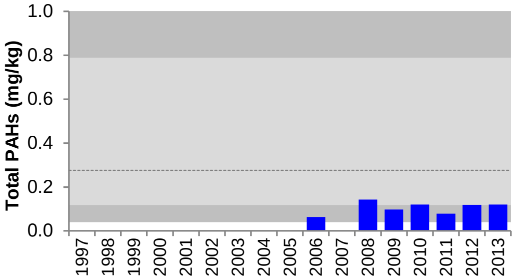
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



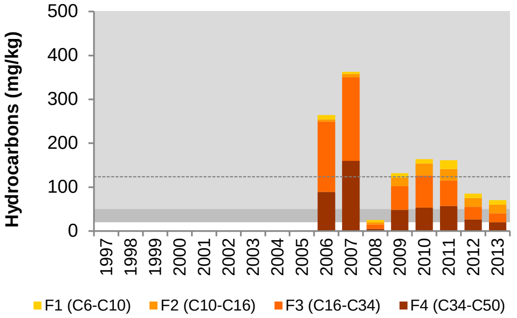
Total PAHs



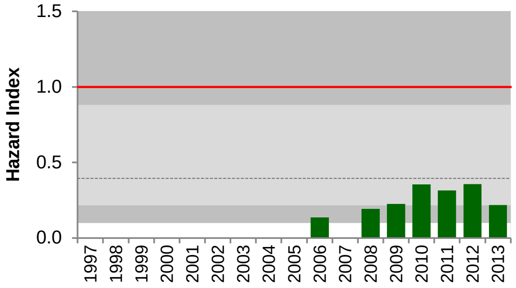
Total PAHs normalized to 1% TOC



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 (1997-2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

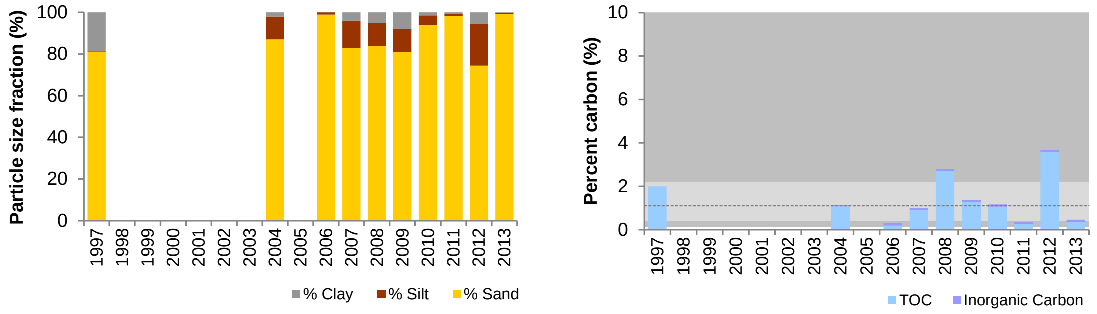
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.2-26 Variation in sediment quality measurement endpoints in Jackpine Creek, *test* station JAC-D1.

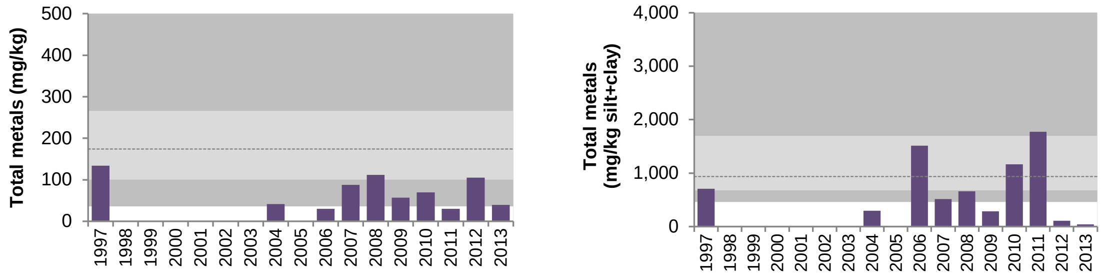
Particle size distribution

Carbon Content[1]



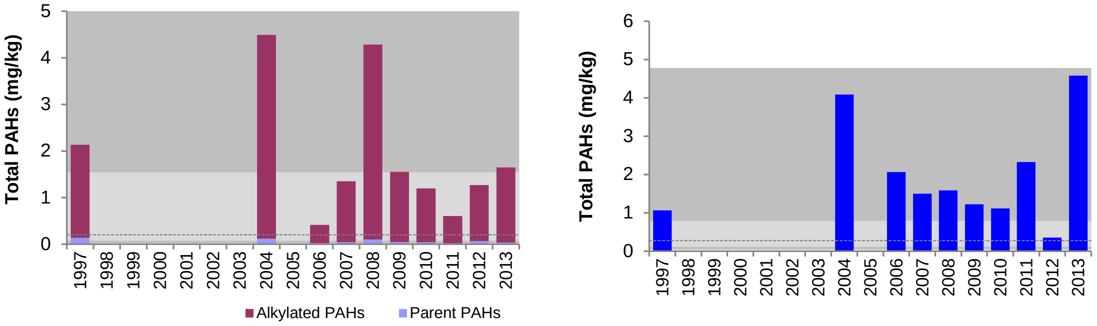
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



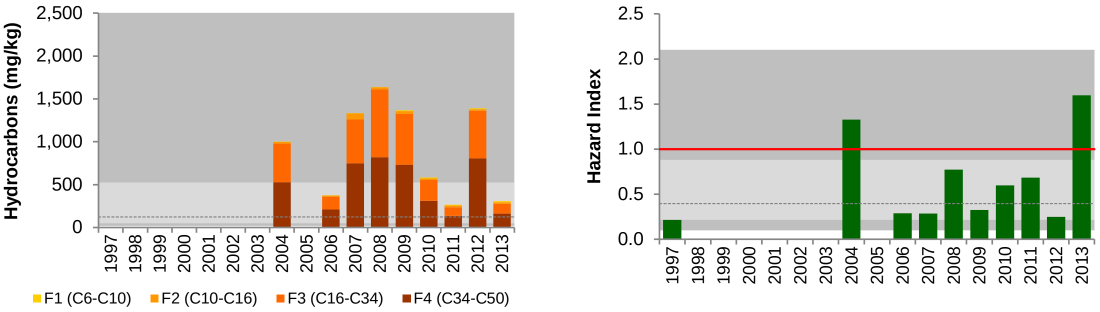
Total PAHs

Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]

PAH Hazard Index[3]



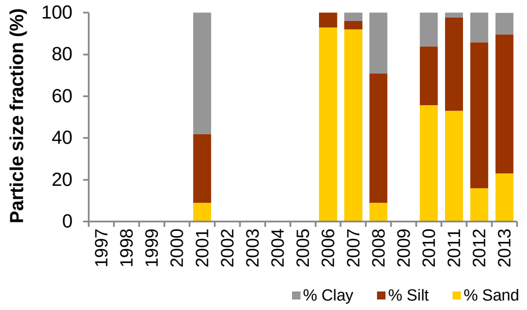
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2013).

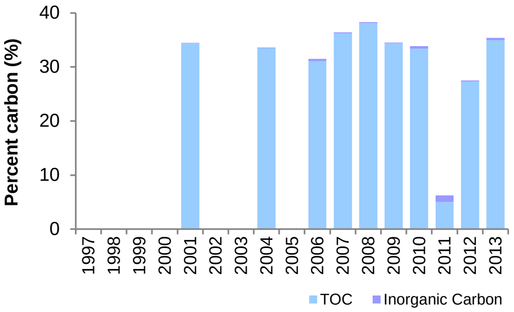
[1] Regional *baseline* values represent "total" values for multi-variable data.

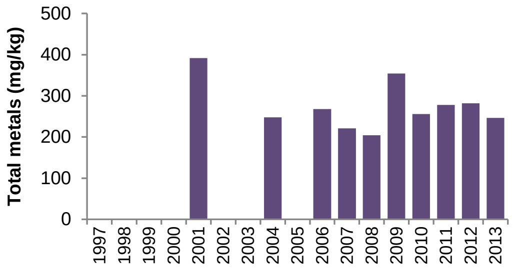
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

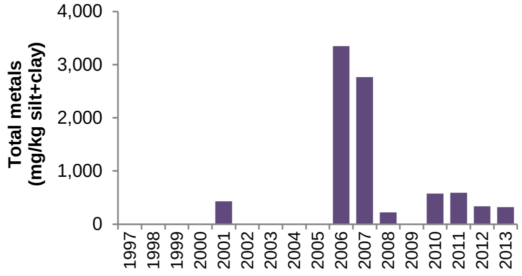
[3] Red line indicates potential chronic effects level (HI = 1.0).

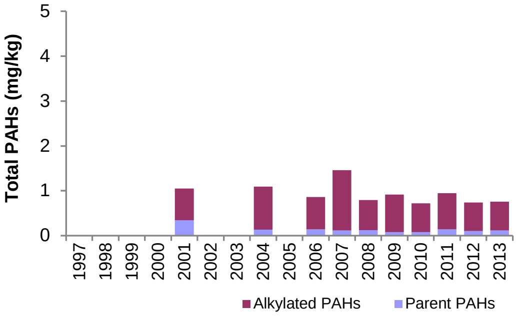
Figure 5.2-27 Variation in sediment quality measurement endpoints in Kearl Lake, *test* station KEL-1.

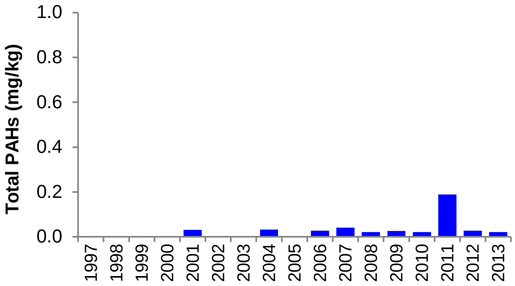

Particle size distribution

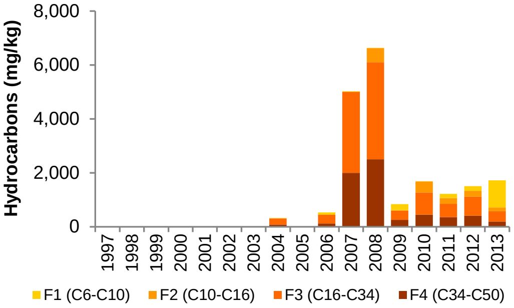

Carbon Content

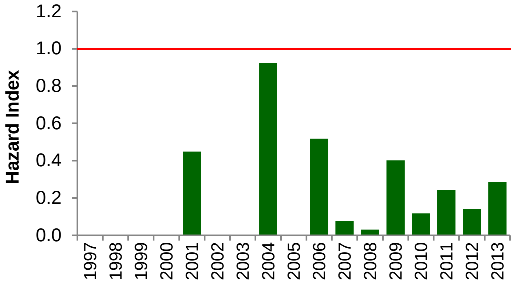

Total Metals[1]


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]

[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 2013) for Muskeg River watershed stations.

Station Identifier	Location	2013 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*	97.9	Negligible-Low
MUR-D3	upper Muskeg River	*test*	100.0	Negligible-Low

Table 5.2-35 Average habitat characteristics of fish assemblage monitoring locations of the Muskeg River.

Variable	Units	MUR-F1 Lower *Test* Reach of the Muskeg River	MUR-F2 Middle *Test* Reach of the Muskeg River	MUR-F3 Upper *Test* Reach of the Muskeg River
Sample date		Sept 14, 2013	Sept 8, 2013	Sept 13, 2013
Habitat type	-	run/riffle	run	run
Maximum depth	m	0.71	1.24	1.07
Mean depth	m	0.61	1.12	0.94
Bankfull channel width	m	26.6	16.8	9.6
Wetted channel width	m	16.1	13.1	8.8
Substrate				
Dominant	-	gravel	sand	fines
Subdominant	-	cobble	-	sand
Instream cover				
Dominant	-	boulders, filamentous algae	filamentous algae, macrophytes, small woody debris, overhanging vegetation	small woody debris
Subdominant	-	small woody debris	live trees and roots, undercut banks	overhanging vegetation, undercut banks
Field water quality				
Dissolved oxygen	mg/L	9.2	5.2	5.4
Conductivity	µS/cm	325	331	376
pH	pH units	8.38	8.11	7.76
Water temperature	^{0}C	12.2	17.9	13.4
Water velocity*				
Left bank velocity	m/s	0.36	0.09	-
Left bank water depth	m	0.52	1.26	0.79
Centre of channel velocity	m/s	0.27	0.12	-
Centre of channel water depth	m	0.92	1.00	1.07
Right bank velocity	m/s	0.04	0.06	-
Right bank water depth	m	0.40	1.30	0.95
Riparian cover - understory (<5 m)				
Dominant	-	woody shrubs and samplings	woody shrubs and samplings	woody shrubs and samplings
Subdominant	-	-	overhanging vegetation	overhanging vegetation

* Velocity measurements were not collected at reach MUR-F3 due to equipment failure.

Table 5.2-36 Total number and percent composition of fish species captured in reaches of the Muskeg River, 2009 to 2013.

Common Name	Code	Total Species											Percent of Total Catch										
		Test Reach MUR-F1					*Test* Reach MUR-F2			*Test* Reach MUR-F3			*Test* Reach MUR-F1					*Test* Reach MUR-F2			*Test* Reach MUR-F3		
		2009	**2010**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**
brook stickleback	BRST	3	5	1	-	-	-	-	-	33	1	-	5.2	5.4	1.4	0	0	0	0	0	84.6	100	0
burbot	BURB	1	-	-	-	8	-	-	-	-	-	-	1.7	0	0	0	29.6	0	0	0	0	0	0
finescale dace	FNDC	-	15	-	-	-	-	-	-	-	-	-	0	16.1	0	0	0	0	0	0	0	0	0
lake chub	LKCH	4	8	1	-	2	-	-	2	-	-	-	6.9	8.6	1.4	0	7.4	0	0	20.0	0	0	0
longnose dace	LNDC	-	10	7	1	-	-	-	-	-	-	-	0	10.8	9.9	16.7	0	0	0	0.0	0	0	0
longnose sucker	LNSC	5	4	49	-	3	-	-	1	-	-	-	8.6	4.3	69.0	0	11.1	0	0	10.0	0	0	0
northern pike	NRPK	-	-	-	1	1	2	-	1	-	-	-	0	0	0	16.7	3.7	66.7	0	10.0	0	0	0
pearl dace	PRDC	-	35	2	-	-	-	-	2	2	-	-	0	37.6	2.8	0	0	0	0	20.0	5.1	0	0
slimy sculpin	SLSC	43	11	5	1	7	-	-	-	-	-	-	74.1	11.8	7.0	16.7	25.9	0	0	0.0	0	0	0
spoonhead sculpin	SPSC	1	3	-	1	1	-	-	-	-	-	-	1.7	3.2	0	16.7	3.7	0	0	0.0	0	0	0
walleye	WALL	-	-	1	-	-	-	-	-	-	-	-	0	0	1.4	0	0	0	0	0.0	0	0	0
white sucker	WHSC	-	2	5	-	3	1	-	4	-	-	1	0	2.2	7.0	0	11.1	33.3	0	40.0	0	0	100
yellow perch	YLPR	-	-	-	2	2	-	-	-	-	-	-	0	0.0	0	33.3	7.4	0	0	0.0	0	0	0
sucker sp. *		1	-	-	-	-	-	-	-	-	-	-	1.7	0	0	0	0	0	0	0.0	0	0	0
unknown sp. *		-	-	-	-	-	-	-	-	4	-	-	0	0	0	0	0	0	0	0.0	10.3	0	0
Total Count		**58**	**93**	**71**	**6**	**27**	**3**	**0**	**10**	**39**	**1**	**1**	**100**	**100**	**100**	**100**	**100**	**100**	**-**	**100**	**100**	**100**	**100**
Total Species Richness		**7**	**9**	**8**	**5**	**8**	**2**	**0**	**5**	**3**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**2,051**	**4,623**	**1,267**	**1,526**	**2,274**	**1,178**	**1,841**	**1,853**	**1,297**	**1,763**	**1,551**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* Unknown species not included in the calculation of species richness.

Table 5.2-37 Summary of fish assemblage measurement endpoints in reaches of the Muskeg River and Jackpine Creek, 2009 to 2013.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MUR-F1	2009	0.15	-	7	-	-	0.43	-	3.65	-	2.78	-
	2010	0.19	0.08	9	4	2.38	0.64	0.29	6.10	0.51	3.90	2.01
	2011	0.28	0.09	8	4	1.10	0.47	0.13	5.15	0.39	5.64	1.87
	2012	0.03	0.02	5	1	0.84	0.20	0.27	6.05	2.13	0.40	0.27
	2013	0.05	0.04	8	3	2.07	0.53	0.32	5.07	1.89	1.19	0.97
MUR-F2	2011	0.01	0.02	2	1	0.89	0.10	0.22	7.75	0.07	0.23	0.35
	2012	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2013	0.01	0.01	5	2	1.23	0.54	0.31	6.90	1.14	0.54	0.31
MUR-F3	2011	0.16	0.10	3	1	0.55	0.14	0.22	9.06	0.59	3.00	1.84
	2012	0.004	0.01	1	0	0.45	0.00	0.00	9.40	0.00	0.06	0.14
	2013	0.004	0.01	1	0	0.45	0.00	0.00	7.60	-	0.06	0.14
JAC-F1	2009	0.02	-	3	-	-	0.57	-	6.41	-	0.32	-
	2010	0.65	0.59	8	4	2.38	0.53	0.29	7.72	0.51	4.31	4.01
	2011	1.03	1.04	6	3	0.84	0.20	0.20	5.74	0.35	17.15	21.14
	2012	0.01	0.01	1	0	0.55	0.00	0.00	3.00	0.00	0.13	0.17
	2013	0.05	0.02	2	1	0.55	0.18	0.24	3.24	0.36	0.76	0.34
JAC-F2	2009	0.42	-	4	-	-	0.48	-	6.56	-	4.36	-
	2010	0.10	-	5	-	-	0.69	-	7.85	-	4.51	-
	2011	0.69	0.62	4	3	0.84	0.50	0.16	8.18	0.61	10.43	10.88
	2012	0.02	0.02	2	1	0.55	0.00	0.00	6.80	2.25	0.30	0.33
	2013	0.12	0.10	3	2	0.84	0.19	0.21	8.26	1.73	2.25	1.73

* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

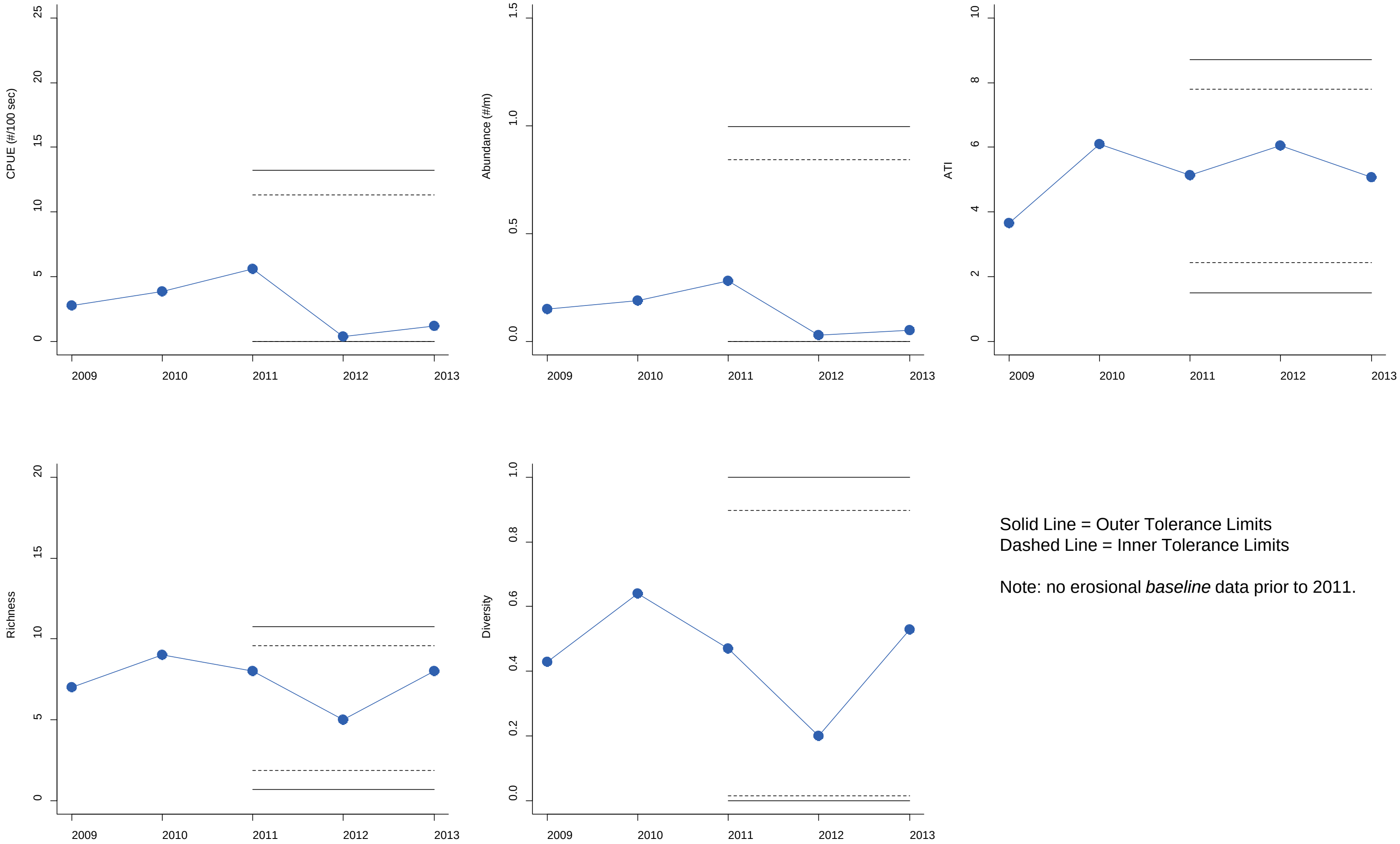
Table 5.2-38 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in the lower Muskeg River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**0.003**	32.4	Decreasing over time.
Richness	0.079	12.8	No change.
Diversity	0.098	11.4	No change.
ATI	0.230	6.4	No change.
CPUE (No./100 sec)	**0.003**	32.0	Decreasing over time.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Figure 5.2-28 Variation in fish assemblage measurement endpoints at the lower erosional reach (MUR-F1) of the Muskeg River from 2009 to 2013 relative to regional *baseline* conditions.

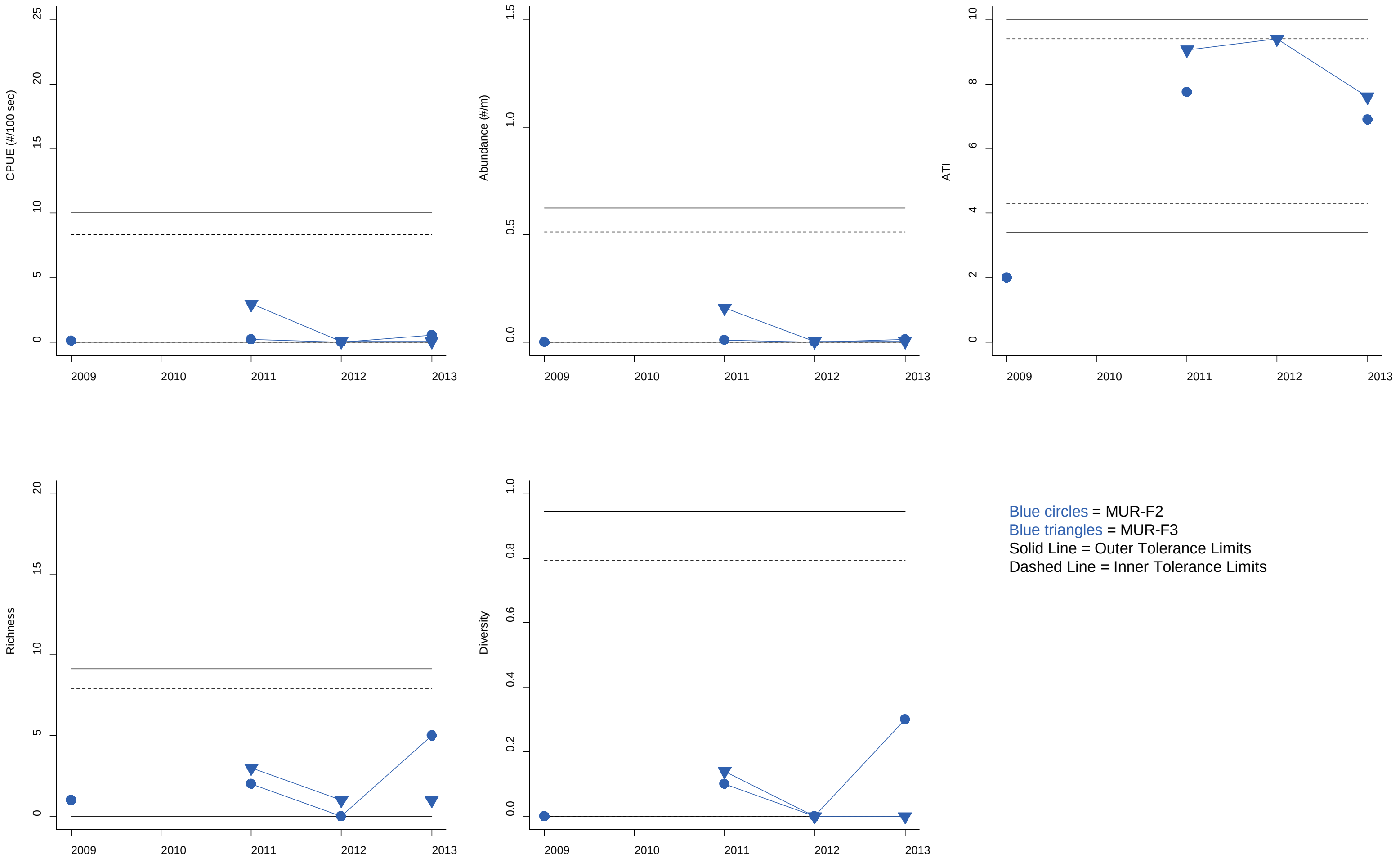


Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

Note: no erosional *baseline* data prior to 2011.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using all regional *baseline* erosional data.

Figure 5.2-29 Variation in fish assemblage measurement endpoints at depositional reaches (MUR-F2 and MUR-F3) in the Muskeg River from 2009 to 2013 relative to regional *baseline* conditions.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using all regional *baseline* depositional data.

Table 5.2-39 Average habitat characteristics of fish assemblage monitoring locations of Jackpine Creek in 2013.

Variable	**Units**	**JAC-F1 Lower *Test* Reach of Jackpine Creek**	**JAC-F2 Upper *Baseline* Reach of Jackpine Creek**
Sample date	-	Sept 8, 2013	Sept 13, 2013
Habitat type	-	run	run
Maximum depth	m	0.75	0.80
Mean depth	m	0.49	0.58
Bankfull channel width	m	9.9	5.5
Wetted channel width	m	8.6	3.6
Substrate			
Dominant	-	sand	sand
Subdominant	-	-	coarse gravel
Instream cover			
Dominant	-	overhanging vegetation, small woody debris	small woody debris
Subdominant	-	live trees and roots, undercut banks	overhanging vegetation
Field water quality			
Dissolved oxygen	mg/L	8.0	8.6
Conductivity	µS/cm	260	250
pH	pH units	8.20	8.16
Water temperature	^{0}C	14.1	12.3
Water velocity			
Left bank velocity	m/s	0.04	0.03
Left bank water depth	m	0.34	0.57
Centre of channel velocity	m/s	0.15	0.06
Centre of channel water depth	m	0.54	0.61
Right bank velocity	m/s	0.10	0.05
Right bank water depth	m	0.59	0.55
Riparian cover - understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.2-40 Total number and percent composition of fish species captured in reaches of Jackpine Creek, 2009 to 2013.

Common Name	Code	Total Species										Percent of Total Catch									
		Test Reach JAC-F1					*Baseline* Reach JAC-F2					*Test* Reach JAC-F1					*Baseline* Reach JAC-F2				
		2009	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**
brook stickleback	BRST	-	19	2	-	-	14	29	36	1	16	0	11.4	1.3	0	0	23.7	47.5	35.0	25.0	44.4
finescale dace	FNDC	-	75	-	-	-	-	12	-	-	-	0	44.9	0	0	0	0	19.7	0	0	0
lake chub	LKCH	1	-	138	-	-	40	10	-	3	18	14.3	0	89.6	0	0	67.8	16.4	0	75.0	50.0
longnose sucker	LNSC	2	3	5	-	2	-	-	-	-	-	28.6	1.8	3.2	0	16.7	0	0	0	0	0
northern pike	NRPK	-	1	-	-	-	-	-	-	-	-	0	0.6	0	0	0	0	0	0	0	0
northern redbelly dace	NRDC	-	-	-	-	-	-	-	2	-	-	0	0	0	0	0	0	0	1.9	0	0
pearl dace	PRDC	-	21	-	-	-	3	9	50	-	-	0	12.6	0	0	0	5.1	14.8	48.5	0	0
slimy sculpin	SLSC	-	23	2	2	10	-	-	-	-	-	0	13.8	1.3	100.0	83.3	0	0	0	0	0
trout-perch	TRPR	-	9	5	-	-	-	-	-	-	-	0	5.4	3.2	0	0	0	0	0	0	0
white sucker	WHSC	4	16	2	-	-	2	1	15	-	2	57.1	9.6	1.3	0	0	3.4	1.6	14.6	0	5.6
Total Count		**7**	**167**	**154**	**2**	**12**	**59**	**61**	**103**	**4**	**36**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**3**	**8**	**6**	**1**	**2**	**4**	**5**	**4**	**2**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**2,221**	**3,863**	**1,052**	**1,590**	**1,564**	**1,352**	**4,183**	**973**	**1,316**	**1,564**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

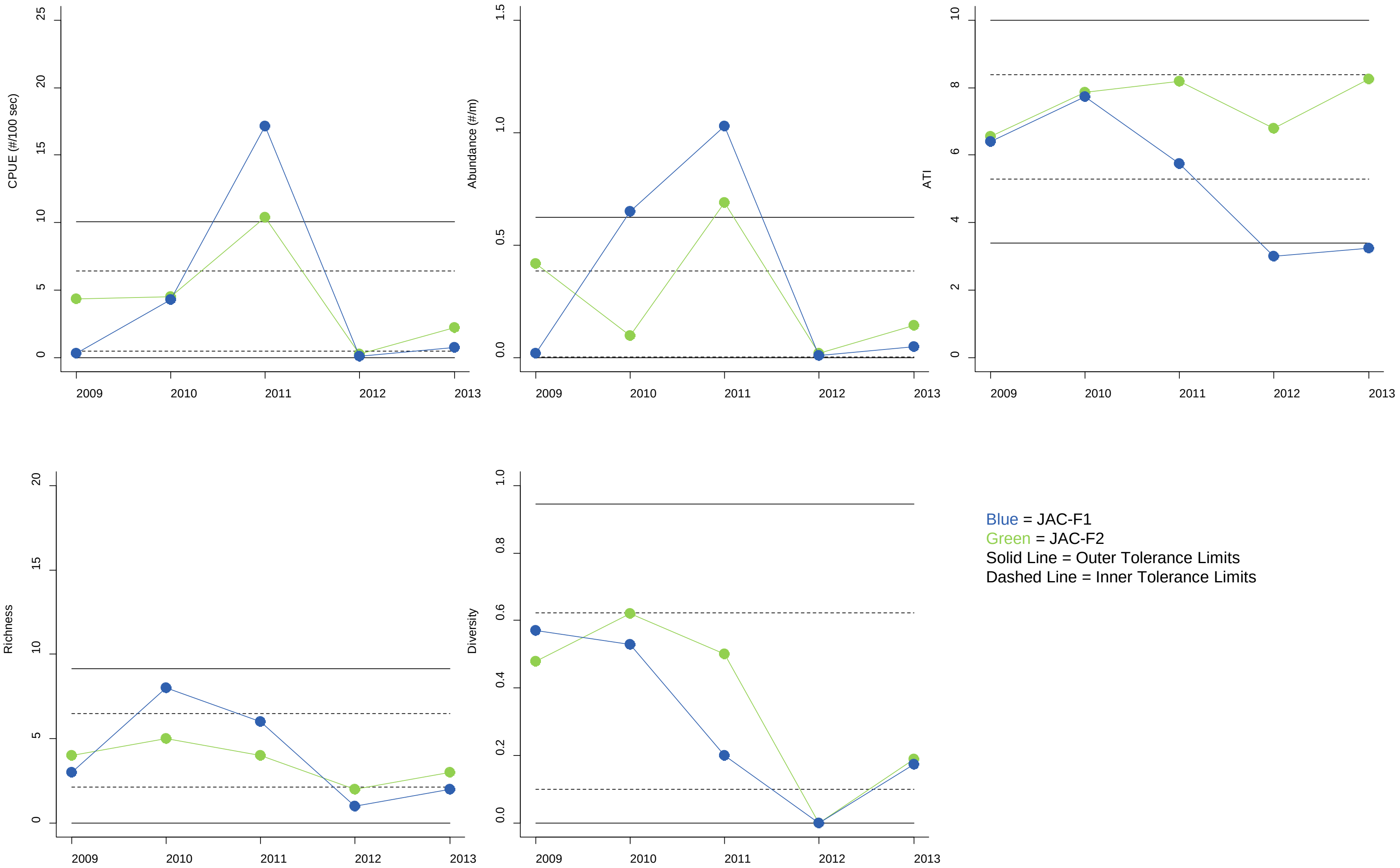
Table 5.2-41 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in Jackpine Creek.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*test* reach)	***Baseline*** **Reach vs.** ***Test*** **Reach**	Time Trend (*test* reach)	***Baseline*** **Reach vs.** ***Test*** **Reach**	
Abundance	**0.013**	0.593	23.7	1.0	Decreasing over time.
Richness	**0.003**	0.737	32.3	1.0	Decreasing over time.
Diversity	**0.003**	0.158	32.5	7.0	Decreasing over time.
ATI	**<0.001**	0.221	89.9	6.0	Decreasing over time.
CPUE (No./100 sec)	**0.040**	0.425	16.9	2.0	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Figure 5.2-30 Variation in fish assemblage measurement endpoints at depositional reaches (JAC-F1 and JAC-F2) of Jackpine Creek from 2009 to 2013 relative to regional *baseline* conditions.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using all regional *baseline* depositional data.

5.3 STEEPBANK RIVER WATERSHED

Table 5.3-1 Summary of results for the Steepbank River watershed.

Steepbank River Watershed	**Summary of 2013 Conditions**			
	Steepbank River			***North Steepbank River***
Climate and Hydrology				
Criteria	**07DA006** 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	**STR-F1** lower reach	no reach sampled	**STR-F2** upper reach	no reach sampled
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.

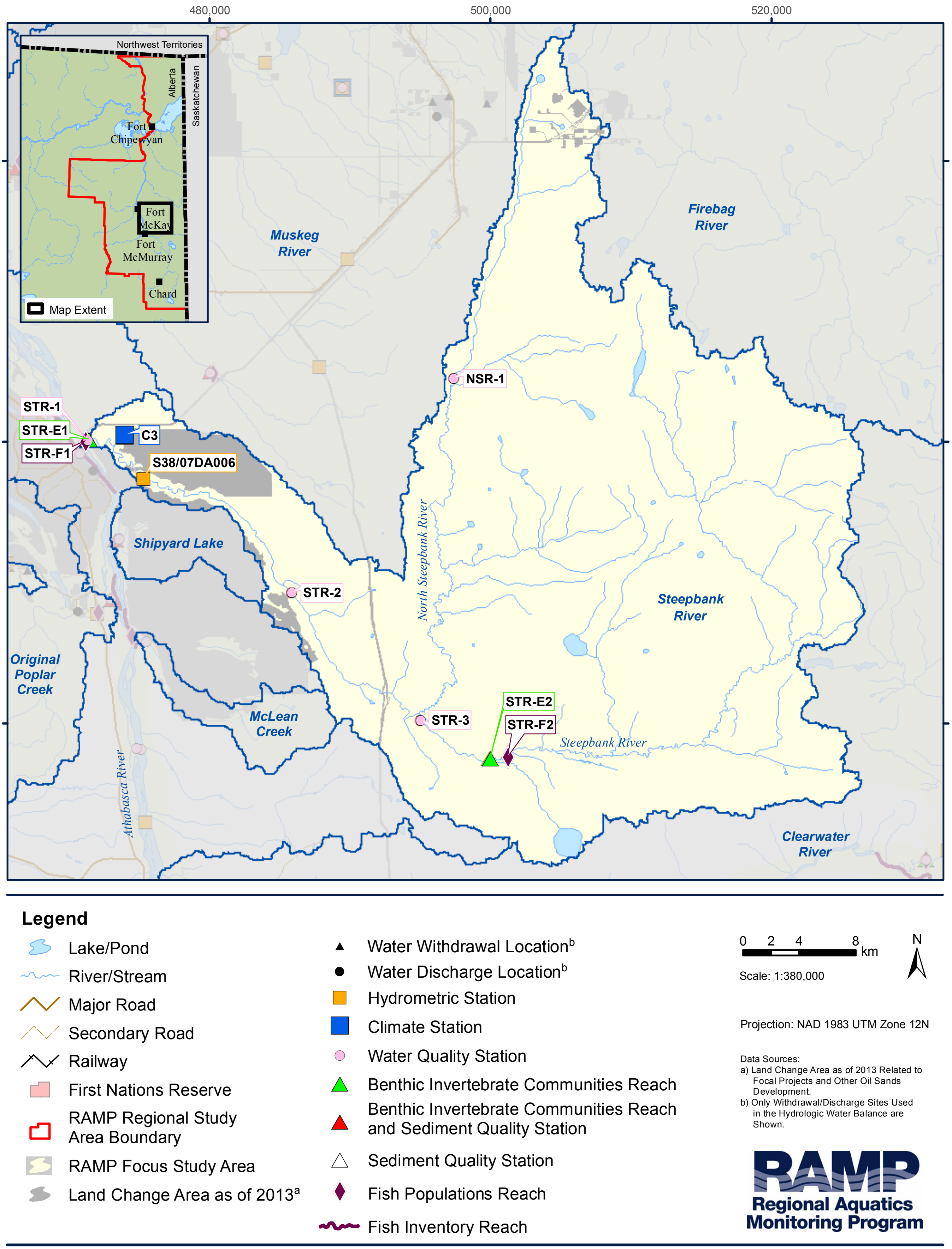
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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 3.2.4.4 for a description of the classification methodology.

Figure 5.3-1 Steepbank River watershed.



K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K03_Steepbank_20140224_ss.mxd

Figure 5.3-2 Representative monitoring stations of the Steepbank River, fall 2013.

Benthic Invertebrate Reach STR-E1: Centre Channel, facing downstream

Benthic Invertebrate and Fish Assemblage Reach STR-E2/STR-F2: Left Downstream Bank

Water Quality Station STR-2: facing downstream

Water Quality Station NSR-1: North Steepbank River, facing downstream.

5.3.1 Summary of 2013 Conditions

Approximately 4% (5,400 ha) of the Steepbank River watershed had undergone land change as of 2013 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 2013 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 2013. Table 5.3-1 is a summary of the 2013 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 2013. Figure 5.3-2 contains photos of representative monitoring stations in the watershed taken in fall 2013.

Hydrology The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.33% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of most water quality measurement endpoints in the Steepbank River watershed in fall 2013 were within previously-measured concentrations. When compared to regional *baseline* conditions, concentrations of water quality measurement endpoints were generally consistent. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2013 was similar to previous years. Differences in water quality in fall 2013 at water quality monitoring stations 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 of the benthic invertebrate community at *test* reach STR-E1 were classified as **Moderate** because of the significantly lower abundance, richness, CA Axis 1 and 2 scores, and percent EPT compared to *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach. Differences in the benthic invertebrate communities between the upper and lower reaches may be related to natural differences in substrate texture. The substrate at *test* reach STR-E1 was slightly more dominated by finer cobble, gravel, and sand than *baseline* reach STR-E2, and was more embedded; therefore, there was less surface area for benthic organisms to colonize.

Fish Populations (fish assemblages) Differences in measurement endpoints of the fish assemblage at *test* reach STR-F1 were classified as **Moderate** because CPUE and abundance were lower than the range of regional *baseline* variability and there was a decrease in abundance, richness, and CPUE over time. These changes were indicative of potential negative changes in the fish assemblage, although the increased embedded substrate at this reach could have resulted in less cover and suitable habitat for fish over time.

5.3.2 Hydrologic Conditions: 2013 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 2013 WY.

Continuous annual hydrometric data have been collected at WSC Station 07DA006 (RAMP Station S38) from 1974 to 1986 and more recently from 2009 to 2013, 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 2013 WY was 274.6 million m^3, which was 103% higher than the historical mean open-water runoff volume of 135.2 million m^3. Flows decreased from November 2012 to March 2013, with flows from November to February fluctuating near historical maximum values (Figure 5.3-3). Flows increased during spring freshet in April and early May 2013, to a freshet peak of 70.2 m^3/s on May 9, which was 6% lower than the historical maximum flow for this date. Following the freshet peak, flows decreased until June 8, but generally remained between the historical upper quartile and the historical maximum values. Flows then increased in response to rainfall events in mid-June, reaching a maximum open-water daily flow of 70.5 m^3/s on June 16. This value was 106% higher than the historical mean open-water maximum daily flow of 34.2 m^3/s (Figure 5.3-3). Following this peak, flows generally decreased to late September, before increasing in early October to above historical upper quartile values due to rainfall events. The minimum open-water daily flow of 1.39 m^3/s occurred on September 16 and was 17% lower than the historical mean open-water minimum daily flow of 1.67 m^3/s.

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 2013 was estimated to be 5.4 km^2 (Table 2.5-1). The loss of flow to the Steepbank River that would have otherwise occurred from this land area was estimated at 1.23 million m^3.
2. As of 2013, the area of land change in the Steepbank watershed that was not closed-circuited was estimated to be 48.8 km^2 (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 2.23 million m^3.

Classification of Results The estimated cumulative effect of oil sands development was an increase in flow of 1.0 million m^3 in the 2013 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 0.33% greater 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 2013, water quality samples were taken from:

- the Steepbank River near its mouth (*test* station STR-1), sampled from 1997 to 2013;
- 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 2013;
- the Steepbank River upstream of the confluence with the North Steepbank River (*baseline* station STR-3), sampled from 2004 to 2013; and
- the North Steepbank River (*test* station NSR-1), designated as *baseline* from 2002 to 2008 and *test* from 2009 to 2013.

Temporal Trends The following significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- An increasing concentration of total arsenic at *test* station STR-1;
- A decreasing concentration of chloride and an increasing concentration of total arsenic at *test* station STR-2;
- Decreasing concentrations of chloride and sulphate and an increasing concentration of arsenic at *baseline* station STR-3; and
- An increasing concentration of total arsenic at *test* station NSR-1.

2013 Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2013 had similar concentrations to historical results with a few exceptions (Table 5.3-4 to Table 5.3-7):

- Calcium, magnesium, total arsenic, and total molybdenum, with concentrations that exceeded previously-measured maximum concentrations at *test* station STR-2;
- Conductivity, dissolved phosphorus, total dissolved solids, calcium, total alkalinity, total molybdenum, and total strontium, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station STR-3; and
- Dissolved phosphorus, with a concentration that exceeded the previously-measured maximum concentration at *test* station NSR-1.

All water quality measurement endpoints were within previously-measured concentrations at *test* station STR-1.

Ion Balance In fall 2013, 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 (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 2013 were below water quality guidelines, with the exception of dissolved phosphorus at *baseline* station STR-3 (Table 5.3-6).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Steepbank River watershed in fall 2013 (Table 5.3-8):

- Total phosphorus at *test* stations STR-2 and NSR-1, and *baseline* station STR-3; and
- Total iron, dissolved iron, sulphide, and total phenols at *test* stations STR-1, STR-2, and NSR-1, and *baseline* station STR-3.

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints in fall 2013 at *test* stations STR-1, STR-2, and NSR-1 and *baseline* station STR-3 were within regional *baseline* concentrations with the following exceptions (Figure 5.3-5):

- Dissolved phosphorus, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-2, NSR-1, and *baseline* station STR-3;
- Total boron, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-1 and *baseline* station STR-3;
- Total arsenic, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station NSR-1;
- Sulphate, with a concentration below the 5th percentile of the regional *baseline* at *test* station NSR-1; and
- Sulphate and chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station STR-1.

Water Quality Index WQI values for all stations in the Steepbank River watershed indicated **Negligible-Low** differences from regional *baseline* at all stations in fall 2013. WQI values ranged from 89.8 to 92.4, with *test* station STR-1 having the lowest value and *baseline* station STR-3 having the highest WQI value (Table 5.3-9).

Classification of Results Concentrations of most water quality measurement endpoints in the Steepbank River watershed in fall 2013 were within previously-measured concentrations. When compared with regional *baseline* conditions, concentrations of water quality measurement endpoints were generally consistent. The ionic composition at all water quality monitoring stations in the Steepbank River watershed in fall 2013 was similar to previous years. Differences in water quality in fall 2013 at water quality monitoring stations 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.

2013 Habitat Conditions Water at *test* reach STR-E1 in fall 2013 was shallow (0.2 m), with a moderate velocity (0.64 m/s), moderate conductivity (350 µS/cm), and high dissolved oxygen concentration (9.9 mg/L) (Table 5.3-10). Periphyton chlorophyll *a* biomass at *test* reach STR-E1 averaged 18.6 mg/m^2, which was within the normal range of values for regional *baseline* conditions (Figure 5.3-6).

Water at *baseline* reach STR-E2 was shallow (0.2 m), with a relatively fast velocity (~1 m/s), basic (pH: 8.0), with moderate conductivity (312 µS/cm), and high dissolved oxygen (10.4 mg/L) (Table 5.3-10). Periphyton chlorophyll *a* biomass at *baseline* reach STR-E2 averaged 23.8 mg/m^2, which was within the normal range of values for 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 Ephemeroptera (34%) and chironomids (32%), with subdominant taxa consisting of naidid worms (12%) (Table 5.3-11). Chironomids consisted of many common forms (Wiederholm 1983) such as *Cricotopus*/ *Orthocladius*, *Polypedilum,* and *Rheotanytarsus*, as well as other forms that are more restricted to clean cold water (Mandeville 2001) such as *Tvetenia*. Ephemeroptera were diverse with ten taxa and included the widely-distributed *Baetis*, as well as *Ephemerella*, *Rhithrogena*, *Heptagenia*, and *Acentrella*. Bivalves and gastropods were absent at *test* reach STR-E1 in 2013; however, other sensitive taxa such as stoneflies (*Isoperla*, *Skwala*) and caddisflies (*Hydropsyche*, *Cheumatopsyche*, *Myatrichia*, and *Micrasema*) were present.

The benthic invertebrate community at *baseline* reach STR-E2 was dominated by Chironomidae (35%) and Ephemeroptera (34%), with subdominant taxa consisting of naidid worms (12%) and Trichoptera (7%) (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. Mayflies were diverse and abundant and included the ubiquitous *Baetis*, *Acerpenna pygmaea,* and the sensitive *Ephemerella*. Ten kinds of stoneflies, the most dominant being *Zapada,* were present in 2013.

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 2013, Hypothesis 6, Section 3.2.3.1); and
- changes between 2013 values and the mean of all previous years of sampling (1998 to 2012).

Spatial comparisons for *test* reach STR-E1 included testing for:

- differences from *baseline* reach STR-E2 over time (Hypothesis 2, section 3.2.3.1); and
- differences between 2013 values and the mean of all available *baseline* data (2004 to present).

Abundance and richness were significantly higher at *baseline* reach STR-E2 than *test* reach STR-E1, accounting for 30% and 25% of the variance in annual means, respectively (Table 5.3-13). The percentage of EPT taxa was significantly higher at *baseline* reach STR-E2 than *test* reach STR-E1, accounting for 36% of the variance in annual means (Table 5.3-13).

The upper *baseline* and lower *test* reaches of the Steepbank River were fundamentally different in terms of taxa composition which resulted in different CA Axis scores (Figure 5.3-7). CA Axis 1 and 2 scores were higher at *baseline* reach STR-E2 and accounted for a large amount of variation in annual means (Table 5.3-13). The lower *test* reach STR-E1 had higher relative abundances of tubificid worms and the upper *baseline* reach STR-E2 had higher relative abundances of caddisflies (Figure 5.3-7).

Comparison to Published Literature The benthic invertebrate community at *test* reach STR-E1 was diverse with a mean of over 20 taxa per sample, and contained genera that require colder and cleaner water such as the chironomid *Tvetenia* and the mayfly *Ephemerella* (Mandeville 2001). Permanent benthic forms such as fingernail clams (*Pisidium/Sphaerium*) and gastropods (*Ferrissia rivularis*), which were present in previous years, were not found at *test* reach STR-E1 in 2013; however, the high relative abundance of sensitive forms such as stoneflies, caddisflies, and mayflies suggested good overall water quality.

The benthic invertebrate community at *baseline* reach STR-E2 was diverse and contained a benthic fauna that reflected good water and substrate quality. The percentage of the community as worms was low (<15% total), while chironomids accounted for 35% of the fauna. The percentage of the fauna as EPT taxa, as in previous years, was also high (43%), which generally indicates the presence of a robust community, reflecting good water and sediment quality (Hynes 1960; Griffiths 1998).

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach STR-E1 has more than eight years of data (1998 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for *baseline* reach STR-E2 were evaluated. Values of all measurement endpoints at *test* reach STR-E1 were within the inner tolerance limits of the normal range of variation for means from that reach in previous years (Figure 5.3-7 and Figure 5.3-8). Periphyton chlorophyll *a* biomass at the upper *baseline* and lower *test* reaches of the Steepbank River were within the inner tolerance limits of the normal range of variation for regional *baseline* erosional reaches (Figure 5.3-6).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* reach STR-E1 were classified as **Moderate** because of significantly lower abundance, richness, CA Axis 1 and 2 scores, and percent EPT compared to *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach. Differences in the benthic composition between the upper and lower reaches may be related to natural differences in substrate texture. The substrate at *test* reach STR-E1 was slightly more dominated by finer cobble, gravel, and sand than *baseline* reach STR-E2, and was more embedded; therefore, there was less surface area for benthic organisms to colonize.

5.3.4.2 Sediment Quality

No sediment quality sampling was conducted in the Steepbank River in 2013. 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

Fish assemblages were sampled in fall 2013 at:

- erosional *test* reach STR-F1, near the mouth of the Steepbank River, sampled continuously since 2009 (this reach is in the same location as benthic invertebrate community *test* reach STR-E1); and
- erosional *baseline* reach STR-F2, sampled since 2011 (this reach is in the same location as benthic invertebrate community *baseline* reach STR-E2).

2013 Habitat Conditions *Test* reach STR-F1 was comprised of run habitat, with a wetted width of 16.6 and a bankfull width of 29.8 m (Table 5.3-14). The substrate was dominated by coarse gravel with embedded fine material. Water at *test* reach STR-F1 had a mean depth of 0.52 m and a moderate velocity of 0.35 m/s, was alkaline (pH: 8.54), with moderate conductivity (302 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 15.7°C. Instream cover consisted primarily of woody debris with smaller amounts of filamentous algae, live tree roots, overhanging vegetation, and boulders (Table 5.3-14).

Baseline reach STR-F2 was comprised of riffle and run habitat, with a wetted width of 13.9 m and a bankfull width of 16.2 m (Table 5.3-14). The maximum depth was 0.47 m, with a moderate velocity of 0.38 m/s. Water at *baseline* reach STR-F2 was alkaline (pH: 8.30), with moderate conductivity (294 µS/cm), high dissolved oxygen (9.0 mg/L), and a temperature of 10.5˚CInstream cover consisted primarily of boulders with low amounts of filamentous algae and large woody debris (Table 5.3-14).

Relative Abundance of Fish Species The fish assemblage at *test* reach STR-F1 was dominated by burbot (43%) (Table 5.3-15). Burbot were common near the mouths of many of the tributaries to the Athabasca River in fall 2013 and were caught in numbers not previously observed during the RAMP program. The notable exception to that was in 2010 at *test* reach STR-F1, when burbot were last captured, although the proportion of burbot of the total catch was substantially lower than 2013 (Table 5.3-15). The fish assemblage at *baseline* reach STR-F2 was dominated by slimy sculpin (63%) (Table 5.3-15), which is a common species observed in riffle habitat of rivers in the oil sands region. Species composition at *baseline* reach STR-F2 was comparable to 2011; however, the total catch was slightly lower.

Temporal and Spatial Comparisons Temporal comparisons for *test* reach STR-F1 included testing for changes over time (2009 to 2013, Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach STR-F1 included testing for differences from *baseline* reach STR-F2 over time (Hypothesis 2, Section 3.2.4.4).

There was a significant decrease in abundance ($p<0.001$), richness ($p=0.011$), and total CPUE ($p<0.001$) over time at *test* reach STR-F1, explaining greater than 20% in the variance of annual means (Table 5.3-16, Table 5.3-17). As a result of the high proportion of burbot, which is considered a sensitive species, the assemblage tolerance index at *test* reach STR-F1 was also the lowest recorded but showed no significant trend over time (Table 5.3-17).

Abundance and total CPUE at *baseline* reach STR-F2 in 2013 were higher than 2012 (Table 5.3-16). The higher proportion of sculpin species at *baseline* reach STR-F2 in 2013 resulted in the lowest ATI value observed during the three years of sampling. Measurement endpoints at *baseline* reach STR-F2 were slightly higher than *test* reach STR-F1 (Table 5.3-16) but showed the same decreasing trends over time (Figure 5.3-9). The similarities in trends over time resulted in the lack of significant differences in any measurement endpoints between the *test* and *baseline* reaches of the Steepbank River (Table 5.3-17).

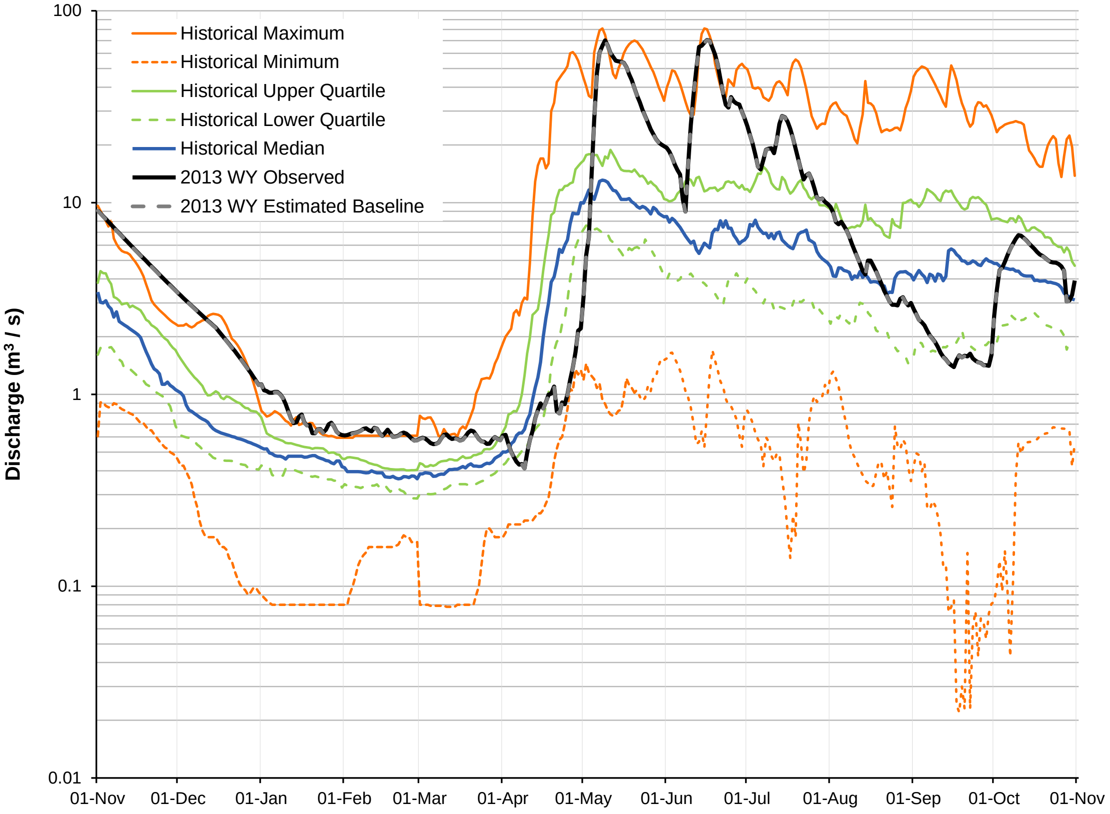
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution 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 16 species from 2009 to 2013. 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 2013. 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 2013, RAMP has documented habitat conditions at *test* reach STR-F1 consisting of riffles and runs, with a greater amount of embedded 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.

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *test* reach STR-F1 were within the inner tolerance limits for the normal range of erosional *baseline* conditions, with the exception of CPUE and abundance, which were below the inner tolerance limit for the 5th percentile (Figure 5.3-9). Mean values of all measurement endpoints at *baseline* reach STR-F2 were within also within the normal range of erosional *baseline* conditions (Figure 5.3-9).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach STR-F1 were classified as **Moderate** because CPUE and abundance were lower than the range of regional *baseline* variability and there was a decrease in abundance, richness, and CPUE over time. These changes were indicative of potential negative changes in the fish assemblage, although the increased embedded substrate at this reach could have resulted in less cover and suitable habitat for fish over time.

Figure 5.3-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Steepbank River in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on Steepbank River near Fort McMurray, WSC Station 07DA006 provisional data from January 1 to October 31, 2013 and RAMP Station S38 from November 1 to December 31, 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 2012, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1986 and from 2009 to 2012.

Table 5.3-2 Estimated water balance at WSC Station 07DA006 (RAMP Station S38), Steepbank River near Fort McMurray, 2013 WY.

Component	Volume (million m³)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**302.97**	**Observed discharge from Steepbank River near Fort McMurray, WSC Station 07DA006 (RAMP Station S38)**
Closed-circuited area water loss from the observed *test* hydrograph	-1.23	Estimated 5.4 km² of the Steepbank River watershed is closed-circuited as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+2.23	Estimated 48.8 km² of the Steepbank River watershed with land change as of 2013 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Steepbank River watershed from focal projects	0	None reported
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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**301.97**	**Estimated *baseline* discharge at Steepbank River near Fort McMurray, WSC Station 07DA006 (RAMP Station S38)**
Incremental flow (change in total discharge)	+1.00	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**+0.33%**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on Steepbank River near Fort McMurray, WSC Station 07DA006 provisional data from January 1 to October 31, 2013 and RAMP Station S38 from November 1 to December 31, 2012. The upstream drainage area of WSC Station 07DA006 is 1,320 km², which is slightly smaller than the size of the entire Steepbank River watershed (1,364 km², Table 2.5-1).

Table 5.3-3 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m³/s)	Value from *Test* Hydrograph (m³/s)	Relative Change
Mean open-water season discharge	17.214	17.271	+0.33%
Mean winter discharge	1.995	2.001	+0.33%
Annual maximum daily discharge	70.267	70.500	+0.33%
Open-water season minimum daily discharge	1.385	1.390	+0.33%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on Steepbank River near Fort McMurray, WSC Station 07DA006 provisional data from January 1 to October 31, 2013 and RAMP Station S38 from November 1 to December 31, 2012.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and two decimal places, respectively.

Note: 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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.37	15	7.70	8.20	8.60
Total suspended solids	mg/L	-	4.0	15	<3.0	8.0	60.0
Conductivity	µS/cm	-	357	15	141	210	516
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.032	15	0.006	0.019	0.039
Total nitrogen	mg/L	1	0.591	15	0.250	0.900	**2.40**
Nitrate+nitrite	mg/L	3	<0.071	15	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	22.8	15	10.0	22.7	30.0
Ions							
Sodium	mg/L	-	20.1	15	6.00	10.0	38.0
Calcium	mg/L	-	42.7	15	17.2	27.5	50.3
Magnesium	mg/L	-	12.3	15	5.40	8.30	16.2
Chloride	mg/L	120	3.78	15	<0.70	2.00	8.40
Sulphate	mg/L	270	9.75	15	2.45	4.60	12.3
Total dissolved solids	mg/L	-	252	15	120	180	320
Total alkalinity	mg/L	-	179	15	63.0	105	263
Selected metals							
Total aluminum	mg/L	0.1	0.075	15	0.040	**0.188**	**2.79**
Dissolved aluminum	mg/L	0.1	0.0118	15	<0.0044	0.0148	0.0987
Total arsenic	mg/L	0.005	0.0009	15	<0.0005	0.0008	0.0013
Total boron	mg/L	1.2	0.128	15	0.025	0.052	0.200
Total molybdenum	mg/L	0.073	0.00037	15	0.00015	0.00020	0.00050
Total mercury (ultra-trace)	ng/L	5, 13	1.40	10	<1.20	<1.40	5.00
Total strontium	mg/L	-	0.174	15	0.063	0.102	0.252
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.60	2	0.19	0.23	0.26
Oilsands Extractable	mg/L	-	1.27	2	0.52	0.80	1.08
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	1.540	2	9.420	31.56	53.70
Total dibenzothiophenes	ng/L	-	89.17	2	114.1	896.1	1,678
Total PAHs	ng/L	-	325.4	2	529.8	2,652	4,775
Total Parent PAHs	ng/L	-	27.69	2	32.26	64.84	97.42
Total Alkylated PAHs	ng/L	-	297.7	2	497.5	2,587	4,677
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.719**	15	0.187	**0.373**	**0.599**
Sulphide	mg/L	0.002	**0.003**	15	<0.003	**0.006**	**0.041**
Total iron	mg/L	0.3	**1.01**	15	**0.470**	**0.84**	**2.48**
Total phenols	mg/L	0.004	**0.008**	15	<0.001	**0.006**	**0.013**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.38	11	7.80	8.10	8.42
Total suspended solids	mg/L	-	<3.0	11	<3.0	5.0	28
Conductivity	µS/cm	-	327	11	121	191	329
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.045	11	0.014	0.025	0.048
Total nitrogen	mg/L	1	0.651	11	0.600	0.800	**1.99**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	0.100
Dissolved organic carbon	mg/L	-	23.0	11	14.0	25.0	30.1
Ions							
Sodium	mg/L	-	16.4	11	5.00	8.10	18.5
Calcium	mg/L	-	41.4	11	16.8	25.5	35.9
Magnesium	mg/L	-	11.6	11	5.30	7.44	11.4
Chloride	mg/L	120	0.92	11	<0.50	1.00	3.00
Sulphate	mg/L	270	3.97	11	<0.50	2.60	5.50
Total dissolved solids	mg/L	-	234	11	139	165	249
Total alkalinity	mg/L	-	176	11	61.0	97.7	178
Selected metals							
Total aluminum	mg/L	0.1	0.066	11	0.018	**0.160**	**0.536**
Dissolved aluminum	mg/L	0.1	0.0083	11	0.0023	0.0146	0.0294
Total arsenic	mg/L	0.005	0.00091	11	0.00050	0.00067	0.00085
Total boron	mg/L	1.2	0.107	11	0.023	0.048	0.157
Total molybdenum	mg/L	0.073	0.00032	11	0.00010	0.00016	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	1.40	10	0.60	1.35	3.40
Total strontium	mg/L	-	0.157	11	0.053	0.097	0.167
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.19	2	0.15	0.17	0.18
Oilsands Extractable	mg/L	-	0.67	2	0.31	0.73	1.14
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	1.300	2	3.990	15.75	27.50
Total dibenzothiophenes	ng/L	-	7.060	2	6.372	20.98	35.60
Total PAHs	ng/L	-	103.3	2	188.0	205.0	221.9
Total Parent PAHs	ng/L	-	22.59	2	16.61	18.62	20.63
Total Alkylated PAHs	ng/L	-	80.74	2	167.4	186.4	205.3
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.846**	11	0.273	**0.459**	**0.597**
Sulphide	mg/L	0.002	**0.0057**	11	<0.003	**0.0057**	**0.0120**
Total iron	mg/L	0.3	**1.21**	11	**0.733**	**0.812**	**1.40**
Total phenols	mg/L	0.004	**0.0088**	11	<0.0010	**0.0070**	**0.0120**
Total phosphorus	mg/L	0.05	**0.055**	11	0.035	0.039	**0.069**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.29	9	7.88	8.12	8.46
Total suspended solids	mg/L	-	<3.0	9	<3.0	<3.0	15
Conductivity	µS/cm	-	357	9	128	229	346
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.070**	9	0.024	0.039	0.046
Total nitrogen	mg/L	1	0.601	9	0.571	0.800	**1.85**
Nitrate+nitrite	mg/L	3	<0.071	9	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	20.7	9	14.0	25.0	32.4
Ions							
Sodium	mg/L	-	19.0	9	5.40	11.0	22.8
Calcium	mg/L	-	45.4	9	17.1	30.0	40.7
Magnesium	mg/L	-	12.4	9	5.24	9.10	13.2
Chloride	mg/L	120	0.59	9	<0.50	1.00	2.00
Sulphate	mg/L	270	1.87	9	0.83	2.10	3.40
Total dissolved solids	mg/L	-	247	9	140	186	234
Total alkalinity	mg/L	-	194	9	63.6	121	186
Selected metals							
Total aluminum	mg/L	0.1	0.028	9	0.015	0.041	**0.240**
Dissolved aluminum	mg/L	0.1	0.007	9	0.004	0.014	0.030
Total arsenic	mg/L	0.005	0.00083	9	0.00046	0.00067	0.00083
Total boron	mg/L	1.2	0.127	9	0.025	0.058	0.134
Total molybdenum	mg/L	0.073	0.00032	9	0.00014	0.00019	0.00028
Total mercury (ultra-trace)	ng/L	5, 13	1.20	9	0.60	1.20	3.50
Total strontium	mg/L	-	0.158	9	0.057	0.106	0.150
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.26	2	0.03	0.16	0.28
Oilsands Extractable	mg/L	-	0.84	2	0.25	0.69	1.12
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	3.500	2	2.590	7.395	12.20
Total dibenzothiophenes	ng/L	-	6.672	2	5.936	20.62	35.30
Total PAHs	ng/L	-	106.3	2	171.7	194.3	217.0
Total Parent PAHs	ng/L	-	22.96	2	16.41	18.19	19.98
Total Alkylated PAHs	ng/L	-	83.32	2	151.7	176.2	200.6
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.975**	9	**0.336**	**0.554**	**0.751**
Sulphide	mg/L	0.002	**0.003**	9	**0.004**	**0.006**	**0.011**
Total iron	mg/L	0.3	**1.41**	9	**0.698**	**0.932**	**1.37**
Total phenols	mg/L	0.004	**0.008**	9	0.001	**0.006**	**0.019**
Total phosphorus	mg/L	0.05	**0.086**	9	0.043	**0.052**	**0.083**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.28	11	7.50	8.00	8.42
Total suspended solids	mg/L	-	<3.0	11	<3.0	<3.0	20.0
Conductivity	µS/cm	-	222	11	110	164	311
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.050	11	0.015	0.024	0.042
Total nitrogen	mg/L	1	0.621	11	0.400	0.700	**1.27**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	0.403
Dissolved organic carbon	mg/L	-	22.7	11	13.0	20.0	23.1
Ions							
Sodium	mg/L	-	3.30	11	2.00	3.00	6.10
Calcium	mg/L	-	33.4	11	16.5	23.1	42.9
Magnesium	mg/L	-	9.11	11	4.90	6.50	12.5
Chloride	mg/L	120	1.47	11	<0.50	1.00	4.79
Sulphate	mg/L	270	<0.50	11	<0.50	<1.20	<6.50
Total dissolved solids	mg/L	-	167	11	102	139	219
Total alkalinity	mg/L	-	117	11	55.0	82.0	169
Selected metals							
Total aluminum	mg/L	0.1	0.025	11	0.018	0.054	**0.241**
Dissolved aluminum	mg/L	0.1	0.0093	11	0.0030	0.0111	0.0148
Total arsenic	mg/L	0.005	0.0014	11	0.0005	0.0008	0.0014
Total boron	mg/L	1.2	0.018	11	0.010	0.015	0.050
Total molybdenum	mg/L	0.073	0.00038	11	0.00013	0.00020	0.00080
Total mercury (ultra-trace)	ng/L	5, 13	1.20	10	<0.60	<1.20	3.30
Total strontium	mg/L	-	0.118	11	0.049	0.081	0.245
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.25	2	0.25	0.26	0.27
Oilsands Extractable	mg/L	-	0.24	2	0.89	1.00	1.11
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	0.732	2	<2.071	4.405	6.740
Total dibenzothiophenes	ng/L	-	6.672	2	5.922	20.61	35.30
Total PAHs	ng/L	-	102.6	2	178.5	192.8	207.1
Total Parent PAHs	ng/L	-	22.57	2	16.42	17.96	19.51
Total Alkylated PAHs	ng/L	-	80.05	2	159.0	174.8	190.7
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**1.08**	11	0.226	**0.495**	**0.772**
Total iron	mg/L	0.3	**1.51**	11	**0.507**	**0.897**	**1.92**
Total phenols	mg/L	0.004	**0.005**	11	<0.001	**0.006**	**0.010**
Total phosphorus	mg/L	0.05	**0.062**	11	0.027	0.038	**0.076**
Sulphide	mg/L	0.002	**0.004**	11	<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 2013.

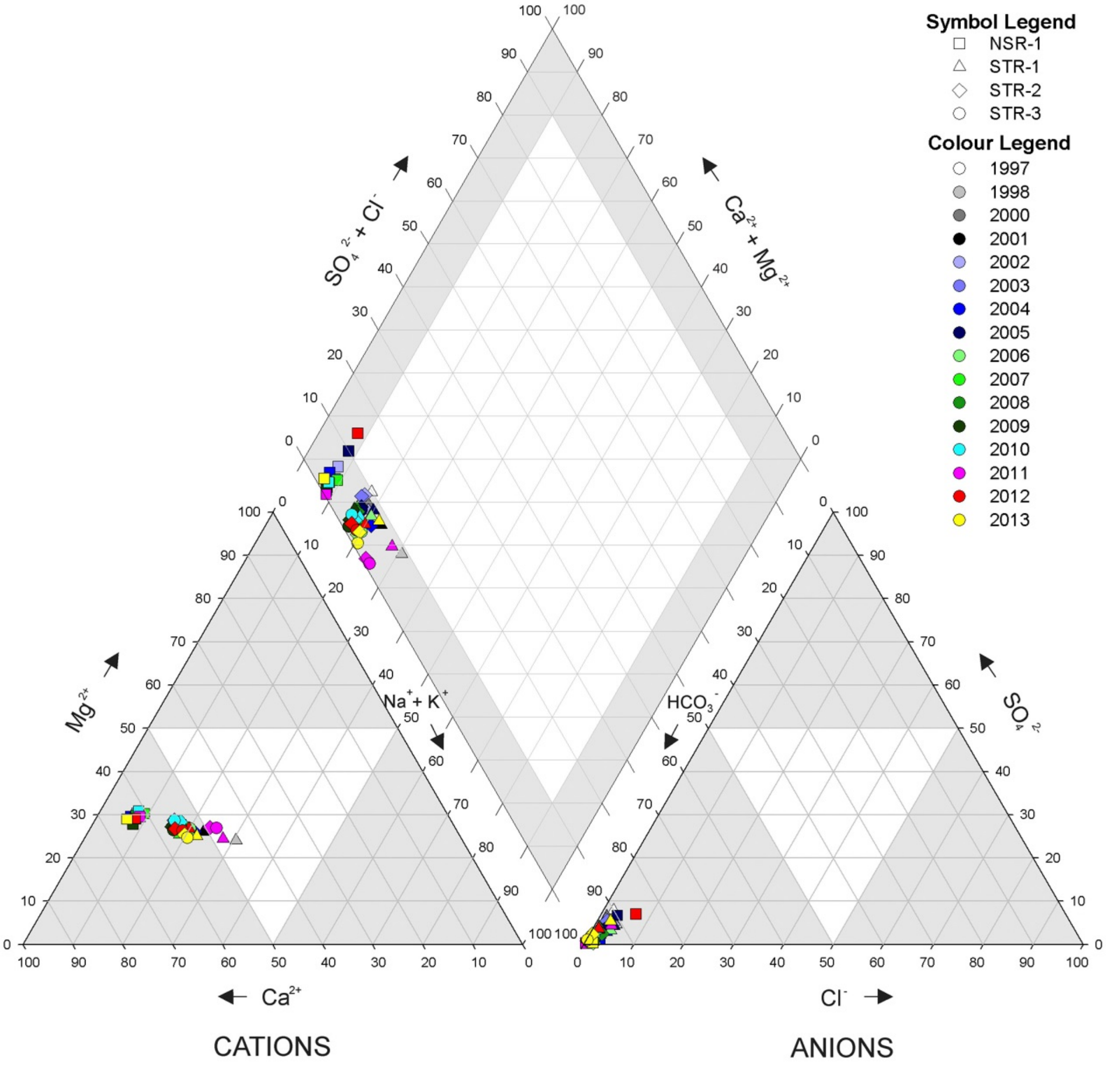


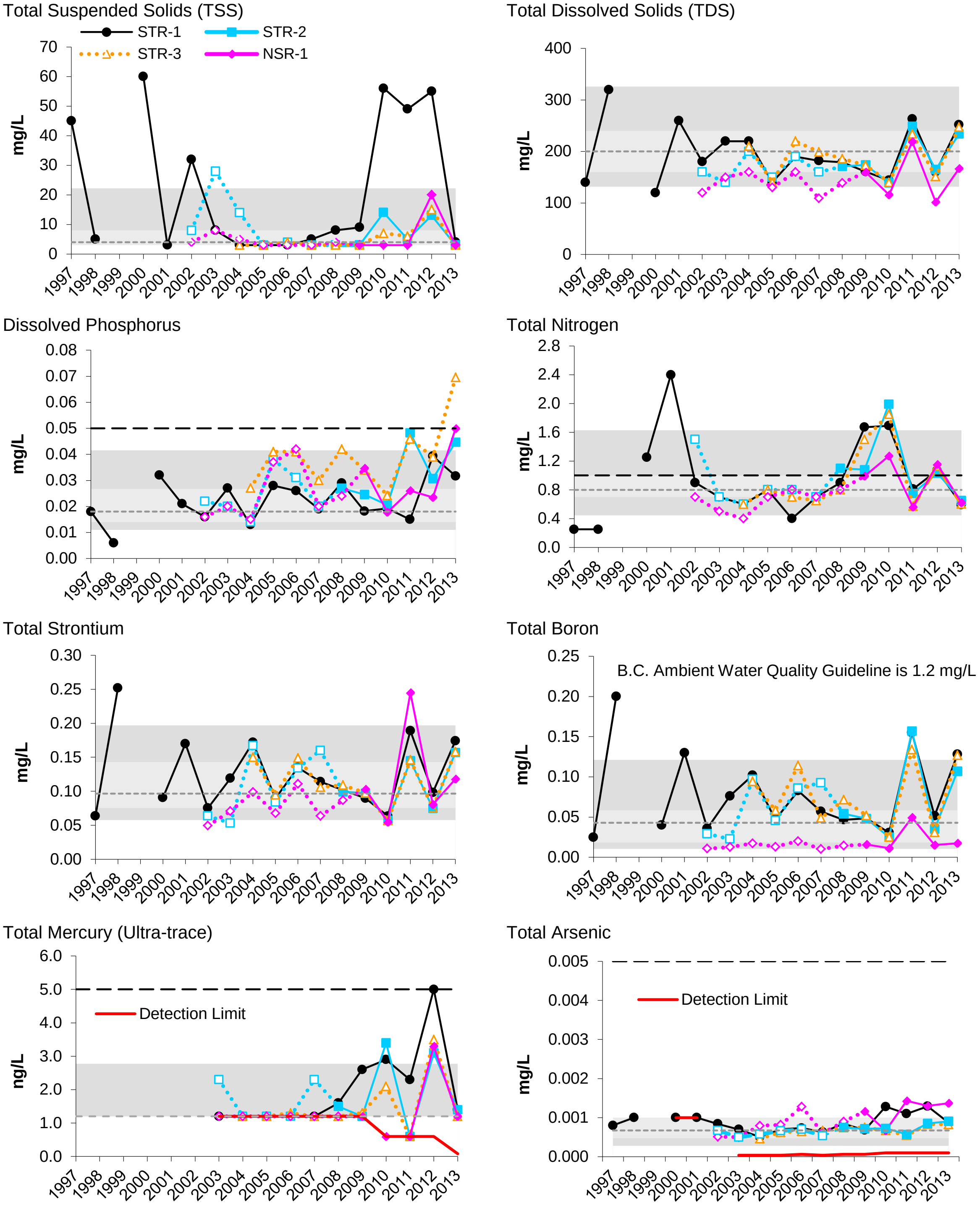
Table 5.3-8 Water quality guideline exceedances, Steepbank River watershed, fall 2013.

Variable	Units	Guideline[a]	STR-1	STR-2	STR-3	NSR-1
Dissolved iron	mg/L	0.3	0.72	0.85	0.98	1.08
Dissolved phosphorus	mg/L	0.05	-	-	0.07	-
Sulphide	mg/L	0.002	0.0034	0.0057	0.0031	0.0043
Total iron	mg/L	0.3	1.01	1.21	1.41	1.51
Total phenols	mg/L	0.004	0.0083	0.0088	0.0077	0.0051
Total phosphorus	mg/L	0.05	-	0.055	0.086	0.062

[a] Sources for all guidelines are outlined in Table 3.2-5.

Underline denotes baseline station.

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

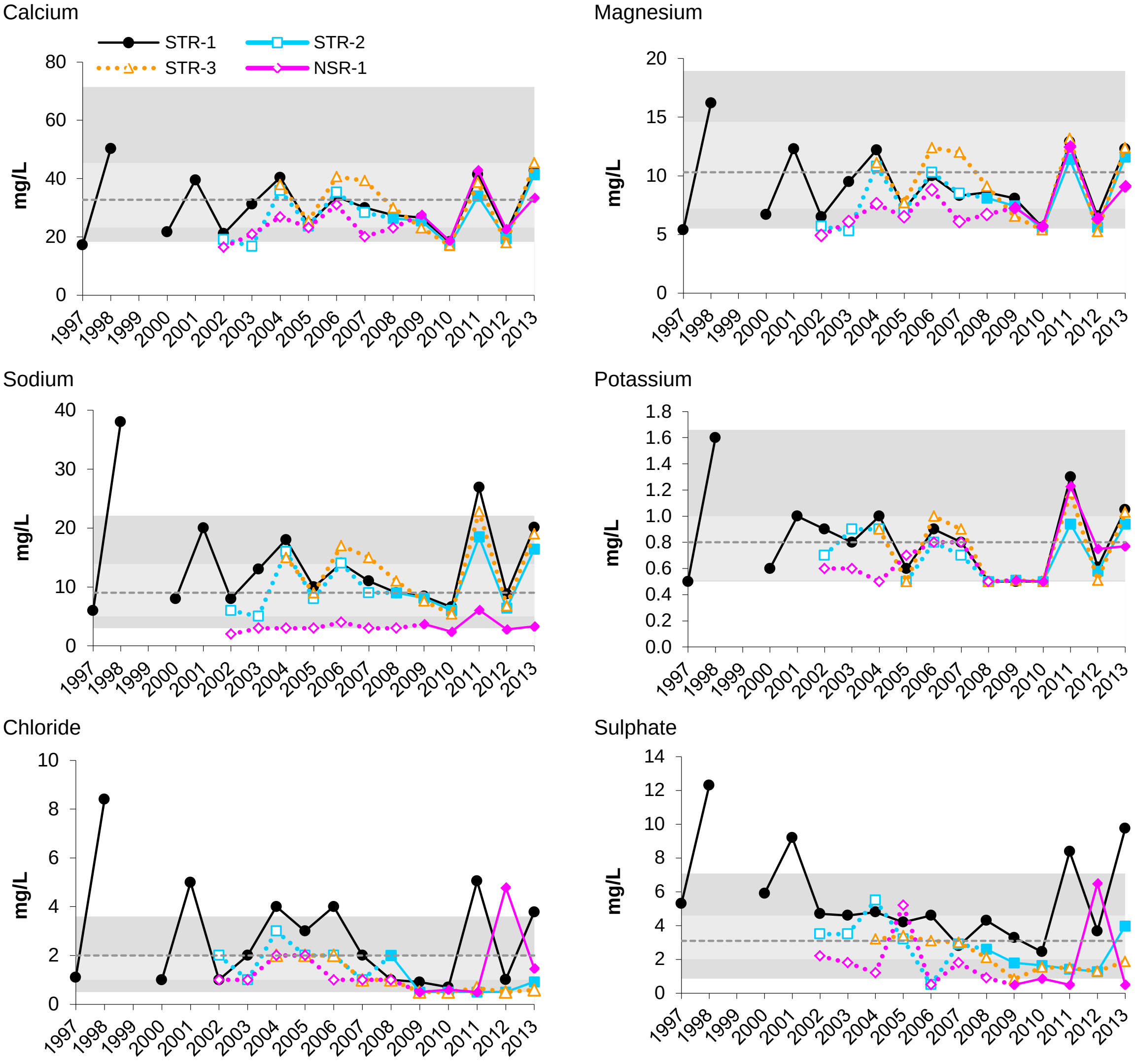
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.3-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ 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 3.2.2.2 for a discussion of this approach.

Table 5.3-9 Water quality index (fall 2013) for Steepbank River watershed stations.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
STR-1	Lower Steepbank River	*test*	89.8	Negligible-Low
STR-2	Upstream of Project Millennium	*test*	89.9	Negligible-Low
STR-3	Upstream of North Steepbank River	*baseline*	92.4	Negligible-Low
NSR-1	North Steepbank River	*test*	92.3	Negligible-Low

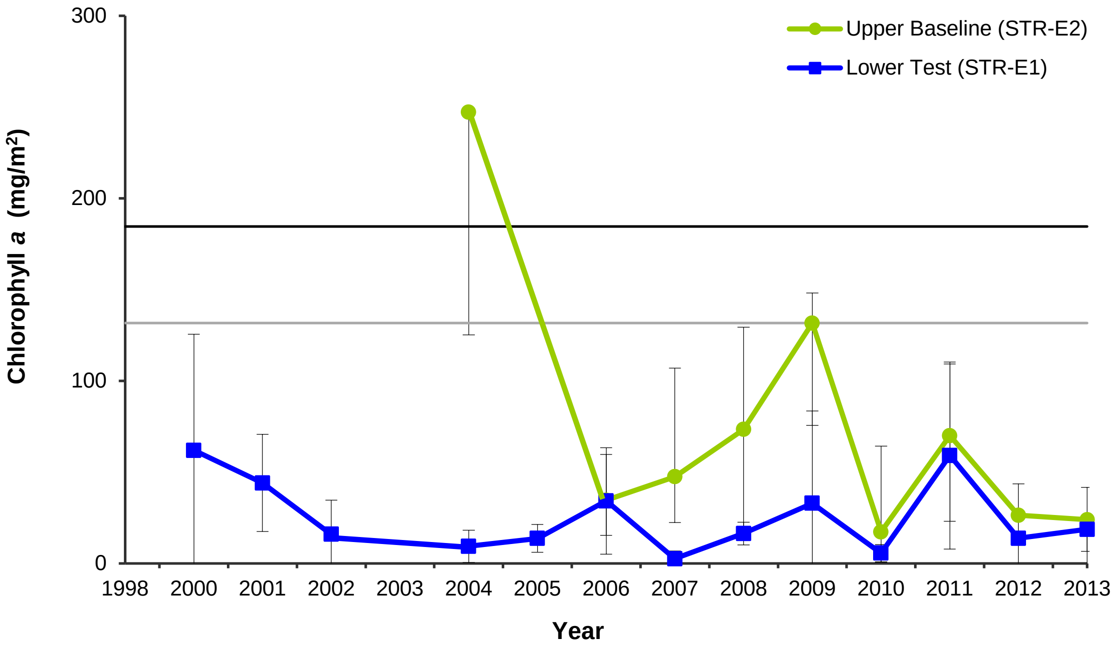
Note: see Figure 5.3-1 for the locations of these water quality stations.

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 2013.

Variable	Units	STR-E1 Lower *Test* Reach of the Steepbank River	STR-E2 Upper *Baseline* Reach of the Steepbank River
Sample date	-	Sept 11, 2013	Sept 11, 2013
Habitat	-	Erosional	Erosional
Water depth	m	0.2	0.2
Current velocity	m/s	0.64	0.87
Field Water Quality			
Dissolved oxygen	mg/L	9.9	10.4
Conductivity	µS/cm	350	312
pH	pH units	8.2	8.0
Water temperature	°C	12.4	10.7
Sediment Composition			
Sand/Silt/Clay	%	12	7
Small Gravel	%	17	9
Large Gravel	%	20	19
Small Cobble	%	26	27
Large Cobble	%	22	30
Boulder	%	3	9
Bedrock	%	0	0

Figure 5.3-6 Periphyton chlorophyll *a* biomass in the Steepbank River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years up to and including 2012.

Table 5.3-11 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the lower Steepbank River.

Taxon	**Percent Major Taxa Enumerated in Each Year**		
	***Test* Reach STR-E1**		
	1998	**2000 to 2012**	**2013**
Nematoda	1	<1 to 3	1
Oligochaeta		0 to <1	<1
Naididae	2	2 to 41	12
Tubificidae	2	<1 to 23	2
Enchytraeidae	1	1 to 15	8
Hydracarina	6	3 to 20	2
Gastropoda	<1	0 to 6	
Bivalvia		0 to <1	
Ceratopogonidae	<1	0 to 3	<1
Chironomidae	31	15 to 43	32
Diptera (misc.)	<1	<1 to 9	7
Dolichopodidae		0 to <1	
Coleoptera		0 to <1	<1
Ephemeroptera	51	1 to 51	34
Odonata	<1	<1 to 1	<1
Plecoptera	<1	<1 to 1	<1
Trichoptera	1	<1 to 2	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	679	156 to 2,326	384
Richness	41	17 to 41	23
Equitability	0.11	0.13 to 0.42	0.32
% EPT	47	10 to 47	36

Table 5.3-12 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the upper Steepbank River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach STR-E2		
	2004	2005 to 2012	2013
Hydra		0 to <1	
Nematoda	3	1 to 6	3
Naididae	2	1 to 24	12
Tubificidae	<1	0 to 1	<1
Enchytraeidae	<1	0 to 1	<1
Lumbriculidae		0 to <1	
Hydracarina	7	3 to 12	3
Gastropoda		0 to <1	
Bivalvia		0 to 4	
Ceratopogonidae		0 to 7	
Chironomidae	46	24 to 52	35
Diptera (misc.)	<1	<1 to 8	4
Coleoptera		0 to <1	<1
Ephemeroptera	18	6 to 35	34
Odonata	<1	0 to <1	<1
Plecoptera	2	1 to 4	2
Trichoptera	9	6 to 34	7
Heteroptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	3,443	919 to 5,857	3,024
Richness	34	29 to 46	35
Equitability	0.28	0.11 to 0.32	0.20
% EPT	29	26 to 56	43

Table 5.3-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Steepbank River.

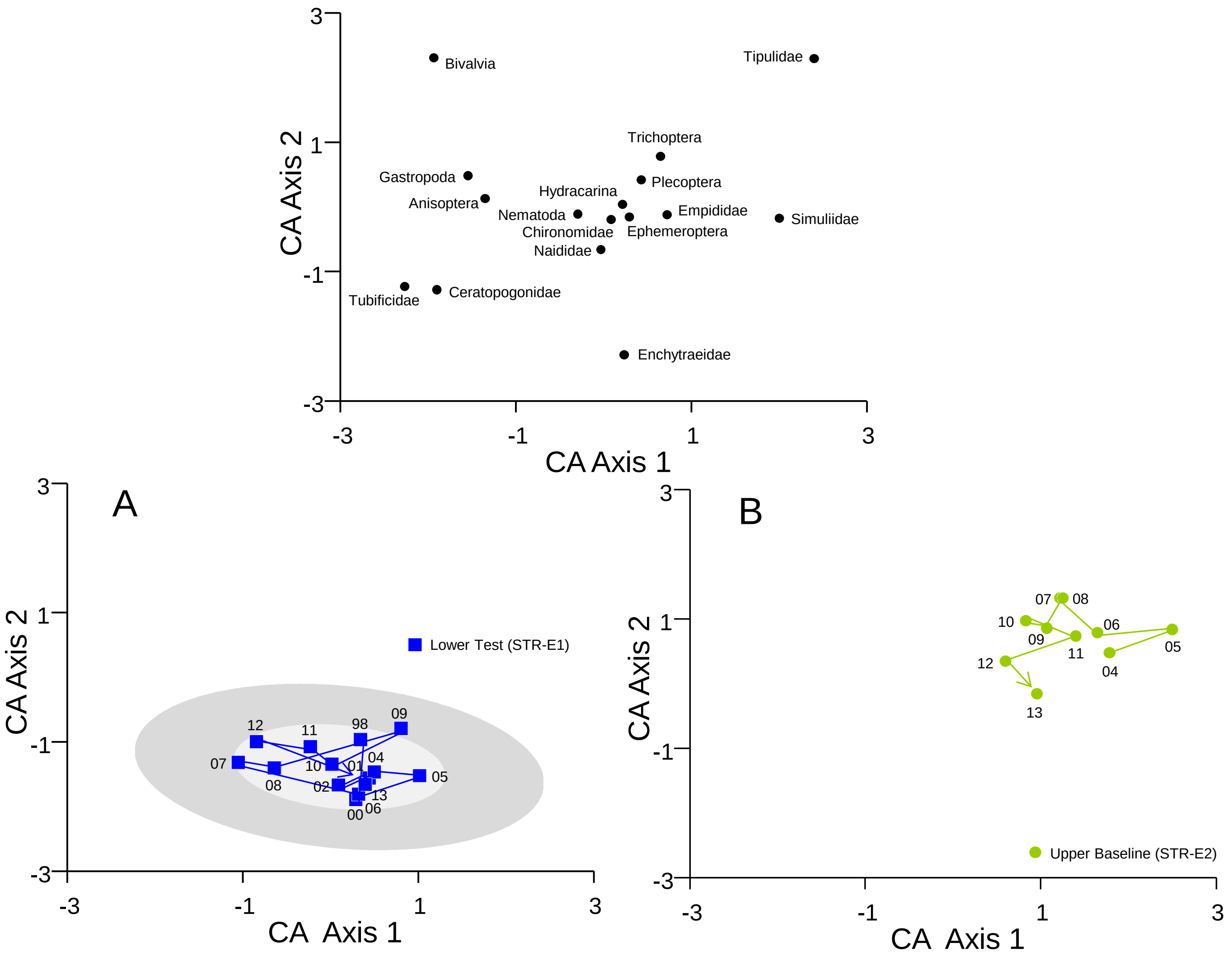
Measurement Endpoint	**P-value**					**Variance Explained**					**Nature of Change(s)**
	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*Test* Period)**	**Difference in Time Trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time Trend (*Test* Period)**	**Difference in Time Trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log of Abundance	**<0.001**	**<0.001**	**0.00002**	**<0.001**	0.091	30	3	3	10	0	Higher at *baseline* reach; increasing over time at *test* reach; lower in 2013 at *test* reach than mean of al years at *baseline* reach.
Log of Richness	**<0.001**	**<0.001**	**0.014**	**<0.001**	0.088	25	8	2	7	1	Higher at *baseline* reach; increasing over time at *test* reach; lower in 2013 at *test* reach than mean of all years at *baseline* reach.
Equitability	**<0.001**	0.185	**<0.001**	**0.004**	0.769	20	1	9	5	0	Higher at *test* reach; increasing at *baseline* reach while remaining relatively constant at *test* reach.
Log of EPT	**<0.001**	**0.006**	**0.049**	0.079	0.581	36	3	2	1	0	Higher at *baseline* reach; increasing over time at *test* reach and at a greater rate than *baseline* reach.
CA Axis 1	**<0.001**	**0.001**	**0.025**	**<0.001**	**0.007**	46	4	1	5	1	Higher at *baseline* reach; decreasing over time at both *test* and *baseline* reaches but at a greater rate in *baseline* reach; lower in 2013 at *test* reach than mean of all years at *baseline* reach; higher in 2013 than mean of previous years.
CA Axis 2	**<0.001**	**0.054**	**<0.001**	**<0.001**	0.357	55	0	1	16	0	Higher at *baseline* reach; increasing over time at *test* reach; decreasing over time at *baseline* reach; lower in 2013 at *test* reach than mean of all years at *baseline* reach.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

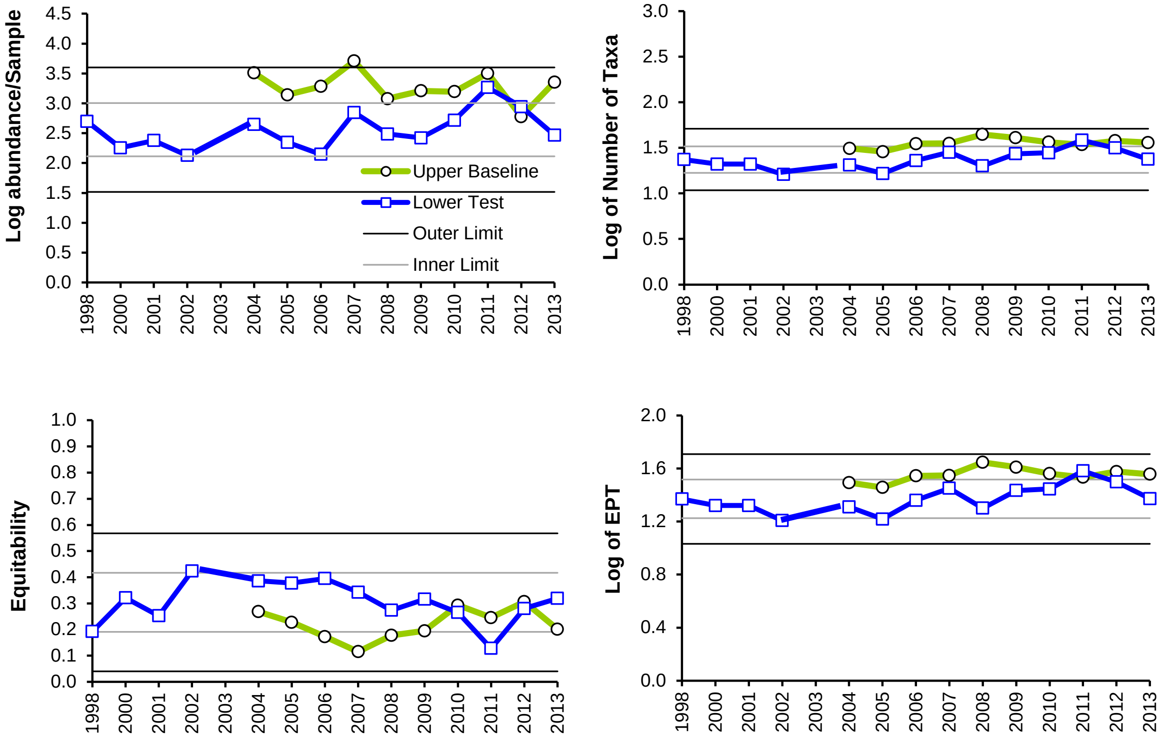
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.3-7 Ordination (Correspondence Analysis) of benthic invertebrate communities in erosional reaches, showing the lower *test* reach (STR-E1) and upper *baseline* reach (STR-E2) of the Steepbank River.



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at STR-E1 (1998 to 2012).

Figure 5.3-8 Variation in benthic invertebrate community measurement endpoints in the Steepbank River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years for *test* reach STR-E1 (1998 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.3-14 Average habitat characteristics of fish assemblage monitoring locations in the Steepbank River.

Variable	Units	STR-F1 Lower *Test* Reach of the Steepbank River	STR-F2 Upper *Baseline* Reach of the Steepbank River
Sample date	-	Sept 7, 2013	Sept 7, 2013
Habitat type	-	run	riffle/run
Maximum depth	m	0.84	0.47
Mean depth	m	0.52	0.32
Bankfull channel width	m	29.8	16.2
Wetted channel width	m	16.6	13.9
Substrate			
Dominant	-	coarse gravel/fines	cobble
Subdominant	-	sand/cobble	fine gravel
Instream cover			
Dominant	-	large woody debris, small woody debris	boulders
Subdominant	-	filamentous algae, live trees and roots, overhanging vegetation, boulders	filamentous algae, large woody debris
Field water quality			
Dissolved oxygen	mg/L	9.6	9.0
Conductivity	µS/cm	302	295
pH	pH units	8.54	8.30
Water temperature	^{0}C	15.7	10.5
Water velocity			
Left bank velocity	m/s	0.24	0.41
Left bank water depth	m	0.67	0.36
Centre of channel velocity	m/s	0.44	0.36
Centre of channel water depth	m	0.51	0.39
Right bank velocity	m/s	0.37	0.37
Right bank water depth	m	0.38	0.23
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings, and overhanging vegetation
Subdominant	-	overhanging vegetation	-

Table 5.3-15 Total catch and percent composition of fish species captured in reaches of the Steepbank River, 2009 to 2013.

Common Name	**Code**	**Total Species**								**Percent of Total Catch**							
		***Test* Reach STR-F1**					***Baseline* Reach STR-F2**			***Test* Reach STR-F1**					***Baseline* Reach STR-F2**		
		2009	**2010**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**
Arctic grayling	ARGR	-	-	-	-	-	-	-	1	0	0	0	0	0	0	0	2.2
brook stickleback	BRST	-	-	-	-	-	5	1	-	0	0	0	0	0	6.3	50.0	0
burbot	BURB	-	8	-	-	6	-	-	-	0	3.8	0	0	42.9	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
finescale dace	FNDC	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
lake chub	LKCH	2	-	-	3	-	5	1	3	6.1	0	0	30.0	0	6.3	50.0	6.5
lake whitefish	LKWH	-	-	-	-	-	1	-	-	0	0	0	0	0	1.3	0	0
longnose dace	LNDC	1	63	2	2	1	9	-	3	3.0	30.0	7.7	20.0	7.1	11.4	0	6.5
longnose sucker	LNSC	2	-	1	1	2	3	-	3	6	0	3.8	10.0	14.3	3.8	0	6.5
northern pike	NRPK	-	-	-	1	-	-	-	-	0	0	0	10.0	0	0	0	0
northern redbelly dace	NRDC	16	-	-	-	-	1	-	-	48.5	0	0	0	0	1.3	0	0
pearl dace	PRDC	2	64	-	-	-	-	-	-	6.1	30.5	0	0	0	0	0	0
slimy sculpin	SLSC	2	60	8	2	2	35	-	29	6.1	28.6	30.8	20.0	14.3	44.3	0	63.0
spoonhead sculpin	SPSC	-	3	3	-	-	-	-	-	0	1.4	11.5	0	0	0	0	0
spottail shiner	SPSH	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
trout-perch	TRPR	1	7	-	-	1	20	-	7	3.0	3.3	0	0	7.1	25.3	0	15.2
walleye	WALL	1	-	-	-	1	-	-	-	3.0	0	0	0	7.1	0	0	0
white sucker	WHSC	1	4	12	1	-	-	-	-	3.0	1.9	46.2	10.0	0	0	0	0
yellow perch	YLPR	-	1	-	-	1	-	-	-	0	0.5	0	0	7.1	0	0	0
unknown sp. *		5	-	-	-	-	-	-	-	15.2	0	0	0	0	0	0	0
Total Count		**33**	**210**	**26**	**10**	**14**	**79**	**2**	**46**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**9**	**8**	**5**	**6**	**7**	**8**	**2**	**6**	**9**	**8**	**5**	**6**	**7**	**8**	**2**	**6**
Electrofishing effort (secs)		**3,652**	**4,977**	**1,326**	**1,948**	**1,772**	**1,309**	**1,712**	**2,269**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* 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 2013.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
STR-F1	2009	0.25	-	10	9.00	-	0.13	-	6.92	-	0.90	-
	2010	0.42	0.23	8	3.70	0.95	0.57	0.13	5.42	0.81	4.38	2.60
	2011	0.10	0.07	5	2.60	1.14	0.43	0.29	5.07	1.46	1.96	1.32
	2012	0.04	0.03	6	2.00	1.58	0.38	0.36	5.44	1.28	0.51	0.40
	2013	0.02	0.02	7	2.20	1.30	0.37	1.00	4.25	1.45	0.90	0.83
STR-F2	2011	0.32	0.18	8	4.20	1.30	0.59	0.09	6.02	2.08	5.80	2.82
	2012	0.01	0.01	2	0.40	0.55	0.00	0.00	7.45	2.76	0.12	0.16
	2013	0.18	0.04	6	3.40	1.14	0.51	1.00	4.32	0.64	2.03	0.50

* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

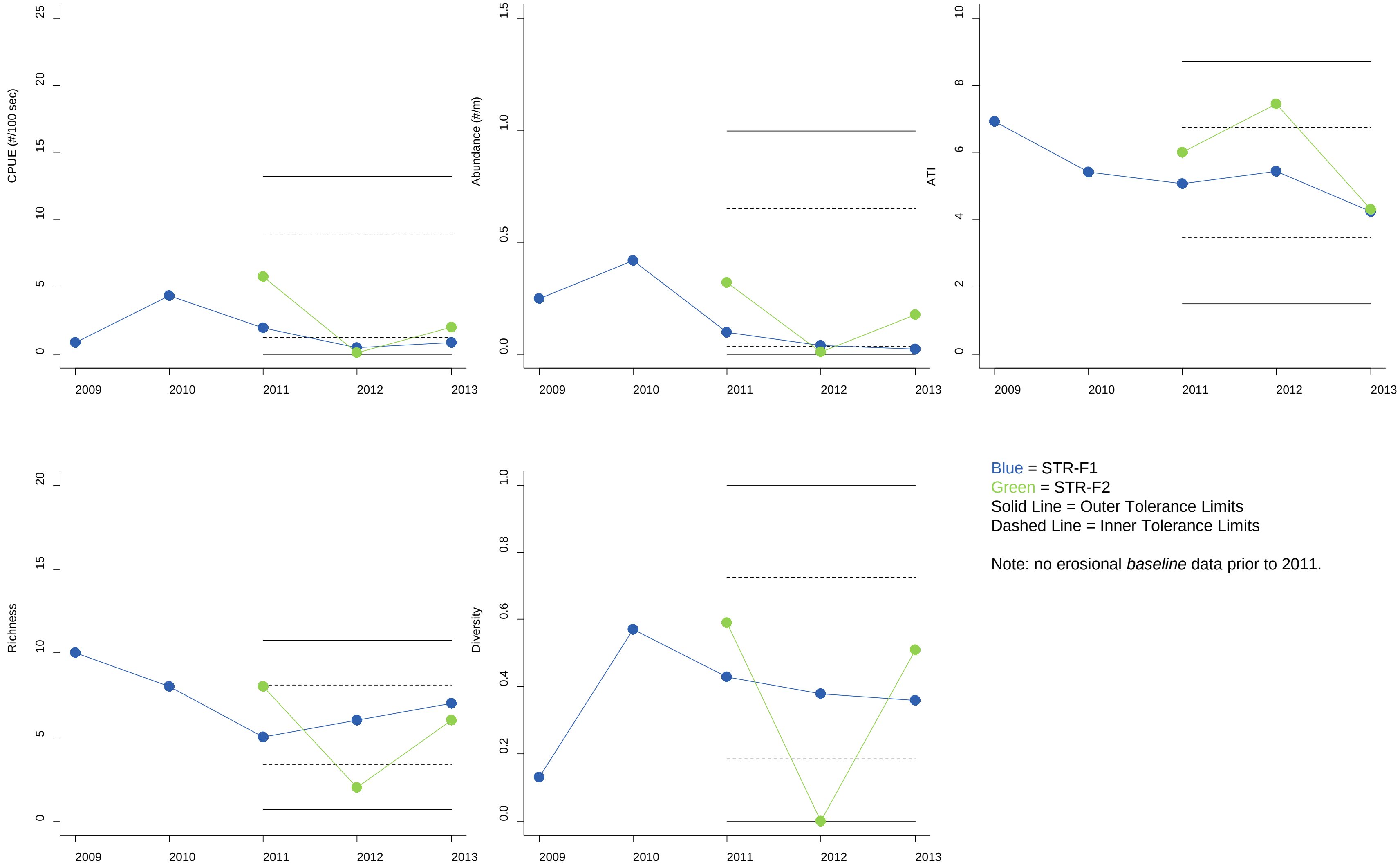
Table 5.3-17 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in the Steepbank River.

Measurement Endpoint	**P-value**		**Variance Explained (%)**		**Nature of Change(s)**
	Time Trend (*test* reach)	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*test* reach)**	***Baseline* Reach vs. *Test* Reach**	
Abundance	**<0.001**	0.486	71.8	2.0	Decreasing over time.
Richness	**0.011**	0.790	25.1	1.0	Decreasing over time.
Diversity	0.121	0.922	10.1	1.0	No change.
ATI	0.137	0.570	9.1	1.0	No change.
CPUE	**<0.001**	0.862	51.6	1.0	Decreasing over time.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Figure 5.3-9 Variation in fish assemblage measurement endpoints in the Steepbank River from 2009 to 2013 relative to regional *baseline* conditions.



Blue = STR-F1
Green = STR-F2
Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

Note: no erosional *baseline* data prior to 2011.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches.

5.4 TAR RIVER WATERSHED

Table 5.4-1 Summary of results for the Tar River watershed.

Tar River Watershed	Summary of 2013 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	🟠	incomplete data[1]
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*

[1] Data for TSS, TDS, nutrients and major ions missing for TAR-2 in fall 2013 because of laboratory error.

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.

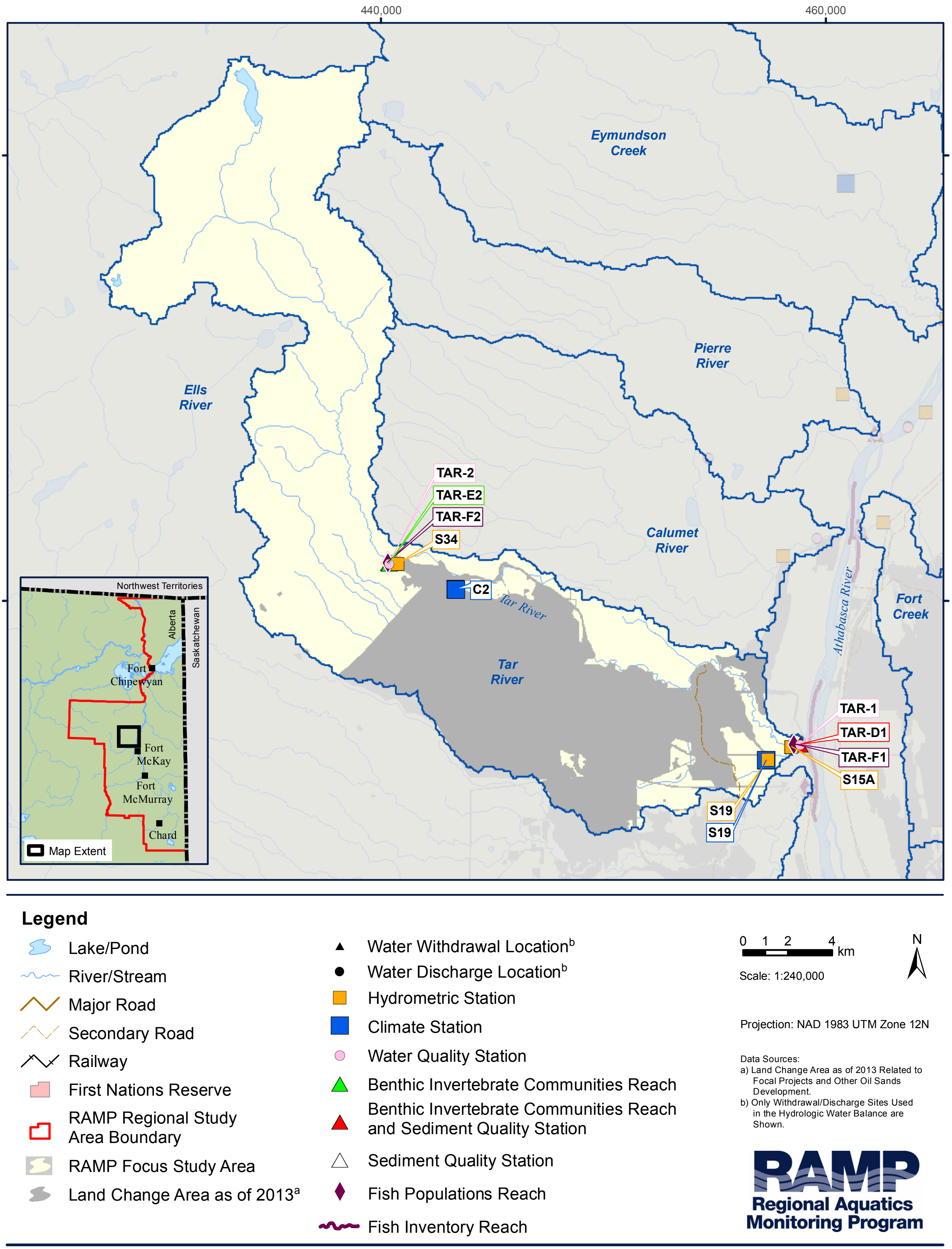
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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 (fish assemblages): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Figure 5.4-1 Tar River watershed.



Scale: 1:240,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2013 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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K04_Tar_20140224_ss.mxd

Figure 5.4-2 Representative monitoring stations of the Tar River, fall 2013.

Benthic Invertebrate and Fish Assemblage Reach TAR-D1/TAR-F1: facing downstream

Hydrology Station S15A: facing downstream

Hydrology Station S34 (above Horizon Lake): facing downstream

Benthic Invertebrate and Fish Assemblage Reach TAR-E2/TAR-F2: facing downstream

5.4.1 Summary of 2013 Conditions

As of 2013, approximately 33.5% (11,155 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 2013. Table 5.4-1 is a summary of the 2013 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 2013. Figure 5.4-2 contains fall 2013 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 28.8% 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 2013 between *test* station TAR-1 and regional *baseline* conditions were classified as **Moderate**. In fall 2013, most water quality measurement endpoints at *baseline* station TAR-2 and *test* station TAR-1 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations, with the exception of total suspended solids and various total metals, which were higher than previously measured at *test* station TAR-1 in fall 2013. A classification was not completed for *baseline* station TAR-2 due to an incomplete set of data, with only total and dissolved metals analyzed for this station in 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of benthic invertebrate community at *test* reach TAR-D1 were classified as **Moderate** because abundance, richness, and equitability differed between the *baseline* and *test* periods for this reach. The percentage of EPT taxa was lower in 2013 than it has been since 2006 and diversity decreased from 2012. All measurement endpoints of benthic invertebrate communities were within the historical range of variation for the lower Tar River, with the caveat that there were no mayflies or caddisflies, which were present during the *baseline* period and in most previous sampling years.

Differences in sediment quality observed in fall 2013 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Moderate**. Concentrations of benz[a]anthracene, benzo[a]pyrene, chrysene, dibenzo(a,h)anthracene, and total arsenic exceeded previously-measured maximum concentrations for *test* station TAR-D1 and also exceeded relevant CCME guidelines.

Fish Populations (fish assemblages) Differences in measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because richness and diversity were higher than the *baseline* range of variability and ATI was lower, indicating an improvement in the fish assemblage at this reach. In addition, there were no significant trends over time in any of the measurement endpoints.

5.4.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the Tar River watershed was conducted at 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 2013 WY, flows increased rapidly from the start of seasonal flow monitoring on April 29 to a peak of 19.0 m^3/s on May 13, 2013. This was the highest flow recorded in the 2013 WY, and was 200% higher than the historical mean open-water maximum daily flow of 6.34 m^3/s (Figure 5.4-3). Following this peak, flows decreased until early June, but values remained above the historical upper quartile range. Rainfall events from early to mid-June increased flows to above the historical maximum values from June 5 to June 26, and peaked at 9.52 m^3/s on June 11. Flows decreased steadily through July and August until the lowest open-water flow of 0.099 m^3/s on

September 17, which was 47% lower than the historical mean open-water minimum daily flow. Flows increased in early to mid-October due to rainfall events to above historical maximum values and then decreased to the historical median values by the end of the 2013 WY.

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 2013 was estimated to be 98.4 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 15.9 million m^3.
2. As of 2013, the area of land change in the Tar River watershed from focal projects that was not closed-circuited was estimated to be 13.1 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 0.422 million m^3.

The estimated cumulative effect of oil sands development was a decrease in flow of 15.5 million m^3 to the Tar River. The observed and estimated *baseline* hydrographs for RAMP Station S15A 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 28.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.4-3). These differences were classified as **High** (Table 5.4-1).

5.4.3 Water Quality

In fall 2013, 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 2013; and
- the upper Tar River (*baseline* station TAR-2), sampled since 2004.

Due to laboratory error, samples collected from *baseline* station TAR-2 for analysis of several conventional water quality variables (e.g., TSS, major ions, nutrients, and total hydrocarbons) were not analyzed; therefore, the analysis and discussion for this station included only data for certain variables (i.e., total and dissolved metals, ultra-trace mercury, and PAHs).

Temporal Trends The concentration of sulphate at *test* station TAR-1 (1998, 2002 to 2013) showed a significant increasing trend since 2004 (α=0.05). In previous years, a significant decreasing trend in the concentration of chloride (α=0.05) was observed at *baseline* station TAR-2; however, chloride was not analyzed in 2013.

2013 Results Relative to Historical Concentrations Concentrations of most water quality measurement endpoints in fall 2013 were within previously-measured concentrations (Table 5.4-4 and Table 5.4-5), with the following exceptions:

- total suspended solids, total aluminum, total arsenic, total mercury (ultra-trace), and dissolved aluminum, with concentrations that exceeded previously-measured maximum concentrations at *test* station TAR-1;
- pH, with a value below the previously-measured minimum value at *test* station TAR-1; and

- total boron, total molybdenum, and total strontium, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station TAR-2.

Ion Balance In fall 2013, the ionic composition of water at *test* station TAR-1 was generally consistent with previous years, but has shown high variability since sampling was initiated in 1998. The ionic composition of water at *test* station TAR-1 in fall 2013 was most similar to 2006, 2007, and 2010 than to more recent sampling years, which had higher anion contributions from chloride and sulphate than fall 2013 (Figure 5.4-4). *Baseline* station TAR-2 was not assessed for ionic composition in 2013 due to missing data.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of total nitrogen, total aluminum, and total mercury (ultra-trace) exceeded water quality guidelines at *test* station TAR-1 in fall 2013 (Table 5.4-4). Of the variables measured at *baseline* station TAR-2 in fall 2013, there were no guideline exceedances (Table 5.4-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Tar River in fall 2013 (Table 5.4-6):

- concentrations of total iron at *test* station TAR-1 and *baseline* station TAR-2; and
- concentrations of dissolved iron, sulphide, total chromium, total copper, total lead, total phenols, total phosphorus, total silver, total titanium, and total zinc at *test* station TAR-1.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of all water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2 were within regional *baseline* concentrations, with the exception of total suspended solids, total mercury (ultra-trace), and total arsenic at *test* station TAR-1, which exceeded the 95th percentile of regional *baseline* concentrations (Figure 5.4-5).

Water Quality Index The WQI value for *test* station TAR-1 (67.9) indicated a **Moderate** difference from fall regional *baseline* conditions in 2013. From 2009 to 2012, the calculated WQI value for *test* station TAR-1 showed a **Negligible-Low** difference from regional *baseline* conditions (WQI from 89.1 to 98.5) and a **High** difference from regional *baseline* conditions in fall 2008 (WQI of 59.8). In 2013, the WQI value for *baseline* station TAR-2 was 98.1; however, due to incomplete data, the 2013 WQI value for TAR-2 was based only on concentrations of total and dissolved metals.

Classification of Results Differences in water quality observed in fall 2013 between *test* station TAR-1 and regional *baseline* conditions were classified as **Moderate**. In fall 2013, most water quality measurement endpoints at *baseline* station TAR-2 and *test* station TAR-1 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations, with the exception of total suspended solids and various total metals, which were higher than previously measured at *test* station TAR-1 in fall 2013. A classification was not completed for *baseline* station TAR-2 due to an incomplete set of data, with only total and dissolved metals analyzed for this station in 2013.

5.4.4 Benthic Invertebrate Communities and Sediment Quality

5.4.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- depositional *test* reach TAR-D1, designated as *baseline* from 2002 to 2003 and as *test* from 2004 to 2013 (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.

2013 Habitat Conditions Water at *test* reach TAR-D1 was shallow (0.2 m), with a moderate velocity (0.4 m/s), alkaline (pH: 8.0), and relatively high conductivity (437 µS/cm) (Table 5.4-7). The substrate was dominated by sand (69%) and silt (21%), with low organic carbon (Table 5.4-7).

Water at *baseline* reach TAR-E2 was shallow (0.2 m), with a moderate velocity (0.5 m/s), weakly alkaline (pH: 7.9), and relatively high conductivity (405 µS/cm) (Table 5.4-7). The substrate was primarily comprised of small cobble and gravel. Periphyton chlorophyll *a* averaged 12.7 mg/m^2, which was within the range of regional *baseline* conditions (Figure 5.4-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach TAR-D1 was dominated by tubificid worms (69%) and chironomids (24%), with subdominant taxa consisting of Hydracarina and nematodes (Table 5.4-8). Chironomids were primarily comprised of the commonly found *Procladius* (Wiederholm 1983), but *Paralauterborniella*, *Saetheria*, and *Polypedilum* were also present. Gastropods and bivalves were present in low relative abundances.

The benthic invertebrate community of *baseline* reach TAR-E2 was dominated by mayflies (Ephemeroptera, 40%) and chironomids (34%), with subdominant taxa consisting of watermites (Hydracarina, 8%), stoneflies (Plecoptera, 5%), and Trichoptera (7%) (Table 5.4-8). A variety of worms including enchytraeids, naidids, nematodes, and oligochaetes were present in low relative abundances (<1% each). *Rheotanytarsus* was the most dominant chironomid, with orthoclads including *Cricotopus/Orthocladius, Lopescladius/Rheosmittia, Eukiefferiella*, and *Tvetenia* present, among other genera. The dominant caddisflies included the net spinner *Hydropsyche*, and the scraper *Glossosoma*, both of which are very common in north-temperate climates (Wiggins 1977). Mayflies were abundant and included members of the Heptageneiidae and Baetidae families, although the sensitive taxa *Empemerella* was present as well. Eleven kinds of stoneflies were present including members of the Capniidae, Chloroperlidae, and Perlidae families. Trichoptera were diverse and most commonly included *Hydropsyche, Glossosoma*, and *Brachycentrus.*

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlines in Section 3.2.3.1 that were possible given the data available for the Tar River watershed.

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 1, Section 3.2.3.1);
- changes over time for the period that the reach was designated as *test* (Hypothesis 2, Section 3.2.3.1);
- changes between 2013 values and the mean of all previous sampling years; and
- changes between 2013 values and the mean of all *baseline* years (2002 and 2003).

Abundance, richness, and CA Axis 2 scores were significantly higher during the *baseline* period at *test* reach TAR-D1, accounting for a large amount of the variance in annual means (>20%) (Table 5.4-9). The higher CA Axis 2 scores were likely due to higher relative abundances of chironomids and ceratopogonids during the *baseline* period (Figure 5.4-7).

Abundance and richness significantly increased while CA Axis 1 scores decreased over time during the *test* period (Table 5.4-9). These changes accounted for a large portion of the variance in annual means (>20%).

Taxa richness and CA Axis 1 scores were lower in 2013 than the mean of previous years, accounting for 28% and 23%, respectively, of the variance in annual means (Table 5.4-9). The lower CA Axis 1 scores in 2013 were likely due to a higher relative abundance of tubificids in 2013 and the absence of mayfly and caddisfly taxa (Figure 5.4-7).

Comparison to Published Literature In 2013, the percent of the benthic invertebrate community as worms at *test* reach TAR-D1 was high (>70%), which was similar to previous years. The high relative abundance of worms suggested that the habitat at *test* reach TAR-D1 was poor (Hynes 1960; Griffiths 1998). Larger permanent aquatic forms (e.g., bivalves and gastropods) were present but in low relative abundances. EPT taxa, which have been present in previous years, were absent in 2013. The decrease in taxa richness, the high relative abundance of worms (69%), and the absence of EPT taxa in 2013 were consistent with degradation at this reach.

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach TAR-D1 has more than eight years of data (2002 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* depositional reaches were evaluated. All benthic measurement endpoints were within the inner tolerance limits of the historical range of variation this reach (Figure 5.4-7 and Figure 5.4-8). However, the historical range for percent EPT taxa included a value of zero percent. The benthic invertebrate communities during the *baseline* period (2002 and 2003) contained mayflies and caddisflies, which are an expected component of the community. Their absence in 2013 was considered an indication of possible habitat degradation.

The variability of measurement endpoints at *baseline* reach TAR-E2 was contributing to the characterization of regional *baseline* erosional conditions. No comparisons to the regional data were conducted (Figure 5.4-10). Abundance has been increasing over time at *baseline* reach TAR-E2, while richness and percent EPT have remained fairly consistent. Equitability has decreased over the last three years (2011 to 2013) (Figure 5.4-9, Figure 5.4-10).

Classification of Results Differences in measurement endpoints of benthic invertebrate community at *test* reach TAR-D1 were classified as **Moderate** because abundance, richness, and equitability differed between *baseline* and *test* periods for this reach. The percentage of EPT taxa was lower in 2013 than it has been since 2006 and diversity decreased from 2012. All measurement endpoints of benthic invertebrate communities were within the historical range of variation for the lower Tar River, with the caveat that there were no mayflies or caddisflies, which were present during the *baseline* period and in most previous sampling years.

5.4.4.2 Sediment Quality

Sediment quality was sampled in fall 2013 in the Tar River, near its mouth (*test* station TAR-D1) in the same location where benthic invertebrate communities were sampled. This station was designated as *baseline* from 1998 to 2003 and as *test* from 2004 to 2013.

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 2013.

2013 Results Relative to Historical Conditions 2013 sediment quality data from *test* reach TAR-D1 were compared directly to data collected from this reach in 2006 and 2009 to 2012. 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 fall 2013 and exhibited a similar composition to previous sampling years, where proportions of silt, clay, and sand were within previously-measured values (Table 5.4-10). Concentrations of all other sediment quality measurement endpoints were within previously-measured concentrations at *test* station TAR-D1, with the exception of CCME F2 and F4 hydrocarbons, total arsenic, benz[a]anthracene, benzo[a]pyrene, chrysene, and dibenz(a,h)anthracene, which exceeded previously-measured maximum concentrations. Low molecular-weight F1 hydrocarbons and BTEX (benzene, toluene, ethylene, and xylene) were not detectable in fall 2013 (Table 5.4-10). Similar to previous years, concentrations of hydrocarbons in the sediments at *test* station TAR-D1 were dominated by F3 and F4 hydrocarbons, which likely indicated the presence of bitumen in sediments. The concentration of total PAHs in sediment (both absolute and carbon-normalized) was within previously-measured concentrations in 2013. The predicted PAH toxicity in fall 2013 was within the range of previously-calculated values, but continued to exceed the potential chronic toxicity threshold of 1.0, as in most recent years of sampling at this station (Table 5.4-10, Figure 5.4-11). Concentrations of total metals and total metals normalized to percent fine sediments were within the range of previously-measured concentrations (Figure 5.4-11).

Direct tests of sediment toxicity to invertebrates at *test* station TAR-D1 showed 80% survival in the amphipod *Hyalella* (Table 5.4-10). The midge *Chironomus* had only a 10% survival rate in fall 2013, which was below the previously-measured minimum value. The ten-day growth of *Chironomus* and 14-day growth of *Hyalella* were within the range of previously-measured values (Table 5.4-10).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines In fall 2013, concentrations of total arsenic, acenaphthene, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz(a,h)anthracene, phenanthrene, and CCME F3 hydrocarbons exceeded relevant CCME sediment quality guidelines at *test* station TAR-D1. The predicted PAH toxicity exceeded the potential threshold toxicity value of 1.0 (Table 5.4-10).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station TAR-D1, with the exception of the PAH hazard index and total metals (Figure 5.4-11). Both the PAH hazard index and total metals exceeded the 95th percentile of regional *baseline* concentrations; however, total metals normalized to percent fines were within the range of regional *baseline* concentrations (Figure 5.4-11).

Sediment Quality Index A SQI of 67.0 was calculated for *test* station TAR-D1 for fall 2013, indicating a **Moderate** difference from regional *baseline* conditions. In 2012, this station had an SQI value that showed **Negligible-Low** differences from regional *baseline* conditions, while in 2011; sediment quality at this station indicated a **Moderate** difference from regional *baseline* conditions.

Classification of Results Differences in sediment quality observed in fall 2013 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Moderate**. Concentrations of benz[a]anthracene, benzo[a]pyrene, chrysene, dibenzo(a,h)anthracene, and total arsenic exceeded previously-measured maximum concentrations for *test* station TAR-D1 and also exceeded relevant CCME guidelines.

5.4.5 Fish Populations

Fish assemblages were sampled in fall 2013 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).

2013 Habitat Conditions *Test* reach TAR-F1 was comprised of run habitat with a wetted width of 6.7 m and a bankfull width of 10.6 m (Table 5.4-11). The substrate was comprised entirely of sand. Water at *test* reach TAR-F1 in fall 2013 was shallow with a mean depth of 0.35 m and a mean velocity of 0.15 m/s. Water at *test* reach TAR-F1 was alkaline (pH: 8.25), with high conductivity (445 µS/cm), high dissolved oxygen (9 mg/L), and a temperature of 8.5˚C. Instream cover was diverse and comprised of small and large woody debris, macrophytes, and overhanging vegetation, with smaller amounts of filamentous algae and tree roots (Table 5.4-11).

Baseline reach TAR-F2 was comprised of riffle habitat, with a wetted width of 3.5 m and a bankfull width of 13 m (Table 5.4-11). The substrate was comprised primarily of cobble, with smaller amounts of small boulders and gravel. Water at *baseline* reach TAR-F2 was shallow with a mean depth of 0.15 m and a mean velocity of 0.17 m/s. The water was slightly acidic (pH: 6.77), with moderate conductivity (384 µS/cm), high dissolved oxygen (10.0 mg/L), and a temperature of 8.5 ˚C. Instream cover was comprised primarily of small woody debris, boulders, and overhanging vegetation, with smaller amounts of large woody debris and live trees (Table 5.4-11).

Relative Abundance of Fish Species The fish assemblage at *test* reach TAR-F1 was dominated by lake chub (45%), with burbot as the subdominant species, comprising approximately 14% of the total catch, which was higher than all previous sampling years (Table 5.4-12). Burbot were common near the confluence of many of the tributaries to the Athabasca River in fall 2013 and were caught in numbers not previously observed during RAMP surveys. With the exception of the large number of burbot, the species composition at *test* reach TAR-F1 in fall 2013 was comparable to previous years (Table 5.4-12).

The fish assemblage at *baseline* reach TAR-F2 was dominated by slimy sculpin (86% of the total catch) (Table 5.4-12). This was typical of this section of the Tar River, with a species composition in fall 2013 similar to previous sampling years.

Temporal and Spatial Comparisons Temporal comparisons were conducted at *test* reach TAR-F1 between 2009 and 2013 to test for changes over time in measurement endpoints (Hypothesis 1, Section 3.2.4.4).

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 were no significant changes in abundance (p=0.637), richness (p=0.505), diversity (p=0.698), or total CPUE (p=0.678) over time at *test* reach TAR-F1 (Table 5.4-13). As a result of the high proportion of burbot, which is considered a sensitive species, the ATI value at *test* reach TAR-F1 was the lowest recorded across sampling years but did not indicate a significant trend over time (p=0.213) (Table 5.4-13).

Mean values of measurement endpoints were relatively similar between 2012 and 2013 at *baseline* reach TAR-F2 (Table 5.4-14 and Figure 5.4-12). There was a slight increase in mean CPUE and diversity, a decrease in abundance, but no change in species richness between 2012 and 2013. The mean ATI value increased slightly in fall 2013 compared to previous years. The increase in mean ATI was likely due to the presence of fathead minnow, which has not been previously captured at *baseline* reach TAR-F2 and is considered a very tolerant species (Whittier et al. 2007).

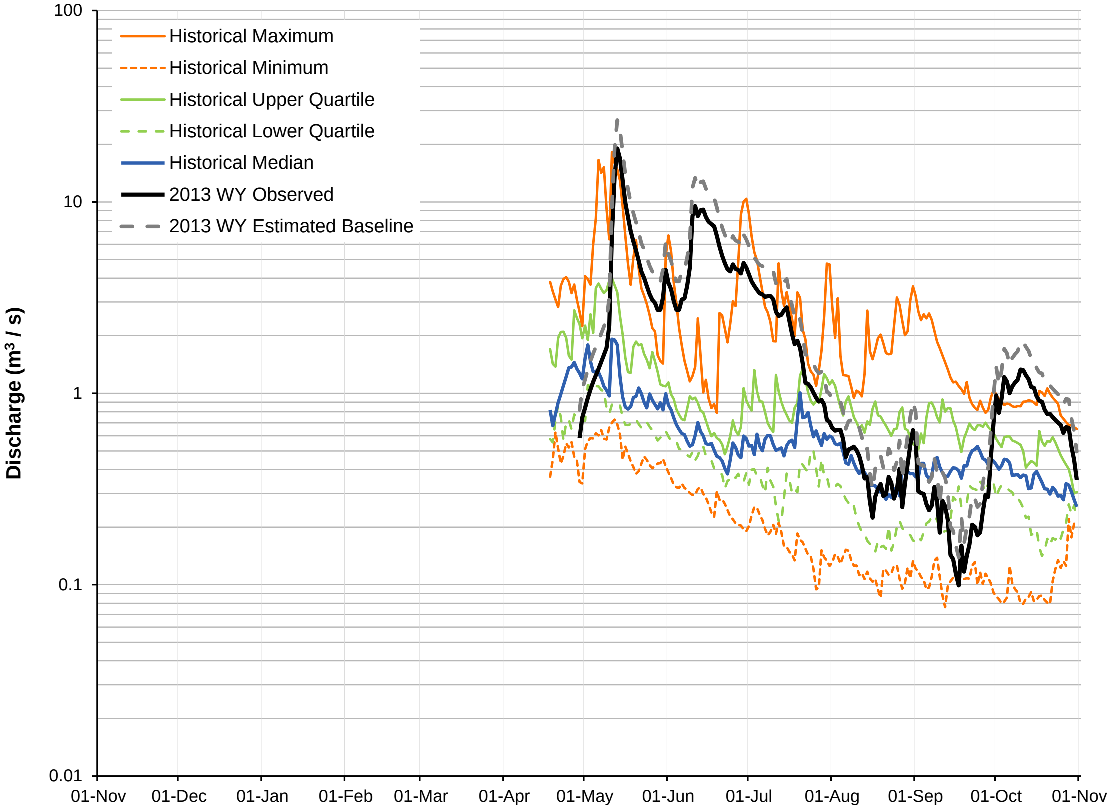
Comparison to Published Literature A summary of fish sampling activities within watersheds in the oil sands region was prepared in Golder (2004). This document provides a thorough assessment of fish species presence in watersheds prior to major oil sands development to capture historical *baseline* fish 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 eight of these fish species between *test* reach TAR-F1 and *baseline* reach TAR-F2 from 2009 to 2013, as well as six additional species that were not previously documented including brassy minnow, fathead minnow, finescale dace, longnose dace, northern redbelly dace, and northern pike (Table 5.4-12). All of the new species captured have been small-bodied species, or large-bodied species in the juvenile life stage, which are specifically targeted by backpack electrofishing methods used for the RAMP fish assemblage monitoring.

Habitat conditions documented by Golder (2004) were similar to conditions observed by RAMP from 2009 to 2013 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.

2013 Results Relative to Regional *Baseline* Conditions Mean values of diversity and richness were above the inner tolerance limit for the 95th percentile for the normal range while ATI was lower than the inner tolerance limit of the 5th percentile of variability for depositional *baseline* conditions at *test* reach TAR-F1, which were not indicative of degraded conditions and showed an improvement in the fish assemblage from 2012 (Figure 5.4-12).

Classification of Results Differences in measurement endpoints for fish assemblages between *test* reach TAR-F1 and regional *baseline* conditions were classified as **Negligible-Low** because richness and diversity were higher than the *baseline* range of variability and ATI was lower, indicating an improvement in the fish assemblage at this reach. In addition, there were no significant trends over time in any of the measurement endpoints.

Figure 5.4-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Tar River in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on Tar River near the mouth, Station S15A, provisional data for April 29 to October 31. The upstream drainage area is 332 km^2. Historic values were 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 2012).

Table 5.4-2 Estimated water balance at RAMP Station S15A, Tar River near the mouth, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**38.200**	**Observed discharge, obtained from Tar River near the mouth, Station S15A**
Closed-circuited area water loss from the observed *test* hydrograph	-15.904	Estimated 98.4 km^2 of the Tar River watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.422	Estimated 13.1 km^2 of the Tar River watershed with land change from focal projects as of 2013 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Tar River watershed from focal projects	0	None reported
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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**53.681**	**Estimated *baseline* discharge at Tar River near the mouth, RAMP Station S15A**
Incremental flow (change in total discharge)	-15.482	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-28.8%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for April 29 to October 31, 2013 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, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	3.367	2.396	-28.8%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	26.754	19.038	-28.8%
Open-water season minimum daily discharge	0.139	0.099	-28.8%

Note: Values were calculated from provisional data for April 29 to October 31, 2013 for Tar River near the mouth, RAMP Station S15A.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and 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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.09	12	8.10	8.20	8.50
Total suspended solids	mg/L	-	372	12	6	15	214
Conductivity	µS/cm	-	437	12	302	460	875
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.034	12	0.012	0.017	**0.125**
Total nitrogen	mg/L	1	**1.66**	12	0.50	0.83	**4.30**
Nitrate+nitrite	mg/L	3	0.11	12	<0.050	<0.10	**3.50**
Dissolved organic carbon	mg/L	-	21.2	12	12.0	17.0	22.6
Ions							
Sodium	mg/L	-	24.5	12	14.6	25.9	50.0
Calcium	mg/L	-	49.0	12	38.0	50.8	88.5
Magnesium	mg/L	-	14.3	12	11.3	16.0	24.3
Chloride	mg/L	120	8.07	12	1.70	4.51	50.00
Sulphate	mg/L	410	74.3	12	20.4	43.8	173.0
Total dissolved solids	mg/L	-	365	12	170	315	590
Total alkalinity	mg/L	-	141	12	121	162	221
Selected metals							
Total aluminum	mg/L	0.1	**16.60**	12	**0.17**	**0.60**	**3.95**
Dissolved aluminum	mg/L	0.1	0.057	12	0.005	0.012	0.026
Total arsenic	mg/L	0.005	0.0037	12	0.0009	0.0016	0.0022
Total boron	mg/L	1.2	0.078	12	0.053	0.083	0.145
Total molybdenum	mg/L	0.073	0.00047	12	0.00037	0.00102	0.00200
Total mercury (ultra-trace)	ng/L	5, 13	**27.0**	10	<1.20	1.45	**5.60**
Total strontium	mg/L	-	0.180	12	0.143	0.198	0.442
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.36	2	0.06	0.35	0.63
Oilsands Extractable	mg/L	-	1.49	2	0.47	0.90	1.33
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	18.50	2	2.47	3.07	3.66
Total dibenzothiophenes	ng/L	-	419.3	2	68.3	83.1	98.0
Total PAHs	ng/L	-	1,664	2	440.4	520.0	599.5
Total Parent PAHs	ng/L	-	100.4	2	36.77	40.28	43.79
Total Alkylated PAHs	ng/L	-	1,564	2	403.6	479.7	555.8
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.706**	12	0.004	**0.314**	**0.947**
Sulphide	mg/L	0.002	**0.018**	12	<0.002	**0.006**	**0.023**
Total chromium	mg/L	0.001	**0.0113**	12	0.0006	0.0009	**0.0059**
Total copper	mg/L	0.0039	**0.0094**	12	0.0008	0.0015	**0.0044**
Total iron	mg/L	0.3	**13.10**	12	**1.38**	**1.69**	**7.03**
Total lead	mg/L	0.0068	**0.0085**	12	0.0001	0.0004	0.0035
Total phenols	mg/L	0.004	**0.0049**	12	0.0010	**0.0060**	**0.0196**
Total phosphorus	mg/L	0.05	**0.398**	12	0.028	**0.078**	**0.232**
Total silver	mg/L	0.0001	**0.00011**	12	<0.00001	0.00001	**0.00040**
Total titanium	mg/L	0.1	**0.108**	12	0.004	0.016	0.042
Total zinc	mg/L	0.03	**0.034**	12	0.002	0.007	0.022

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; underlined values are outside of historical range.

Table 5.4-5 Concentrations of water quality measurement endpoints, upper Tar River (*baseline* station TAR-2), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	nd[1]	9	8.00	8.29	8.40
Total suspended solids	mg/L	-	nd[1]	9	<3.0	5.0	8.0
Conductivity	µS/cm	-	nd[1]	9	233	332	393
Nutrients							
Total dissolved phosphorus	mg/L	0.05	nd[1]	9	0.005	0.035	**0.058**
Total nitrogen	mg/L	1	nd[1]	9	0.40	0.50	**1.43**
Nitrate+nitrite	mg/L	3	nd[1]	9	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	nd[1]	9	8.0	13.0	15.8
Ions							
Sodium	mg/L	-	nd[1]	9	6.0	12.0	16.0
Calcium	mg/L	-	nd[1]	9	31.4	44.0	53.0
Magnesium	mg/L	-	nd[1]	9	8.8	13.2	14.3
Chloride	mg/L	120	nd[1]	9	<0.5	1.0	2.0
Sulphate	mg/L	270	nd[1]	9	20.0	37.2	49.0
Total dissolved solids	mg/L	-	nd[1]	9	160	233	280
Total alkalinity	mg/L	-	nd[1]	9	100	157	162
Selected metals							
Total aluminum	mg/L	0.1	0.096	9	0.073	**0.170**	**0.708**
Dissolved aluminum	mg/L	0.1	0.019	9	0.008	0.025	0.052
Total arsenic	mg/L	0.005	0.0010	9	0.0008	0.0012	0.0014
Total boron	mg/L	1.2	0.109	9	0.035	0.057	0.074
Total molybdenum	mg/L	0.073	0.0016	9	0.0008	0.0013	0.0015
Total mercury (ultra-trace)	ng/L	5, 13	1.10	9	0.80	<1.20	3.40
Total strontium	mg/L	-	0.20	9	0.10	0.16	0.19
Total hydrocarbons							
BTEX	mg/L	-	nd[1]	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	nd[1]	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	nd[1]	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	nd[1]	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	nd[1]	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.16	2	0.02	0.03	0.04
Oilsands Extractable	mg/L	-	0.67	2	0.34	0.59	0.83
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	<0.669	2	0.609	1.340	<2.071
Total dibenzothiophenes	ng/L	-	6.88	2	5.84	20.57	35.30
Total PAHs	ng/L	-	110.16	2	157.03	180.23	203.43
Total Parent PAHs	ng/L	-	25.76	2	16.51	17.87	19.23
Total Alkylated PAHs	ng/L	-	84.40	2	137.80	162.36	186.92
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.65**	9	**0.72**	**1.07**	**1.59**

[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.

[1] nd = no data (samples lost by laboratory and not analyzed).

Figure 5.4-4 Piper diagram of fall ion concentrations, Tar River.

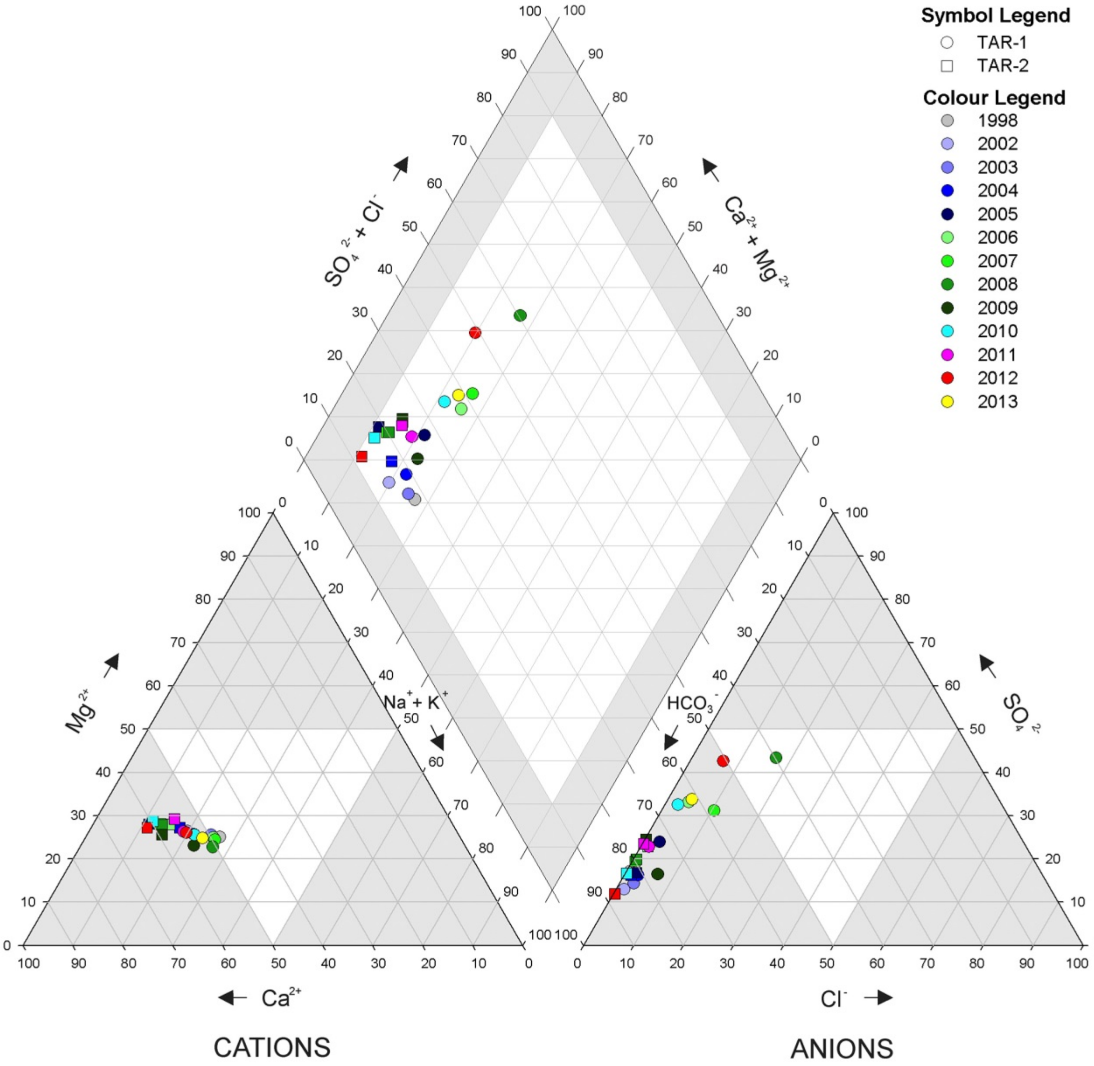


Table 5.4-6 Water quality guideline exceedances, Tar River, fall 2013.

Variable	Units	Guideline[a]	TAR-1	TAR-2
Dissolved iron	mg/L	0.3	0.706	-
Sulphide	mg/L	0.002	0.018	ns
Total chromium	mg/L	0.001	0.011	-
Total copper	mg/L	0.0039	0.0094	-
Total iron	mg/L	0.3	13.10	0.65
Total lead	mg/L	0.0068	0.0085	-
Total phenols	mg/L	0.004	0.005	ns
Total phosphorus	mg/L	0.05	0.398	ns
Total silver	mg/L	0.0001	0.00011	-
Total titanium	mg/L	0.1	0.108	-
Total zinc	mg/L	0.03	0.034	-

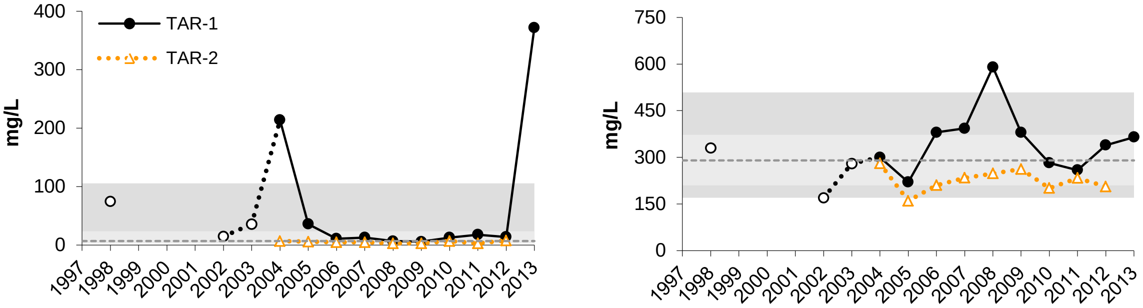
[a] Sources for all guidelines are outlined in Table 3.2-5.

ns = not sampled.

Figure 5.4-5 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to historical concentrations and regional *baseline* fall concentrations[1].

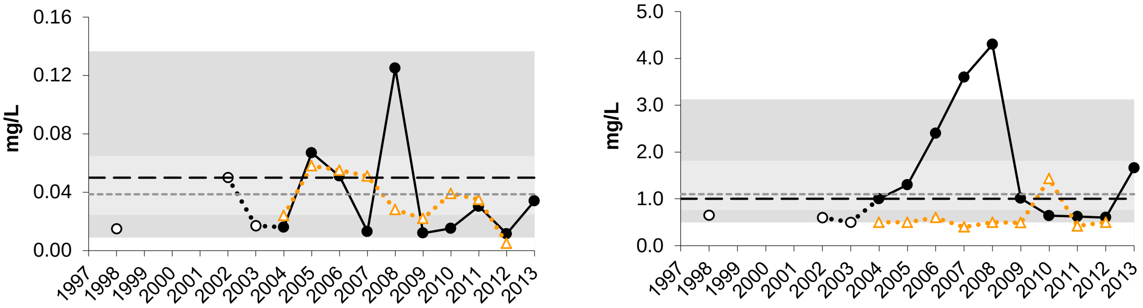
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



Dissolved Phosphorus

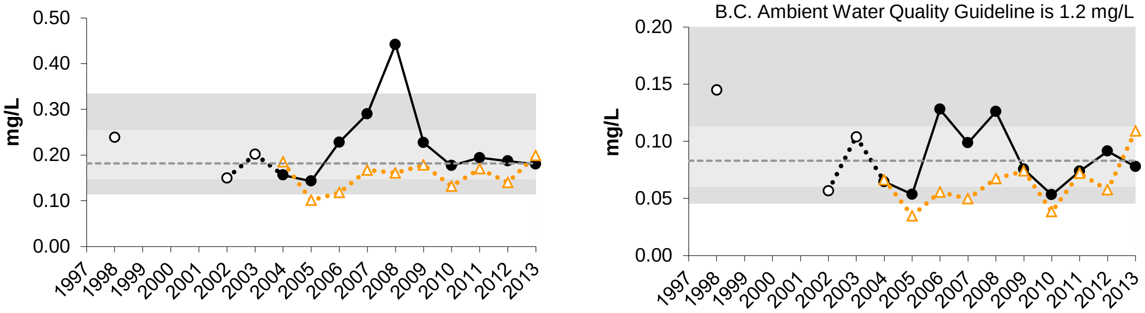
Total Nitrogen



Total Strontium

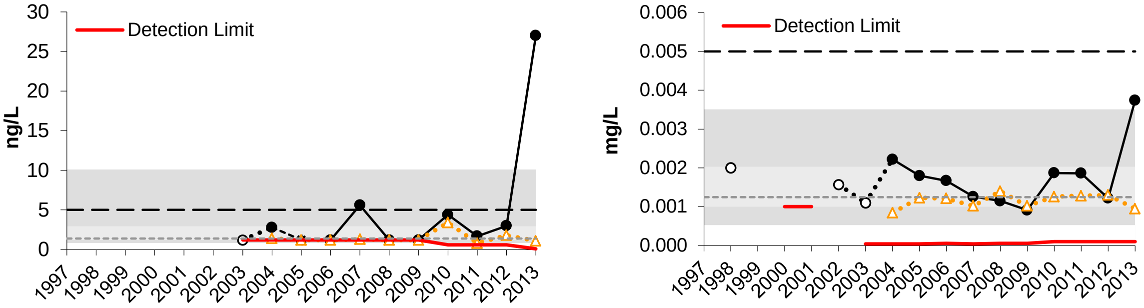
Total Boron

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.

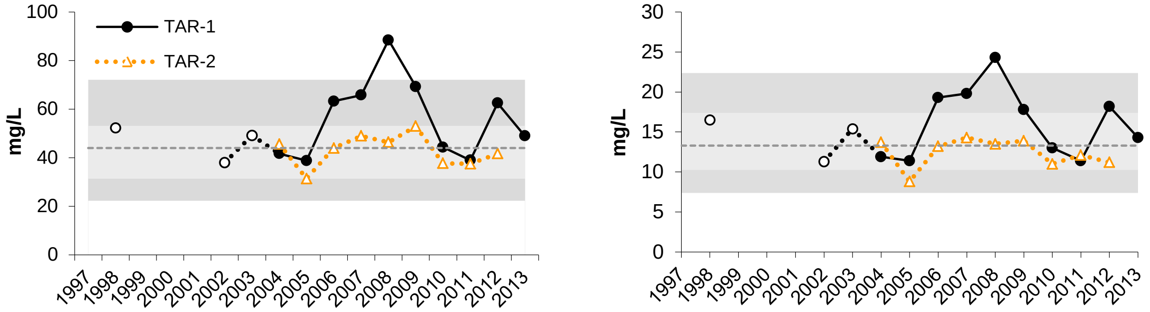
\- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

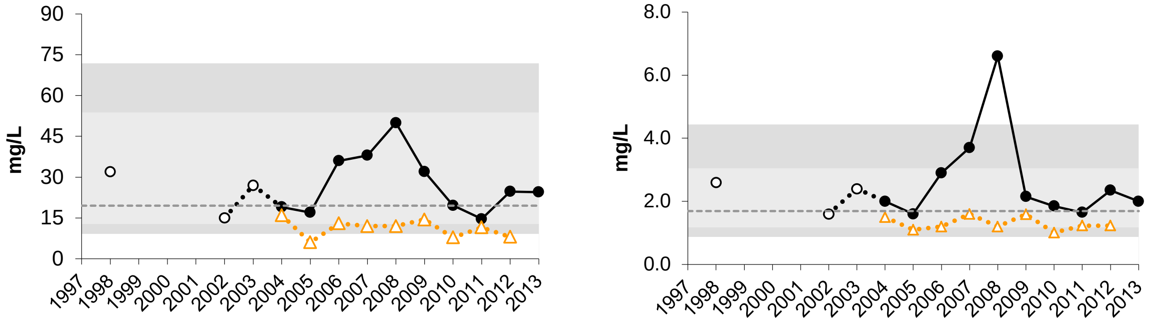
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

[1] Data for TSS, TDS, nutrients, and major ions missing for TAR-2 in fall 2013 because of laboratory error.

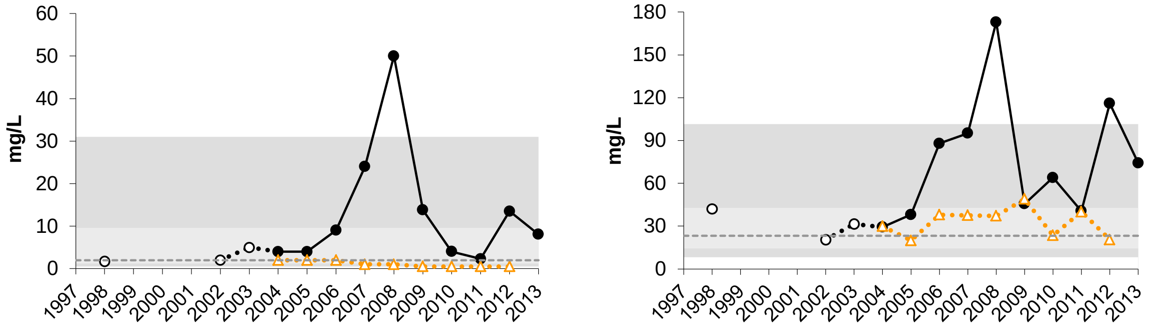
Figure 5.4-5 (Cont'd.)


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

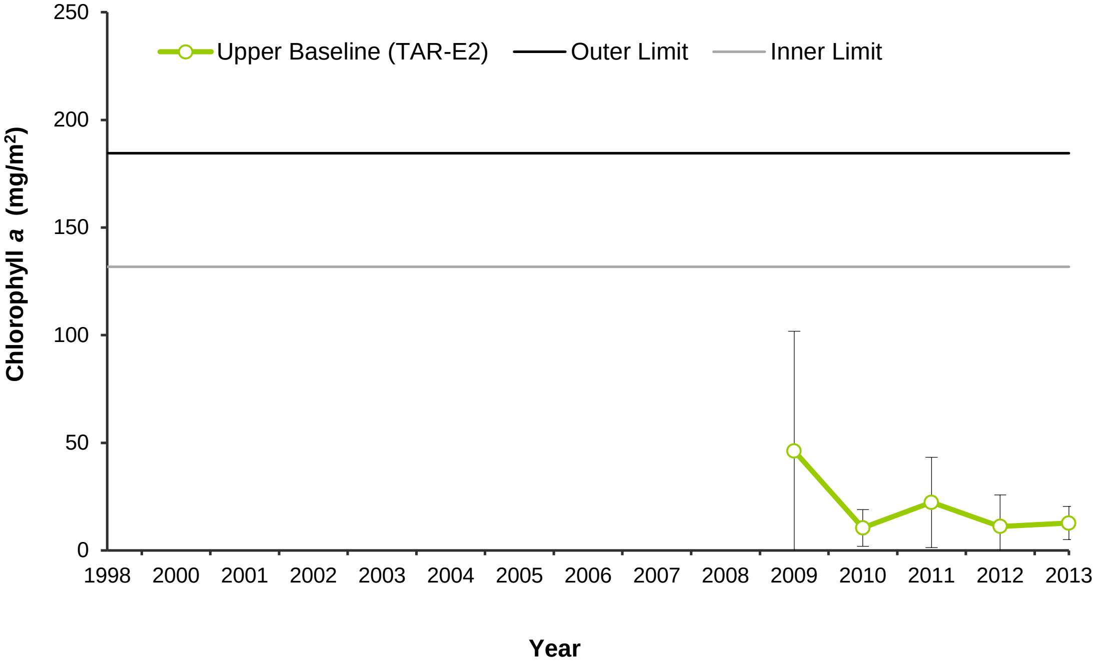
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

[1] Data for TSS, TDS, nutrients, and major ions missing for TAR-2 in fall 2013 because of laboratory error.

Table 5.4-7 Average habitat characteristics of benthic invertebrate community sampling locations in the Tar River, fall 2013.

Variable	**Units**	**TAR-D1** **Lower *Test* Reach of the Tar River**	**TAR-E2** **Upper *Baseline* Reach of the Tar River**
Sample date	-	Sept 11, 2013	Sept 13, 2013
Habitat	-	Depositional	Erosional
Water depth	m	0.2	0.2
Current velocity	m/s	0.42	0.53
Field Water Quality			
Dissolved oxygen	mg/L	8.4	9.5
Conductivity	µS/cm	437	405
pH	pH units	8.0	7.9
Water temperature	°C	10.3	12.5
Sediment Composition			
Sand	%	69	-
Silt	%	21	-
Clay	%	9	-
Total Organic Carbon	%	1.52	-
Sand/Silt/Clay	%	-	10
Small Gravel	%	-	14
Large Gravel	%	-	19
Small Cobble	%	-	31
Large Cobble	%	-	18
Boulder	%	-	9
Bedrock	%	-	0

Figure 5.4-6 Periphyton chlorophyll *a* biomass at *baseline* reach TAR-E2 of the Tar River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using regional *baseline* erosional data from years up to and including 2012.

Table 5.4-8 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at reaches of the Tar River.

Taxon	**Percent Major Taxa Enumerated in Each Year**					
	***Test* Reach TAR-D1**			***Baseline* Reach TAR-E2**		
	2002	**2003 to 2012**	**2013**	**2009**	**2010 to 2012**	**2013**
Nematoda	2	0 to 4	2	<1	<1 to 2	<1
Oligochaeta	-	-	-	-	<1	<1
Naididae	<1	0 to 4	-	<1	<1 to 2	1
Tubificidae	7	1 to 55	69	<1	1 to 2	-
Enchytraeidae	-	0 to 5	-	6	1 to 4	1
Lumbriculidae	-	-	-	-	0 to <1	-
Erpobdellidae	<1	0 to <1	-	-	-	-
Hirudinea	-	-	<1	-	-	-
Hydracarina	<1	0 to 2	2	4	8 to 13	8
Amphipoda	<1	-	-	-	-	-
Gastropoda	<1	0 to 2	<1	-	-	-
Bivalvia	1	0 to 2	1	-	-	-
Ceratopogonidae	1	0 to 16	<1	-	0 to <1	-
Chironomidae	86	<1 to 90	24	28	26 to 50	34
Diptera (misc.)	1	0 to 37	<1	27	0 to 5	4
Coleoptera	<1	0 to <1	-	-	<1	-
Ephemeroptera	<1	0 to 1	-	1	18 to 26	40
Odonata	<1	0 to <1	-	-	-	-
Plecoptera	<1	0 to <1	-	15	3 to 21	5
Trichoptera	<1	0 to <1	-	16	8 to 17	7
Lepidoptera	-	-	-	-	<1	-
Collembola	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	1,562	9 to 559	389	187	415 to 762	921
Richness	22	4 to 18	5	25	23 to 32	26
Equitability	0.27	0.27 to 0.73	0.44	0.33	0.29 to 0.37	0.25
% EPT	<1	0 to 2	0	56	5 to 37	52

Table 5.4-9 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach TAR-D1.

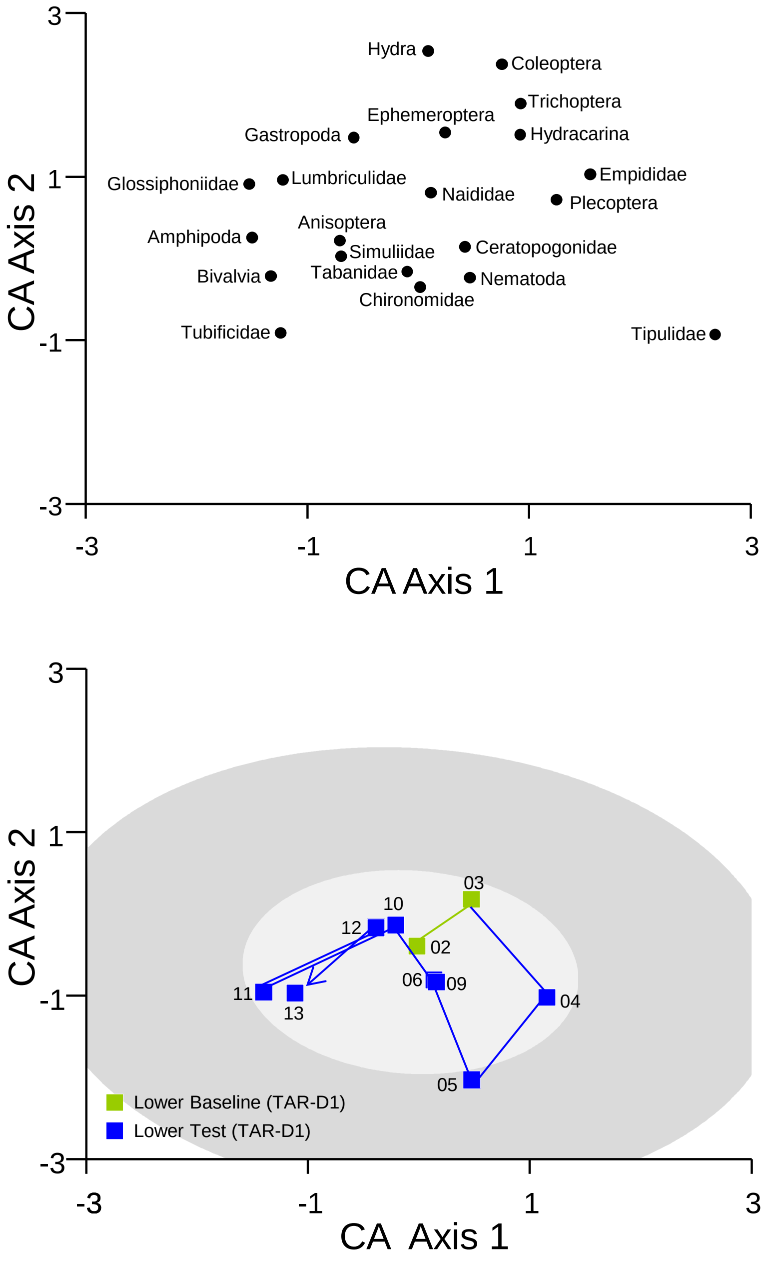
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Baseline **Period vs.** ***Test*** **Period**	**Time trend (*test* period)**	**2013 vs.** ***Baseline*** **Years**	**2013 vs. Previous Years**	***Baseline*** **Period vs.** ***Test*** **Period**	**Time trend (*test* period)**	**2013 vs.** ***Baseline*** **Years**	**2013 vs. Previous Years**	
Log Abundance	**<0.001**	**<0.001**	**0.004**	0.212	39	20	7	1	Higher during *baseline* period; increasing over time in *test* period; higher in 2013 than mean of previous years.
Log Richness	**<0.001**	**0.002**	0.510	**0.011**	38	4	28	4	Higher during *baseline* period; increasing over time in *test* period; higher in 2013 than mean of previous years.
Equitability	0.072	**0.001**	0.282	0.982	8	29	3	0	Decreasing over time in *test* period.
Log EPT	0.359	0.892	0.322	0.061	5	0	5	19	No change.
CA Axis 1	0.098	**<0.001**	**0.001**	**0.002**	5	69	23	18	Decreasing over time in *test* period; lower in 2013 than mean of *baseline* years and mean of all previous years.
CA Axis 2	**<0.001**	**0.002**	**0.006**	0.689	33	18	15	0	Higher during *baseline* period; increasing over time in *test* period; lower in 2013 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).

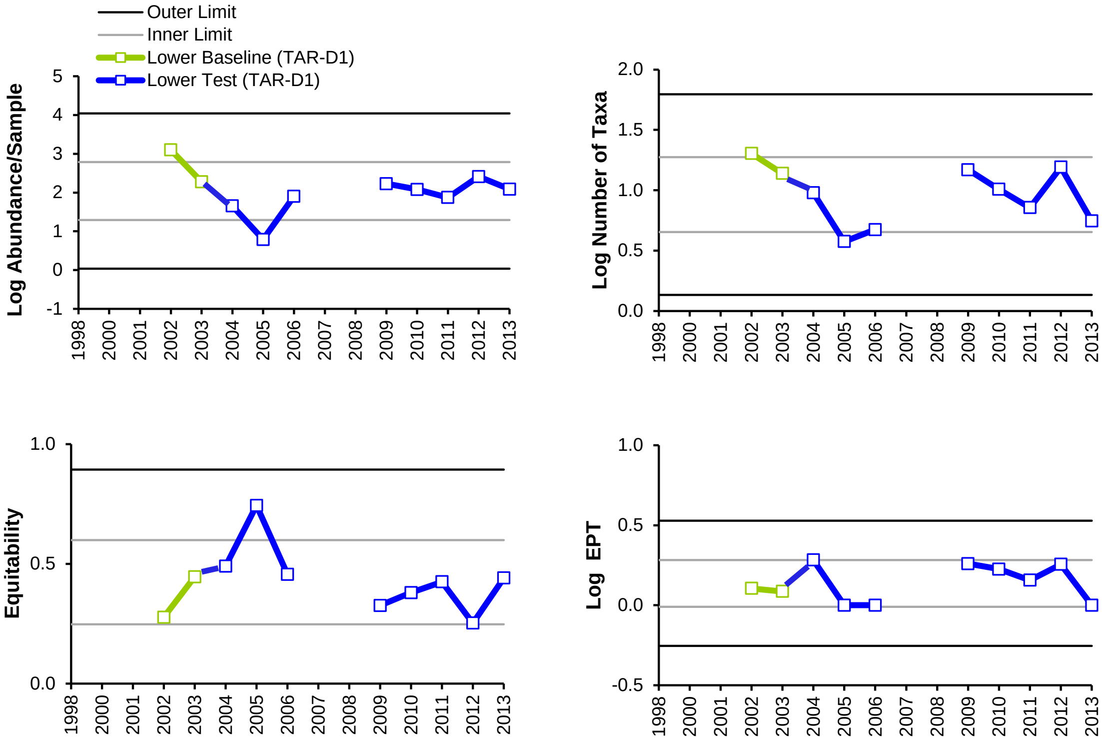
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.4-7 Ordination (Correspondence Analysis) of benthic invertebrate communities in the lower Tar River (*test* reach TAR-D1).



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores. The ellipses in the lower panel are the 5th and 95th tolerance limits for previous years in the lower Tar River.

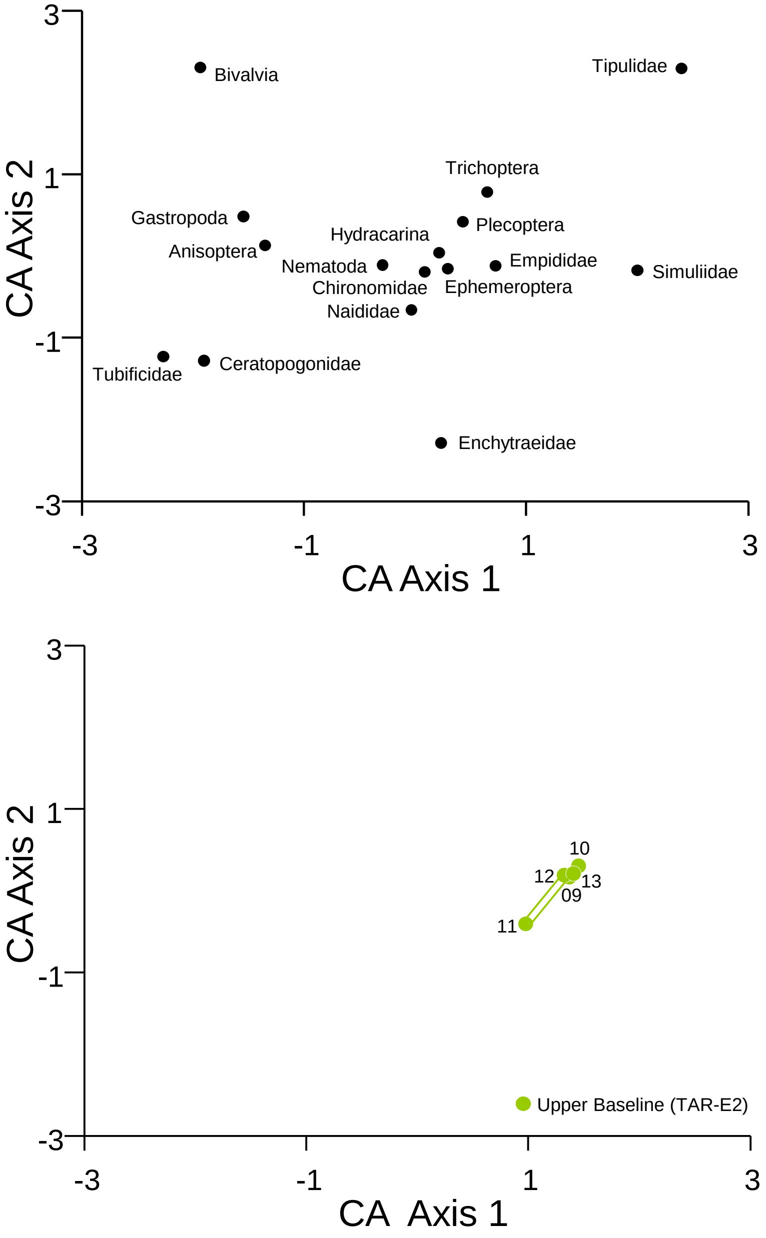
Figure 5.4-8 Variation in benthic invertebrate community measurement endpoints in the Tar River (*test* reach TAR-D1).



Note: Tolerance limits for the 5th and 95th percentiles were calculate using data from previous years (2002 to 2012).

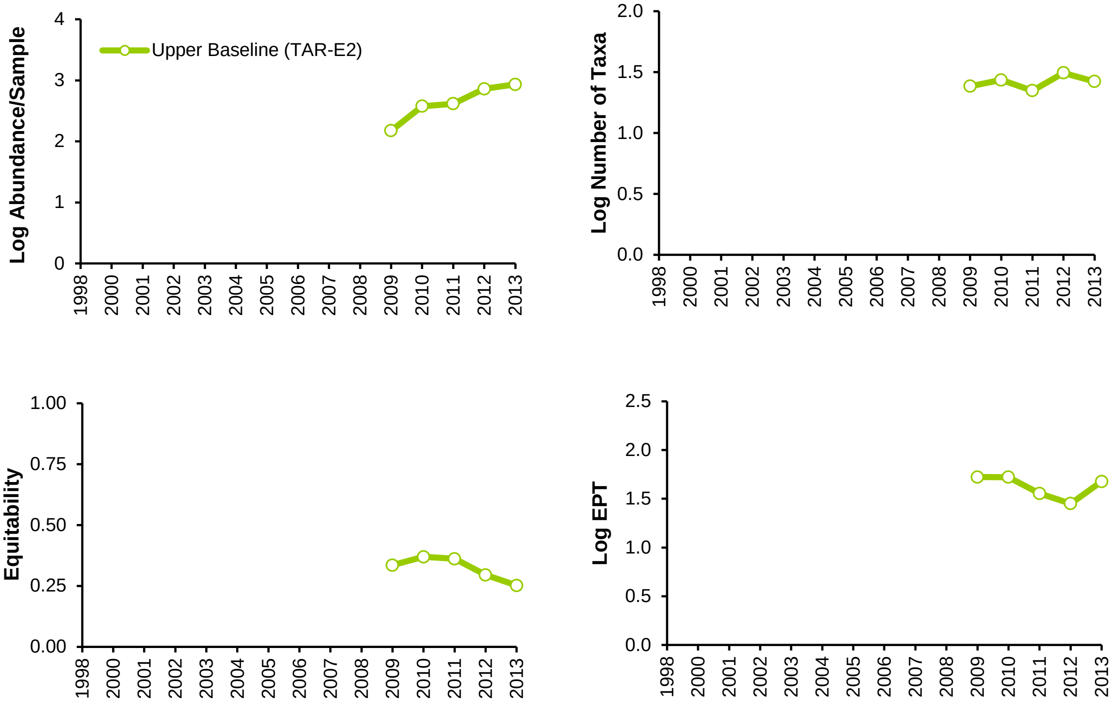
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.4-9 Ordination (Correspondence Analysis) of benthic invertebrate communities in the upper Tar River (*baseline* reach TAR-E2).



Note: Lower panel is the scatterplot of sample scores while the upper panel is the scatterplot of taxa scores.

Figure 5.4-10 Variation in benthic invertebrate community measurement endpoints in the Tar River (*baseline* reach TAR-E2).



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.4-10 Concentrations of selected sediment measurement endpoints, Tar River (*test* station TAR-D1), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**	**2001-2012 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	21	10	3	14	29
Silt	%	-	67	10	3	17	50
Sand	%	-	12	10	21	70	94
Total organic carbon	%	-	5.0	10	0.3	1.3	6.3
Total hydrocarbons							
BTEX	mg/kg	-	<30	7	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<30	7	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	105	7	13	29	100
Fraction 3 (C16-C34)	mg/kg	300[1]	**780**	7	220	**267**	**860**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	483	7	119	215	460
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.005	10	0.001	0.004	0.015
Retene	mg/kg	-	0.138	9	0.012	0.069	2.190
Total dibenzothiophenes	mg/kg	-	3.69	10	0.15	0.83	6.26
Total PAHs	mg/kg	-	12.27	10	0.62	3.35	19.14
Total Parent PAHs	mg/kg	-	0.427	10	0.047	0.110	0.449
Total Alkylated PAHs	mg/kg	-	11.84	10	0.52	3.17	18.69
Predicted PAH toxicity[3]	H.I.	1.0	**2.58**	10	0.21	**2.12**	**4.40**
Metals that exceed CCME guidelines in 2013							
Total arsenic	mg/kg	5.9	**10.8**	10	3.2	**6.2**	**9.5**
Other analytes that exceeded CCME guidelines in 2013							
Acenaphthene	mg/kg	0.00671	**0.00854**	10	0.00033	0.00225	**0.01940**
Benz[a]anthracene	mg/kg	0.0317	**0.0383**	10	0.0005	0.0036	**0.0381**
Benzo[a]pyrene	mg/kg	0.0319	**0.039**	10	0.002	0.006	**0.037**
Chrysene	mg/kg	0.0571	**0.101**	10	0.016	0.025	**0.093**
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.02530**	10	0.00065	0.00275	**0.02250**
Phenanthrene	mg/kg	0.0419	**0.0846**	10	0.0028	0.0163	**0.1670**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	1.0	7	5.0	7.0	9.8
Chironomus growth - 10d	mg/organism	-	2.01	7	0.90	1.92	4.00
Hyalella survival - 14d	# surviving	-	8.0	7	6.6	8.8	10.0
Hyalella growth - 14d	mg/organism	-	0.28	7	0.10	0.19	0.56

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

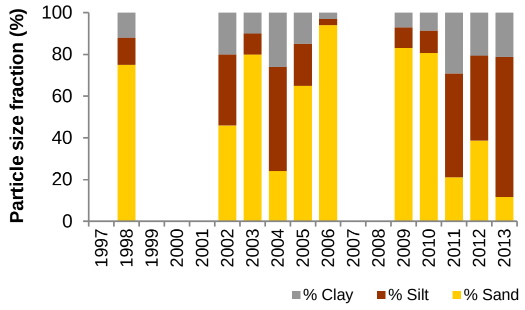
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

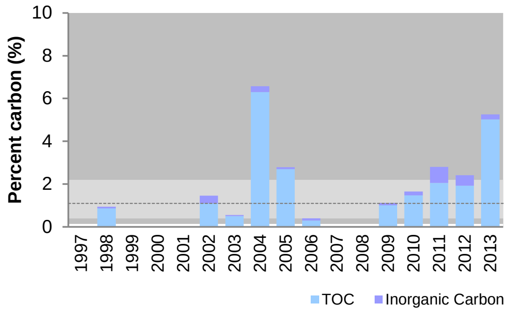
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.4-11 Variation in sediment quality measurement endpoints in the Tar River, *test* station TAR-D1.

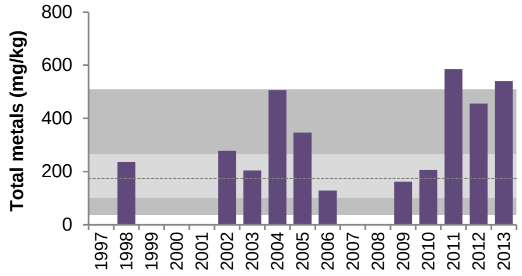
Particle size distribution



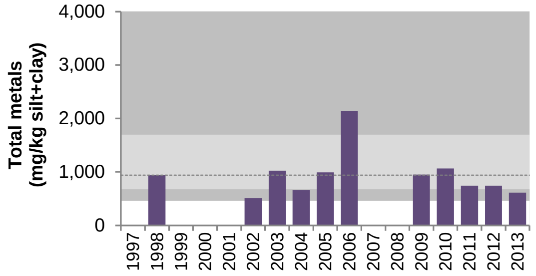
Carbon Content[1]



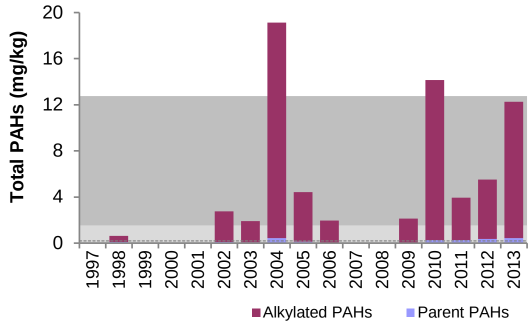
Total Metals[2]



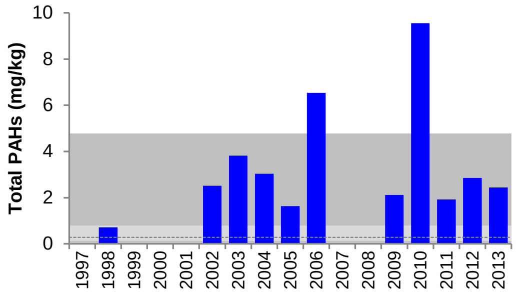
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



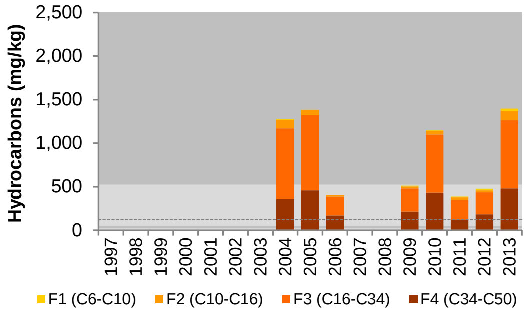
Total PAHs



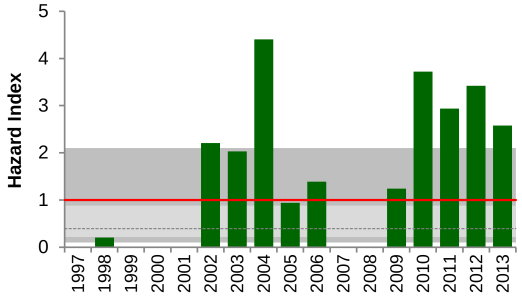
Total PAHs normalized to 1% TOC



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 2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.4-11 Average habitat characteristics of fish assemblage monitoring locations at *test* reach TAR-F1 and *baseline* reach TAR-F2 of the Tar River, fall 2013.

Variable	Units	TAR-F1 Lower *Test* Reach of the Tar River	TAR-F2 Upper *Baseline* Reach of the Tar River
Sample date	-	Sept 11, 2013	Sept 12, 2013
Habitat type	-	run	riffle
Maximum depth	m	0.47	0.24
Mean depth	m	0.35	0.15
Bankfull channel width	m	10.6	13.0
Wetted channel width	m	6.7	3.5
Substrate			
Dominant	-	sand	cobble
Subdominant	-	fines	small boulders
Instream cover			
Dominant	-	macrophytes, large woody debris, small woody debris, overhanging vegetation	small woody debris, overhanging vegetation, boulders
Subdominant	-	filamentous algae, live trees and roots	large woody debris, live trees and roots
Field water quality			
Dissolved oxygen	mg/L	9.0	10.0
Conductivity	µS/cm	445	384
pH	pH units	8.25	6.77
Water temperature	^{0}C	8.5	8.5
Water velocity			
Left bank velocity	m/s	0.16	0.19
Left bank water depth	m	0.25	0.12
Centre of channel velocity	m/s	0.17	0.21
Centre of channel water depth	m	0.39	0.19
Right bank velocity	m/s	0.14	0.12
Right bank water depth	m	0.43	0.15
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings, overhanging vegetation
Subdominant	-	overhanging vegetation	-

Table 5.4-12 Total number and percent composition of fish species captured at *test* reach TAR-F1 and *baseline* reach TAR-F2 of the Tar River, 2009 to 2013.

Common Name	Code	Total Species							Percent of Total Catch						
		TAR-F1				TAR-F2			TAR-F1				TAR-F2		
		2009	2011	2012	2013	2011	2012	2013	2009	2011	2012	2013	2011	2012	2013
Arctic grayling	ARGR	-	-	-	-	1	2	1	0	0	0	0	0.9	1.6	0.9
brassy minnow	BRMN	-	-	-	-	-	1	-	0	0	0	0	0	0.8	0
brook stickleback	BRST	2	2	-	-	-	-	-	18.2	3.9	0	0	0	0	0
burbot	BURB	-	-	-	10	-	-	-	0	0	0	13.5	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	7	0	0	0	0	0	0	6.3
finescale dace	FNDC	-	5	1	-	-	-	-	0	9.8	7.1	0	0	0	0
lake chub	LKCH	4	26	-	33	5	-	8	36.4	51.0	0	44.6	4.7	0	7.1
longnose dace	LNDC	-	1	-	-	-	-	-	0	2.0	0	0	0	0	0
longnose sucker	LNSC	-	4	3	5	-	7	-	0	7.8	21.4	6.76	0	5.7	0
northern pike	NRPK	1	1	-	5	-	-	-	9.1	2.0	0	6.76	0	0	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	0	0	0	1.35	0	0	0
slimy sculpin	SLSC	-	-	2	1	101	113	96	0	0	14.3	1.35	94.4	92.6	85.7
trout-perch	TRPR	-	8	1	2	-	-	-	0	15.7	7.1	2.7	0	0	0
white sucker	WHSC	4	4	7	17	-	-	-	36.4	7.8	50.0	23	0	0	0
Total Count		**11**	**51**	**14**	**74**	**107**	**122**	**112**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**4**	**8**	**5**	**8**	**3**	**4**	**4**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,552**	**743**	**1,905**	**1,786**	**1,043**	**1,526**	**1,347**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 5.4-13 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in the Tar River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	0.637	6.2	No change.
Richness	0.505	3.4	No change.
Diversity	0.698	1.1	No change.
ATI	0.213	12.6	No change.
CPUE (No./100 sec)	0.678	1.4	No change.

Bold values indicate significant difference ($p<0.05$).

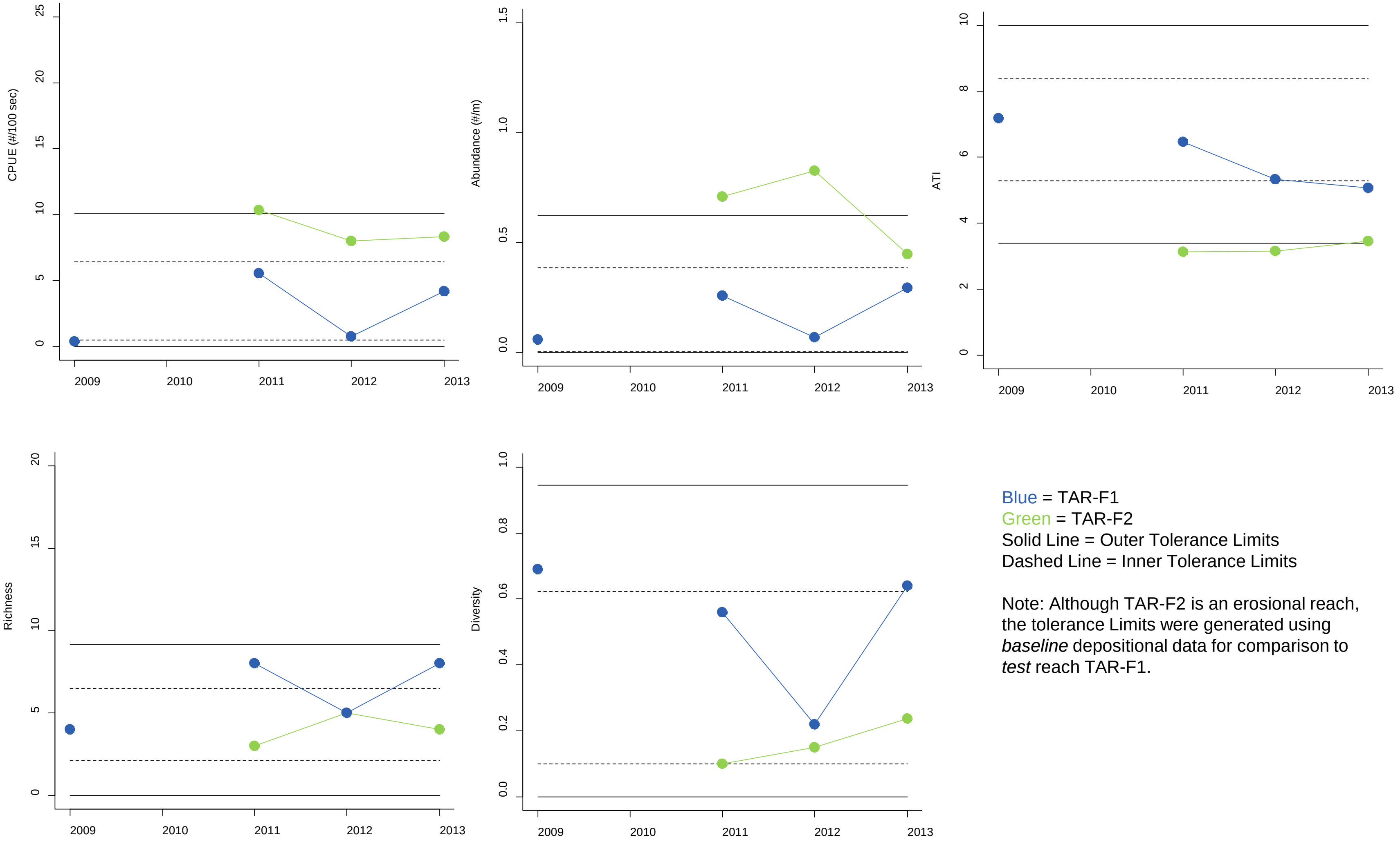
Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Table 5.4-14 Summary of fish assemblage measurement endpoints (±1SD) in reaches of the Tar River, 2009 to 2013.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TAR-F1	2009	0.06	-	4	4	-	0.69	-	7.18	-	0.39	-
	2011	0.26	0.28	8	4	2.59	0.53	0.32	6.43	0.65	5.56	6.57
	2012	0.07	0.09	5	2	1.30	0.22	0.31	5.33	2.19	0.75	0.96
	2013	0.30	0.35	8	5	1.92	0.64	0.17	5.08	1.32	4.20	5.07
TAR-F2	2011	0.71	0.24	3	2	0.55	0.10	0.13	3.13	0.22	10.36	3.94
	2012	0.83	0.21	4	2	0.84	0.15	0.11	3.16	0.20	7.98	2.05
	2013	0.45	0.08	4	3	0.45	0.24	0.11	3.46	0.34	8.33	1.59

SD = standard deviation across sub-reaches within a reach.

Figure 5.4-12 **Variation in fish assemblage measurement endpoints in the Tar River from 2009 to 2013, relative to regional *baseline* conditions.**



Blue = TAR-F1
Green = TAR-F2
Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

Note: Although TAR-F2 is an erosional reach, the tolerance Limits were generated using *baseline* depositional data for comparison to *test* reach TAR-F1.

This page intentionally left blank for printing purposes.

5.5 MACKAY RIVER WATERSHED

Table 5.5-1 Summary of results for the MacKay River watershed.

MacKay River Watershed	Summary of 2013 Conditions		
Climate and Hydrology			
Criteria	**07DB001** near Fort McKay	**S40** at Petro-Canada Bridge	no station sampled
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	**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 2013			
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.

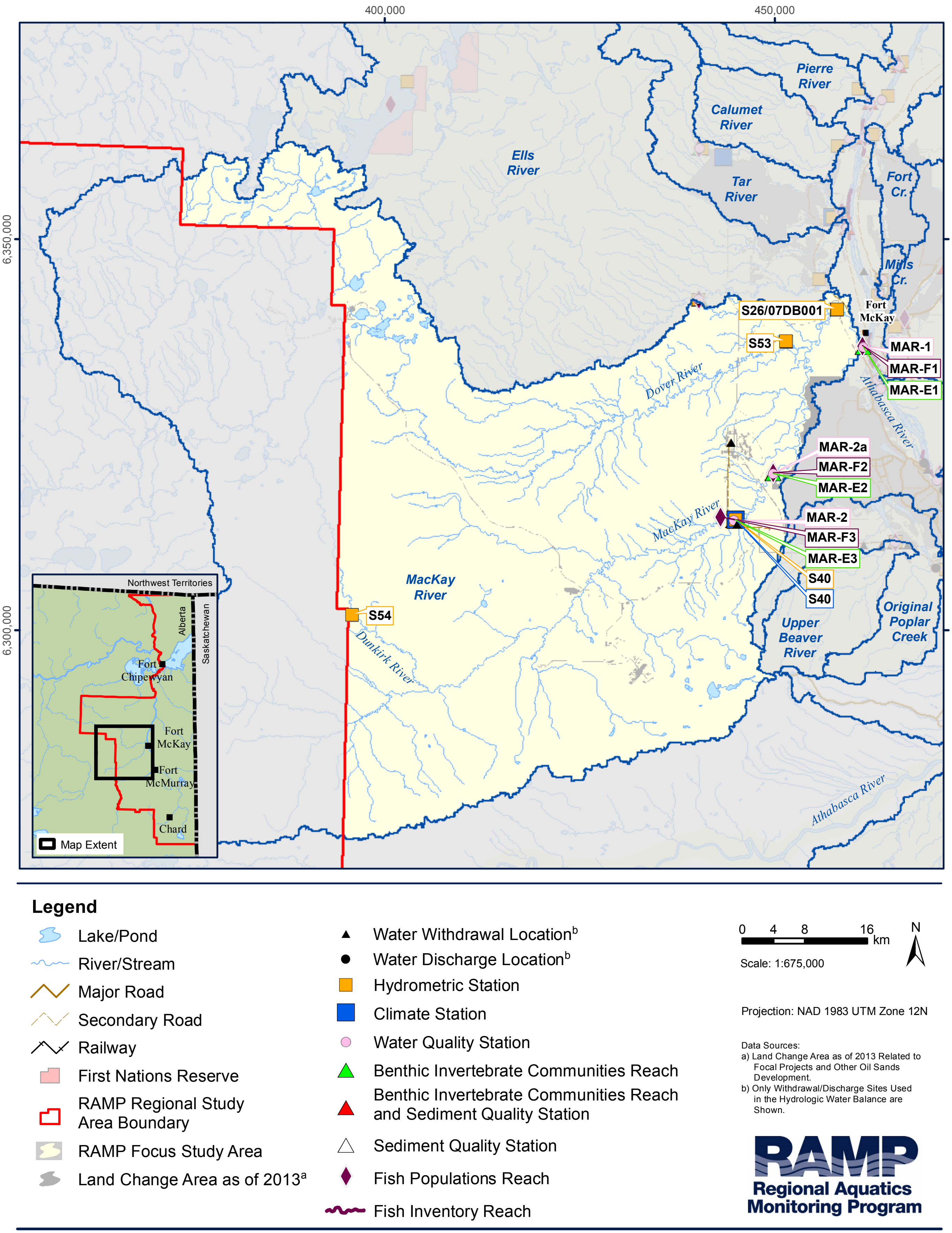
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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 (fish assemblages): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.4 for a detailed description of the classification methodology.

Figure 5.5-1 MacKay River watershed.



K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K05_MacKay_20140224_ss.mxd

Figure 5.5-2 Representative monitoring stations of the MacKay River watershed, fall 2013.

Benthic Invertebrate Reach MAR-E1: facing upstream

Benthic Invertebrate Reach MAR-E2: facing upstream

Hydrology Station S54: Dunkirk River near Fort McKay

Benthic Invertebrate Reach MAR-E3: facing downstream

5.5.1 Summary of 2013 Conditions

As of 2013, approximately 1% (4,587 ha) of the MacKay River watershed had undergone land change as a result of focal projects (Table 2.5-1). The designations of specific areas of the watershed are as follows:

1. The MacKay River watershed downstream of the Suncor MacKay River in situ operations and the part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 5.5-1) are designated as *test*.
2. The remainder of the watershed is designated as *baseline*.

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 2013. Table 5.5-1 is a summary of the 2013 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 2013. Figure 5.5-2 contains fall 2013 photos of monitoring stations in the watershed.

Hydrology The 2013 WY water balance was calculated for two different cases: (i) only focal projects in the MacKay River watershed; and (ii) focal projects plus other oil sands developments in the MacKay River watershed. The 2013 WY water balance mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge for the first case were 0.006%, 0.004%, 0.004%, and 0.004% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. For the second case these same measurement endpoints were 0.010%, 0.012%, 0.012%, and 0.012% larger, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. For both cases, these differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints in the MacKay River watershed were within the range of previously-measured concentrations, with the exception of phosphorus, which was higher than previously-measured maximum concentrations at all stations in fall 2013. Water quality measurement endpoints in the MacKay River watershed in fall 2013 were within the range of regional *baseline* concentrations, with the exception of potassium, which was below the 5th percentile at all stations and chloride, which was below the 5th percentile of regional *baseline* concentrations at *test* station MAR-2A and *baseline* station MAR-2. Differences between water quality in fall 2013 at *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 and regional *baseline* water quality conditions were classified as **Negligible-Low**.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *baseline* station MAR-2. Typically, the maximum concentration of total and dissolved metals occurred in April or May. Generally the maximum concentration of ions occurred in May and minimum concentrations occurred in April. The decrease in alkalinity and other ions in spring likely resulted from base-cation dilution by snowmelt and not from consumption of alkalinity by acidic compounds in snow. Despite the observed changes in ion concentrations, the ionic composition remained relatively stable throughout the year but was slightly less dominated by calcium in winter months.

Benthic Invertebrate Communities Differences in measurement endpoints of benthic invertebrate communities at *test* reach MAR-E1 were classified as **Moderate** because equitability has significantly increased over time; percent EPT was significantly lower in 2013 compared to *baseline* reach MAR-E3; and richness was lower than the historical and regional *baseline* variability. It should be noted; however, that there was an increase in the relative proportion of EPT taxa and a decrease in relative worm abundance from 2012 indicating an improvement in taxa composition from 2012 to 2013 at *test* reach MAR-E1.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach MAR-E2 were classified as **Negligible-Low** because the significant increase in percent EPT over time was not indicative of a negative change. The benthic invertebrate community at *test* reach MAR-E2 was representative of good overall water quality, with a high proportion of EPT taxa and a low relative abundance of worms.

Fish Populations (fish assemblages) Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F1 were classified as **High** because four of the five measurement endpoints (CPUE, abundance, ATI, and diversity) were near the outer tolerance limit for the 5th percentile of regional *baseline* variability; there were significant decreases in diversity and richness over time; and diversity was significantly lower than *baseline* reach MAR-F3. Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F2 were classified as **Moderate** because abundance was near the outer tolerance limit for the 5th percentile of regional *baseline* variability and there were significant decreases in CPUE and abundance of fish over time.

5.5.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the MacKay River watershed was conducted at 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 WSC Station 07DB001 (RAMP Station S26) from 1973 to 1986 and more recently from 2002 to 2013, 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 2013 WY was 808 million m^3. This value was 107% higher than the mean historical annual runoff volume based on the available period of record. Flows steadily decreased from November 2012 to March 2013, with flows from mid-December 2012 to early March 2013 near the historical maximum values (Figure 5.5-3). Flows increased from mid-April to early May to a freshet peak of 155 m^3/s on May 8. Flows decreased until early June before increasing due to rainfall events that occurred in early to mid-June. The maximum daily flow of 187 m^3/s occurred on June 13, which was 77% higher than the historical mean annual maximum daily flow. Following this peak, flows decreased until late September before rain events in early October caused flows to exceed historical median values until the end of the 2013 WY. The minimum open-water daily flow of 1.92 m^3/s was recorded on September 24 and was 48% lower than the historical mean minimum daily flow of 3.66 m^3/s for the open-water period.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at WSC Station 07DB001 (RAMP Station S26) is presented for two different cases (Table 5.5-2): (i) only focal projects in the MacKay River watershed; and (ii) focal projects plus other oil sands developments in the MacKay River watershed.

Case 1 – Only focal projects in the MacKay River watershed:

1. The closed-circuited land area from focal projects as of 2013 was estimated to be 7.11 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 1.03 million m^3.
2. As of 2013, the area of land change in the MacKay River watershed from focal projects that was not closed-circuited was estimated to be 34.3 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 1.00 million m^3.
3. In the 2013 WY, Suncor withdrew approximately 8,680 m^3 of water for dust suppression activities.

The estimated cumulative effect of focal project developments in the 2013 WY was a loss of flow of 0.045 million m^3 at WSC Station 07DB001 (RAMP Station S26). The 2013 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.006%, 0.004%, 0.004%, and 0.004% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.5-3); these differences were classified as **Negligible-Low** (Table 5.5-1).

Case 2 – Focal projects plus other oil sands developments in the MacKay River watershed:

1. The closed-circuited land area from focal projects plus other oil sands developments as of 2013 was estimated to be 7.11 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 1.03 million m^3.
2. As of 2013, the area of land change in the MacKay River watershed from focal projects plus other oil sands developments that was not closed-circuited was estimated to be 38.8 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 1.12 million m^3.
3. In the 2013 WY, Suncor withdrew approximately 8,680 m^3 of water for dust suppression.

The estimated cumulative effect of all oil sands development in the 2013 WY was a loss of flow of 0.045 million m^3 at WSC Station 07DB001 (RAMP Station S26). The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.5-3. The 2013 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.010%, 0.012%, 0.012%, and 0.012% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.5-3); these differences were classified as **Negligible-Low** (Table 5.5-1).

5.5.3 Water Quality

In fall 2013, 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 2013;
- 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 2013, excluded from the 2013 regional *baseline* calculations because of upstream, non-RAMP oil-sands activities.

Monthly water quality sampling was also conducted at *baseline* station MAR-2 in 2013.

Temporal Trends Significant (α=0.05) decreasing trends in fall concentrations of total boron, total potassium, and sulphate and an increasing trend of total arsenic were observed over time at *test* station MAR-1 (1998 to 2013). A decreasing trend in chloride and an increasing trend in total arsenic were observed at *baseline* station MAR-2 (2002 to 2013). Trend analysis was not conducted for *test* station MAR-2A given that there were only four years of data.

2013 Results Relative to Historical Concentrations In fall 2013, concentrations of water quality measurement endpoints were within previously-measured concentrations (Table 5.5-4 to Table 5.5-6), with the exception of the following:

- dissolved phosphorus, with concentration that exceeded previously-measured maximum concentrations at *test* stations MAR-1 and MAR-2A, and *baseline* station MAR-2; and
- Sodium, magnesium, and chloride, with concentrations that exceed previously-measured maximum concentrations at *test* station MAR-2A.

Ion Balance In fall 2013, the ionic composition of water at all stations in the MacKay River was consistent with previous sampling years and dominated by bicarbonate and calcium (Figure 5.5-4). In 2013, the ionic composition was slightly more dominated by calcium than observed in 2012 at all stations.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2 in fall 2013 exceeded the published guideline (Table 5.5-4 to Table 5.5-6). The guideline for total nitrogen was exceeded at *test* station MAR-2A and *baseline* station MAR-2 and the guideline for dissolved phosphorus was also exceeded at *baseline* station MAR-2.

Other Fall Water Quality Guideline Exceedances Other water quality guideline exceedances measured in the MacKay River in fall 2013 included dissolved iron, total iron, sulphide, total phenols, and total phosphorus at *test* stations MAR-1 and MAR-2A and *baseline* station MAR-2 (Table 5.5-7).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, all water quality measurement endpoints were within the range of regional *baseline* concentrations, with the exception of the following (Figure 5.5-5):

- Potassium, with concentrations below the 5th percentile of regional *baseline* concentrations at all stations; and
- Chloride, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* station MAR-2A and *baseline* station MAR-2.

Water Quality Index The WQI for *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 were 100, 100, and 98.7, respectively, indicating **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2013.

Monthly Water Quality Results Water quality in 2013 was collected monthly at *baseline* station MAR-2 (Table 5.5-8). The maximum concentrations of most ions occurred in April and minimum concentrations occurred most frequently in May. The highest concentrations of total and dissolved metals were typically observed in April or May.

Monthly Water Quality Guideline Exceedances Water quality exceedances measured at *baseline* station MAR-2 in 2013 included (Table 5.5-9):

- dissolved phosphorus in January, February, March, June, July, August, and September;
- total mercury (ultra-trace), total silver, total titanium, and dissolved aluminum in May;
- total chromium in May, June, and July;
- total phenols in all months, with the exception of June;
- sulphide in all months, with the exception of October;
- total aluminum in all months, with the exception of November;
- total phosphorus in all months, with the exception of October and November; and
- total iron, dissolved iron, and total nitrogen in all months.

2013 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2013, most monthly data collected at *baseline* station MAR-2 were within regional *baseline* conditions for fall, with the exception of (Figure 5.5-6):

- total suspended solids in May, when the maximum concentration in 2013 exceeded the 95th percentile of regional *baseline* fall concentrations;
- total dissolved solids in May, when the minimum concentration in 2013 was below the 5th percentile of regional *baseline* fall concentrations;
- total strontium in May and June, when minimum concentrations in 2013 was below the 5th percentile of regional *baseline* fall concentrations;
- calcium and magnesium, with concentrations below the 5th percentile of regional *baseline* concentrations in May (yearly minimum), June, July, August, and October;
- sodium, with concentrations below the 5th percentile of regional *baseline* concentrations in May (yearly minimum), June, and July;
- potassium, with concentrations below the 5th percentile of the regional *baseline* concentration in July, August (yearly minimum), September, October, and November;
- sulphate, with concentrations below the 5th percentile of regional *baseline* concentrations in May, June, July (yearly minimum), and August;
- total alkalinity, with concentrations below the 5th percentile of regional *baseline* concentrations in May (yearly minimum), June, July, and August; and
- hardness, with values below the 5th percentile of regional *baseline* concentrations in May (yearly minimum), June, July, August, and October.

Monthly Ion Balance The ionic composition of water at *baseline* station MAR-2 remained fairly consistent across months in 2013. This station was consistently dominated by bicarbonate and calcium throughout the year and showed slightly less dominance in calcium in winter months (Figure 5.5-7).

Classification of Fall Results Concentrations of most water quality measurement endpoints in the MacKay River watershed were within the range of previously-measured concentrations, with the exception of phosphorus, which was higher than previously-measured maximum concentrations at all stations in fall 2013. Water quality measurement endpoints in the MacKay River watershed in fall 2013 were within the range of regional *baseline* concentrations, with the exception of potassium, which was below the 5th percentile at all stations and chloride, which was below the 5th percentile of regional *baseline* concentrations at *test* station MAR-2A and *baseline* station MAR-2. Differences between water quality in fall 2013 at *test* stations MAR-1, MAR-2A, and *baseline* station MAR-2 relative and regional *baseline* water quality conditions were classified as **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *baseline* station MAR-2. Typically, the maximum concentration of total and dissolved metals occurred in April or May. Generally the maximum concentration of ions occurred in May and minimum concentrations occurred in April. The decrease in alkalinity and other ions in spring likely resulted from base-cation dilution by snowmelt and not from consumption of alkalinity by acidic compounds in snow. Despite the observed changes in ion concentrations, the ionic composition remained relatively stable throughout the year but was slightly less dominated by calcium in winter months.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- erosional *test* reach MAR-E1, near the mouth, 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.

2013 Habitat Conditions Water at *test* reach MAR-E1 in fall 2013 was shallow (0.26 m), with a moderate velocity (0.4 m/s), and alkaline (pH: 8.1), with moderate conductivity (279µS/cm), and high dissolved oxygen (Table 5.5-10). The substrate was dominated by sand/silt/clay (40%) and gravel (small, 19% and large, 20%) (Table 5.5-10). Periphyton chlorophyll *a* biomass averaged 5.7 mg/m^2, which was within the range of *baseline* variability (Figure 5.5-8).

Water at *test* reach MAR-E2 was shallow (0.25 m), with a fast velocity (0.6 m/s), and alkaline (pH: 8.1), with moderate conductivity (239 µS/cm). The substrate at *test* reach MAR-E2 was dominated by small and large cobble (23% and 40%, respectively) (Table 5.5-10). Periphyton chlorophyll *a* biomass averaged 3.12 mg/m^2, which was within the range of *baseline* variability (Figure 5.5-8).

Water at *baseline* reach MAR-E3 was also shallow (0.24 m), with a moderate velocity (0.5 m/s), and weakly alkaline (pH: 7.9), with moderate conductivity (210 µS/cm), and high dissolved oxygen (Table 5.5-10). The substrate was primarily large and small gravel (31% and 18%, respectively) and sand/silt/clay (17%) (Table 5.5-10). Periphyton chlorophyll *a* biomass averaged 6.81 mg/m^2, which was within the range of *baseline* variability (Figure 5.5-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach MAR-E1 in fall 2013 was dominated by chironomids (44%) and mayflies (23%), with subdominant taxa consisting of tubificid worms (10%) and naidid worms (7%) (Table 5.5-11). Chironomid taxa at *test* reach MAR-E1 were numerous and included the common genera *Polypedilum*, *Rheotanytarsus,* and *Thienemannimyia gr*. Mayflies (Ephemeroptera) included the common *Baetis*, *Acerpenna pygmaea*, *Ephemerella, Heptagenia*, and *Tricorythodes*. Stoneflies (Plecoptera) were primarily of the genera *Isoperla* while caddisflies were represented by *Hydropsyche* and *Oecetis*.

The benthic invertebrate community at *test* reach MAR-E2 in fall 2013 was dominated by chironomids (43%) and Ephemeroptera (31%), with subdominant taxa consisting of naidid worms (12%) and water mites (5%) (Table 5.5-12). Chironomid taxa were diverse and dominated by *Polypedilum*, *Rheotanytarsus, Cricotopus / Orthocladius, Lopescladius,* and *Acamptocladius dentolatens)*. Similar to the lower reach, mayflies (Ephemeroptera) present at *test* reach MAR-E2 were primarily *Acerpenna pygmaea, Baetis, Ephemerella, and Heptagenia,* but *Rhithrogenia* were also abundant. Stoneflies (Plecoptera) were represented by *Isoperla, Claassenia sabulosa,* Chlorperlidae*, and Skwala*. Caddisflies were primarily *Lepidostoma*, *Cheumatopsyche*, and *Hydropsyche* (Table 5.5-12).

The benthic invertebrate community at *baseline* reach MAR-E3 in fall 2013 was dominated by chironomids (64%) and Ephemeroptera (14%), with subdominant taxa consisting of naidid worms (6%) and Hydracarina (4%) (Table 5.5-12). Dominant chironomids included *Polypedilum* and *Lopescladius.* Mayflies were abundant and diverse, represented primarily by the genera *Baetis, Acerpenna, Tricorythodes*, *Heptagenia,* and *Ephemerella*. Plecoptera (Chloroperlidae, *Claassenia sabulosa,* and *Isoperla*) and Trichoptera (*Brachycentrus, Hydropsyche, Cheumatopsyche*, and *Lepidostoma*) were also present at *baseline* reach MAR-E3. Gastropods (*Ferrissia rivularis)* were present but in low relative abundance 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 1, Section 3.2.3.1);
- changes over time for the period that reach MAR-E1 has been designated as *test* (i.e., since 2002, Hypothesis 2, Section 3.2.3.1);
- changes between 2013 values and the mean of all *baseline* years; and
- changes between 2013 values and the mean of all previous years of sampling (1998 to 2012).

Temporal comparisons for *test* reach MAR-E2 included testing for:

- changes over time (Hypothesis 2, Section 3.2.3.1);
- changes between 2013 values and the mean of all *baseline* years; and
- changes between 2013 values and the mean of all previous years of sampling (2002 to 2012).

Spatial comparisons for *test* reaches MAR-E1 and MAR-E2 included testing for:

- differences from *baseline* reach MAR-E3 over the last four years (2010 to 2013) (Hypothesis 4, Section 3.2.3.1); and
- differences in 2013 values from all years at *baseline* reach MAR-E3.

Equitability was significantly higher at *test* reach MAR-E1, explaining 20% of the variance in annual means (Table 5.5-13). CA Axis 1 scores significantly decreased trend over time at *test* reach MAR-E1, and were lower in 2013 than the mean of *baseline* years and compared to *baseline* reach MAR-E3, all explaining greater than 20% of the variance in annual means (Table 5.5-13). CA Axis 2 scores significantly increased over time at *test* reach MAR-E1. Differences in CA Axis scores were primarily due to higher relative abundances of mayflies and ceratopogonids at the lower *test* reach compared to the upper *baseline* reach (Figure 5.5-9). The percentage of the fauna as EPT taxa was significantly lower in 2013 at *test* reach MAR-E1 than the mean of *baseline* years, accounting for 58% of the variance in annual means (Table 5.5-13).

The percentage of the fauna as EPT taxa has significantly increased over time at *test* reach MAR-E2, accounting for 38% of the variance in annual means (Table 5.5-14).

There were no significant differences between the *test* reaches and *baseline* MAR-E3 that accounted for greater than 20% of the variance in annual means (Table 5.5-13, Table 5.5-14).

Comparison to Published Literature The benthic invertebrate community at *test* reach MAR-E1 has improved since 2012, with a decrease in the proportion of naidid worms in 2013 (Table 5.5-11). Ephemeroptera were present in 2013, with the sensitive *Ephemerella* being one of the more dominant species. Other sensitive taxa including Plecoptera and Trichoptera were also noted indicating a stable, cold-water habitat (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at *test* reach MAR-E2 reflected favourable conditions, with high relative abundances of chironomids and Ephemeroptera and the presence of Plecoptera (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at *baseline* reach MAR-E3 reflected good water quality conditions, with the presence of Plecoptera, and high relative abundances of chironomids and Ephemeroptera and a low relative abundance of worms (Griffiths 1998).

2013 Results Comparison to Historical or *Baseline* Conditions *Test* reaches MAR-E1 and MAR-E2 have more than eight years of data (1998 to 2013 and 2002 to 2013, respectively); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for each reach. If there were exceedances of the inner tolerance limits for these reaches, comparisons to the tolerance limits for regional *baseline* erosional reaches were evaluated.

Richness was below the inner tolerance limit of the 5th percentile of the variation in means from previous years at *test* reach MAR-E1, and abundance was near the lower inner tolerance limit (Figure 5.5-10). When compared to regional *baseline* variability, abundance was within the inner tolerance limits; however, richness was still between the inner and outer tolerance limits for the 5th percentile of regional *baseline* variability.

The percentage of the fauna as EPT taxa at *test* reach MAR-E2 exceeded the inner tolerance limit for the 95th percentile of variability from means of previous sampling years at this reach (Figure 5.5-11). When compared to regional *baseline* variability, percent EPT was within the inner tolerance limits of the 5th and 95th percentiles.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach MAR-E1 were classified as **Moderate** because equitability has significantly increased over time; percent EPT was significantly lower in 2013 compared to *baseline* reach MAR-E3; and richness was lower than the historical and regional *baseline* variability. It should be noted; however, that there was an increase in the relative proportion of EPT taxa and a decrease in relative worm abundance from 2012 indicating an improvement in taxa composition from 2012 to 2013 at *test* reach MAR-E1. Differences in measurement endpoints of benthic invertebrate communities at *test* reach MAR-E2 were classified as **Negligible-Low** because the significant increase in percent EPT over time was not indicative of a negative change. The benthic invertebrate community at *test* reach MAR-E2 was representative of good overall water quality, with a high proportion of EPT taxa and a low relative abundance of worms.

5.5.4.2 Sediment Quality

No sediment quality sampling was conducted in the MacKay River in 2013 because the reaches of the MacKay River where benthic invertebrate communities were sampled are erosional and sediment quality is only sampled in depositional reaches.

5.5.5 Fish Populations

Fish assemblages were sampled in fall 2013 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).

2013 Habitat Conditions *Test* reach MAR-F1 was comprised entirely of run habitat with a wetted width of 50.0 m and a bankfull width of 60.0 m (Table 5.5-15). The substrate was primarily comprised of sand with some gravel. Water at *test* reach MAR-F1 in fall 2013 had a mean depth of 0.44 m and a moderate velocity (0.30 m/s), was alkaline (pH: 8.42), with moderate conductivity (234 µS/cm), moderate dissolved oxygen (8.8 mg/L), and a temperature of 16.1˚C. Instream cover consisted primarily of macrophytes with small woody debris, boulders, and some filamentous algae (Table 5.5-15).

Test reach MAR-F2 was comprised of riffle habitat with a wetted width of 35.0 m and a bankfull width of 48.0 m (Table 5.5-15). The substrate was primarily cobble with some boulders. Water at *test* reach MAR-F2 in fall 2013 had a mean depth of 0.39 m and a moderate velocity (0.30 m/s), was slightly acidic (pH: 6.97), with moderate conductivity (224 µS/cm), high dissolved oxygen (9.6 mg/L), and a temperature of 16.0˚C. Instream cover consisted primarily of boulders with some filamentous algae (Table 5.5-15).

Baseline reach MAR-F3 was comprised of run and riffle habitat with a wetted width of 42.0 m and a bankfull width of 46.0 m (Table 5.5-15). The substrate was primarily cobble and gravel, with some sand. Water at *baseline* reach MAR-F3 in fall 2013 had a mean depth of 0.52 m and a faster velocity (0.63 m/s), was alkaline (pH: 7.95), with low conductivity (195 µS/cm), low dissolved oxygen (3.0 mg/L), and a temperature of 15.5˚C. Instream cover consisted primarily of boulders with some filamentous algae, macrophytes, and overhanging vegetation (Table 5.5-15).

Relative Abundance of Fish Species The fish assemblage at *test* reach MAR-F1 was limited but dominated by burbot (50%) (Table 5.5-16). Burbot were common near the mouth of many of the tributaries to the Athabasca River in fall 2013 and were caught in numbers not previously observed during the RAMP program. The fish assemblages at *test* reach MAR-F2 and *baseline* reach MAR-F3 were dominated by longnose dace (64.3% and 50%, respectively) (Table 5.5-16), which was similar to previous years but in lower abundances in 2013.

Temporal and Spatial Comparisons Temporal comparisons for *test* reach MAR-F1 included testing for changes over time in measurement endpoints (2009 to 2013, Hypothesis 1, Section 3.2.4.4). Temporal comparisons for *test* reach MAR-F2 included testing for changes over time in measurement endpoints (2011 to 2013, Hypothesis 1, Section 3.2.4.4). Spatial comparisons included testing for differences in measurement endpoints between *baseline* reach MAR-F3 and the two *test* reaches (MAR-F1 and MAR-F2) over time (Hypothesis 2, Section 3.2.4.4).

There were significant decreases in richness ($p=0.02$) and diversity ($p=0.03$) over time at *test* reach MAR-F1, explaining greater than 20% of the variance in annual means (Table 5.5-17). As a result of the high proportion of burbot, which is considered a sensitive species, the assemblage tolerance index at *test* reach MAR-F1 was also the lowest recorded (Table 5.5-18), but showed no significant trend over time. There were significant decreases in mean abundance ($p<0.001$) and CPUE ($p=0.007$) of fish from 2009 to 2013 at *test* reach MAR-F2, explaining greater than 20% of the variance in annual means (Table 5.5-17).

Diversity was significantly higher at *baseline* reach MAR-F3 than *test* reach MAR-F1 ($p=0.016$), explaining 20% of the variance in annual means. All other measurement endpoints for fish assemblages were relatively consistent between *test* reach MAR-F1 and *baseline* reach MAR-F3 ($p>0.05$) (Table 5.5-17). There were no significant differences in measurement endpoints between *test* reach MAR-F2 and *baseline* reach MAR-F3 of the MacKay River ($p>0.05$) (Table 5.5-17).

Abundance and CPUE were lower at *baseline* reach MAR-F3 in 2013 compared to previous years; however, richness and diversity were similar over time (Table 5.5-18). The ATI value increased in 2012 at *baseline* reach MAR-F3 due to the dominance of trout-perch (a more tolerant species) and then decreased in 2013 due to a higher catch of slimy sculpin and longnose dace, which are less tolerant species (Table 5.5-17).

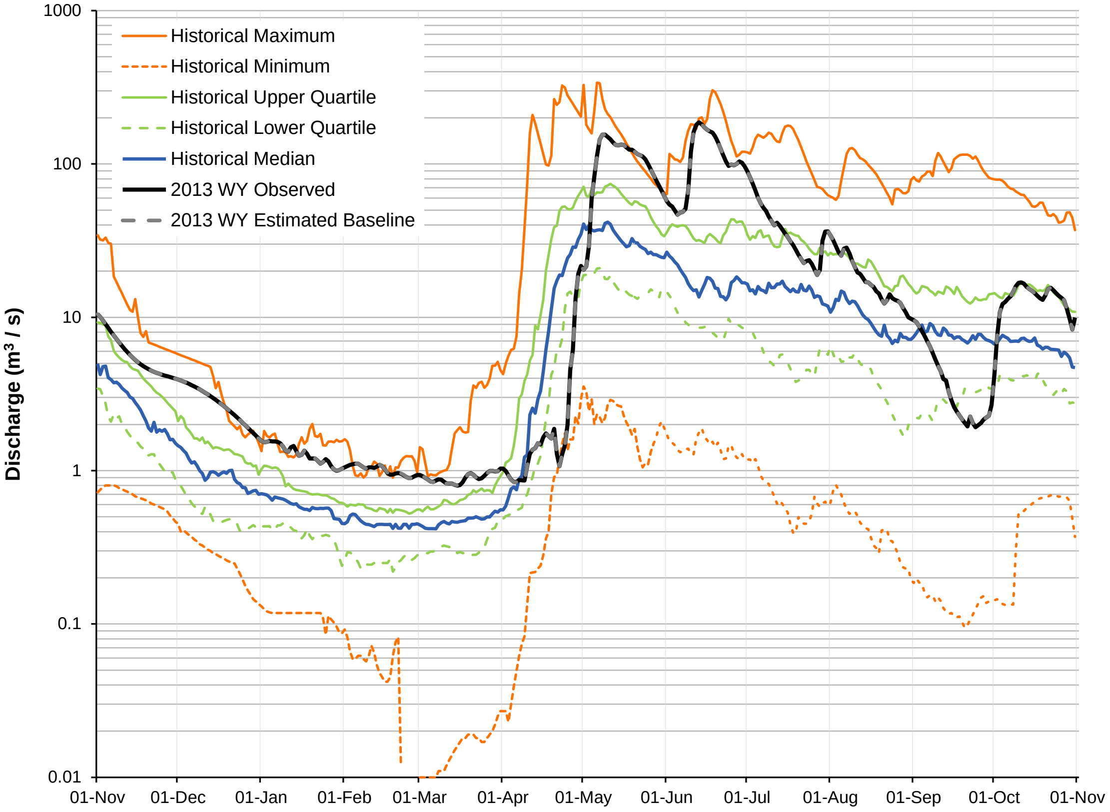
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution 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 17 species from 2009 to 2013. 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 and run habitat, with substrate consisting of sand, gravel, cobble, and boulders in the area of the river where both *test* reaches (MAR-F1 and MAR-F2), and the *baseline* reach (MAR-F3) are located (i.e., 1 km to 112 km from the mouth of the river), which was consistent with habitat conditions documented in fall 2013 (Table 5.5-15). This section of the river provides moderate to high fisheries potential (Golder 2004).

2013 Results Relative to Regional *Baseline* Conditions Mean values of CPUE, abundance, ATI, and diversity at *test* reach MAR-F1 were between the inner and outer tolerance limits for the 5th percentile of regional *baseline* variability. Mean values of all measurement endpoints in fall 2013 at *test* reach MAR-F2 were within the range of regional *baseline* conditions, with the exception of abundance, which was lower than inner tolerance limit of the 5th percentile of the range of variability for erosional *baseline* reaches (Figure 5.5-12).

Classification of Results Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F1 were classified as **High** because four of the five measurement endpoints (CPUE, abundance, ATI, and diversity) were near the outer tolerance limit for the 5th percentile of regional *baseline* variability; there were significant decreases in diversity and richness over time; and diversity was significantly lower than *baseline* reach MAR-F3. Differences in measurement endpoints for the fish assemblage at *test* reach MAR-F2 were classified as **Moderate** because abundance was near the outer tolerance limit for the 5th percentile of regional *baseline* variability and there were significant decreases in CPUE and abundance of fish over time.

Figure 5.5-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the MacKay River in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on MacKay River near Fort McKay, WSC Station 07DB001 (RAMP Station S26) provisional data from January 1 to October 31, 2013 and RAMP Station S26 from November 1 to December 31, 2012. The upstream drainage area is 5,569.3 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1972 to 2012, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1987 and from 2002 to 2012.

Note: For clarity, the estimated *baseline* flow resulting from focal projects in the MacKay River watershed was only shown here; differences between this and the estimated *baseline* hydrograph resulting from other oil sands developments in the MacKay River watershed were negligible and not detectable on this graph.

Table 5.5-2 Estimated water balance at WSC Station 07DB001 (RAMP Station S26), MacKay River near Fort McKay, 2013 WY.

Component	Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus Other Oil Sands Developments	
Observed *test* hydrograph (total discharge)	**807.771**	**807.771**	**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	-1.031	-1.031	Estimated 7.11 km^2 of the MacKay River watershed is closed-circuited from focal projects or from focal projects plus other oil sands developments as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.995	+1.124	Estimated 34.3 km^2 and 38.8 km^2 of the MacKay River watershed with land change from focal projects and from focal projects plus other oil sands developments as of 2013, respectively, that is not closed-circuited (Table 2.5-1)
Water withdrawals from the MacKay River watershed from projects	-0.009	-0.009	Water withdrawals by Suncor (daily values provided)
Water releases into the MacKay 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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**807.816**	**807.687**	**Estimated *baseline* discharge at MacKay River near Fort McKay, WSC Station 07DB001 (RAMP Station S26)**
Incremental flow (change in total annual discharge)	-0.045	+0.084	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-0.006%**	**-0.010%**	**Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for March 1 to October 31, 2013 for WSC Station 07DB001 and on RAMP Station S26 for other months in the 2013 WY.

Table 5.5-3 Calculated change in hydrologic measurement endpoints for the MacKay River watershed, 2013 WY.

Measurement Endpoint	**Value from *Test* Hydrograph (m^3/s)**	**Value from *Baseline* Hydrograph (m^3/s)**		**Relative Change**	
		Focal Projects	**Focal Projects Plus Other Oil Sands Developments**	**Focal Projects**	**Focal Projects Plus Other Oil Sands Developments**
Mean open-water season discharge	48.319	48.321	48.314	-0.006%	+0.010%
Mean winter discharge	2.397	2.397	2.396	-0.004%	+0.012%
Annual maximum daily discharge	187.000	187.008	186.978	-0.004%	+0.012%
Open-water season minimum daily discharge	1.920	1.920	1.920	-0.004%	+0.012%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for January 1 to October 31, 2013 for WSC Station 07DB001 and on RAMP Station S26 for other months in the 2013 WY.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.5-4 Concentrations of water quality measurement endpoints, mouth of MacKay River (*test* station MAR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	14	7.6	8.2	8.6
Total suspended solids	mg/L	-	<3.0	14	<2.0	7.0	41
Conductivity	µS/cm	-	283	14	183	267	576
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.048	14	0.004	0.025	0.047
Total nitrogen	mg/L	1	0.951	14	0.400	**1.136**	**3.200**
Nitrate+nitrite	mg/L	3	<0.071	14	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	34.7	14	20.0	28.2	40.0
Ions							
Sodium	mg/L	-	20.3	14	15.0	20.0	60.0
Calcium	mg/L	-	32.4	14	20.8	26.7	44.7
Magnesium	mg/L	-	9.84	14	7.26	9.00	15.90
Chloride	mg/L	120	4.59	14	1.20	4.00	41.20
Sulphate	mg/L	270	12.5	14	9.3	17.0	35.5
Total dissolved solids	mg/L	-	259	14	170	212	342
Total alkalinity	mg/L		130	14	80	121	202
Selected metals							
Total aluminum	mg/L	0.1	**0.183**	14	0.050	**0.253**	**1.740**
Dissolved aluminum	mg/L	0.1	0.026	14	0.007	0.022	0.046
Total arsenic	mg/L	0.005	0.0012	14	0.0007	0.0010	0.0013
Total boron	mg/L	1.2	0.070	14	0.051	0.082	0.140
Total molybdenum	mg/L	0.073	0.00028	14	0.00015	0.00036	0.00060
Total mercury (ultra-trace)	ng/L	5, 13	1.8	10	<1.2	<1.2	**6.3**
Total strontium	mg/L	-	0.182	14	0.108	0.154	0.287
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.30	2	0.06	0.12	0.17
Oilsands Extractable	mg/L	-	0.80	2	0.56	0.87	1.18
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	2.05	2	<2.07	3.81	5.55
Total dibenzothiophenes	ng/L	-	68.5	2	49.9	170	289
Total PAHs	ng/L	-	267	2	272	650	1028
Total Parent PAHs	ng/L	-	25.6	2	21.9	26.1	30.4
Total Alkylated PAHs	ng/L	-	241	2	250	624	998
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	1.110	14	0.230	**0.475**	**0.787**
Sulphide	mg/L	0.002	**0.014**	14	**0.003**	**0.012**	**0.032**
Total iron	mg/L	0.3	**1.44**	14	**0.31**	**0.98**	**23.30**
Total phenols	mg/L	0.004	**0.009**	14	0.001	**0.006**	**0.020**
Total phosphorus	mg/L	0.05	**0.059**	14	0.011	0.044	**0.072**

[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 5.5-5 Concentrations of water quality measurement endpoints, middle MacKay River (*test* station MAR-2A), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2009-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	3	8.0	8.3	8.4
Total suspended solids	mg/L	-	<3	3	<3	<5	<376
Conductivity	µS/cm	-	251	3	196	223	268
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.046	3	0.027	0.034	0.038
Total nitrogen	mg/L	1	**1.15**	3	**1.11**	**1.67**	**1.75**
Nitrate+nitrite	mg/L	3	<0.071	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	39.6	3	24.7	35.8	39.6
Ions							
Sodium	mg/L	-	15.6	3	12.9	14.1	15.1
Calcium	mg/L	-	31.3	3	19.4	24.7	31.3
Magnesium	mg/L	-	10.00	3	6.77	7.76	9.13
Chloride	mg/L	120	0.74	3	0.53	0.58	0.69
Sulphate	mg/L	270	10.3	3	7.6	10.8	18.4
Total dissolved solids	mg/L	-	213	3	198	218	244
Total alkalinity	mg/L		121	3	91.9	102	122
Selected metals							
Total aluminum	mg/L	0.1	**0.150**	3	**0.116**	**0.140**	**9.650**
Dissolved aluminum	mg/L	0.1	0.028	3	0.017	0.022	**0.147**
Total arsenic	mg/L	0.005	0.0012	3	0.0011	0.0011	0.0023
Total boron	mg/L	1.2	0.057	3	0.056	0.072	0.080
Total molybdenum	mg/L	0.073	0.0003	3	<0.0001	0.0003	0.0006
Total mercury (ultra-trace)	ng/L	5, 13	1.7	3	0.6	2.6	**10.6**
Total strontium	mg/L	-	0.159	3	0.109	0.129	0.168
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.36	2	0.06	0.23	0.39
Oilsands Extractable	mg/L	-	0.91	2	0.42	0.77	1.12
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.000	2	4.150	16.375	28.600
Total dibenzothiophenes	ng/L	-	6.672	2	8.454	41.944	75.434
Total PAHs	ng/L	-	102.5	2	171.4	444.3	717.3
Total Parent PAHs	ng/L	-	22.44	2	19.82	38.27	56.72
Total Alkylated PAHs	ng/L	-	80.05	2	151.55	406.05	660.55
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**1.160**	3	**0.521**	**0.737**	**0.847**
Sulphide	mg/L	0.002	**0.005**	3	**0.012**	**0.013**	**0.018**
Total iron	mg/L	0.3	**1.46**	3	**1.05**	**1.26**	**6.44**
Total phenols	mg/L	0.004	**0.011**	3	**0.008**	**0.009**	**0.010**
Total phosphorus	mg/L	0.05	**0.061**	3	0.043	0.054	**0.265**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	11	7.8	8.2	8.3
Total suspended solids	mg/L	-	10.0	11	<3.0	<3.0	23.0
Conductivity	µS/cm	-	234	11	164	220	264
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.052**	11	0.008	0.035	0.043
Total nitrogen	mg/L	1	**1.01**	11	0.80	**1.30**	**3.10**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	0.100
Dissolved organic carbon	mg/L	-	34.4	11	22.0	32.0	41.0
Ions							
Sodium	mg/L	-	14.4	11	11.0	15.0	19.0
Calcium	mg/L	-	30.1	11	17.8	23.8	34.5
Magnesium	mg/L	-	10.4	11	6.3	8.4	11.0
Chloride	mg/L	120	<0.5	11	<0.5	2.0	3.0
Sulphate	mg/L	270	8.96	11	6.58	11.00	23.70
Total dissolved solids	mg/L	-	209	11	160	190	240
Total alkalinity	mg/L		111	11	75	104	128
Selected metals							
Total aluminum	mg/L	0.1	**0.473**	11	0.020	**0.159**	**1.080**
Dissolved aluminum	mg/L	0.1	0.030	11	<0.001	0.025	0.044
Total arsenic	mg/L	0.005	0.0013	11	0.0006	0.0010	0.0011
Total boron	mg/L	1.2	0.053	11	0.043	0.058	0.105
Total molybdenum	mg/L	0.073	0.00031	11	0.00013	0.00030	0.00055
Total mercury (ultra-trace)	ng/L	5, 13	1.60	10	0.60	1.45	**5.00**
Total strontium	mg/L	-	0.153	11	0.105	0.127	0.197
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.16	2	0.15	0.25	0.25
Oilsands Extractable	mg/L	-	1.21	2	0.18	0.49	0.79
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	0.98	2	1.19	1.63	<2.07
Total dibenzothiophenes	ng/L	-	6.67	2	16.11	25.72	35.33
Total PAHs	ng/L	-	102.6	2	193.4	199.2	205.1
Total Parent PAHs	ng/L	-	22.44	2	16.73	18.37	20.01
Total Alkylated PAHs	ng/L	-	80.2	2	173.4	180.9	188.3
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**1.240**	10	0.289	**0.564**	**0.841**
Sulphide	mg/L	0.002	**0.005**	10	**0.008**	**0.020**	**0.030**
Total iron	mg/L	0.3	**1.66**	10	**0.39**	**0.98**	**1.34**
Total phenols	mg/L	0.004	**0.009**	10	<0.001	**0.009**	**0.020**
Total phosphorus	mg/L	0.05	**0.062**	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.

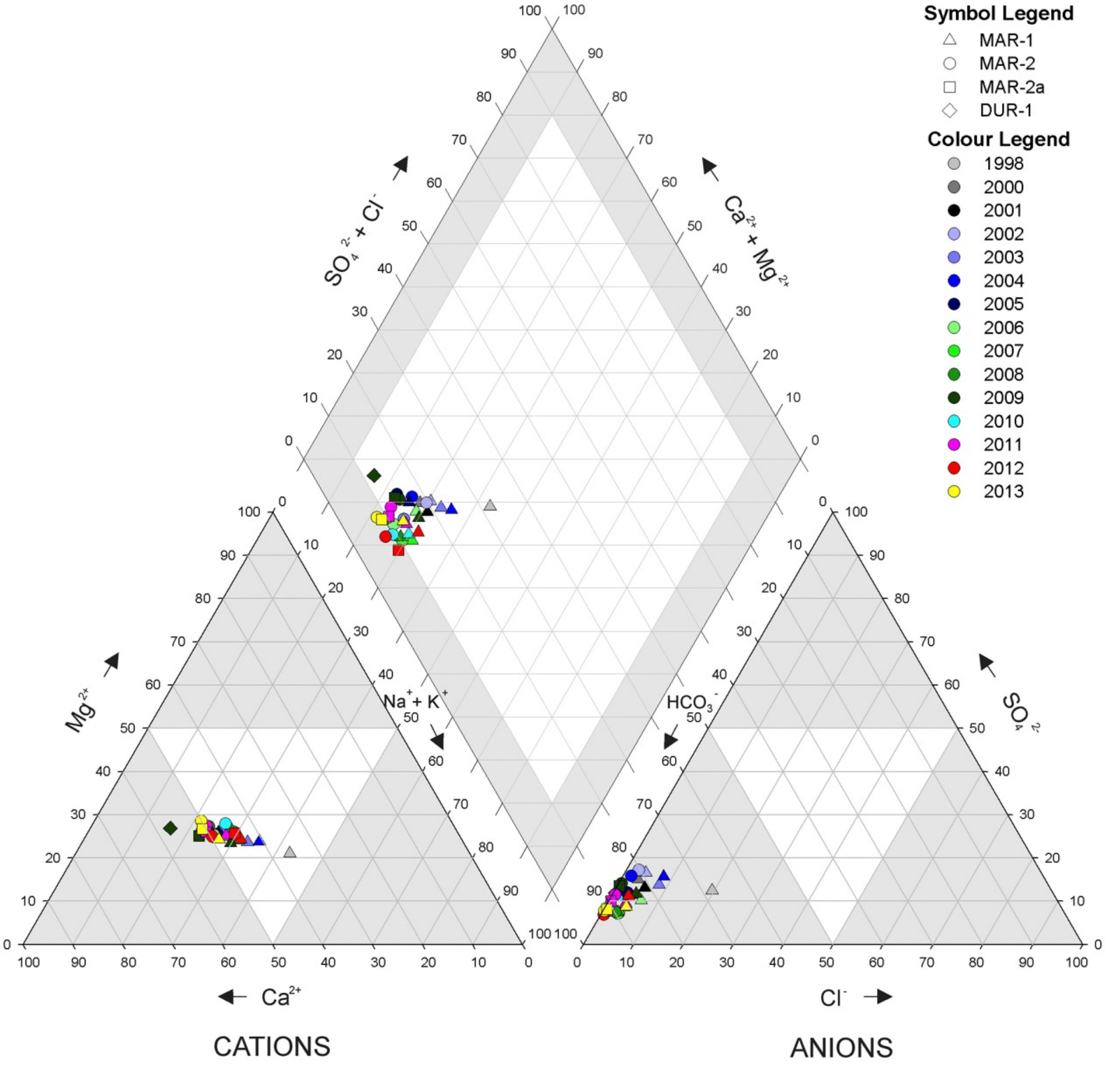


Table 5.5-7 Water quality guideline exceedances, MacKay River watershed, fall 2013.

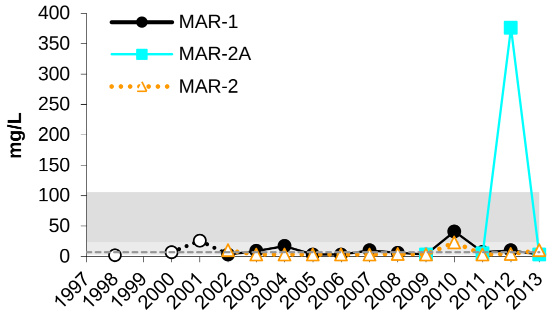
Variable	Units	Guideline[a]	MAR-1	MAR-2	MAR-2A
Dissolved iron	mg/L	0.3	1.11	1.24	1.16
Dissolved phosphorus	mg/L	0.05	-	0.05	-
Sulphide	mg/L	0.002	0.014	0.005	0.005
Total aluminum	mg/L	0.1	0.18	0.47	0.15
Total iron	mg/L	0.3	1.44	1.66	1.46
Total nitrogen	mg/L	1	-	1.01	1.15
Total phenols	mg/L	0.004	0.009	0.009	0.011
Total phosphorus	mg/L	0.05	0.059	0.062	0.061

[a] Sources for all guidelines are outlined in Table 3.2-5.

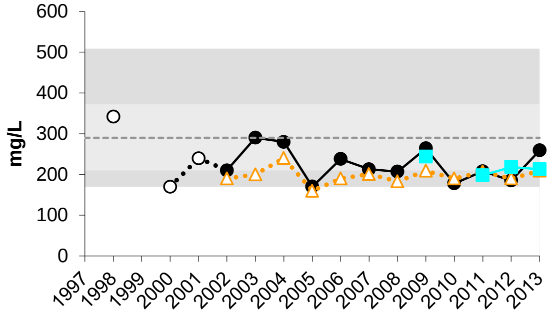
ns = not sampled

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.

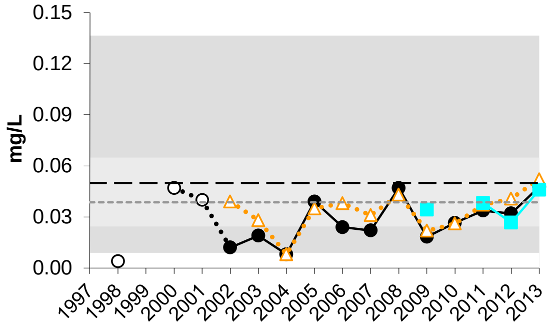
Total Suspended Solids (TSS)



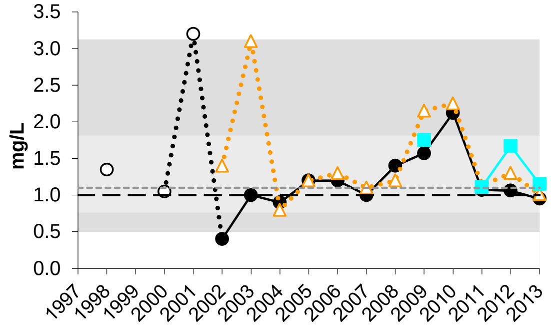
Total Dissolved Solids (TDS)



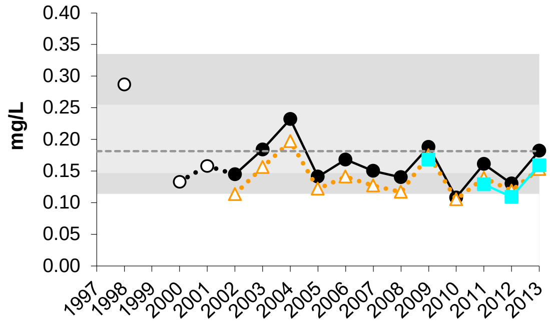
Dissolved Phosphorus



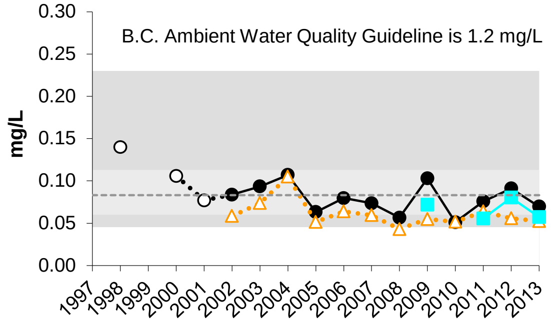
Total Nitrogen



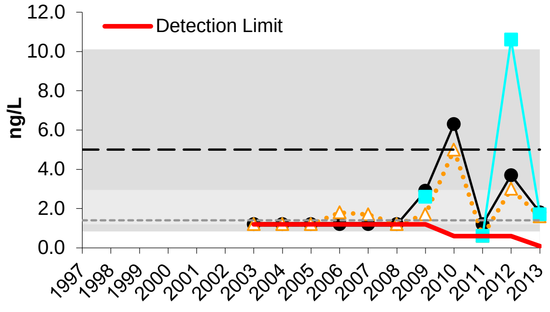
Total Strontium



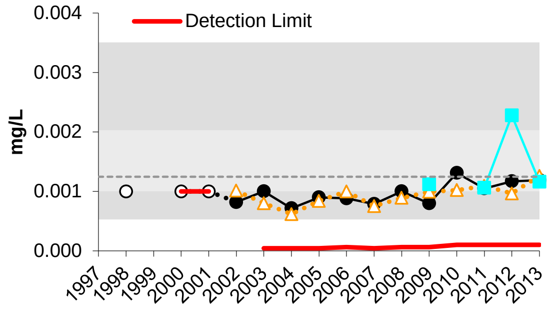
Total Boron



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.

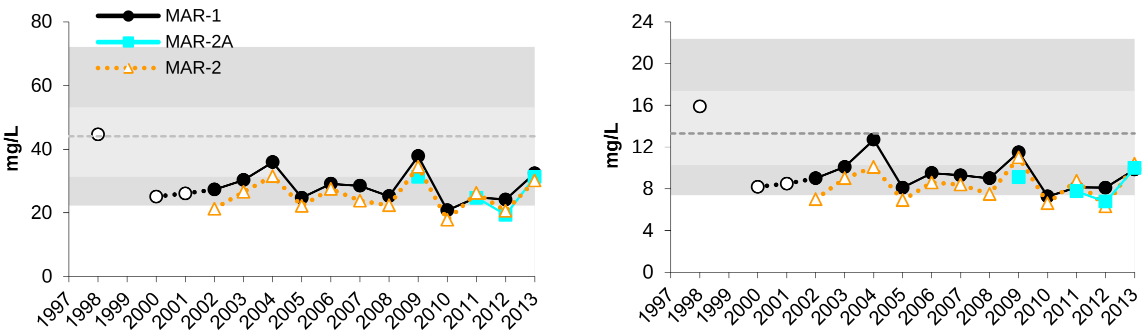
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.5-5 (Cont'd.)

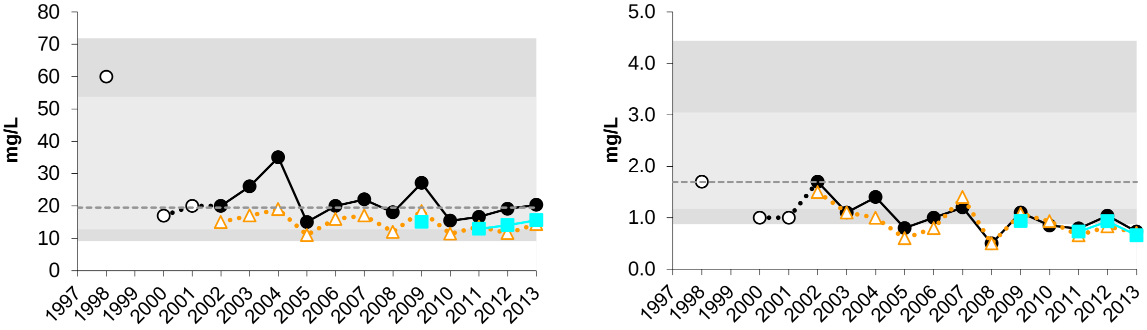
Calcium

Magnesium



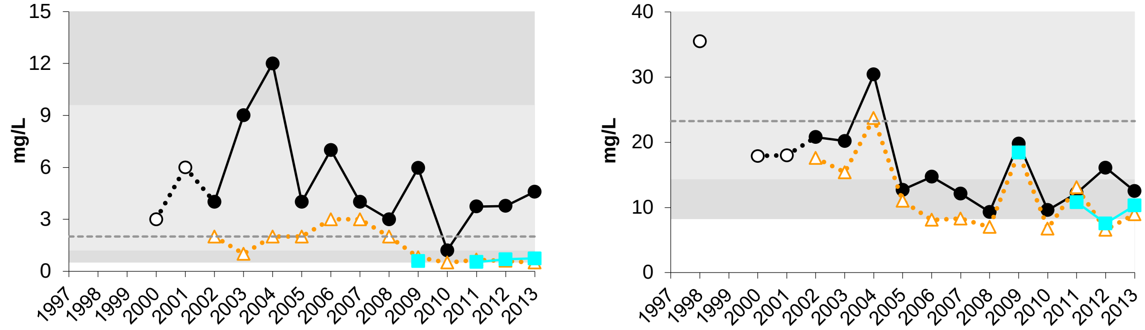
Sodium

Potassium



Chloride

Sulphate



Non-detectable values are shown at the detection limit.

\- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

Table 5.5-8 Monthly water quality measurement endpoints, upper MacKay River (*baseline* station MAR-2), January to December 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	12	7.78	(May)	7.94	8.18	(September)
Total suspended solids	mg/L	-	12	<3	-	6	201	(May)
Conductivity	µS/cm	-	12	93	(May)	229	532	(April)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	12	0.030	(November)	**0.051**	**0.085**	(July)
Total nitrogen	mg/L	1.0	12	**1.001**	(October)	**1.241**	**1.591**	(July)
Nitrate+nitrite	mg/L	3	12	<0.070	-	<0.071	0.447	(March)
Dissolved organic carbon	mg/L	-	12	6.7	(April)	31.4	38.5	(August)
Ions								
Sodium	mg/L	-	12	6.8	(May)	14.2	42.4	(April)
Calcium	mg/L	-	12	9.4	(May)	27.0	55.0	(April)
Magnesium	mg/L	-	12	3.2	(May)	9.1	17.2	(April)
Chloride	mg/L	120	12	<0.50	-	0.62	6.33	(April)
Sulphate	mg/L	410	12	4.6	(July)	11.3	47.8	(April)
Total dissolved solids	mg/L	-	12	138	(May)	225	370	(April)
Total alkalinity	mg/L	-	12	40	(May)	107	230	(March)
Selected metals								
Total aluminum	mg/L	0.1	12	0.076	(November)	**0.475**	**9.57**	(May)
Dissolved aluminum	mg/L	0.1	12	0.014	(April)	0.036	**0.116**	(May)
Total arsenic	mg/L	0.005	12	0.0008	(November)	0.0010	0.0023	(May)
Total boron	mg/L	1.2	12	0.048	(July)	0.058	0.173	(April)
Total molybdenum	mg/L	0.073	12	0.00013	(May)	0.00033	0.00054	(April)
Total mercury (ultra-trace)	ng/L	5, 13	12	<1.20	(March)	1.63	**6.20**	(May)
Total strontium	mg/L	-	12	0.067	(May)	0.139	0.319	(April)
Total hydrocarbons								
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	12	0.05	(February)	0.22	0.60	(January)
Oilsands Extractable	mg/L	-	12	0.27	(March)	0.48	1.21	(September)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	11	<15.16	-	<15.16	29.10	(February)
Retene	ng/L	-	11	0.90	(March)	1.41	52.00	(July)
Total dibenzothiophenes	ng/L	-	11	6.67	(March)	7.11	28.14	(May)
Total PAHs	ng/L	-	11	102.6	(August)	123.2	362.4	(June)
Total Parent PAHs	ng/L	-	11	22.4	-	23.1	45.3	(April)
Total Alkylated PAHs	ng/L	-	11	80.2	(September)	100.8	336.5	(June)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	12	<0.001	(June)	**0.008**	**0.011**	(July)
Sulphide	mg/L	0.002	12	**0.0446**	(October)	**0.0981**	**0.2700**	(May)
Total phosphorus	mg/L	0.05	12	**0.690**	(April)	**0.990**	**1.520**	(July)
Total Kjeldahl Nitrogen	mg/L	1.0	6	0.69	(April)	0.99	**1.52**	(July)
Total iron	mg/L	0.3	12	**1.080**	(November)	**2.255**	**7.160**	(May)
Dissolved iron	mg/L	0.3	12	**0.445**	(May)	**1.013**	**1.680**	(March)
Total chromium	mg/L	0.001	12	<0.0003	January/March	0.0007	**0.0092**	(May)
Total silver	mg/L	0.0001	12	0.00001	-	<0.000010	**0.000105**	(May)
Total titanium	mg/L	0.1	12	0.003	(November)	0.009	**0.139**	(May)

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

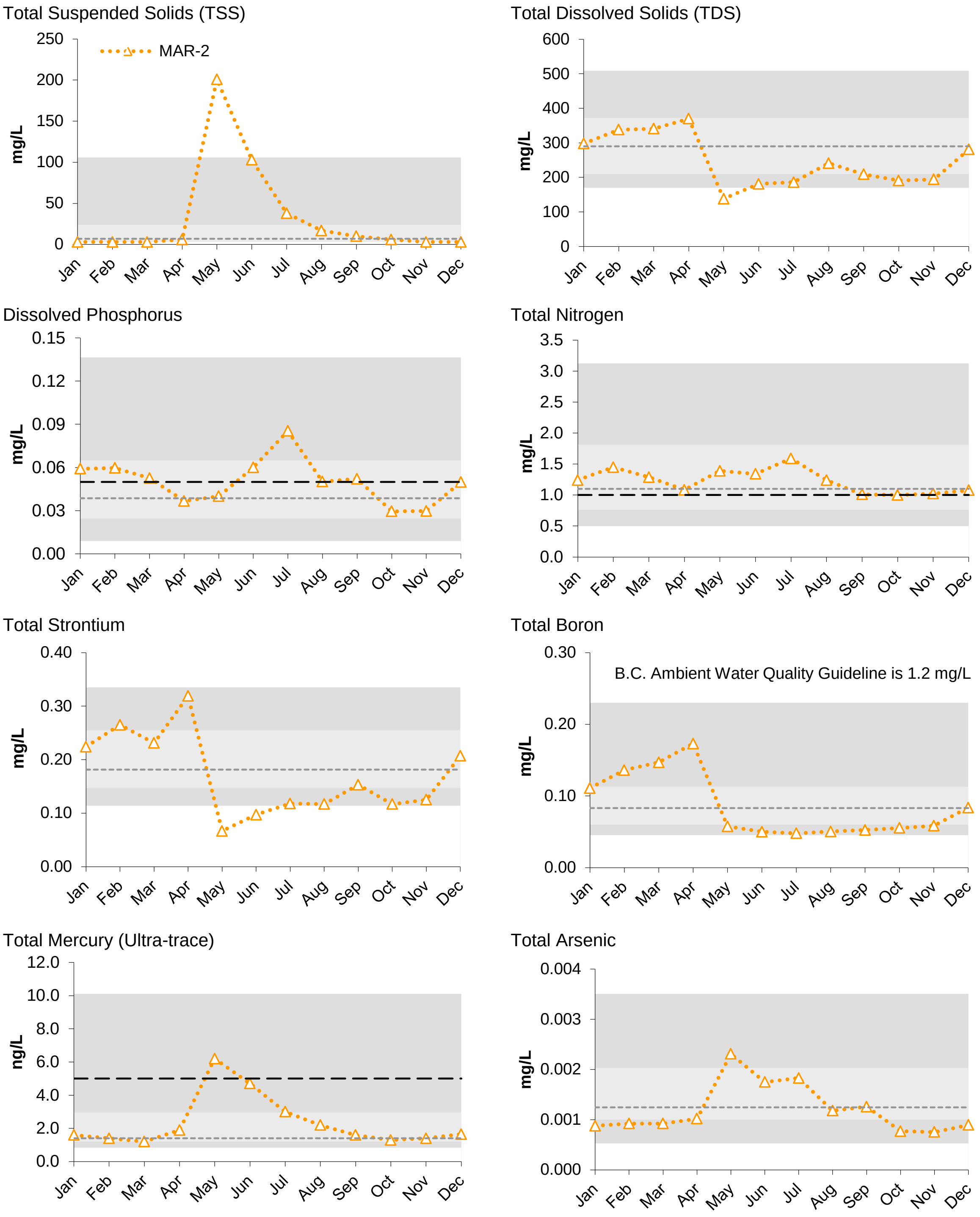
[1] n value refers to number of exceedances in 2013.

Table 5.5-9 Monthly water quality guideline exceedances, upper MacKay River (*baseline* station MAR-2), January to December 2013.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0084	0.0084	0.0067	0.0072	0.0100	-	0.0109	0.0090	0.0089	0.0054	0.0065	0.0042
Sulphide	mg/L	0.002	0.0121	0.0151	0.0103	0.0046	0.0200	0.0306	0.0290	0.0189	0.0048	-	0.0161	0.0059
Dissolved phosphorus	mg/L	0.05	0.0591	0.0596	0.0526	-	-	0.0574	0.0854	0.0501	0.0521	-	-	-
Total phosphorus	mg/L	0.05	0.091	0.106	0.109	0.105	0.270	0.140	0.167	0.074	0.062	-	-	0.078
Total nitrogen	mg/L	1.0	1.241	1.449	1.287	1.082	1.390	1.341	1.591	1.241	1.011	1.001	1.021	1.077
Total aluminum	mg/L	0.1	0.181	0.154	0.124	0.476	9.570	4.390	2.290	0.674	0.473	0.701	-	0.416
Dissolved aluminum	mg/L	0.1	-	-	0.0518	-	0.1160	0.0746	-	-	-	-	-	-
Total iron	mg/L	0.3	2.24	2.27	2.32	2.48	7.16	3.14	2.97	1.62	1.66	1.10	1.08	1.72
Dissolved iron	mg/L	0.3000	1.64	1.60	1.68	0.79	0.45	0.71	1.36	0.77	1.24	0.62	0.72	1.29
Total chromium	mg/L	0.001	-	-	-	-	0.0092	0.0038	0.0020	-	-	-	-	-
Total mercury (ultra-trace)	mg/L	5, 13	-	-	-	-	6.2	-	-	-	-	-	-	-
Total silver	mg/L	0.0001	-	-	-	-	0.00011	-	-	-	-	-	-	-
Total titanium	mg/L	0.1	-	-	-	-	0.139	-	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.5-6 Concentrations of selected water quality measurement endpoints in the upper MacKay River (monthly data) relative to regional *baseline* fall concentrations.



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

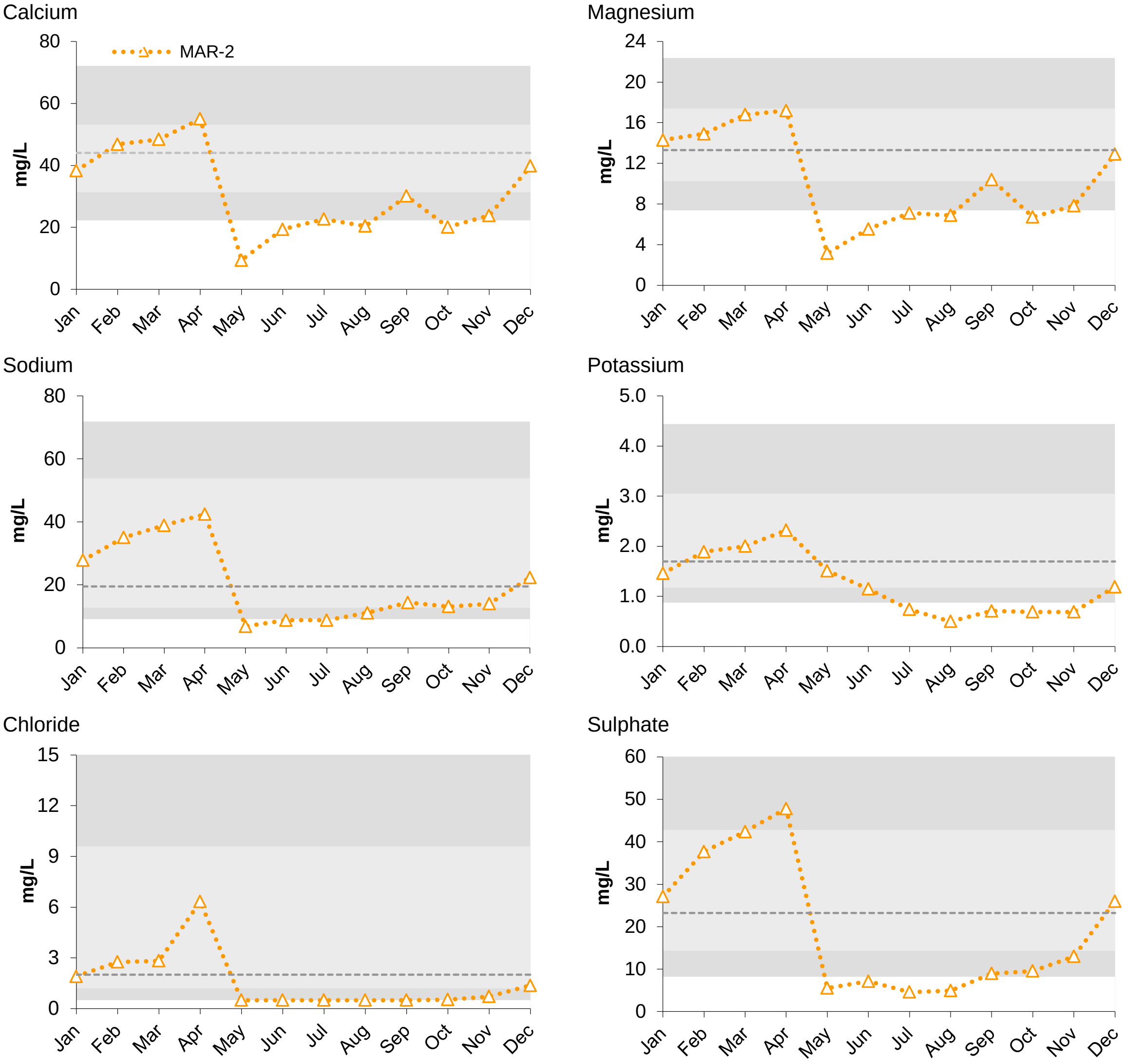
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.5-6 (Cont'd.)



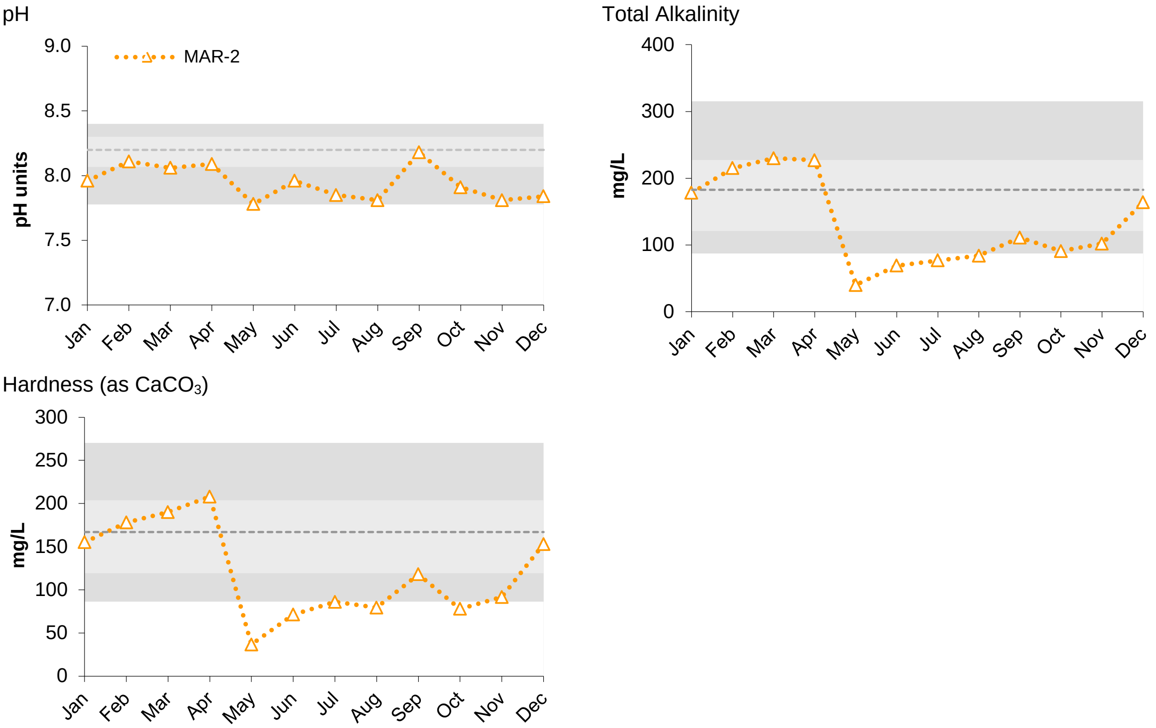
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.5-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.5-7 Piper diagram of monthly ion concentrations in the upper MacKay River (*baseline* station MAR-2).

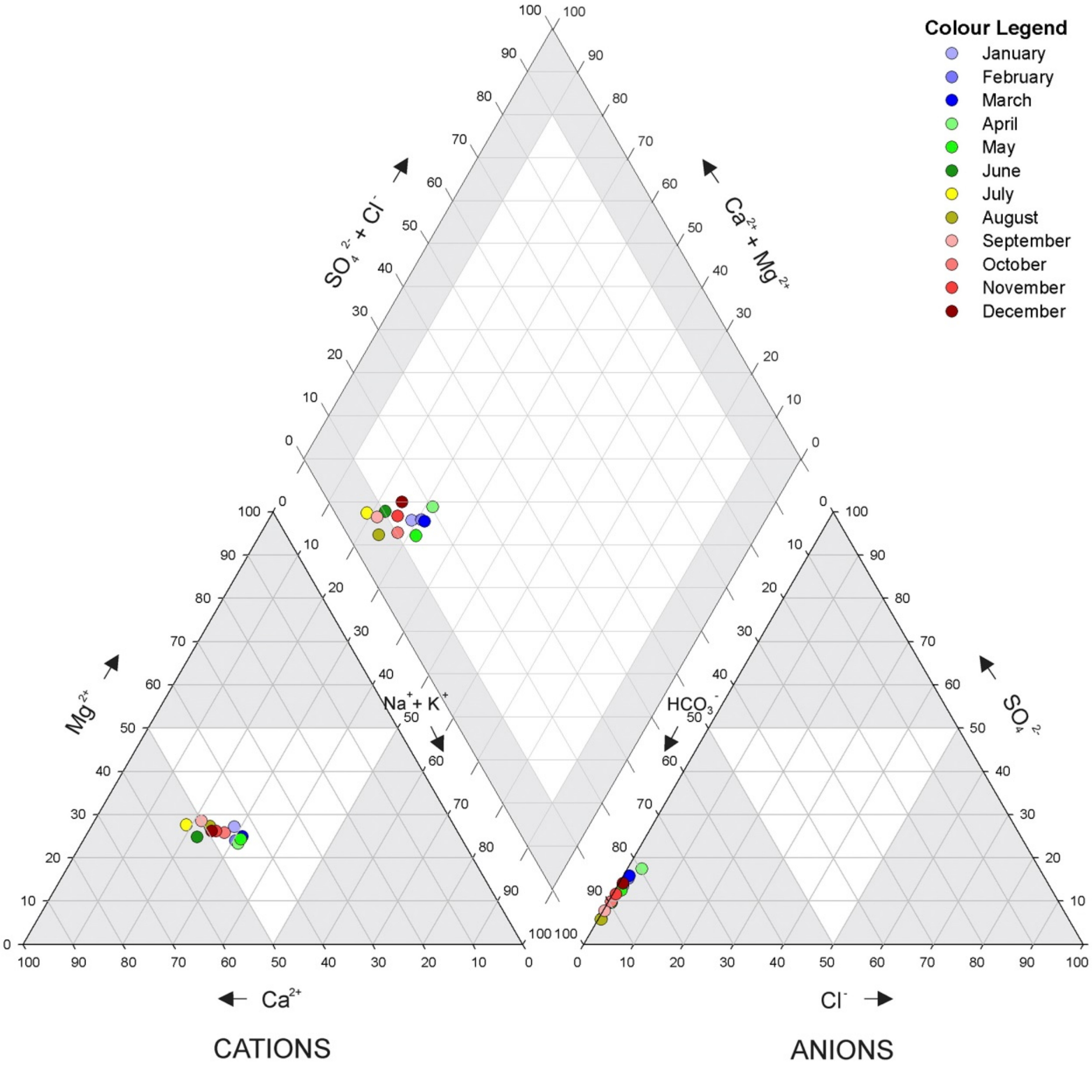
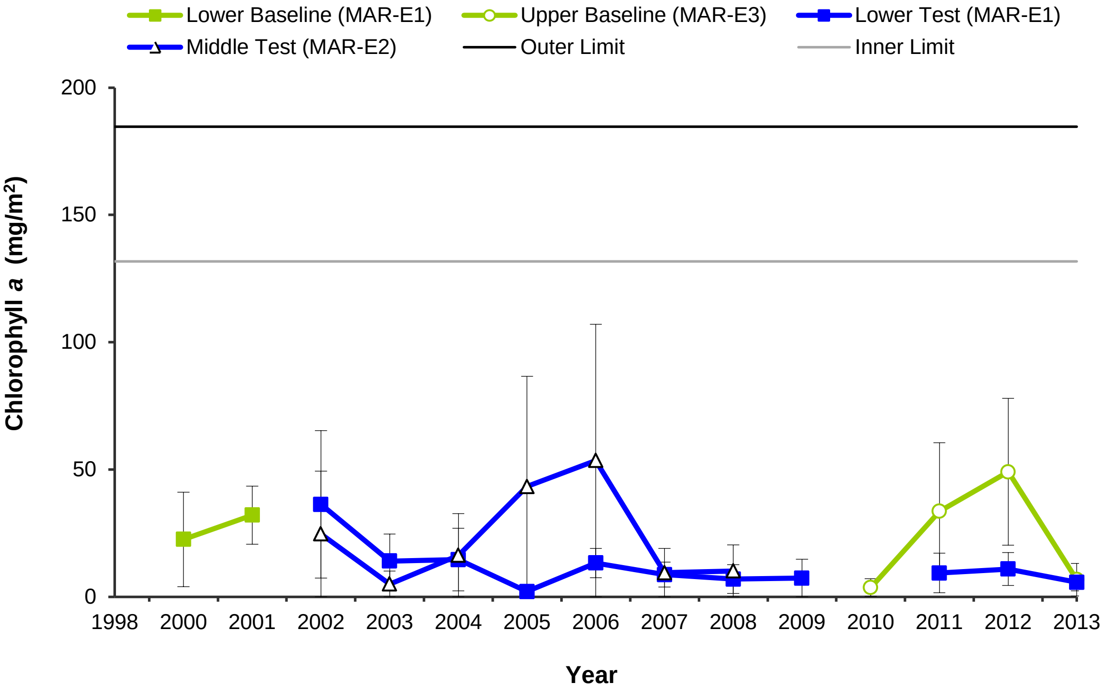


Table 5.5-10 Average habitat characteristics of benthic invertebrate sampling locations in the MacKay River, fall 2013.

Variable	**Units**	**MAR-E1** **Lower *Test* Reach of the MacKay River**	**MAR-E2** **Middle *Test* Reach of the MacKay River**	**MAR-E3** **Upper *Baseline* Reach of the MacKay River**
Sample date	-	Sept 10, 2013	Sept 10, 2013	Sept 10, 2013
Habitat	-	Erosional	Erosional	Erosional
Water depth	m	0.26	0.25	0.24
Current velocity	m/s	0.36	0.64	0.48
Field Water Quality				
Dissolved oxygen	mg/L	8.7	8.2	8.1
Conductivity	µS/cm	279	239	210
pH	pH units	8.1	8.1	7.9
Water temperature	°C	14.5	15.3	14.3
Sediment Composition				
Sand/Silt/Clay	%	44	3	17
Small Gravel	%	19	4	18
Large Gravel	%	20	12	31
Small Cobble	%	13	23	16
Large Cobble	%	3	40	14
Boulder	%	1	17	3
Bedrock	%	0	0	0

Figure 5.5-8 Periphyton chlorophyll *a* biomass in *test* (MAR-E1 and MAR-E2) and *baseline* (MAR-E3) reaches of the MacKay River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* reaches for years up to and including 2012.

Table 5.5-11 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community in the lower MacKay River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach MAR-E1		
	1998	2000 to 2012	2013
Hydra	<1	0 to <1	-
Nematoda	2	1 to 8	1
Naididae	2	2 to 30	7
Tubificidae	2	<1 to 23	10
Enchytraeidae	4	1 to 12	2
Lumbriculidae	-	0 to <1	-
Erpobdellidae	-	0 to <1	-
Hydracarina	1	<1 to 18	5
Gastropoda	<1	0 to 3	<1
Bivalvia	-	0 to 4	-
Ceratopogonidae	1	<1 to 5	1
Chironomidae	57	2 to 69	44
Diptera (misc.)	1	0 to 12	3
Coleoptera	<1	0 to <1	-
Ephemeroptera	26	6 to 29	23
Odonata	1	<1 to 5	2
Plecoptera	2	<1 to 8	2
Trichoptera	<1	<1 to 5	<1
Heteroptera	<1	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	1,276	221 to 1,200	379
Richness	49	23 to 38	23
Equitability	0.16	0.23 to 0.38	0.33
% EPT	26	7 to 42	26

Table 5.5-12 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in the middle and upper reaches of the MacKay River.

Taxon	**Percent Major Taxa Enumerated in Each Year**					
	***Test* Reach MAR-E2**			***Baseline* Reach MAR-E3**		
	2002	**2003 to 2012**	**2013**	**2010**	**2011 to 2012**	**2013**
Hydra	<1	-	-	-	-	-
Nematoda	3	1 to 4	2	1	<1 to 1	3
Naididae	48	2 to 32	12	41	15 to 18	6
Tubificidae	<1	<1 to 8	-	<1	<1 to <1	<1
Enchytraeidae	1	<1 to 4	1	2	<1 to 3	2
Lumbriculidae	-	0 to 3	-	-	-	-
Erpobdellidae	-	0 to <1	-	-	-	-
Hydracarina	7	4 to 21	5	5	8 to 13	4
Gastropoda	<1	0 to 2	<1	1	<1 to <1	<1
Bivalvia	<1	0 to 4	-	1	<1 to 1	-
Ceratopogonidae	<1	<1 to 3	<1	1	<1 to <1	<1
Chironomidae	31	3 to 63	43	25	35 to 38	64
Diptera (misc.)	1	<1 to 5	<1	<1	<1 to <1	2
Coleoptera	-	0 to <1	<1	<1	<1 to 1	<1
Ephemeroptera	2	1 to 20	31	9	14 to 18	14
Odonata	<1	<1 to 1	<1	<1	<1 to 1	<1
Plecoptera	<1	1 to 3	3	3	2 to 4	2
Neuroptera	-	-	-	-	<1	-
Trichoptera	6	1 to 12	2	8	7 to 10	2
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	2,524	320 to 1,662	844	618	533 to 1,206	1,153
Richness	40	27 to 41	34	35	31 to 43	29
Equitability	0.11	0.16 to 0.40	0.27	0.24	0.26 to 0.32	0.22
% EPT	8	16 to 32	36	22	26 to 29	20

Table 5.5-13 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E1 of the MacKay River.

Variable	P-value					Variance Explained (%)					Nature of Change(s)
	***Baseline* Reach vs. *Test* Reach**	***Baseline* Period vs. *Test* Period**	**Time trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	***Baseline* Period vs. *Test* Period**	**Time trend (*Test* Period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log Abundance	0.559	0.985	**<0.001**	0.564	**0.004**	0	0	13	0	6	Decreasing over time in *test* period; lower in 2013 than mean of previous years.
Log Richness	**0.001**	0.725	**0.016**	0.084	**0.004**	17	0	9	5	13	Higher at *baseline* reach; decreasing over time; lower in 2013 than mean of previous years.
Equitability	**0.001**	0.380	0.694	**0.006**	0.423	20	1	0	14	1	Higher at *test* reach than *baseline* reach; higher in 2013 than mean of *baseline* reach years.
Log EPT	0.060	**0.020**	**0.002**	**<0.001**	0.562	4	6	11	58	0	Decreasing over time at *test* reach; higher in *baseline* period at *test* reach; lower at *test* reach in 2013 than mean of *baseline* reach years.
CA Axis 1	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.797	30	9	29	43	0	Decreasing over time; higher at *baseline* reach; higher in *baseline* period at *test* reach; lower at *test* reach in 2013 than mean of *baseline* reach years.
CA Axis 2	**<0.001**	**<0.001**	**0.007**	0.402	**0.049**	27	11	5	0	3	Increasing over time; higher at *baseline* reach; higher in *test* period at *test* reach; lower at *test* reach in 2013 than mean of previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.5-14 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints for *test* reach MAR-E2 of the MacKay River.

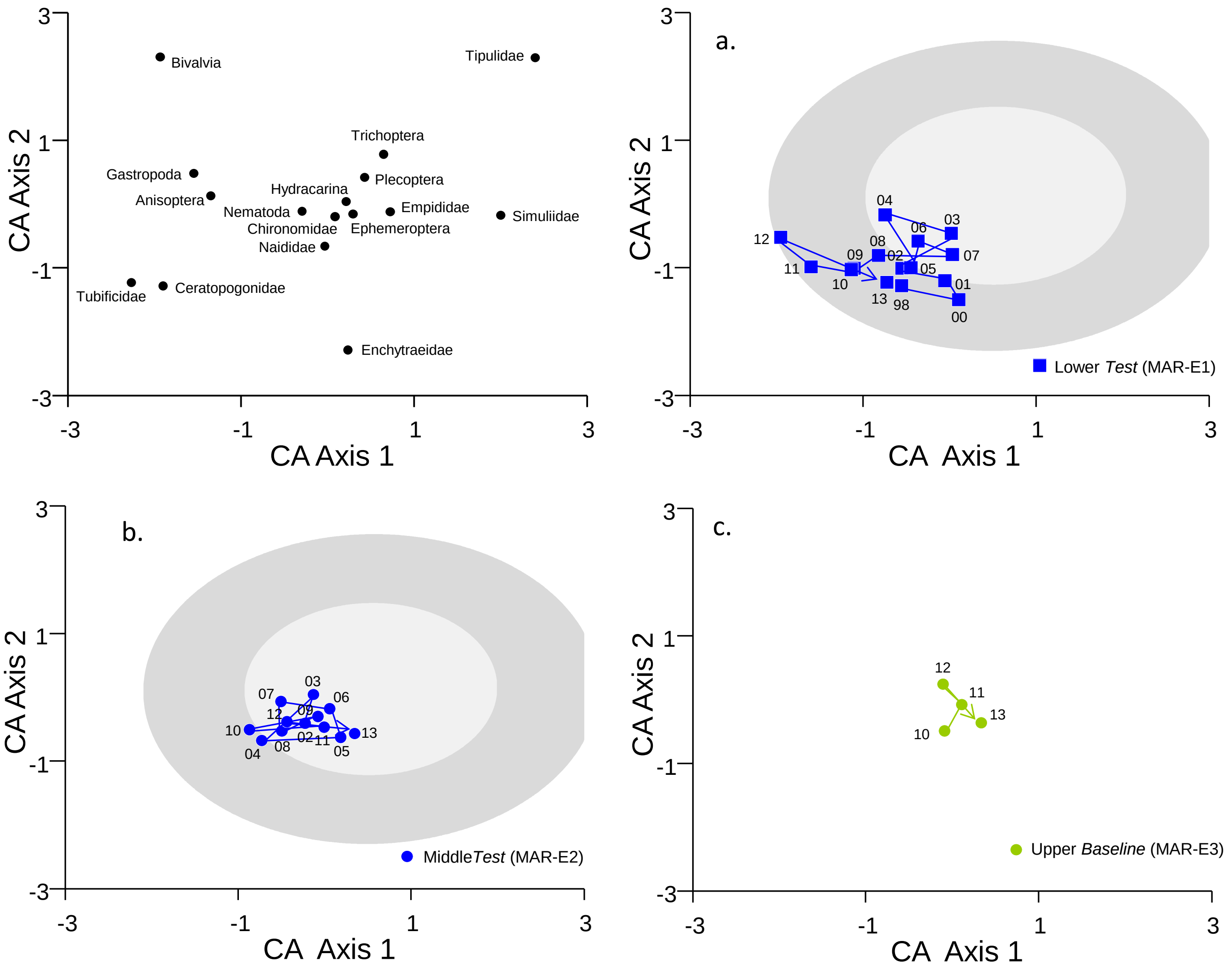
Variable	**P-value**				**Variance Explained (%)**				**Nature of Change(s)**
	***Baseline* Reach vs. *Test* Reach**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log Abundance	**0.047**	**<0.001**	0.639	0.501	3	13	0	4	Higher at *test* reach; decreasing over time.
Log Richness	0.667	0.755	0.290	0.325	0	0	2	12	No change.
Equitability	0.421	**0.040**	0.579	0.872	1	4	0	10	Increasing over time at *test* reach.
Log EPT	0.617	**<0.001**	**0.022**	**0.003**	0	38	7	0	Increasing over time at *test* reach; higher in 2013 than mean of *baseline* reach years and all previous years at *test* reach.
CA Axis 1	<0.001	0.001	0.327	0.090	13	1	3	18	Higher at *test* reach; increasing over time.
CA Axis 2	0.059	0.323	0.074	0.340	12	3	11	3	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

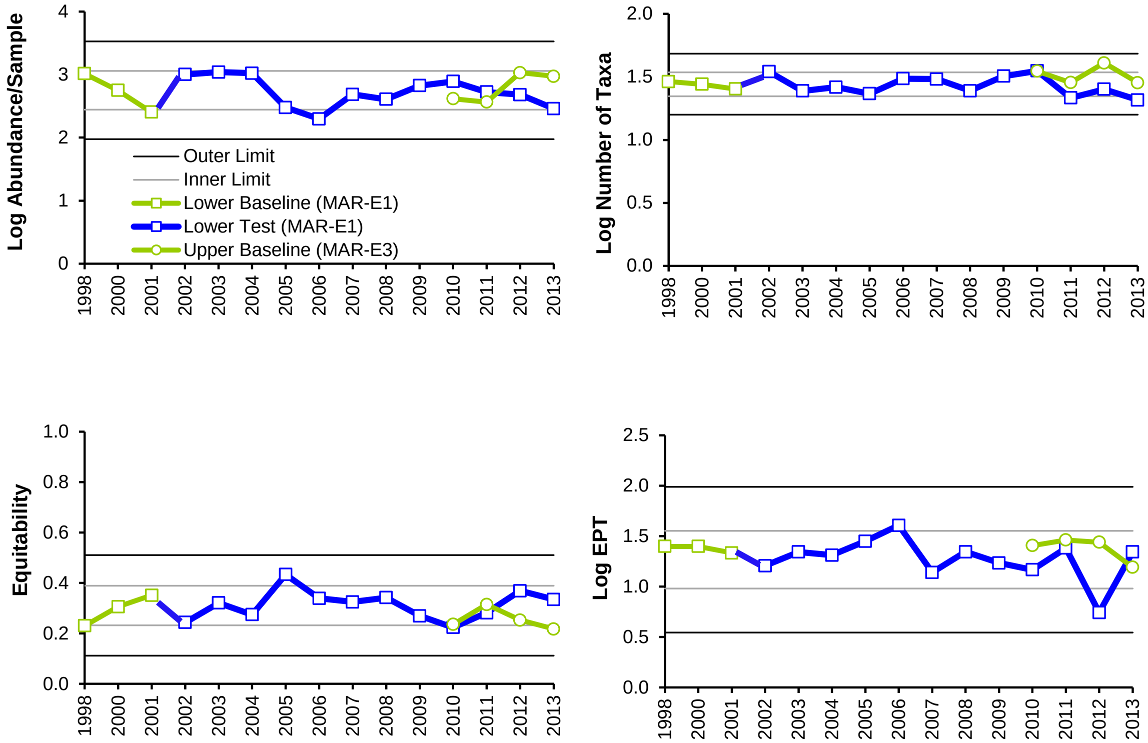
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.5-9 **Ordination (Correspondence Analysis) of benthic invertebrate communities in erosional reaches, showing the lower *test* reach (MAR-E1), middle *test* reach (MAR-E2), and upper *baseline* reach (MAR-E3) of the MacKay River.**



Note: Top left panel is the scatterplot of taxa scores, all other panels are scatterplots of sample scores. Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at either *test* reach (1998 to 2012).

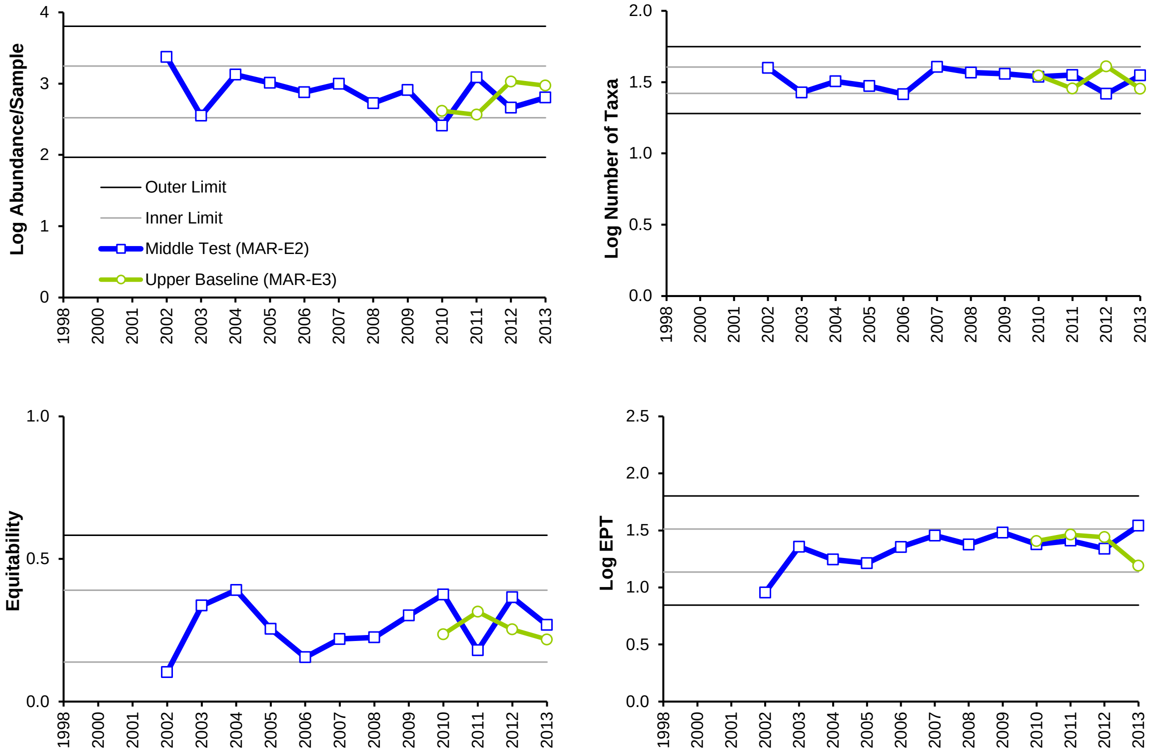
Figure 5.5-10 Variation in benthic invertebrate community measurement endpoints in the lower *test* reach (MAR-E1) and upper *baseline* reach (MAR-E3) of the MacKay River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at the lower *test* reach (1998 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.5-11 Variation in benthic invertebrate community measurement endpoints in the middle *test* reach (MAR-E2) and upper *baseline* reach (MAR-E3) of the MacKay River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at the middle *test* reach (2002 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.5-15 Average habitat characteristics of fish assemblage monitoring locations in the MacKay River, fall 2013.

Variable	Units	MAR-F1 Lower *Test* Reach of the MacKay River	MAR-F2 Middle *Test* Reach of the MacKay River	MAR-F3 Upper *Baseline* Reach of the MacKay River
Sample date	-	Sept 11, 2013	Sept 12, 2013	Sept 4, 2013
Habitat type	-	run	riffle	riffle/run
Maximum depth	m	0.61	0.53	0.86
Mean depth	m	0.44	0.39	0.52
Bankfull channel width	m	60	48	46
Wetted channel width	m	50	35	42
Substrate				
Dominant	-	sand	cobble	cobble/gravel
Subdominant	-	gravel	boulder	sand
Instream cover				
Dominant	-	macrophytes, small woody debris, boulders	boulders	boulders
Subdominant	-	filamentous algae	filamentous algae	filamentous algae, macrophytes, overhanging vegetation
Field water quality				
Dissolved oxygen	mg/L	8.8	9.6	3.0
Conductivity	µS/cm	234	224	195
pH	pH units	8.42	6.97	7.95
Water temperature	^{0}C	16.1	16.0	15.5
Water velocity				
Left bank velocity	m/s	0.28	0.41	0.27
Left bank water depth	m	0.43	0.40	0.39
Centre of channel velocity	m/s	0.30	0.30	0.63
Centre of channel water depth	m	0.52	0.38	0.53
Right bank velocity	m/s	0.26	0.47	0.26
Right bank water depth	m	0.36	0.40	0.65
Riparian cover – understory (<5 m)				
Dominant	-	woody shrubs and saplings	-	overhanging vegetation
Subdominant	-	-	-	woody shrubs and saplings

Table 5.5-16 Total number and percent composition of fish species captured at reaches of the MacKay River, 2009 to 2013.

Common Name	**Code**	**Total Species**										**Percent of Total Catch**									
		***Test* Reach MAR-F1**				***Test* Reach MAR-F2**			***Baseline* Reach MAR-F3**			***Test* Reach MAR-F1**				***Test* Reach MAR-F2**			***Baseline* Reach MAR-F3**		
		2009	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2009**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**
Arctic grayling	ARGR	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
brook stickleback	BRST	1	-	1	-	-	-	-	-	-	-	5.6	0	0.7	0	0	0	0	0	0	0
burbot	BURB	-	-	-	5	-	-	-	-	-	-	0	0	0	50.0	0	0	0	0	0	0
flathead chub	FLCH	-	-	1	-	-	-	-	-	-	-	0	0	0.7	0	0	0	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	-	1	-	-	-	1	-	-	-	-	0	3.4	0	0	0	2.4	0	0	0	0
goldeye	GOLD	-	-	1	-	-	-	-	-	-	-	0	0	0.7	0	0	0	0	0	0	0
lake chub	LKCH	1	3	-	-	22	30	12	6	3	1	5.6	10.3	0	0	40.7	71.4	21.4	15.8	7.3	4.5
lake whitefish	LKWH	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
longnose dace	LNDC	-	4	-	-	21	3	36	1	1	11	0	13.8	0	0	38.9	7.1	64.3	2.6	2.4	50.0
longnose sucker	LNSC	-	1	-	-	2	1	3	1	1	2	0	3.4	0	0	3.7	2.4	5.4	2.6	2.4	9.1
northern pike	NRPK	1	-	-	-	-	-	1	-	1	-	5.6	0	0	0	0	0	1.8	0	2.4	0
northern redbelly dace	NRDC	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
pearl dace	PRDC	-	-	7	-	-	-	-	-	-	-	0	0	4.7	0	0	0	0	0	0	0
slimy sculpin	SLSC	-	1	-	3	1	2	4	21	12	7	0	3.4	0	30.0	1.9	4.8	7.1	55.3	29.3	31.8
spoonhead sculpin	SPSC	9	7	-	-	-	-	-	-	-	-	50	24.1	0	0	0	0	0	0	0	0
spottail shiner	SPSH	-	-	2	-	-	-	-	-	-	-	0	0	1.3	0	0	0	0	0	0	0
trout-perch	TRPR	6	10	133	-	8	5	-	9	23	1	33.3	34.5	88.7	0	14.8	11.9	0	23.7	56.1	4.5
walleye	WALL	-	-	2	1	-	-	-	-	-	-	0	0	1.3	10.0	0	0	0	0	0	0
white sucker	WHSC	-	2	3	-	-	-	-	-	-	-	0	6.9	2.0	0	0	0	0	0	0	0
yellow perch	YLPR	-	-	-	1	-	-	-	-	-	-	0	0	0	10.0	0	0	0	0	0	0
Total		**18**	**29**	**150**	**10**	**54**	**42**	**56**	**38**	**41**	**22**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**8**	**8**	**4**	**5**	**6**	**5**	**5**	**6**	**5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**2,980**	**1,372**	**2,920**	**3,015**	**1,480**	**2,017**	**2,529**	**1,375**	**1,977**	**2,509**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 5.5-17 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in the MacKay River.

Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Time Trend (*test* reach MAR-F1)	***Baseline*** **Reach vs.** ***Test*** **Reach MAR-F1**	Time Trend (*test* reach MAR-F2)	***Baseline*** **Reach vs.** ***Test*** **Reach MAR-F2**	Time Trend (*test* reach MAR-F1)	***Baseline*** **Reach vs.** ***Test*** **Reach MAR-F1**	Time Trend (*test* reach MAR-F2)	***Baseline*** **Reach vs.** ***Test*** **Reach MAR-F2**	
Abundance	0.141	0.824	**<0.001**	0.921	15.8	1.0	76.4	1.0	Decreasing over time at *test* reach MAR-F2.
Richness	**0.020**	0.111	0.743	0.515	35.1	9.0	1	2.0	Decreasing over time at *test* reach MAR-F1.
Diversity	**0.003**	**0.016**	0.82	0.723	50.4	20.0	1	1.0	Decreasing over time at *test* reach MAR-F1; higher at *baseline* reach MAR-F3 than *test* reach MAR-F1.
ATI	0.498	0.056	0.127	0.339	3.5	13.0	16.9	3.0	No change.
CPUE (No./100 sec)	0.052	0.990	**0.007**	0.738	26	1.0	43.9	1.0	Decreasing over time at *test* reach MAR-F2.

Bold values indicate significant difference (p<0.05).

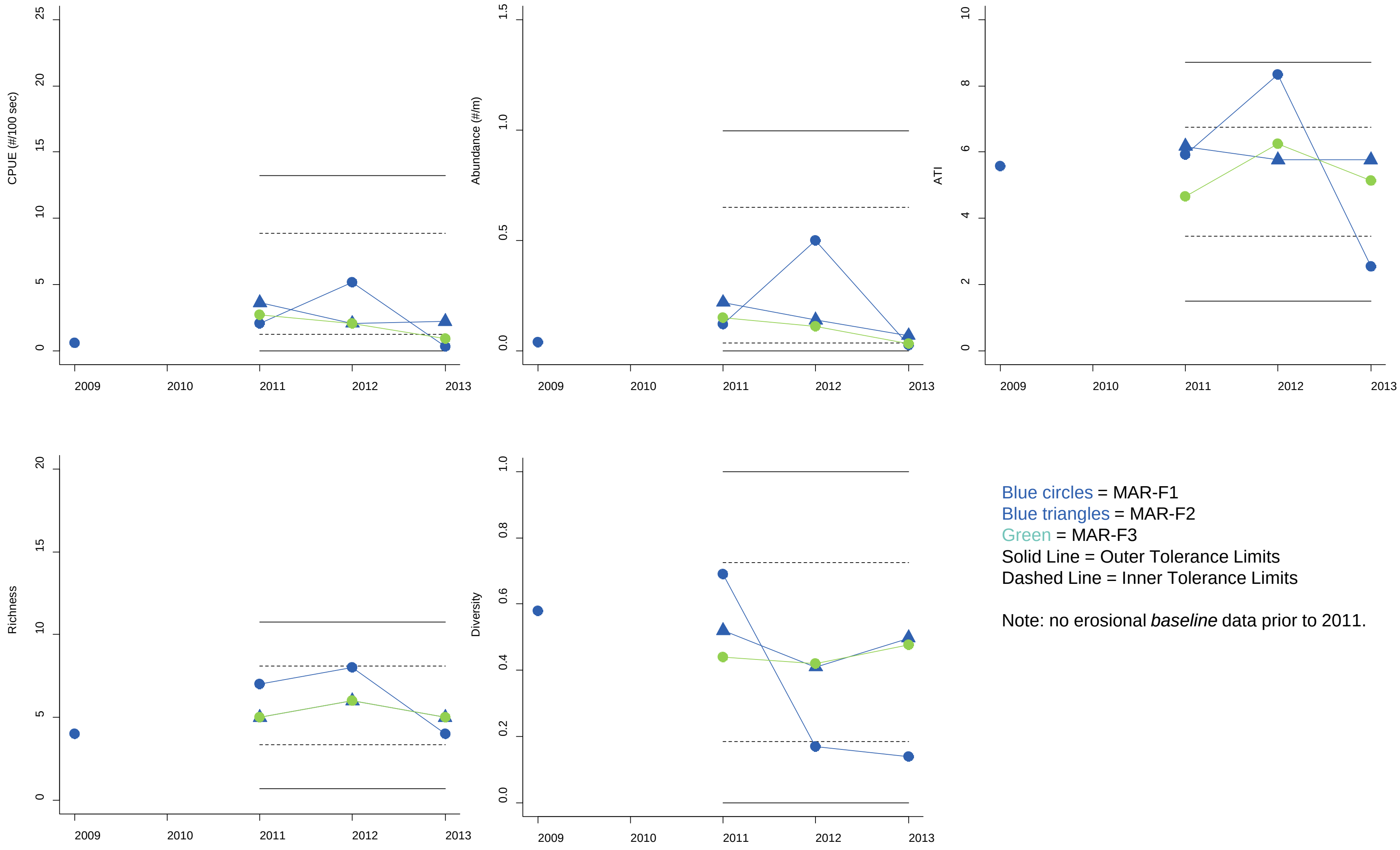
Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-17).

Table 5.5-18 Summary of fish assemblage measurement endpoints (± 1SD) in reaches of the MacKay River, 2009 to 2013.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	**SD**	**Total**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
MAR-F1	2009	0.04	-	5	4	-	0.58	-	5.57	-	3.89	-
	2011	0.12	0.05	8	4	0.84	0.69	0.06	5.93	0.95	2.09	0.87
	2012	0.50	0.30	8	3	1.87	0.17	0.19	8.34	0.16	5.19	3.21
	2013	0.03	0.04	4	1	1.52	0.14	0.31	2.54	1.08	0.33	0.46
MAR-F2	2011	0.22	0.05	5	3	1.10	0.52	0.21	6.17	0.32	3.66	0.81
	2012	0.14	0.03	6	3	0.84	0.41	0.19	5.77	0.56	2.09	0.54
	2013	0.07	0.01	5	3	0.89	0.50	0.07	5.76	0.23	2.21	0.35
MAR-F3	2011	0.15	0.05	5	3	1.30	0.44	0.28	4.66	1.51	2.74	0.88
	2012	0.11	0.08	6	3	1.34	0.42	0.25	6.25	1.48	2.08	1.49
	2013	0.03	0.01	5	2	0.55	0.48	0.13	5.13	0.36	0.96	0.16

SD = standard deviation across sub-reaches within a reach.

Figure 5.5-12 Variation in fish assemblage measurement endpoints at erosional reaches of the MacKay River from 2009 to 2013, relative to regional *baseline* conditions.



Note: no erosional *baseline* data prior to 2011.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* erosional reaches.

5.6 CALUMET RIVER WATERSHED

Table 5.6-1 Summary of results for the Calumet River watershed.

Calumet River Watershed	Summary of 2013 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		
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2013		
Fish Populations		
No Fish Populations component activities conducted in 2013		

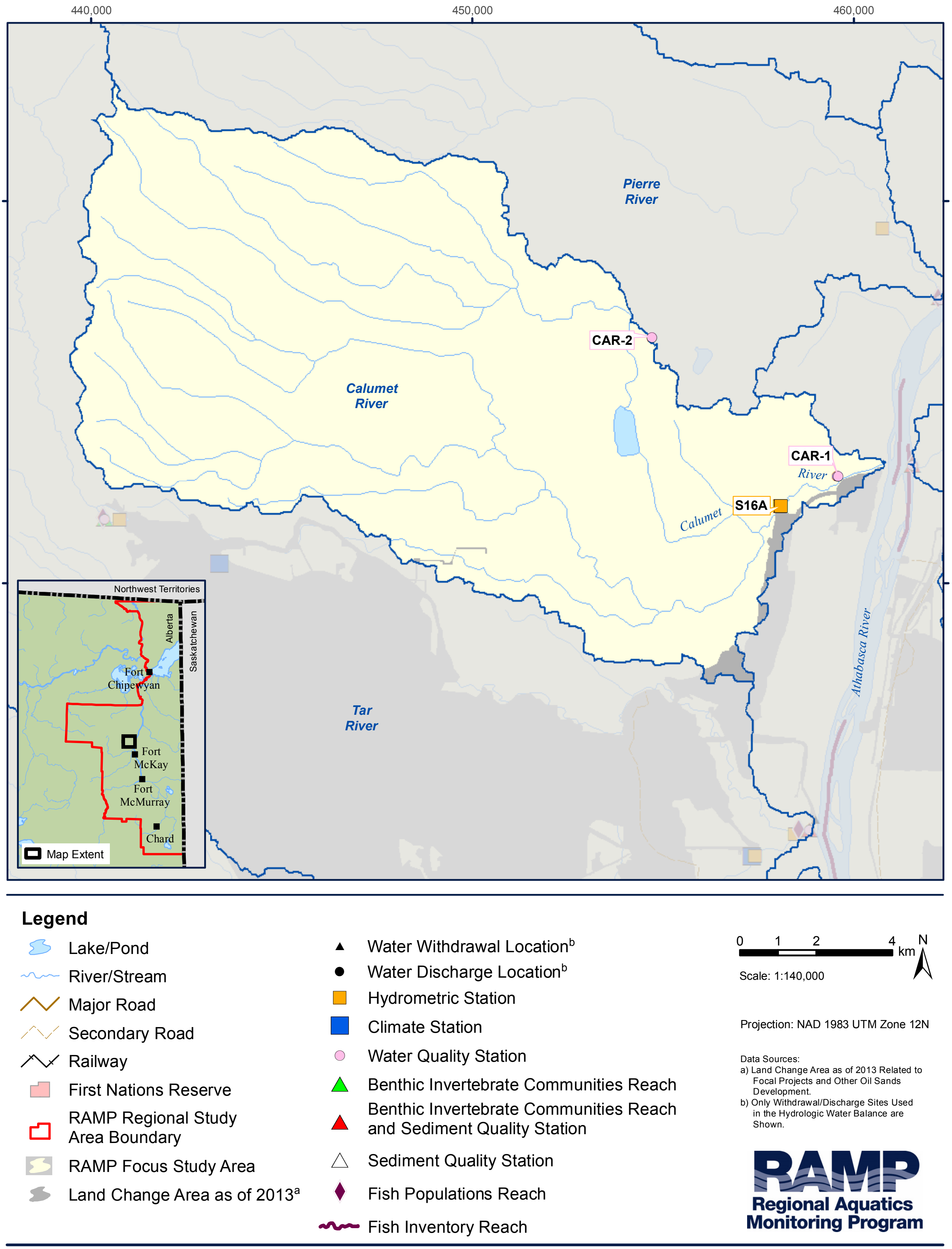
Legend and Notes

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

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.

Figure 5.6-1 Calumet River watershed.



K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K06_Calumet_20140224_ss.mxd

Figure 5.6-2 Representative monitoring stations of the Calumet River, 2013.

Water Quality Station CAR-1:
Left Downstream Bank, facing upstream

Water Quality Station CAR-2:
Right Downstream Bank, facing downstream

Hydrology Station S16A (September):
Centre of Channel, facing downstream

Hydrology Station S16A (August):
Right Downstream Bank, facing downstream

5.6.1 Summary of 2013 Conditions

As of 2013, 1.14% (199 ha) of the Calumet River watershed had undergone land change from focal projects, with no change from 2012 (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 and Water Quality components of RAMP in the Calumet River watershed in 2013. Table 5.6-1 is a summary of the 2013 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 2013. Figure 5.6-2 contains fall 2013 photos of the water quality monitoring stations in the watershed.

Hydrology For the 2013 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge for Station S16A were estimated to be 0.3% lower than from the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2013, water quality at *test* station CAR-1 showed **Negligible-Low** differences from regional *baseline* conditions**,** while *baseline* station CAR-2 showed **Moderate** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within previously-measured ranges at both stations; however, concentrations of many water quality measurement endpoints were outside of the range of regional *baseline* concentrations at *baseline* station CAR-2 in fall 2013 (e.g., major ions). The ionic composition of water at *test* station CAR-1 was consistent with previous years while the ionic composition of water at *baseline* station CAR-2 was less dominated by bicarbonate ions in 2013 than in the previous two sampling years.

5.6.2 Hydrologic Conditions: 2013 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 2013 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 most historical years; therefore, calculated statistics of historical runoff volumes and daily flows for comparison against the 2013 WY data were not as robust.

The annual runoff volume in the 2013 WY was 10.58 million m^3 measured from May 1 to October 31, 2013. Flows increased rapidly from the start of monitoring on May 1 to a peak of 7.26 m^3/s on May 8, 2013. This was the highest flow recorded in the 2013 WY, and was 104% higher than the historical mean open-water maximum daily flow (Figure 5.6-3). Flows decreased following this peak until early June, with the exception of a small increase following rainfall events in mid-May (Figure 5.6-3). Rainfall events from early to mid-June resulted in flows exceeding the historical maximum values, with flow reaching 3.90 m^3/s on June 16, 2013. Following this peak, flows generally decreased until August 23, before increasing again due to late August rainfall events. The minimum open-water daily flow of 0.007 m^3/s, recorded on September 16, was 59% lower than the historical mean open-water mean minimum daily flow of 0.017 m^3/s. Flows increased in late September and early October due to rainfall events and then decreased steadily until the end of the 2013 WY.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the 2013 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 2013 was estimated to be 0.70 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 44,000 m^3.

2. As of 2013, the area of land change in the Calumet River watershed from focal projects that was not closed-circuited was estimated to be 1.29 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 16,000 m^3.

The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 28,000 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 2013 WY, the mean open-water season discharge, annual maximum daily discharge, and open-water minimum daily discharge for Station S16A were estimated to be 0.3% lower than from the estimated *baseline* hydrograph (Table 5.6-3). These differences were classified as **Negligible-Low** (Table 5.6-1).

5.6.3 Water Quality

In fall 2013, 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 2013; 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.

2013 Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2013 exceeded previously-measured maximum concentrations of pH, calcium, magnesium, sulphate, and total strontium at *test* station CAR-1 (Table 5.6-4).

Concentrations of calcium, sulphate, total molybdenum, total strontium, and pH exceeded previously-measured maximum concentrations in *baseline* station CAR-2, while concentrations of dissolved phosphorus and total nitrogen were below previously-measured minimum concentrations (Table 5.6-5).

Ion Balance The ionic composition of water at *test* station CAR-1 in fall 2013 has remained consistent since water quality monitoring first began in 2002, with the exception of fall 2007 when the cation composition was more calcium-dominated than in other years (Figure 5.6-4). In fall 2013, the ionic composition of water at *baseline* station CAR-2 was generally similar to historical results, but with a lower relative concentration of bicarbonate than most previous sampling years. Across sampling years, water at *baseline* station CAR-2 has had a lower relative concentration of bicarbonate than water at *test* station CAR-1 (Figure 5.6-4).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in fall 2013 were below water quality guidelines (Table 5.6-4 and Table 5.6-5), with the exception of:

- dissolved phosphorous and total nitrogen at *test* station CAR-1 and *baseline* station CAR-2; and
- total aluminum at *baseline* station CAR-2.

Other Water Quality Guideline Exceedances Additional guideline exceedances in fall 2013 at *test* station CAR-1 and *baseline* station CAR-2 were observed for dissolved iron, sulphide, total iron, total phenols, and total phosphorous (Table 5.6-6).

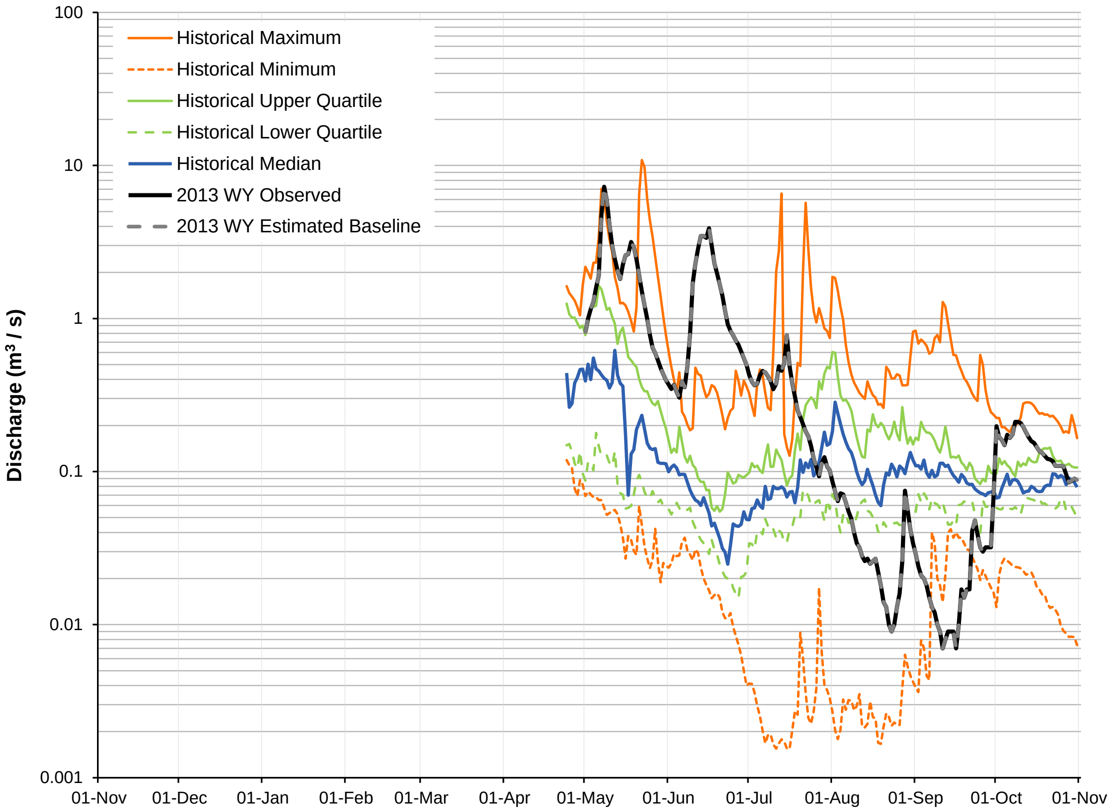
2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of several dissolved ions were outside the range of regional *baseline* concentrations at *test* station CAR-1 and *baseline* station CAR-2, including (Figure 5.6-5):

- calcium and magnesium, with concentrations that exceeded the 95th percentile of the regional *baseline* concentrations at *test* station CAR-1; and
- total dissolved solids, total strontium, calcium, magnesium, sodium, potassium, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station CAR-2.

Water Quality Index The WQI value for *test* station CAR-1 (89.9) indicated a **Negligible-Low** difference from regional *baseline* conditions, while the WQI value for *baseline* station CAR-2 (78.6) indicated a **Moderate** difference from the regional *baseline* conditions in fall 2013. Both *test* station CAR-1 and *baseline* station CAR-2 have had **Negligible-Low** differences from the regional *baseline* conditions in the previous three years (WQI values ranging from 80.9 to 100 from 2010 to 2012), but in 2009, *baseline* station CAR-2 also showed a **Moderate** difference. Historically the WQI values have been more variable at *baseline* station CAR-2.

Classification of Results In fall 2013, water quality at *test* station CAR-1 indicated **Negligible-Low** differences from regional *baseline* conditions, while *baseline* station CAR-2 showed **Moderate** differences from regional *baseline* conditions (Table 5.6-1). Concentrations of most water quality measurement endpoints were within previously-measured ranges at both stations; however, concentrations of many water quality measurement endpoints were outside of the range of regional *baseline* concentrations at *baseline* station CAR-2 in fall 2013 (e.g., major ions). The ionic composition of water at *test* station CAR-1 was consistent with previous years while the ionic composition of water at *baseline* station CAR-2 was less dominated by bicarbonate ions in 2013 than in the previous two sampling years.

Figure 5.6-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Calumet River in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on Calumet River near the mouth, RAMP Station S16A, provisional data for May 1 to October 31, 2013. The upstream drainage area is 169 km^2. Historical values from 2001 to 2012 were used in the calculation for the open-water period at Station S16 (2001 to 2004), Station CR-1 (2005 to 2009), and Station S16A (2010 to 2012).

Table 5.6-2 Estimated water balance at Station S16A, Calumet River near the mouth, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**10.581**	**Observed discharge from Calumet River near the mouth, RAMP Station S16A**
Closed-circuited area water loss from the observed *test* hydrograph	-0.044	Estimated 0.70 km^2 of the Calumet River watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.016	Estimated 1.29 km^2 of the Calumet River watershed with land change from focal projects as of 2013 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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**10.608**	**Estimated *baseline* discharge from Calumet River near the mouth, RAMP Station S16A.**
Incremental flow (change in total discharge)	-0.028	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**-0.26%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for May 1 to October 31, 2013 for RAMP Station S16A, Calumet River near the mouth.

Table 5.6-3 Calculated change in hydrologic measurement endpoints in the Calumet River watershed, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.667	0.666	-0.26%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	7.276	7.257	-0.26%
Open-water season minimum daily discharge	0.007	0.007	-0.26%

Note: Values were calculated from provisional data for May 1 to October 31, 2013 for Calumet River near the mouth, RAMP Station S16A.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three 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 5.6-4 Concentrations of water quality measurement endpoints, mouth of Calumet River (*test* station CAR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.6	11	8.1	8.2	8.4
Total suspended solids	mg/L	-	<3.0	11	<3.0	11	66.0
Conductivity	µS/cm	-	668	11	188	554	702
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.052**	11	0.025	**0.055**	**0.122**
Total nitrogen	mg/L	1.0	**1.01**	11	0.80	**1.35**	**1.54**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	31.7	11	22.0	32.5	40.7
Ions							
Sodium	mg/L	-	51.6	11	7.0	48.4	71.0
Calcium	mg/L	-	74.2	11	25.3	55.3	67.3
Magnesium	mg/L	-	23.4	11	7.80	17.9	22.5
Chloride	mg/L	120	19.2	11	2.0	14.0	34.0
Sulphate	mg/L	270	23.5	11	3.6	12.3	20.5
Total dissolved solids	mg/L	-	461	11	151	394	480
Total alkalinity	mg/L	-	327	11	96	275	337
Selected metals							
Total aluminum	mg/L	0.1	0.068	11	0.040	**0.158**	**1.280**
Dissolved aluminum	mg/L	0.1	0.0052	11	0.0013	0.0036	0.0058
Total arsenic	mg/L	0.005	0.0012	11	0.0009	0.0011	0.0016
Total boron	mg/L	1.2	0.100	11	0.074	0.085	0.122
Total molybdenum	mg/L	0.073	0.00013	11	0.00011	0.00015	0.00030
Total mercury (ultratrace)	ng/L	5, 13	0.94	10	<1.20	<1.20	3.80
Total strontium	mg/L	-	0.32	11	0.16	0.23	0.30
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	0.26	0.26
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.16	2	0.05	0.30	0.55
Oilsands Extractable	mg/L	-	1.42	2	0.55	1.71	2.87
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	1.11	2	3.35	9.23	15.10
Total dibenzothiophenes	ng/L	-	54.7	2	67.1	86.1	105.0
Total PAHs	ng/L	-	245	2	387	440	494
Total Parent PAHs	ng/L	-	25.8	2	23.6	26.3	29.1
Total Alkylated PAHs	ng/L	-	219	2	364	414	464
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.30	**0.527**	11	0.273	**0.492**	**0.911**
Sulphide	mg/L	0.002	**0.010**	11	**0.005**	**0.014**	**0.028**
Total iron	mg/L	0.3	**2.00**	11	**0.54**	**1.46**	**3.14**
Total phenols	mg/L	0.004	**0.016**	10	<0.001	**0.009**	**0.013**
Total phosphorous	mg/L	0.05	**0.107**	11	**0.066**	**0.094**	**0.209**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	8	7.7	8.1	8.2
Total suspended solids	mg/L	-	9.0	8	<3.0	4.0	208
Conductivity	µS/cm	-	734	8	494	597	772
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.068**	8	**0.079**	**0.124**	**0.305**
Total nitrogen	mg/L	1.0	**1.7**	8	**1.8**	**2.0**	**5.5**
Nitrate+nitrite	mg/L	3	<0.071	8	<0.071	<0.086	<0.100
Dissolved organic carbon	mg/L	-	47.4	8	36.1	47.5	54.4
Ions							
Sodium	mg/L	-	74.4	8	53.0	67.0	76.0
Calcium	mg/L	-	72.5	8	29.6	47.9	68.2
Magnesium	mg/L	-	24.4	8	12.3	19.5	26.6
Chloride	mg/L	120	13.6	8	12.3	15.7	24.3
Sulphate	mg/L	270	103.0	8	23.5	53.2	101.0
Total dissolved solids	mg/L	-	535	8	323	467	547
Total alkalinity	mg/L		275	8	188	236	315
Selected metals							
Total aluminum	mg/L	0.1	**0.242**	8	0.020	0.056	**4.100**
Dissolved aluminum	mg/L	0.1	0.007	8	0.004	0.012	0.024
Total arsenic	mg/L	0.005	0.0024	8	0.0009	0.0025	**0.0050**
Total boron	mg/L	1.2	0.127	8	0.076	0.091	0.128
Total molybdenum	mg/L	0.073	0.00102	8	0.00009	0.00044	0.00080
Total mercury (ultra-trace)	ng/L	5, 13	1.4	8	<1.2	1.3	4.4
Total strontium	mg/L	-	0.37	8	0.15	0.28	0.36
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	0.45	0.65
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	0.37	0.49
Naphthenic Acids	mg/L	-	0.50	2	0.11	0.28	0.45
Oilsands Extractable	mg/L	-	0.90	2	0.73	1.36	1.98
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.2	2	<8.8	<11.4	<14.1
Retene	ng/L	-	10.80	2	0.97	2.35	3.73
Total dibenzothiophenes	ng/L	-	6.67	2	5.88	20.65	35.41
Total PAHs	ng/L	-	115	2	151	179	207
Total Parent PAHs	ng/L	-	22.5	2	17.4	18.3	19.3
Total Alkylated PAHs	ng/L	-	92.8	2	132.0	160.8	189.7
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.30	**0.578**	8	0.110	**0.387**	**1.500**
Sulphide	mg/L	0.002	**0.029**	8	**0.024**	**0.036**	**0.588**
Total iron	mg/L	0.30	**1.250**	8	0.167	**0.986**	**6.680**
Total phenols	mg/L	0.004	**0.011**	8	**0.008**	**0.016**	**0.041**
Total phosphorous	mg/L	0.05	**0.138**	8	**0.081**	**0.305**	**1.480**

[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.

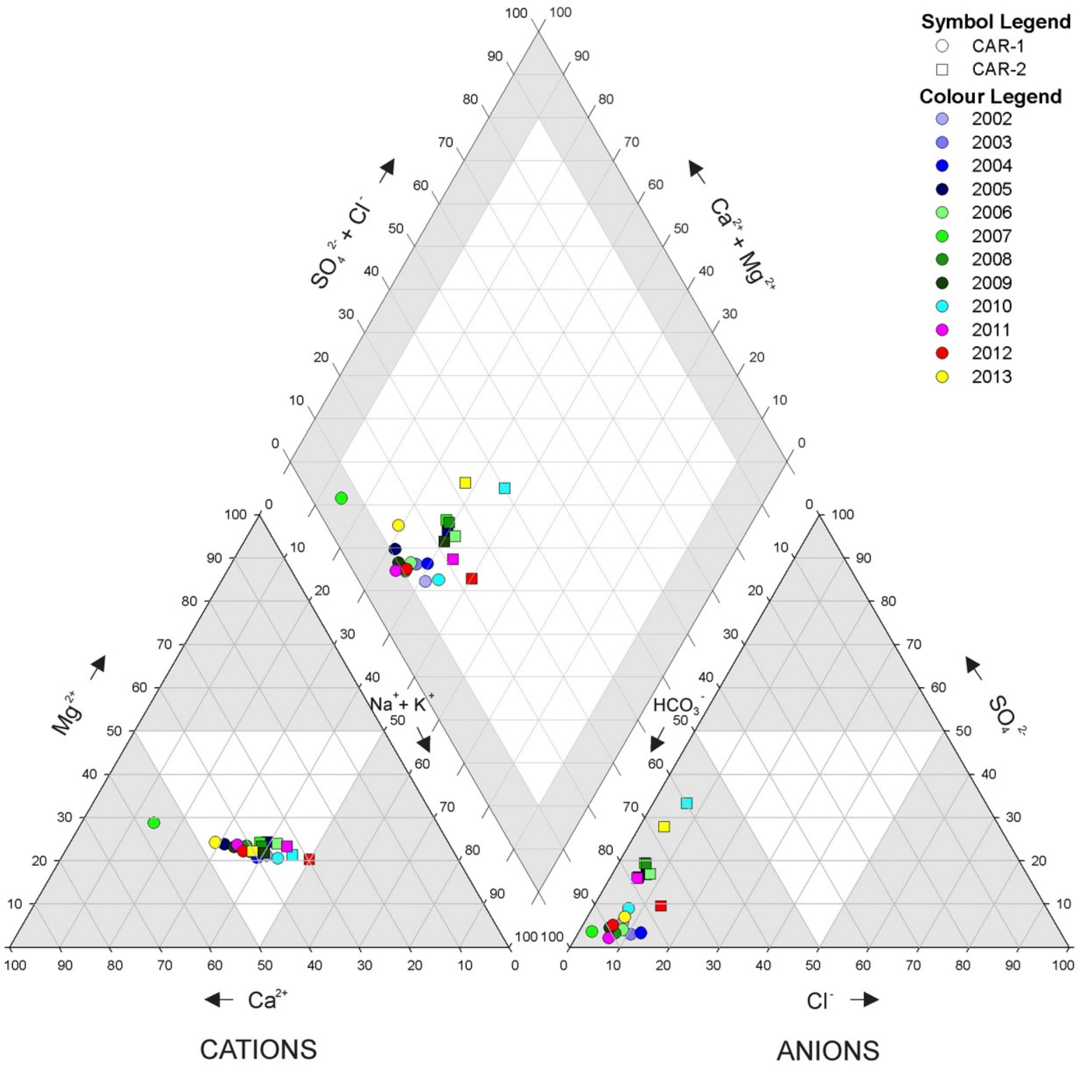
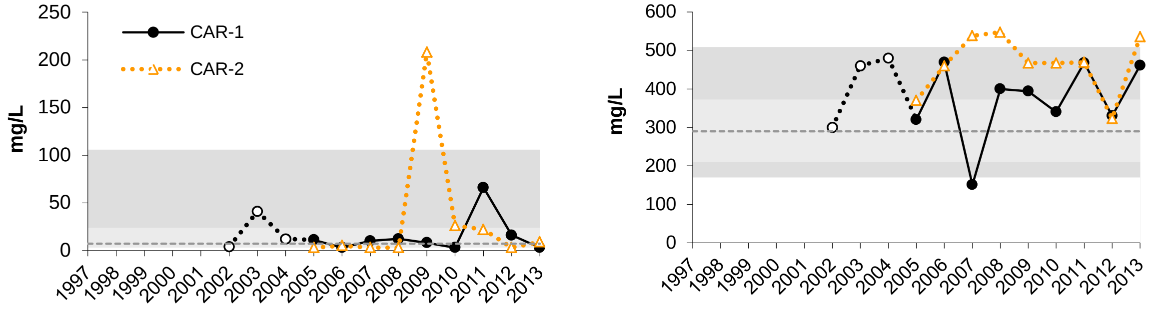


Table 5.6-6 Water quality guideline exceedances, Calumet River watershed, fall 2013.

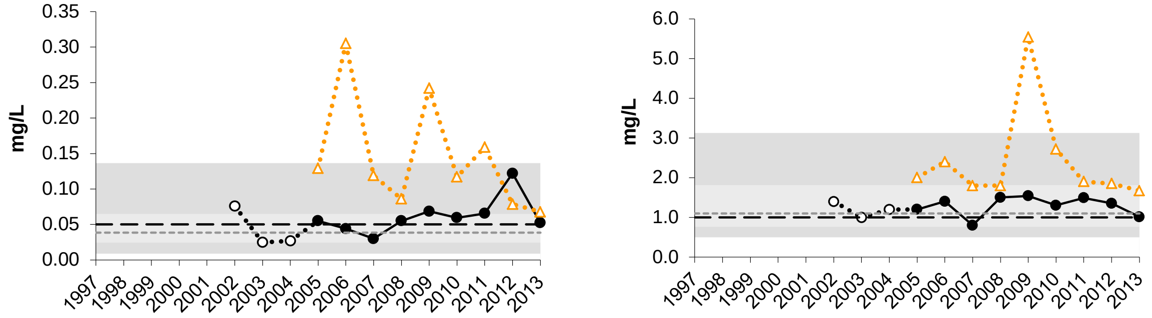
Variable	Units	Guideline[a]	CAR-1	CAR-2
Dissolved iron	mg/L	0.3	0.527	0.578
Sulphide	mg/L	0.002	0.010	0.029
Total aluminum	mg/L	0.1	-	0.242
Total dissolved phosphorus	mg/L	0.05	0.052	0.068
Total iron	mg/L	0.3	2.00	1.25
Total nitrogen	mg/L	1	1.01	1.67
Total phenols	mg/L	0.004	0.016	0.011
Total phosphorous	mg/L	0.05	0.107	0.138

[a] Sources for all guidelines are outlined in Table 3.2-5.

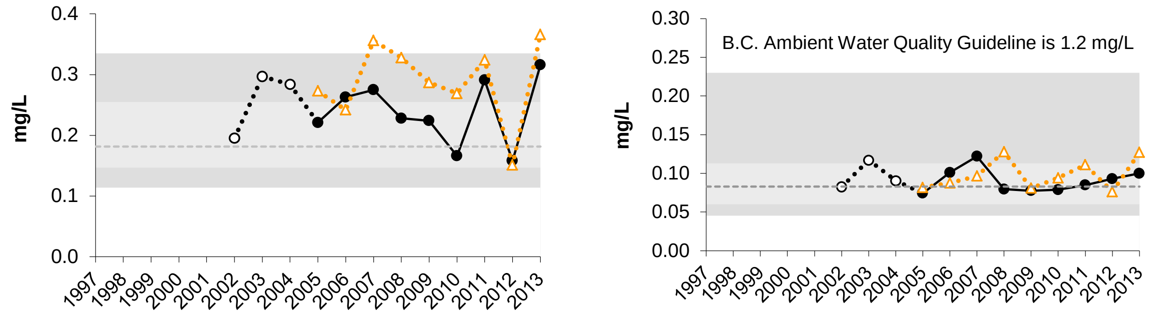
Figure 5.6-5 Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

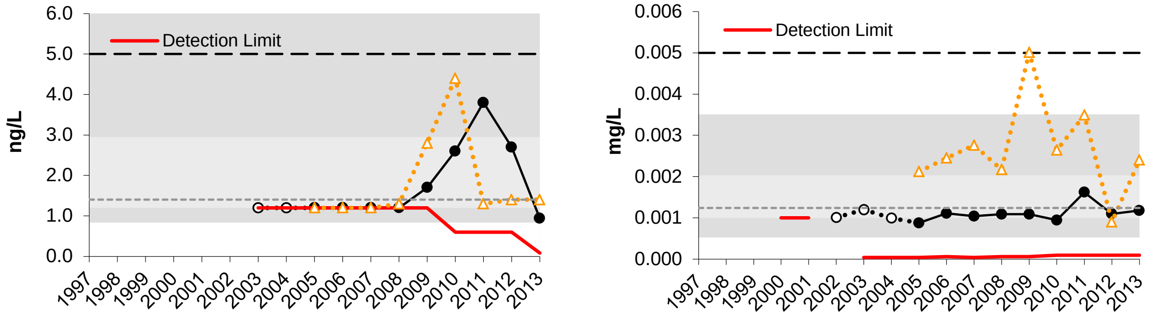
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

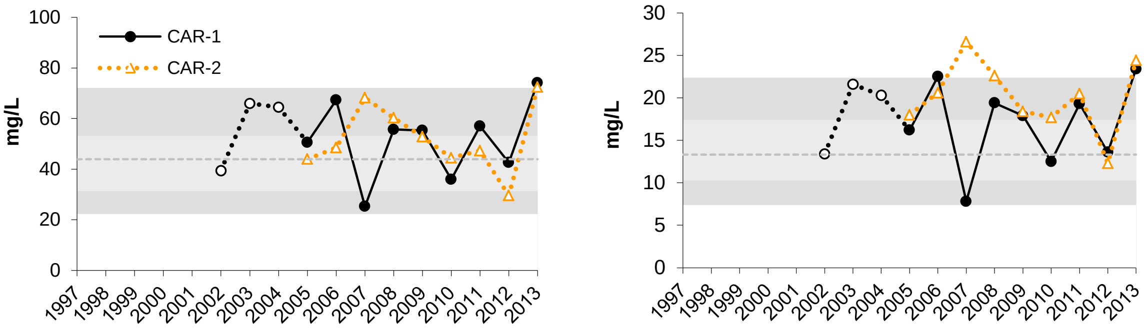
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

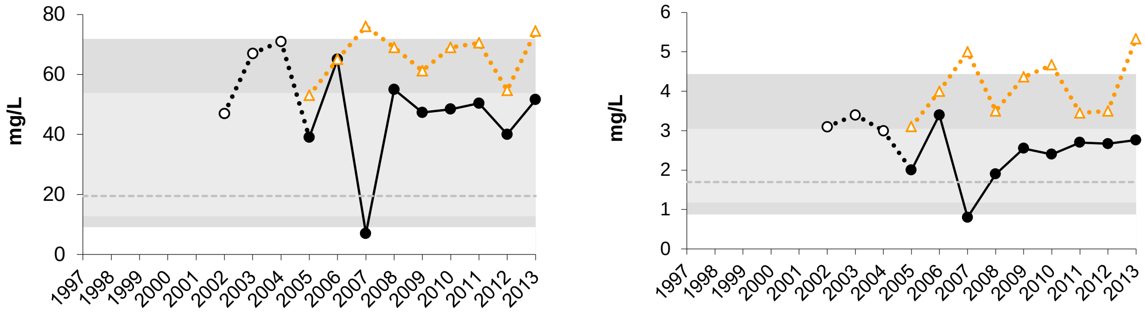
○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

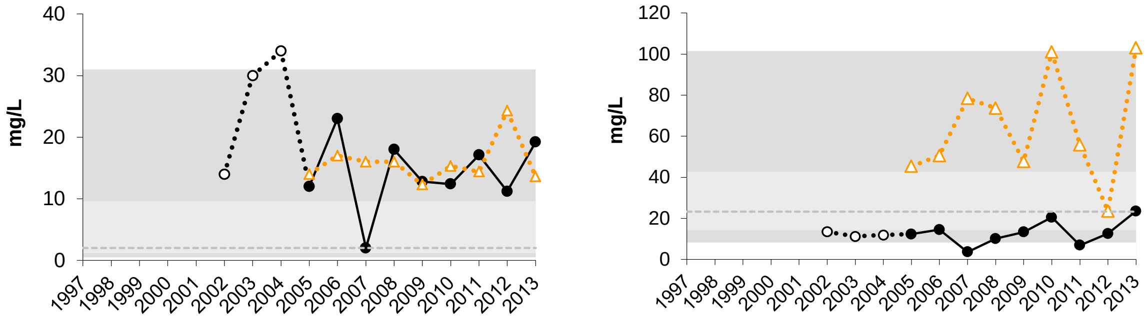
Figure 5.6-5 (Cont'd.)


Calcium

Magnesium


Sodium

Potassium


Chloride

Sulphate

Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

5.7 FIREBAG RIVER WATERSHED

Table 5.7-1 Summary of results for the Firebag River watershed.

Firebag River Watershed	Summary of 2013 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	🟡	n/a	🟡	n/a
Sediment Quality Index	🟡	not sampled	n/a	n/a
Fish Populations				
Criteria	**FIR-F1** at the mouth	**FIR-F2** upstream of Suncor Firebag	no station sampled	no station sampled
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. 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.

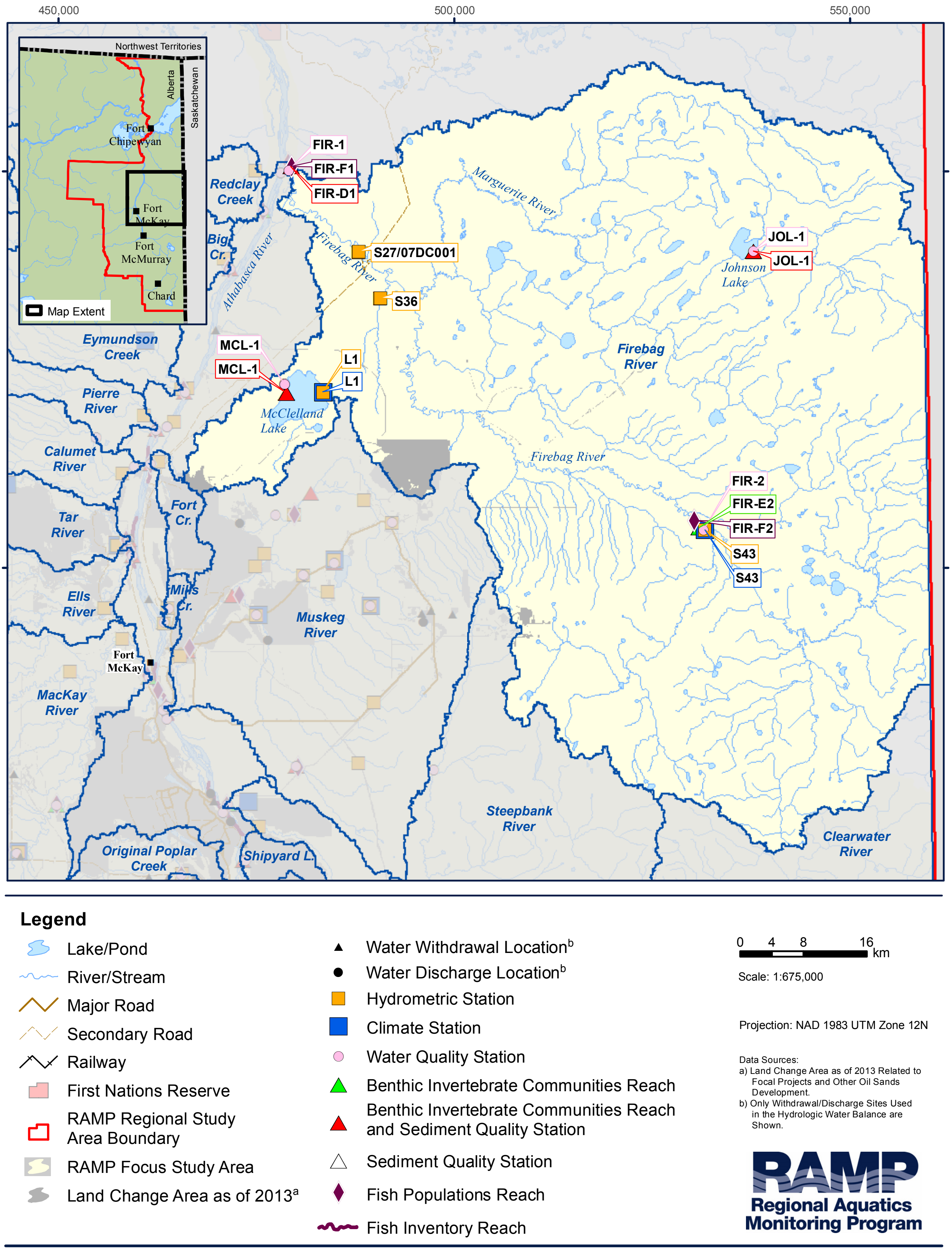
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* 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.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.7-1 Firebag River watershed.



Scale: 1:675,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2013 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\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K07_Firebag_20140224_ss.mxd

Figure 5.7-2 Representative monitoring stations of the Firebag River watershed, fall 2013.

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:
Johnson Lake, aerial view

Hydrology Station L1:
McClelland Lake

Water Quality Station MCL-1:
McClelland Lake

5.7.1 Summary of 2013 Conditions

Approximately 1.2% (6,724 ha) of the Firebag River watershed underwent land change as of 2013 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, and Fish Populations components of RAMP in the Firebag River watershed in 2013. Table 5.7-1 is a summary of the 2013 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 2013. Figure 5.7-2 contains fall 2013 photos from a number of monitoring stations in the watershed.

Hydrology The 2013 WY mean winter and 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**.

Water levels recorded at Station L1, McClelland Lake, were generally near the upper quartile and maximum values in the 2013 WY due to rainfall events in mid-June. Lake levels from July to mid-September varied between the historical median and upper quartile values.

Water Quality In fall 2013, 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 2013 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 2013. 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.

Benthic Invertebrate Communities and Sediment Quality Differences in benthic invertebrate communities for *test* reach FIR-D1 were classified as **Negligible-Low** because the significant increase in taxa richness over time and shift in CA Axis 2 scores due to a decrease in chironomids were not indicative of degradation. Total abundance and equitability were within the range of previous sampling years and *test* reach FIR-D1 contained a variety of EPT taxa.

Differences in benthic invertebrate communities of McClelland Lake were classified as **Negligible-Low** because although there were statistically significant changes in measurement endpoints, the changes were not indicative of negative conditions in the lake. Richness and the percentage of fauna as EPT taxa were significantly higher in 2013 than previous sampling years. The general composition of the benthic invertebrate community in terms of the presence of fully aquatic forms and presence of generally sensitive taxa including the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent with *baseline* conditions.

The benthic invertebrate community of Johnson Lake had no EPT taxa in fall 2013, which have been observed in previous years; however, given that the number of EPT taxa has been very low in previous years, the absence of these taxa was not considered a negative change in the benthic invertebrate community of Johnson Lake. Worms (Tubifidae and Naididae) had a higher relative abundance in fall 2013 than previous years; however, bivalve clams had the highest abundance of all taxa, indicating that Johnson Lake is generally in fair condition.

Concentrations of sediment quality measurement endpoints at *test* stations MCL-1 and FIR-D1 and *baseline* station JOL-1 were generally within the range of previously-measured concentrations for all sediment quality measurement endpoints in fall 2013. An exception was observed at *test* station MCL-1, where concentrations of PAHs exceeded previously-measured maximum concentrations and resulted in a higher PAH toxicity index. In fall 2013, sediment toxicity testing showed higher growth rates for the midge *Chironomus* at all stations, and higher growth rates for the amphipod *Hyalella* at *test* stations MCL-1 and FIR-D1. The sediment quality index value for *test* station FIR-D1 indicated a **Negligible-Low** difference between the regional *baseline* conditions.

Fish Populations (fish assemblages) Differences in measurement endpoints of fish assemblages in fall 2013 at *test* reach FIR-F1 were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the range of variability for regional *baseline* depositional reaches, with the exception of species richness. However, the higher species richness that exceeded the inner tolerance limit of the 95th percentile was not indicative of a negative change to the fish assemblage.

5.7.2 Hydrologic Conditions: 2013 Water Year

Firebag River

Hydrometric monitoring for the Firebag River watershed was conducted at 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 at WSC Station 07DC001 (RAMP Station S27), Firebag River near the mouth, from 1972 to 2013. The 2013 WY annual runoff volume was 1,489 million m^3, which was 87% higher than the historical mean annual runoff volume of 798 million m^3. The runoff volume in the 2013 open-water period (May to October) was 1,219 million m^3, which was 106% higher than the historical mean open-water runoff volume of 593 million m^3. Although, flows decreased from November 2012 to mid-March 2013, flows from November to mid-January exceeding the historical upper quartile values (Figure 5.7-3). Flows increased during spring freshet in April and early May 2013, to a peak of 213 m^3/s on May 10. Following the freshet peak, flows decreased until early June, with values remaining above the historical upper quartile values. Rainfall events in early to mid-June caused an increase in flow that exceeded the historical maximum daily flow from June 10 to June 23, 2013. The annual peak flow of 373 m^3/s on June 15 was 236% higher than the annual historical maximum daily flow. Flows generally decreased following the annual peak until the lowest open-water flow of 19.9 m^3/s on September 16, which was 28% higher than the historical mean open-water minimum daily flow of 15.6 m^3/s. Flows increased in early to mid-October to above historical upper quartile values due to rainfall events in early October, and then decreased steadily until the end of the 2013 WY (Figure 5.7-3).

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 2013 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 3.38 million m^3.
2. As of 2013, the area of land change in the Firebag River watershed from focal projects that was not closed-circuited was estimated to be 53.7 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 2.67 million m^3.

The estimated cumulative effect of oil sands development was a loss of flow of 0.71 million m^3 to the Firebag River. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.7-3. The 2013 WY mean winter and 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 5.7-3). These differences were classified as **Negligible-Low** (Table 5.7-1).

McClelland Lake

Continuous lake level data have been collected at Station L1, McClelland Lake, since 1997, with several periods of missing data over the data record. In the 2013 WY, water levels increased from mid-November until monitoring temporarily ceased on December 25, with values below the historical minimum water level values (Figure 5.7-4). Lake water levels were still increasing when monitoring resumed on May 13 before decreasing slightly in late May and early June 2013. Lake levels increased in response to the rainfall events in mid-June, reaching the historical upper quartile values on June 21. The lake level of 294.60 masl recorded on July 12 was the maximum lake level recorded from the available data in the 2013 WY and was 0.06 m higher than the historical median lake level of 294.54 masl on the same date. Lake levels from July to mid-September varied between the historical median and upper quartile values.

5.7.3 Water Quality

In fall 2013, 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 developments (*baseline* station FIR-2), first sampled in 2003;
- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2000 to 2009 and *test* since 2010; and
- Johnson Lake (*baseline* station JOL-1), added to the program in 2011.

Water quality samples were also collected at *baseline* station JOL-1 in winter, spring, and summer 2013.

Temporal Trends The following significant (α=0.05) trends in fall concentrations of water quality measurement endpoints were detected:

- Decreasing concentrations of total chloride and sulphate at *test* station MCL-1 and *baseline* station FIR-2;
- An increasing concentration of total arsenic at *baseline* station FIR-2; and
- An increasing concentration of total boron at *test* station FIR-1.

Trend analysis could not be conducted on *baseline* station JOL-1 because only three years of data were available.

2013 Results Relative to Historical Concentrations Water quality measurement endpoints that were outside the range of previously-measured concentrations in fall 2013 included (Table 5.7-4 to Table 5.7-7):

- dissolved phosphorus and total arsenic, with concentrations that exceeded previously-measured maximum concentrations, and sulphate, with a concentration below the previously-measured minimum concentration at *baseline* station FIR-2; and
- total strontium, with a concentration that exceeded the previously-measured maximum concentration, and total mercury (ultra-trace), with a concentration below the previously-measured minimum concentration at *test* station MCL-1.

All water quality measurement endpoints were within previously-measured concentrations in fall 2013 at *test* station FIR-1. Historical comparisons of data at *baseline* station JOL-1 were not conducted given that 2013 was only the third year that this station was sampled, although concentrations were generally lower in fall 2013 than the past two years (Table 5.7-7).

Ion Balance The ionic composition of water sampled in fall 2013 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 McClelland Lake (*test* station MCL-1) in fall 2013 was consistent with previous years and dominated by magnesium and bicarbonate (Figure 5.7-5). *Baseline* station JOL-1 had an ionic composition similar to *test* station FIR-1 and *baseline* station FIR-2 (Figure 5.7-5).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in fall 2013 were below water quality guidelines, with the exception of total aluminum at *test* station FIR-1 (Table 5.7-4), dissolved phosphorus at *baseline* station FIR-2 (Table 5.7-5), and total nitrogen at *test* station MCL-1 (Table 5.7-6).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in fall 2013 (Table 5.7-8):

- total iron, dissolved iron, sulphide, total phenols, and total phosphorus at *test* station FIR-1 and *baseline* station FIR-2;
- total phenols at *test* station MCL-1; and
- total phosphorus and total iron 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, total phenols, and total nitrogen in winter;
- sulphide and total iron in spring; and
- sulphide and total phenols in summer.

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *test* station FIR-1 were within the regional *baseline* range of variability. In fall 2013, concentration of measurement endpoints at *baseline* station FIR-2 were within the regional *baseline* concentrations, with the exception of (Figure 5.7-6):

- dissolved phosphorus, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station FIR-2; and
- sodium and sulphate, with concentrations that were lower than the 5th percentile of regional *baseline* concentrations at *baseline* station FIR-2.

Concentrations of water quality measurement endpoints in McClelland Lake (*test* station MCL-1) and Johnson Lake (*baseline* station JOL-1) were not compared to the regional *baseline* conditions because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers (Figure 5.7-7).

Water Quality Index The WQI values for *test* station FIR-1 (100) and *baseline* station FIR-2 (97.5) in the Firebag River watershed in fall 2013 indicated **Negligible-Low** differences from regional *baseline* conditions, and were similar to previous WQI values. WQI values were not calculated for McClelland Lake and Johnson Lake because lakes were not compared to regional *baseline* conditions.

Classification of Results In fall 2013, 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 2013 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 2013. 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.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- the Firebag River near its mouth (*test* reach FIR-D1), first sampled in 2003;
- the Firebag River upstream of all focal project developments (*baseline* reach FIR-E2), first sampled in 2003;
- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2009 and as *test* from 2010 to 2013; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

Firebag River

2013 Habitat Conditions Water at *test* reach FIR-D1 in fall 2013 was alkaline (pH: 8.2), with high dissolved oxygen (8.5 mg/L), and moderate conductivity (199 µS/cm). The substrate was primarily comprised of sand (98%) (Table 5.7-9). Total organic carbon was low (<1 %).

Water at *baseline* reach FIR-E2 in fall 2013 was relatively shallow (0.3 m), with a fast velocity (0.66 m/s), and slightly alkaline (pH: 8.2), with low conductivity (138 µS/cm). The substrate was dominated by cobble (small, 22% and large, 25%) and gravel (small, 17% and large, 21%) (Table 5.7-9). Periphyton chlorophyll *a* biomass at *baseline* reach FIR-E2 averaged 167 mg/m^2, which was within the inner tolerance limits of regional *baseline* variability (Figure 5.7-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach FIR-Dl in fall 2013 was dominated by chironomids (80%), with subdominant taxa consisting of tubificids (15%) (Table 5.7-10). Bivalves (*Pisidium/Sphaerium*) were present in low relative abundances (Table 5.7-10). A small number of flying insects (Ephemeroptera: *Tricorythodes* and *Paraleptophlebia*; Plecoptera: *Perlodidae*; and Trichoptera: *Hydroptilla* and *Oxyethira*) were present at *test* reach FIR-D1 in 2013. Chironomids were diverse at the lower *test* reach and primarily consisted of the common forms *Polypedilum Microspectra/Tanytarsus,* and *Paralauterborniella* (Wiederholm 1983).

The benthic invertebrate community of *baseline* reach FIR-E2 in fall 2013 was dominated by chironomids (66%) and Ephemeroptera (11%), with subdominant taxa consisting of Hydracarina (4%), Trichoptera (4%), miscellaneous Diptera (4%), and Nematoda (4%) (Table 5.7-10). Bivalves and gastropods were present in low relative abundances. Chironomids were primarily *Microspecrta/Tanytarsus, Lopescladius/Rheosmittia*, *Polypedilum*, and the rheophilic *Rheotanytarsus*. Ephemeroptera were diverse but mostly *Acerpenna pygmaea* and *Baetis*. Trichoptera were also well represented with over ten kinds including the common forms *Hydropsyche*, *Oecetis*, and *Hydroptila* (Wiggins 1977). Plecoptera were primarily of the forms *Isoperla* and *Taeniopterygidae*.

Temporal and Spatial Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the Firebag River. Spatial comparisons were not conducted because *test* reach FIR-D1 is depositional and *baseline* reach FIR-E2 is erosional.

Temporal comparisons for *test* reach FIR-D1 and *baseline* reach FIR-E2 included testing for:

- changes over time (Hypothesis 1, Section 3.2.3.1); and
- changes between 2013 values and the mean of all previous sampling years.

Richness at *test* reach FIR-D1 increased over time and was higher in 2013 than the mean of all previous sampling years. These changes accounted for 73% and 35% of the variance in the annual means, respectively (Table 5.7-11, Figure 5.7-9).

CA Axis 2 scores were significantly higher in 2013 than previous years at *test* reach FIR-D1, accounting for 42% of the variance in annual means. The increase was possibly due to a decrease in tubificid worms at this reach (Figure 5.7-10).

Comparison to Published Literature In fall 2013, lower *test* reach FIR-Dl had low diversity and a high relative percent abundance of tubificid worms (15%), potentially indicating some level of degradation (Hynes 1960; Griffiths 1998). Although flying insects

(Ephemeroptera, Plecoptera, and Trichoptera) were present at this reach in fall 2013, they were found in low relative abundances (Table 5.7-10). The only permanent aquatic form found at this reach was the fingernail clam which was also found in low relative abundance.

In fall 2013, benthic invertebrate communities at *baseline* reach FIR-E2 indicated better health than the lower *test* reach (FIR-D1). The *baseline* reach had a diverse faunal composition including several species of chironomids and sensitive taxa including Ephemeroptera, Trichoptera and Plectoptera. Clams and snails were noted in both reaches but in low relative abundances. The presence of these taxa is indicative of a long-term, high-quality benthic habitat (Hynes 1960; Griffiths 1998; Mandeville 2001).

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach FIR-D1 has more than eight years of data (2003 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* depositional reaches were evaluated. Mean values of all measurement endpoints at lower *test* reach FIR-D1 were within the inner tolerance limits of variability for means from *baseline* depositional reaches in previous sampling years (Figure 5.7-9, Figure 5.7-10).

The variability of measurement endpoints at *baseline* reach FIR-E2 was contributing to the characterization of regional *baseline* erosional conditions. No comparison to the regional data were conducted (Figure 5.7-13, Figure 5.7-12). Periphyton chlorophyll *a* biomass at *baseline* reach FIR-E2 in fall 2013 was within the inner tolerance limits of variability for regional *baseline* reaches (Figure 5.7-8).

Classification of Results Differences in benthic invertebrate communities for *test* reach FIR-D1 were classified as **Negligible-Low** because the significant increase in taxa richness over time and shift in CA Axis 2 scores due to a decrease in chironomids were not indicative of degradation. Total abundance and equitability were within the range of previous sampling years and *test* reach FIR-D1 contained a variety of EPT taxa.

McClelland Lake

2013 Habitat Conditions Samples were taken at a depth of 1.0 m in McClelland Lake. The lake substrate was primarily comprised of silt (80%), with small amounts of sand (12%) and clay (8%). The organic content in McClelland lake was very high in 2013 (TOC: 33%). Water in McClelland Lake was slightly alkaline (pH: 8.9), with moderate conductivity (193 µS/cm), which was consistent with previous years.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of McClelland Lake in fall 2013 was dominated by chironomids (45%), and Ephemeroptera (20%), with subdominant taxa consisting of naidid worms (15%) (Table 5.7-13). Permanent aquatic forms including bivalve clams (*Pisidium/Sphaerium*), gastropod snails (*Gyraulus, Helisoma,* and *Valvata sincera*), and amphipods (*Hyalella azteca*) were found in McClelland Lake indicating good long-term water quality. Mayflies (*Caenis*) and six types of caddisflies were also present (Table 5.7-13). Dominant chironomids included *Dicrotendipes*, *Tanytarsus*, *Paratanytarsus*, *Polypedilum,* and *Endochironomus,* all of which are very common in northern temperate lakes (Wiederholm 1983).

Temporal Comparisons Below are the temporal comparisons of benthic invertebrate communities outlined in Section 3.2.3.1 that were possible given the data available for the McClelland Lake.

Temporal comparisons for *test* station MCL-1 included testing for:

- Changes from the *baseline* (2002 to 2009) to *test* (2010 to present) period (Hypothesis 2, Section 3.2.3.1);
- Changes over time in the *test* period (i.e., 2010 to present);
- Changes between 2013 values and the mean of all *baseline* years; and
- Changes between 2013 values and the mean of all previous years of sampling.

Richness was significantly higher in fall 2013 than either the mean of all *baseline* years or the mean of all previous sampling years, explaining 25% and 22% of the variance in annual means, respectively (Table 5.7-14).

The percentage of the fauna as EPT taxa significantly increased over time during the *test* period accounting for 29% of the variance in annual means (Table 5.7-14). The percent EPT in 2013 was higher than during the *baseline* period (2002 to 2009) and the mean of all previous sampling years, accounting for 48% and 53% of the variance in annual means, respectively (Table 5.7-14).

CA Axis 1 and Axis 2 scores were higher during the *baseline* period, explaining 40% and 21% of the variance in annual means, respectively (Table 5.7-14). Higher Axis 1 scores during the *baseline* period reflected a shift in taxa composition to a higher relative abundance of Ephemeroptera during the *test* period (Table 5.7-13). Higher Axis 2 scores were likely due to a decrease in the relative abundance of gastropods in the *test* period (Table 5.7-13).

Comparison to Published Literature The benthic invertebrate community of McClelland Lake had a fauna typical of a shallow lake environment (Parsons et al. 2010; Pennak 1989). McClelland Lake contained several taxa considered to be permanent aquatic forms such as bivalves and gastropods in addition to flying insects (Ephemeroptera and Trichoptera) indicating good long-term water quality (Niemi et al. 1990).

2013 Results Relative to Historical Conditions Mean values of all measurement endpoints for benthic invertebrate communities in fall 2013 at *test* station MCL-1 were within the inner tolerance limits of the normal range of variation for means from previous sampling years in McClelland Lake (Figure 5.7-13). The percent EPT was nearly the outer tolerance limit for the 95th percentile; however, that was not indicative of a negative change (Figure 5.7-13).

Classification of Results Differences in benthic invertebrate communities of McClelland Lake are classified as **Negligible-Low** because although there were statistically significant changes in measurement endpoints, the changes were not indicative of negative conditions in the lake. Richness and the percentage of fauna as EPT taxa were significantly higher in 2013 than previous sampling years. The general composition of the benthic invertebrate community in terms of the presence of fully aquatic forms and presence of generally sensitive taxa including the mayfly *Caenis* and six types of caddisflies suggested that the benthic invertebrate community of McClelland Lake was in good condition and generally consistent with *baseline* conditions.

Johnson Lake

2013 Habitat Conditions Samples were taken at a depth of 1.0 m in Johnson Lake. Water in Johnson Lake in fall 2013 was alkaline (pH: 8.2), with moderate conductivity (239 µS/cm) (Table 5.7-12).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Johnson Lake at *baseline* station JOL-1 in fall 2013 was dominated by bivalves (31%), chironomids (23%), and tubificids (18%), with subdominant taxa consisting of nematodes (13%) (Table 5.7-13). Amphipods included *Hyalella azteca* and *Gammarus lacustris*, which are commonly distributed in Canada (Väinölä et al. 2008). Bivalves (*Pisidium/Sphaerium*) were abundant and gastropods were well represented (*Helisoma, Gyraulus, Lymnaea, Valvata sincera,* and *Menetus cooperi*). Chironomids were diverse with 13 genera and dominated by the common forms *Microtendipes*, *Procladius,* and *Microtendipes.* (Table 5.7-13).

Temporal Comparisons As outlined in Section 3.2.3.1, the following temporal comparisons were possible for Johnson Lake, given the available data:

- Changes over time (i.e., 2011 to present); and
- Changes between 2013 values and the mean of all previous years of sampling.

CA Axis 1 and 2 scores and the percentage of fauna as EPT taxa significantly decreased over time, accounting for 63%, 89%, and 96% of the variance in annual means, respectively (Table 5.7-15). CA Axis 1 and 2 scores and percent EPT were also significantly lower in 2013 compared to previous sampling years (Table 5.7-15), likely due to the absence of EPT taxa and the higher abundance of worms in 2013 (Table 5.7-13).

Comparison to Published Literature The benthic invertebrate community of Johnson Lake contained a benthic fauna in fall 2013 that reflected good water quality and lentic (lake-like) conditions. The benthic invertebrate community contained several permanent aquatic forms including Amphipoda (21%) and fingernail clams (Bivalvia: Sphaeriidae), which are consistent with good long-term water quality (Niemi et al. 1990; Pennak 1989). However, the abundance of worms (Tubificidae and Naididae) was higher in 2013 than previous sampling years in Johnson Lake and the percentage of EPT taxa, which have been present in very low relative abundance in previous years were absent in 2013.

2013 Results Relative to Historical Conditions Johnson Lake has been a *baseline* lake since monitoring began in 2011. In 2013, all measurement endpoints of benthic invertebrate communities were similar to previous years (Table 5.7-13). The abundance decreased slightly from 2012, but has always been low (<500 organisms per sample) (Table 5.7-13). There were no EPT taxa found in 2013; however, given that there was only a single *Caenis* mayfly found in Johnson Lake in fall 2012, the difference was minimal and not indicative of a negative change.

Classification of Results The benthic invertebrate community of Johnson Lake had no EPT taxa in fall 2013, which have been observed in previous years; however, given that the number of EPT taxa has been very low in previous years, the absence of these taxa was not considered a negative change in the benthic invertebrate community of Johnson Lake. Worms (Tubifidae and Naididae) had a higher relative abundance in fall 2013 than previous years; however, bivalve clams had the highest abundance of all taxa, indicating that Johnson Lake is generally in fair condition.

5.7.4.2 Sediment Quality

In fall 2013, sediment quality samples were collected from:

- Firebag River (*test* station FIR-D1), sampled in 2002 to 2004, 2006 to 2007, 2010, and 2013;

- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2009 and as *test* from 2010 to 2013; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

Temporal Trends Similar to 2012, a significant decreasing trend ($\alpha=0.05$) in the concentration of total arsenic in sediment from *test* lake MCL-1 was observed in fall 2013. The concentration of arsenic was 1.49 mg/kg in fall 2013, which was well below the CCME ISQG guideline of 5.9 mg/kg. There were no significant trends at *test* station FIR-D1; trend analysis was not completed for *baseline* station JOL-1, given the station has only been sampled for three years.

2013 Results Relative to Historical Concentrations Generally sediment collected at *test* station FIR-D1 had concentrations of sediment quality measurement endpoints within the range of historical concentrations, with the exception of naphthalene (Table 5.7-16). Naphthalene was below the previously-measured minimum concentration in fall 2013 (Table 5.7-16). Results of toxicity tests yielded survival rates within previously-measured values, but showed higher growth rates for both the amphipod *Hyalella* and the midge *Chironomus* at *test* station FIR-D1 in fall 2013 (Table 5.7-16).

Sediment collected at *test* station MCL-1 was predominantly sand and had physical characteristics within the range of previously-measured values (Table 5.7-17). In 2013, PAH concentrations exceeded previously-measured maximum concentrations at *test* station MCL-1; however, when total PAHs was normalized to 1% TOC, the concentration was lower than 2012. The predicted PAH toxicity index also exceeded the previously-measured value at *test* station MCL-1. Relative to previous years, direct tests of sediment toxicity indicated a lower survival rate (74%), but a higher growth rate of the midge *Chironomus*, along with a higher growth rate in the amphipod *Hyalella* at *test* station MCL-1 in fall 2013 (Table 5.7-17).

Sediments collected at *baseline* station JOL-1 were more dominated by silt and had higher total organic carbon than has been observed over the previous two years of sampling (Table 5.7-18). Results were generally similar across sampling years, with the exception of total metals (normalized to percent sand and clay) and total PAHs (normalized to 1% TOC), which had slightly lower concentrations in fall 2013 than previously-measured minimum concentrations (Table 5.7-18). Direct tests of sediment toxicity indicated lower survival of the amphipod *Hyalella* (84%) and the midge *Chironomus* (86%) relative to previous years but a higher growth rate of *Chironomus* relative to previous years (Table 5.7-18). Growth of *Hyalella* was within previously-measured values (Table 5.7-18).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of hydrocarbons, PAHs, and metals measured at *test* station FIR-D1 and *baseline* station JOL-1 were below relevant sediment or soil quality guidelines in fall 2013 (Table 5.7-16 and Table 5.7-18). At *test* station MCL-1, all sediment quality measurement endpoints were below relevant sediment quality guidelines, with the exception of pyrene, with a concentration that exceeded the guideline for the first time in fall 2013 (Table 5.7-17).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station FIR-D1 (Figure 5.7-16). Because lakes were not included in the regional *baseline* calculations, and given the ecological differences between lakes and rivers, *test* station MCL-1 and *baseline* station JOL-1 were not compared to the regional *baseline* concentrations in fall 2013 (Figure 5.7-17 and Figure 5.7-18).

Sediment Quality Index The sediment quality index value (98.3) for *test* station FIR-D1 in fall 2013 indicated a **Negligible-Low** difference from regional *baseline* conditions. 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* stations MCL-1 and FIR-D1 and *baseline* station JOL-1 were generally within the range of previously-measured concentrations for all sediment quality measurement endpoints in fall 2013. An exception was observed at *test* station MCL-1, where concentrations of PAHs exceeded previously-measured maximum concentrations and resulted in a higher PAH toxicity index. In fall 2013, sediment toxicity testing showed higher growth rates at all stations for the midge *Chironomus*, and higher growth rates for the amphipod *Hyalella* at *test* stations MCL-1 and FIR-D1. The sediment quality index value for *test* station FIR-D1 indicated a **Negligible-Low** difference between the regional *baseline* conditions.

5.7.5 Fish Populations

Fish assemblages were sampled for the first time in the Firebag River in fall 2013 at:

- depositional *test* reach FIR-F1 (this reach is in the same location of benthic invertebrate community *test* reach FIR-D1); and
- erosional *baseline* reach FIR-F2 (this reach is in the same location of benthic invertebrate community *baseline* reach FIR-E2).

2013 Habitat Conditions *Test* reach FIR-F1 was comprised of run habitat with a wetted width of 67.0 m and bankfull width of 86.5 m. The substrate was dominated by sand and fine materials. Water at *test* reach FIR-F1 had a mean depth of 0.73 m and a moderate velocity (0.35 m/s), was alkaline (pH: 8.22), with moderate conductivity (207 µS/cm), moderate dissolved oxygen (7.8 mg/L), and a temperature of 15.1˚C. Instream cover consisted primarily of algae and small woody debris (Table 5.7-19).

Baseline reach FIR-F2 was comprised of a mixture of run and riffle habitat with a wetted width of 43.5 and bankfull width of 46.0 m. Water at *baseline* reach FIR-F2 had a mean depth of 0.58 m and a moderate velocity (0.35 m/s), was alkaline (pH: 8.22), with low conductivity (151 µS/cm), high dissolved oxygen (9.4 mg/L), and a temperature of 15.9˚C. Instream cover consisted primarily of macrophytes with smaller amounts of filamentous algae, small woody debris, boulders, and overhanging vegetation (Table 5.7-19).

Relative Abundance of Fish Species The fish assemblage at *test* reach FIR-F1 in fall 2013 was dominated by burbot (42%) and trout-perch (32%) (Table 5.7-20). The fish assemblage at *baseline* reach FIR-F2 in fall 2013 was dominated by longnose sucker (28%), with subdominant species consisting of longnose dace (12%) and slimy sculpin (8%) (Table 5.7-20).

Temporal and Spatial Comparisons Sampling at *test* reach FIR-F1 and *baseline* reach FIR-F2 were added to the RAMP fish assemblage program in 2013; therefore, temporal comparisons could not be conducted. All measurement endpoints were slightly higher at *baseline* reach FIR-F2 than *test* reach FIR-F1 (Table 5.7-21). The lower ATI value at *test* reach FIR-F1 was due to the presence of burbot, which is a sensitive species (Figure 5.7-19). The slight differences between measurement endpoint values was likely due to differences in habitat conditions between the two reaches (depositional at *test* reach FIR-F1 and erosional at *baseline* reach FIR-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. Previous studies in the Firebag River watershed have found a total of 16 species in the mainstem of the Firebag River and an additional two species in tributaries for a total of 18 species known to occur in the watershed (Golder 2004).

Previous fish sampling on the Firebag River was detailed enough to be able to separate species distribution based on distance from the mouth (Golder 2004). Previous studies found a total of six species within the section of river that includes *test* reach FIR-F1, which included northern pike, white sucker, and lake whitefish, which were not documented during the RAMP survey in 2013. RAMP found nine species at *test* reach FIR-F1 including four species that were not previously captured in this section of the river (i.e., brook stickleback, burbot, northern redbelly dace, and spottail shiner) of which two species have not previously been captured in the Firebag River (northern redbelly dace and spottail shiner) (Table 5.7-20). Five of these were small-bodied fish, which have a higher capture success using backpack electrofishing employed during the RAMP fish survey compared to previous studies using a combination of gill and seine nets (Golder 2004).

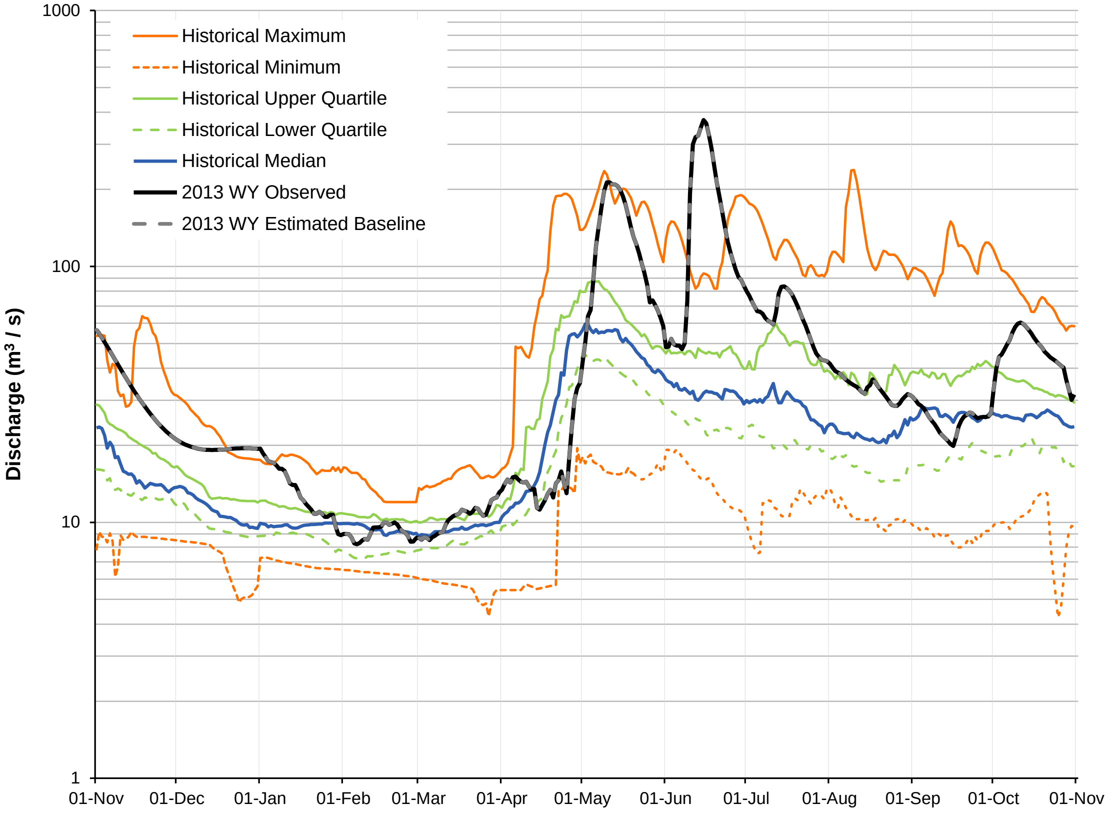
Previous studies in the upper portion of the Firebag River found a total of ten species (Golder 2004), including sportfish (northern pike, Arctic grayling, and walleye), which were not documented in 2013 by RAMP. Sampling at *baseline* reach FIR-F2 in fall 2013 also found ten species, many of which were the same as the previous studies cited in Golder (2004), with only two species not previously observed in this section of the river (burbot and lake chub) and one not previously documented in the river (northern redbelly dace).

Habitat conditions documented in Golder (2004) were similar to that observed by RAMP in 2013. The lower portion of the river is comprised of runs and pools with sand substrate that provides excellent northern pike and walleye habitat while the portion in the vicinity of *baseline* reach FIR-F2 had a steeper gradient, with good sportfish habitat.

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *test* reach FIR-F1 were within the inner tolerance limits of the range of variation for means for *baseline* depositional reaches, with the exception of richness and diversity, which were between the inner and outer tolerance limits for the 95th percentile (Table 5.7-21).

Classification of Results Differences in measurement endpoints of fish assemblages in fall 2013 at *test* reach FIR-F1 and regional *baseline* depositional conditions were classified as **Negligible-Low** because although richness and diversity were higher than the range of variability for regional *baseline* depositional reaches, these differences were not indicative of a negative change in the fish assemblage.

Figure 5.7-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Firebag River in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on provisional data for Firebag River near the mouth, WSC Station 07DC001 (January 1 to October 31, 2013) and on data for RAMP Station S27 from November 1 to December 31, 2012. The upstream drainage area is 5,988 km^2. Historical daily values from March 1 to October 31 calculated from data collected from 1972 to 2012, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1986 and from 2002 to 2012.

Table 5.7-2 Estimated water balance at WSC Station 07DC001 (RAMP Station S27), Firebag River near the mouth, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**1,488.66**	**Observed discharge, obtained from Firebag River near the mouth, WSC Station 07DC001 (RAMP Station S27)**
Closed-circuited area water loss from the observed hydrograph	-3.38	Estimated 13.6 km^2 of the Firebag River watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+2.67	Estimated 53.7 km^2 of the Firebag River watershed with land change from focal projects as of 2013 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	0.00	None reported
Diversions into or out of the watershed	0.00	None reported
The difference between observed and estimated hydrographs on tributary streams	0.00	Not applicable
Estimated *baseline* hydrograph (total discharge)	**1,489.37**	**Estimated *baseline* discharge at Firebag River near the mouth, WSC Station 07DC001 (RAMP Station S27)**
Incremental flow (change in total discharge)	-0.71	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 were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for January 1 to October 31, 2013 for Firebag River near the mouth, WSC Station 07DC001, and from RAMP Station S27 from November 1 to December 31, 2012.

Table 5.7-3 Calculated change in hydrologic measurement endpoints for the Firebag River near the mouth, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	76.72	76.68	-0.05%
Mean winter discharge	17.48	17.47	-0.05%
Annual maximum daily discharge	373.18	373.00	-0.05%
Open-water season minimum daily discharge	19.91	19.90	-0.05%

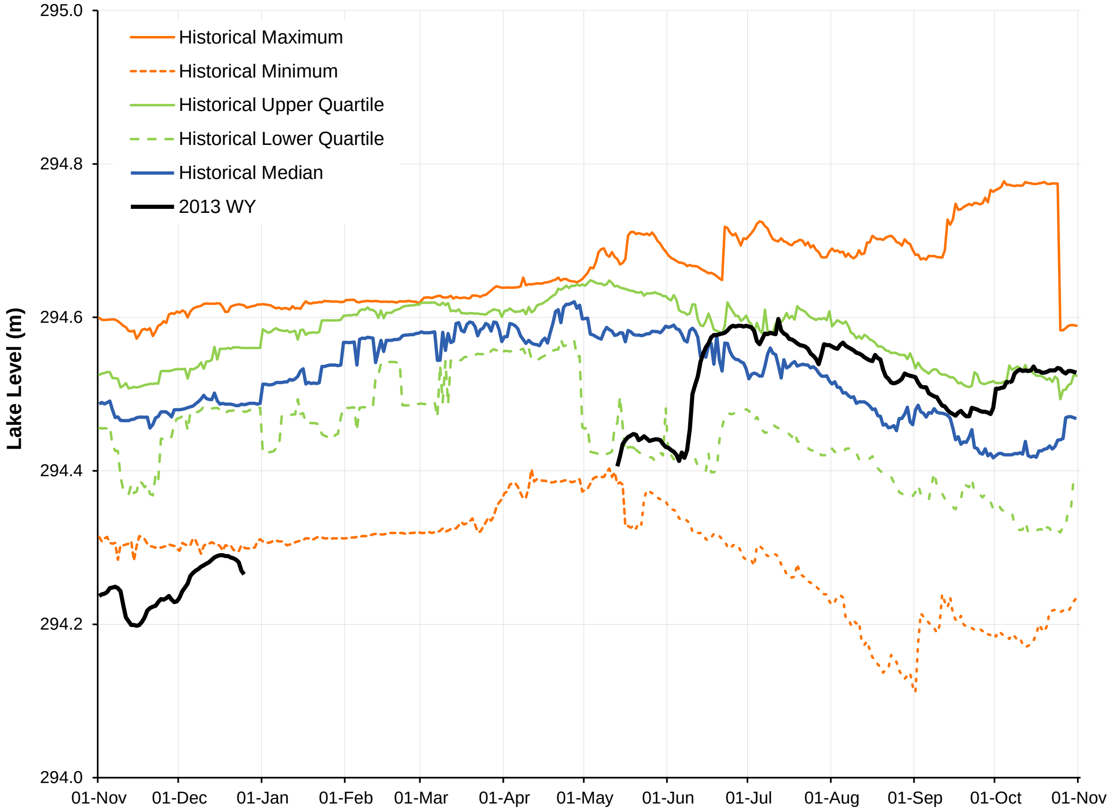
Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for January 1 to October 31, 2013 for Firebag River near the mouth, WSC Station 07DC001, and from RAMP Station S27 from November 1 to December 31, 2012.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to 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 2013 WY, compared to historical values.



Note: Observed 2013 WY record based on McClelland Lake, RAMP Station L1 2013 provisional data. Historical values calculated for the period from 1997 to 2012 with numerous periods of missing data over the data record.

Note: Maximum and minimum data values were calculated based on the data record, which included numerous data gaps.

Table 5.7-4 Concentrations of water quality measurement endpoints, mouth of the Firebag River (*test* station FIR-1) in fall 2013, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	11	7.9	8.2	8.5
Total suspended solids	mg/L	-	<3.0	11	<3.0	7.0	23
Conductivity	µS/cm	-	225	11	171	214	248
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.038	11	0.012	0.029	**0.057**
Total nitrogen	mg/L	1	0.471	11	0.361	0.600	**1.70**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	13.0	11	8.0	13.0	16.2
Ions							
Sodium	mg/L	-	3.6	11	2.0	4.0	4.6
Calcium	mg/L	-	31.7	11	22.6	30.2	33.2
Magnesium	mg/L	-	9.1	11	6.8	8.5	9.7
Chloride	mg/L	120	1.8	11	1.0	2.0	3.1
Sulphate	mg/L	270	2.3	11	1.7	2.8	10.3
Total dissolved solids	mg/L	-	143	11	60	140	170
Total alkalinity	mg/L		117	11	85	110	124
Selected metals							
Total aluminum	mg/L	0.1	**0.101**	11	0.033	0.094	**0.428**
Dissolved aluminum	mg/L	0.1	0.0072	11	0.0015	0.0049	0.0089
Total arsenic	mg/L	0.005	0.00051	11	0.00028	0.00045	0.00062
Total boron	mg/L	1.2	0.022	11	0.014	0.018	0.022
Total molybdenum	mg/L	0.073	0.00015	10	0.00011	0.00014	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	1.00	10	0.60	<1.20	4.40
Total strontium	mg/L	-	0.076	10	0.051	0.071	0.083
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.29	2	0.34	0.44	0.44
Oilsands Extractable	mg/L	-	0.25	2	0.86	0.89	0.89
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.2	2	<8.8	<11.44	<14.1
Retene	ng/L	-	3.43	2	2.07	2.75	3.43
Total dibenzothiophenes	ng/L	-	13.2	2	9.11	33.6	58.1
Total PAHs	ng/L	-	137	2	177	260	344
Total Parent PAHs	ng/L	-	24.07	2	22.27	22.88	23.48
Total Alkylated PAHs	ng/L	-	113	2	153	238	322
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.781**	11	**0.394**	**0.785**	**1.40**
Total phosphorus	mg/L	0.05	**0.094**	11	0.027	**0.057**	**0.094**
Dissolved iron	mg/L	0.3	**0.301**	11	0.056	**0.301**	**0.540**
Total phenols	mg/L	0.004	**0.005**	10	<0.001	**0.004**	**0.007**
Suphide	mg/L	0.002	**0.0031**	11	<0.002	0.0030	**0.0060**

[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) in fall 2013, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	11	7.4	8.1	8.3
Total suspended solids	mg/L	-	<3.0	11	<3.0	3.0	8.0
Conductivity	µS/cm	-	159	11	113	171	261
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.117**	11	0.009	**0.060**	**0.096**
Total nitrogen	mg/L	1	0.571	11	0.500	0.700	**1.28**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	13.3	11	8.00	13.1	17.4
Ions							
Sodium	mg/L	-	2.7	11	2.0	4.0	16
Calcium	mg/L	-	23.0	11	16.4	24.3	28.4
Magnesium	mg/L	-	6.0	11	5.1	6.4	8.7
Chloride	mg/L	120	<0.50	11	0.50	1.00	2.00
Sulphate	mg/L	270	<0.50	11	0.810	1.70	22.6
Total dissolved solids	mg/L	-	120	11	110	134	158
Total alkalinity	mg/L		83.7	11	57.0	91.0	114
Selected metals							
Total aluminum	mg/L	0.1	0.031	11	0.015	0.036	0.082
Dissolved aluminum	mg/L	0.1	0.008	11	0.001	0.004	0.011
Total arsenic	mg/L	0.005	0.00069	11	0.00010	0.00057	0.00062
Total boron	mg/L	1.2	0.014	11	0.008	0.013	0.035
Total molybdenum	mg/L	0.073	0.00019	11	0.00004	0.00018	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	1.3	10	<0.6	<1.2	2.2
Total strontium	mg/L	-	0.047	11	0.028	0.049	0.068
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Naphthenic Acids	mg/L	-	0.20	2	0.06	0.06	0.27
Oilsands Extractable	mg/L	-	0.20	2	0.91	0.91	0.99
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.8	<11.44	<14.1
Retene	ng/L	-	1.26	2	1.21	1.64	<2.07
Total dibenzothiophenes	ng/L	-	6.67	2	5.84	20.6	35.3
Total PAHs	ng/L	-	103	2	151	179	206
Total Parent PAHs	ng/L	-	22.4	2	16.5	17.8	19.2
Total Alkylated PAHs	ng/L	-	80.5	2	132	161	190
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total phosphorus	mg/L	0.05	**0.138**	10	0.047	**0.097**	**0.134**
Dissolved iron	mg/L	0.3	**0.446**	10	0.052	**0.344**	**0.886**
Sulphide	mg/L	0.002	**0.003**	10	<0.002	**0.004**	**0.009**
Total iron	mg/L	0.3	**0.721**	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) in fall 2013, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	11	8.1	8.5	8.7
Total suspended solids	mg/L	-	<3.0	11	<3.0	3.0	9.0
Conductivity	µS/cm	-	252	11	224	240	267
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.006	11	0.002	0.004	0.013
Total nitrogen	mg/L	1	**1.05**	11	0.55	**1.00**	**2.00**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	14.3	11	11.0	13.0	17.0
Ions							
Sodium	mg/L	-	5.0	11	4.0	4.7	6.0
Calcium	mg/L	-	23.1	11	19.3	21.3	25.8
Magnesium	mg/L	-	17.0	11	14.6	16.6	18.0
Chloride	mg/L	120	<0.5	11	<0.5	<1.0	1.0
Sulphate	mg/L	270	<0.5	11	<0.5	0.6	4.3
Total dissolved solids	mg/L	-	154	11	80.0	155	194
Total alkalinity	mg/L		138	11	122	129	145
Selected metals							
Total aluminum	mg/L	0.1	0.004	11	0.003	0.014	0.026
Dissolved aluminum	mg/L	0.1	0.002	11	<0.001	<0.001	0.010
Total arsenic	mg/L	0.005	0.00023	11	0.00019	0.00021	<0.0010
Total boron	mg/L	1.2	0.075	11	0.051	0.065	0.089
Total molybdenum	mg/L	0.073	<0.0001	11	<0.00001	<0.00003	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	0.32	8	<0.6	<1.2	2.4
Total strontium	mg/L	-	0.153	11	0.110	0.132	0.145
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.34	2	0.09	0.38	0.38
Oilsands Extractable	mg/L	-	0.54	2	0.45	1.14	1.14
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	12.50	13.32	<14.1
Retene	ng/L	-	<0.669	2	<0.509	<1.29	<2.07
Total dibenzothiophenes	ng/L	-	7.58	2	6.62	20.96	35.30
Total PAHs	ng/L	-	105	2	165	193	221
Total Parent PAHs	ng/L	-	23.5	2	20.5	20.6	20.6
Total Alkylated PAHs	ng/L	-	81.8	2	145	173	201
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total phenols	mg/L	0.004	**0.0045**	11	<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; underlined values are outside of historical range.

Table 5.7-7 Concentrations of water quality measurement endpoints, Johnson Lake (*baseline* station JOL-1) in fall 2013, compared to historical values.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	2	8.2	8.3	8.4
Total suspended solids	mg/L	-	5.0	2	<3.0	32	61
Conductivity	µS/cm	-	294	2	323	332	341
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.019	2	0.004	0.008	0.013
Total nitrogen	mg/L	1	0.881	2	**1.20**	**1.70**	**2.20**
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	13.7	2	12.2	13.4	14.6
Ions							
Sodium	mg/L	-	3.9	2	5.8	6.2	6.6
Calcium	mg/L	-	44.0	2	37.8	39.7	41.6
Magnesium	mg/L	-	12.3	2	13.5	14.7	15.8
Chloride	mg/L	120	2.64	2	4.75	5.41	6.07
Sulphate	mg/L	270	1.29	2	1.02	1.26	1.49
Total dissolved solids	mg/L	-	190	2	199	218	236
Total alkalinity	mg/L		154	2	165	169	172
Selected metals							
Total aluminum	mg/L	0.1	0.017	2	0.012	0.072	0.132
Dissolved aluminum	mg/L	0.1	0.005	2	0.001	0.008	0.016
Total arsenic	mg/L	0.005	0.00030	2	0.00023	0.00031	0.00039
Total boron	mg/L	1.2	0.096	2	0.173	0.213	0.252
Total molybdenum	mg/L	0.073	<0.00010	2	<0.00010	0.00012	0.00014
Total mercury (ultra-trace)	ng/L	5, 13	1.20	2	0.90	1.35	1.80
Total strontium	mg/L	-	0.109	2	0.107	0.123	0.138
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.51	2	0.11	0.17	0.22
Oilsands Extractable	mg/L	-	0.58	2	0.45	1.00	1.54
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	9.360	11.75	<14.13
Retene	ng/L	-	1.250	2	0.643	8.972	17.30
Total dibenzothiophenes	ng/L	-	6.672	2	6.664	20.98	35.30
Total PAHs	ng/L	-	104.5	2	168.5	190.2	212.0
Total Parent PAHs	ng/L	-	24.11	2	17.55	18.65	19.74
Total Alkylated PAHs	ng/L	-	80.40	2	148.7	171.6	194.4
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.417**	2	0.155	**0.492**	**0.828**
Total phosphorus	mg/L	0.05	**0.050**	2	0.035	**0.104**	**0.172**

[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 2013.

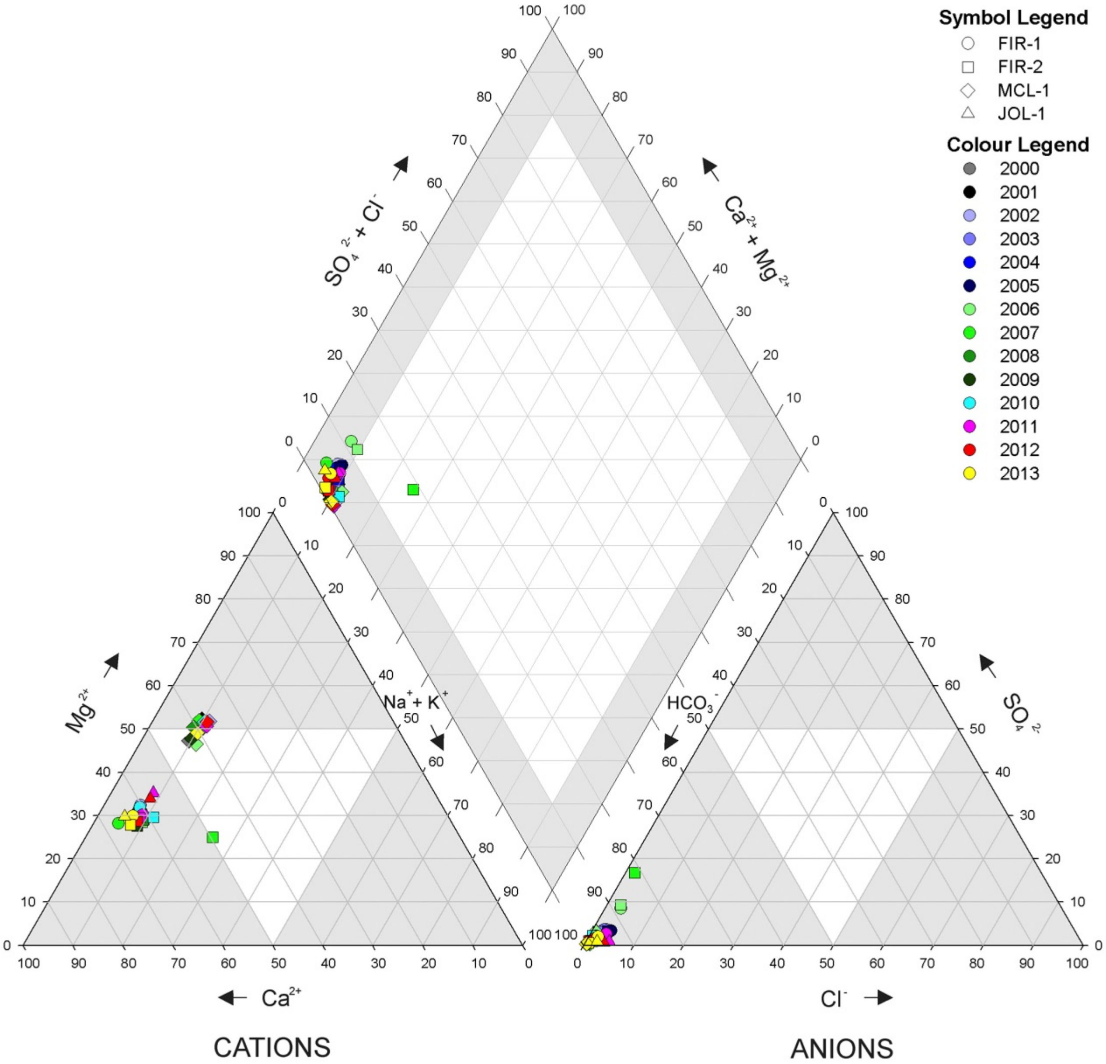


Table 5.7-8 Water quality guideline exceedances, Firebag River watershed, 2013.

Variable	Units	Guideline[a]	FIR-1	FIR-2	MCL-1	JOL-1
Winter						
Sulphide	mg/L	0.002	ns	ns	ns	0.014
Total iron	mg/L	0.3	ns	ns	ns	0.512
Total nitrogen	mg/L	1	ns	ns	ns	1.52
Total phenols	mg/L	0.004	ns	ns	ns	0.005
Spring						
Sulphide	mg/L	0.002	ns	ns	ns	0.005
Total iron	mg/L	0.3	ns	ns	ns	0.407
Summer						
Sulphide	mg/L	0.002	ns	ns	ns	0.0028
Total phenols	mg/L	0.004	ns	ns	ns	0.0043
Fall						
Dissolved iron	mg/L	0.3	0.301	0.446	-	-
Dissolved phosphorus	mg/L	0.05	-	0.117	-	-
Sulphide	mg/L	0.002	0.003	0.003	-	-
Total aluminum	mg/L	0.1	0.101	-	-	-
Total iron	mg/L	0.3	0.781	0.721	-	0.417
Total nitrogen	mg/L	1	-	-	1.05	-
Total phenols	mg/L	0.004	0.005	0.006	0.005	-
Total phosphorus	mg/L	0.05	0.094	0.138	-	0.050

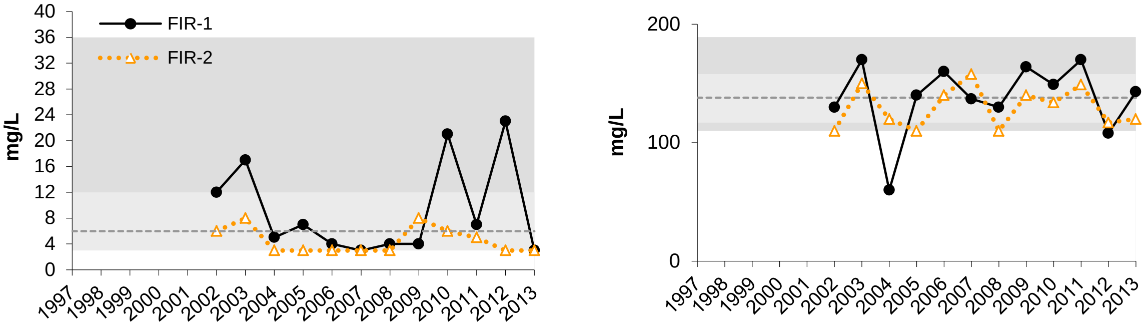
[a] Sources for all guidelines are outlined in Table 3.2-5.

ns = not sampled

Figure 5.7-6 Concentrations of selected water quality measurement endpoints in the Firebag River (fall 2013) relative to historical concentrations and regional *baseline* fall concentrations.

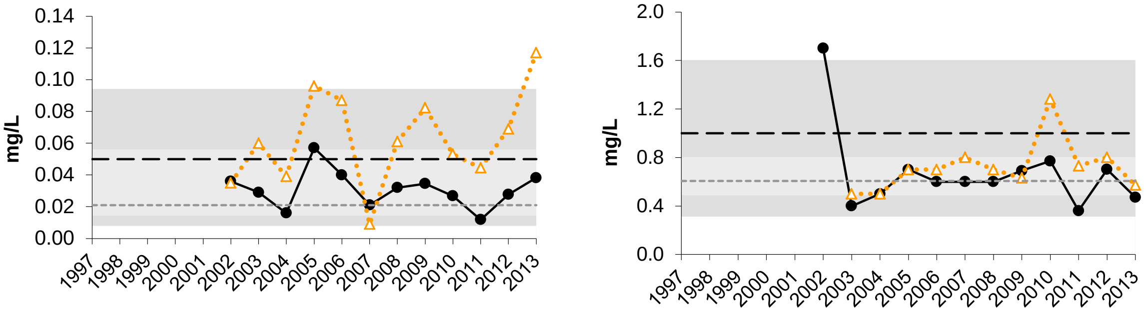
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



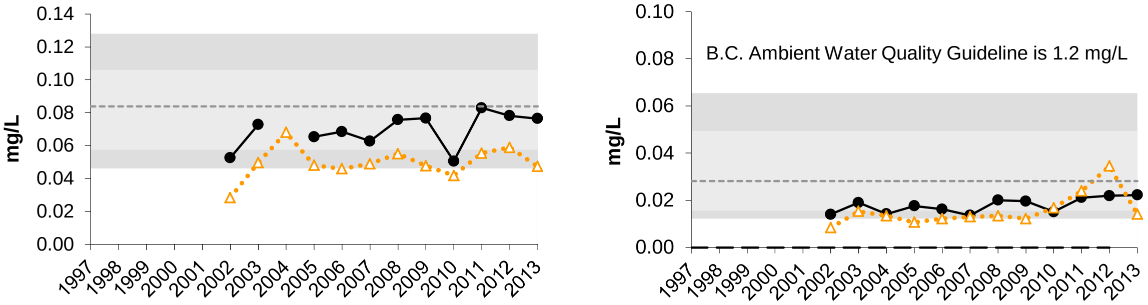
Dissolved Phosphorus

Total Nitrogen



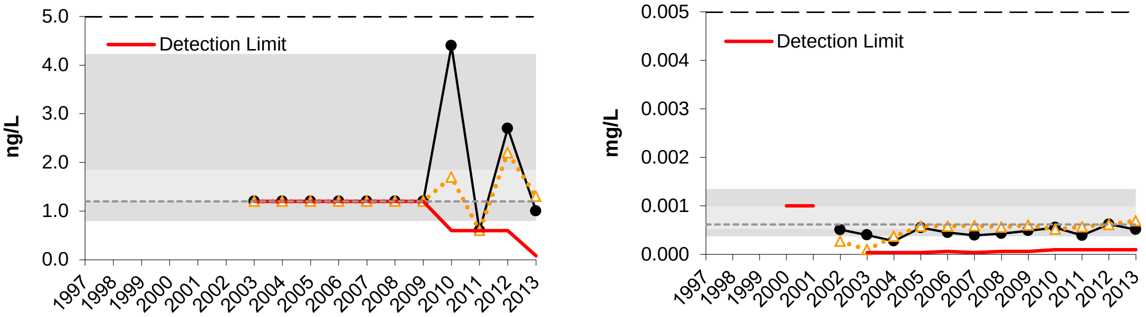
Total Strontium

Total Boron



Total Mercury (Ultra-trace)

Total Arsenic



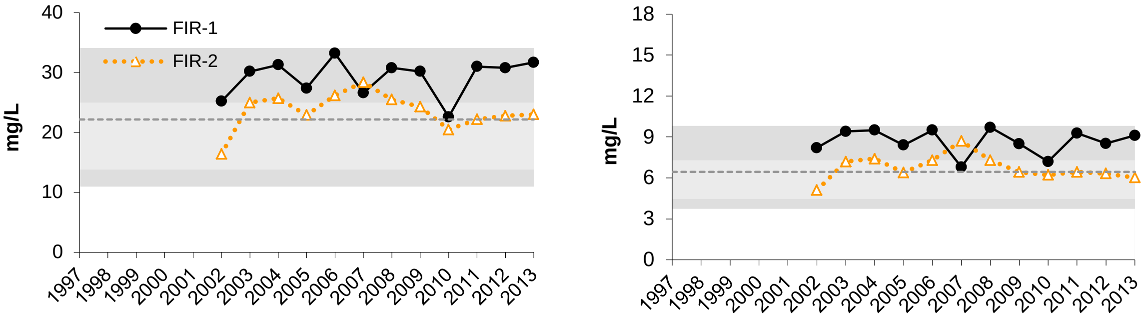
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

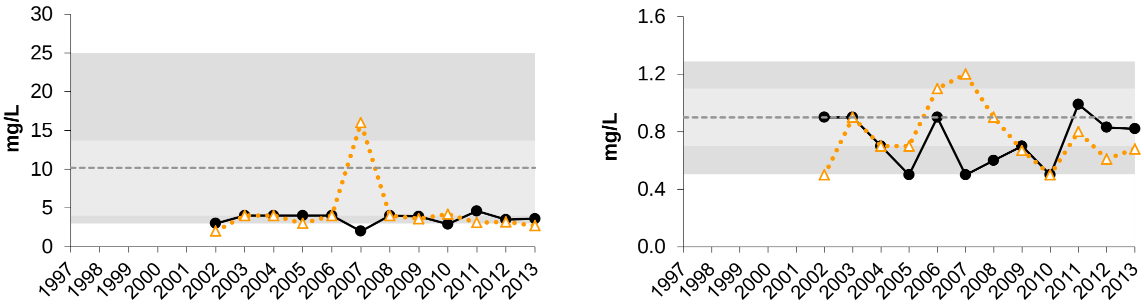
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.7-6 (Cont'd.)



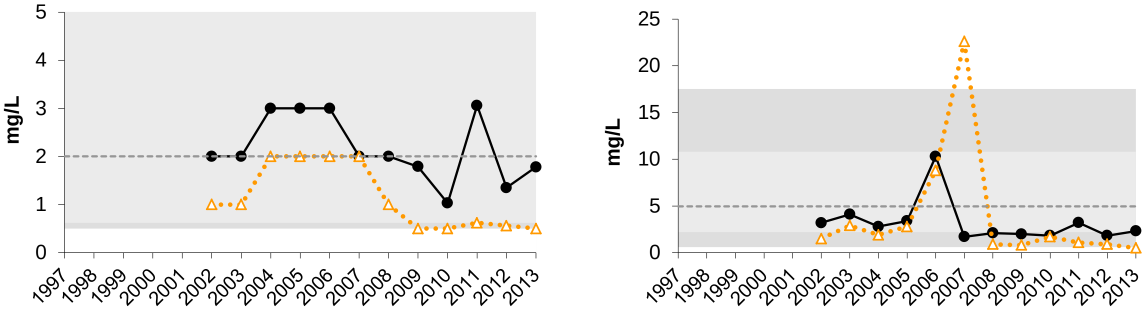
Calcium

Magnesium



Sodium

Potassium



Chloride

Sulphate

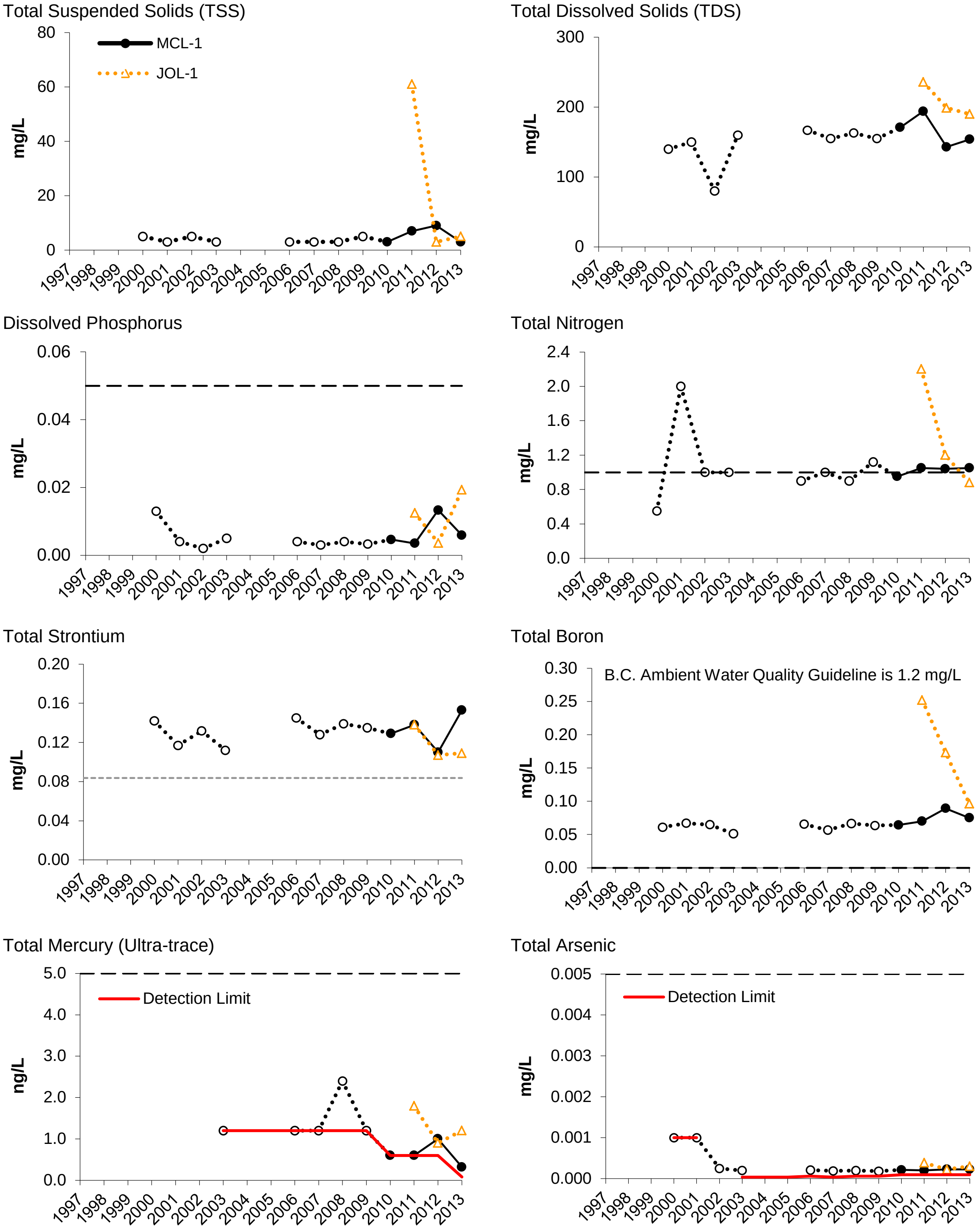
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.7-7 Concentrations of selected water quality measurement endpoints in McClelland Lake and Johnson Lake (fall 2013) 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

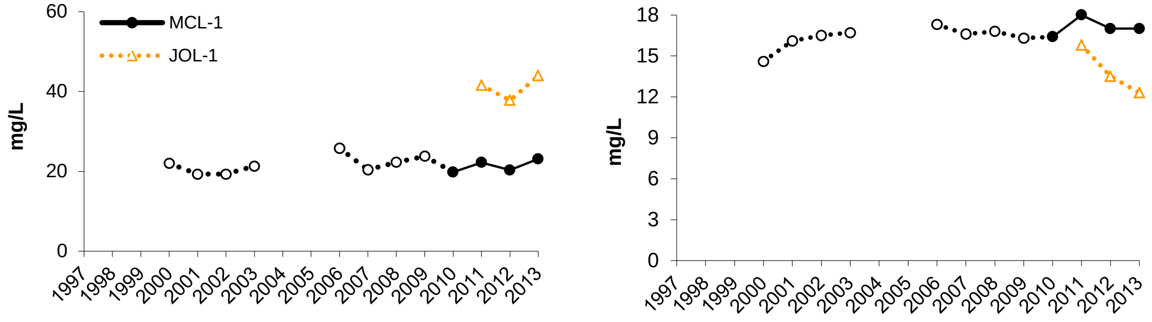
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

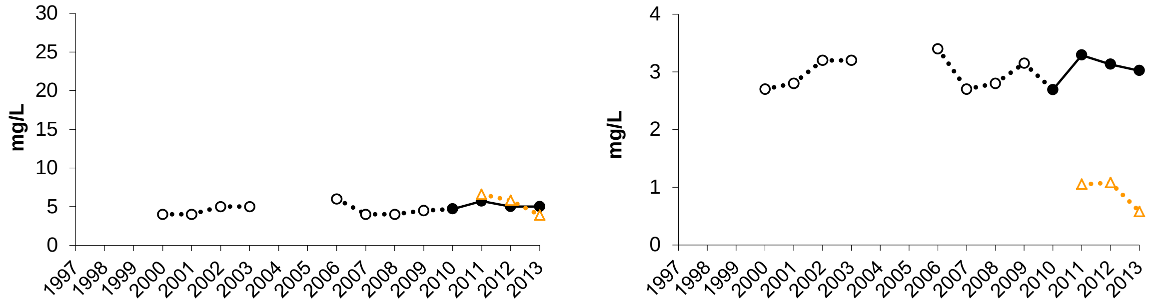
○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.7-7 (Cont'd.)

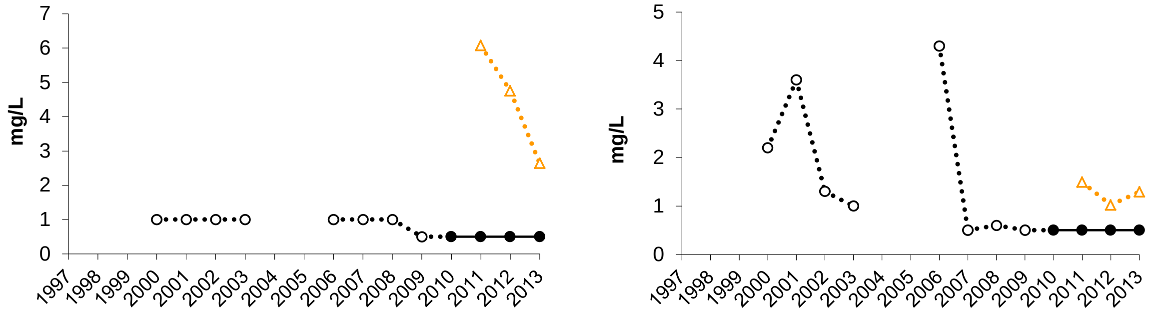
Calcium   Magnesium



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

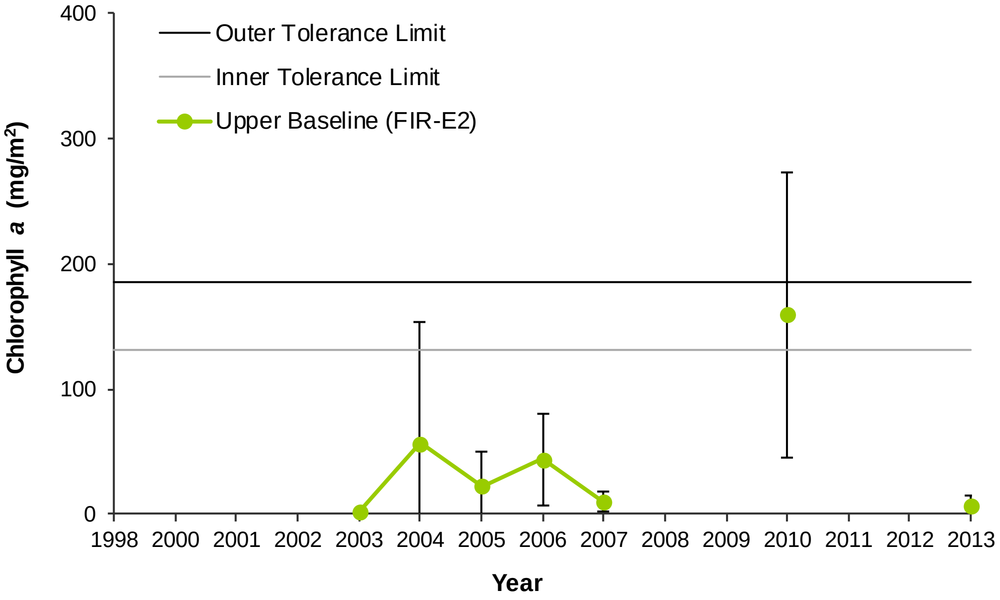
Table 5.7-9 Average habitat characteristics of benthic invertebrate sampling reaches of the Firebag River, fall 2013.

Variable	Units	*Test R*each FIR-D1 of the Firebag River	*Baseline* Reach FIR-E2 of the Firebag River
Sample date	-	Sept 4, 2013	Sept 4, 2013
Habitat	-	Depositional	Erosional
Water depth	m	0.5	0.3
Current velocity	m/s	0.38	0.66
Field Water Quality			
Dissolved oxygen	mg/L	8.5	8.5
Conductivity	µS/cm	199	138
pH	pH units	8.2	8.2
Water temperature	°C	16.1	17.9
Sediment Composition			
Sand	%	98	-
Silt	%	1	-
Clay	%	1	-
Total Organic Carbon	%	0.32	-
Sand/Silt/Clay	%	-	19
Small Gravel	%	-	17
Large Gravel	%	-	21
Small Cobble	%	-	22
Large Cobble	%	-	25
Boulder	%	-	0
Bedrock	%	-	0

Table 5.7-10 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate communities in the Firebag River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test reach FIR-D1			*Baseline* reach FIR-E2		
	2003	2004 to 2010	2013	2003	2004 to 2010	2013
Hydra	**-**	**-**	**-**	<1	0 to <1	-
Nematoda	<1	<1 to 4	<1	2	1 to 4	4
Naididae	1	0 to 2	<1	2	2 to 12	3
Tubificidae	1	6 to 49	15	1	<1 to 3	<1
Enchytraeidae	-	0 to 5	-	1	<1 to 1	<1
Lumbriculidae	-	0 to <1	-	<1	0 to <1	<1
Glossiphoniidae	-	-	-	<1	0 to <1	-
Hydracarina	-	0 to <1	-	5	1 to 12	4
Amphipoda	-	-	-	<1	0 to <1	-
Gastropoda	-	0 to <1	-	1	0 to 3	<1
Bivalvia	-	0 to 14	<1	3	0 to 6	1
Ceratopogonidae	<1	<1 to 6	1	-	0 to 1	1
Chironomidae	96	17 to 96	80	63	7 to 48	66
Diptera (misc)	<1	1 to 6	1	1	<1 to 16	4
Coleoptera	-	-	-	2	3 to 8	<1
Ephemeroptera	<1	0 to 3	<1	9	8 to 15	11
Odonata	<1	0 to 1	<1	<1	<1	<1
Plecoptera	<1	0 to <1	<1	2	1 to 2	2
Trichoptera	-	0 to 1	<1	5	1 to 7	4
Heteroptera	1	0 to 1	-	<1	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	647	22 to 274	137	740	1,046 to 1,906	1,956
Richness	7	6 to 14	13	39	38 to 50	40
Equitability	0.32	0.36 to 0.53	0.34	0.33	0.25 to 0.37	0.16
% EPT	0	<1 to 20	1	22	1 to 25	16

Figure 5.7-8 **Periphyton chlorophyll a biomass at *baseline* reach FIR-E2 of the upper Firebag River.**



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* reaches up to and including 2012.

Table 5.7-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the lower Firebag River (*test* station FIR-D1).

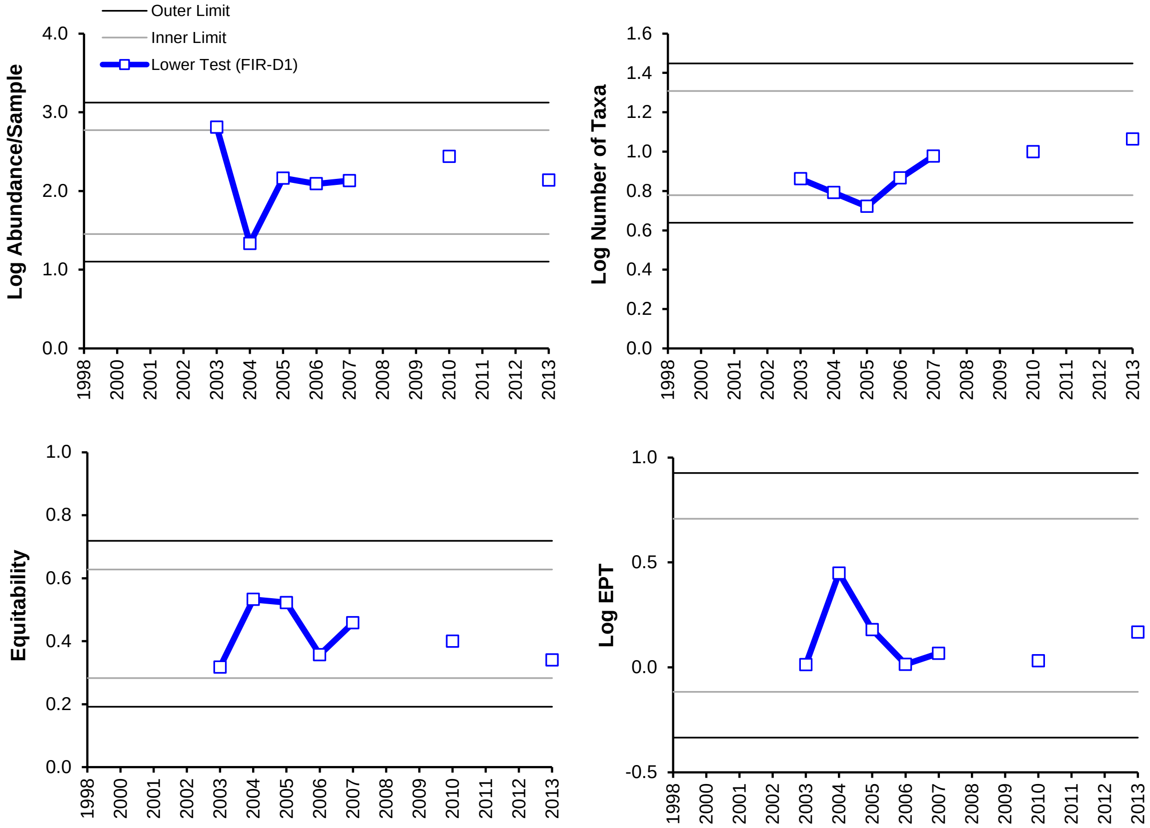
Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time trend	2013 vs. Previous Years	Time trend	2013 vs. Previous Years	
Log Abundance	0.889	0.921	0	0	No change.
Log Richness	**0.003**	**0.040**	**73**	**35**	Increasing over time and higher in 2013 than the mean of previous years.
Equitability	0.373	0.324	7	9	No change.
Log EPT	0.335	0.701	5	1	No change.
CA Axis 1	0.571	0.768	2	1	No change.
CA Axis 2	0.536	**0.028**	3	42	Higher in 2013 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 3.2-8).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

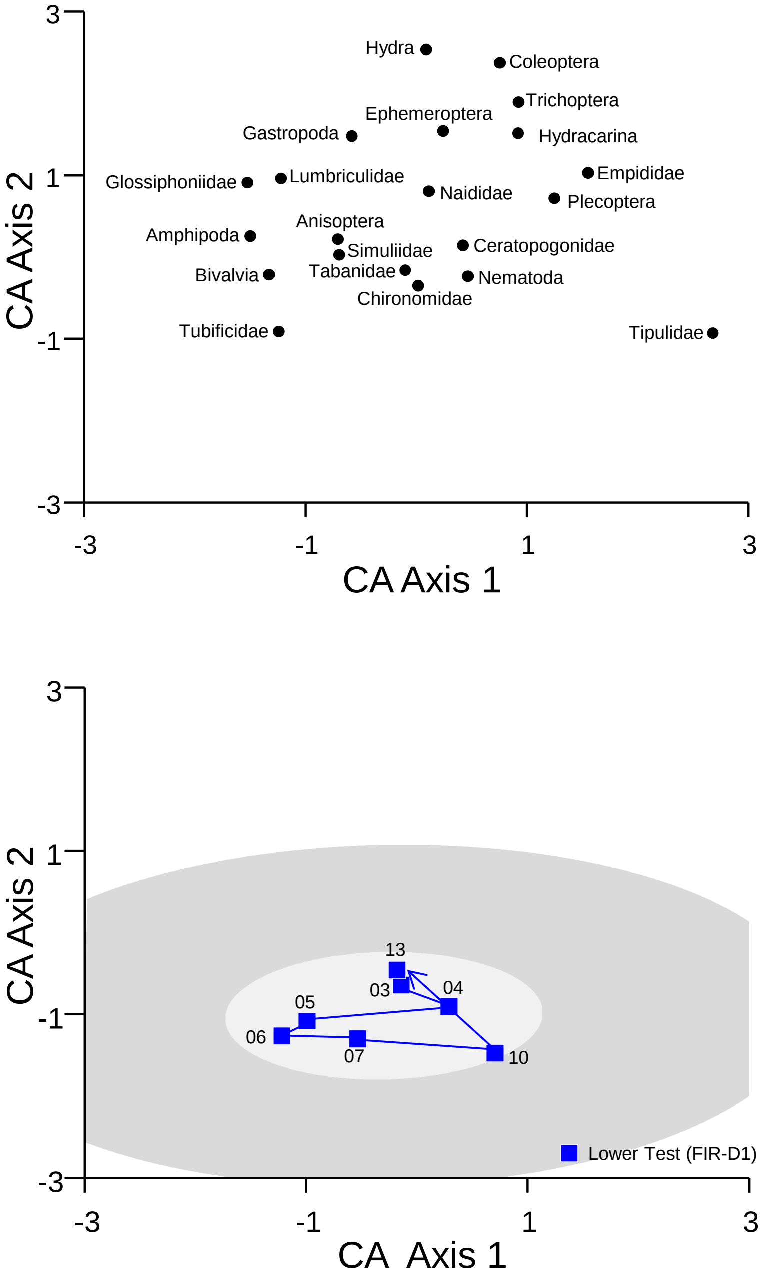
Figure 5.7-9 Variation in benthic invertebrate community measurement endpoints in the lower Firebag River (*test* reach FIR-D1) relative to the historical range of variability.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years of sampling at this reach.

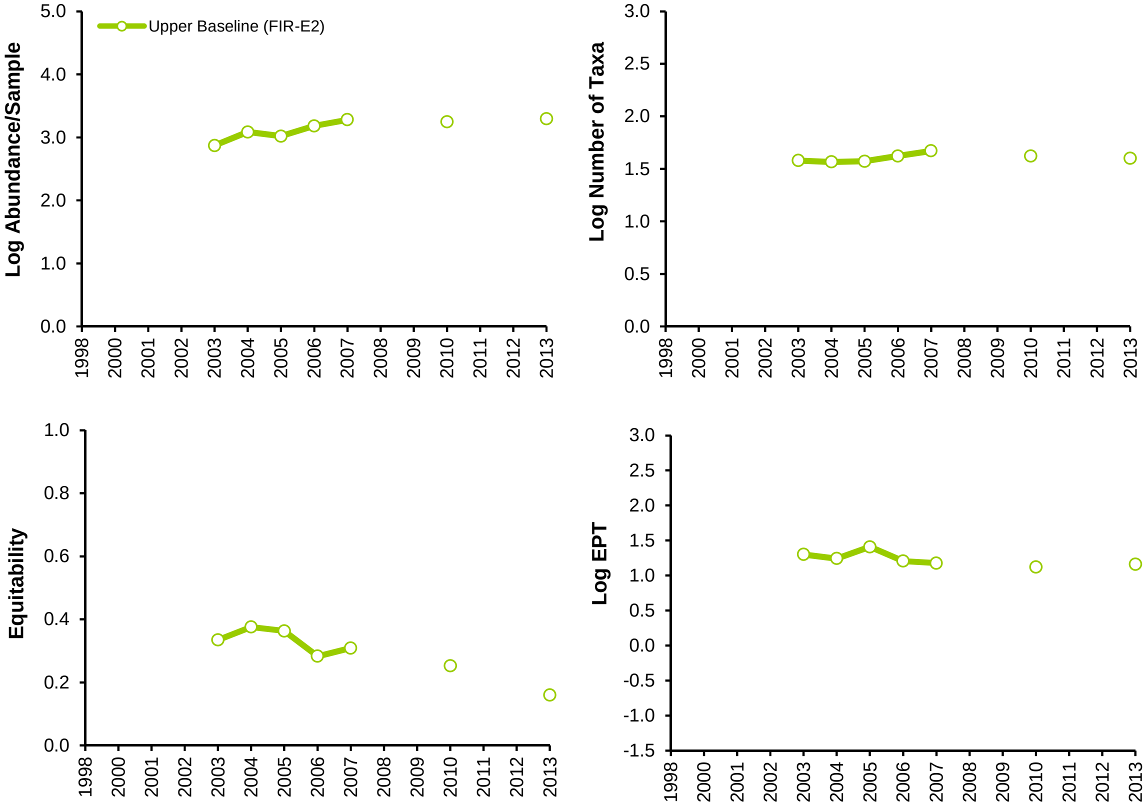
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-10 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Firebag River (FIR-D1).



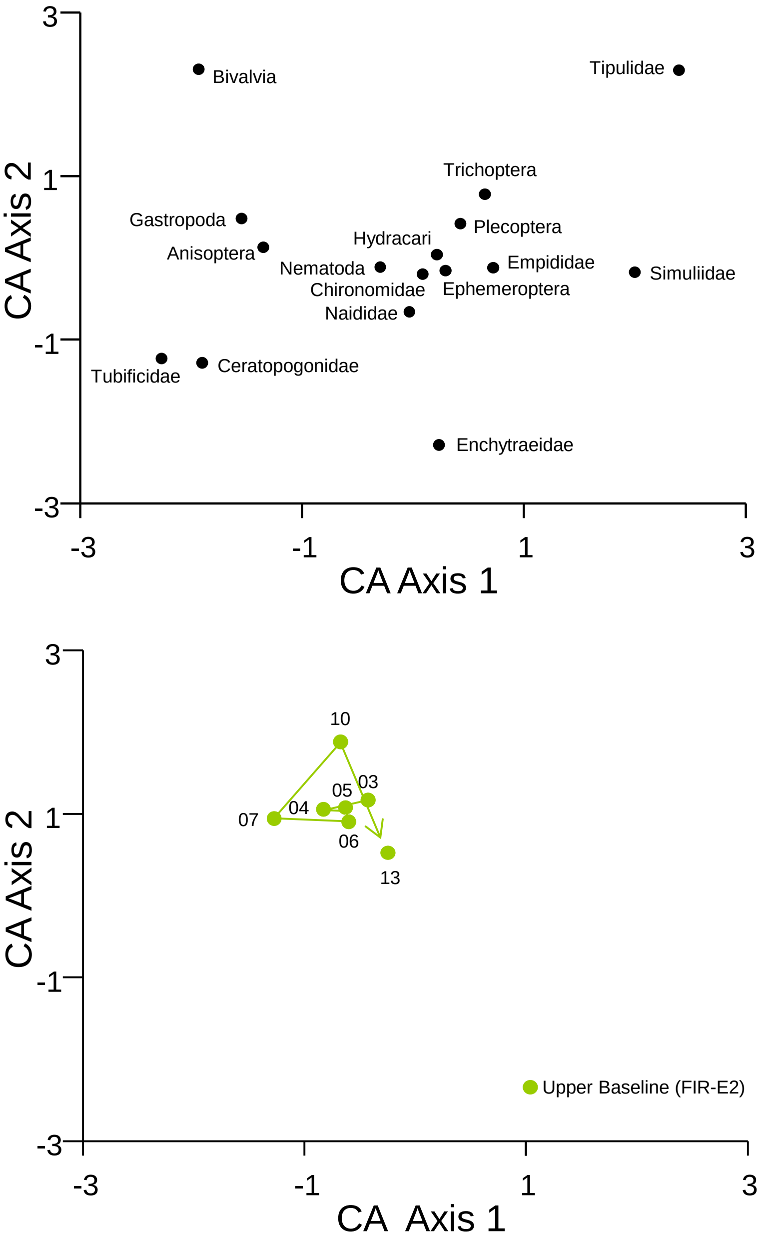
Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches in the RAMP FSA.

Figure 5.7-11 Variation in benthic invertebrate community measurement endpoints at the upper Firebag River (*baseline* station FIR-E2).



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-12 **Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the upper *baseline* reach of the Firebag River (FIR-E2).**



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.7-12 Average habitat characteristics of benthic invertebrate sampling locations in McClelland Lake and Johnson Lake, fall 2013.

Variable	Units	McClelland Lake	Johnson Lake
Sample date	-	Sept 5, 2013	Sept 5, 2013
Habitat	-	Depositional	Depositional
Water depth	m	1	1
Field Water Quality			
Dissolved oxygen	mg/L	5.7	6.0
Conductivity	µS/cm	193	239
pH	pH units	8.9	8.2
Water temperature	°C	21.1	18.3
Sediment Composition			
Sand	%	12	16
Silt	%	80	80
Clay	%	8	4
Total Organic Carbon	%	33.2	27.2

Table 5.7-13 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in McClelland Lake and Johnson Lake.

Taxon	Percent Major Taxa Enumerated in Each Year					
	***Test* Station MCL-1**			***Baseline* Station JOL-1**		
	2002	**2003 to 2012**	**2013**	**2011**	**2012**	**2013**
Nematoda	1	0 to 5	3	1	<1	13
Erpobdellidae	1	0 to <1	<1	-	-	-
Naididae	14	2 to 17	15	<1	2	7
Tubificidae	-	0 to 6	2	3	4	18
Enchytraeidae	-	-	<1	-	<1	-
Lumbriculidae	-	0 to 8	-	-	<1	-
Hirudinea	-	-	-	1	2	<1
Hydracarina	1	0 to 12	1	<1	2	-
Amphipoda	11	0 to 22	3	37	21	3
Gastropoda	<1	0 to 22	2	<1	<1	2
Bivalvia	2	1 to 9	5	19	7	31
Ceratopogonidae	-	0 to 1	-	1	-	<1
Chironomidae	58	24 to 91	45	33	53	23
Diptera (misc.)	-	-	-	<1	<1	-
Ephemeroptera	1	<1 to 12	20	-	<1	-
Odonata	-	0 to 1	<1	-	-	-
Trichoptera	1	0 to 3	3	<1	-	-
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	129	2,409	763	230	397	170
Richness	11	6 to 24	23	11	11	10
Equitability	0.51	0.22 to 0.73	0.36	0.44	0.46	0.40
% EPT	2	1 to 10	24	<1	<1	0

Table 5.7-14 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in McClelland Lake.

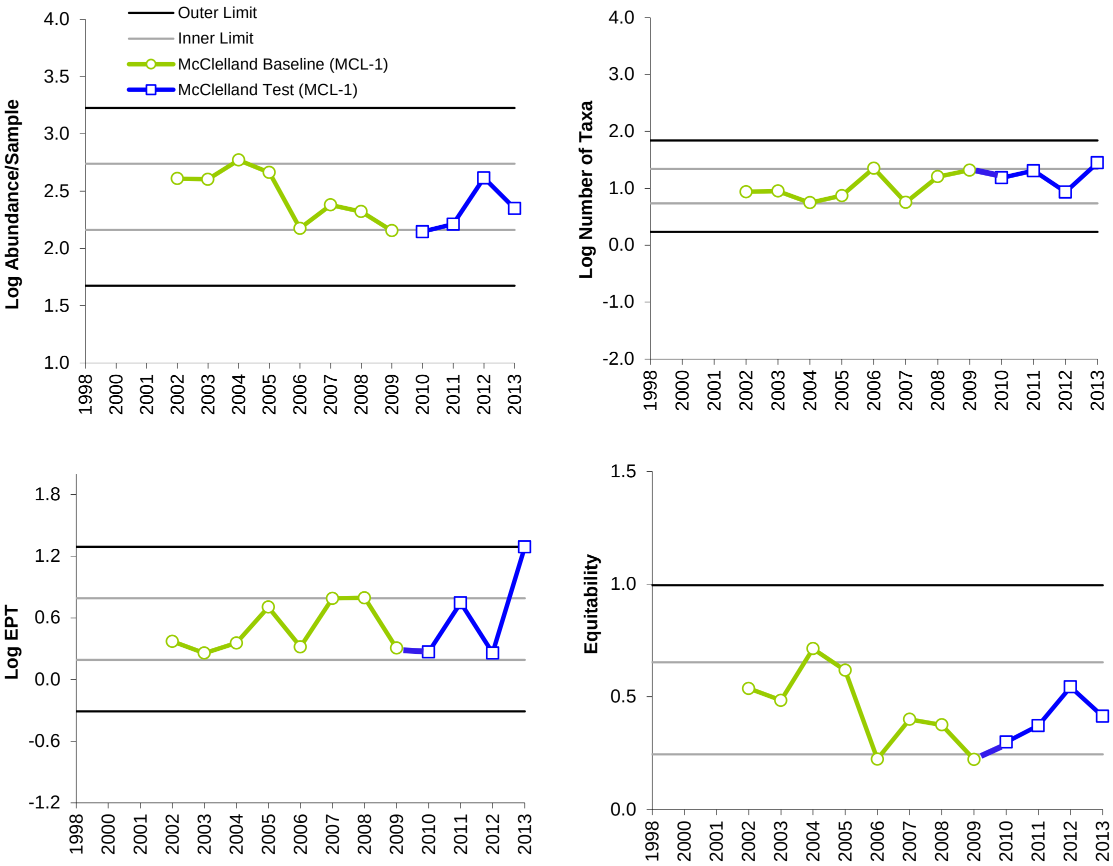
Variable	P-value				Variance Explained (%)				Nature of Change(s)
	***Baseline* period vs. *Test* period**	**Time trend in *test* period**	**2013 vs. *baseline* period**	**2013 vs. previous years**	***Baseline* period vs. *Test* period**	**Time trend in *test* period**	**2013 vs. *baseline* period**	**2013 vs. previous years**	
Log of Abundance	**0.005**	**0.002**	0.156	0.337	8	9	2	1	Lower in *test* period; increasing over time in *test* period.
Log of Richness	**<0.001**	0.270	**<0.001**	**<0.001**	17	1	25	22	Higher in *test* period and higher in 2013 than the mean of *baseline* years and mean of previous years.
Equitability	0.260	**0.045**	0.577	0.724	2	5	0	0	Increasing over time in *test* period.
Log of EPT	0.081	**<0.001**	**<0.001**	**<0.001**	5	29	48	53	Increasing over time in *test* period; higher in 2013 than the mean of *baseline* years and mean of previous years.
CA Axis 1	**<0.001**	0.802	0.055	0.170	40	0	12	6	Higher in *baseline* period.
CA Axis 2	**0.012**	0.183	0.216	0.405	21	6	5	2	Higher in *baseline* period.

Bold values indicate significant difference (p<0.05).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-8).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

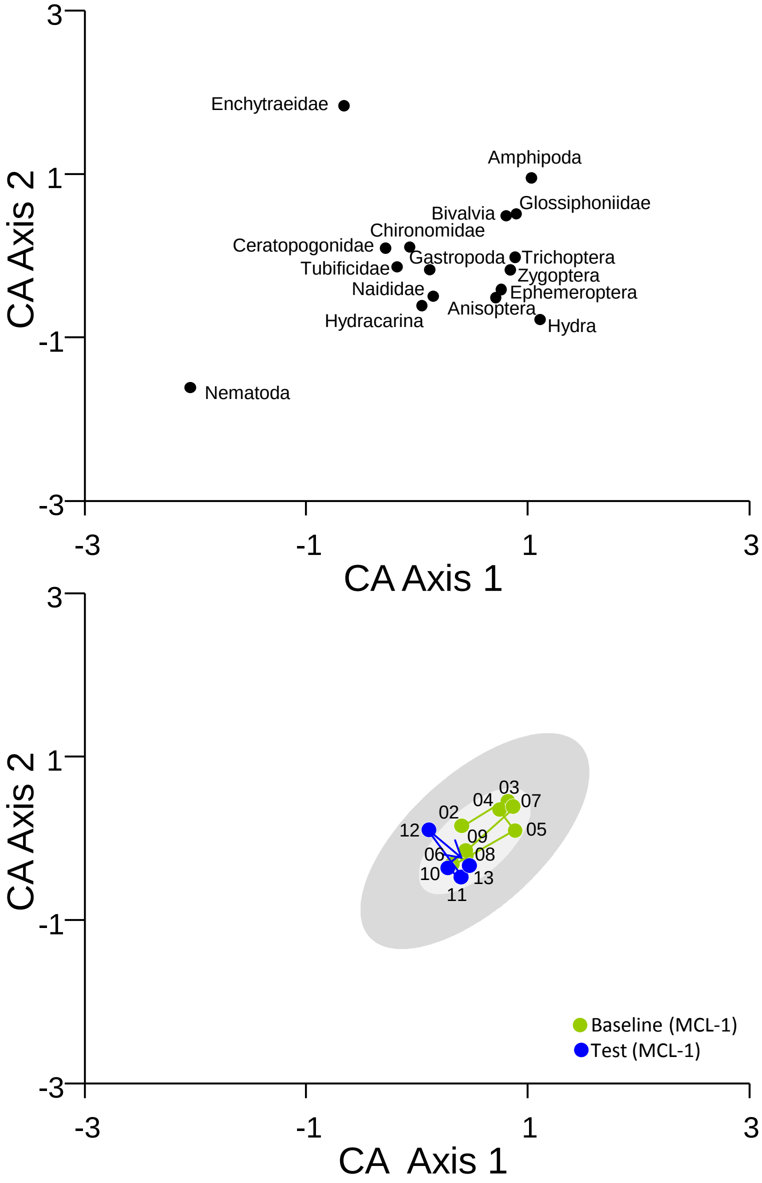
Figure 5.7-13 Variation in benthic invertebrate community measurement endpoints in McClelland Lake relative to the historical range of variability.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all previous years (2002 to 2012).

Note: Abundance, richness and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-14 **Ordination (Correspondence Analysis) of benthic invertebrate communities of RAMP lakes, showing McClelland Lake.**



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.7-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Johnson Lake.

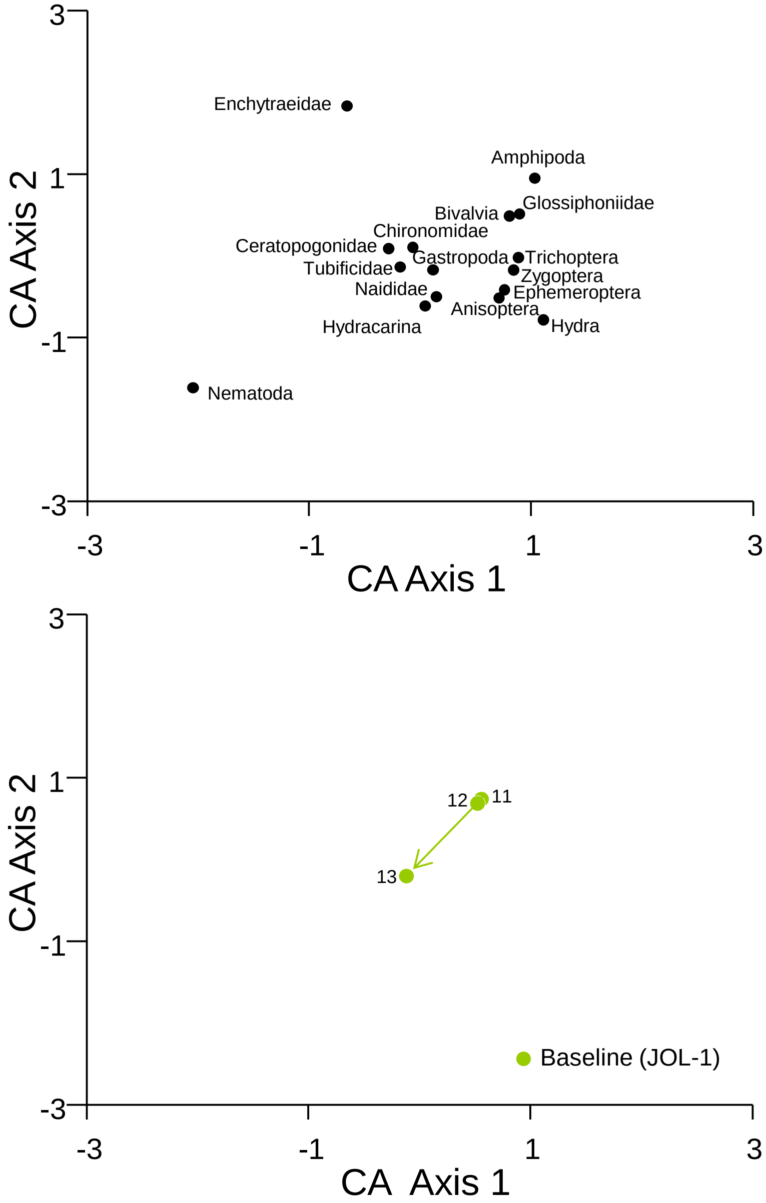
Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. previous years	Time Trend	2013 vs. previous years	
Log of Abundance	0.865	0.764	23	73	No change.
Log of Richness	0.564	0.151	8	53	No change.
Equitability	0.723	0.874	71	14	No change.
Log of EPT	**<0.001**	**<0.001**	96	91	Decreasing over time; lower in 2013 than mean of previous years.
CA Axis 1	**0.005**	**0.001**	63	98	Decreasing over time; lower in 2013 than the mean of previous years.
CA Axis 2	**<0.001**	**<0.001**	89	97	Decreasing over time; lower in 2013 than mean of previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-15 Ordination (Correspondence Analysis) of benthic invertebrate communities of RAMP lakes, showing Johnson Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.7-16 Concentrations of sediment quality measurement endpoints, Firebag River (*test* station FIR-D1), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**	**2002-2012 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.0	6	<0.1	3.00	8.00
Silt	%	-	<1.0	6	0.26	5.50	38.0
Sand	%	-	96.4	6	54.0	92.0	100
Total organic carbon	%	-	0.32	5	0.12	0.80	13.2
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<5.0	<5.0	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<5.0	<5.0	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	20.0	4	14.0	26.0	40.0
Fraction 3 (C16-C34)	mg/kg	300[1]	94.0	4	21.0	235	**1,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	77.0	4	31.0	215	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0005</u>	6	0.0010	0.0027	0.0100
Retene	mg/kg	-	0.007	5	0.002	0.061	9.06
Total dibenzothiophenes	mg/kg	-	0.093	6	0.020	0.277	2.12
Total PAHs	mg/kg	-	0.588	6	0.169	1.07	17.2
Total Parent PAHs	mg/kg	-	0.015	6	0.013	0.054	0.288
Total Alkylated PAHs	mg/kg	-	0.573	6	0.156	1.02	16.9
Predicted PAH toxicity[3]	H.I.	1.0	0.875	6	0.345	0.771	**1.45**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.2	4	7.0	7.5	9.0
Chironomus growth - 10d	mg/organism	-	<u>2.73</u>	4	1.90	2.00	2.60
Hyalella survival - 14d	# surviving	-	9.6	4	5.0	8.9	9.6
Hyalella growth - 14d	mg/organism	-	<u>1.20</u>	4	0.06	0.16	0.27

Values in **bold** indicate concentrations exceeding guidelines.

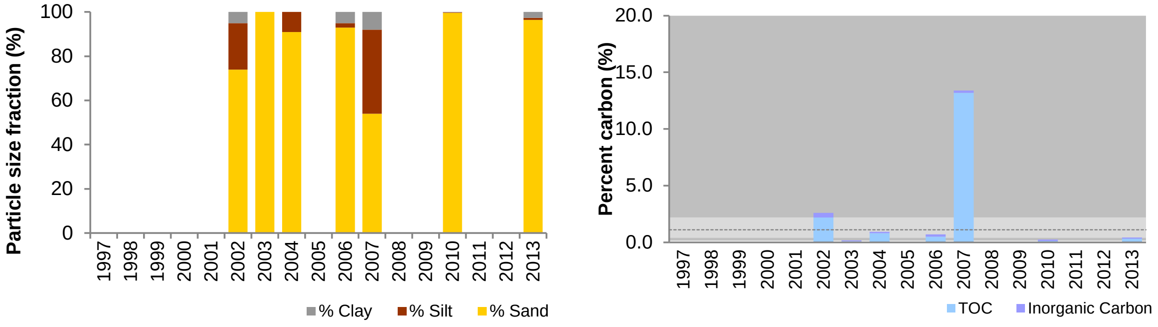
Values <u>underlined</u> indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

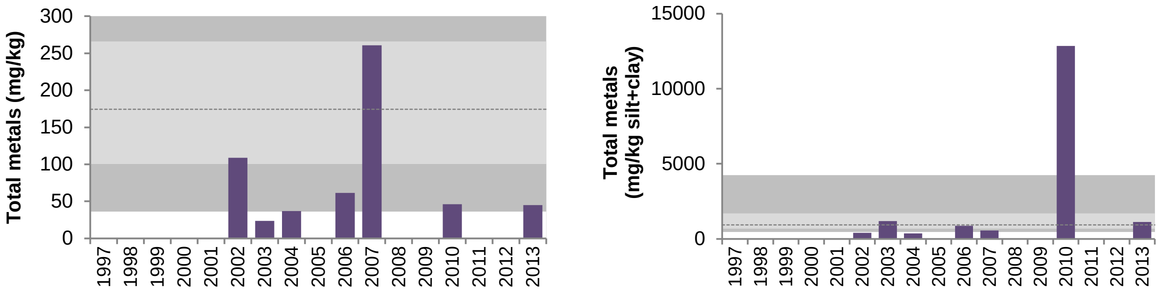
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-16 Variation in sediment quality measurement endpoints in the Firebag River, *test* station FIR-D1.



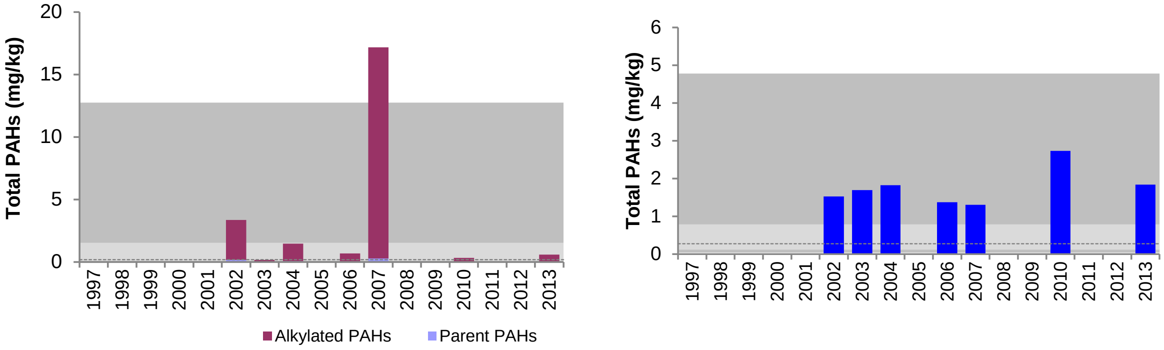
Particle size distribution

Carbon Content



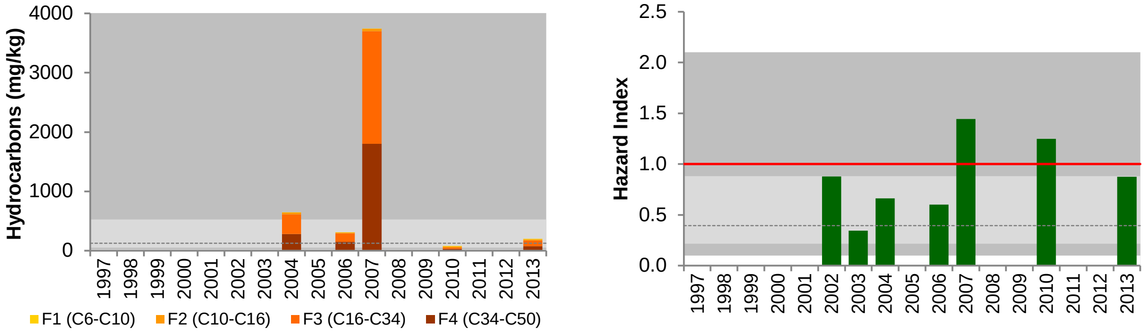
Total Metals[1]

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]

---

[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 5.7-17 Concentrations of sediment quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2013.

Variables	Units	Guideline	September 2013	2002-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	16.0	9	0.5	10.1	49.0
Silt	%	-	19.0	9	0.2	23.0	80.1
Sand	%	-	65.0	9	9.8	37.8	99.4
Total organic carbon	%	-	28.80	9	0.40	27.60	33.90
Total hydrocarbons							
BTEX	mg/kg	-	<140	7	<5	<10	<150
Fraction 1 (C6-C10)	mg/kg	30[1]	<140	7	<5	<10	<150
Fraction 2 (C10-C16)	mg/kg	150[1]	<137	7	<5	65	**288**
Fraction 3 (C16-C34)	mg/kg	300[1]	**404**	7	**20**	**486**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	181	7	20	288	2,400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0095	6	0.0004	0.0082	0.0241
Retene	mg/kg	-	0.134	9	0.001	0.084	0.161
Total dibenzothiophenes	mg/kg	-	0.309	9	0.002	0.029	0.083
Total PAHs	mg/kg	-	1.947	9	0.034	0.525	0.753
Total Parent PAHs	mg/kg	-	0.139	9	0.003	0.063	0.107
Total Alkylated PAHs	mg/kg	-	1.808	9	0.031	0.458	0.691
Predicted PAH toxicity[3]	H.I.	1.0	0.78	9	0.04	0.15	0.37
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Other analytes that exceeded CCME guidelines in 2013							
Pyrene	mg/kg	0.053	**0.0588**	9	0.0001	0.0040	0.0070
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7.4	5	7.8	9.2	9.6
Chironomus growth - 10d	mg/organism	-	2.12	5	1.45	1.53	1.86
Hyalella survival - 14d	# surviving	-	7.8	5	7.4	8.8	9.8
Hyalella growth - 14d	mg/organism	-	0.49	5	0.22	0.31	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).

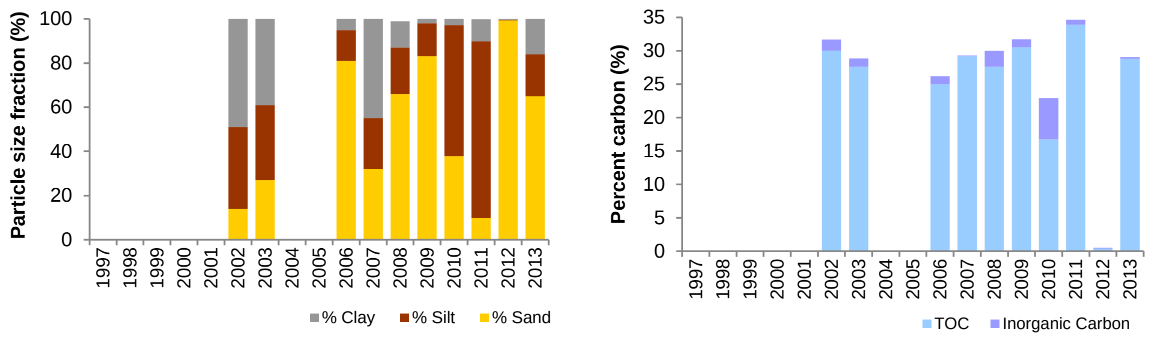
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.7-17 Variation in sediment quality measurement endpoints in McClelland Lake, *test* station MCL-1.

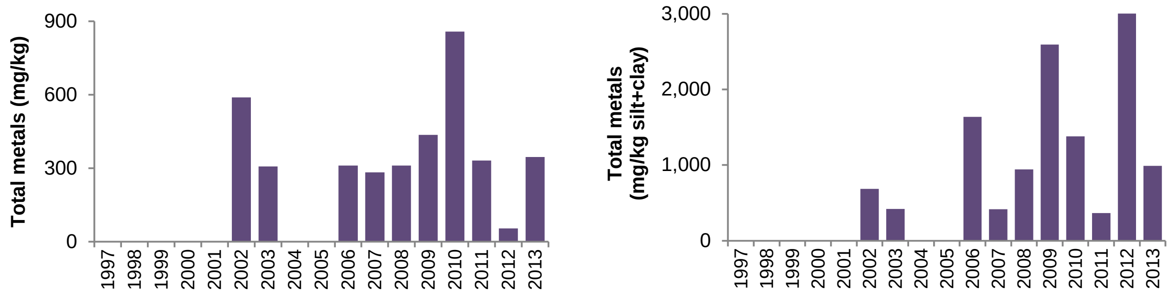
Particle size distribution

Carbon Content



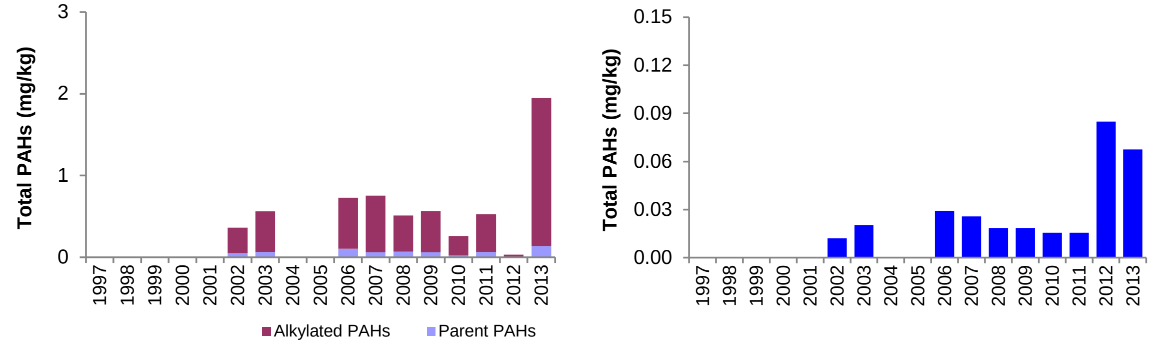
Total Metals[1]

Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



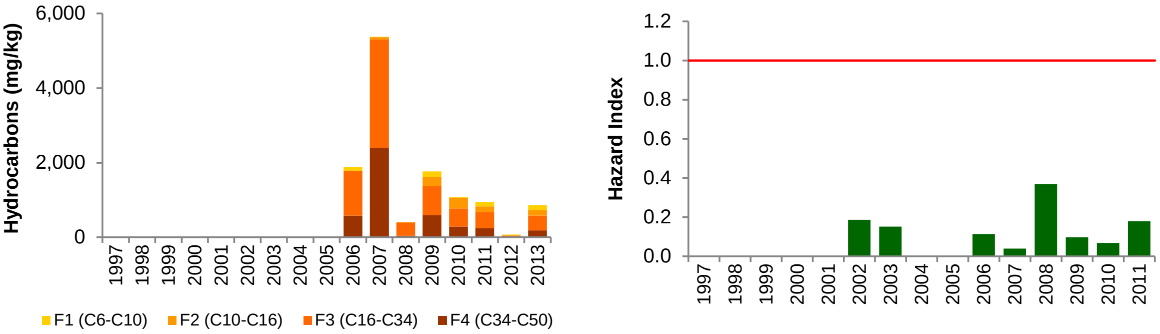
Total PAHs

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 5.7-18 Concentrations of sediment quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2013.

Variables	Units	Guideline	September 2013	2011-2012 (fall data only)	
			Value	Min	Max
Physical variables					
Clay	%	-	5.0	8.0	18.1
Silt	%	-	94.3	34.1	63.6
Sand	%	-	0.8	28.4	47.7
Total organic carbon	%	-	38.0	19.0	26.2
Total hydrocarbons					
BTEX	mg/kg	-	<130	<90	<160
Fraction 1 (C6-C10)	mg/kg	30[1]	<130	<90	<160
Fraction 2 (C10-C16)	mg/kg	150[1]	<165	<107	<187
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,070**	281	**1,300**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	464	174	760
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	mg/kg	0.0346[2]	0.0062	0.0042	0.0062
Retene	mg/kg	-	0.113	0.108	0.219
Total dibenzothiophenes	mg/kg	-	0.049	0.030	0.037
Total PAHs	mg/kg	-	0.555	0.547	1.029
Total Parent PAHs	mg/kg	-	0.035	0.030	0.054
Total Alkylated PAHs	mg/kg	-	0.519	0.517	0.975
Predicted PAH toxicity[3]	H.I.	1.0	0.09	0.12	0.30
Metals that exceeded CCME guidelines in 2013					
none	mg/kg	-			
Chronic toxicity					
Chironomus survival - 10d	# surviving	-	8.6	9.0	9.4
Chironomus growth - 10d	mg/organism	-	1.93	1.17	1.9
Hyalella survival - 14d	# surviving	-	8.4	8.4	9.2
Hyalella growth - 14d	mg/organism	-	0.29	0.20	0.37

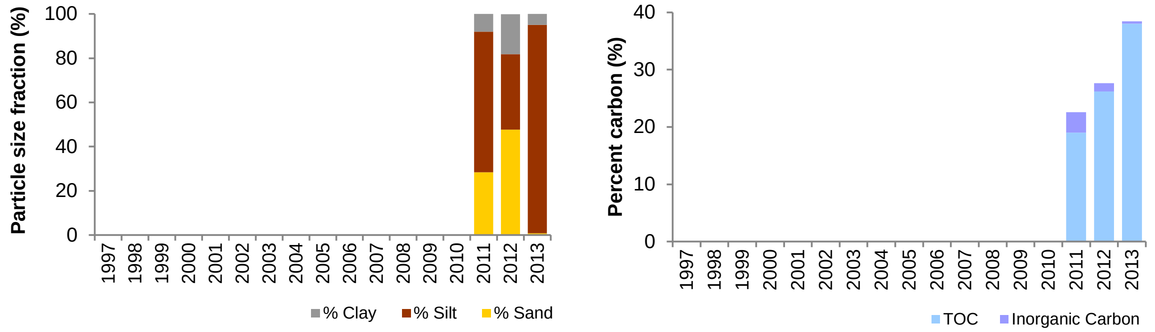
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

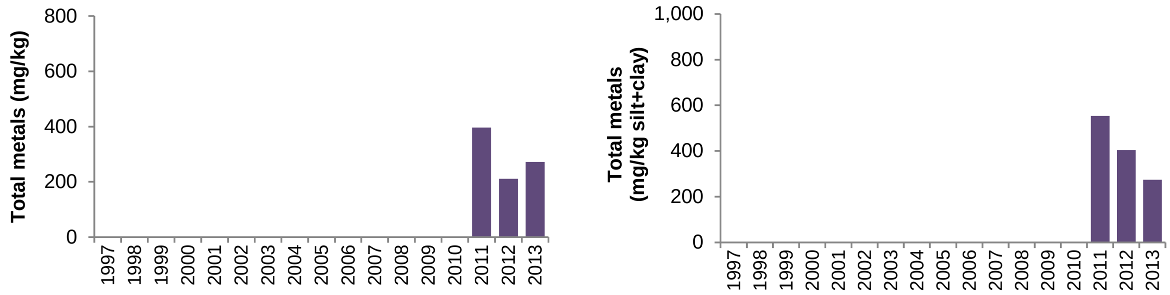
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

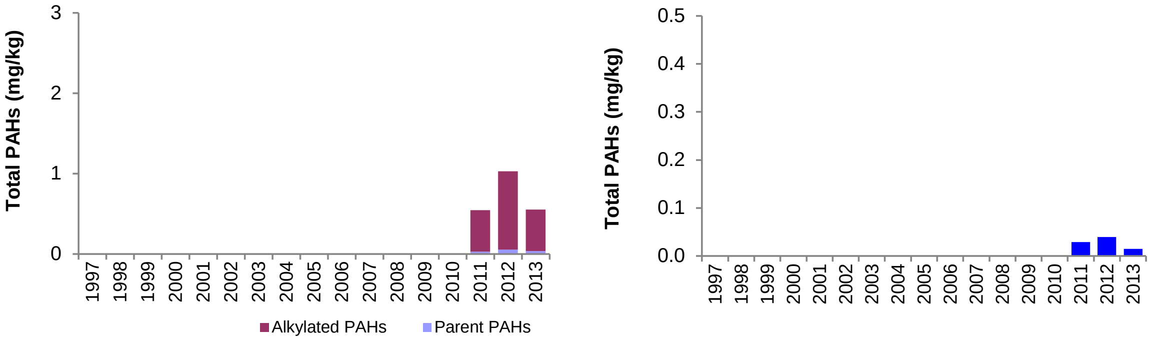
Figure 5.7-18 Variation in sediment quality measurement endpoints in Johnson Lake, *baseline* station JOL-1.


Particle size distribution

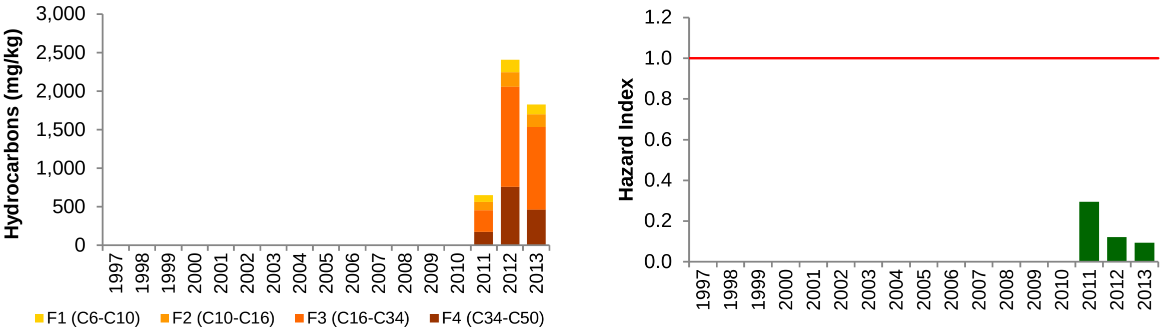
Carbon Content


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]

[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 5.7-19 Average habitat characteristics of fish assemblage monitoring locations in the Firebag River, fall 2013.

Variable	Units	FIR-F1 Lower *Test* Reach of the Firebag River	FIR-F2 Upper *Baseline* Reach of the Firebag River
Sample date	-	Sept 9, 2013	Sept 9, 2013
Habitat type	-	run	run/riffle
Maximum depth	m	1.16	0.84
Mean depth	m	0.73	0.58
Bankfull channel width	m	86.5	46.0
Wetted channel width	m	67.0	43.5
Substrate			
Dominant	-	sand	cobble
Subdominant	-	fines	coarse gravel, small boulder
Instream cover			
Dominant	-	filamentous algae, small woody debris	macrophytes
Subdominant	-	-	filamentous algae, small woody debris, overhanging vegetation, boulders
Field water quality			
Dissolved oxygen	mg/L	7.8	9.4
Conductivity	µS/cm	207	151
pH	pH units	8.22	8.45
Water temperature	^{0}C	15.1	15.9
Water velocity			
Left bank velocity	m/s	0.34	0.42
Left bank water depth	m	0.84	0.53
Centre of channel velocity	m/s	0.33	0.47
Centre of channel water depth	m	0.77	0.68
Right bank velocity	m/s	0.37	0.28
Right bank water depth	m	0.59	0.53
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	-	-

Table 5.7-20 Total number and percent composition of fish species captured at reaches of the Firebag River, 2013.

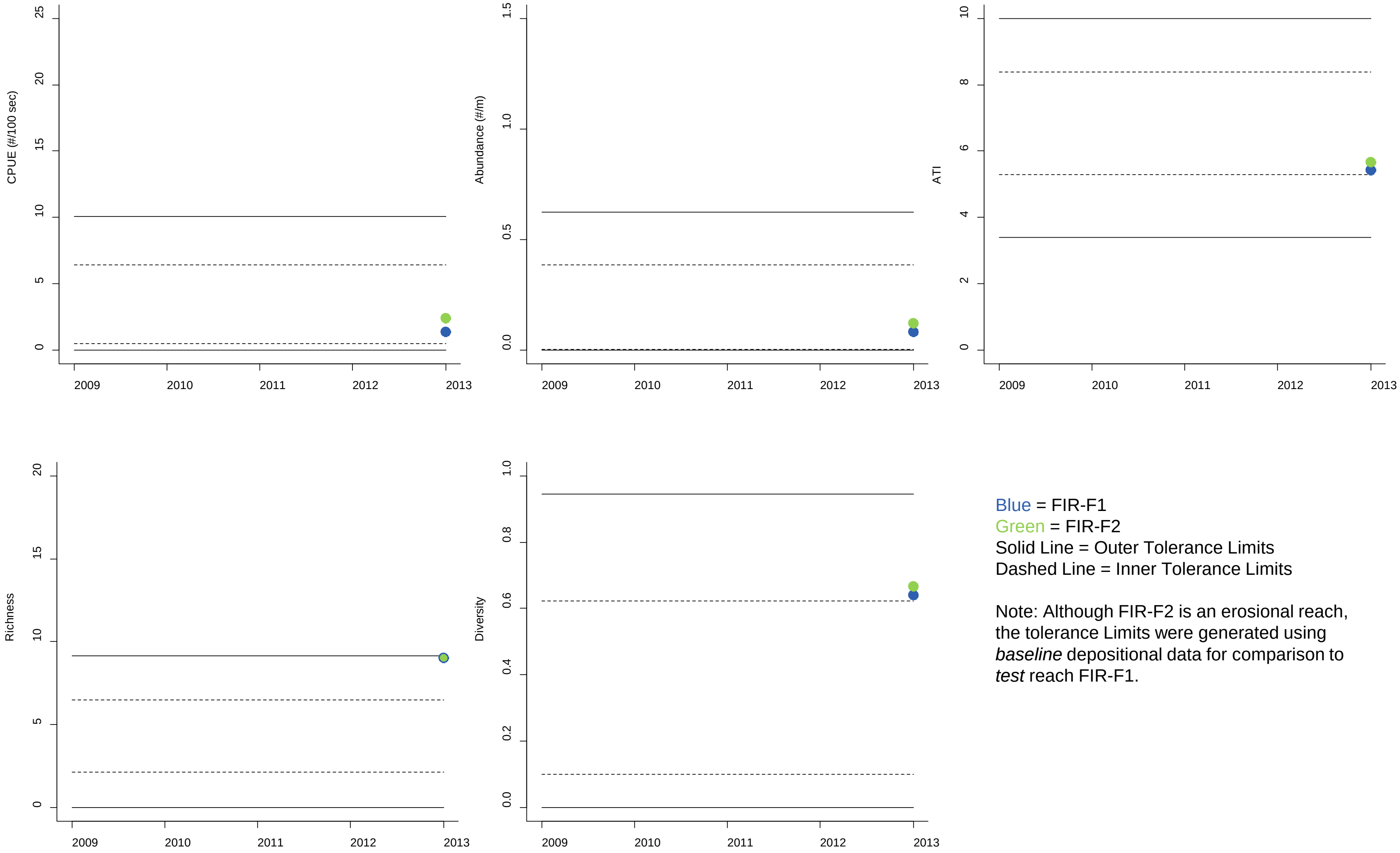
Common Name	Code	Total Species Catch		Percent of Total Catch	
		Test **Reach FIR-F1**	***Baseline*** **Reach FIR-F2**	***Test*** **Reach FIR-F1**	***Baseline*** **Reach FIR-F2**
brook stickleback	BRST	1	-	2.4	0
burbot	BURB	17	3	41.5	5
lake chub	LKCH	1	9	2.4	15
longnose dace	LNDC	-	7	0	11.7
longnose sucker	LNSC	1	17	2.4	28.3
northern redbelly dace	NRDC	2	2	4.9	3.3
pearl dace	PRDC	-	1	0	1.7
slimy sculpin	SLSC	1	5	2.4	8.3
spottail shiner	SPSH	4	-	9.8	0
trout-perch	TRPR	13	2	31.7	3.3
walleye	WALL	1	-	2.4	0
white sucker	WHSC	-	14	0	23.3
Total Count		**41**	**60**	**100**	**100**
Total Species Richness		**9**	**9**	**-**	**-**
Electrofishing effort (secs)		**1,278**	**1,557**	**-**	**-**

Table 5.7-21 Summary of fish assemblage measurement endpoints for reaches of the Firebag River, fall 2013.

Reach	Abundance		Richness			Diversity		ATI		CPUE	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FIR-F1	0.08	0.02	9	4	0.5	0.64	0.05	5.42	0.62	1.36	0.33
FIR-F2	0.12	0.07	9	5	1.3	0.67	0.17	5.66	0.61	2.39	1.30

SD=standard deviation across sub-reaches within a reach.

Figure 5.7-19 Variation in fish assemblage measurement endpoints in the Firebag River (*test* reach FIR-F1 and *baseline* reach FIR-F2) relative to regional *baseline* depositional conditions.



Note: Although FIR-F2 is an erosional reach, the tolerance Limits were generated using *baseline* depositional data for comparison to *test* reach FIR-F1.

This page intentionally left blank for printing purposes.

5.8 ELLS RIVER WATERSHED

Table 5.8-1 Summary of results for the Ells River watershed.

Ells River Watershed	Summary of 2013 Conditions		
	Ells River		Namur Lake
Climate and Hydrology			
Criteria	**S14A** at Canadian Natural Bridge		**L4 Namur Lake**
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	**ELR-1** at the mouth	**ELR-3** upstream of development	no station sampled
Water Quality Index	🟡	🟡	
Benthic Invertebrate Communities and Sediment Quality			
Criteria	**ELR-D1** lower reach	**ELR-E3** upstream of development	no station sampled
Benthic Invertebrate Communities	🟠	n/a	
Sediment Quality Index	🟠	not sampled	
Fish Populations			
Criteria	**ELR-F1** lower reach	**ELR-F3** upstream of development	**Namur Lake**
Fish Assemblages	🟠	n/a	not sampled
Human Health		LKWH[1]	Sub[2] 🟡 Gen[2] 🟡
		LKTR[1]	Sub[2] 🟤 Gen[2] 🟤

Legend and Notes

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

[1] Species (Sp.): LKWH= lake whitefish, LKTR=lake trout

[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/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.

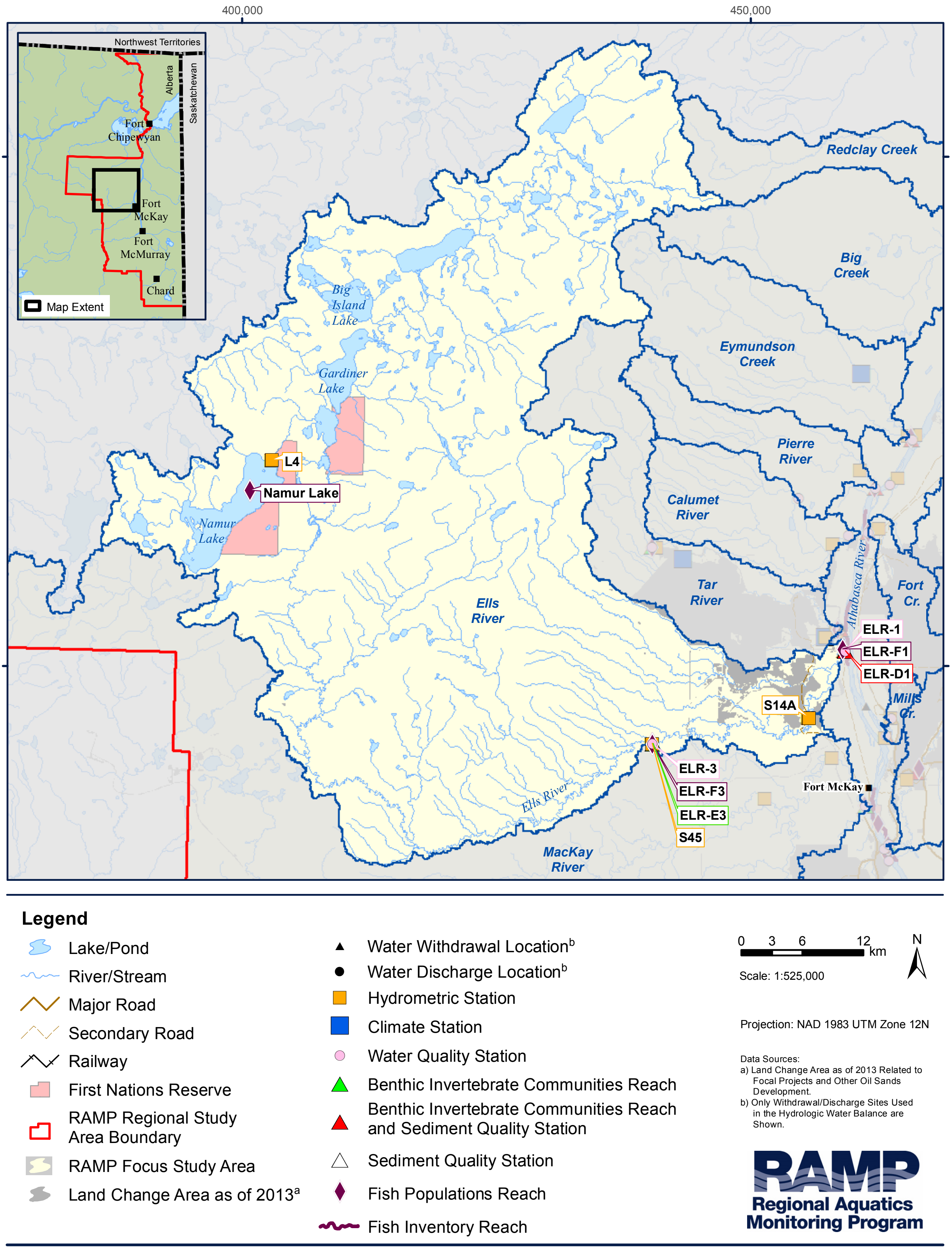
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

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

Fish Populations (human health): Uses various Health Canada criteria for risks to human health from fish tissue concentrations of mercury, see Section 3.2.4.2 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 2013 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\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K08_Ells_20140224_ss.mxd

Figure 5.8-2 Representative monitoring stations of the Ells River, fall 2013.

Benthic Invertebrate Reach ELR-D1:
Mid-Channel, facing upstream

Water Quality Station ELR-3:
facing upstream

Hydrology Station L4 (Namur Lake)

Hydrology Station S14A:
at the Canadian Natural Bridge

5.8.1 Summary of 2013 Conditions

Approximately 1.25% (3,394 ha) of the Ells River watershed had undergone land change as of 2013 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 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 2013. Table 5.8-1 is a summary of the 2013 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 2013. Figure 5.8-2 contains fall 2013 photos of a number of monitoring stations in the watershed.

Hydrology The calculated mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.10% 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 2013 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* station ELR-1 and were within the range of previously-measured concentrations and regional *baseline* conditions. *Baseline* station ELR-3, initiated in 2013, showed similar water quality to *test* station ELR-1, and was within regional *baseline* conditions in fall 2013.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 were classified as **Moderate** because the significant decrease in abundance, EPT, and richness over time were indicative of potentially degrading conditions. Abundance in fall 2013 (48 organisms per sample or about 2,000 individuals per m^2) was the lowest observed in the lower Ells River, and has previously ranged between 8,000 and 32,000 individuals per m^2. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) that have previously been sparse were absent in 2013. All of the smaller and previously abundant organisms remained abundant in 2013. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Water velocity at the lower Ells River in 2013 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and likely considered to be the explanation for the absence of larger forms of benthic invertebrates at *test* reach ELR-D1 in 2013. Flows were generally high in the 2013 open-water season due to significant rain events in June.

Differences in sediment quality observed in fall 2013 between *test* station ELR-D1 and regional *baseline* conditions were classified as **Moderate,** likely due to high PAH concentrations compared to the regional range of *baseline* variability.

Fish Populations (fish assemblages) Differences in the fish assemblage observed in fall 2013 at *test* reach ELR-F1 relative to past years and regional *baseline* variability were classified as **Moderate** because although the lower ATI value indicated a greater proportion of sensitive fish species (i.e., burbot, spoonhead sculpin), there were significant decreases in abundance and diversity over time.

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Namur Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in lake trout from Namur Lake in 2013 were above Health Canada consumption guidelines for subsistence fishers and general consumers indicating a **High** risk to the health of both consumers of lake trout.

5.8.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the Ells River watershed was conducted at 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 since 2004. 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 2013 WY annual runoff volume measured at Station S14A was 359 million m^3, which was 69% higher than the historical mean annual runoff volume. Flows during the winter period decreased from November 2012 to March 2013, with values from January to mid-March 2013 often exceeding the historical maximum values (Figure 5.8-3). Flows increased during the spring freshet to a peak of 63.4 m^3/s on May 17, which was the maximum daily flow recorded in the 2013 WY and 17% higher than the historical mean annual maximum daily flow of 54.1 m^3/s. Following the freshet peak, flows decreased until early June, but remained above historical upper quartile values. Rainfall in mid-June resulted in flows exceeding the historical maximum flows, and reaching 61.4 m^3/s on June 13, 2013. Flows then decreased steadily until the lowest open-water daily flow of 3.26 m^3/s on September 29. This value was 35% higher than the historical mean open-water minimum daily flow. Rainfall events in early October increased flows to above the historical median values until the end of the 2013 WY.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The 2013 WY estimated water balance for the Ells River was based on recorded flows at RAMP Station S14A, which is upstream of focal projects located within the Ells River watershed. The station cannot be located downstream of all focal projects because of backwater effects from the Athabasca River in the downstream reach of the Ells River. Consequently, the analysis was conservative, with differences between the observed *test* hydrograph and the estimated *baseline* hydrograph expected to be lower at the mouth than currently estimated. The 2013 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 2013 in the Ells River watershed was estimated to be 3.55 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 0.526 million m^3.

2. As of 2013, the area of land change in the Ells River watershed from focal projects that was not closed-circuited was estimated to be 30.2 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 0.897 million m^3.

The estimated cumulative effect of oil sands development in the 2013 WY was an increase of flow of approximately 0.370 million m^3 at RAMP Station S14A in the 2013 WY. The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.8-3. The calculated mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.10% 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 2013, water quality samples were taken from:

- the Ells River near its mouth (*test* station ELR-1), established in 1998, sampled annually since 2002; and
- the Ells River upstream of development (*baseline* station ELR-3), a new station established in 2013 to replace *baseline* station ELR-2A, as a result of increasing development.

Baseline station ELR-3 was also sampled in winter, spring, and summer 2013.

Temporal Trends There were no significant trends (α=0.05) in fall concentrations of water quality measurement endpoints detected over time at *test* station ELR-1. No trend analysis could be conducted for *baseline* station ELR-3, given 2013 was the first sampling year.

2013 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations in fall 2013 at *test* station ELR-1, with the exception of total mercury (ultra-trace), which exceeded the previously-measured maximum concentration (Table 5.8-4). Water quality at *baseline* station ELR-3 was measured for the first time in 2013; therefore, historical data does not exist (Table 5.8-5).

Ion Balance The ionic composition of water in fall 2013 was similar at both water quality stations and dominated by calcium and bicarbonate (Figure 5.8-4). The ionic composition of water at *test* station ELR-1 has remained consistent since monitoring first began in 1998.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of all water quality measurement endpoints in the Ells River in fall 2013 were below water quality guidelines (Table 5.8-4 and Table 5.8-5), with the exception of total aluminum at *test* station ELR-1 and *baseline* station ELR-3.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Ells River watershed in fall 2013 (Table 5.8-6):

- total iron, total phenols, and sulphide at *test* station ELR-1; and
- total iron at *baseline* station ELR-3.

The following water quality guideline exceedances were measured in other seasons at *baseline* station ELR-3 (Table 5.8-6).

- total iron, total aluminum and sulphide in winter;
- dissolved aluminum, dissolved iron, sulphide, total aluminum, total chromium, total copper, total iron, total lead, total nitrogen, total phenols, total phosphorus, and total silver in spring; and
- sulphide, total aluminum, total chromium, total iron, total phenols, and total phosphorus in summer.

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints in fall 2013 were within the range of regional *baseline* concentrations at both stations (Figure 5.8-5).

Water Quality Index The WQI value was 97.5 for *test* station ELR-1 and 100 for *baseline* station ELR-3, indicating **Negligible-Low** differences from regional *baseline* water quality conditions at both stations in fall 2013.

Classification of Results Differences in water quality in fall 2013 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years at *test* station ELR-1 and were within the range of previously-measured concentrations and regional *baseline* conditions. *Baseline* station ELR-3, initiated in 2013, showed similar water quality to *test* station ELR-1, and was within regional *baseline* conditions in fall 2013.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- depositional *test* reach ELR-D1, sampled since 2003; and
- erosional *baseline* reach ELR-E3, sampled for the first time in 2013.

2013 Habitat Conditions Water at *test* reach ELR-D1 in fall 2013 was deep (0.8 m), with a fast velocity (0.6 m/s), alkaline (pH: 8.0), with high dissolved oxygen (9.1 mg/L), and moderate conductivity (168 µS/cm) (Table 5.8-7). The substrate was dominated almost entirely by sand (97%), with low total organic carbon content (<1 %) (Table 5.8-7).

Water at *baseline* reach ELR-E3 in fall 2013 was relatively shallow (0.3 m), with a fast velocity (0.6 m/s), weakly alkaline (pH: 7.9), with moderate conductivity (170 µS/cm) (Table 5.8-7). The substrate was dominated by small and large cobble (20% and 19%, respectively), with smaller amounts of gravel (small, 15% and large, 16%) (Table 5.8-7). Periphyton chlorophyll *a* biomass at *baseline* reach ELR-E3 averaged 46 mg/m^2, which was within the inner tolerance limits for the range of variation for regional *baseline* conditions (Figure 5.8-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach ELR-Dl in fall 2013 was dominated by chironomids (76%) and tubificid worms (22%) (Table 5.8-8). Chironomids were not diverse at this reach and were mostly comprised of *Lopescladius/Rheosmittia*, and *Polypedilum*. Permanent aquatic forms such as bivalves, gastropods, amphipods and flying insects (Ephemeroptera, Plecoptera, Trichoptera) were not present in 2013.

The benthic invertebrate community of *baseline* reach ELR-E3 in fall 2013 was dominated by chironomids (58%) and Ephemeroptera (12%), with subdominant taxa consisting of Hydracarina (9%) and naidid worms (8%) (Table 5.8-9). Chironomids were diverse and included the rheophilic *Rheotanytarsus,* and the common forms *Polypedilum*, *Microspectra, Tventia,* and *Thienemannimyia gr*. Bivalves and gastropods were present in low relative abundances. Ephemeroptera were diverse and included common forms of the family Baetidae and Heptageniidae and sensitive forms (*Ephemerella*). Stoneflies (*Isoperla*, Chloroperlidae, *Taeniopteryx*) and caddisflies (*Cheumatopsyche, Hydropsyche, Hydroptilla*) were well represented at *baseline* reach ELR-E3. Permanent aquatic forms such as fingernail clams (*Pisidium/Sphaerium*) and *Ferrissia* were found in low relative abundances (Table 5.8-9).

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* reach ELR-D1 included testing for:

- changes over time (Hypothesis 7, Section 3.2.3.1); and
- changes between 2013 values and the mean of all previous years of sampling (1998 to 2012).

Abundance, richness, and EPT taxa significantly decreased over time at *test* reach ELR-D1, accounting for 48%, 66%, and 50% of the variance in annual means, respectively (Table 5.8-10).

Comparison to Published Literature *Test* reach ELR-Dl had low diversity and a relatively high percentage of the fauna as worms (~25%) in fall 2013, potentially indicating some level of degradation (Hynes 1960; Griffiths 1998). The benthic invertebrate community at *test* reach ELR-Dl also contained no EPT taxa and no permanent aquatic forms, which might indicate that dissolved oxygen levels may not have been consistently high in that area of the river.

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach ELR-D1 has more than eight years of data (1998 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* conditions were evaluated (there was no upstream depositional *baseline* reach on the Ells River to make a direct comparison to *test* reach ELR-D1).

Abundance at *test* reach ELR-D1 in fall 2013 was below the outer tolerance limit for the 5th percentile of the normal range of variation for means of previous years at this reach (Figure 5.8-7). Richness was near the outer tolerance limit for the 5th percentile. The percentage of fauna as EPT taxa was at the inner tolerance limit of the 95th percentile of the normal range of variation for means from previous years (Figure 5.8-7). Only equitability and CA Axis 1 and 2 scores were within the inner tolerance limits for the range of variability for previous years (Figure 5.8-7, Figure 5.8-8).

When **c**ompared to tolerance limits of the normal range of variation for means from regional *baseline* depositional reaches, abundance, and EPT were within the inner tolerance limits, indicating that that changes observed in 2013 at this reach were still within regional variability. Richness was within the inner and outer tolerance limits for the 5th percentile of the normal range of variability of regional *baseline* depositional reaches, indicating that the low richness observed at *test* reach ELR-D1 was generally lower compared to regional *baseline* conditions.

The variability of measurement endpoints at *baseline* reach ELR-E3 was contributing to the characterization of regional *baseline* erosional conditions. No comparison to the regional data were conducted (Figure 5.8-9, Figure 5.8-10).

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 were classified as **Moderate** because the significant decrease in abundance, EPT, and richness over time were indicative of potentially degrading conditions. Abundance in fall 2013 (48 organisms per sample or about 2,000 individuals per m^2) was the lowest observed in the lower Ells River, and has previously ranged between 8,000 and 32,000 individuals per m^2. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) that have previously been sparse were absent in 2013. All of the smaller and previously abundant organisms remained abundant in 2013. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Water velocity at the lower Ells River in 2013 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and likely considered to be the explanation for the absence of larger forms of benthic invertebrates at *test* reach ELR-D1 in 2013. Flows were generally high in the 2013 open-water season due to significant rain events in June (Figure 5.8-3).

5.8.4.2 Sediment Quality

Sediment quality was sampled in fall 2013 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 present.

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station ELR-D1 in fall 2013, with the exception of increasing trends of F3 and F4 hydrocarbons, despite lower concentrations in 2013 relative to the historical mean (Table 5.8-11).

2013 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 corresponds to pre-2006 sediment quality station ELR-1. 2013 sediment quality data from *test* station ELR-D1 were compared to all available data collected at this location (including pre-2006 results).

Sediments at *test* station ELR-D1 in fall 2013 were dominated by sand, with proportions of sand, silt, and clay within previously-measured values and most similar to 2003 (Table 5.8-11, Figure 5.8-11). In fall 2013, 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. As in previous years, sediment hydrocarbon concentrations were dominated by fractions 3 and 4, which likely indicated the presence of bitumen in sediments (Table 5.8-11). All hydrocarbon fractions and total PAHs (absolute and carbon-normalized concentrations) were within the range of previously-measured concentrations (Table 5.8-11). In 2013, the predicted PAH toxicity (3.5) exceeded the potential chronic toxicity threshold of 1.0 and exceeded the previously-measured maximum value at this station (Table 5.8-11, Figure 5.8-11).

Direct tests of sediment toxicity to invertebrates at *test* station ELR-D1 showed 92% survival in the amphipod *Hyalella* and 38% survival in the midge *Chironomus.* Survival of the midge *Chironomus* was lower than the previously-measured minimum value. 14-day growth of *Hyalella* was within previously-measured values, while ten-day growth of *Chironomus* exceeded the previously-measured maximum value (Table 5.8-11).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints that exceeded relevant CCME sediment quality guidelines at *test* station ELR-D1 in fall 2013 included F2 and F3 hydrocarbons, pyrene, benz[a]anthracene, chrysene, and dibenz(a,h)anthracene (Table 5.8-11).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of all sediment quality measurement endpoints at *test* station ELR-D1 were within the range of regional *baseline* concentrations, with the exception of total PAHs normalized to 1% TOC and the PAH Hazard Index, which exceeded the 95th percentile of regional *baseline* concentrations (Figure 5.8-11).

Sediment Quality Index A SQI of 69.3 was calculated for *test* station ELR-D1 for fall 2013, indicating a **Moderate** difference from regional *baseline* conditions. Since 1998, this station has shown a **Moderate** difference from regional *baseline* conditions in most years, due primarily to regionally high hydrocarbon and PAH concentrations at this station.

Classification of Results Sediment quality in fall 2013 at *test* station ELR-D1 showed a **Moderate** difference from regional *baseline* conditions, likely due to high PAH concentrations compared to the regional range of *baseline* variability.

5.8.5 Fish Populations

In 2013, fish populations monitoring in the Ells River watershed consisted of fish assemblage monitoring at reaches of the Ells River and a fish tissue survey on Namur Lake.

5.8.5.1 Fish Assemblage Monitoring

Fish assemblages were sampled in fall 2013 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); and
- erosional *baseline* reach ELR-F3, this reach was sampled for the first time in 2013 and is upstream from reach ELR-F2A, which was sampled from 2010 to 2012. The *baseline* reach was moved further upstream in 2013 due to expanding development in the watershed.

2013 Habitat Conditions *Test* reach ELR-F1 was comprised entirely of run habitat with a wetted width of 19.5 m and a bankfull width of 38 m (Table 5.8-12). 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 2013 had a mean depth of 0.66 m and moderate velocity (0.37 m/s), with low conductivity (192 µS/cm), moderate dissolved oxygen (7.5 mg/L), and a temperature of 12.4˚C. Instream cover was primarily dominated by small woody debris and macrophytes with small amounts of large woody debris and algae (Table 5.8-12).

Baseline reach ELR-F3 was comprised of riffle and run habitat with a wetted width of 30.2 m and a bankfull width of 35.4 m (Table 5.8-12). The substrate was dominated by sand, with smaller amounts of cobble. Water at *baseline* reach ELR-F3 in fall 2013 had a mean depth of 0.46 m and moderate velocity (0.37 m/s), was alkaline (pH: 8.24), with low conductivity (146 µ/cm), high dissolved oxygen (9 mg/L), and a temperature of 13.0˚C. Instream cover was dominated by larger woody debris and filamentous macrophytes with smaller amounts of small woody debris and overhanging vegetation (Table 5.8-12). Habitat at *baseline* reach ELR-F3 was shallower, with higher velocity than recorded at *baseline* reach ELR-F2A in 2012. However, overall habitat type and substrate were similar between the two locations.

Relative Abundance of Fish Species The fish assemblage at *test* reach ELR-F1 was dominated by burbot and lake chub, with spoonhead sculpin and white sucker as the subdominant species (Table 5.8-13). Burbot have not been observed in the lower Ells River by RAMP in previous years. The fish assemblage at *baseline* reach ELR-F3 was dominated by pearl dace and longnose dace, both of which are representative of fast-flowing water, with hard substrate (Table 5.8-13). Species composition at both reaches was similar (Table 5.8-13), but a much higher number of fish were captured at *baseline* reach ELR-F3.

Temporal and Spatial Comparisons Temporal comparisons for *test* reach ELR-F1 included testing for changes over time in measurement endpoints (2010 to 2013, Hypothesis 1, Section 3.2.4.4). Spatial comparisons were not conducted given the differences in habitat conditions between *test* reach ELR-F1 (depositional) and *baseline* reach ELR-F3 (erosional).

There were significant decreases in abundance and diversity over time at *test* reach ELR-F1; however, only the decrease in abundance explained greater than 20% in the variance of annual means (Table 5.8-14, Table 5.8-15, Figure 5.8-12).

With the exception of species richness and ATI, all measurement endpoints at *baseline* reach ELR-F3 were lower in 2013 compared to 2012 at *baseline* reach ELR-F2A (Table 5.8-14). ATI increased very slightly in the *baseline* area of the river (ELR-F2A and ELR-F3) from 2012 to 2013. ATI at *test* reach ELR-F1 was the lowest observed in four years of sampling; largely due to the number of juvenile burbot that were captured at *test* reach ELR-F1 compared to previous years and also the presence of spoonhead sculpin in 2013, which has not been observed in previous years. Burbot and spoonhead sculpin represented nearly half of the fish captured (Table 5.8-13) and both have very low tolerance values (Whittier et al. 2007). Juvenile burbot were observed at many of the reaches in the region in 2013 compared to previous years.

All measurement endpoints were lower at *test* reach ELR-F1 compared to *baseline* reach ELR-F3 (Table 5.8-14), likely due to greater productivity typically found in riffle habitat at *baseline* reach ELR-F3.

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 (Golder 2004). An additional species, finescale dace, which was not recorded by Golder (2004) was found by RAMP in 2012. In 2013, northern redbelly dace were also found, which have not previously been documented in the Ells River. Two species (burbot and spoonhead sculpin) were found in 2013 that are known to occur in the Ells River but have not been captured during the RAMP Fish Assemblage monitoring program. This brings the total number of fish species to 15 that RAMP has observed between 2010 and 2013. 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-F3 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 2013 (Table 5.8-12).

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *test* reach ELR-F1 were within the inner tolerance limits of the range of regional *baseline* variability for depositional reaches, with the exception of the ATI value, which was lower than the inner tolerance limit for the 5th percentile (Figure 5.8-12).

Classification of Results Differences in the fish assemblage observed in fall 2013 at *test* reach ELR-F1 relative to past years were classified as **Moderate** because although the lower ATI value indicated a greater proportion of sensitive fish species (i.e., burbot, spoonhead sculpin), there were significant decreases in abundance and diversity over time, with the change in abundance explaining greater than 20% of the variance in annual means.

5.8.5.2 Namur Lake Fish Tissue Monitoring

A fish tissue program to assess mercury in sportfish species (lake whitefish and lake trout) was conducted in summer 2013 in Namur Lake in collaboration with AESRD's Summer Profundal Index Netting (SPIN) Program. Namur Lake is located northwest of Fort McMurray in the Birch Mountains Wildland Provincial Park in the northwest section of the Ells River watershed, adjacent to Aboriginal land, and used for recreational and subsistence fishing. This lake is 90 km away from the oil sands development and 113 km away from Fort McMurray. Namur Lake is approximately 43 km^2 and approximately 27 m deep in the deepest portion of the lake. Fish tissue samples have been previously collected and analyzed by RAMP and AESRD in 2007 (lake trout only) (RAMP 2008) and by Environment Canada in 2000 (lake trout [Evans and Talbot 2012] and lake whitefish [Evans pers. comm. 2014]).

This section includes 2013 results from Namur Lake as well as comparisons to results from the survey conducted in 2000; results from other lakes/rivers sampled by RAMP and AESRD in the RAMP RSA from 2002 to 2013; and results from other studies in Alberta (1975 to 2003).

Whole-Organism Metrics

In 2013, a total of 21 lake whitefish (13 female and eight male) and 20 lake trout (11 female and nine male) from Namur Lake were sampled for fish tissue (muscle) analysis of mercury. Age was only assessed for lake trout fish. Fork lengths of fish sampled were as follows:

1. Lake whitefish – fork length ranged from a 261 mm four year old female fish to a 547 mm 11 year old mature male. On average, male lake whitefish (mean fork length: 446 mm, mean age: 14 years) were larger than female fish (mean fork length: 317 mm, mean age nine years). The mean fork length of all sampled fish was 366 mm and the mean age was ten years.
2. Lake trout – fork length ranged from a 443 mm 13 year old male to a 690 mm mature 22 year old female. On average, female lake trout (mean fork length: 585 mm, mean age: 11 years) were larger than male fish (mean fork length: 559 mm, mean age: 12 years). The mean fork length of all sampled fish was 573 mm and the mean age was 12 years.

Mercury Concentrations

Concentrations of mercury in muscle of individual lake whitefish and lake trout collected from Namur Lake in 2013 are presented in Table 5.8-16:

1. The mean mercury concentration in lake whitefish was 0.047 mg/kg and ranged from 0.021 mg/kg in a 300 mm, 12 year old female to 0.118 mg/kg in a 483 mm 14 year old male.
2. The mean mercury concentration in lake trout was 0.438 mg/kg and ranged from 0.171 mg/kg in a 489 mm immature eight year old female to 0.707 mg/kg in a 592 mm mature 14 year old female fish.

Regressions between mercury concentration ($\log_{10}$-transformed) and fork length were statistically significant for lake whitefish ($p=0.002$, $r^2=0.39$) and lake trout ($p<0.001$; $r^2=0.59$) with positive slopes indicating that longer, or larger fish have greater concentrations of mercury than shorter, or smaller fish. The regression, with the addition of age as a factor, did not show a significant relationship between mercury concentrations in fish and age (lake whitefish $p=0.51$; lake trout $p=0.50$.

Potential Risks of Mercury in Fish Tissue to Human Health

A comparison between mercury concentrations in muscle tissue of lake whitefish and lake trout from Namur Lake in 2013 to Health Canada fish consumption guidelines is as follows:

Lake Whitefish Mercury concentrations in all lake whitefish captured from Namur 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). Across size classes, concentrations of mercury in lake whitefish in 2013 were higher than concentrations recorded in 2000 at Namur Lake (Figure 5.8-13).

Lake Trout Mercury concentrations in 19 lake trout captured from Namur Lake were above the Health Canada guideline for subsistence fishers (0.2 mg/kg), eight of which were above the guideline for general consumers (0.5 mg/kg). Across size classes, concentrations of mercury in lake trout in 2013 were similar to concentrations recorded in 2007, but higher than 2000 at Namur Lake (Figure 5.8-14).

Additional exceedances of USEPA mercury consumption guidelines are outlined in Table 5.8-16.

Temporal and Spatial Comparisons

Namur Lake Temporal comparisons were made across two years of sampling (2000 [Evans pers. comm. 2014] and 2013) for lake whitefish and three years of sampling (2000 [Evans and Talbot 2012], 2007, and 2013) for lake trout from Namur Lake (Figure 5.8-15 and Figure 5.8-16). Lake whitefish captured in 2013 were generally larger than those caught in 2000 (note: the sample size in 2000 was lower than 2013 and not reflective of all size classes). Mercury concentrations in lake whitefish were $\log_{10}$-transformed and rank-transformed for lake trout (Conover and Ima 1982) to meet analysis of covariance (ANCOVA) assumptions (i.e., equal slopes). The results from the ANCOVA indicated that differences in mercury concentrations in fish tissue relative to fork length across years were statistically significant for lake whitefish ($p<0.001$) and lake trout ($p<0.001$). Mercury concentrations in lake whitefish, were higher in 2013 than 2000; mercury concentrations in lake trout, were higher in both 2007 and 2013 than in 2000, but were not significantly different between years 2007 and 2013 ($p=0.44$).

Lakes in the RAMP RSA Comparisons of mercury concentrations in lake whitefish were conducted between Namur Lake in 2013 and other lakes sampled by RAMP and AESRD in the RAMP RSA from 2002 to 2013, and results from other studies in Alberta (1975 to 2003). Mercury concentrations in lake trout from other lakes in the region were not available.

Length-normalized concentrations of mercury in lake whitefish sampled from lakes by RAMP and AESRD between 2002 and 2013 are provided in Figure 5.8-17. Most of the sampled lakes are in the southern portion (i.e., Gregoire Lake, Christina Lake, and Winefred Lake) and northern portion of the RAMP RSA (i.e., Jackson, Net, and Brutus lakes), while some are on the western border of the RAMP RSA (Big Island and Gardiner lakes) where Namur Lake is located and Lake Claire is in the Athabasca River Delta (RAMP 2009b).

Mercury concentrations in lake whitefish from Namur Lake were within the range of mercury concentrations recorded from other lakes sampled by RAMP and AESRD. In general, the highest concentrations of mercury in fish were recorded at Net Lake in 2010 (RAMP 2011) and the lowest were recorded at Big Island Lake in 2008 (RAMP 2009a). Spatial comparisons using an ANCOVA for lake whitefish indicated that there were significant differences in mercury concentrations in fish across lakes ($p < 0.001$), likely related to the depth and size of the lake and the surrounding habitat (i.e., muskeg or forested land cover).

Lakes in Alberta To provide a regional context for the results from the 2013 RAMP Fish Tissue program, length-normalized mercury concentrations in lake whitefish were compared across lakes in northern Alberta (AOSERP 1977; Grey et al. 1995; NRBS 1996; RAMP 2003; RAMP 2004; RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2012; RAMP 2013) (Figure 5.8-18).

Mean mercury concentrations in lake whitefish were normalized to the mean fork length of fish from all samples (392 mm). Length-normalized mean concentrations of mercury ranged from 0.01 mg/kg (Primrose Lake in 1983) to 0.155 mg/kg (Lake Athabasca in 1975) (Figure 5.8-18). In waterbodies sampled for lake whitefish, all length-normalized mean concentrations of mercury were below Health Canada subsistence fisher (0.2 mg/kg) and general consumer (0.5 mg/kg) guidelines

Classification of Results

Mercury concentrations were classified based on the potential risk to subsistence fishers and general consumers (Table 5.8-16). Mercury concentrations in lake whitefish from Namur Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in lake trout from Namur Lake in 2013 were above Health Canada consumption guidelines for subsistence fishers and general consumers indicating a **High** risk to the health of both consumers of lake trout.

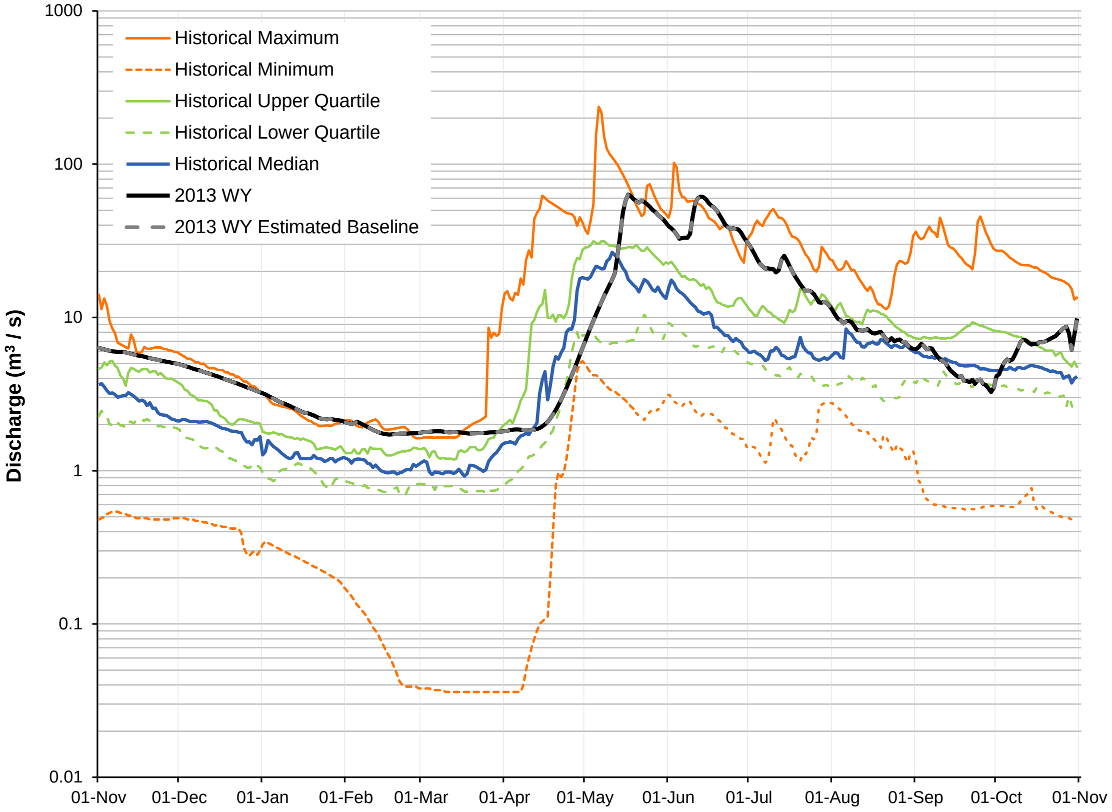
Mercury concentrations in fish depend on their position in the food chain. Mercury bioaccumulates in aquatic systems through trophic transport where piscivorous species (e.g., lake trout) accumulate the highest amounts of mercury, followed by ominivores, detritivores, and herbivores (e.g., lake whitefish) species (Barbosa et al. 2003). The rate at which mercury accumulates through the food chain may depend on the mercury absorption rate of phytoplankton in the system. For example, Monikh et al. (2013) found that the time and amount of mercury uptake differs between phytoplankton dependent on cell wall structure and lipid content, and that mercury concentrations at upper trophic levels depend on concentrations at lower tropic levels (2013). The higher mercury concentrations in lake trout compared to lake whitefish was likely due to their position in the food chain and the greater accumulation of mercury that occurs in piscivorous lake trout.

Summary Assessment

The results indicated that concentrations of mercury have increased in lake whitefish and lake trout from Namur Lake. Mercury concentrations in 2013 were significantly higher than those observed in previous years; however, mercury concentrations were still below the subsistence and general consumer guidelines in lake whitefish indicating a

Negligible-Low risk to human health. Furthermore, mercury concentrations in lake whitefish from Namur Lake appeared to be similar to those found in other regional lakes. Conversely, mercury concentrations in lake trout from Namur Lake exceeded subsistence and general consumer guidelines in 2000, 2007, and 2013, indicating a high risk to human health. Concentrations of mercury have increased from 2000 to 2007 but remained consistent between 2007 and 2013. Evans and Talbot (2012) also found significantly higher mercury concentrations in lake trout from Namur Lake in 2007 compared to 2000. Without lake trout data from other lakes in the region, it is unclear whether Namur Lake has unusually high concentrations of mercury in lake trout or whether these concentrations are relatively typical of this piscivorous fish species. Overall, trends in mercury concentrations in fish tissue may be due to a number of influential factors (e.g., levels of mercury emissions, general habitat conditions and water quality of lakes). Although Namur Lake is 90 km north of the oil sands development, atmospheric deposition of contaminants is widespread (Kelly et al. 2010). Therefore, monitoring fish in Namur Lake should continue to determine whether mercury concentrations in fish are increasing.

Figure 5.8-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Ells River in the 2013 WY, compared to historical values.



Note: The observed 2013 WY hydrograph was based on Ells River at the Canadian Natural Bridge, Station S14A, 2013 provisional data. The upstream drainage area is 2,420 km^2. Historical values were calculated for the period from 1975 to 1986 and 2001 to 2012 during the open-water period (May to October), and for the period from 1976 to 1986 and 2004 to 2012 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), 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**359.329**	**Observed discharge at Ells River at CNRL Bridge, RAMP Station S14A**
Closed-circuited area water loss from the observed *test* hydrograph	-0.526	Estimated 3.55 km^2 of the Ells River watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.897	Estimated 30.2 km^2 of the Ells River watershed with land change from focal projects as of 2013 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Ells River watershed from focal projects	0	None reported
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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**358.959**	**Estimated *baseline* discharge at Ells River at the Canadian Natural Bridge, RAMP Station S14A**
Incremental flow (change in total discharge)	+0.370	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**+0.10%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on Ells River at the Canadian Natural Bridge, RAMP Station S14A, 2013 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, 2013 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	19.532	19.552	+0.10%
Mean winter discharge	3.178	3.181	+0.10%
Annual maximum daily discharge	63.366	63.431	+0.10%
Open-water season minimum daily discharge	3.260	3.263	+0.10%

Note: Based on Ells River at the Canadian Natural Bridge, RAMP Station S14A, 2013 WY provisional data.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three 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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	12	7.8	8.2	8.4
Total suspended solids	mg/L	-	8.0	12	<3.0	6.5	16
Conductivity	µS/cm	-	209	12	175	227	272
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.016	12	0.003	0.010	0.020
Total nitrogen	mg/L	1	0.6	12	0.3	0.6	**1.3**
Nitrate+nitrite	mg/L	3	<0.071	12	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	18	12	11	15	20
Ions							
Sodium	mg/L	-	10.6	12	8.0	11.0	18.0
Calcium	mg/L	-	25.4	12	21.6	24.3	30.4
Magnesium	mg/L	-	7.3	12	6.5	7.3	9.1
Chloride	mg/L	120	1.1	12	<0.5	1.9	4.0
Sulphate	mg/L	270	14.3	12	10.5	15.7	27.9
Total dissolved solids	mg/L	-	149	12	110	166	220
Total alkalinity	mg/L		91	12	76	98	117
Selected metals							
Total aluminum	mg/L	0.1	**0.623**	12	0.060	**0.294**	**0.673**
Dissolved aluminum	mg/L	0.1	0.014	12	0.006	0.014	0.078
Total arsenic	mg/L	0.005	0.0010	12	<0.0005	0.0009	0.0012
Total boron	mg/L	1.2	0.060	12	0.041	0.062	0.083
Total molybdenum	mg/L	0.073	0.00065	12	0.00064	0.00070	0.00084
Total mercury (ultra-trace)	ng/L	5, 13	<u>2.0</u>	10	<0.9	<1.2	1.5
Total strontium	mg/L	-	0.115	12	0.095	0.123	0.140
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.49	2	0.07	0.15	0.23
Oilsands Extractable	mg/L	-	0.64	2	0.43	0.84	1.25
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	15.20	2	3.77	4.10	4.43
Total dibenzothiophenes	ng/L	-	239	2	120	127	135
Total PAHs	ng/L	-	903	2	448	499	551
Total Parent PAHs	ng/L	-	36.3	2	24.9	25.1	25.2
Total Alkylated PAHs	ng/L	-	867	2	423	474	526
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.899**	12	**0.448**	**0.694**	**1.140**
Sulphide	mg/L	0.002	**0.008**	12	0.002	**0.005**	**0.135**
Total phenolics	mg/L	0.004	**0.007**	12	0.001	0.004	**0.011**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline; <u>underlined</u> values are outside of historical range.

Table 5.8-5 Concentrations of water quality measurement endpoints, Ells River upstream of development (*baseline* station ELR-3), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.0
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	191
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.014
Total nitrogen	mg/L	1	0.571
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	13.7
Ions			
Sodium	mg/L	-	8.70
Calcium	mg/L	-	24.5
Magnesium	mg/L	-	7.16
Chloride	mg/L	120	0.520
Sulphate	mg/L	270	12.1
Total dissolved solids	mg/L	-	133
Total alkalinity	mg/L		84.9
Selected metals			
Total aluminum	mg/L	0.1	**0.134**
Dissolved aluminum	mg/L	0.1	0.0076
Total arsenic	mg/L	0.005	0.00082
Total boron	mg/L	1.2	0.049
Total molybdenum	mg/L	0.073	0.00064
Total mercury (ultra-trace)	ng/L	5, 13	0.880
Total strontium	mg/L	-	0.102
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	-	0.23
Oilsands Extractable	mg/L	-	0.27
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	1.22
Total dibenzothiophenes	ng/L	-	6.67
Total PAHs	ng/L	-	102
Total Parent PAHs	ng/L	-	22.4
Total Alkylated PAHs	ng/L	-	80.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Total iron	mg/L	0.3	**0.474**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Figure 5.8-4 Piper diagram of fall ion concentrations in the Ells River watershed.

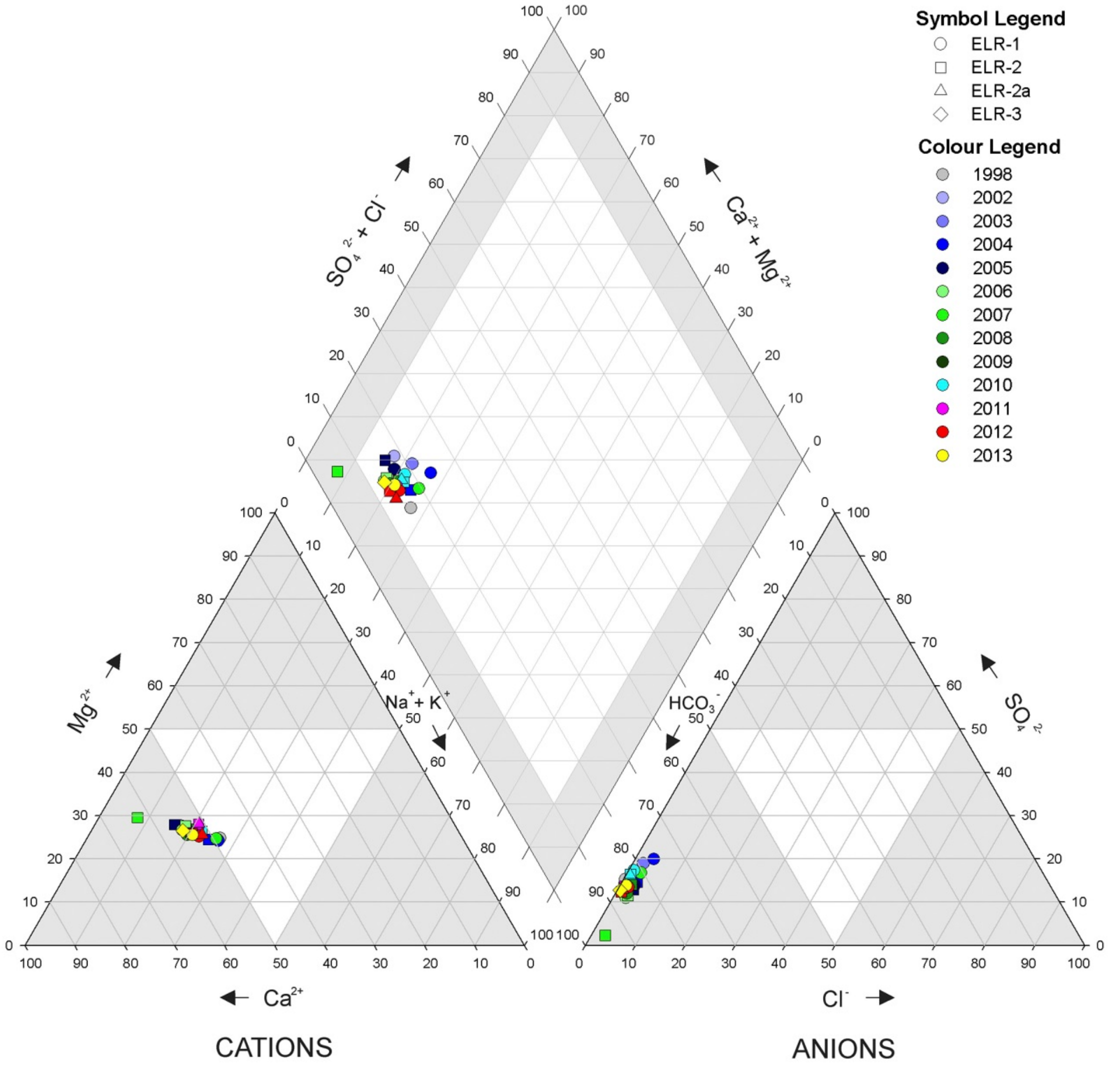


Table 5.8-6 Water quality guideline exceedances, Ells River, 2013.

Variable	Units	Guideline[a]	ELR-1	ELR-3
Winter				
Sulphide	mg/L	0.002	ns	0.0021
Total aluminum	mg/L	0.1	ns	0.172
Total iron	mg/L	0.3	ns	0.5630
Spring				
Dissolved aluminum	mg/L	0.1	ns	0.143
Dissolved iron	mg/L	0.3	ns	0.418
Sulphide	mg/L	0.002	ns	0.0465
Total aluminum	mg/L	0.1	ns	11.9
Total chromium	mg/L	0.001	ns	0.00997
Total copper	mg/L	0.002[b]	ns	0.00726
Total iron	mg/L	0.3	ns	11.7
Total lead	mg/L	0.0017[b]	ns	0.00748
Total nitrogen	mg/L	1	ns	1.881
Total phenols	mg/L	0.004	ns	0.0079
Total phosphorus	mg/L	0.05	ns	0.55
Total silver	mg/L	0.0001	ns	0.0002
Summer				
Sulphide	mg/L	0.002	ns	0.0067
Total aluminum	mg/L	0.1	ns	2.36
Total chromium	mg/L	0.001	ns	0.00178
Total iron	mg/L	0.3	ns	1.59
Total phenols	mg/L	0.004	ns	0.005
Total phosphorus	mg/L	0.05	ns	0.0594
Fall				
Sulphide	mg/L	0.002	0.008	-
Total aluminum	mg/L	0.1	0.623	0.134
Total iron	mg/L	0.3	0.899	0.474
Total phenols	mg/L	0.004	0.007	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

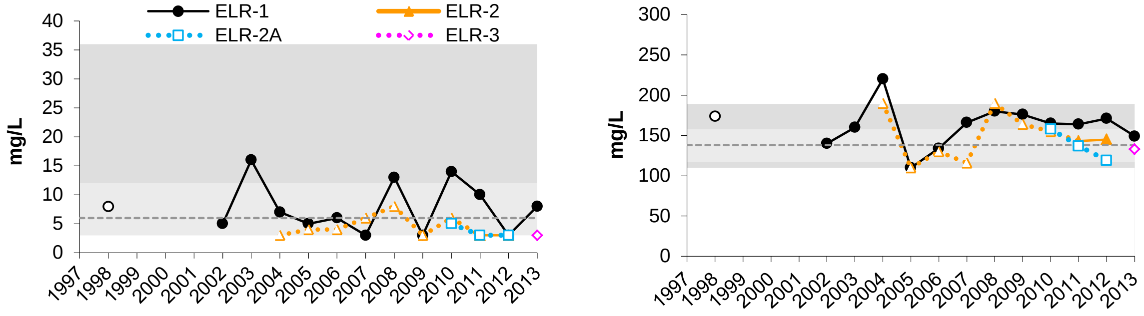
[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

ns = not sampled

Figure 5.8-5 Selected water quality measurement endpoints in the Ells River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

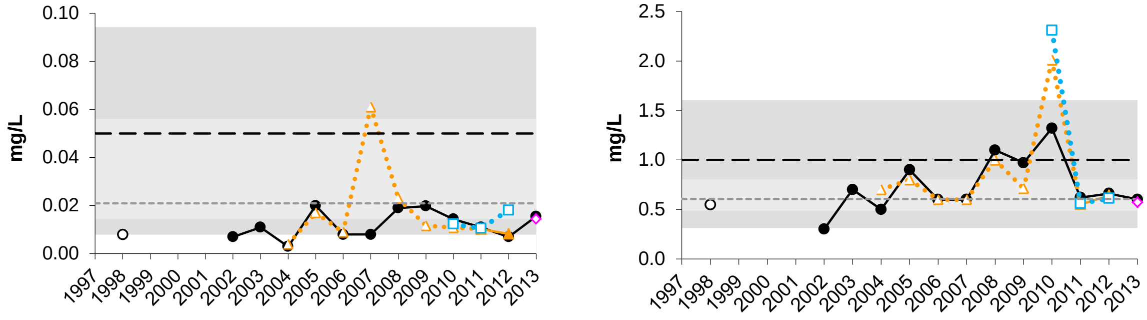
Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)



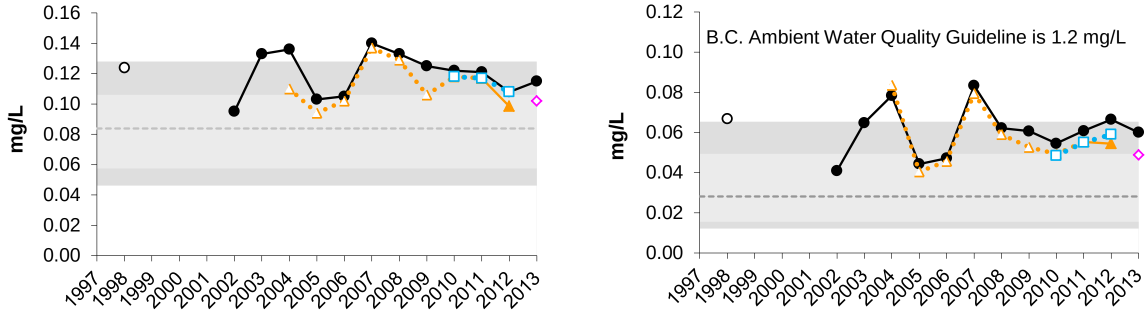
Dissolved Phosphorus

Total Nitrogen



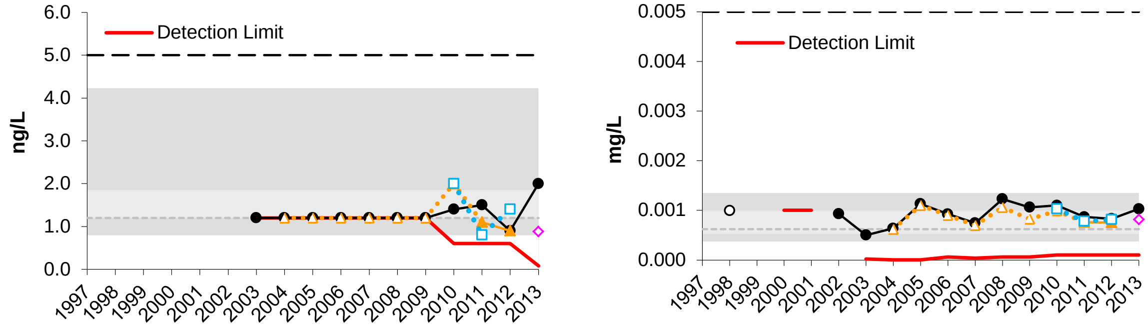
Total Strontium

Total Boron



Total Mercury (Ultra-trace)

Total Arsenic



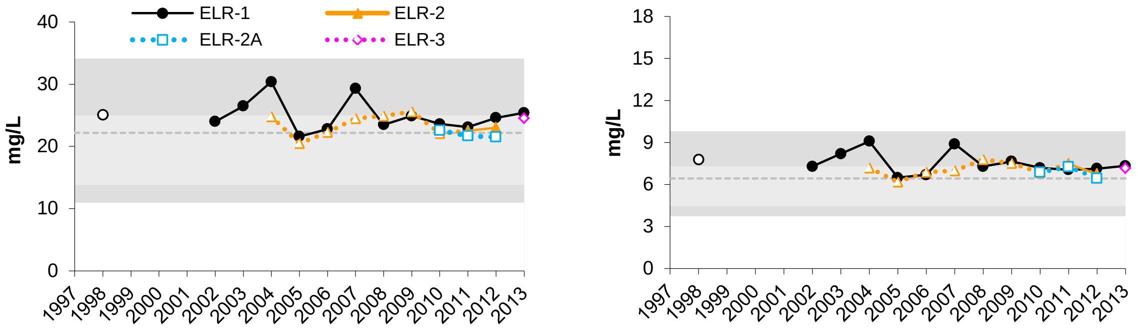
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

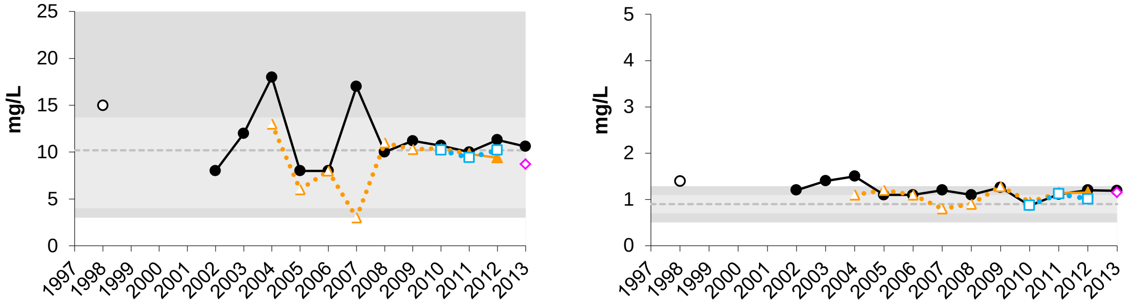
○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

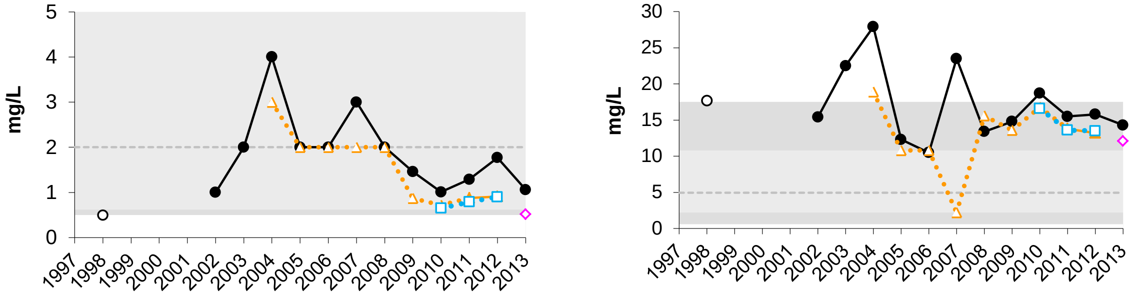
Figure 5.8-5 (Cont'd.)


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.

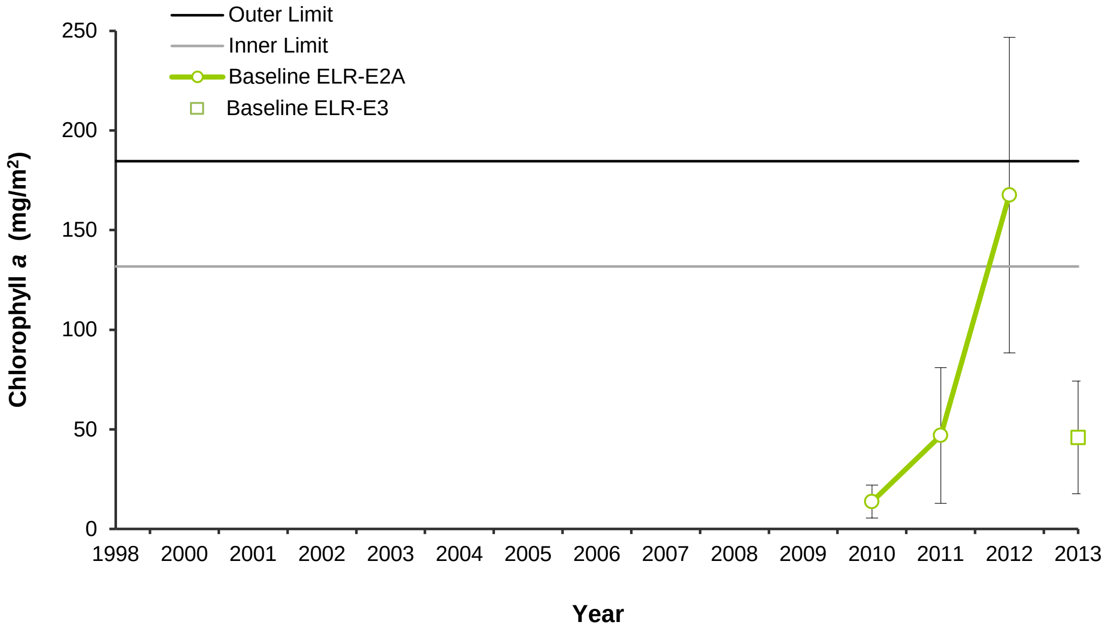
○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Table 5.8-7 Average habitat characteristics of benthic invertebrate sampling locations in the Ells River, fall 2013.

Variable	Units	ELR-D1 Lower *Test* Reach of the Ells River	ELR-E3 Upper *Baseline* Reach of the Ells River
Sample date	-	Sept 8, 2013	Sept 19, 2013
Habitat	-	Depositional	Erosional
Water depth	m	0.8	0.3
Current velocity	m/s	0.60	0.60
Field Water Quality			
Dissolved oxygen	mg/L	9.1	10.4
Conductivity	µS/cm	168	170
pH	pH units	8.0	7.9
Water temperature	°C	15.4	9.5
Sediment Composition			
Sand	%	97	-
Silt	%	2	-
Clay	%	1	-
Total Organic Carbon	%	0.86	-
Sand/Silt/Clay	%	-	18
Small Gravel	%	-	15
Large Gravel	%	-	16
Small Cobble	%	-	20
Large Cobble	%	-	19
Boulder	%	-	12
Bedrock	%	-	0

Figure 5.8-6 Periphyton chlorophyll *a* biomass in *baseline* reaches ELR-E2A and ELR-E3 of the Ells River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2012.

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Table 5.8-8 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community at the lower Ells River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach ELR-D1		
	2003	**2004 to 2012**	**2013**
Nematoda	<1	<1 to 3	
Oligochaeta		0 to 1	<1
Naididae	24	2 to 17	<1
Tubificidae	52	18 to 62	22
Enchytraeidae		0 to <1	
Hydracarina	<1	0 to 2	
Gastropoda	<1	0 to 1	
Bivalvia	<1	0 to 2	
Ceratopogonidae	3	1 to 7	
Chironomidae	19	17 to 56	76
Diptera (misc.)		0 to 2	<1
Coleoptera		0 to <1	
Ephemeroptera	<1	<1 to 1	
Odonata	<1	0 to <1	
Trichoptera	<1	0 to <1	
Heteroptera	<1		
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	715	178 to 732	48
Richness	12	9 to 20	4
Equitability	0.38	0.27 to 0.57	0.47
% EPT	1	0 to 1	0

Table 5.8-9 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at the upper Ells River.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach ELR-E2A		*Baseline* Reach ELR-E3
	2010	**2011 to 2012**	**2013**
Nematoda	2	<1 to 2	3
Oligochaeta		<1	
Naididae	10	4 to 4	8
Tubificidae	<1	<1 to 1	1
Enchytraeidae	1	<1 to <1	1
Hydracarina	9	9 to 13	9
Gastropoda	<1	<1 to 1	<1
Bivalvia	<1	<1 to <1	<1
Ceratopogonidae	1	<1 to <1	<1
Chironomidae	43	42 to 60	58
Diptera (misc.)	2	<1 to 1	1
Coleoptera	<1	<1	<1
Ephemeroptera	18	9 to 20	12
Odonata	<1	<1 to <1	1
Plecoptera	2	2 to 2	3
Trichoptera	10	6 to 15	3
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	1,109	1,217 to 1,899	2,238
Richness	38	38 to 42	43
Equitability	0.31	0.22 to 0.24	0.24
% EPT	30	17 to 37	20

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Table 5.8-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach ELR-D1.

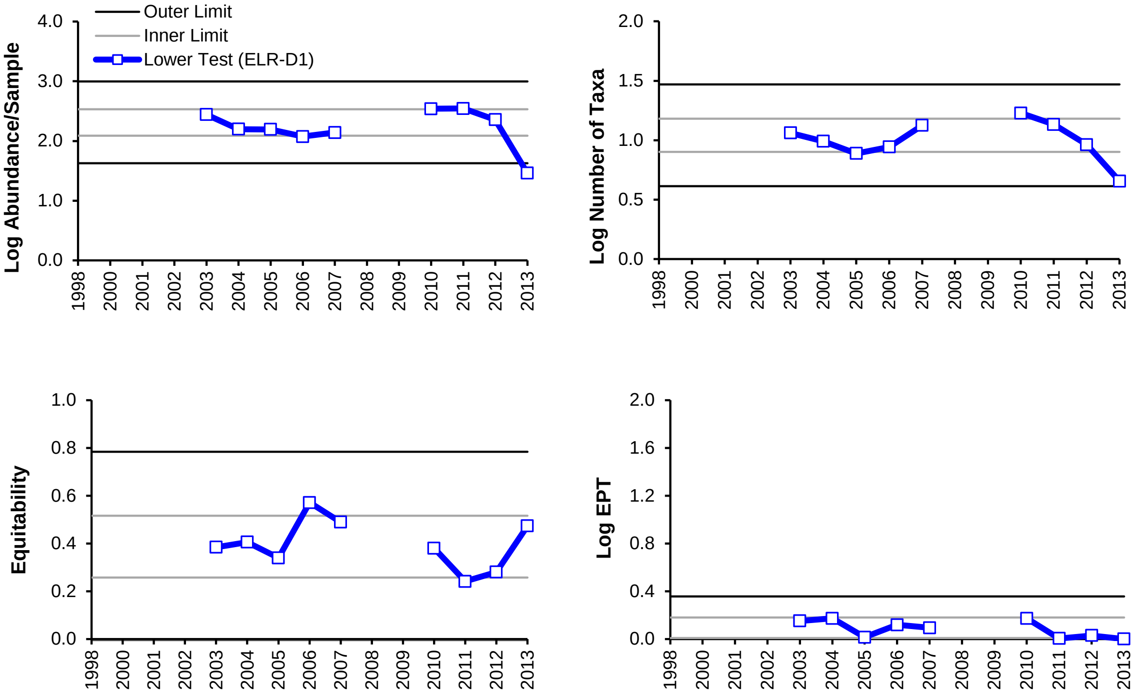
Measurement Endpoint	**P-value**		**Variance Explained (%)**		**Nature of Change(s)**
	Time Trend (test period)	**2013 vs. Previous Years**	**Time Trend (test period)**	**2013 vs. Previous Years**	
Log Abundance	**<0.001**	**<0.001**	48	19	Decreasing over time; lower in 2013 than mean of previous years.
Log Richness	**<0.001**	**<0.001**	66	11	Decreasing over time; lower in 2013 than mean of previous years.
Equitability	**0.050**	0.132	8	5	Decreasing over time.
Log EPT	**<0.001**	0.130	50	0	Decreasing over time.
CA Axis 1	0.243	0.819	4	0	No change.
CA Axis 2	0.052	0.039	15	17	Lower in 203 than mean of previous years.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

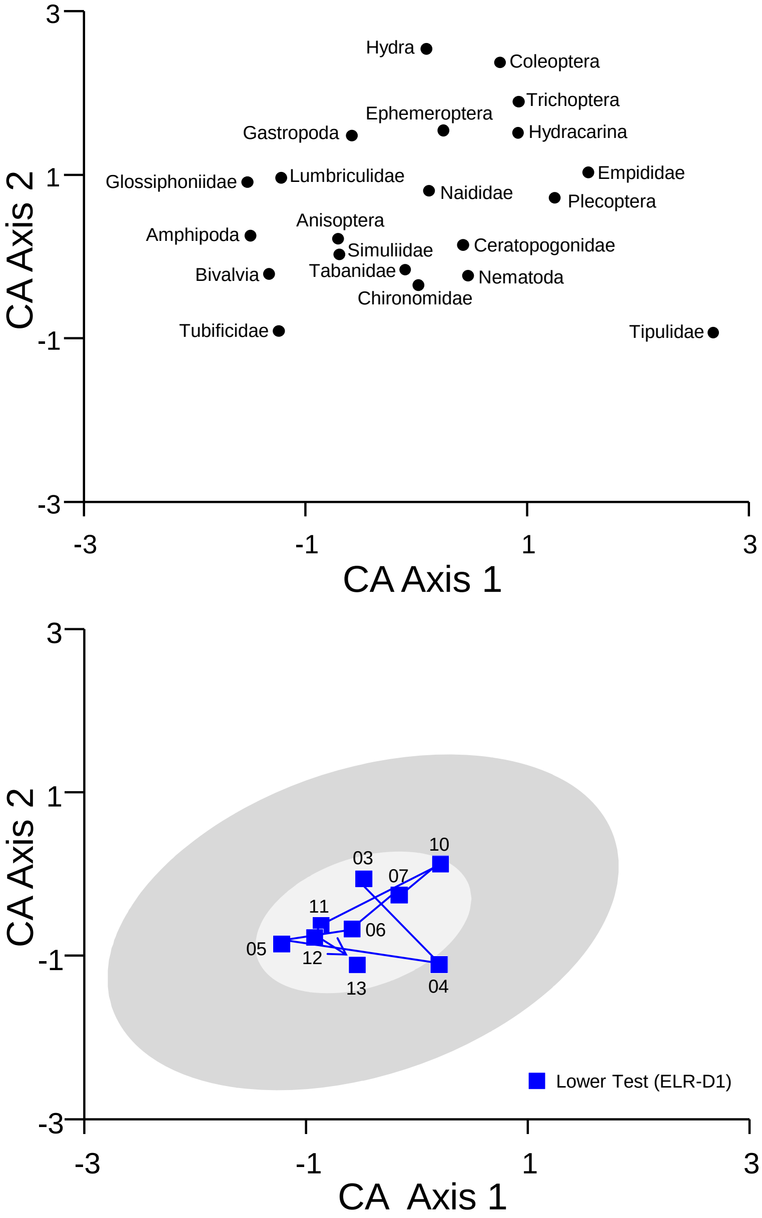
Figure 5.8-7 Variation in benthic invertebrate community measurement endpoints at *test* reach ELR-D1 of the Ells River relative to the historical range of variability.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach ELR-D1 (1998 to 2012).

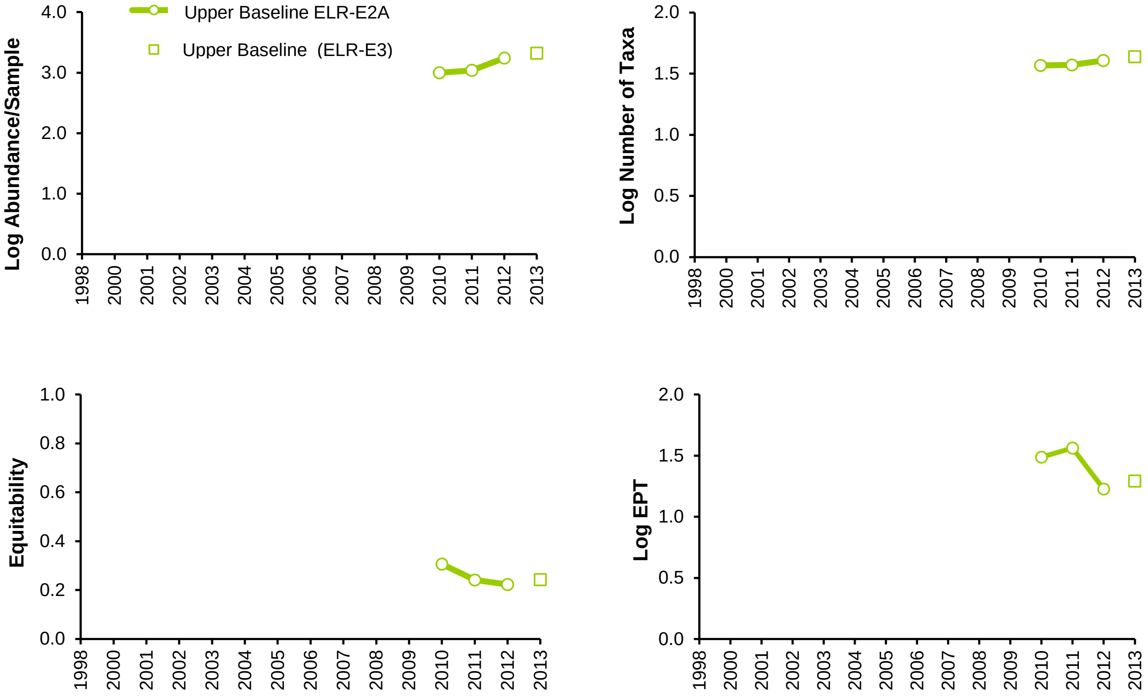
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.8-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Ells River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

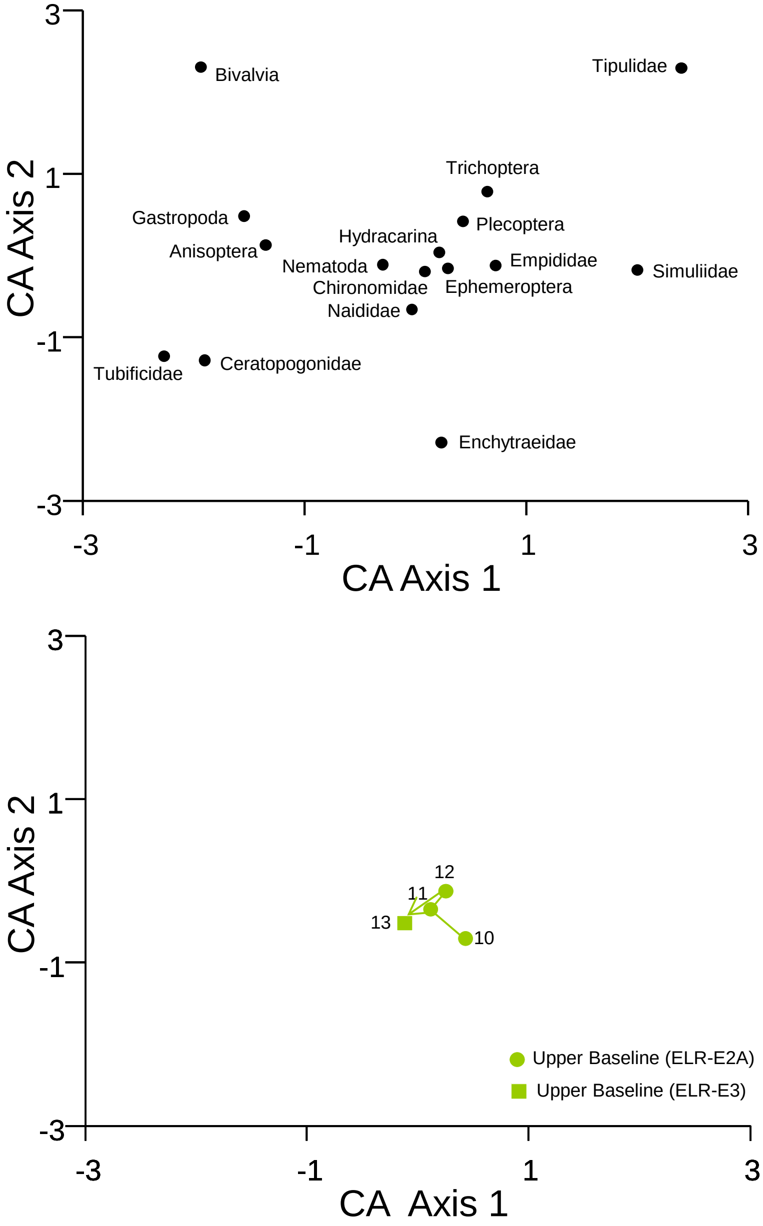
Figure 5.8-9 Variation in benthic invertebrate community measurement endpoints at *baseline* reaches ELR-E2A and ELR-E3 of the Ells River.



Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.8-10 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the upper *baseline* reaches of the Ells River.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Table 5.8-11 Concentrations of selected sediment quality measurement endpoints, Ells River (*test* station ELR-D1), fall 2013.

Variables	Units	Guideline	September 2013	1998-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6.4	10	3.0	7.0	26.0
Silt	%	-	11.6	10	3.0	17.5	51.0
Sand	%	-	81.9	10	23.0	77.9	94.0
Total organic carbon	%	-	2.13	10	0.40	2.01	2.82
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<5	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<5	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	**187**	7	73	**198**	**320**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,320**	7	**890**	**1,690**	**3,000**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	757	7	510	899	1,600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0014	10	0.0009	0.0039	0.0094
Retene	mg/kg	-	0.185	9	0.067	0.195	0.713
Total dibenzothiophenes	mg/kg	-	3.69	10	1.28	5.62	9.88
Total PAHs	mg/kg	-	12.3	10	4.8	16.5	25.1
Total Parent PAHs	mg/kg	-	0.427	10	0.218	0.401	0.571
Total Alkylated PAHs	mg/kg	-	11.8	10	4.5	16.1	24.5
Predicted PAH toxicity[3]	H.I.	1.0	**3.50**	10	**1.18**	**1.79**	**2.51**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Other analytes that exceeded CCME guidelines in 2013							
Pyrene	mg/kg	0.053	**0.058**	10	0.024	0.035	**0.071**
Benz[a]anthracene	mg/kg	0.0317	**0.036**	10	0.008	0.016	**0.134**
Chrysene	mg/kg	0.0571	**0.226**	10	**0.072**	**0.118**	**0.204**
Dibenz(a,h)anthracene	mg/kg	0.0062	**0.0117**	10	0.0042	**0.0096**	**0.0130**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	3.8	7	5.0	7.0	8.8
Chironomus growth - 10d	mg/organism	-	3.74	7	0.72	1.97	2.80
Hyalella survival - 14d	# surviving	-	9.2	8	8.0	9.0	10.0
Hyalella growth - 14d	mg/organism	-	0.13	8	0.10	0.17	1.60

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

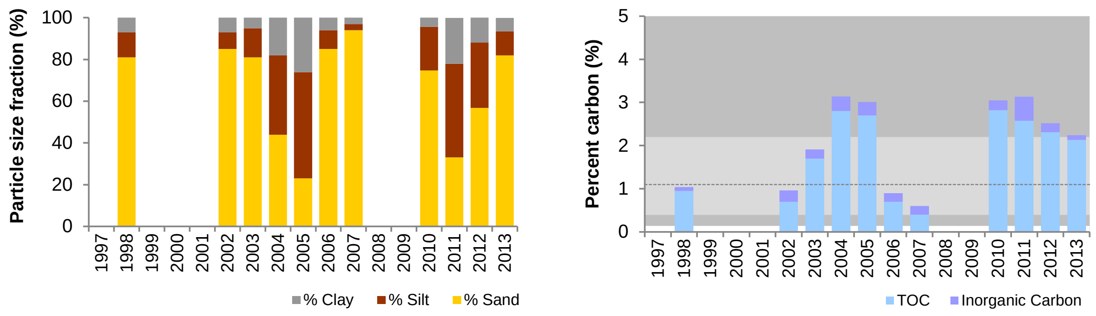
ns = not sampled

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

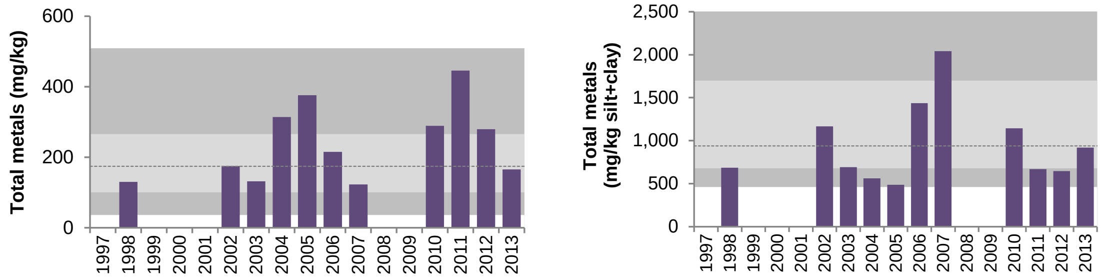
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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.

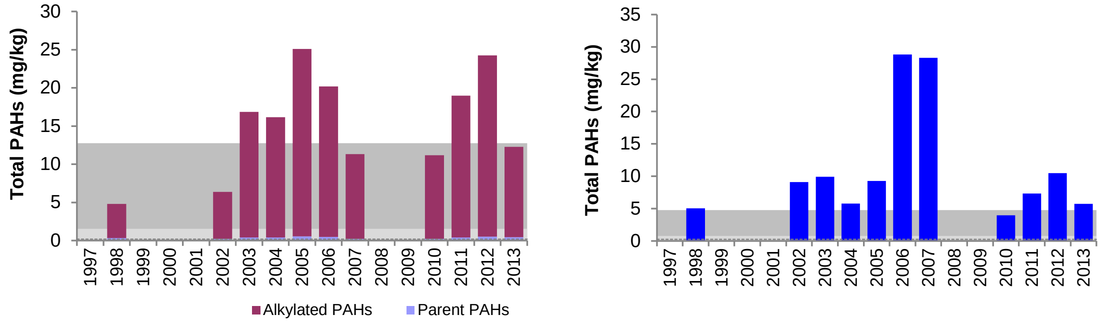
Figure 5.8-11 Variation in sediment quality measurement endpoints in the Ells River, *test* station ELR-D1.


Particle size distribution

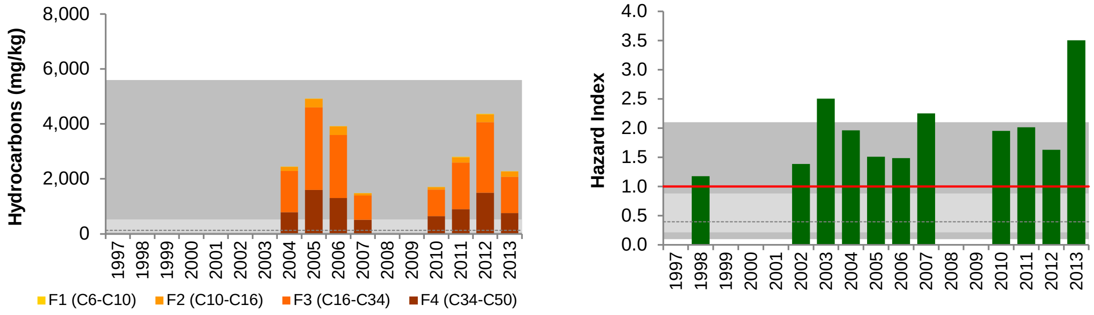
Carbon Content[1]


Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)


Total PAHs

Total PAHs normalized to 1% TOC


CCME Hydrocarbon Fractions[1]

PAH Hazard Index[3]

Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2013).

[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 5.8-12 Average habitat characteristics of fish assemblage monitoring locations of the Ells River, fall 2013.

Variable	Units	ELR-F1 Lower *Test* Reach of the Ells River	ELR-F3 Upper *Baseline* Reach of the Ells River
Sample date	-	Sept 14, 2013	Sept 12, 2013
Habitat type	-	run	run/riffle
Maximum depth	m	1.12	0.66
Mean depth	m	0.66	0.46
Bankfull channel width	m	38.0	35.4
Wetted channel width	m	19.5	30.2
Substrate			
Dominant	-	fines	sand
Subdominant	-	sand	cobble
Instream cover			
Dominant	-	small woody debris and macrophytes	large woody debris and macrophytes
Subdominant	-	large woody debris and filamentous algae	small woody debris and overhanging vegetation
Field water quality			
Dissolved oxygen	mg/L	7.5	9.1
Conductivity	µS/cm	192	149
pH	pH units	-[1]	8.24
Water temperature	^{0}C	12.4	13.0
Water velocity			
Left bank velocity	m/s	0.41	0.24
Left bank water depth	m	0.56	0.49
Centre of channel velocity	m/s	0.38	0.50
Centre of channel water depth	m	0.81	0.37
Right bank velocity	m/s	0.36	0.40
Right bank water depth	m	0.63	0.53
Riparian cover – understory (<5 m)			
Dominant	-	none	overhanging vegetation
Subdominant	-	none	none

[1] in situ pH not collected from ELR-F1 due to equipment failure

Table 5.8-13 Total number and percent composition of fish species captured at reaches of the Ells River, 2010 to 2013.

Common Name	**Code**	**Total Species**								**Percent of Total Catch**							
		***Test* Reach ELR-F1**				***Baseline* Reach ELR-F2A**			***Baseline* Reach ELR-F3**	***Test* Reach ELR-F1**				***Baseline* Reach ELR-F2A**			***Baseline* Reach ELR-F3**
		2010	**2011**	**2012**	**2013**	**2010**	**2011**	**2012**	**2013**	**2010**	**2011**	**2012**	**2013**	**2010**	**2011**	**2012**	**2013**
burbot	BURB	-	-	-	5	-	-	-	1	0	0	0	29.4	0	0	0	0.5
finescale dace	FNDC	34	-	-	-	160	-	-	1	30.6	0	0	0	52.5	0	0	0.5
lake chub	LKCH	-	4	5	4	-	1	99	-	0	26.7	11.6	23.5	0	1.4	43.6	0
lake whitefish	LKWH	-	-	9	-	-	-	-	-	0	0	20.9	0	0	0	0	0
longnose dace	LNDC	2	2	-	-	-	19	18	51	1.8	13.3	0	0	0	26.4	7.9	26.4
longnose sucker	LNSC	-	-	1	-	13	-	25	4	0	0	2.3	0	4.3	0	11.0	2.1
northern pike	NRPK	-	-	-	-	-	-	1	-	0	0	0	0	0	0	0.4	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	-	0	0	0	5.9	0	0	0	0
pearl dace	PRDC	46	-	7	-	82	43	-	97	41.4	0	16.3	0	26.9	59.7	0	50.3
slimy sculpin	SLSC	-	-	-	-	-	1	-	4	0	0	0	0	0	1.4	0	2.1
spoonhead sculpin	SPSC	-	-	-	3	-	-	-	1	0	0	0	17.6	0	0	0	0.5
spottail shiner	SPSH	-	1	-	-	-	-	-	-	0	6.7	0	0	0	0	0	0
trout-perch	TRPR	1	6	18	1	4	6	48	24	0.9	40	41.9	5.9	1.3	8.3	21.1	12.4
white sucker	WHSC	12	-	2	3	46	2	36	11	10.8	0	4.7	17.6	15.1	2.8	15.9	5.7
yellow perch	YLPR	15	2	1	-	-	-	-	-	13.5	13.3	2.3	0	0	0	0	0
sucker sp. *		1	-		-	-	-	-	-	0.9	0	0	0	0	0	0	0
Total		**111**	**15**	**43**	**17**	**305**	**72**	**227**	**193**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**5**	**7**	**6**	**5**	**6**	**6**	**9**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**5,258**	**1,307**	**1,979**	**2,209**	**3,959**	**1,614**	**1,956**	**2,522**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

* Not included in total species richness count.

Table 5.8-14 Summary of fish assemblage measurement endpoints (±1SD) in reaches of the Ells River, 2010 to 2013.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ELR-F1	2010	0.37	0.25	7	3.4	1.08	0.58	0.17	7.02	0.21	2.35	1.53
	2011	0.06	0.07	6	1.4	1.34	0.30	0.27	6.92	0.65	1.08	1.18
	2012	0.14	0.11	7	3.0	1.87	0.38	0.25	7.07	1.54	2.18	1.68
	2013	0.04	0.03	6	2.0	1.00	0.32	0.29	4.85	2.34	0.77	0.59
ELR-F2A	2010	0.61	0.26	5	3.9	0.74	0.55	0.11	6.89	0.23	7.76	3.40
	2011	0.29	0.13	6	3.2	0.84	0.54	0.28	6.62	0.29	4.54	2.22
	2012	0.91	0.25	6	5.0	0.71	0.70	0.06	6.44	0.30	11.63	3.27
ELR-F3	2013	0.35	0.13	8	5.6	1.52	0.64	0.03	6.68	0.19	7.69	2.81

* Unknown species not included in the calculation.

SD=standard deviation across sub-reaches within a reach.

Note: *Baseline* reach ELR-E2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-E3) in 2013.

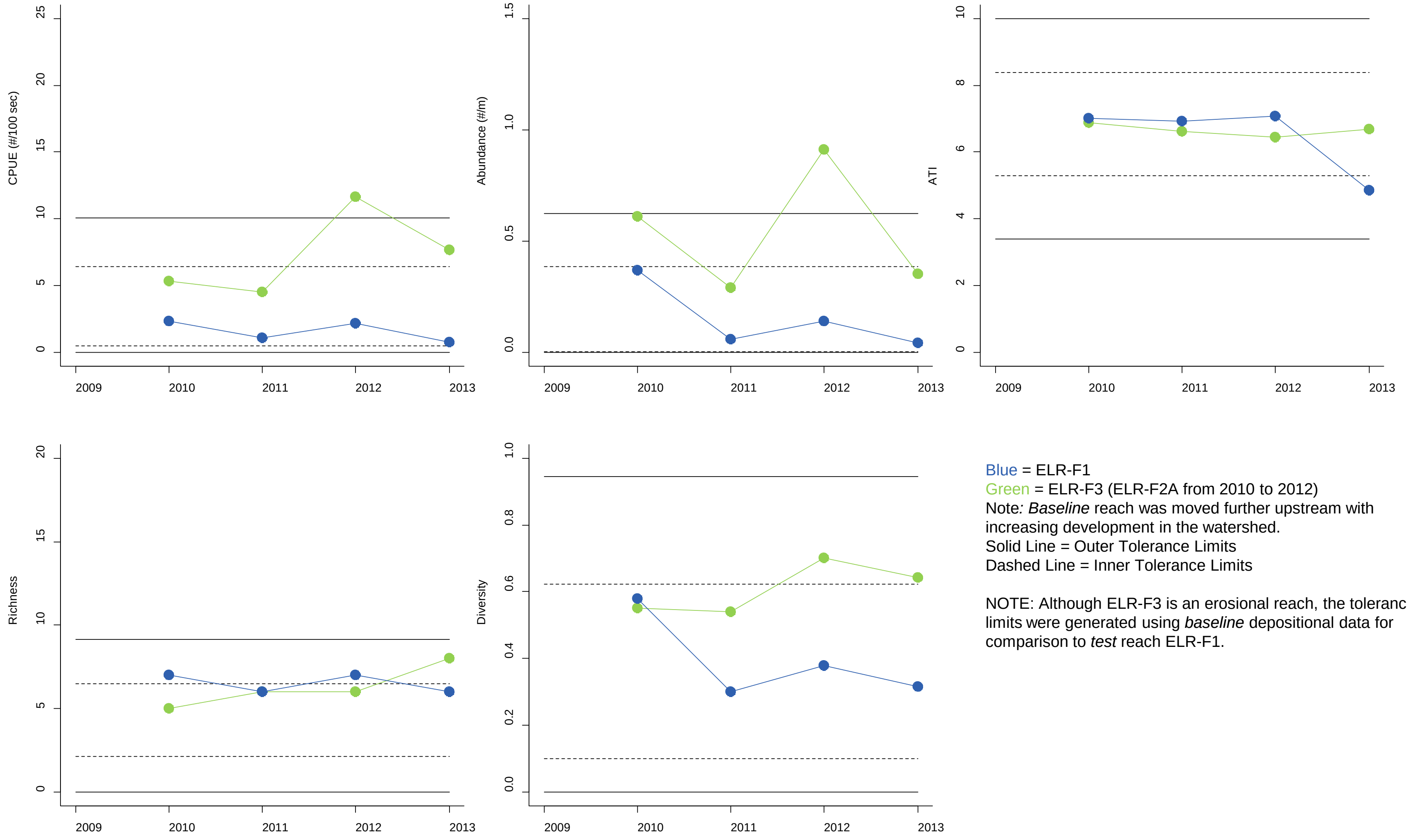
Table 5.8-15 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints for *test* reach ELR-F1 of the Ells River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
	Time Trend	Time Trend	
Abundance	**<0.001**	39.5	Decreasing over time.
Richness	0.158	12.1	No change.
Diversity	**0.037**	17.5	Decreasing over time.
ATI	0.211	6.7	No change.
CPUE (No./100 sec)	0.110	1.4	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 3.2-15).

Figure 5.8-12 Fish assemblage measurement endpoints in reaches of the Ells River, 2010 to 2013.



Blue = ELR-F1
Green = ELR-F3 (ELR-F2A from 2010 to 2012)
Note*:* *Baseline* reach was moved further upstream with increasing development in the watershed.
Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

NOTE: Although ELR-F3 is an erosional reach, the tolerance limits were generated using *baseline* depositional data for comparison to *test* reach ELR-F1.

Table 5.8-16 Summary of metrics and mercury concentrations in lake whitefish and lake trout from Namur Lake, fall 2013, relative to criteria for fish consumption for the protection of human health.

Species	Sample ID	Sex	Fork Length (mm)	Weight (g)	Age	Hg (mg/kg)
Lake trout	NL-1	M	658	2,950	19	**0.542**
	NL-10	F	641	3,100	16	**0.679**
	NL-13	M	576	1,950	13	**0.654**
	NL-14	F	592	1,950	14	**0.707**
	NL-17	F	534	1,600	8	0.362
	NL-19	F	489	1,200	8	0.171
	NL-2	M	533	1,500	7	0.217
	NL-22	F	515	1,325	8	0.214
	NL-23	M	567	1,950	9	0.347
	NL-25	F	568	2,000	9	0.368
	NL-26	M	611	2,550	16	**0.559**
	NL-27	F	641	3,100	-	**0.496**
	NL-28	M	443	1,100	13	0.260
	NL-3	F	625	2,300	10	**0.588**
	NL-30	F	605	2,500	-	**0.601**
	NL-36	M	530	1,725	9	0.360
	NL-5	M	540	1,800	13	0.266
	NL-6	M	570	2,250	11	0.297
	NL-7	F	690	3,000	22	**0.635**
	NL-9	F	530	1,950	8	0.438
Lake whitefish	NL-4	M	432	1,000	21	0.063
	NL-8	M	459	1,100	15	0.077
	NL-11	F	357	500	6	0.029
	NL-12	F	272	225	7	0.033
	NL-15	M	440	1,050	-	0.079
	NL-16	M	483	1,425	14	0.118
	NL-18	F	294	300	4	0.040
	NL-20	F	295	275	7	0.041
	NL-21	F	467	1,300	23	0.066
	NL-24	F	300	375	9	0.022
	NL-29	F	261	200	4	0.044
	NL-31	M	430	1,000	-	0.032
	NL-32	F	300	350	12	0.021
	NL-33	F	266	200	-	0.033
	NL-34	F	315	350	7	0.022
	NL-35	M	547	1,750	11	0.037
	NL-37	F	266	200	4	0.037
	NL-38	M	312	350	4	0.034
	NL-39	F	265	225	6	0.026
	NL-40	M	462*	1,450	16	0.054
	NL-41	F	461	1,175	14	0.071

M-Male; F-Female; U-Undetermined

Shading denotes exceedance of Health Canada guideline for subsistence fishers (0.20 mg/kg)

Shading denotes exceedance of Health Canada guideline for general consumers (0.50 mg/kg)

Bolded value denotes exceedance of USEPA guideline for recreational fishers (0.4 mg/kg)

Underlined value denotes exceedance of USEPA guideline for subsistence fishers (0.049 mg/kg)

* Fork length calculated from total length based on correlation equation.

Figure 5.8-13 **Temporal comparison of mercury concentrations in lake whitefish from Namur Lake, 2000 (Evans pers. comm. 2014) and 2013.**

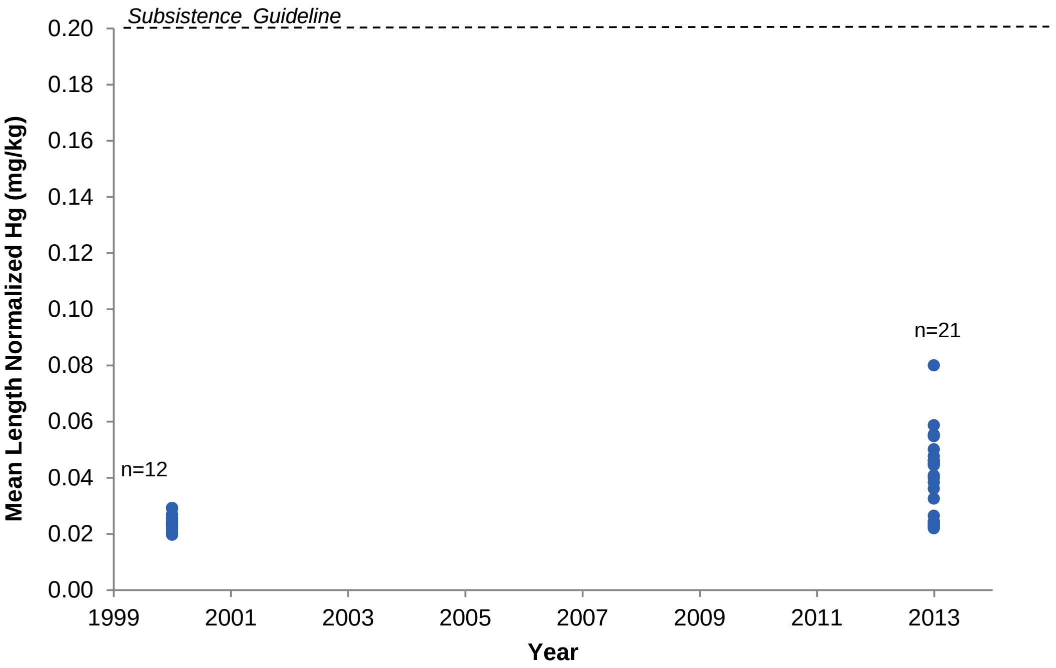


Figure 5.8-14 **Temporal comparison of mercury concentrations in lake trout from Namur Lake, 2000 (Evans and Talbot 2012), 2007, and 2013.**

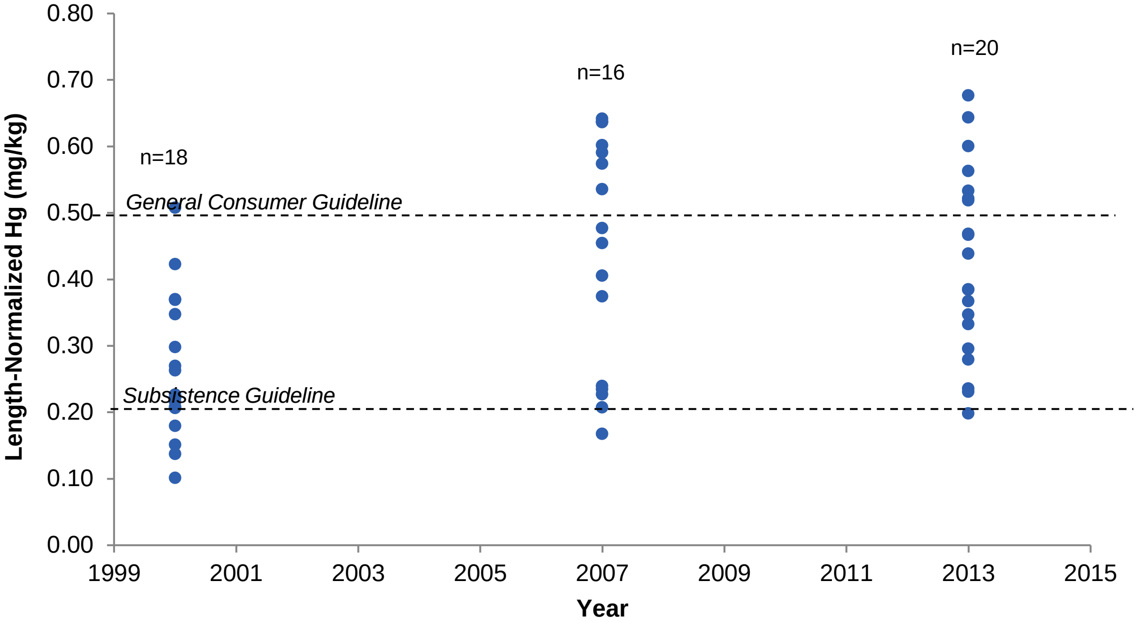


Figure 5.8-15 **Temporal comparison of the relationship between rank-transformed fork length and mercury concentrations in the tissue of lake whitefish from Namur Lake, 2000 (Evans pers. comm. 2014) and 2013.**

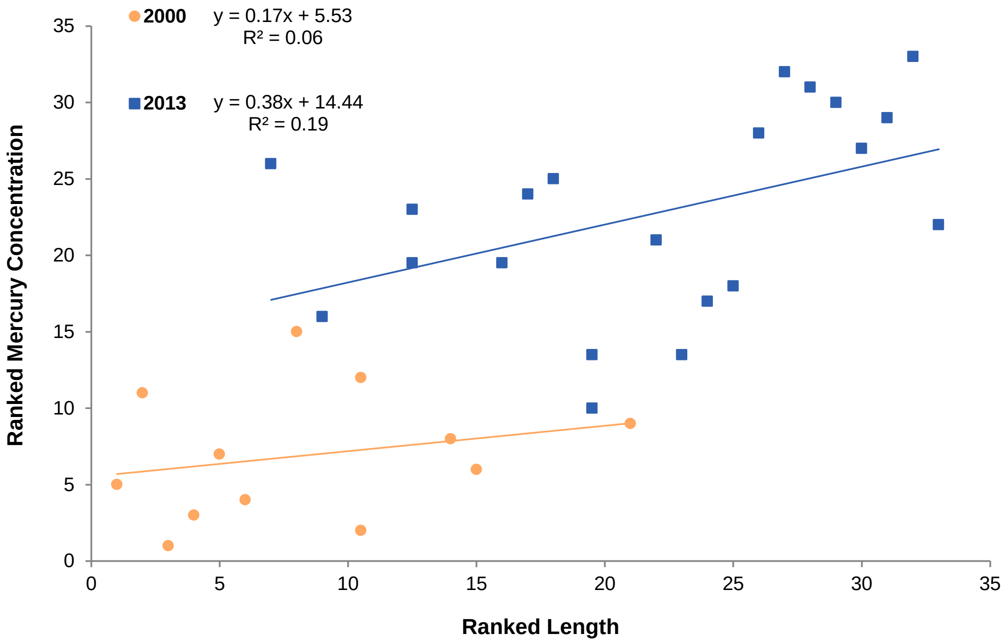


Figure 5.8-16 **Temporal comparison of the relationship between fork length and mercury concentrations in the tissue of lake trout from Namur Lake, 2000 (Evans and Talbot 2012), 2007, and 2013.**

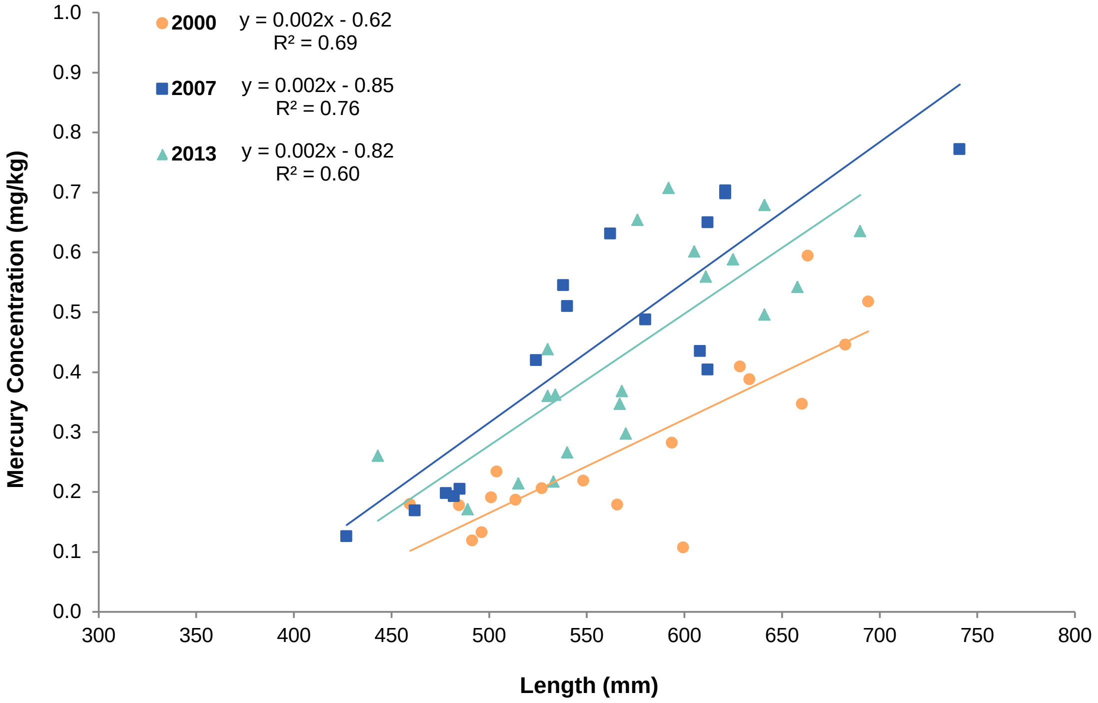
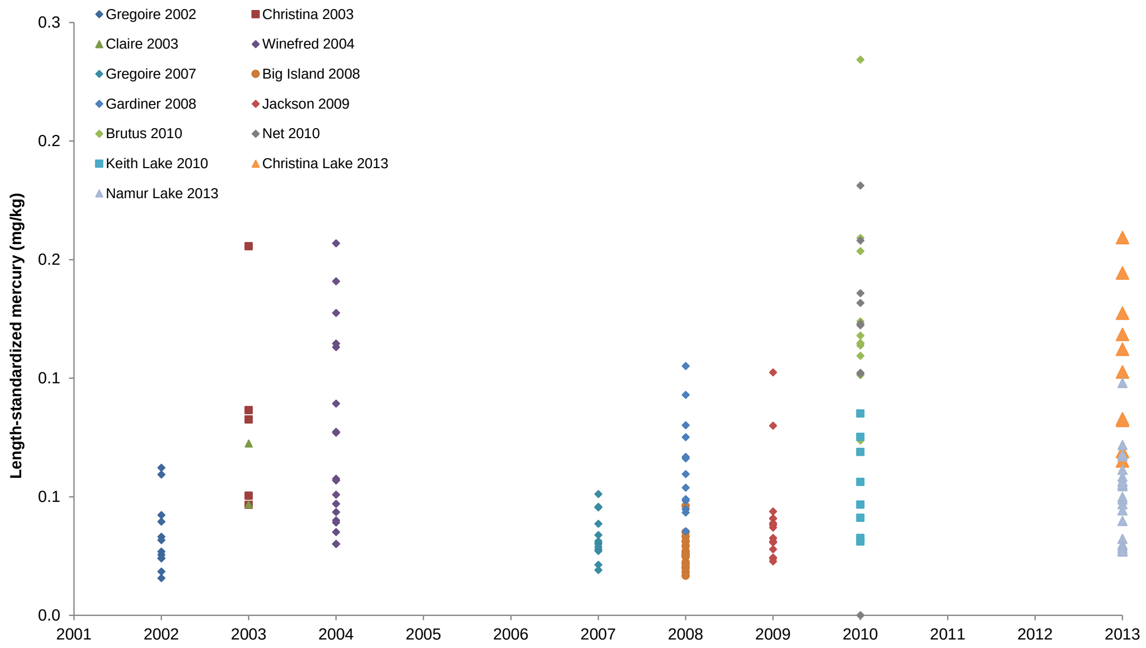
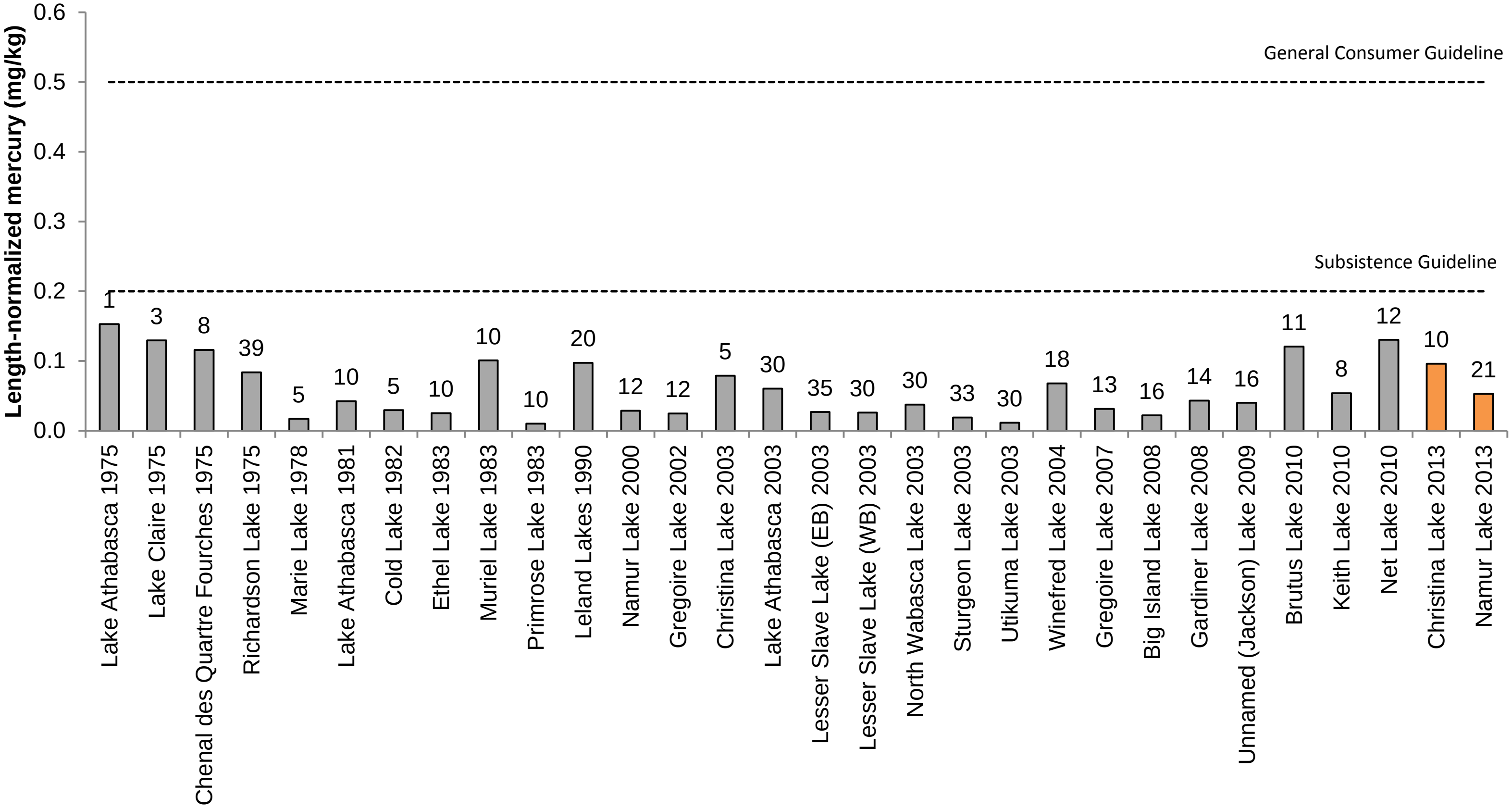


Figure 5.8-17 **Regional comparison of mean length-normalized concentrations of mercury in lake whitefish in lakes sampled by RAMP and AESRD, 2002 to 2013.**



Sources: RAMP 2003; 2004; 2008, 2009a; 2010; and 2011.

Figure 5.8-18 Comparison of mean length-normalized concentrations of mercury in lake whitefish from lakes in Alberta, 1973 to 2013.



Note: orange shading denotes results from current sampling year; sample size represented by number above each bar.

Sources: AOSERP 1977; RAMP 2003; 2004 2005; 2008; 2009a; 2010; 2011; Grey et al. 1995.

5.9 CLEARWATER RIVER WATERSHED

Table 5.9-1 Summary of results for the Clearwater River watershed.

Clearwater River Watershed	**Summary of 2013 Conditions**		
	Clearwater River		***High Hills River***
Climate and Hydrology			
Criteria	**07CD001** at Draper	**07CD005/S42** above the Christina River	**S51** near the Mouth
Mean open-water season discharge	not measured	not measured	not measured
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	not measured	not measured	not measured
Minimum open-water season discharge	not measured	not measured	not measured
Water Quality			
Criteria	**CLR-1** upstream of Fort McMurray	**CLR-2** upstream of Christina River	**HHR-1** at the mouth
Water Quality	🟡	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality			
Criteria	**CLR-D1** upstream of Fort McMurray	**CLR-D2** upstream of Christina River	**HHR-E1** at the mouth
Benthic Invertebrate Communities	not sampled	not sampled	n/a
No Sediment Quality component activities conducted in 2013			
Fish Populations			
Criteria	**Fish Inventory Reaches (CR1, CR2, CR3)**		**HHR-F1** at the mouth
Fish Assemblages	classification not conducted		n/a

Legend and Notes

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

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

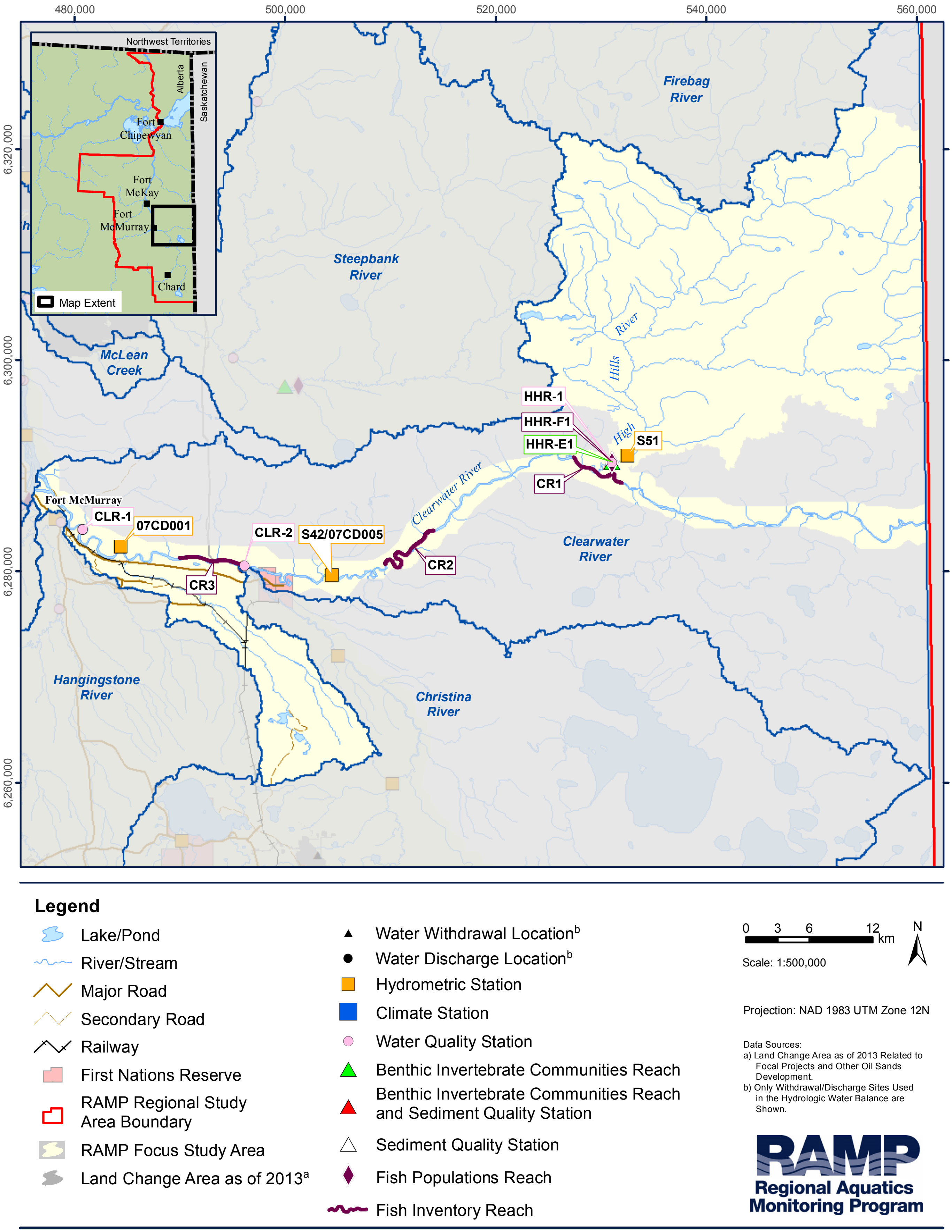
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of focal projects and other oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water 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 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.9-1 Clearwater River watershed.



K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K09_Clearwater_20140224_ss.mxd

Figure 5.9-2 Representative monitoring stations of the Clearwater River watershed, fall 2013

Benthic Invertebrate Reach HHR-E1 (High Hills River): facing downstream

Fish Assemblage Reach HHR-F1 (High Hills River): facing upstream

Water Quality Station CLR-1 (Clearwater River): cross channel

Water Quality Station CLR-2 (Clearwater River): facing upstream

5.9.1 Summary of 2013 Conditions

As of 2013, 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 and the increasing oil sands development in the Christina River watershed, the designations of specific areas of the Clearwater River watershed are as follows:

1. The Clearwater River downstream of the confluence with the Christina River is designated as *test*.
2. The Clearwater River upstream of the confluence with the Christina River is designated as *baseline*.

Monitoring activities were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Populations components of RAMP in the Clearwater River watershed in 2013. Table 5.9-1 is a summary of the 2013 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 2013, water quality at all stations indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. All stations showed similar ionic composition and no trends in measurement endpoints over time, with the exception of a decreasing trend in potassium at *test* station CLR-1. In 2013, there were many water quality guideline exceedances, particularly at *baseline* station HHR-1 in spring and summer. Concentrations of many water quality variables fluctuated across months in 2013 at *test* station CLR-1 and *baseline* station CLR-2. Despite these fluctuations, the ionic composition at both stations in the Clearwater River remained fairly consistent across the year. Concentrations of many water quality variables (e.g., metals) in May at *baseline* station CLR-2 exceeded guidelines and frequently exceeded the regional baseline range for fall water quality.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate community at *baseline* reach HHR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and a relatively high diversity of chironomids. Historically, this reach contained a high relative abundance of naidid worms (42%), but the percentage of the fauna comprised by naidids in 2013 was considerably lower (19%) than previous years. *Baseline* reach HHR-E1 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) The Clearwater fish inventory is a community-based initiative primarily suited for assessing general trends in population variables such as species richness, abundance, and composition. Coupled with a decrease in total catch, species richness and abundance were relatively low in the Clearwater River watershed in 2013. Compared to 2012, total catch was notably lower in summer and fall, likely due to a decrease in available habitat resulting from lower discharge in the sampling reaches. White sucker and longnose sucker continue to dominate overall species composition while the abundance of goldeye has returned to historical ranges after an increase in summer and fall 2012. The transient increase in goldeye abundance could be related to the warm, calm spring season that occurred in 2011 and 2012, but was not observed in 2013.

Following a shift towards a younger dominant age class in 2012, there was an increase in catch of older northern pike in 2013. In addition, significant increases in size-at-age across the last three years indicate that northern pike were larger at age in 2013. Conversely, a dominance of younger size classes continued to persist for walleye. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

Mean condition factor was relatively similar for the large-bodied KIR species between *test* and *baseline* reaches in summer and fall 2013; northern pike and walleye showed slight differences, with higher condition at the *test* reach compared to the *baseline* reaches in summer. Historical data indicated considerable increases in condition for both longnose sucker and walleye in 2013. The percentage of external abnormalities increased slightly in 2013 compared to 2012, with the majority of abnormalities observed in white sucker and a higher percentage of abnormalities observed in summer.

Fish Populations (fish assemblages) The fish assemblage at *baseline* reach HHR-F1 was consistent with other *baseline* erosional reaches. Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

5.9.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the Clearwater River watershed was conducted at WSC Station 07CD001, Clearwater River at Draper. The data from this station were used to describe the 2013 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 WSC Station 07CD001, Clearwater River at Draper, since 1958. The annual runoff and open-water runoff volumes in the 2013 WY were 5,699 million m^3 and 4,468 million m^3, respectively. The annual runoff and the open-water runoff volumes were 52% and 73% higher than the historical mean annual runoff and the historical mean open-water runoff volumes, respectively. Flows decreased from November 2012 to March 2013, with values varying between the historical upper quartile and the historical maximum values (Figure 5.9-3). Flows increased during freshet in April and early May to a peak of 624 m^3/s on May 14. Following the freshet, flows decreased until early June but remained above the historical upper quartile values. Rainfall events in mid-June resulted in increased flows to a peak of 770 m^3/s on June 18, which was the maximum daily flow recorded in the 2013 WY and 100% higher than the historical mean annual maximum daily flow of 385 m^3/s. Following the 2013 WY peak, flows decreased until late September before rain events in early October caused an increase in flows that exceeded the historical median until the end of the 2013 WY. The minimum open-water daily flow of 101 m^3/s was recorded on September 18 and was 14% higher than the historical mean minimum daily flow of 89 m^3/s for the open-water period.

There was no effect in the Clearwater River watershed related to focal projects and other oil sands development in 2013. Accordingly, no assessment of current versus *baseline* hydrologic conditions was warranted.

5.9.3 Water Quality

In fall 2013, 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, 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 of 2013 in an effort to obtain three years of seasonal *baseline* data. Additionally, *test* station CLR-1 was sampled from January to April, and *baseline* station CLR-2 was sampled from May to December as part of the monthly sampling program in 2013 (monthly sampling was switched from CLR-1 to CLR-2 based on direction from AESRD as part of the JOSMP).

Temporal Trends The only significant trend (α=0.05) in fall concentrations of water quality measurement endpoints over time was a decreasing concentration of potassium at *test* station CLR-1. There were no significant trends at *baseline* station CLR-2. Trend analysis was not conducted on *baseline* station HHR-1 because only three years of data have been collected.

2013 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 strontium at *test* station CLR-1, which exceeded the previously-measured maximum concentration. No historical comparisons were conducted for the High Hills River (*baseline* station HHR-1), given only three years of data existed for this station.

Ion Balance The ionic composition of water at all stations in the Clearwater River watershed in fall 2013 was similar to previous years (Figure 5.9-4). Stations on the Clearwater River (*test* station CLR-1 and *baseline* station CLR-2) were dominated by calcium and sodium while *baseline* station HHR-1 of the High Hills River was dominated by calcium bicarbonate.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of total aluminum exceeded the water quality guideline at all stations in the Clearwater River watershed in fall 2013. The concentration of dissolved phosphorus also exceeded the guideline at *baseline* station HHR-1 (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 2013 (Table 5.9-5):

- total and dissolved iron, sulphide, total chromium, total phenols, and total phosphorus at *test* station CLR-1;
- total and dissolved iron, sulphide, total chromium, and total phenols at *baseline* station CLR-2; and
- total and dissolved iron, 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):

- Winter - dissolved iron, dissolved phosphorus, total aluminum, total iron, and total phosphorus in winter;
- Spring - dissolved aluminum, dissolved iron, sulphide, total aluminum, total chromium, total copper, total iron, total lead, total mercury (ultra-trace), total nitrogen, total phenols, total phosphorus, and total silver in spring; and
- Summer - dissolved iron, dissolved phosphorus, sulphide, total aluminum, total chromium, total copper, total iron, total lead, total mercury, total nitrogen, total phenols, total phosphorus, and total silver in summer.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, 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, which exceeded the 95th percentile of the regional *baseline* concentrations at *test* station CLR-1; and
- magnesium, which exceeded the 95th percentile of the regional *baseline* concentrations at *baseline* station HHR-1.

Water Quality Index WQI values in fall 2013 at *test* station CLR-1 (98.6) and *baseline* stations CLR-2 (100) and HHR-1 (88.7) indicated **Negligible-Low** differences from regional *baseline* water quality conditions.

Monthly Water Quality Results Water quality samples were collected monthly on the Clearwater River in 2013. Monthly sampling was initiated at *test* station CLR-1, but was shifted to *baseline* station CLR-2 in May 2013 as requested by AESRD. Monthly results for each station are summarized in Table 5.9-6 and Table 5.9-7, respectively.

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances at *test* station CLR-1 and *baseline* station CLR-2 in months other than September when the fall program was conducted (Table 5.9-8 and Table 5.9-9) included:

- sulphide, total aluminum, total iron, and dissolved iron in January, February, and April at *test* station CLR-1;
- total aluminum, total iron, and dissolved iron in March at *test* station CLR-1;
- total phenols, sulphide, total phosphorus, total aluminum, dissolved aluminum, total iron, dissolved iron, total chromium, total mercury (ultra-trace), total silver, and total titanium in May at *baseline* station CLR-2;
- sulphide, total phosphorus, total aluminum, total iron, dissolved iron, and total chromium in June, August, and October at *baseline* station CLR-2;
- total phenols, sulphide, total phosphorus, total aluminum, total iron, dissolved iron, and total chromium in July at *baseline* station CLR-2;
- total and dissolved iron in November at *baseline* station CLR-2; and
- sulphide and total and dissolved iron in December at *baseline* station CLR-2.

2013 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2013, most monthly water quality data collected at *test* station CLR-1 and *baseline* station CLR-2 were within the range of the regional *baseline* concentrations observed in fall (Figure 5.9-6), with the exception of:

- dissolved phosphorus in January at *test* station CLR-1, with a concentration below the 5th percentile of fall regional *baseline* concentrations;
- sodium, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations at *test* station CLR-1 from January to April;
- chloride, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations at *test* station CLR-1 from February to April;
- total suspended solids and total arsenic in May at *baseline* station CLR-2, with concentrations that exceeded the 95th percentile of fall regional *baseline* concentrations;
- total dissolved solids, calcium, total alkalinity, and total hardness in May at *baseline* station CLR-2, with concentrations below the 5th percentile of fall regional *baseline* concentrations;
- total mercury at *baseline* station CLR-2, with a concentration that exceeded the 95th percentile of fall regional *baseline* concentrations in May and was below the 5th percentile of fall regional *baseline* concentrations in November;
- magnesium in May, November, and December at *baseline* station CLR-2, with a concentration below the 5th percentile of fall regional *baseline* concentrations; and
- total nitrogen and pH in December at *baseline* station CLR-2, with concentrations below the 5th percentile of fall regional *baseline* concentrations.

Monthly Ion Balance The ionic balance remained consistent across months in 2013 in the Clearwater River, with no clear dominance in composition but primarily consisted of sodium and calcium (Figure 5.9-7).

Classification of Fall Results In fall 2013, water quality at all stations indicated **Negligible-Low** differences from regional *baseline* conditions. Concentrations of most water quality measurement endpoints were within the range of previously-measured concentrations and were within the range of regional *baseline* conditions. All stations showed similar ionic composition and no trends in measurement endpoints over time, with the exception of a decreasing trend in potassium at *test* station CLR-1. In 2013, there were many water quality guideline exceedances, particularly at *baseline* station HHR-1 in spring and summer.

Summary of Monthly Results Concentrations of many water quality variables fluctuated across months in 2013 at *test* station CLR-1 and *baseline* station CLR-2. Despite these fluctuations, the ionic composition at both stations in the Clearwater River remained fairly consistent across the year. Concentrations of many water quality variables (e.g., metals) in May at *baseline* station CLR-2 exceeded guidelines and frequently exceeded the regional *baseline* range observed in fall.

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 2013 at *baseline* reach HHR-E1 (erosional, sampled since 2011).

2013 Habitat Conditions Water at *baseline* reach HHR-E1 in fall 2013 was shallow (0.2 m in sampled areas), basic (pH: 8.2), with a fast velocity (1.4 m/s), high dissolved oxygen (10.5 mg/L), and moderate conductivity (231 µS/cm) (Table 5.9-10). The substrate consisted primarily of small (19%) and large cobble (34%) (Table 5.9-10). Periphyton chlorophyll *a* averaged 8 mg/m^2, which was consistent to 2012 and within the normal range of variation for *baseline* reaches (Figure 5.9-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *baseline* reach HHR-E1 was dominated by Ephemeroptera (36%), chironomids (23%), and naidid worms (19%), with subdominant taxa consisting of Trichoptera (7%) and Hydracarina (4%) (Table 5.9-11). Mayflies were diverse and dominated by *Baetis* and *Ephemerella*. Plecoptera were represented by seven genera, including *Zapada* and *Claessenia*, which were relatively abundant. There were five kinds of Trichoptera, with *Hydropsyche* and *Lepidostoma* as the most abundant. Chironomids were represented by 20 genera, with the most abundant being *Cricotopus*/*Orthocladius* gp., *Subletta*, *Rheotanytarsus*, and various orthoclads.

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 2013.

Comparison to Published Literature The benthic invertebrate community of *baseline* reach HHR-E1 reflected good water and sediment quality, with a decrease in the percentage of the community as worms from 2012 and an increase in the percentage of EPT taxa from 27% in 2011 to 46% in 2013. The mayfly, stonefly, and caddisfly assemblage was diverse and typical of a stone-bottomed river in good condition (Mandeville 2002).

2013 Results Relative to Historical Conditions Values of all measurement endpoints in fall 2013 showed improvement in the benthic invertebrate community compared to 2012, with an increase in abundance and the percentage of EPT taxa and a decrease in equitability (higher diversity) (Figure 5.9-9). CA Axis scores were similar to observations in 2011 (Figure 5.9-10).

Summary of Results The benthic invertebrate community at *baseline* reach HHR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies, and a relatively high diversity of chironomids. Historically, this reach contained a high relative abundance of naidid worms (42%), but the percentage of the fauna comprised by naidids in 2013 was considerably lower (19%) than previous years. *Baseline* reach HHR-E1 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 2013 because the reach of the High Hills River where benthic invertebrate communities were sampled is erosional and sediment quality is only sampled in depositional reaches.

5.9.5 Fish Populations

Fish population monitoring throughout the Clearwater River watershed in 2013 consisted of a spring, summer, and fall inventory. With the exception of fall 2011, *baseline* reaches (CR1 and CR2) have been continually sampled in spring and fall since 2003. The *test* reach (CR3) has also been sampled since 2003 in spring and fall; all three reaches have been sampled in summer since 2009.

In addition to the 2013 Clearwater River fish inventory, fish assemblage monitoring was conducted in fall at the lower section of the High Hills River, a tributary of the Clearwater River.

5.9.5.1 Clearwater River Fish Inventory

Temporal and Spatial Comparisons

Temporal and spatial comparisons were conducted to assess changes by season and area of the river for the following measurement endpoints: species composition, species richness, catch per unit effort (CPUE), age-frequency distribution, size-at-age (growth), and condition factor.

Total Catch and Species Composition A total of 1,801 fish were captured in the three reaches of the Clearwater River during the 2013 spring, summer, and fall inventories (Table 5.9-12 and Figure 5.9-11), of which:

- 548 fish representing 13 species were captured in spring;
- 667 fish representing 13 species were captured in summer; and
- 586 fish representing 14 species were captured in fall.

A total of 19 species were captured across all three seasons during the 2013 Clearwater River fish inventory. The dominant large-bodied fish species captured across seasons was white sucker (spring: 24.3%, summer: 20.2%, and fall: 43.3% of the total catch); the sub-dominant large-bodied fish species was longnose sucker (spring: 16.6%, summer: 12.4%, and fall: 13.1% of the total catch). Spottail shiner was the dominant small-bodied species in spring (18.0%) and summer (29.2%) and trout-perch was dominant in fall (12.2%).

Total Catch versus River Discharge Variability in total catch across years during 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 and accessibility for fishing is limited. Total catch was compared to the discharge in the Clearwater River during the period when fall fish inventories were conducted (Figure 5.9-12). Prior to 2009, discharge measurements were taken from a hydrology station downstream of *test* reach CR3 (WSC station 07CD001). From 2009 to 2013, 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 weak prior to 2009; however, the older WSC hydrology station was located in an area with deep, slow moving water, whereas the inventory sampling reaches were shallower with faster flowing water. From 2010 to 2013, total catch was lower in years when discharge was typically low (Figure 5.9-12). In fall 2011, when it was not possible to sample the *baseline* reaches, discharge was measured at a historical low (48.4 m^3/s); consequently, total catch was very low (269 fish). After a marked increase in 2012 (103.7 m^3/s; 898 fish), discharge in fall 2013 was lower as was the total catch in 2013 (79.1 m^3/s; 586 fish).

Species Richness Species richness was compared between *baseline* reaches CR1 and CR2 and *test* reach CR3. Across seasons in 2013, the number of species caught at *test* reach CR3 was greater than those caught at *baseline* reaches CR1 and CR2 (Table 5.9-12).

In 2013, species richness was lower at the *baseline* reaches across seasons when compared to 2012. Richness at the *test* reach was similar between the two years; species count in spring and summer were the same while only two fewer species were documented in fall 2013. Species richness across seasons and reaches has been generally consistent across sampling years (Figure 5.9-13).

Catch Per Unit Effort Seasonal catch per unit effort (CPUE) for large-bodied KIR fish species between *test* and *baseline* reaches is presented in Figure 5.9-14. Across seasons in 2013, white sucker had the highest CPUE at the *baseline* reaches while longnose sucker was most abundant at the *test* reach.

Annual CPUE for each season is presented in Figure 5.9-15. White sucker continues to be the large-bodied KIR species with the highest CPUE in spring. However, relative spring abundance of this species has been decreasing since 2011, while CPUE for longnose sucker continues to increase. CPUE for goldeye has returned to historical ranges following marked increases in summer and fall 2012. Similarly, there were considerable decreases in summer CPUE for white sucker and longnose sucker following a spike in 2012.

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 5.9-16 to Figure 5.9-20. With the exception of additional ageing data collected from 2004 to 2009 for northern pike and walleye, all species-specific results pertain to datasets from 2011 to 2013. Statistical differences in size-at-age were tested using analysis of covariance (ANCOVA) followed by Tukey post-hoc tests to determine significant differences between 2011, 2012, and 2013 data. Only large-bodied KIR fish species with adequate samples sizes ($n \geq 20$) and regression lines with equal slopes ($p > 0.01$) were included and only significant differences were reported. Results are as follows:

1. The dominant age class for goldeye in 2013 was six years with subdominant age classes of three and eight years. In 2012, the dominant age class was five years while the dominant age class in 2011 was ten years (Figure 5.9-16). A shift to a younger dominant age class has been observed in the last three years, although it should be noted that the sample size has been relatively small across years.

2. Ageing data collected in 2013 for longnose sucker exhibited a bimodal age distribution, with co-dominant age classes of three and eight years. Conversely, there was only one dominant age class of two and four years observed in 2012 and 2011, respectively (Figure 5.9-17).
3. The dominant age classes of northern pike in 2013 were two and three years with a subdominant age class of five years, with an absence of fish older than nine years that has been observed in previous years. The increase in fish at five years of age suggested a slight shift in population structure with the presence of older individuals (Figure 5.9-18). Significant differences in size-at-age were observed between 2013 and 2011 ($p<0.001$) and 2013 and 2012 ($p=0.042$), indicating a higher size-at-age of northern pike in 2013 compared to previous years.
4. The dominant age classes of walleye in 2013 were three and four years with a subdominant age class of six years, indicating a slight shift to a younger population in 2013 compared to previous years (Figure 5.9-19). Dominance of younger walleye in the Clearwater River has been documented since the beginning of data collection in 2004 (Figure 5.9-19).
5. Ageing data collected in 2013 for white sucker exhibited a bimodal age distribution, with a dominant age class of two years and sub-dominant age classes of five and six years. This distribution has not been observed in previous years, when there was a higher dominance of younger age classes (three and four years in 2011 and 2012, respectively) with few older individuals (Figure 5.9-20).

Condition Factor Mean condition factor for large-bodied KIR fish species were compared between reaches and season. Fish captured in spring were excluded from comparisons due to the influence of spawning on condition (i.e. an increase in reproductive tissue). Summer and fall mean condition (± 2SD) were compared between species captured in the *test* and *baseline* reaches in 2013 (Figure 5.9-21). Historical trends in mean condition across all reaches from 2003 to 2013 are presented in Figure 5.9-22. Statistical analysis to determine significant differences between comparisons was not performed due to insufficient sample sizes. Notable trends were as follows:

1. Comparisons of mean condition of goldeye between *test* and *baseline* reaches were not completed given that goldeye were not captured in the *baseline* reaches (Figure 5.9-21). Condition factor for goldeye captured in 2013 in the *test* reach was slightly higher than 2012 in both summer and fall (Figure 5.9-22).
2. Comparisons of mean condition of longnose sucker between *test* and *baseline* reaches were not completed given that longnose sucker were not captured in the *baseline* reaches (Figure 5.9-21). Mean condition factor of longnose sucker in summer 2013 was higher than all previous sampling years (Figure 5.9-22).
3. Mean condition of northern pike exceeded the 95th percentile of the *baseline* range of variability at the *test* reach in summer but was within the *baseline* range in fall (Figure 5.9-21). Mean condition of northern pike has been relatively stable across years (Figure 5.9-22).
4. Mean condition of walleye exceeded the 95th percentile of the *baseline* range of variability at the *test* reach in summer but was within the *baseline* range in fall (Figure 5.9-21). Mean condition of walleye was higher in 2013 compared to previous years although within the historical range in both summer and fall (Figure 5.9-22).

5. Mean condition of white sucker at the *test* reach was within the *baseline* range of variability in summer and fall (Figure 5.9-21). With the exception of slightly lower condition in summer 2012, mean condition has been relatively stable across years in both seasons (Figure 5.9-22).

External Health Assessment

Abnormalities present among fish captured in 2013 were primarily associated with minor skin aberrations or wounds, scars, and fin erosion. In 2013, 1.5%, 5.0%, and 2.9% of fish captured were found to have some sort of external abnormality in spring, summer, and fall, respectively. Compared to 2012, the percentage of external abnormalities in 2013 were lower in spring (-1.0%); and higher in summer (+1.7%) and fall (+0.4%).

The annual percentage of fish exhibiting some form of external pathology from 2003 to 2013 is summarized in Table 5.9-13 and Figure 5.9-23. Of the 1,801 fish captured in 2013, 58 (3.2%) had some form of external pathological abnormality such as growths/ lesions, parasites, or body deformities. The incidence of growths/lesions increased from 2012 (+0.22%); however, there was a decrease in observed parasites (-0.07%) and body deformities (-0.09%). Species with external abnormalities in 2013 included goldeye, longnose sucker, northern pike, walleye, and white sucker. Abnormalities in 2011 and 2012 (1.5%) and 2013 (2.3%) were primarily observed in white sucker.

Summary

The Clearwater fish inventory is a community-based initiative primarily suited for assessing general trends in population variables such as species richness, abundance, and composition. The program also aims to determine age, growth, and health of individuals within these populations with focus on large-bodied KIR species.

Coupled with a decrease in total catch, species richness and abundance were relatively low in the Clearwater River watershed in 2013. Compared to 2012, total catch was notably lower in summer and fall, likely due to a decrease in available habitat resulting from lower discharge in the sampling reaches. White sucker and longnose sucker continue to dominate overall species composition while the abundance of goldeye has returned to historical ranges after an increase in summer and fall 2012. The transient increase in goldeye abundance could be related to the warm, calm spring season that occurred in 2011 and 2012 but was not observed in 2013. These conditions have proven to be favourable for goldeye recruitment (Paul 2013).

Following a shift towards a younger dominant age class in 2012, there was an increase in catch of older northern pike in 2013. In addition, significant increases in size-at-age across the last three years indicate that northern pike were larger at age in 2013. Conversely, a dominance of younger size classes continued to persist for walleye. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals (Almodóvar and Nicola 2004).

Mean condition factor was relatively similar for the large-bodied KIR species between *test* and *baseline* reaches in summer and fall 2013; northern pike and walleye showed slight differences with higher condition at the *test* reach compared to the *baseline* reaches in summer. Historical data indicated considerable increases in condition for both longnose sucker and walleye in 2013. The percentage of external abnormalities increased slightly in 2013 compared to 2012, with the majority of abnormalities observed in white sucker and a higher percentage of abnormalities observed in summer.

5.9.5.2 High Hills River Fish Assemblage Monitoring

Fish assemblages were sampled in fall 2013 at erosional *baseline* reach HHR-F1, which has been sampled since 2011 and is at the same location as the benthic invertebrate community *baseline* reach HHR-E1.

2013 Habitat Conditions *Baseline* reach HHR-F1 was comprised of riffle and run habitat, with a wetted width of 18.5 m and a bankfull width of 30.5 m (Table 5.9-14). The substrate was dominated by coarse gravel with small amounts of sand. Water at *baseline* reach HHR-F1 had a mean depth of 0.49 m and moderate velocity (0.55 m/s), was alkaline (pH: 8.25), with low conductivity (233 µS/cm), high dissolved oxygen (10.0 mg/L), and a temperature of 12.3˚C (Table 5.9-14). Instream cover was dominated by small and large woody debris (Table 5.9-14).

Relative Abundance of Fish Species The fish assemblage at *baseline* reach HHR-F1 was dominated by slimy sculpin (41%) and longnose sucker (31%) and had a similar species composition to previous sampling years (Table 5.9-15).

Temporal and Spatial Comparisons Sampling was initiated in High Hills River in fall 2011; therefore, temporal comparisons were conducted for 2011 to 2013.

There has been a decrease in CPUE and abundance across years at *baseline* reach HHR-F1; however, species richness and diversity were higher in 2013 compared to 2011 and 2012 (Table 5.9-15 and Table 5.9-16). There was an increase in the ATI value in fall 2013 to a value that was more consistent to 2011. The majority of fish captured in 2012 were slimy sculpin, which resulted in a lower ATI value compared to 2011 and 2013. In 2011 and 2013, there was a higher relative abundance of sucker species, which have higher tolerance values (Whittier et al. 2007) resulting in higher ATI values for these years (Table 5.9-15).

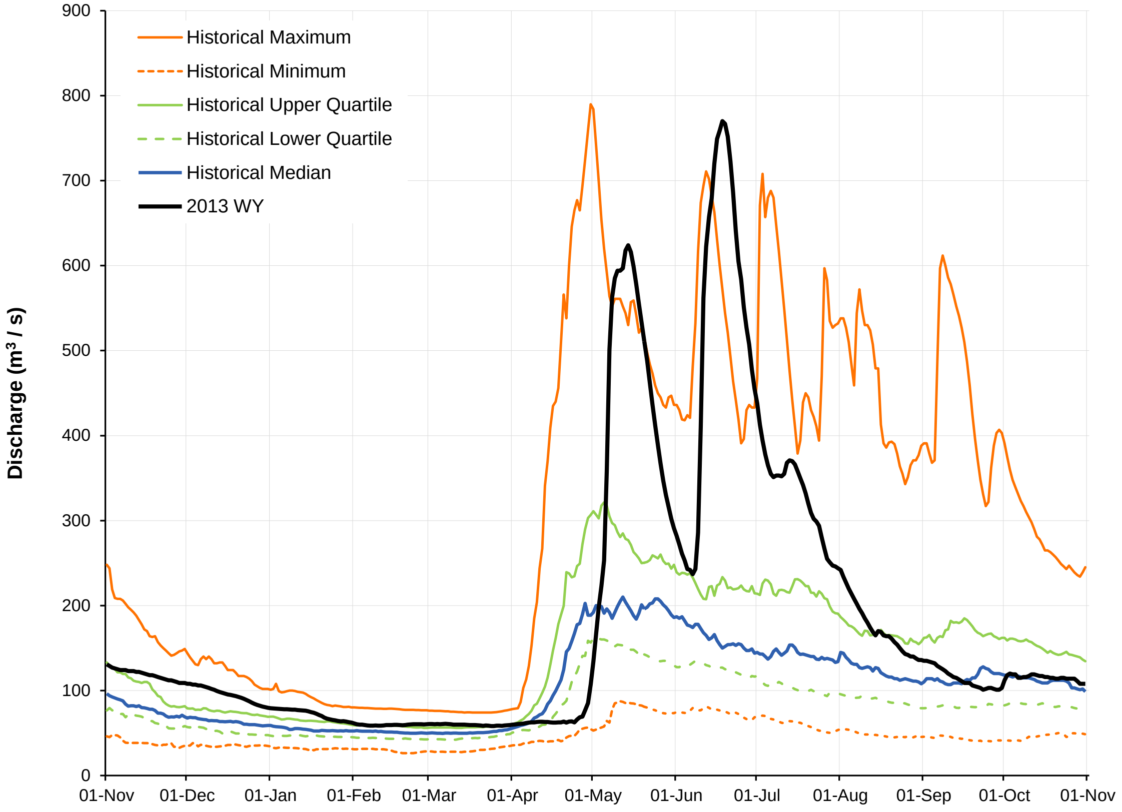
Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region. Most studies were conducted prior to large-scale oil sands development and provide important *baseline* data on fish presence and distribution 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; between 2011 and 2013, RAMP has documented a total of nine fish species of which three have not been previously recorded in the High Hills River. Three sportfish species (Arctic grayling, mountain whitefish, and northern pike) have been previously documented, although further upstream on the High Hills River, and have not been documented by RAMP.

Golder (2004) documented similar habitat conditions to what have been observed by RAMP in 2013, with habitat consisting of pools and riffles, and substrate consisting of gravel in the riffles and sand, silt, and gravel in the pools in the section of the river where *baseline* reach HHR-F1 is located. These conditions provide excellent refugia and habitat for sportfish species coming from the Clearwater River.

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *baseline* reach HHR-F1 were within the range of regional *baseline* conditions for erosional reaches (Figure 5.9-24).

Classification of Results The fish assemblage at *baseline* reach HHR-F1 was consistent with other *baseline* erosional reaches. Fish species captured at this reach were consistent with fish assemblages commonly observed in fast-flowing riffle habitat (e.g., slimy sculpin, longnose sucker, longnose dace).

Figure 5.9-3 Hydrograph for the Clearwater River at Draper for the 2013 WY, compared to historical values.



Note: 2013 WY hydrograph based on WSC Station 07CD001, Clearwater River at Draper, provisional data for November 1, 2012 to October 31, 2013. Historical values were calculated for the period from 1958 to 2012.

Table 5.9-2 Concentrations of water quality measurement endpoints, mouth of Clearwater River (*test* station CLR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	12	7.5	8.0	8.2
Total suspended solids	mg/L	-	59	12	<3	16	209
Conductivity	µS/cm	-	228	12	177	222	300
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.019	12	0.006	0.021	0.044
Total nitrogen	mg/L	1	0.53	12	0.30	0.60	**1.72**
Nitrate+nitrite	mg/L	3	<0.071	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	12.2	12	8.0	10.9	20.4
Ions							
Sodium	mg/L	-	20.9	12	13.1	20.0	31.0
Calcium	mg/L	-	19.1	12	14.7	17.3	20.1
Magnesium	mg/L	-	5.6	12	5.0	5.7	6.5
Chloride	mg/L	120	24.9	12	13.2	25.0	43.0
Sulphate	mg/L	270	5.50	12	1.40	5.85	7.70
Total dissolved solids	mg/L	-	137	12	60	150	200
Total alkalinity	mg/L		68	12	56	67	79
Selected metals							
Total aluminum	mg/L	0.1	**1.97**	12	**0.14**	**0.59**	**4.97**
Dissolved aluminum	mg/L	0.1	0.014	12	0.006	0.009	**0.125**
Total arsenic	mg/L	0.005	0.0010	12	0.0005	0.0008	0.0016
Total boron	mg/L	1.2	0.034	12	0.021	0.033	0.055
Total molybdenum	mg/L	0.073	0.00023	12	0.00012	0.00020	0.00036
Total mercury (ultra-trace)	ng/L	5, 13	4.2	10	<0.6	<1.2	**13.5**
Total strontium	mg/L	-	0.0966	12	<0.000005	0.000007	0.0835
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.19	2	0.05	0.10	0.15
Oilsands Extractable	mg/L	-	0.20	2	0.32	0.48	0.64
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	14.03	19.30
Retene	ng/L	-	3.70	2	<2.07	8.74	15.40
Total dibenzothiophenes	ng/L	-	40.5	2	6.57	35.40	64.23
Total PAHs	ng/L	-	259	2	173	319	465
Total Parent PAHs	ng/L	-	25.7	2	25.2	31.0	36.9
Total Alkylated PAHs	ng/L	-	234	2	147	288	428
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.004**	12	**0.003**	**0.004**	**0.009**
Total iron	mg/L	0.3	**2.09**	12	**0.51**	**1.20**	**5.04**
Dissolved iron	mg/L	0.3	**0.723**	12	0.139	**0.318**	**0.756**
Total phenols	mg/L	0.004	**0.006**	12	<0.001	**0.004**	**0.009**
Total phosphorus	mg/L	0.05	**0.088**	12	0.033	**0.057**	**0.211**
Total chromium	mg/L	0.001	**0.0016**	12	0.0003	0.0008	**0.0062**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	12	7.2	7.9	8.1
Total suspended solids	mg/L	-	19	12	3	18	174
Conductivity	µS/cm	-	187	12	138	193	253
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.020	12	0.008	0.018	0.026
Total nitrogen	mg/L	1	0.39	12	0.30	0.50	**1.20**
Nitrate+nitrite	mg/L	3	<0.071	12	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	8.3	12	6.0	8.5	24.2
Ions							
Sodium	mg/L	-	19.9	12	11.0	16.5	29.0
Calcium	mg/L	-	11.6	12	10.0	12.0	21.6
Magnesium	mg/L	-	4.0	12	3.4	4.2	7.0
Chloride	mg/L	120	26.6	12	14.8	26.0	43.0
Sulphate	mg/L	195	4.8	12	<0.5	5.7	7.7
Total dissolved solids	mg/L	-	111	12	40	130	177
Total alkalinity	mg/L		43.2	12	39.0	48.5	57.6
Selected metals							
Total aluminum	mg/L	0.1	**1.08**	12	**0.10**	**0.28**	**5.00**
Dissolved aluminum	mg/L	0.1	0.014	12	0.003	0.008	**0.185**
Total arsenic	mg/L	0.005	0.0006	12	0.0004	0.0005	0.0014
Total boron	mg/L	1.2	0.022	12	0.014	0.024	0.051
Total molybdenum	mg/L	0.073	0.00012	12	0.00009	0.00012	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	1.8	10	0.8	<1.2	**13.7**
Total strontium	mg/L	-	0.080	12	0.061	0.081	0.103
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.3	<0.25	<0.3
Naphthenic Acids	mg/L	-	0.21	2	0.02	0.04	0.06
Oilsands Extractable	mg/L	-	0.19	2	0.34	0.53	0.72
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	9.61	2	<2.07	19.99	37.90
Total dibenzothiophenes	ng/L	-	6.67	2	5.84	21.01	36.18
Total PAHs	ng/L	-	114	2	151	235	318
Total Parent PAHs	ng/L	-	22.4	2	19.2	24.6	29.9
Total Alkylated PAHs	ng/L	-	91.6	2	131.9	210.1	288.3
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**1.320**	12	**0.545**	**1.003**	**5.360**
Dissolved iron	mg/L	0.3	**0.572**	12	0.096	0.251	**0.672**
Sulphide	mg/L	0.002	**0.003**	12	0.002	**0.005**	**0.013**
Total chromium	mg/L	0.001	**0.0010**	12	**0.0003**	**0.0006**	**0.0066**
Total phenols	mg/L	0.004	**0.0066**	12	<0.0010	0.0033	**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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.0	8.2	8.4
Total suspended solids	mg/L	-	36	2	6	31	55
Conductivity	µS/cm	-	259	2	160	205	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.050**	2	**0.056**	**0.063**	**0.069**
Total nitrogen	mg/L	1	0.451	2	0.381	0.596	0.811
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	11.1	2	12.8	19.7	26.5
Ions							
Sodium	mg/L	-	9.0	2	5.8	7.5	9.2
Calcium	mg/L	-	33.4	2	20.9	25.9	30.8
Magnesium	mg/L	-	10.50	2	6.07	7.91	9.74
Chloride	mg/L	120	0.50	2	0.50	0.56	0.62
Sulphate	mg/L	270	4.40	2	2.07	2.36	2.64
Total dissolved solids	mg/L	-	174	2	114	135	155
Total alkalinity	mg/L		135	2	81	105	129
Selected metals							
Total aluminum	mg/L	0.1	**3.57**	2	**0.28**	**0.76**	**1.23**
Dissolved aluminum	mg/L	0.1	0.017	2	0.009	0.032	0.055
Total arsenic	mg/L	0.005	0.00093	2	0.00052	0.00073	0.00094
Total boron	mg/L	1.2	0.054	2	0.041	0.049	0.057
Total molybdenum	mg/L	0.073	0.00027	2	0.00024	0.00025	0.00025
Total mercury (ultra-trace)	ng/L	5, 13	3.20	2	0.700	2.75	4.80
Total strontium	mg/L	-	0.098	2	0.058	0.074	0.090
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.24	2	0.03	0.08	0.12
Oilsands Extractable	mg/L	-	0.28	2	0.38	0.40	0.42
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	7.57	8.84	10.10
Retene	ng/L	-	4.58	2	0.91	5.13	9.34
Total dibenzothiophenes	ng/L	-	6.67	2	5.84	20.58	35.32
Total PAHs	ng/L	-	111	2	151	194	237
Total Parent PAHs	ng/L	-	22.9	2	18.8	19.0	19.2
Total Alkylated PAHs	ng/L	-	88	2	132	175	218
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**1.98**	2	**0.62**	**1.45**	**2.28**
Dissolved Iron	mg/L	0.3	**0.572**	2	0.250	**0.399**	**0.548**
Total phosphorous	mg/L	0.05	**0.0496**	2	**0.0917**	**0.1124**	**0.1330**
Total chromium	mg/L	0.001	**0.0010**	2	0.0003	**0.0010**	**0.0018**

[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.

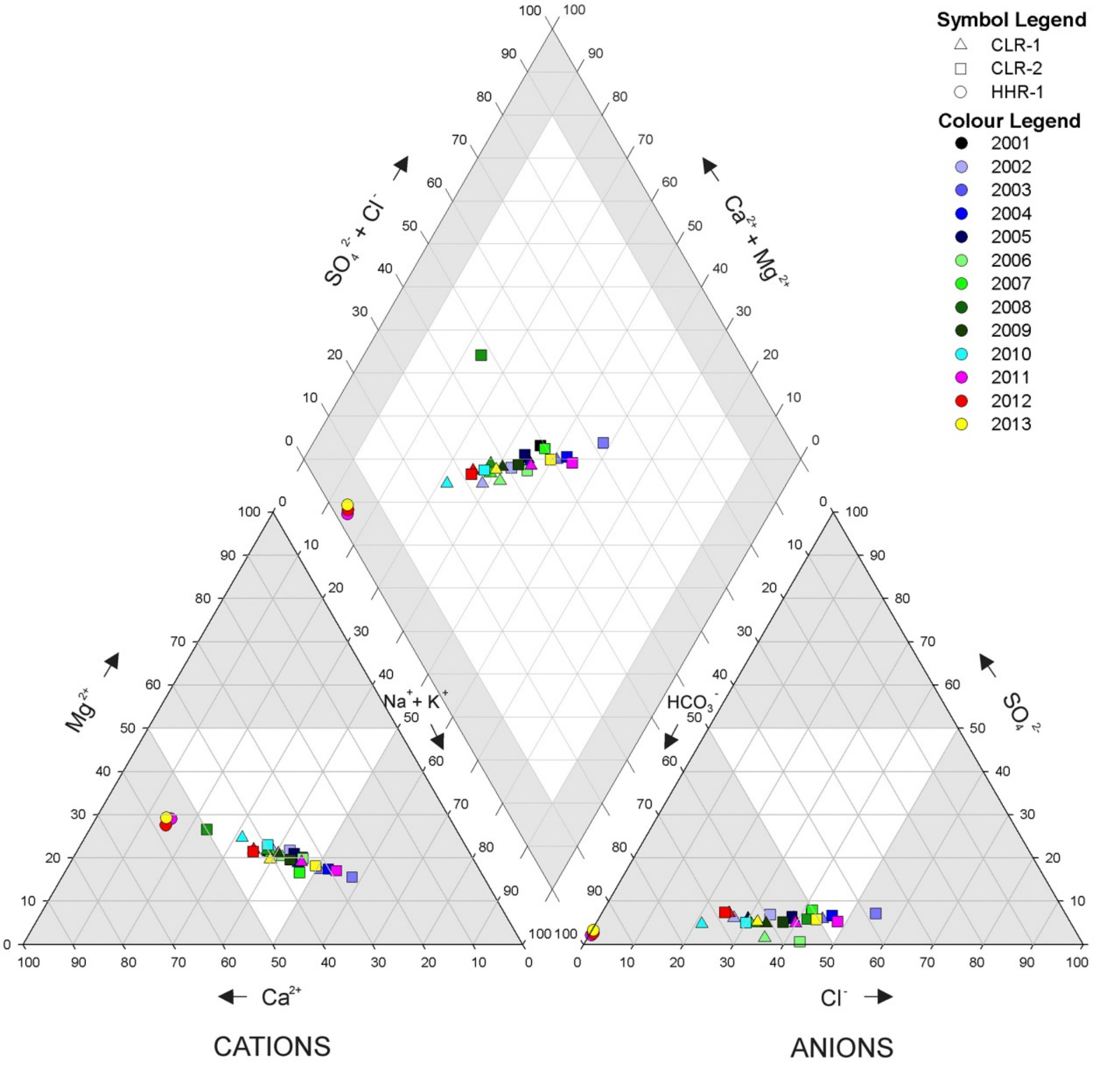


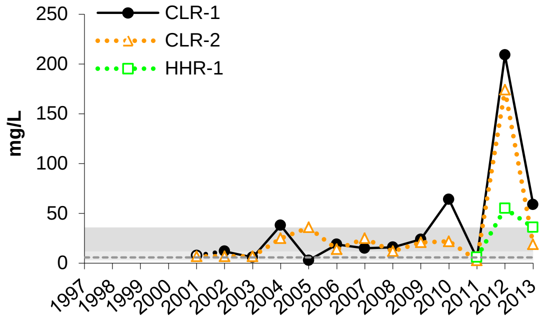
Table 5.9-5 Seasonal water quality guideline exceedances, Clearwater River watershed, 2013.

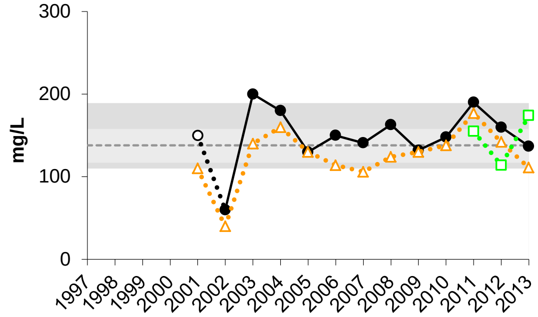
Variable	Units	Guideline[a]	HHR-1
Winter			
Dissolved iron	mg/L	0.3	0.616
Dissolved phosphorous	mg/L	0.05	0.0639
Total aluminum	mg/L	0.1	0.540
Total iron	mg/L	0.3	1.35
Total phosphorus	mg/L	0.05	0.149
Spring			
Dissolved aluminum	mg/L	0.1	0.17
Dissolved iron	mg/L	0.3	0.555
Sulphide	mg/L	0.002	0.0238
Total aluminum	mg/L	0.1	17.30
Total chromium	mg/L	0.001	0.016
Total copper	mg/L	0.002[b]	0.009
Total iron	mg/L	0.3	14.80
Total lead	mg/L	0.0008[b]	0.01
Total ultra-trace mercury	ng/L	5	6.30
Total nitrogen	mg/L	1	1.37
Total phenols	mg/L	0.004	0.0083
Total phosphorus	mg/L	0.05	0.710
Total silver	mg/L	0.0001	0.000163
Summer			
Dissolved iron	mg/L	0.3	0.48
Dissolved phosphorous	mg/L	0.05	0.077
Sulphide	mg/L	0.002	0.0110
Total aluminum	mg/L	0.1	23.20
Total chromium	mg/L	0.001	0.01460
Total copper	mg/L	0.0022[b]	0.00917
Total iron	mg/L	0.3	15.40
Total lead	mg/L	0.0028[b]	0.01
Total ultra-trace mercury	ng/L	5	16.00
Total nitrogen	mg/L	1	1.68
Total phenols	mg/L	0.004	0.0065
Total phosphorus	mg/L	0.05	0.6540
Total silver	mg/L	0.0001	0.00013
Fall			
Dissolved iron	mg/L	0.3	0.572
Dissolved phosphorous	mg/L	0.05	0.0503
Sulphide	mg/L	0.002	-
Total aluminum	mg/L	0.1	3.57
Total chromium	mg/L	0.001	0.00101
Total iron	mg/L	0.3	1.98
Total phenols	mg/L	0.004	-
Total phosphorus	mg/L	0.05	0.0496

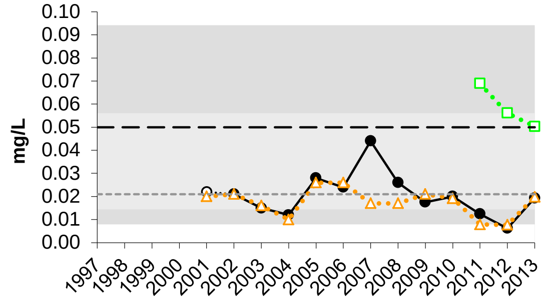
[a] Sources for all guidelines are outlined in Table 3.2-5.

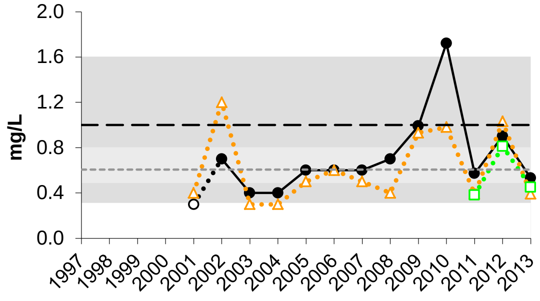
[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

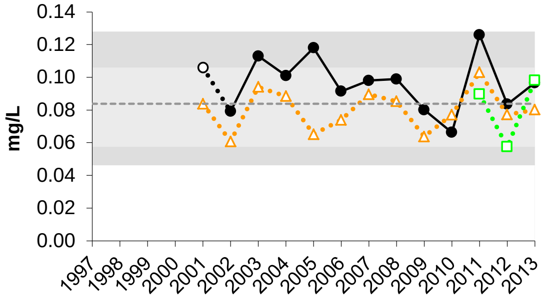
Figure 5.9-5 Concentrations of selected water quality measurement endpoints in the Clearwater watershed (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

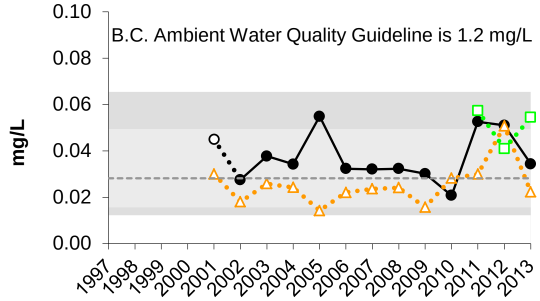

Total Suspended Solids (TSS)

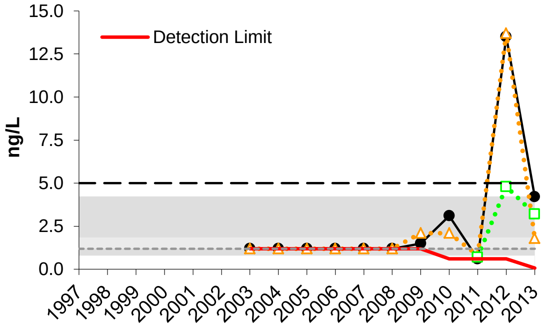

Total Dissolved Solids (TDS)

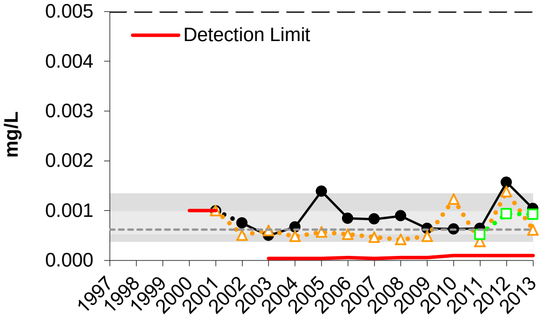

Dissolved Phosphorus


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.

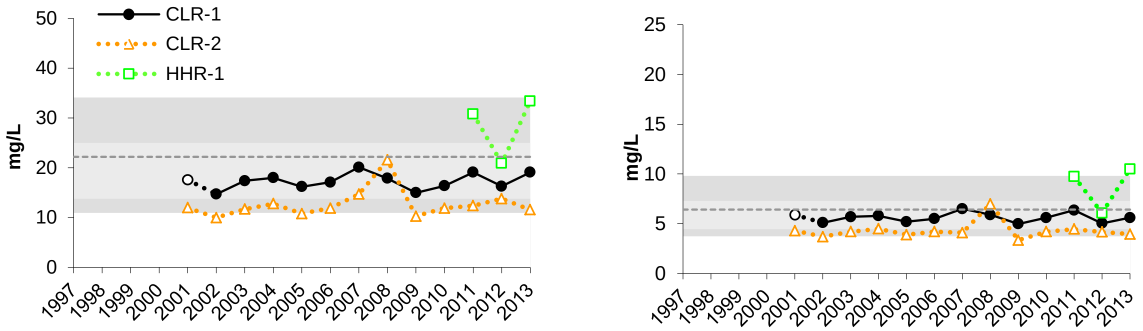
○·······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.9-5 (Cont'd.)

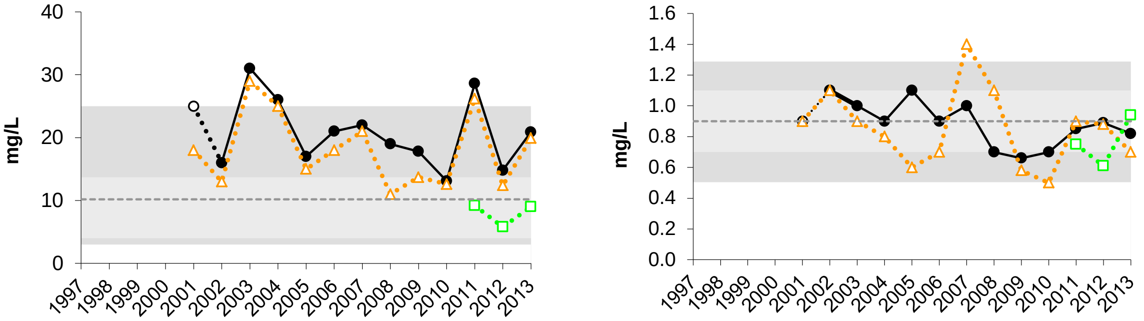
Calcium

Magnesium



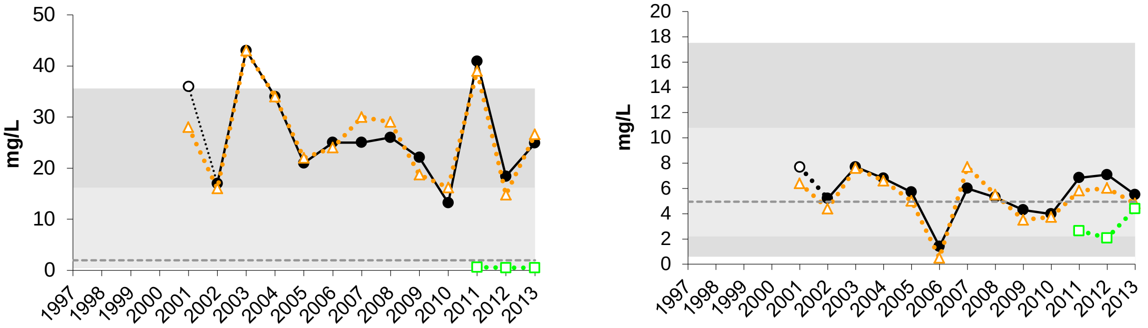
Sodium

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 3.2.2.2 for a discussion of this approach.

Table 5.9-6 Monthly water quality measurement endpoints for the mouth of the Clearwater River (*test* station CLR-1), January to April and September 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	5	7.52	(January)	7.67	8.09	(September)
Total suspended solids	mg/L	-	5	<3	-	<3	59	(September)
Conductivity	µS/cm	-	5	228	(September)	273	287	(February)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	5	0.003	(January)	0.019	0.028	(March)
Total nitrogen	mg/L	1.0	5	0.366	(March)	0.456	0.531	(September)
Nitrate+nitrite	mg/L	3	5	<0.071	(September)	0.146	0.160	(April)
Dissolved organic carbon	mg/L	-	5	6.4	(April)	7.9	12.2	(September)
Ions								
Sodium	mg/L	-	5	20.9	(September)	29.2	30.0	(February)
Calcium	mg/L	-	5	17.2	(February)	18.1	19.1	(September)
Magnesium	mg/L	-	5	5.6	(September)	5.8	6.1	(February)
Chloride	mg/L	120	5	24.9	(September)	37.7	40.2	(February)
Sulphate	mg/L	410	5	5.5	(September)	7.0	7.6	(February)
Total dissolved solids	mg/L	-	5	137	(September)	164	180	(March)
Total alkalinity	mg/L	-	5	63.5	(January)	67.9	73.2	(March)
Selected metals								
Total aluminum	mg/L	0.1	5	0.152	(January)	**0.207**	**1.970**	(September)
Dissolved aluminum	mg/L	0.1	5	0.008	(April)	0.011	0.014	(September)
Total arsenic	mg/L	0.005	5	0.0003	(April)	0.0004	0.0010	(September)
Total boron	mg/L	1.2	5	0.032	(January)	0.032	0.034	(September)
Total molybdenum	mg/L	0.073	5	0.00012	(January)	0.00016	0.00260	(April)
Total mercury (ultra-trace)	ng/L	5, 13	5	0.70	(February)	1.00	4.20	(September)
Total strontium	mg/L	-	5	0.097	(September)	0.105	0.108	(March/April)
Total hydrocarbons								
BTEX	mg/L	-	5	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	5	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	5	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	5	0.05	(February)	0.19	0.29	(January)
Oilsands Extractable	mg/L	-	5	0.11	(February)	0.32	0.36	(January)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	5	<15.16	-	<15.16	<15.16	-
Retene	ng/L	-	5	0.94	(February)	1.10	3.70	(September)
Total dibenzothiophenes	ng/L	-	5	105.9	(January)	109.2	259.4	(September)
Total PAHs	ng/L	-	5	6.7	(January)	7.2	40.5	(September)
Total Parent PAHs	ng/L	-	5	22.4	(April)	22.9	25.7	(September)
Total Alkylated PAHs	ng/L	-	5	82.8	(January)	86.6	233.7	(September)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	1	<0.001	(January)	0.003	**0.006**	(September)
Sulphide	mg/L	0.002	4	<0.002	(March)	0.002	**0.004**	(September)
Total phosphorus	mg/L	0.05	1	0.0037	(January)	0.0489	**0.0877**	(September)
Total iron	mg/L	0.3	5	**0.830**	(January)	**1.030**	**2.090**	(September)
Dissolved iron	mg/L	0.3	5	**0.490**	(January)	**0.518**	**0.723**	(September)
Total chromium	mg/L	0.001	1	<0.0003	(January/February)	0.0004	**0.0016**	(September)

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

[1] n value refers to number of exceedances in 2013.

Table 5.9-7 Monthly water quality measurement endpoints for the upper Clearwater River (*baseline* station CLR-2), May to December 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	8	7.29	(December)	7.68	7.81	(June)
Total suspended solids	mg/L	-	8	<3	(November/ December)	27	192	(May)
Conductivity	µS/cm	-	8	92	(May)	172	197	(November)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	8	0.010	(May)	0.020	0.026	(July)
Total nitrogen	mg/L	1.0	8	0.271	(December)	0.471	**0.881**	(July)
Nitrate+nitrite	mg/L	3	8	<0.070	-	<0.071	<0.071	-
Dissolved organic carbon	mg/L	-	8	6.3	(December)	9.4	15.1	(July)
Ions								
Sodium	mg/L	-	8	6.7	(May)	17.3	19.9	(September)
Calcium	mg/L	-	8	8.6	(May)	11.5	11.9	(September)
Magnesium	mg/L	-	8	2.5	(May)	3.9	4.0	(September)
Chloride	mg/L	120	8	6.6	(May)	24.7	29.0	(November)
Sulphate	mg/L	410	8	2.6	(May)	4.5	5.3	(November)
Total dissolved solids	mg/L	-	8	101	(May)	120	150	(August)
Total alkalinity	mg/L	-	8	32.5	(May)	43.4	46.8	(November)
Selected metals								
Total aluminum	mg/L	0.1	8	0.048	(November)	**1.090**	**8.190**	(May)
Dissolved aluminum	mg/L	0.1	8	0.010	(December)	0.014	0.089	(May)
Total arsenic	mg/L	0.005	8	0.0003	(December)	0.0007	0.0016	(May)
Total boron	mg/L	1.2	8	0.019	(December)	0.023	0.028	(May)
Total molybdenum	mg/L	0.073	8	<0.00010	(December)	0.00011	0.00014	(June)
Total mercury (ultra-trace)	ng/L	5, 13	8	0.69	(November)	2.20	**9.70**	(May)
Total strontium	mg/L	-	8	0.056	(May)	0.075	0.080	(September)
Total hydrocarbons								
BTEX	mg/L	-	8	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	8	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	8	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	8	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	8	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	8	0.04	(June)	0.17	0.31	(July)
Oilsands Extractable	mg/L	-	8	0.08	(October)	0.18	0.48	(July)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	8	<15.16	-	<15.16	<15.16	-
Retene	ng/L	-	8	1.33	(December)	5.50	16.70	(May)
Total dibenzothiophenes	ng/L	-	8	6.67	-	6.67	8.43	(May)
Total PAHs	ng/L	-	8	102.5	(November)	111.0	191.9	(June)
Total Parent PAHs	ng/L	-	8	22.4	-	22.5	29.1	(May)
Total Alkylated PAHs	ng/L	-	8	80.0	(November)	88.5	169.4	(June)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	3	0.001	(December)	0.003	**0.010**	(May)
Sulphide	mg/L	0.002	7	<0.002	(November)	**0.003**	**0.010**	(May)
Total phosphorus	mg/L	0.05	5	**0.0299**	(November)	**0.0532**	**0.2500**	(May)
Total iron	mg/L	0.3	8	**0.740**	(December)	**1.495**	**6.520**	(May)
Dissolved iron	mg/L	0.3	8	**0.433**	(October)	**0.516**	**1.150**	(July)
Total chromium	mg/L	0.001	6	<0.0003	(December)	**0.0011**	**0.0087**	(May)
Total silver	mg/L	0.0001	1	<0.00001	-	0.00002	**0.00012**	(May)
Total titanium	mg/L	0.03	1	0.002	(November)	0.017	**0.172**	(May)

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above guideline; underlined values are outside of historical range.

[1] n value refers to number of exceedances in 2013.

Table 5.9-8 Monthly water quality guideline exceedances for the mouth of the Clearwater River (*test* station CLR-1), January to April and September 2013.

Variable	Units	Guideline[a]	January	February	March	April	September
Total phenols	mg/L	0.004	-	-	-	-	0.0064
Sulphide	mg/L	0.002	0.0029	0.0022	-	0.0022	0.0038
Total phosphorus	mg/L	0.05	-	-	-	-	0.088
Total aluminum	mg/L	0.1	0.152	0.207	0.236	0.180	1.970
Total iron	mg/L	0.3	0.83	0.91	1.03	1.09	2.09
Dissolved iron	mg/L	0.3000	0.490	0.518	0.537	0.499	0.723
Total chromium	mg/L	0.001	-	-	-	-	0.00164

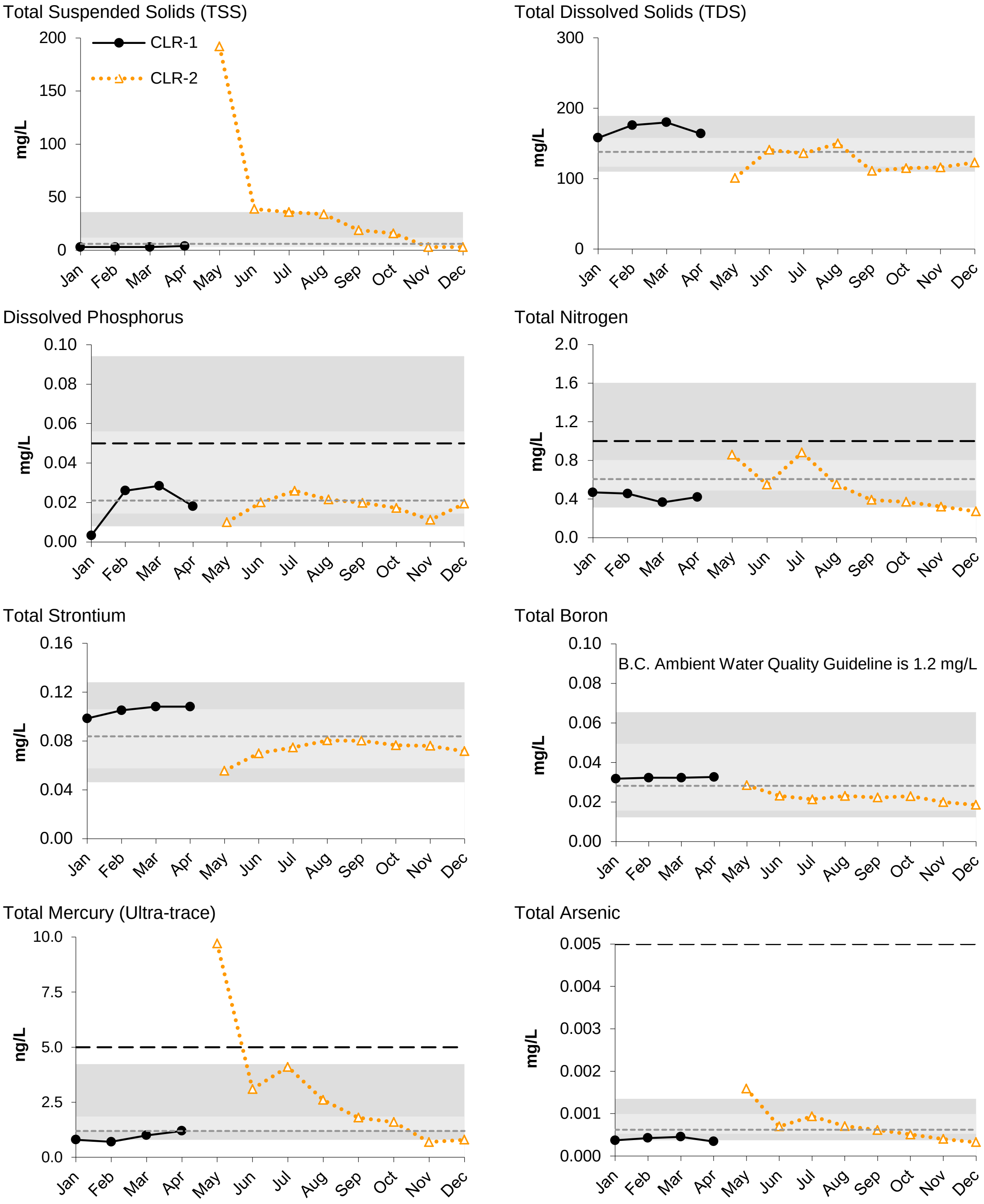
[a] Sources for all guidelines are outlined in Table 3.2-5.

Table 5.9-9 Monthly water quality guideline exceedances for the upper Clearwater River (*baseline* station CLR-2), May to December 2013.

Variable	Units	Guideline[a]	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0100	-	0.0060	-	0.0066	-	-	-
Sulphide	mg/L	0.002	0.0100	0.0029	0.0063	0.0042	0.0030	0.0023	-	0.0022
Total phosphorus	mg/L	0.05	0.250	0.592	0.806	0.053	-	0.053	-	-
Total aluminum	mg/L	0.1	8.190	1.610	1.710	0.839	1.080	1.100	-	-
Dissolved aluminum	mg/L	0.1	0.0887	-	-	-	-	-	-	-
Total iron	mg/L	0.3	6.52	1.69	2.86	1.65	1.32	1.34	0.75	0.74
Dissolved iron	mg/L	0.3000	0.619	0.459	1.150	0.645	0.572	0.433	0.451	0.457
Total chromium	mg/L	0.001	0.0087	0.0017	0.0014	0.0011	0.0010	0.00107	-	-
Total mercury (ultra-trace)	mg/L	5, 13	9.7	-	-	-	-	-	-	-
Total silver	mg/L	0.0001	0.00012	-	-	-	-	-	-	-
Total titanium	mg/L	0.1	0.0172	-	-	-	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.9-6 Concentrations of selected water quality measurement endpoints in the Clearwater watershed (monthly data) relative to regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

Total Arsenic

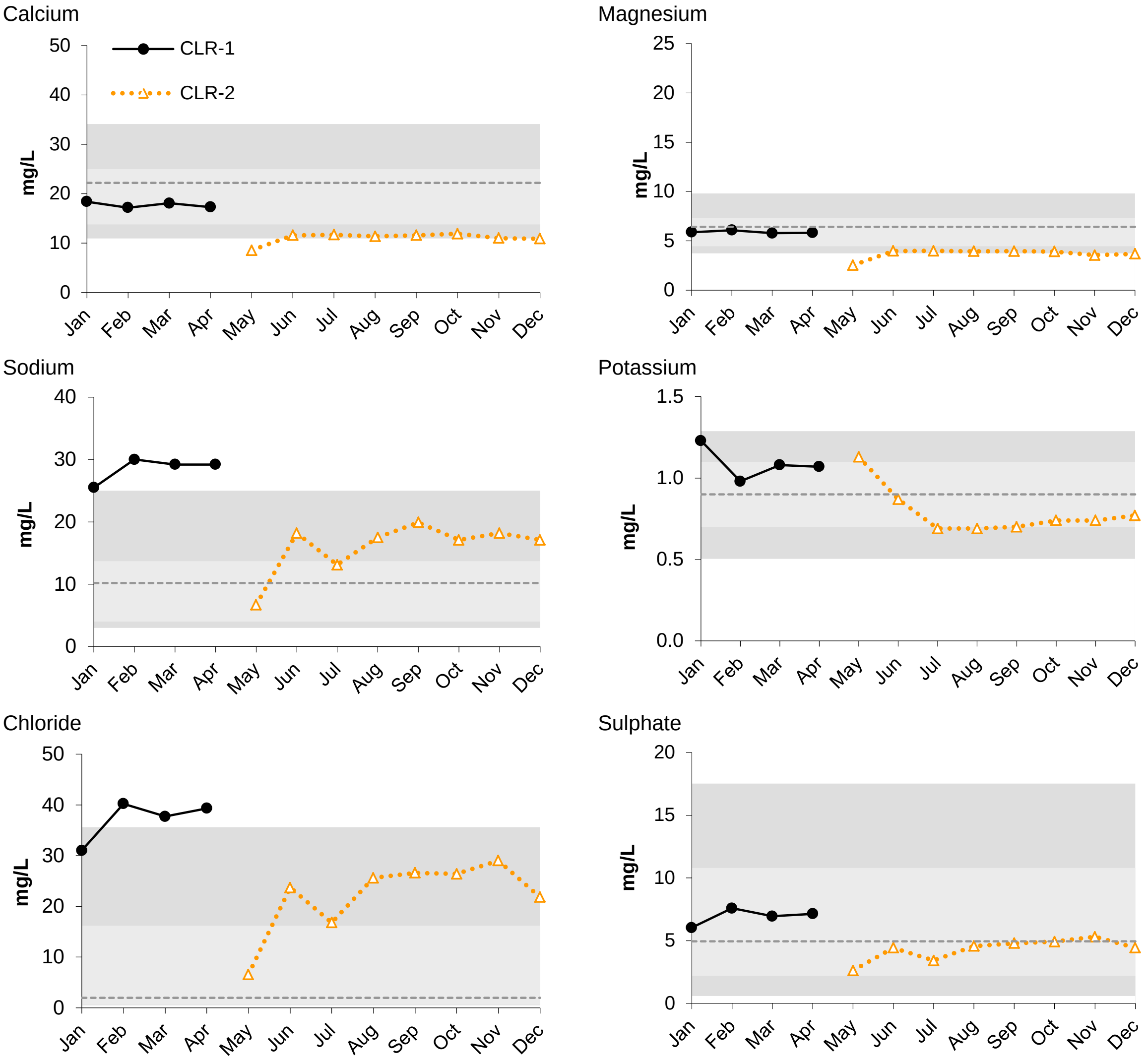
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.9-6 (Cont'd.)



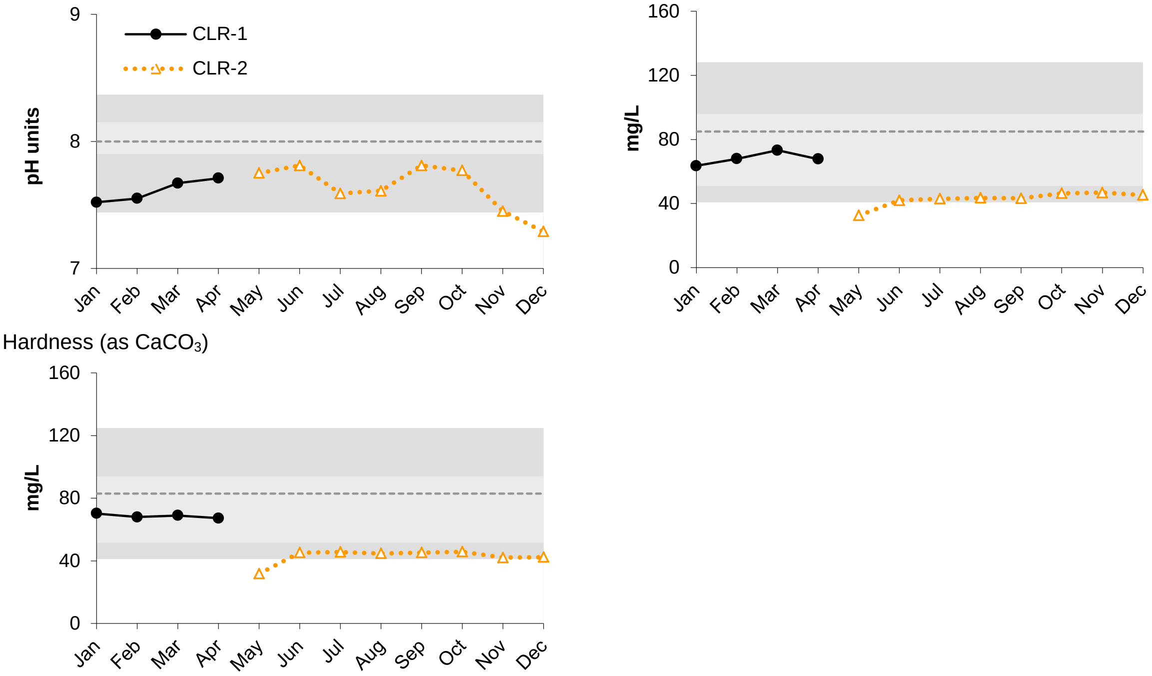
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.9-6 (Cont'd.)



pH

Total Alkalinity

Hardness (as $CaCO_3$)

Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

Figure 5.9-7 Piper diagram of monthly ion concentrations in the Clearwater River watershed.

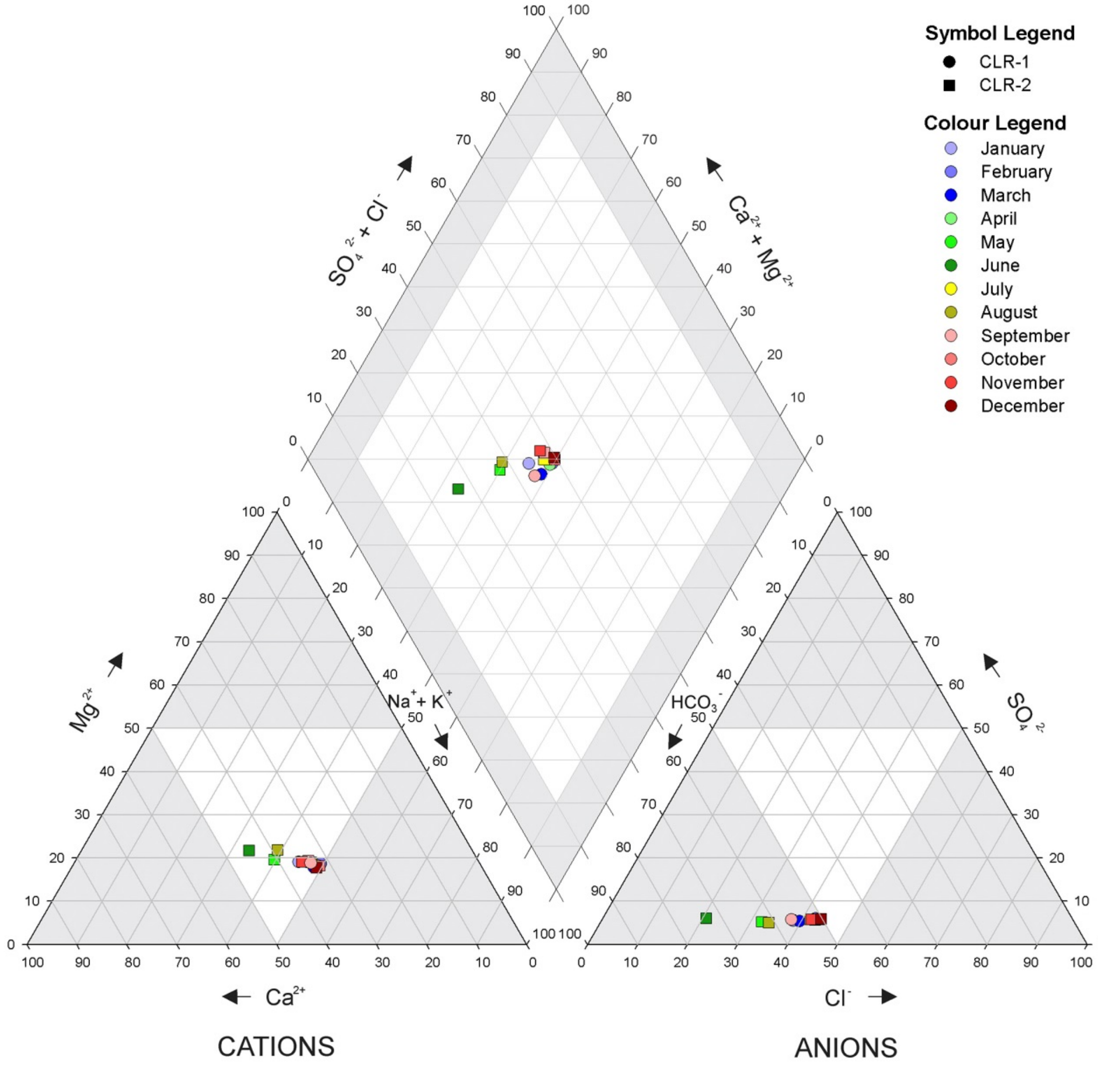
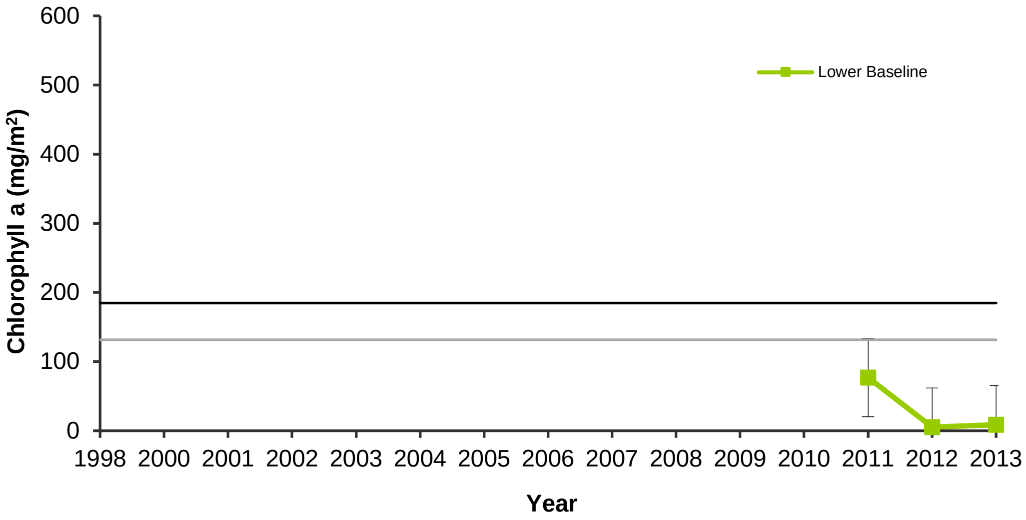


Table 5.9-10 Average habitat characteristics of the benthic invertebrate community sampling location of the High Hills River, fall 2013.

Variable	Units	HHR-E1 *Baseline* Reach of the High Hills River
Sample date	-	Sept 18, 2013
Habitat	-	Erosional
Water depth	m	0.2
Current velocity	m/s	1.36
Field Water Quality		
Dissolved oxygen	mg/L	10.5
Conductivity	µS/cm	231
pH	pH units	8.2
Water temperature	°C	10.4
Sediment Composition		
Sand/Silt/Clay	%	17
Small Gravel	%	11
Large Gravel	%	6
Small Cobble	%	19
Large Cobble	%	34
Boulder	%	13
Bedrock	%	

Figure 5.9-8 Periphyton chlorophyll *a* biomass in the High Hills River.

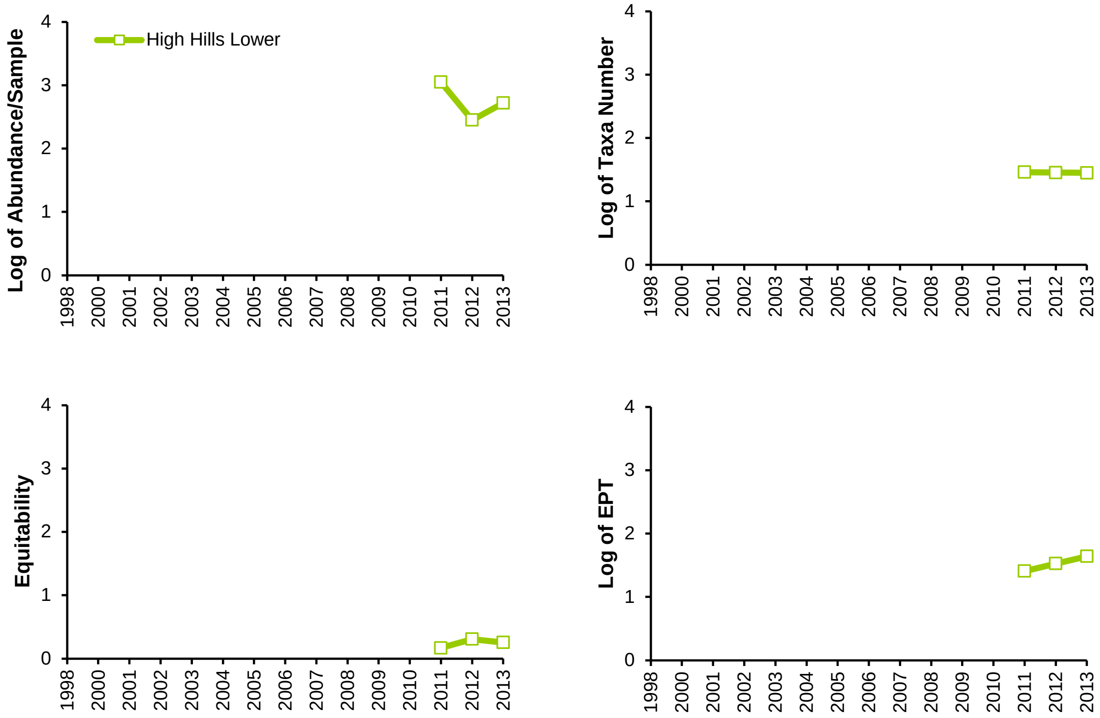


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2012.

Table 5.9-11 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community of the High Hills River.

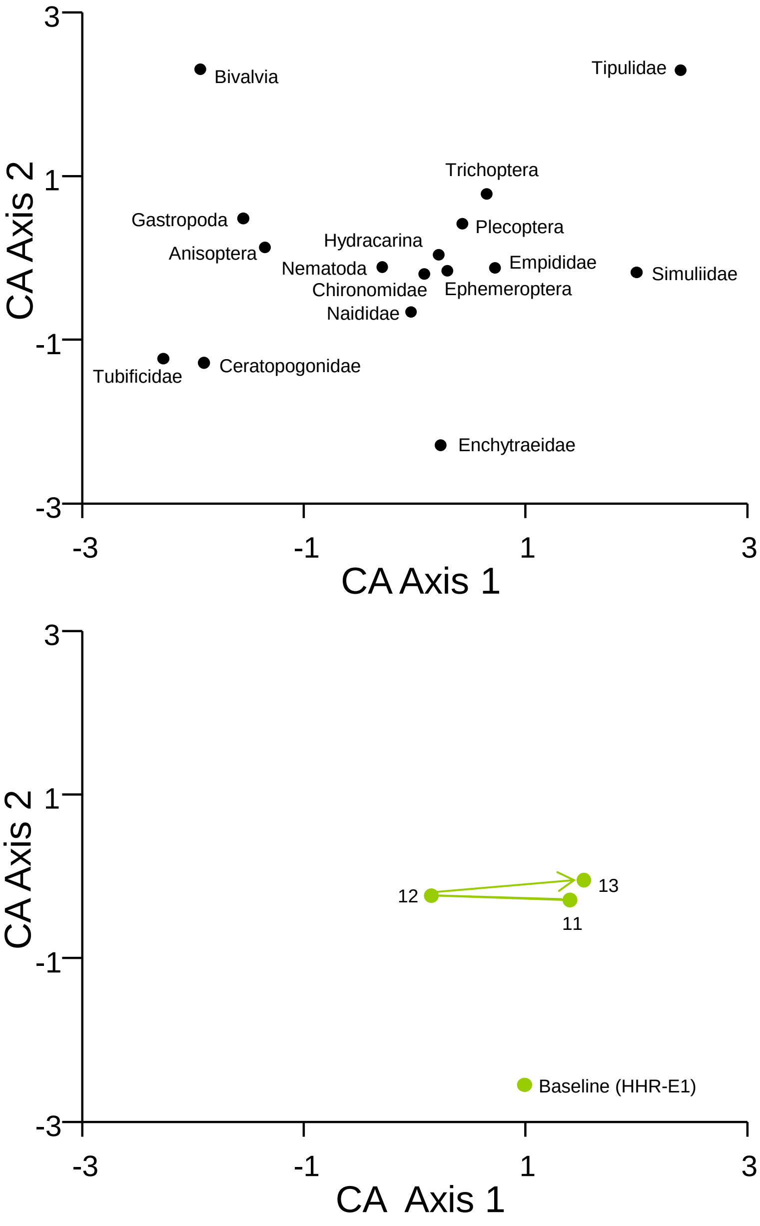
Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach HHR-E1		
	2011	**2012**	**2013**
Nematoda	<1	2	<1
Naididae	42	24	19
Tubificidae	-	2	-
Enchytraeidae	7	5	1
Hydracarina	5	5	4
Gastropoda	<1	4	-
Bivalvia	-	<1	-
Ceratopogonidae	-	3	<1
Chironomidae	13	11	23
Dolichopodidae	-	<1	-
Psychodidae	<1	-	-
Diptera (misc.)	3	3	8
Coleoptera	<1	<1	-
Ephemeroptera	19	26	36
Odonata	<1	<1	<1
Plecoptera	1	2	3
Trichoptera	6	9	7
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	1,219	362	610
Richness	30	30	28
Equitability	0.17	0.31	0.3
% EPT	27	37	46

Figure 5.9-9 Variation in benthic invertebrate community measurement endpoints in the High Hills River.



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.9-10 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the High Hills River (*baseline* reach HHR-E1).



Note: The top panel is the scatterplot of taxa scores while the bottom panel is the scatterplot of sample scores.

Table 5.9-12 Fish species composition at *baseline* (CR1, CR2) and *test* (CR3) reaches of the Clearwater River during spring, summer, and fall 2013.

Species	Spring				Summer				Fall			
	Baseline	**%**	***Test***	**%**	***Baseline***	**%**	***Test***	**%**	***Baseline***	**%**	***Test***	**%**
Arctic grayling	-	-	-	-	3	0.7	1	0.5	-	-	-	-
brook stickleback	-	-	1	0.3	-	-	-	-	-	-	-	-
burbot	-	-	-	-	-	-	-	-	2	0.6	4	1.5
emerald shiner	-	-	-	-	-	-	-	-	-	-	3	1.1
flathead chub	1	0.4	19	6.6	1	0.2	28	13.3	-	-	-	-
goldeye	6	2.3	21	7.3	20	4.4	21	10.0	-	-	5	1.8
lake chub	23	8.9	41	14.2	38	8.3	31	14.8	9	2.9	3	1.1
lake whitefish	-	-	-	-	1	0.2	-	-	-	-	-	-
longnose sucker	13	5.0	78	27.0	28	6.1	55	26.2	11	3.5	66	24.1
mountain whitefish	-	-	-	-	-	-	-	-	1	0.3	-	-
northern redbelly dace	1	0.4	7	2.4	-	-	-	-	-	-	-	-
northern pike	5	1.9	11	3.8	41	9.0	4	1.9	24	7.7	18	6.6
slimy sculpin	1	0.4	-	-	-	-	1	0.5	6	1.9	13	4.7
spoonhead sculpin	3	1.2	-	-	-	-	-	-	1	0.3	4	1.5
spottail shiner	91	35.1	8	2.8	190	41.6	5	2.4	42	13.5	15	5.5
trout-perch	25	9.7	26	9.0	6	1.3	11	5.2	22	7.1	50	18.2
walleye	5	1.9	29	10.0	12	2.6	25	11.9	5	1.6	21	7.7
white sucker	85	32.8	48	16.6	113	24.7	22	10.5	184	59.0	70	25.5
yellow perch	-	-	-	-	4	0.9	6	2.9	5	1.6	2	0.7
Total # Species	**12**	**-**	**15**	**-**	**12**	-	**16**	-	**12**	-	**13**	-
Total # Fish	**259**	**100**	**289**	**100**	**457**	**100**	**210**	**100**	**312**	**100**	**274**	**100**

Figure 5.9-11 Total catch and number of species captured during the Clearwater River spring, summer, and fall fish inventories, 2003 to 2013.

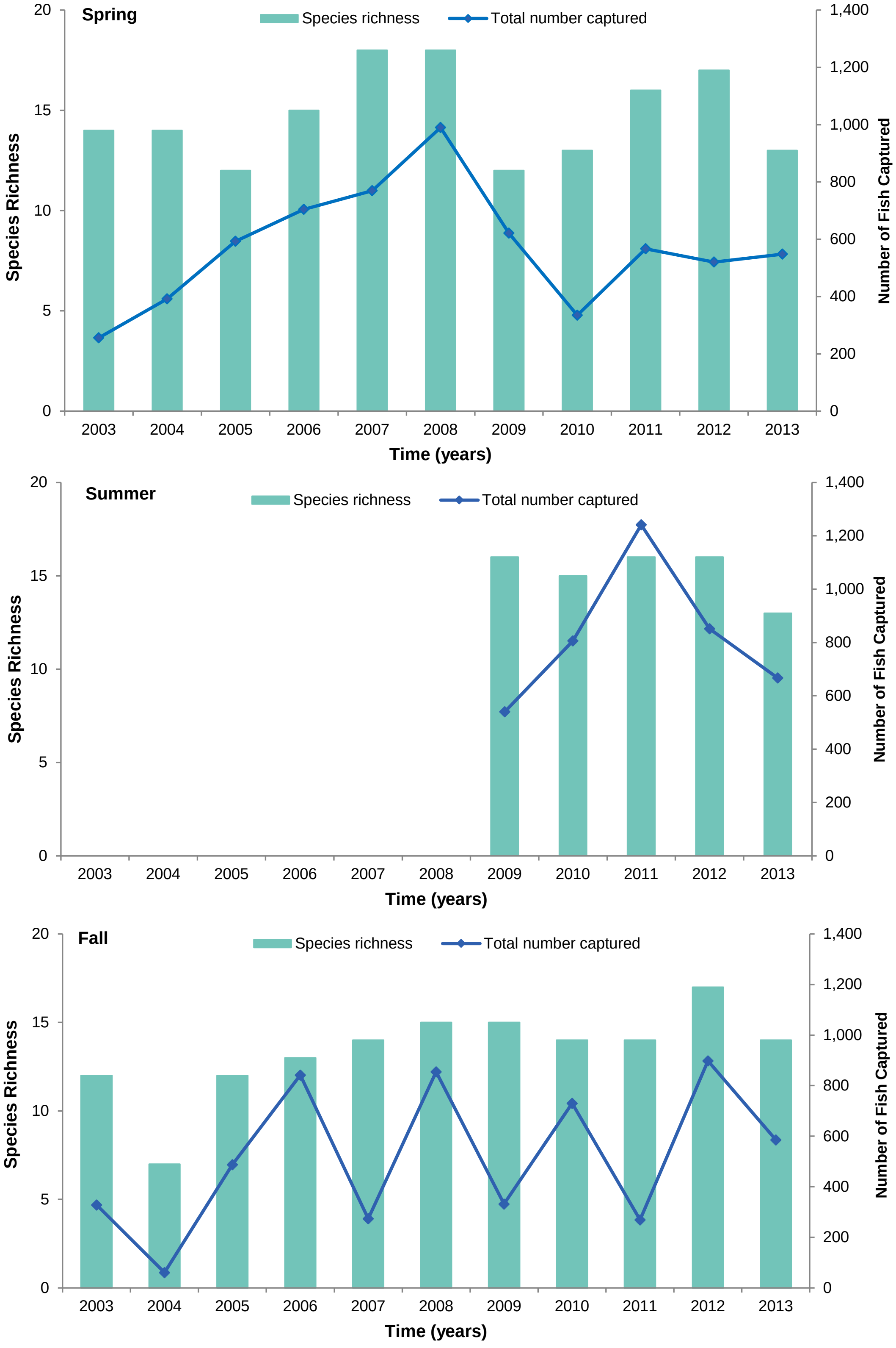
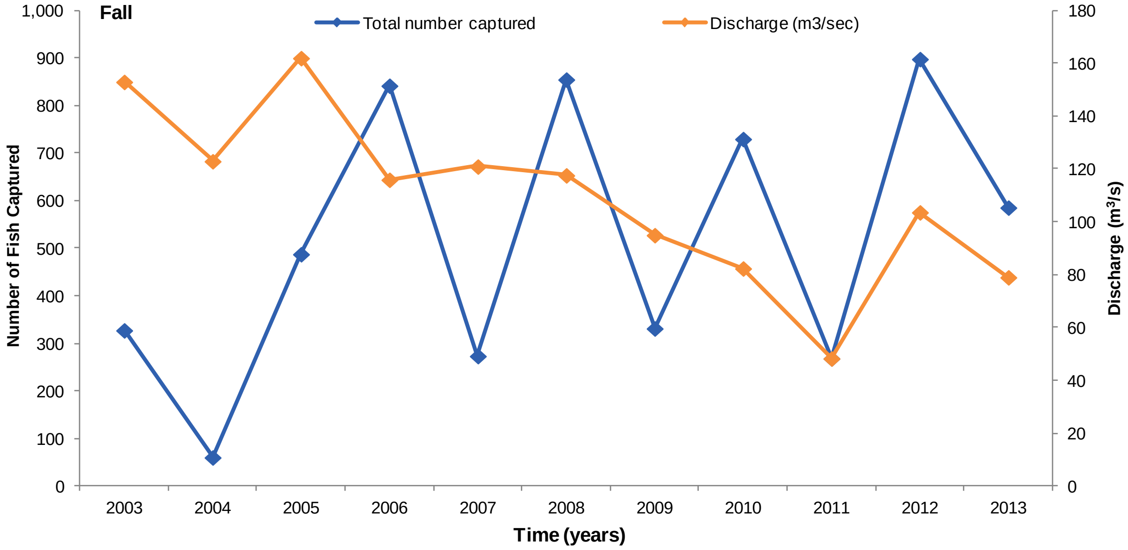


Figure 5.9-12 **Relationship between total catch and discharge (m^3/s) of the Clearwater River, Fall 2003 to 2013.**



Note: Discharge data were taken from WSC hydrology station 07CD001 from 2003 to 2008; discharge data from 2009 to 2013 were taken from RAMP hydrology station S42.

Figure 5.9-13 **Number of species captured in *test* and *baseline* reaches during the Clearwater River spring, summer, and fall fish inventories, 2003 to 2013.**

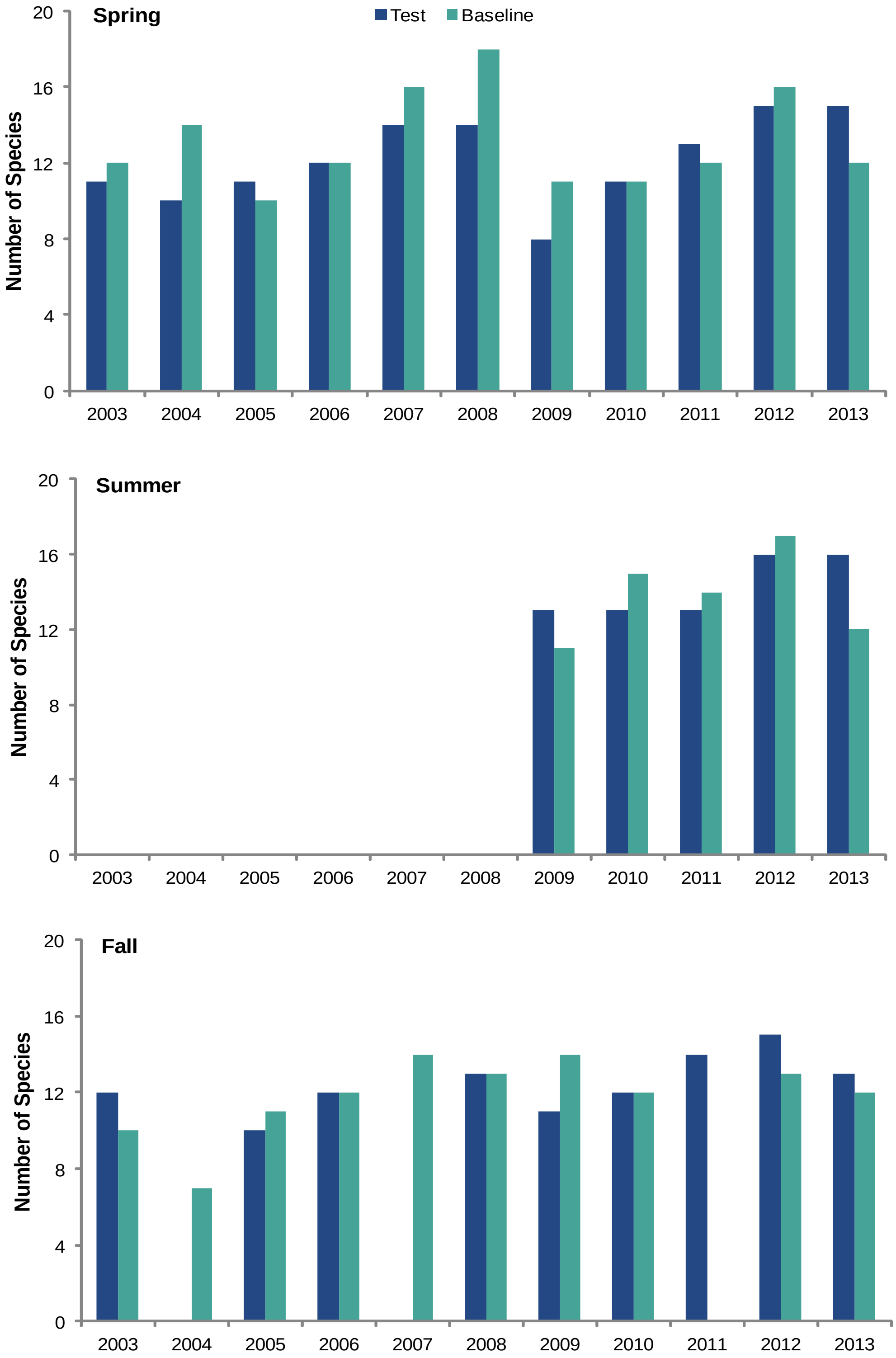


Figure 5.9-14 Seasonal catch per unit effort (CPUE ± 1SD) of large-bodied KIR fish species and other species at *test* and *baseline* reaches in the Clearwater River, 2013.

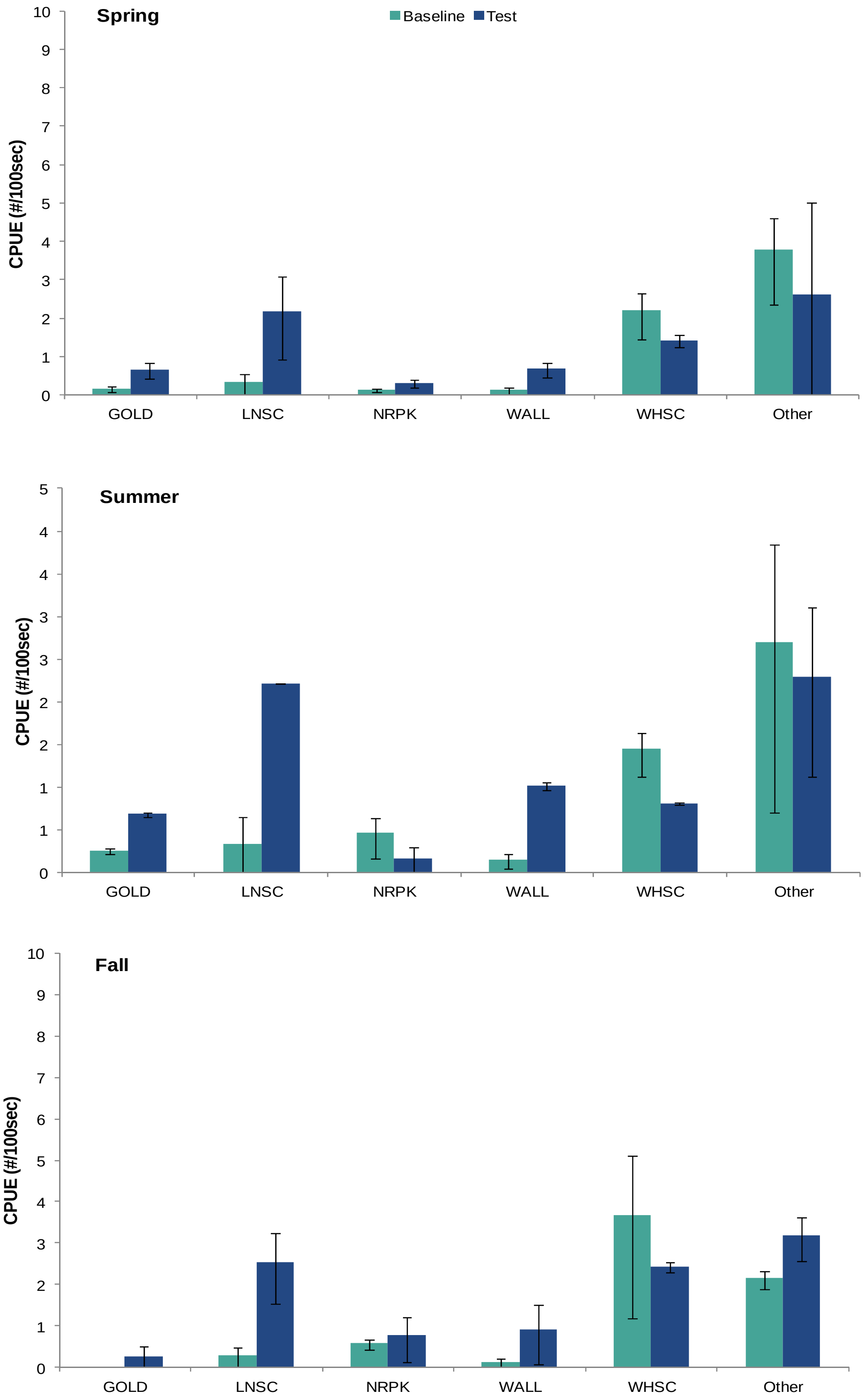


Figure 5.9-15 Seasonal catch per unit effort (CPUE ± 1SD) of large-bodied KIR fish species and other species in the Clearwater River, 2003 to 2013.

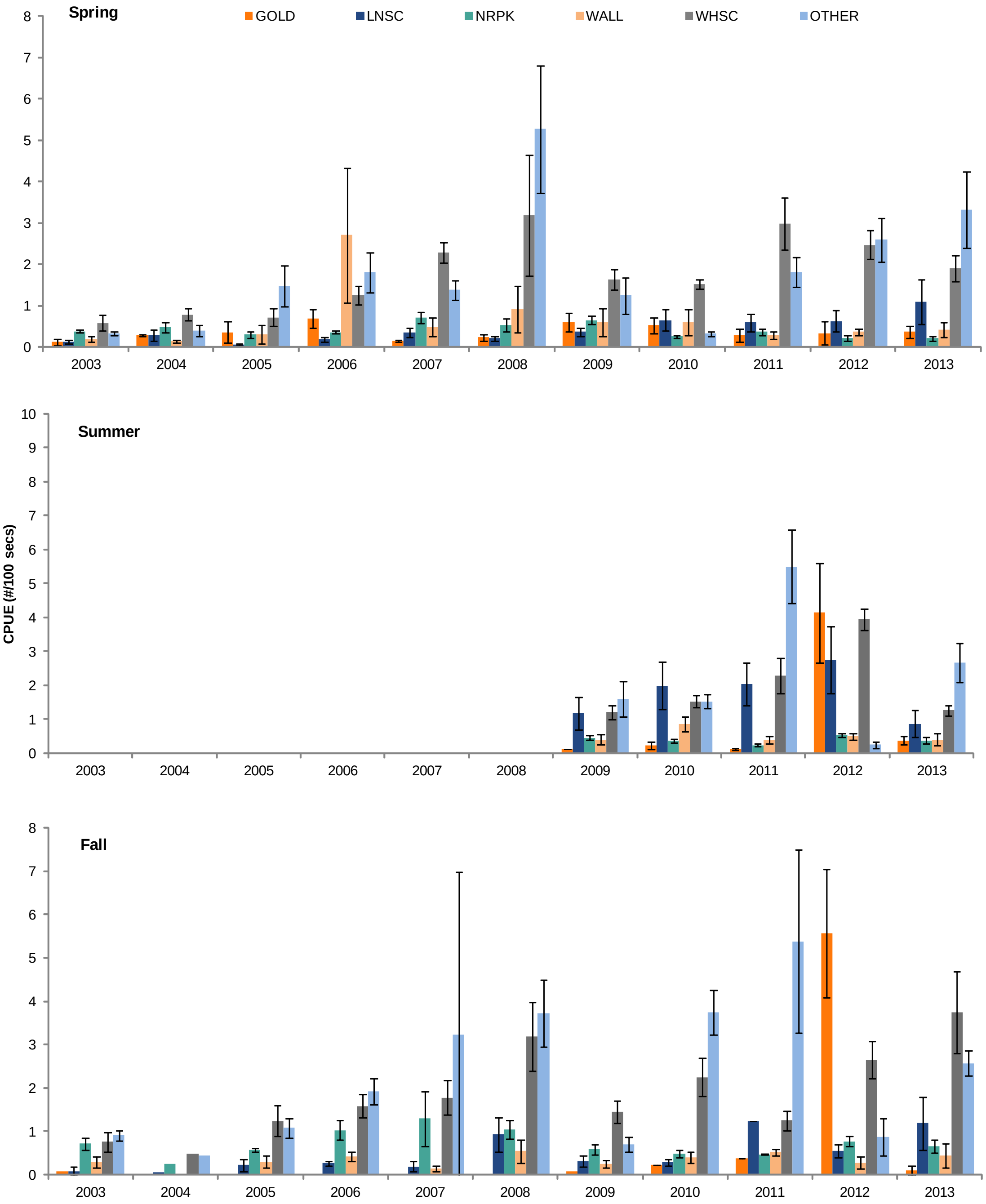
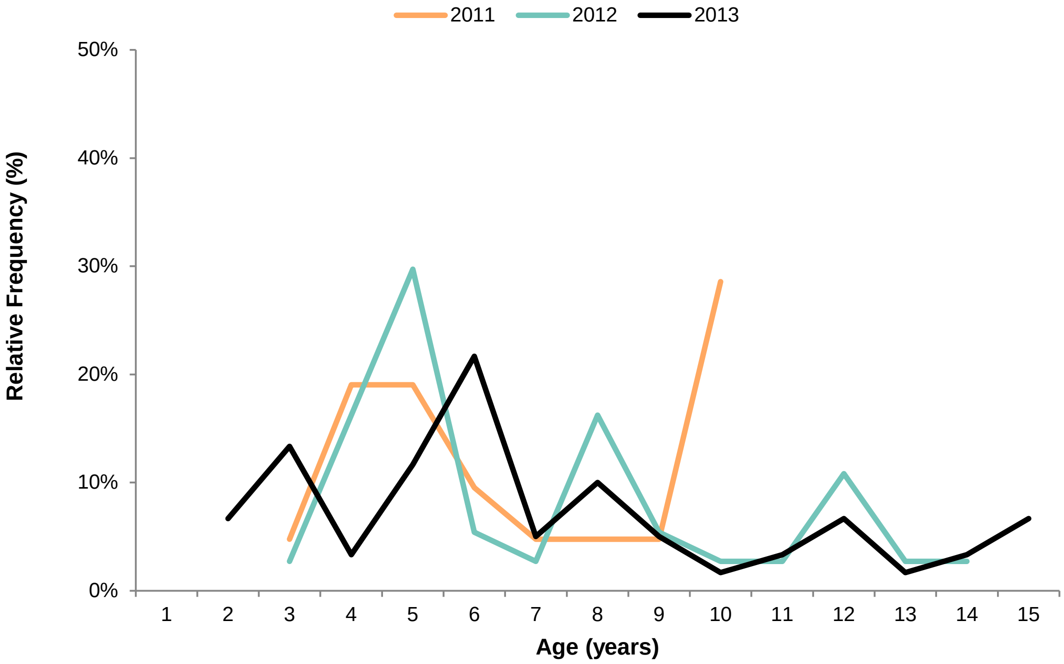


Figure 5.9-16 Relative age-frequency distributions and size-at-age relationships for goldeye in spring, summer, and fall, 2011 to 2013.



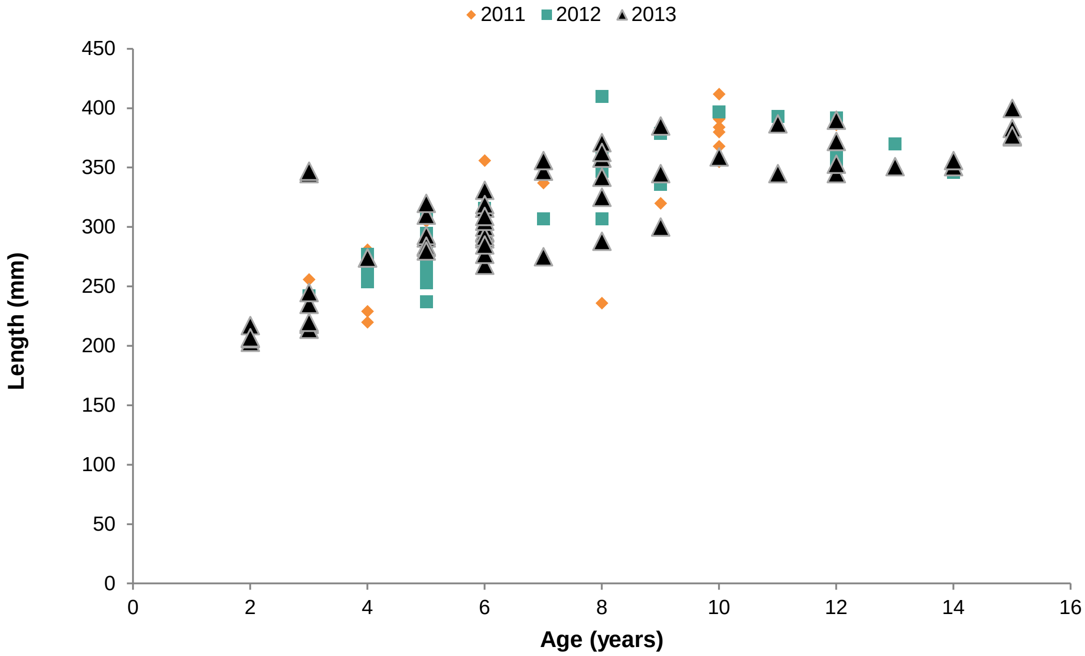
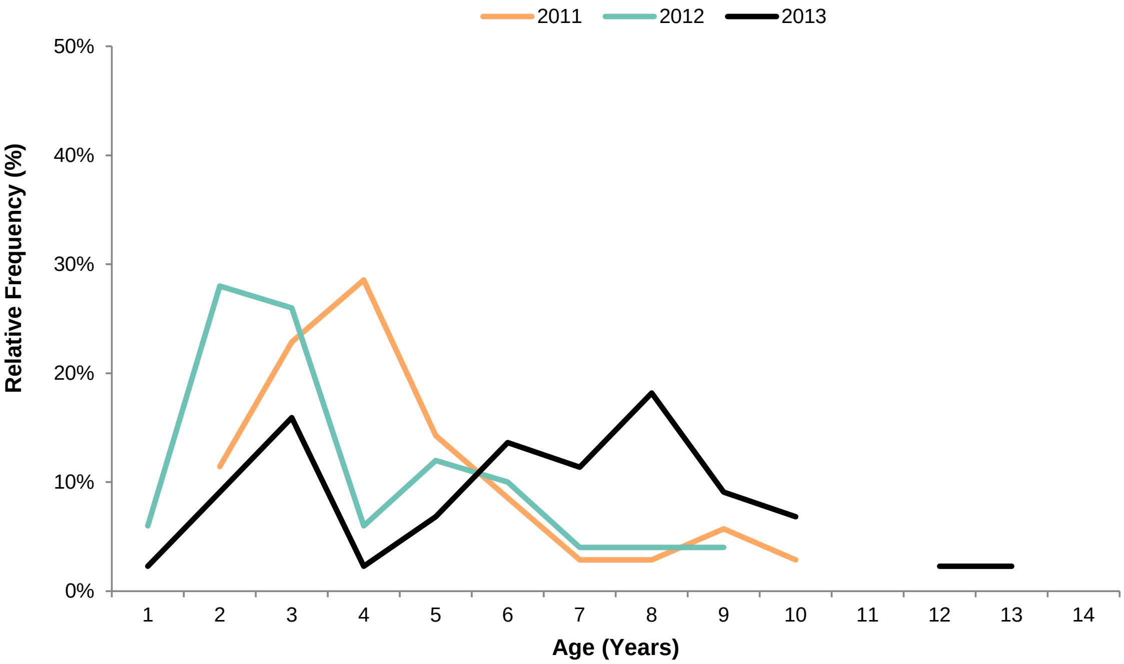


Figure 5.9-17 Relative age-frequency distributions and size-at-age relationships for longnose sucker in spring, summer, and fall, 2004 to 2013.



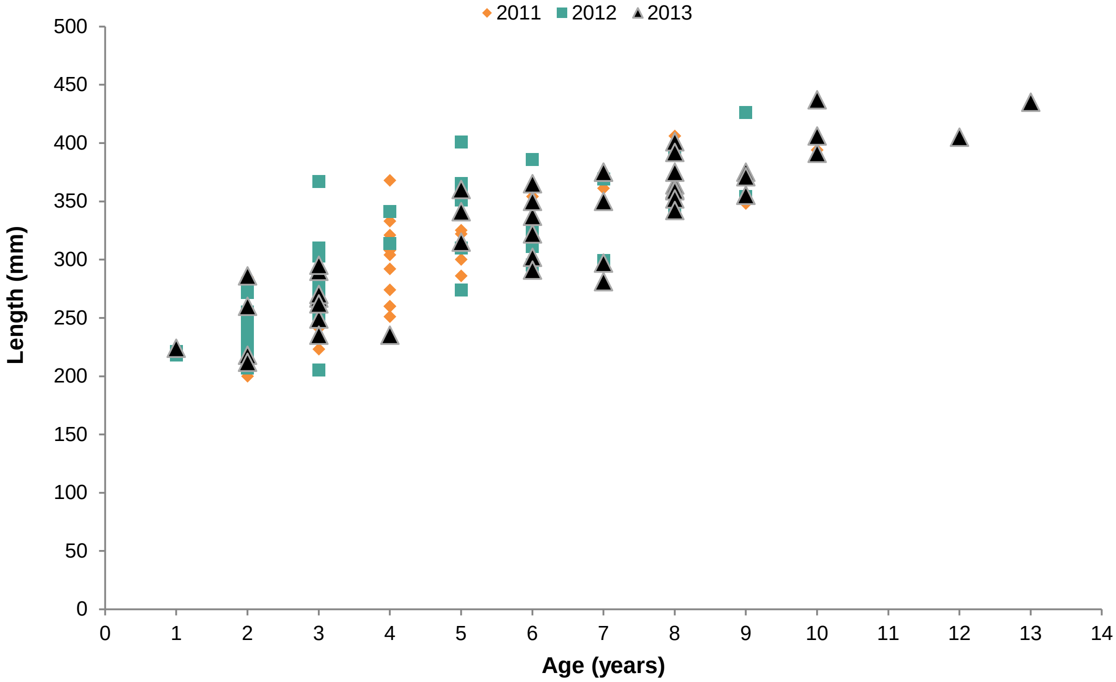
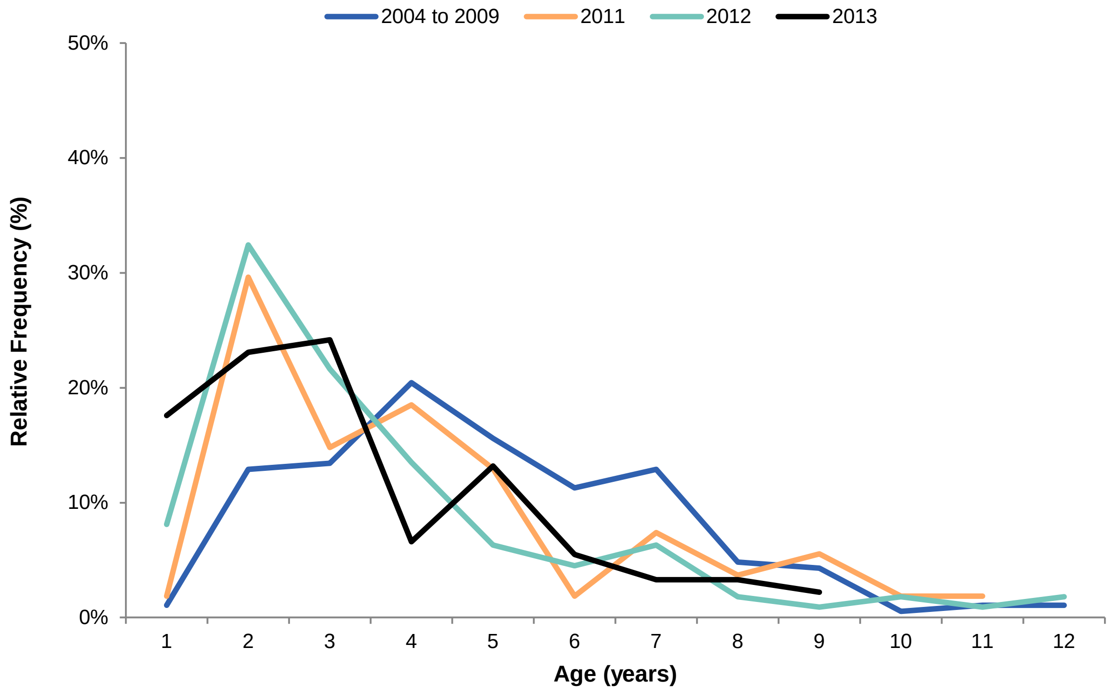


Figure 5.9-18 Relative age-frequency distributions and size-at-age relationships for northern pike in spring, summer, and fall, 2004 to 2013.



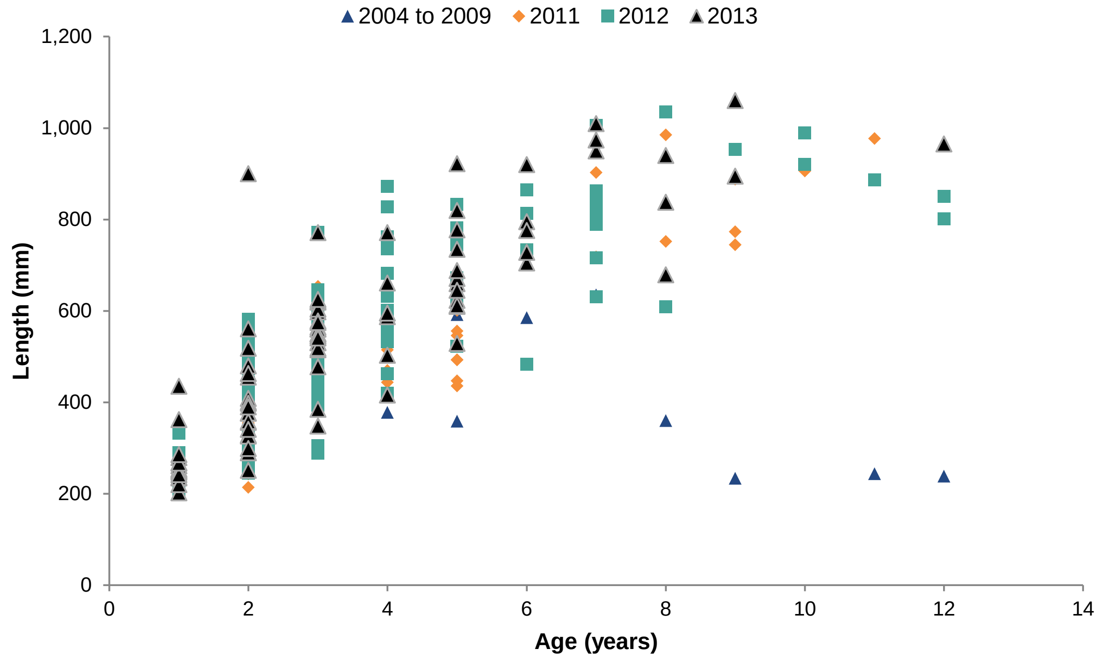
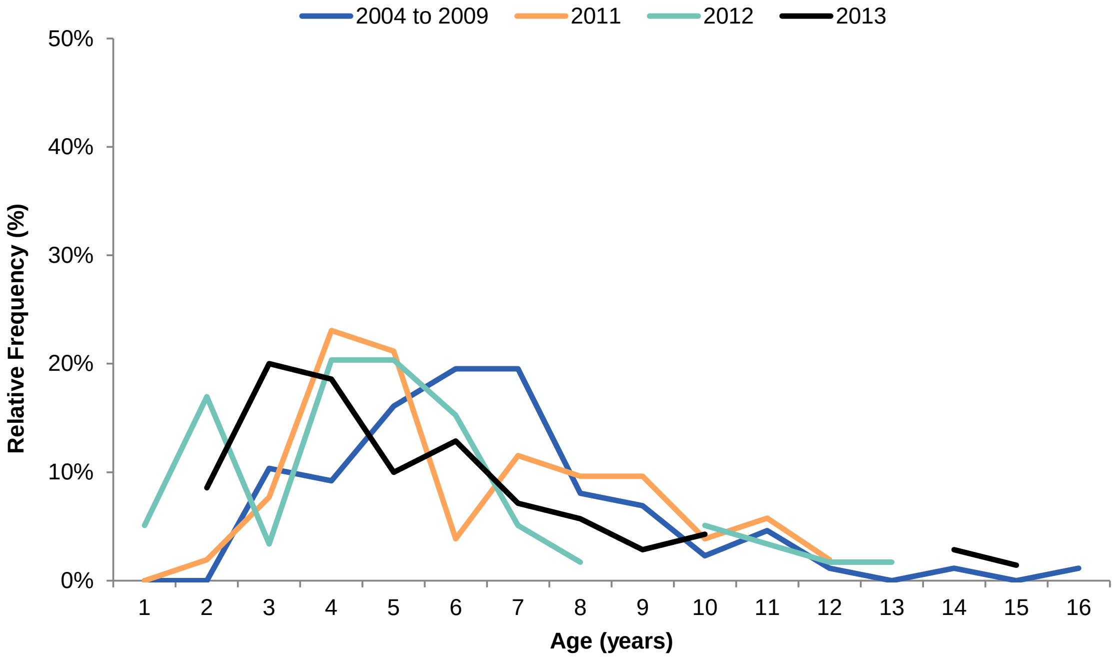


Figure 5.9-19 Relative age-frequency distributions and size-at-age relationships for walleye in spring, summer, and fall, 2004 to 2013.



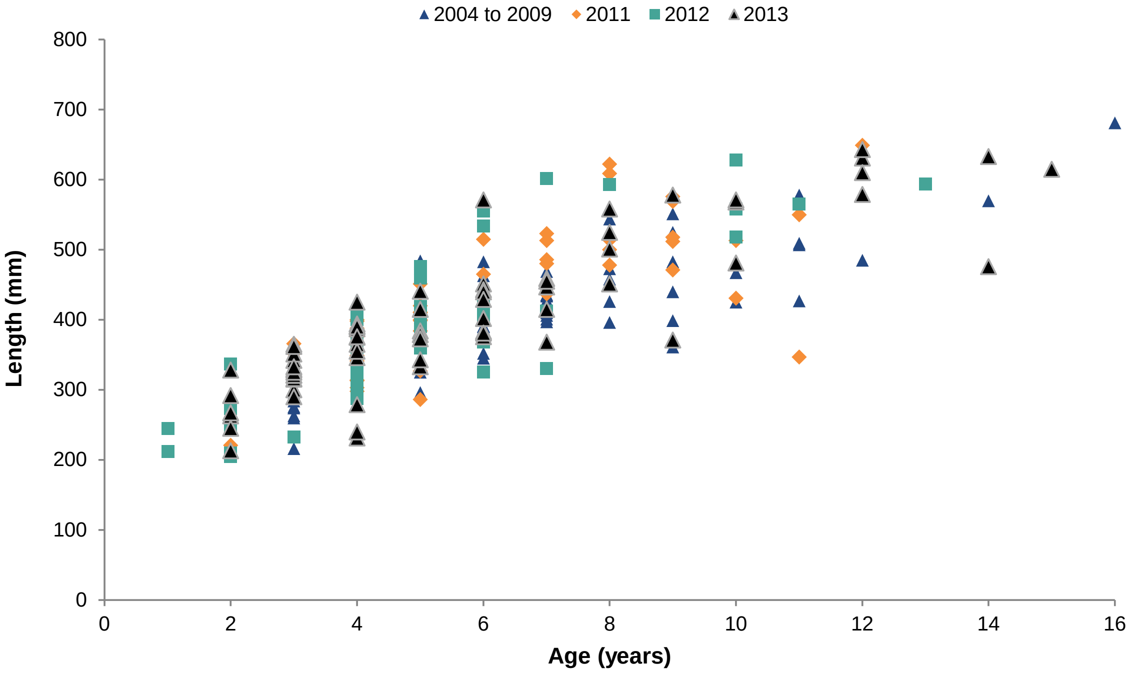
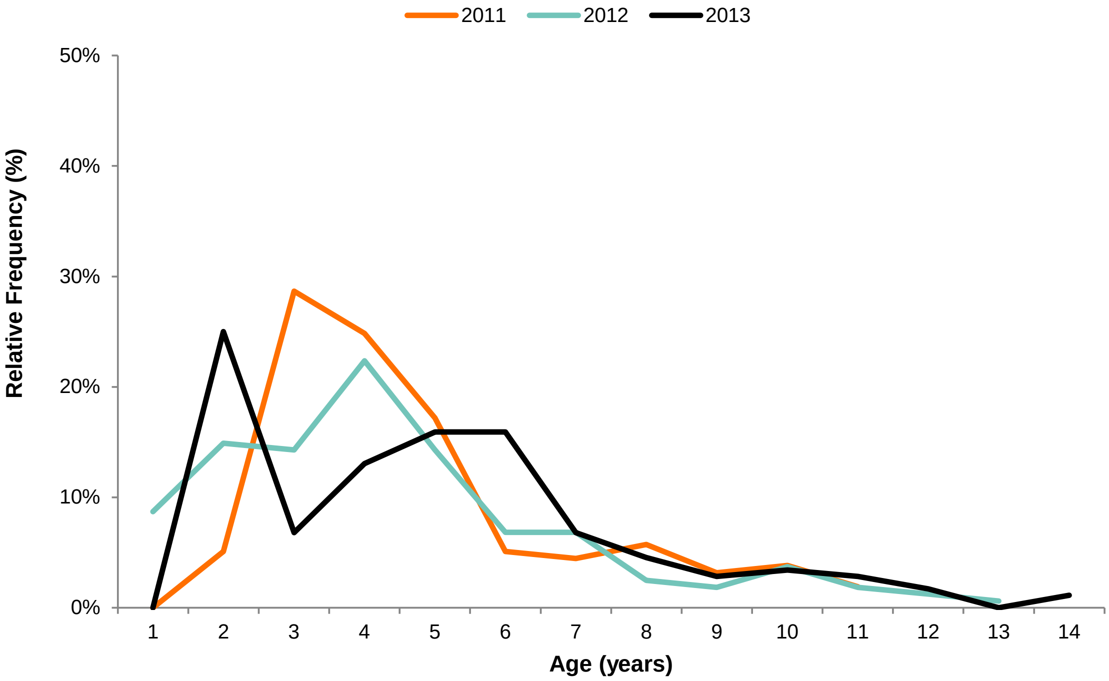


Figure 5.9-20 Relative age-frequency distributions and size-at-age relationships for white sucker in spring, summer, and fall, 2011 to 2013.



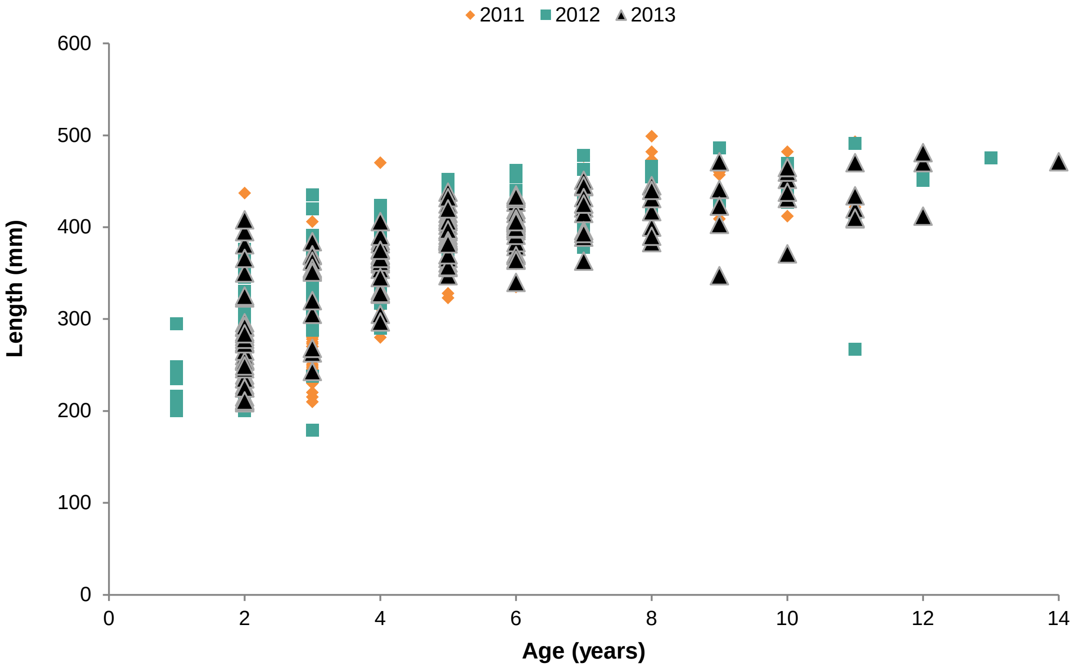
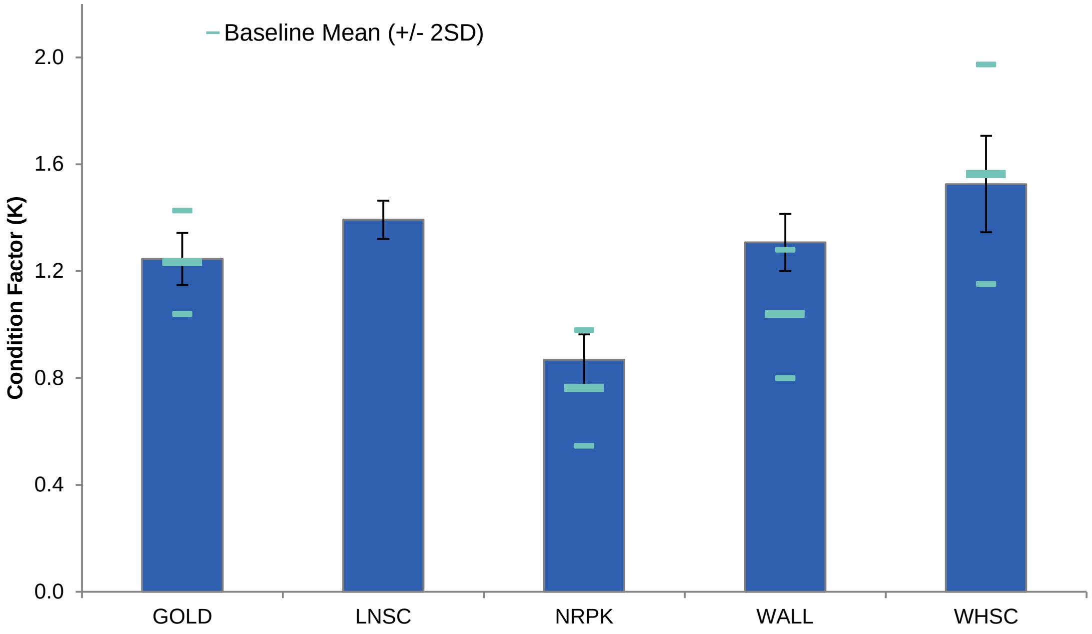


Figure 5.9-21 **Condition factor (±2SD) for large-bodied KIR fish species captured in *test* areas of the Clearwater River during the summer and fall fish inventories, relative to the *baseline* range of variability, 2013.**

Summer



Fall

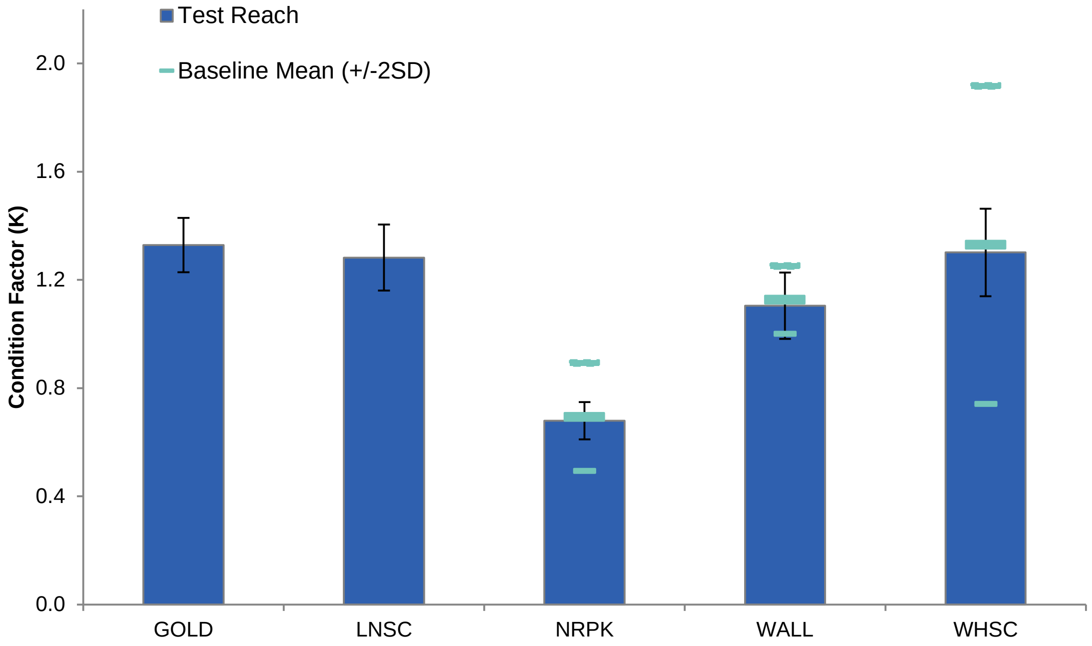
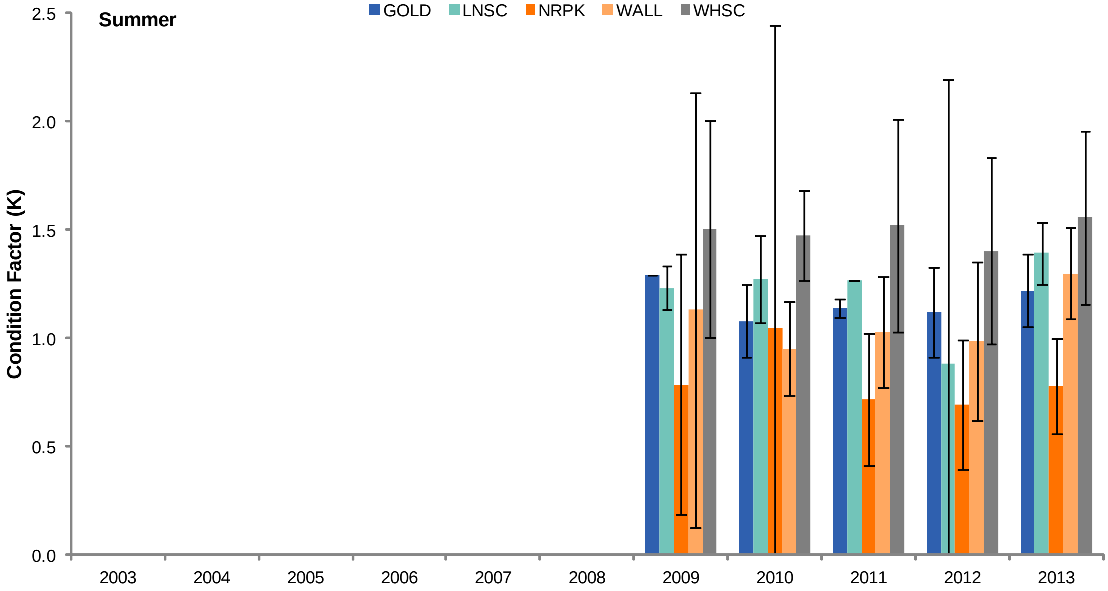


Figure 5.9-22 Condition factor (±2SD) for large-bodied KIR fish species captured in the Clearwater River, summer and fall 2003 to 2013.



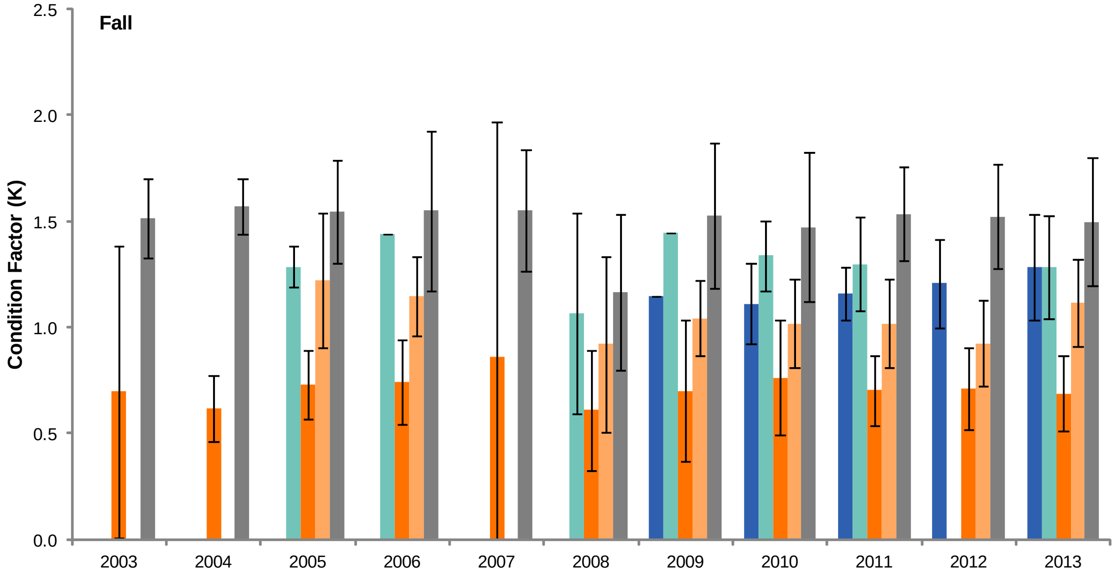


Table 5.9-13 Percent of total fish captured by species with external pathology (i.e., growth/lesion, deformity, and parasite), 2003 to 2013.

Year	% Growth/Lesion	% Deformity (body/fins)	% Parasites	Total # fish
1999	2.78	1.39	1.39	72
2003	0.17	0.51	0.17	584
2004	0.00	0.00	0.88	453
2005	0.19	0.00	0.00	1,081
2006	0.26	0.13	0.65	1,546
2007	0.38	0.19	0.48	1,043
2008	0.49	0.05	0.60	1,845
2009	0.27	0.13	1.67	1,493
2010	0.53	0.21	0.64	1,871
2011	0.19	0.14	0.24	2,077
2012	0.22	0.31	0.13	2,271
2013	0.44	0.22	0.06	1,801

Figure 5.9-23 Percent of total fish captured in the Clearwater River with external pathology, 2003 to 2013.

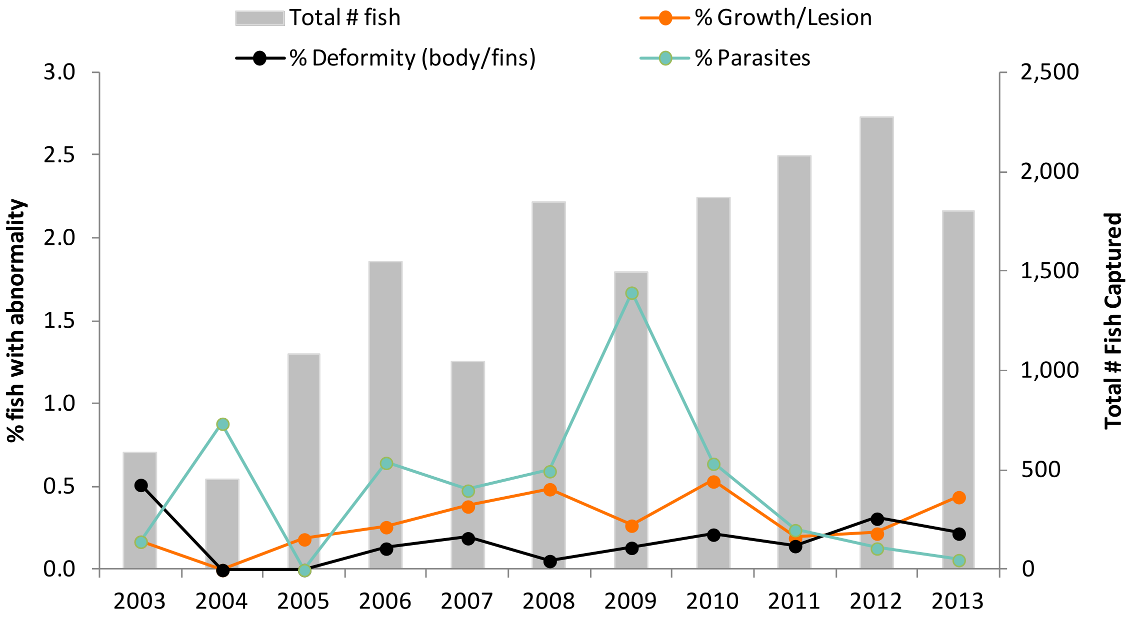


Table 5.9-14 Average habitat characteristics of fish assemblage monitoring locations of High Hills River, fall 2013.

Variable	Units	HHR-F1 Lower *Baseline* Reach of the High Hills River
Sample date	-	Sept 13, 2013
Habitat type	-	run/riffle
Maximum depth	m	1.06
Mean depth	m	0.49
Bankfull channel width	m	30.5
Wetted channel width	m	18.5
Substrate		
Dominant	-	coarse gravel
Subdominant	-	sand
Instream cover		
Dominant	-	large woody debris, small woody debris, overhanging vegetation, boulders
Subdominant	-	undercut banks
Field water quality		
Dissolved oxygen	mg/L	10.0
Conductivity	µS/cm	233
pH	pH units	8.25
Water temperature	^{0}C	12.3
Water velocity		
Left bank velocity	m/s	0.59
Left bank water depth	m	0.74
Centre of channel velocity	m/s	0.64
Centre of channel water depth	m	0.68
Right bank velocity	m/s	0.43
Right bank water depth	m	0.38
Riparian cover – understory (<5 m)		
Dominant	-	overhanging vegetation
Subdominant	-	woody shrubs and saplings

Table 5.9-15 Total number and percent composition of fish species captured at the lower reach of the High Hills River, 2011 to 2013.

Common Name	Code	Total Species			Percent of Total Catch		
		Baseline Reach HHR-F1			*Baseline* Reach HHR-F1		
		2011	**2012**	**2013**	**2011**	**2012**	**2013**
burbot	BURB	-	1	1	0	2	2.1
finescale dace	FNDC	-	2	-	0	4	0
lake chub	LKCH	-	-	4	0	0	8.3
lake whitefish	LKWH	-	-	-	0	0	0
longnose dace	LNDC	8	-	8	8	0	16.7
longnose sucker	LNSC	22	-	13	22	0	27.1
slimy sculpin	SLSC	47	48	18	47	94	37.5
spoonhead sculpin	SPSC	6	-	1	6	0	2.1
trout-perch	TRPR	-	-	1	0	0	2.1
walleye	WALL	-	-	-	0	0	0
white sucker	WHSC	17	-	1	17	0	2.1
sucker sp. *		-	-	1	0	0	2.1
Total Count		**100**	**51**	**48**	**100**	**100**	**100**
Total Species Richness		**5**	**3**	**8**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,355**	**1,520**	**2,027**	**-**	**-**	**-**

* not included in total species richness count.

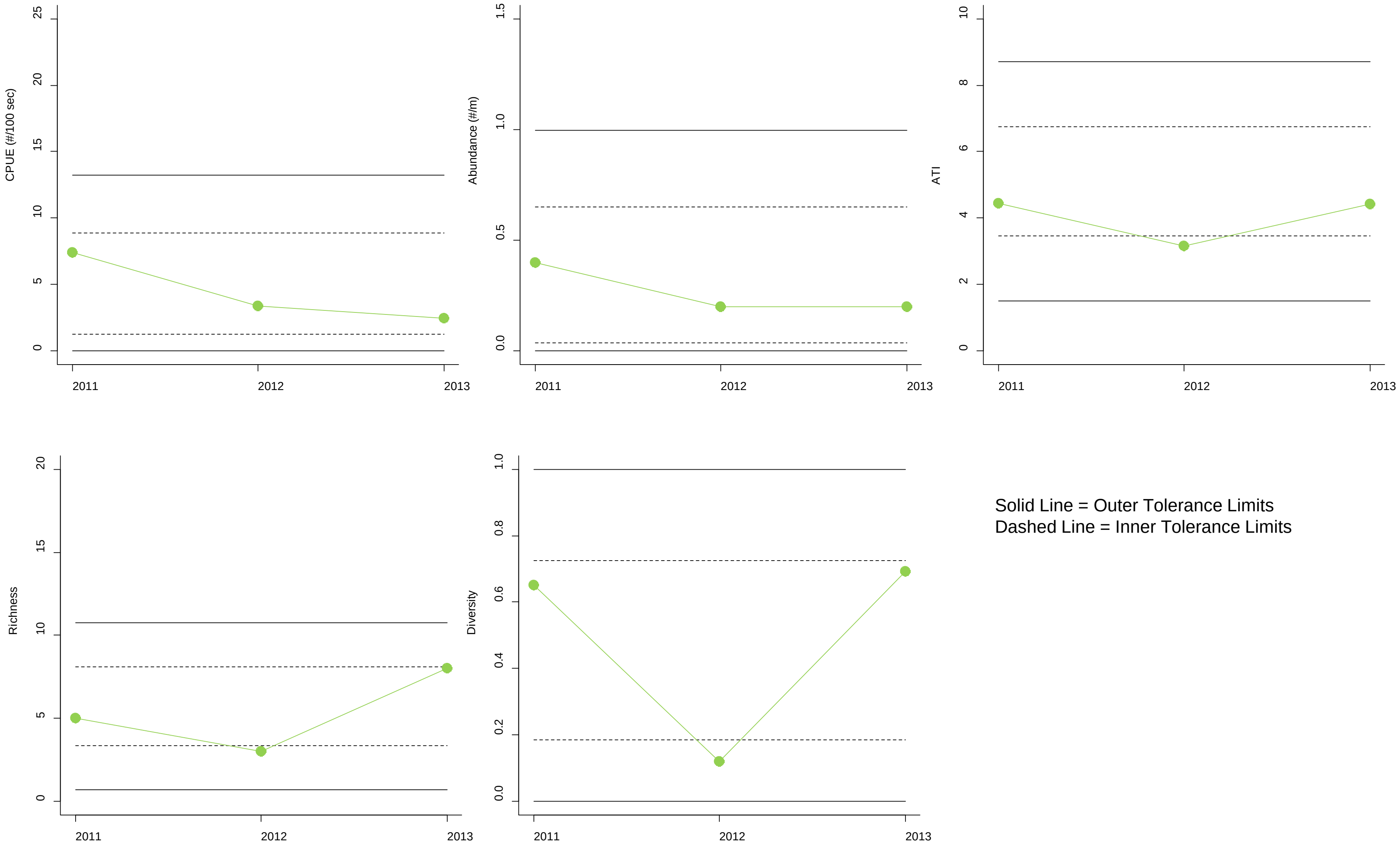
Table 5.9-16 Summary of fish assemblage measurement endpoints for *baseline* reach HHR-F1 in the High Hills River, 2011 to 2013.

Year	Abundance		Richness*			Diversity*		ATI*		CPUE	
	Mean	**SD**	**Total**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
2011	0.40	0.09	5	5	0.55	0.65	0.08	4.44	0.67	7.40	1.66
2012	0.20	0.07	3	2	0.89	0.12	0.16	3.17	0.26	3.36	1.21
2013	0.20	0.04	8	5	1.14	0.69	0.06	4.42	0.41	2.47	1.26

* unknown species not included in calculation.

SD = standard deviation across sub-reaches within a reach.

Figure 5.9-24 Variation in fish assemblage measurement endpoints in the High Hills River from 2011 to 2013, relative to regional *baseline* conditions.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using all available *baseline* erosional data.

5.10 CHRISTINA RIVER WATERSHED

Table 5.10-1 Summary of results for the Christina River watershed.

Christina River Watershed	Summary of 2013 Conditions											
	Christina River				*Tributaries to Christina Lake*							*Lakes*
Climate and Hydrology												
Criteria	**S47A** near the mouth	**07CE002/S29** near Chard			**SAC-1** Sawbones Creek	**SUC-1** Sunday Creek					**JAR-1** Jackfish River at the mouth	**07CE906** Christina Lake
Mean open-water season discharge	🟡	not measured			not measured	not measured					not measured	not measured
Mean winter discharge	🟡	not measured			not measured	not measured					not measured	not measured
Annual maximum daily discharge	🟡	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
Water Quality												
Criteria	**CHR-1** at the mouth	**CHR-2** upstream of Janvier	**CHR-3** upstream of Jackfish River	**CHR-4** upstream of development	**SAC-1** Sawbones Creek	**SUC-1** Sunday Creek at Christina Lake inlet	**SUC-2** upstream	**UNC-2** east of Christina Lake	**UNC-3** south of Christina Lake	**BRC-1** Birch Creek	**JAR-1** Jackfish River at the mouth	**CHL-1** Christina Lake
Water Quality	🟡	🟡	🟡	🟠	🟡	🟡	🟡	🟡	🟡	🟠	🟡	n/a
Benthic Invertebrate Communities and Sediment Quality												
Criteria	**CHR-D1** at the mouth	**CHR-D2** upstream of Janvier	**CHR-E3** upstream of Jackfish River	**CHR-D4** upstream of development	**SAC-D1** Sawbones Creek	**SUC-D1** Sunday Creek at Christina Lake inlet	**SUC-D2** upstream	**UNC-D2** east of Christina Lake	**UNC-D3** south of Christina Lake	**BRC-D1** Birch Creek	**JAR-E1** Jackfish River at the mouth	**CHL-1** Christina Lake
Benthic Invertebrate Communities	not sampled	not sampled	n/a	n/a	🟡	🟡	n/a	🟡	🟡	n/a	🟡	🟡
Sediment Quality Index	not sampled	not sampled	n/a	🟡	🟡	🟡	🟡	🟡	🟡	🟡	n/a	n/a
Fish Populations												
Criteria	**CHR-F1** at the mouth	**CHR-F2** upstream of Janvier	**CHR-F3** upstream of Jackfish River	**CHR-F4** upstream of development	**SAC-F1** Sawbones Creek	**SUC-F1** Sunday Creek at Christina Lake inlet	**SUC-F2** upstream	**UNC-F2** east of Christina Lake	**UNC-F3** south of Christina Lake	**BRC-F1** Birch Creek	**JAR-F1** Jackfish River at the mouth	**CHL-1** Christina Lake
Fish Assemblages	not sampled	not sampled	🟡	n/a	🟤	🟡	n/a	🟤	🟤	n/a	🟡	n/a
Human Health	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	not sampled	Sub[2] Gen[2] LKWH[1] 🟡 🟡 NRPK[1] 🟤 🟠 WALL[1] 🟤 🟠

Legend and Notes

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

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

[1] Species (Sp.): LKWH=lake whitefish; NRPK=northern pike; WALL=walleye

[2] Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.2.4.2)

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.

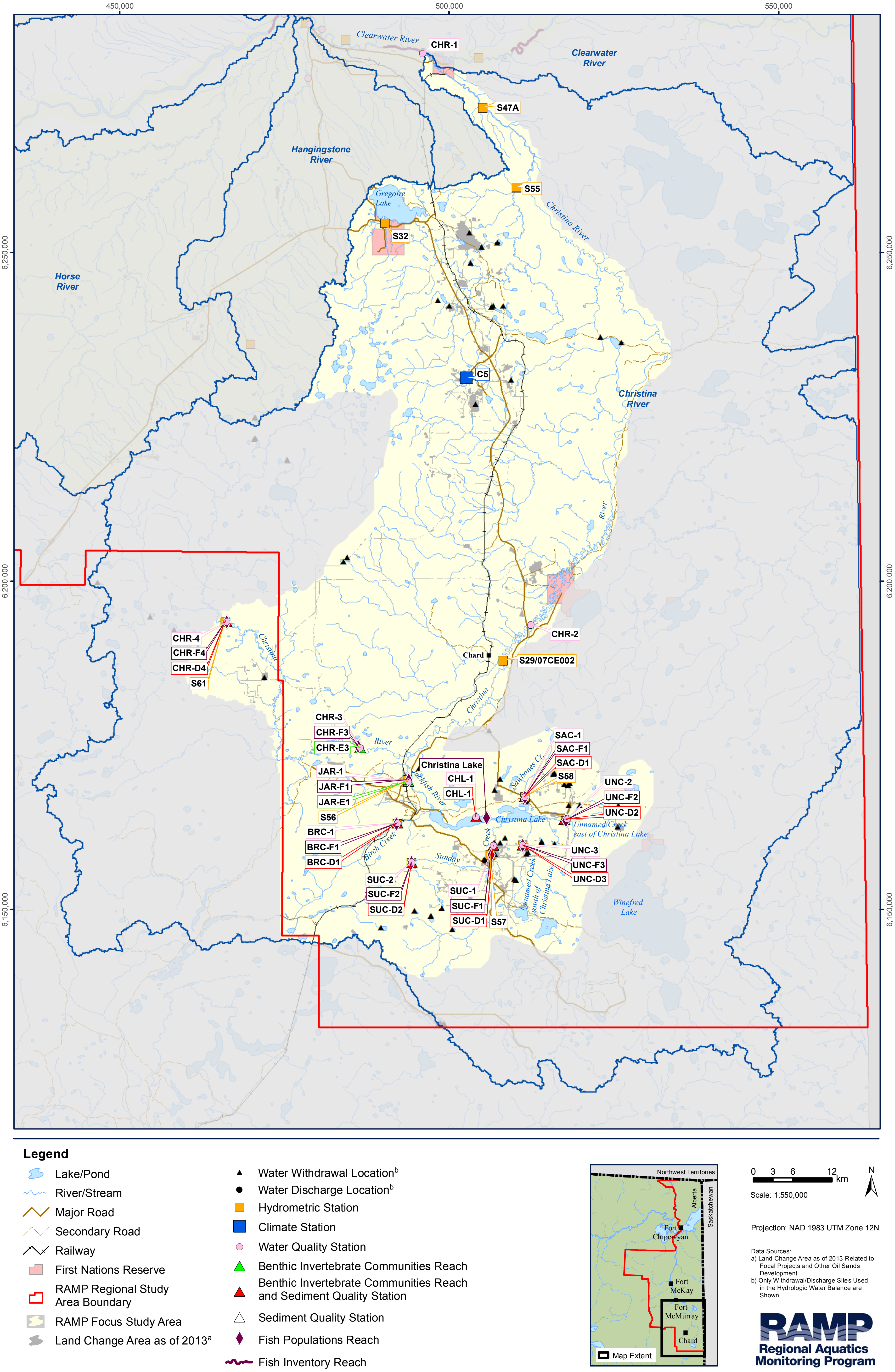
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* areas as well as comparison to regional *baselines*; see Section 3.2.3.1 for a detailed description of the classification methodology.

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.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Fish Populations (human health): Uses various Health Canada criteria for risks to human health from fish tissue concentrations of mercury, see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.10-1 Christina River watershed.



Data Sources:
a) Land Change Area as of 2013 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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K10_Christina_20140307_ss.mxd

Figure 5.10-2 Representative monitoring stations of the Christina River watershed, fall 2013.

Benthic and Sediment Quality Reach CHR-D4 (Christina River): Left Downstream Bank

Benthic and Sediment Quality Reach UNC-D3 (Unnamed Creek south of Christina Lake): facing downstream

Benthic Reach JAR-E1 (Jackfish River): facing upstream

Benthic and Sediment Quality Reach SUC-D2 (Sunday Creek): facing downstream

Hydrology Station S47A (Christina River near the mouth): facing downstream

Benthic and Sediment Quality Reach BRC-D1 (Birch Creek): facing downstream

5.10.1 Summary of 2013 Conditions

As of 2013, approximately 1% (12,269 ha) of the Christina River watershed had undergone land change from focal projects and other oil sands developments (Table 2.5-1). The Christina River watershed downstream of the Statoil project near the upper portion of the watershed, and the Cenovus, MEG Energy, and Devon projects surrounding Christina Lake is designated as *test*. The tributaries flowing in (e.g., Sawbones and Sunday creeks) and out (Jackfish River) of Christina Lake 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 2013. Table 5.10-1 is a summary of the 2013 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 2013. Figure 5.10-2 contains photos of representative monitoring stations in the watersheds.

Hydrology The 2013 WY water balance was calculated for two difference cases: (i) only focal projects in the Christina River watershed; and (ii) focal projects plus other oil sands developments in the Christina River watershed. The calculated mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge for the first case were 0.05%, 0.05%, and 0.06% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph and for the second case were 0.05%, 0.06%, and 0.06% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.** The mean winter discharge for both cases was 0.06% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

In the 2013 WY, water levels in Christina Lake generally decreased from November 2012 to mid-April 2013. Lake levels increased during freshet in early May to a freshet peak level of 554.907 masl on May 13, before decreasing until early June. Rainfall events in mid-June increased lake levels beyond the historical maximum levels and peaked at 555.335 masl on June 17. This peak lake level was the maximum daily level recorded in the 2013 WY and was 0.661 m higher than the historical mean annual maximum daily lake level. Lake levels steadily decreased from mid-July until the end of the 2013 WY.

Flows in Jackfish River increased during spring freshet and exceeded the historical maximum on May 13. Flows also increased in response to rainfall events in mid-June, exceeding the historical maximum flows from June 11 to July 21, 2013. The peak flow of 65.2 m^3/s on June 17, was the highest flow recorded from available data in the 2013 WY, and was 370% higher than the historical mean open-water maximum daily flow. Following this peak, flows sharply decreased until early July, and then increased due to rainfall events in mid-July. Flows generally decreased from mid-July to September, with values generally remaining above the historical median values.

Water Quality In fall 2013, water quality at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* station SUC-2 indicated **Negligible-Low** differences from regional *baseline* conditions. *Baseline* stations CHR-4 and BRC-1 indicated **Moderate** differences from regional *baseline* water quality conditions given that concentrations of several water quality measurement endpoints (e.g., total metals and nutrients) exceeded relevant guidelines and regional *baseline* conditions in 2013.

Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* station CHR-1. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months. The highest number of water quality guideline exceedances occurred in May, June, and July, which were also the months where maximum yearly concentrations were most frequently reached.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for benthic invertebrate communities at *test* reach CHR-E3 were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the normal range of variation for means from regional *baseline* erosional reaches. In addition the benthic fauna at *test* reach CHR-E3 in fall 2013, were representative of good overall water quality, with high taxa richness and percentage of the fauna as EPT taxa.

Differences in measurement endpoints at *test* reach SUC-D1 were classified as **Negligible-Low.** *Test* reach SUC-D1 contained a benthic invertebrate community representative of a healthy depositional reach. Flying insects and permanent aquatic forms (snails, fingernail clams) complimented a diverse fauna of chironomids. Low overall abundance of worms suggested favourable water quality conditions in fall 2013 at *test* reach SUC-D1.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were classified as **Negligible-Low.** All measurement endpoints, with the exception of richness were within the range of regional *baseline* conditions for depositional reaches. Richness has been high at *test* reach SAC-D1 in both 2012 and 2013, which was not considered to be a negative change. In addition, the benthic invertebrate community of *test* reach SAC-D1 was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects, and a low diversity of worms.

Differences in measurement endpoints of benthic invertebrate communities at *test* reaches UNC-D2 and UNC-D3 were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of variability for regional *baseline* depositional reaches. Richness was above the range of *baseline* variability in 2013 and equitability was just below the lower inner tolerance limit, both of which were indicative of a more diverse community compared to regional *baseline* reaches. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects.

Differences in measurement endpoints of the benthic invertebrate community at *test* station CHL-1 in fall 2013 were classified as **Negligible-Low**, given that the community was relatively similar to 2012 and contained a diverse benthic fauna including several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies and caddisflies).

Differences in measurement endpoints of benthic invertebrate communities at *test* reach JAR-E1 were classified as **Negligible-Low** because the community was highly diverse and the decrease in percent EPT from 2012 was a minor (but statistically detected) change. All measurement endpoints, with the exception of abundance, were within regional *baseline* ranges. Abundance was higher than the inner tolerance limit for the 95th percentile of regional *baseline* reaches.

In fall 2013, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations. Sediment quality in fall 2013 showed **Negligible-Low** differences at all stations from regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012.

Fish Populations (fish assemblages) Information on fish assemblages for the southern oil sands region is just beginning to be collected; therefore, a comparison with *baseline* conditions in the northern region was conducted. Differences in measurement endpoints at *test* reach CHR-F3 were classified as **Negligible-Low** given that most measurement endpoints were with the range of *baseline* variability and the low ATI value was not indicative of a negative change in the fish assemblage.

Differences in measurement endpoints of fish assemblages for erosional *test* reaches SUC-F1 and JAR-F1 on tributaries of Christina Lake were classified as **Negligible-Low** compared to regional *baseline* conditions, with almost all measurement endpoints within the range of *baseline* variability, and lower ATI values, reflecting a greater proportion of sensitive fish species.

Differences in measurement endpoints of fish assemblages for depositional *test* reaches SAC-F1, UNC-F2, and UNC-F3 on tributaries of Christina Lake were classified as **High** because almost all measurement endpoints were lower than the range of variability for *baseline* depositional reaches (i.e., CPUE and abundance at all three; in addition to diversity and richness at SAC-F1 and UNC-F2). In addition, only one fish was captured at *test* reach UNC-F2 and no fish were captured at *test* reach SAC-F1. It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. In future years of monitoring, an effort will be made to sample in better fish habitat to assess fish assemblages in these creeks.

Fish Populations (fish tissue) Mercury concentrations in lake whitefish from Christina Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in northern pike and walleye from Christina Lake in 2013 were above Health Canada consumption subsistence guidelines indicating a **High** risk to the health of subsistence fishers consuming northern pike and walleye. Given that all northern pike and most walleye exceeded the guideline for subsistence fishers, there was a **Moderate** risk to general consumers of northern pike and walleye, dependent on the quantity of fish consumed. Mercury concentrations in fish from Christina Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes.

5.10.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the Christina River watershed was conducted at RAMP Station S47A, 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 (WSC)/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, S60 Unnamed Creek south of Christina Lake, S61 Christina River above Statoil Leismer, S62 Birch Creek at Hwy 881; S63 Sunday Creek at Hwy 881, S64 Unnamed Creek East of 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 the RAMP stations can be found in Appendix C.

Continuous annual hydrometric data have been collected for Station S47A, 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 WSC Station 07CD005, Clearwater River above Christina River, and WSC Station 07CD001, Clearwater River at Draper. Therefore, comparisons of the hydrologic conditions in the 2013 WY to historical values were less robust than for other hydrology stations in the RAMP FSA. In the 2013 WY, continuous data were collected from November 1, 2012 to October 31, 2013, with data missing from May 3 to May 8 and July 23 to August 8. Flows decreased from November 2012 to March 2013 and flows from December to March were generally between historical upper quartile and maximum values (Figure 5.10-3). Flows increased in April and early May during spring freshet until monitoring ceased on May 3. Flows continued to increase when monitoring resumed on May 9, and peaked at 345 m^3/s on May 14. This value was the highest maximum daily flow recorded from the available data in the 2013 WY, and was 108% higher than the historical mean annual maximum values. Following the freshet, flows increased in response to rainfall events in mid-June to a peak value of 301 m^3/s on June 16, followed by decreasing flows until monitoring ceased on July 23. Flows continued to decrease when monitoring resumed on August 9 until the end of September, with values mostly within the historical inter-quartile range. Flows increased again in response to rainfall events in early October to a level similar to historical median values and then decreased until the end of the 2013 WY (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 2013 in the Christina River watershed was estimated to be 13.4 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 1.83 million m^3.
2. As of 2013, the area of land change in the Christina River watershed from focal projects that was not closed-circuited was estimated to be 106 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 2.89 million m^3.
3. In the 2013 WY, Nexen, ConocoPhillips, MEG Energy, Canadian Natural, Cenovus, and Statoil withdrew 0.436 million m^3 of water from various surface water sources to support industrial activities.

The estimated cumulative effect of focal project development in the 2013 WY was an increase of flow of 0.616 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 2013 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge were 0.05%, 0.05%, and 0.06%, 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 0.06% 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 2013 in the Christina River watershed was estimated to be 13.4 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 1.83 million m^3.
2. As of 2013, 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 109 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 2.98 million m^3.
3. Water withdrawals by Nexen, ConocoPhillips, MEG Energy, Canadian Natural, Cenovus, and Statoil of 0.436 million m^3 described above were also applied to this case.

The estimated cumulative effect of all oil sands development in the 2013 WY was an increase in flow of 0.714 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 2013 WY were 0.05%, 0.06%, and 0.06% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 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 0.06% 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 WSC station 07CE906 from 2002 to 2013. In the 2013 WY, lake levels generally decreased from November 2012 to mid-April 2013, with water levels in November following the historical median values and levels from January to March generally varying between historical lower quartile and maximum values (Figure 5.10-4). Lake levels increased during freshet in early May to a freshet peak of 554.907 masl on May 13, before decreasing until early June. Rainfall events in mid-June increased lake levels beyond the historical maximum levels and peaked at 555.335 masl on June 17. This peak lake level was the maximum daily level recorded in the 2013 WY and was 0.661 m higher than the historical mean annual maximum daily lake level. Lake levels steadily decreased from mid-July until the end of the 2013 WY.

Continuous annual hydrometric data have been collected at Station S56 Jackfish River, since May 2012. Seasonal hydrometric data from March to October have been collected at WSC station 07CE005 from 1982 to 1995. The open-water runoff volume in the 2013 WY was 225.6 million m^3, which was 333% higher than the historical mean open-water runoff volume calculated from 14 years of available record. Flows increased during spring freshet and exceeded the historical maximum on May 13, but the peak of freshet was not captured (Figure 5.10-5). Flows also increased in response to rainfall events in mid-June, exceeding the historical maximum flows from June 11 to July 21, 2013. The peak flow of 65.2 m^3/s on June 17, was the highest flow recorded from available data in the 2013 WY, and was 370% higher than the historical mean open-water maximum daily flow.

Following this peak, flows sharply decreased until early July, and then increased due to rainfall events in mid-July. Flows generally decreased from mid-July to September, with values generally remaining above the historical median values. The minimum open-water daily flow of 1.88 m^3/s on September 29 was 154% higher than the historical mean open-water minimum daily flow of 0.741 m^3/s.

5.10.3 Water Quality

In fall 2013, water quality samples were taken from:

- the Christina River near its mouth (*test* station CHR-1), sampled since 2002;
- the Christina River upstream of Janvier (*test* station CHR-2), sampled since 2002, designated as *test* in 2010;
- the Christina River upstream of Jackfish River (*test* station CHR-3), initiated in 2013;
- the Christina River upstream of development (*baseline* station CHR-4), initiated in 2013;
- Sawbones Creek (*test* station SAC-1), sampled since 2012;
- Sunday Creek at the inlet into Christina Lake (*test* station SUC-1), sampled since 2012;
- Sunday Creek upstream (*baseline* station SUC-2), initiated in 2013;
- Birch Creek (*baseline* station BRC-1), initiated in 2013;
- Unnamed Creek east of Christina Lake (*test* station UNC-2), initiated in 2013;
- Unnamed Creek south of Christina Lake (*test* station UNC-3), initiated in 2013;
- Jackfish River (*test* station JAR-1), sampled since 2012; and
- Christina Lake (*test* station CHL-1), sampled since 2012.

Test stations CHR-3, SAC-1, SUC-1, UNC-2, UNC-3, JAR-1, CHL-1, and *baseline* stations CHR-4, BRC-1, and SUC-2 were also sampled in winter, spring, and summer 2013 in an effort to gain three years of seasonal data. *Test* station CHR-1 was sampled monthly in 2013.

Temporal Trends The only significant trend (α=0.05) in fall water quality measurement endpoint concentrations was a decreasing concentration of chloride at *test* station CHR-2 (2001 to 2013). There were no significant trends at *test* station CHR-1. Trend analysis was not conducted for *test* stations CHR-3, SAC-1, SUC-1, UNC-2, UNC-3, JAR-1, and CHL-1, and *baseline* stations CHR-4, BRC-1, and SUC-2 because of insufficient data available.

2013 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 5.10-15), with the exception of:

- total molybdenum and calcium, which exceeded previously-measured maximum concentrations at *test* station CHR-1; and
- dissolved phosphorus, which exceeded the previously-measured maximum concentration at *test* station CHR-2.

No historical comparisons were conducted for *test* stations CHR-3, UNC-2, UNC-3, SAC-1, SUC-1, JAR-1, and CHL-1 and *baseline* stations CHR-4, SUC-2, and BRC-1 due to limited or no historical data available (Table 5.10-6 to Table 5.10-15).

Ion Balance The ionic composition of water at all stations in the Christina River watershed in fall 2013 were dominated by calcium and bicarbonate ions (Figure 5.10-6, Figure 5.10-7). Stations on the mainstem of the Christina River showed consistent ionic composition across sampling years (CHR-1 and CHR-2); however, *test* station CHR-1 differed from the remaining mainstem stations because it had a slightly greater dominance of chloride and slightly lower dominance of calcium (Figure 5.10-6). Tributary stations sampled in fall 2013 had minimal historical data to compare against (i.e., 2012 data only), but were all generally similar in ionic composition and dominated by calcium and bicarbonate, with the exception of *test* station SUC-1, which was dominated slightly less by bicarbonate ions in 2013 relative to 2012 data and to other tributary stations (Figure 5.10-7). Overall, the ionic composition of tributary stations was very similar to mainstem *test* stations CHR-2 and CHR-3, and *baseline* station CHR-4 on the Christina River (Figure 5.10-6 and Figure 5.10-7).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines In fall 2013, concentrations of water quality measurement endpoints at stations in the Christina River watershed were below water quality guidelines (Table 5.10-4 to Table 5.10-15), with the exception of:

- total aluminum at *test* stations CHR-1 and SUC-1, and *baseline* station CHR-4; and
- dissolved phosphorus at *test* stations CHR-2 and CHR-3, and *baseline* station CHR-4.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in the Christina River watershed in fall 2013 (Table 5.10-16):

- dissolved iron at *test* stations CHR-1, CHR-2, CHR-3, SAC-1, UNC-2, and UNC-3, and *baseline* station CHR-4;
- sulphide at *test* station CHR-1, CHR-2, CHR-3, and UNC-2, and *baseline* station CHR-4;
- total chromium at *test* station CHR-1;
- total phenols at *test* stations CHR-1, CHR-2, JAR-1, SAC-1, CHL-1, and *baseline* station SUC-2;
- total iron at *test* stations CHR-1, CHR-2, CHR-3, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* stations BRC-1, SUC-2, and CHR-4; and
- total phosphorus at *test* stations CHR-1, CHR-2, and CHR-3, and *baseline* stations BRC-1 and CHR-4.

There were many water quality guideline exceedances in winter, spring, and summer at *test* stations CHR-3, CHL-1, SAC-1, JAR-1, UNC-2, UNC-3, and SUC-1 and *baseline* stations BRC-1, CHR-4, and SUC-2. Most of these exceedances were the same variables that exceeded guidelines in fall 2013 (Table 5.10-16). Additionally, many total metals exceeded guidelines in spring and summer at *test* station CHR-3 and *baseline* stations BRC-1 and CHR-4. These metals were likely associated with high particulate concentrations in the water, as total suspended solids at these stations were high and dissolved metals remained fairly consistent during these time periods.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, most water quality measurement endpoints were within regional *baseline* concentrations (Figure 5.10-8 and Figure 5.10-9), with the exception of:

- total dissolved solids, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations CHR-1, CHR-2, and SUC-1, and *baseline* station BRC-1;
- dissolved phosphorus, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station CHR-4;
- total strontium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations CHR-1 and CHR-3, and *baseline* station BRC-1;
- total boron, with a concentration below the 5th percentile of regional *baseline* concentrations at *test* station SAC-1;
- total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* stations CHR-2 and CHR-3, and *baseline* stations BRC-1 and CHR-4;
- calcium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station SUC-1 and *baseline* stations BRC-1, CHR-4, and SUC-2;
- total magnesium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station SUC-1 and *baseline* stations SUC-2 and BRC-1;
- sodium, with a concentration below the 5th percentile of regional *baseline* concentrations at *test* station UNC-2;
- potassium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station SUC-1 and *baseline* station BRC-1, and concentrations below the 5th percentile at *test* stations SAC-1 and UNC-2; and
- sulphate, with concentrations below the 5th percentile of regional *baseline* concentrations at *test* stations SAC-1, UNC-2, and UNC-3.

Lakes do not contribute to the regional *baseline* concentration calculations; therefore, Christina Lake was not compared to regional *baseline* conditions (Figure 5.10-10).

Water Quality Index The WQI values at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* station SUC-2 indicated **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2013 (Table 5.10-17). The WQI at *baseline* stations CHR-4 and BRC-1 indicated **Moderate** differences from regional *baseline* water quality conditions. A WQI was not generated for *test* station CHL-1 (Christina Lake) because lakes were not compared to regional *baseline* concentrations.

Monthly Water Quality Results Monthly water quality samples were collected in 2013 at *test* station CHR-1 (Table 5.10-18). Generally the lowest concentration of ions and the highest concentration of PAHs occurred in May.

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances that were measured at *test* station CHR-1 in 2013 included (Table 5.10-19):

- total phenols in January, May, July, August, September, and November;
- total nitrogen in January, May, June, and July;
- total chromium from April to September;
- total titanium in May; and
- dissolved aluminum in May, June, and July;
- total copper and total silver in May and July;
- total zinc in May, July, and November.
- total mercury (ultra-trace) in June and July;
- dissolved phosphorus in November;
- sulphide in all months, with the exception of March;
- total aluminum in all months, with the exception of November; and
- total iron, dissolved iron, and total phosphorus in all months.

2013 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2013, most monthly data collected at *test* station CHR-1 were within regional *baseline* conditions observed in fall (Figure 5.10-11), with the exception of:

- total suspended solids, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in May, June, July (yearly maximum), and August;
- total dissolved solids, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in all months, with the exception of May (yearly minimum) and August;
- dissolved phosphorus, with a yearly minimum concentration below the 5th percentile of regional *baseline* fall concentrations in January;
- total nitrogen, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in May and July (yearly maximum);
- total strontium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in all months, with the exception of May (yearly minimum), June, and August;
- total boron, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in January, February, March, April (yearly maximum), October, November, and December;
- total mercury (ultra-trace), with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations in June and July;
- total arsenic, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from May (yearly maximum) to August;
- calcium, chloride, and magnesium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, November, and December;

- sodium, total alkalinity, and hardness, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to April, October, November, and December; and
- potassium, with concentrations that exceeded the 95th percentile of regional *baseline* fall concentrations from January to May (yearly maximum), November, and December.

Monthly Ion Balance The ionic composition of water at *test* station CHR-1 was dominated by calcium and bicarbonate throughout 2013. Seasonal changes in ionic composition were apparent at *test* station CHR-1, where the ionic composition was dominated more by chloride and less by calcium in winter (January to April) and shifted to a greater dominance in calcium and less by chloride in summer (May to August) (Figure 5.10-12).

Classification of Fall Results In fall 2013, water quality at *test* stations CHR-1, CHR-2, CHR-3, JAR-1, SAC-1, SUC-1, UNC-2, and UNC-3, and *baseline* station SUC-2 indicated **Negligible-Low** differences from regional *baseline* conditions. *Baseline* stations CHR-4 and BRC-1 indicated **Moderate** changes from regional *baseline* water quality conditions given that concentrations of several water quality measurement endpoints (e.g., total metals and nutrients) exceeded relevant guidelines and regional *baseline* conditions in 2013.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited fluctuations across months at *test* station CHR-1. Typically, a higher dominance of calcium and lower dominance of chloride occurred in summer months. The highest number of water quality guideline exceedances occurred in May, June, and July, which were also the months where maximum yearly concentrations were most frequently reached.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- erosional *test* reach CHR-E3, initiated as a new reach in fall 2013;
- depositional *baseline* reach CHR-D4, initiated as a new reach in fall 2013;
- depositional *test* reach SUC-D1, sampled since 2012;
- depositional *baseline* reach SUC-D2, initiated as a new reach in fall 2013;
- depositional *test* reach SAC-D1, sampled since 2012;
- depositional *test* reach UNC-D2, initiated as a new reach in fall 2013;
- depositional *test* reach UNC-D3, initiated as a new reach in fall 2013;
- erosional *baseline* reach BRC-D1, initiated as a new reach in fall 2013;
- erosional *test* reach JAR-E1, sampled since 2012; and
- Christina Lake (*test* station CHL-1), sampled since 2012.

Christina River Mainstem

2013 Habitat Conditions Water at *test* reach CHR-E3 in fall 2013 was shallow (0.3 m) and alkaline (pH: 8.2), with a moderate velocity (0.5 m/s), high dissolved oxygen (8.8 mg/L), and moderate conductivity (236 µS/cm) (Table 5.10-20). The substrate consisted mostly of large cobbles (27%), sand/silt/clay (21%), and large gravel (14%) (Table 5.10-20). Periphyton chlorophyll *a* biomass at *test* reach CHR-E3 averaged 85.9 mg/m^2, which was within the inner tolerance limits for the range of variation for regional *baseline* conditions (Figure 5.10-13).

Water at *baseline* reach CHR-D4 in fall 2013 was shallow (0.5 m), neutral (pH: 6.8), with a moderate velocity (0.3 m/s), moderate dissolved oxygen (6.8 mg/L), and moderate conductivity (244 µS/cm). The substrate consisted almost entirely of sand (88%), with low total organic carbon content (0.53%) (Table 5.10-20).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach CHR-E3 was dominated by chironomids (64%), with subdominant taxa consisting of Ephemeroptera (8%), Nematoda (7%), and Trichoptera (6%) (Table 5.10-21). Chironomids were primarily of the genera *Polypedilum* and *Micropsectra*/T*anytarsus,* and *Circotopus/Orthocladius.* Several flying insects (mayflies: *Baetidae*, *Ephemerellidae*, *Heptageniidae*; stoneflies: *Perlodidae*, *Chloroperlidae*; and caddisflies: *Hydropsychidae*) were found at this reach in 2013. Bivalves (*Pisidium*/*Sphaerium*) were present in very low abundances (Table 5.10-21).

The benthic invertebrate community at *baseline* reach CHR-D4 was dominated by chironomids (79%), with subdominant taxa consisting of Tubificidae (6%), Hydracarina (5%), and Nematoda (3%). Chironomids were diverse and included *Polypedilum*, *Tanytarsus*, and *Rheotanytarsus*. Several flying insects (mayflies: *Caenidae*, *Heptageniidae*; caddisflies: *Leptoceridae*, *Limnephilidae*) were found at this reach in 2013, along with low abundances of gastropods (*Planorbidae*) and bivalves (*Pisidium*/*Sphaerium*) (Table 5.10-21).

Temporal and Spatial Comparisons Given that *test* reach CHR-E3 and *baseline* reach CHR-D4 were sampled for the first time in fall 2013, no temporal comparisons were conducted. Spatial comparisons were not conducted given that *test* reach CHR-E3 was erosional habitat and *baseline* reach CHR-D4 had depositional habitat.

Comparison to Published Literature *Test* reach CHR-E3 contained a benthic invertebrate community typical of a cobble-bottomed river, with a high relative abundance of EPT taxa indicating good overall water quality. The benthic invertebrate community consisted of a mean of 31 taxa and 21% EPT taxa, both of which were relatively high for erosional habitat of rivers in the RAMP FSA, but still within the range of regional variability. Plecoptera were present in high relative abundances (4%). Equitability was 0.36, which was well within the range of regional *baseline* variability.

Baseline reach CHR-D4 contained a benthic invertebrate community representative of a healthy, sandy-bottomed river. The community was dominated by chironomids and the relative abundance of worms was low (~10%). EPT taxa were present in low relative abundances and several permanent aquatic forms (fingernail clams and gastropods) were present, consistent with the sand-dominated substrate characteristics of the reach.

2013 Results Relative to Regional *Baseline* Conditions With only one year of data, *test* reach CHR-E3 was compared to the regional range of *baseline* variability. Values of all measurement endpoints at *test* reach CHR-E3 were within the inner tolerance limits of the normal range of variation for means from regional *baseline* erosional reaches (Figure 5.10-14).

Classification of Results Differences in values of measurement endpoints for benthic invertebrate communities at *test* reach CHR-E3 were classified as **Negligible-Low** because all measurement endpoints were within the inner tolerance limits of the normal range of variation for means from regional *baseline* erosional reaches. In addition the benthic fauna at *test* reach CHR-E3 in fall 2013, were representative of good overall water quality, with high taxa richness and percentage of the fauna as EPT taxa.

Sunday Creek

2013 Habitat Conditions Water at *test* reach SUC-D1 in fall 2013 was shallow (0.6 m), slightly alkaline (pH: 7.6), with a moderate velocity (0.3 m/s), high dissolved oxygen (8.1 mg/L), and moderate conductivity (310 µS/cm). The substrate consisted almost entirely of sand (96%), with small amounts of total organic carbon (0.29%) (Table 5.10-22).

Water at *baseline* reach SUC-D2 in fall 2013 was shallow (0.3 m), slightly alkaline (pH: 7.5), with a slow velocity (0.15 m/s), high dissolved oxygen (8.2 mg/L), and moderate conductivity (203 µS/cm). The substrate consisted almost entirely of sand (98%), with small amounts of total organic carbon (0.05%) (Table 5.10-22).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach SUC-D1 was dominated by chironomids (87%), with subdominant taxa consisting of Ceratopogonidae (4%), miscellaneous Diptera (3%), and nematodes (3%) (Table 5.10-23). Dominant chironomids included the genera *Chironomus*, *Paracladopelma*, *Polypedilum*, and *Rheosmittia*. Miscellaneous Diptera included members of the families *Tipulidae*, *Empididae*, and *Tabanidae*. Flying insects (Ephemeroptera and Plecoptera) were sparse at *test* reach SUC-D1 in 2013. Permanent aquatic forms such as *Pisidium*/*Sphaerium* clams were present in low relative abundances.

The benthic invertebrate community at *baseline* reach SUC-D2 was dominated by chironomids (78%), with subdominant taxa consisting of Ceratopogonidae (7%), Naididae (4%), and Nematoda (3%) (Table 5.10-23). Chironomids were diverse and included *Micropsectra/Tanytarsus*, *Rheosmittia*, and *Cricotopus/Orthocladius*. Several flying insects (mayflies: *Leptophlebiidae*; caddisflies: *Leptoceridae*) were present at *baseline* reach SUC-D2 in 2013, along with low numbers of gastropods (*Planorbidae*, *Ancylidae*), and bivalves (*Sphaeriidae*) (Table 5.10-23).

Temporal and Spatial Comparisons Given that *test* reach SUC-D1 was only sampled in 2012 and 2013, and *baseline* reach SUC-D2 was first sampled in fall 2013, no temporal or spatial comparisons were conducted.

Comparison to Published Literature T*est* reach SUC-D1 contained a benthic invertebrate community typical of a sandy-bottomed reach, with dominant taxa consisting of chironomids, and with the presence of mayflies (*Caenis, Ephemerella, Haptagenia limbata*), clams (*Pisidium/Sphaerium*), and worms accounting for only a moderate fraction (<10%) of the community.

Baseline reach SUC-D2 contained a benthic invertebrate community typical of a creek with a soft, sand-based bottom. Chironomids were dominant, with common forms that were moderately tolerant of degraded water quality conditions (Mandeville 2002). The benthic invertebrate community at *baseline* reach SUC-D2 also included a variety of worms, in addition to mayflies, caddisflies, and fingernail clams, all in low relative abundances.

2013 Results Relative to Regional *Baseline* Conditions With only two years of data, *test* reach SUC-D1 was compared to the regional range of variability for *baseline* depositional reaches. All measurement endpoints of benthic invertebrate communities at *test* reach SUC-D1 were within the inner tolerance limits of the normal range of variation for means from the regional *baseline* depositional reaches in previous years (Figure 5.10-16, Figure 5.10-17).

Classification of Results Differences in measurement endpoints at *test* reach SUC-D1 were classified as **Negligible-Low.** *Test* reach SUC-D1 contained a benthic invertebrate community representative of a healthy depositional reach. Flying insects and permanent aquatic forms (snails, fingernail clams) complimented a diverse fauna of chironomids. Low overall abundance of worms suggested favourable water quality conditions in fall 2013 at *test* reach SUC-D1.

Sawbones Creek, Birch Creek, and Unnamed Creeks

2013 Habitat Conditions Water at *test* reach SAC-D1 in fall 2013 was deep (1.1 m), neutral (pH: 6.7), with a slow velocity (0.1 m/s), moderate dissolved oxygen (6.4 mg/L), and moderate conductivity (120 µS/cm). The substrate consisted primarily of sand (87%) with low total organic carbon (~2%) (Table 5.10-24).

Water at *test* reach UNC-D2 in fall 2013 was 0.6 m in depth, alkaline (pH: 7.9), with high dissolved oxygen (7.2 mg/L), and moderate conductivity (122 µS/cm). The substrate consisted primarily of sand (75%) and silt (21%), with low total organic carbon (4.6%) (Table 5.10-24).

Water at *test* reach UNC-D3 in fall 2013 was deep (0.7 m), neutral (pH: 7.2), with high dissolved oxygen (7.7 mg/L), and moderate conductivity (222 µS/cm). The substrate consisted almost entirely of sand (96%), with low total organic carbon (0.59%) (Table 5.10-24).

Water at *baseline* reach BRC-D1 in fall 2013 was 0.5 m in depth, alkaline (pH: 8.0), with a moderate velocity (0.38 m/s), high dissolved oxygen (7.4 mg/L), and moderate conductivity (304 µS/cm). The substrate consisted almost entirely of sand, with low total organic carbon (Table 5.10-24).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach SAC-D1 was dominated by chironomids (77%), with subdominant taxa consisting of Ceratopogonidae (7%), nematodes (4%), and tubificid worms (3%) (Table 5.10-25). Dominant chironomids included *Micropsectra/Tanytarsus, Nilotanypus, Paralauterborniella*, and *Polypedilum*. Ephemeroptera (*Callibaetis, Hexagenia limbata*, *Heptageniidae*) were present in low relative abundances, as were gastropods (*Gyraulus*) and bivalves (*Pisidium/Sphaerium*).

The benthic invertebrate community at *test* reach UNC-D2 was dominated by chironomids (77%), with subdominant taxa consisting of Ceratopogonidae (9%), nematodes (4%), and bivalves (3%) (Table 5.10-25). Chironomids were diverse and included *Polypedilum, Cladotanytarsus, Micropsectra/Tanytarsus, Rheotanytarsus*, and *Procladius*. Several flying insects (mayflies: Leptophlebiidae; stoneflies: Capniidae; caddisflies: Leptoceridae) were found in 2013. Amphipods (Talitridae), gastropods (Planorbidae), and bivalves (Sphaeriidae) were all present at *test* reach UNC-D2 in fall 2013 (Table 5.10-25).

The benthic invertebrate community at *test* reach UNC-D3 was dominated by chironomids (75%), with subdominant taxa consisting of Ceratopogonidae (8%), miscellaneous Diptera (5%), and Trichoptera (3%) (Table 5.10-25). Chironomids were diverse and consisted of *Micropsectra/Tanytarsus, Micropsectra, Tanytarsus,* and *Rheosmittia*. Several flying insects (mayflies: Baetiscidae; stoneflies: Capniidae; caddisflies: Limnephilidae) were present in 2013. Amphipods (Talitridae), gastropods (Planorbidae), and bivalves (Sphaeriidae) were also found at *test* reach UNC-D3 (Table 5.10-25).

The benthic invertebrate community at *baseline* reach BRC-D1 was dominated by chironomids (67%), with subdominant taxa consisting of miscellaneous Diptera (13%), Ceratopogonidae (9%), and nematodes (8%) (Table 5.10-25). Chironomids were primarily of the genera *Rheosmittia* and *Tanytarsus*. Several flying insects (mayflies: Leptophlebiidae; stoneflies: Capniidae) were present in 2013 (Table 5.10-25).

Temporal and Spatial Comparisons Temporal and spatial comparisons were not conducted for *test* reaches SAC-D1, UNC-D2, and UNC-D3 and *baseline* reach BRC-D1 given that *test* reach SAC-D1 has only been sampled for two years (2012 and 2013), and 2013 was the first year of sampling at reaches UNC-D2, and UNC-D3, and BRC-D1.

Comparison to Published Literature The benthic invertebrate community at *test* reach SAC-D1 had a low relative abundance of worms (<10%) in both 2012 and 2013, and relatively high diversity of benthic fauna for a sandy-bottomed creek. Chironomids were abundant and diverse; and flying insects and permanent aquatic forms were also present, indicating good water quality (Hynes 1960; Griffiths 1998; Mandeville 2001).

The benthic invertebrate community of *test* reach UNC-D2 was representative of a depositional, sandy-bottomed river, with a high diversity of chironomids and low relative abundance of worms (<10%). The presence of permanent aquatic forms (amphipods, bivalves, and gastropods) and flying insects (mayflies, stoneflies, and caddisflies) suggested good long-term water quality.

Similar to *test* reach UNC-D2, the benthic invertebrate community of *test* reach UNC-D3 was representative of a depositional, sandy-bottomed river. Chironomids were abundant and diverse and comprised of many commonly-observed forms. The relative abundance of worms was low and EPT taxa were relatively abundant. Richness and abundance at *test* reach UNC-D2 were similar to *test* reach UNC-D3; however, the percentage of fauna as EPT taxa was much lower at *test* reach UNC-D2.

The benthic invertebrate community of *baseline* reach BRC-D1 was representative of a depositional, sandy-bottomed river, with a high diversity of chironomids and low relative abundance of worms. The abundance, richness and EPT taxa were relatively low compared to the other depositional reaches on tributaries to Christina Lake (i.e., UNC-D2, UNC-D3, SAC-D1).

Comparison to Regional *Baseline* Conditions Mean values of measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were within the inner tolerance limits of regional *baseline* conditions for depositional reaches, with the exception of richness (Figure 5.10-18 and Figure 5.10-19). Richness was higher than the inner tolerance limit for the 95th percentile; however, this was not considered to be indicative of negative change. Abundance and richness decreased slightly from 2012 but the percentage of EPT taxa was stable at 2% (Figure 5.10-18).

Abundance, EPT, and CA Axis 1 and 2 scores for *test* reaches of UNC-D2 and UNC-D3 were within the inner tolerance limits of the normal range of variation for means from the regional *baseline* depositional reaches in previous years (Figure 5.10-18, Figure 5.10-20).

Richness exceeded the inner tolerance limit of the 95th percentile and equitability was below the inner tolerance limit for the 5th percentile at both reaches, but were inside the outer tolerance limits for the range of *baseline* variability.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were classified as **Negligible-Low.** All measurement endpoints, with the exception of richness were within the range of regional *baseline* conditions for depositional reaches. Richness has been high at *test* reach SAC-D1 in both 2012 and 2013, which was not considered to be a negative change. In addition, the benthic invertebrate community of *test* reach SAC-D1 was diverse and supported a community with permanent aquatic forms (snails, fingernail clams) and flying insects, and a low diversity of worms.

Differences in measurement endpoints of benthic invertebrate communities at *test* reaches UNC-D2 and UNC-D3 were classified as **Negligible-Low** because all measurement endpoints, with the exception of richness and equitability, were within the range of regional *baseline* depositional reaches. Richness was above the limit in 2013 and equitability was just below the lower inner limit, which were indicative of a more diverse community compared to regional *baseline* reaches. The benthic invertebrate communities of both reaches had low total abundance of worms, high diversity of chironomids, and the presence of permanent aquatic forms and flying insects.

Jackfish River

2013 Habitat Conditions Water at *test* reach JAR-E1 in fall 2013 was shallow (0.3 m in sampled areas), with a fast velocity (0.7 m/s), basic (pH: 7.9), high dissolved oxygen (8.3 mg/L), and moderate conductivity (144 µS/cm) (Table 5.10-26). The substrate consisted primarily of small cobble (30%) and large gravel (29%) (Table 5.10-26). Periphyton chlorophyll *a* biomass at *test* reach JAR-E1 averaged 124 mg/m^2, which was within the inner tolerance limits for the range of variation for regional *baseline* conditions (Figure 5.10-21).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach JAR-E1 was dominated by Ephemeroptera (29%), Chironomidae (33%), and Trichoptera (11%) and similar to 2012 (Table 5.10-27). Subdominant taxa included Hydracarina (8%) and Nematoda (5%). Mayflies were diverse (12 genera) and numerically dominated by *Baetis, Ephemerella,* and *Paraleptophlebia*. Trichoptera was dominated by *Hydopsyche, Oecetis,* and *Chimarra*. Plecoptera (*Acroneuria abnormis* and *Isoperla*), Bivalvia (*Pisidium/Sphaerium*), and Gastropoda (*Ferrissia rivularis and Gyraulus*) were present in low relative abundances. Chironomids consisted primarily of *Polypedilum*, *Rheotanytarsus*, *Lopesocladius,* and *Cricotopus / Orthocladius.*

Temporal and Spatial Comparisons A single temporal comparison was conducted for *test* reach JAR-E1 to assess the differences in mean values of measurement endpoints between 2012 and 2013.

The percentage of EPT taxa was significantly lower in 2013 (43%) compared to 2012 (49%) (Table 5.10-28). The variance in annual means, expressed as a within-station standard deviation, was approximately 0.6, and a relatively minor change between 2012 and 2013 (Environment Canada 2012).

Comparison to Published Literature The benthic invertebrate community of *test* reach JAR-E1 contained a benthic fauna that reflected good water and sediment quality. The percent of the community as worms was low (<5%) and the percentage of EPT taxa was generally high. The presence of permanent aquatic organisms such as bivalves and gastropods was indicative of good long-term water quality. The dominant forms of Chironomidae present were known to represent fair to good water quality (Mandeville 2002). For example, the chironomid *Rheotanytarsus* tends to occur in rocky streams with good flows (Merritt and Cummins 1996).

2013 Results Relative to Regional *Baseline* Conditions Abundance at *test* reach JAR-E1 was relatively high in 2012 and even higher in 2013 and exceeded the inner tolerance limit for the 95th percentile for regional *baseline* erosional reaches (Figure 5.10-22). The total number of organisms (~ 195,000 per m^2 in 2013) was somewhat unusual relative to what is more typical for erosional rivers. Taxa richness (39 taxa per sample, on average) was also higher relative to the normal range from regional *baseline* erosional reaches, but within the inner tolerance limit for the normal range (Figure 5.10-22). CA Axis 1 and 2 scores were within the range of variation for *baseline* erosional reaches (Figure 5.10-23). All other measurement endpoints were within the normal range of variation for *baseline* erosional reaches. The high total abundance was likely related to the location of this reach downstream of Christina Lake, and the relatively heavy growth of periphyton and *Cladophora* on rocks. The high diversity, richness, and percent EPT indicated that habitat in Jackfish River was good.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach JAR-E1 were classified as **Negligible-Low** because the community was highly diverse and the decrease in percent EPT from 2012 was a minor (but statistically detected) change. All measurement endpoints, with the exception of abundance, were within regional normal *baseline* ranges. Abundance was higher than the inner tolerance limit for the 95th percentile of regional *baseline* reaches.

Christina Lake

2013 Habitat Conditions Water in Christina Lake in fall 2013 was slightly alkaline (pH: 8.3), with moderate conductivity (134 µS/cm) (Table 5.10-29). Samples were collected at a depth of 1 m. The substrate of Christina Lake consisted primarily of sand (98%), with small amounts of silt and clay, and low total organic carbon (< 1%) (Table 5.10-29).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Christina Lake at *test* station CHL-1 in fall 2013 was dominated by chironomids (61%), nematodes (12%), and amphipods (11%) (Table 5.10-30). More than 30 kinds of chironomids were present in Christina Lake in fall 2013, with *Tanytarsus*, *Stictochironomus,* and *Procladius* as the most common. Amphipods included *Hyalella azteca* and *Gammarus lacustris*, both of which are commonly distributed throughout Canada (Väinölä et al. 2008). Bivalves (*Pisidium/Sphaerium*) were present and gastropods were relatively diverse and primarily composed of *Valvata sincera* but also included *Gyraulus*, *Menetus cooperi*, and *Valvata tricarinata*. Ephemeroptera (*Caenis, Ephemeridae,* and *Leptophlebidae*) were present as were six types of caddisfly (*Mayatrichia, Heliocpsyche, Mystacides, Oecetis, Phyganea,* and *Polycentropus*).

Comparison to Published Literature The benthic invertebrate community of Christina Lake was diverse and typical of sandy-nearshore lake environments, including two kinds of amphipods, two genera of fingernail clams, and several kinds of snails (gastropods) (Table 5.10-30). The presence of several large insects such as Ephemeroptera, Odonata (though in low relative abundances), and Trichoptera in Christina Lake indicated that the benthic habitat of Christina Lake was in good condition. Low relative abundances of worms also indicated good habitat quality (Niemi et al. 1990; Pennak 1989).

2013 Results Relative to Historical Conditions The benthic invertebrate community of Christina Lake in 2013 was quite similar to 2012. In terms of relative abundance, chironomids dominated, followed by nematodes, and amphipods in both years. Permanent aquatic forms (bivalves, gastropods, amphipods) were present in both years; however, gastropod diversity was slightly lower in 2013. Mayflies and caddisflies were present with a healthy diversity in both years. Abundance, richness, equitability, and CA Axis 2 scores were similar between years (Figure 5.10-24, Figure 5.10-25). The percentage of EPT taxa increased in 2013 resulting in a decrease in CA Axis 1 scores from 2012.

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* station CHL-1 in fall 2013 were classified as **Negligible-Low** given that the community was relatively similar to 2012 and contained a diverse benthic fauna including several permanent aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies, dragonflies, 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 community sampling in fall 2013:

- *baseline* station CHR-D4 on the Christina River upstream of development, sampling initiated in 2013;
- *test* station SAC-D1 on Sawbones Creek, sampling initiated in 2012;
- *test* station SUC-D1 on Sunday Creek at the inlet into Christina Lake, sampling initiated in 2012;
- *baseline* station SUC-D2 on Sunday Creek upstream, sampling initiated in 2013;
- *test* station CHL-1 on Christina Lake, sampling initiated in 2012;
- *baseline* station BRC-D1 on Birch Creek, sampling initiated in 2013;
- *test* station UNC-D2 on Unnamed Creek, east of Christina Lake, sampling initiated in 2013; and
- *test* station UNC-D3 on Unnamed Creek, south of Christina Lake, sampling initiated in 2013.

Temporal Trends Insufficient data existed (n<7) to conduct trend analysis on *test* stations SAC-D1, SUC-D1, UNC-D2, UNC-D3, and CHL-1 and *baseline* stations CHR-D4, BRC-D1 and SUC-D2.

2013 Results Relative to Historical Concentrations Stations sampled in the Christina River watershed in fall 2013 were either initiated in 2012 or 2013; therefore, no historical comparisons were possible.

Sediment at *baseline* station CHR-D4 of the upper Christina River was predominantly composed of sand and generally had low concentrations of PAHs and hydrocarbons (Table 5.10-31).

Sediment at *test* reach SAC-D1 of Sawbones Creek in fall 2013 was predominantly composed of sand and was very similar in composition to 2012 (Table 5.10-32).

Sediment at *test* station SUC-D1 and *baseline* station SUC-D2 of Sunday Creek in fall 2013 was predominantly composed of sand (87.4% and 95.6%, respectively) (Table 5.10-33 and

Table 5.10-34). Sediment quality was generally similar between stations and between years (2012 and 2013) at *test* station SUC-D1 (Table 5.10-33 and Table 5.10-34).

Test station CHL-1 of Christina Lake showed similar results between 2012 and 2013. Concentrations of PAHs and hydrocarbons were generally low, with CCME hydrocarbon fractions below detection limits (Table 5.10-35). Concentrations of total metals normalized to percent fines were lower in 2013 than 2012 (Table 5.10-35).

Sediment at *baseline* station BRC-1 of Birch Creek was primarily composed of sand in fall 2013. Generally, concentrations of PAHs and total hydrocarbons were low, particularly for low molecular-weight hydrocarbon fractions (i.e., CCME F1, F2, and BTEX were below detection limits) (Table 5.10-36).

Sediment at *test* stations UNC-D2 and UNC-D3 of two unnamed creeks flowing into Christina Lake, in fall 2013, was predominately composed of sand, with a much higher composition of sand at UNC-D3 (97%) than UNC-D2 (62.2%). Concentrations of PAHs and hydrocarbons were much higher at UNC-D2 relative to UNC-D3, but direct toxicity measurements were fairly similar between stations (Table 5.10-37 and Table 5.10-38).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment quality measurement endpoints in fall 2013 had concentrations that exceeded relevant CCME sediment quality guidelines at *test* stations CHL-1, SAC-D1, SUC-D1, UNC-D3, and *baseline* stations CHR-D4, BRC-D1, and SUC-D2. The concentration of CCME F3 hydrocarbons exceeded the guideline at *test* station UNC-D2 (Unnamed Creek east of Christina Lake) in fall 2013. The predicted PAH toxicity exceeded the potential effect threshold of 1.0 at *test* station SAC-D1 (Table 5.10-32).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of all sediment quality measurement endpoints were with the range of regional *baseline* concentrations (Figure 5.10-26 to Figure 5.10-32), with the exception of:

- total metals (normalized to percent fines), with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station CHR-D4;
- PAH hazard index, with a value that exceeded the 95th percentile of regional *baseline* values at *test* station SAC-D1; and
- total PAHs and the PAH hazard index, which were below the 5th percentile of regional *baseline* concentrations at *test* station UNC-D3 (Unnamed Creek south of Christina Lake).

Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) because lakes were not included in the calculation of *baseline* concentrations, given the ecological differences between lakes and rivers (Figure 5.10-33).

Sediment Quality Index SQI values for all stations in fall 2013 indicated **Negligible-Low** differences in sediment quality conditions from regional *baseline* conditions (Table 5.10-39). No SQI value was calculated for Christina Lake because lakes were not compared to regional *baseline* conditions.

Classification of Results In fall 2013, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations. Sediment quality in fall 2013 showed **Negligible-**

Low differences at all stations from regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations at Christina Lake (CHL-1) because lakes were not included in the calculation of *baseline* concentrations; however, sediment quality at Christina Lake was similar to conditions observed in 2012.

5.10.5 Fish Populations

In 2013, fish population monitoring in the Christina River watershed consisted of fish assemblage monitoring at reaches of the Christina River and tributaries to Christina Lake, and a fish tissue survey on Christina Lake.

5.10.5.1 Fish Assemblage Monitoring

Christina River Mainstem

Fish assemblages were sampled in for the first time in fall 2013 on the Christina River at:

- erosional *test* reach CHR-F3; and
- depositional *baseline* reach CHR-F4.

2013 Habitat Conditions *Test* reach CHR-F3 was comprised of riffle and run habitat, with a wetted width of 47.6 m and a bankfull width of 50.5 m (Table 5.10-40). The substrate was primarily cobble, with some coarse gravel and fines. Water at *test* reach CHR-F3 had a mean depth of 0.75 m, a moderate velocity (0.62 m/s), slightly alkaline (pH: 7.89), with moderate conductivity (191 µS/cm), moderate dissolved oxygen (8.0 mg/L), and a temperature of 14.2˚C. Instream cover was dominated by boulders with smaller amounts of small woody debris and filamentous algae (Table 5.10-40).

Baseline reach CHR-F4 was comprised of run habitat, with a wetted width of 18.3 m and a bankfull width of 19.5 m (Table 5.10-40). The substrate was comprised entirely of fine material (Table 5.10-40). Water at *baseline* reach CHR-F4 had a mean depth of 1.02 m, a moderate velocity (0.39 m/s), slightly alkaline (pH: 7.52), with moderate conductivity (173 µS/cm), moderate dissolved oxygen (7.2 mg/L), and a temperature of 14.4˚C (Table 5.10-40). Instream cover was dominated by undercut banks with smaller amounts of boulders, overhanging vegetation, and small woody debris.

Relative Abundance of Fish Species The fish assemblage at *test* reach CHR-F3 was dominated by slimy sculpin (43.6%) (Table 5.10-41).The fish assemblage at *baseline* reach CHR-F4 was dominated by pearl dace (64.8%).

Temporal and Spatial Comparisons Sampling was initiated at *test* reach CHR-F3 and *baseline* reach CHR-F4 in fall 2013; therefore, temporal comparisons could not be conducted.

Test reach CHR-F3 had a lower abundance, CPUE, and ATI, and higher richness and diversity than *baseline* reach CHR-F4 (Table 5.10-42, Figure 5.10-34). These differences were likely attributed to the abundance of the dominant species in each reach (i.e., pearl dace at reach CHR-F4 has a higher tolerance value than the dominant slimy sculpin at reach CHR-F3). The differences in measurement endpoint values were also likely due to a difference in habitat conditions, with better habitat and more productivity at erosional reach CHR-F3 where the velocity is faster and the substrate consisted of cobbles and boulders.

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 20 fish species were recorded in the Christina River; whereas RAMP found only 15 species from 2012 to 2013. 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 riffle and run habitat with a moderate flow and substrate consisting of sand, gravel, cobble, and boulders in the Christina river, which was consistent with habitat conditions documented in fall 2013 at *test* reach CHR-F3 (Table 5.10-40). The Christina River provides good habitat for refugia and spawning fish migrating from the Clearwater River and; therefore, has a high potential to support recreational fisheries (Golder 2004). The upper portion of the Christina River where *baseline* reach CHR-F4 is located, has different habitat consisting of deeper depositional areas, unlike habitat observed further downstream.

2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reach CHR-F3 and *baseline* reach CHR-F4 were within the range of regional *baseline* conditions, with the exception of ATI at *test* reach CHR-F3, which was slightly lower than the range of regional *baseline* conditions (Figure 5.10-34). The lower ATI was likely due to a high proportion of slimy sculpin and burbot captured at this reach, which are sensitive species (Whittier et al 2007).

Classification of Results Information on fish assemblages for the southern oil sands region is just beginning to be collected; therefore, a comparison with *baseline* conditions in the northern region was conducted. Differences in measurement endpoints at *test* reach CHR-F3 were classified as **Negligible-Low** given that most measurement endpoints were with the range of *baseline* variability and the low ATI value was not indicative of a negative change in the fish assemblage.

Christina Lake Tributaries

Fish assemblages were sampled in fall 2013 at:

- erosional *test* reach SUC-F1 on Sunday Creek, sampled since 2012;
- depositional *baseline* reach SUC-F2 on Sunday Creek, sampled for the first time in 2013;
- depositional *test* reach UNC-F2 on an unnamed creek east of Christina Lake, sampled for the first time in 2013;
- depositional *test* reach UNC-F3 on an unnamed creek south of Christina Lake, sampled for the first time in 2013;
- depositional *test* reach SAC-F1 on Sawbones Creek, sampled since 2012;
- depositional *baseline* reach BRC-F1 on Birch Creek, sampled for the first time in 2013; and
- erosional *test* reach JAR-F1 on Jackfish River, sampled since 2012.

2013 Habitat Conditions *Test* reach SUC-F1 was comprised of riffle and run habitat, with a wetted width of 9.9 m and a bankfull width of 12.5 m (Table 5.10-43). The substrate was dominated by sand with some cobble. Water at *test* reach SUC-F1 had a mean depth of 0.56 m, a moderate velocity (0.24 m/s), alkaline (pH: 8.16), with moderate conductivity (226 µS/cm), moderate dissolved oxygen (8.6 mg/L), and a temperature of 17.1˚C. Instream cover was dominated by boulders with smaller amounts of macrophytes, small woody debris, overhanging vegetation, and undercut banks (Table 5.10-43).

Baseline reach SUC-F2 was comprised of run habitat, with a wetted width of 6.2 m and a bankfull width of 7.0 m (Table 5.10-43). The substrate was dominated by sand and fine material, with some small boulders. Water at *baseline* reach SUC-F2 had a mean depth of 0.71 m, a slow velocity (0.04 m/s), slightly alkaline (pH: 7.88), with moderate conductivity (192 µS/cm), moderate dissolved oxygen (8.1 mg/L), and a temperature of 13.1˚C. Instream cover was dominated by macrophytes, small woody debris, overhanging vegetation, and boulders with smaller amounts of undercut banks, large woody debris, and filamentous algae.

Test reach UNC-F2 was comprised of deep run habitat, with a wetted and bankfull width of 5.0 m (Table 5.10-43). The substrate was dominated by fines with some sand. Water at *test* reach UNC-F2 had a mean depth of 0.56 m, a moderate velocity (0.56 m/s), slightly alkaline (pH: 7.87), with moderate conductivity (127 µS/cm), moderate dissolved oxygen (7.4 mg/L), and a temperature of 17.2˚C. Instream cover was dominated by macrophytes with smaller amounts of undercut banks (Table 5.10-43).

Test reach UNC-F3 was comprised of run habitat, with a wetted width of 4.1 m and a bankfull width of 5.2 m (Table 5.10-43). The substrate was dominated by sand with some fine material. Water at *test* reach UNC-F3 had a mean depth of 0.52 m, a slow velocity (0.12 m/s), alkaline (pH: 8.02), with moderate conductivity (198 µS/cm), moderate dissolved oxygen (6.5 mg/L), and a temperature of 15.2˚C. Instream cover was dominated by macrophytes with smaller amounts of undercut banks (Table 5.10-43).

Test reach SAC-F1 was comprised of run habitat, with a wetted and bankfull width of 4.0 m (Table 5.10-43). The substrate was dominated by fines. Water at *test* reach SAC-F1 had a mean depth of 1.16 m, a negligible velocity (0.09 m/s), slightly alkaline (pH: 7.58), with moderate conductivity (111 µS/cm), low dissolved oxygen (4.6 mg/L), and a temperature of 18.2˚C. Instream cover was dominated by macrophytes and small woody debris, with smaller amounts of overhanging vegetation and undercut banks.

Baseline reach BRC-F1 was comprised of run habitat, with a wetted width of 6.4 m and a bankfull width of 8.4 m (Table 5.10-43). The substrate was dominated by sand with some small boulders. Water at *baseline* reach BRC-F1 had a mean depth of 0.8 m, a slow velocity (0.06 m/s), slightly alkaline (pH: 8.22), with high conductivity (302 µS/cm), high dissolved oxygen (9.4 mg/L), and a temperature of 5.9˚C. Instream cover was dominated by live trees and roots with smaller amounts of macrophytes, small woody debris, overhanging vegetation, and undercut banks.

Test reach JAR-F1 was comprised of riffle and run habitat, with a wetted width of 30.0 m and a bankfull width of 32.5 m (Table 5.10-43). The substrate was dominated by gravel with some cobble. Water at *test* reach JAR-F1 had a mean depth of 0.53 m, a moderate velocity (0.42 m/s), slightly alkaline (pH: 8.38), with moderate conductivity (138 µS/cm), high dissolved oxygen (9.0 mg/L), and a temperature of 18.9˚C. Instream cover was dominated by boulders with smaller amounts of filamentous algae, macrophytes, and small woody debris.

Relative Abundance of Fish Species In fall 2013, the fish assemblage at *test* reach SUC-F1 was dominated by slimy sculpin (65%), which was similar to 2012 (Table 5.10-44). *Baseline* reach SUC-F2 was also dominated by slimy sculpin (50%). There was only one fish (white sucker) caught at *test* reach UNC-F2; and *test* reach UNC-F3 was dominated by northern pike (60%). There were no fish captured at *test* reach SAC-F1 in fall 2013, while only a single northern pike was captured in 2012. The fish assemblage at *baseline* reach BRC-F1 was dominated by white sucker (75%). The fish assemblage at *test* reach JAR-F1 was dominated by burbot (61%) in fall 2013, which was consistent with 2012.

Temporal and Spatial Comparisons Temporal comparisons between 2012 and 2013 were conducted for *test* reaches SUC-F1, SAC-F1, and JAR-F1. All other reaches were first sampled in 2013; therefore, temporal comparisons could not be conducted. Spatial comparisons were conducted between *test* reach SUC-F1 and *baseline* reach SUC-F2; *test* reaches SAC-F1, UNC-F2, and UNC-F3, and *baseline* reach BRC-F1 for fall 2013. *Test* reach JAR-F1 had no comparable erosional *baseline* reach.

Abundance, richness, ATI, and CPUE were relatively similar between 2012 and 2013 at *test* reach SUC-F1, while diversity was slightly higher in 2013 (Table 5.10-42, Figure 5.10-35). All measurement endpoints were relatively similar between *test* reach SUC-F1 and *baseline* reach SUC-F2 in fall 2013 (Table 5.10-42).

Given there were no fish captured at *test* reach SAC-F1 in 2013, all measurement endpoints were lower than 2012 (Table 5.10-42, Figure 5.10-36). *Test* reaches SAC-F1, UNC-F2, and UNC-F3 and *baseline* reach BRC-F1 had very low abundance, richness, diversity, and CPUE given the low catch at these reaches (Table 5.10-42). It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. In future years of monitoring, an effort will be made to sample in better fish habitat to assess fish assemblages in these creeks.

Abundance, diversity, richness, and ATI were relatively similar between 2012 and 2013 at *test* reach JAR-F1; however, the mean CPUE more than doubled in fall 2013 compared to 2012 (Table 5.10-42, Figure 5.10-35).

Comparison to Published Literature *Baseline* information for the area was limited to data in the AESRD FWMIS (Fisheries and Wildlife Management Information System) database (AESRD 2012). Previous studies at Sunday Creek have documented Arctic grayling, brook stickleback, Iowa darter, lake whitefish, northern pike, slimy sculpin, spottail shiner, walleye, spoonhead sculpin, and white sucker. Six of these ten species were captured at *test* reach SUC-F1 by RAMP in 2012 and 2013 in addition to three species not previously documented including longnose sucker, lake chub, and pearl dace.

Arctic grayling, burbot, longnose sucker, northern pike, slimy sculpin, walleye, and white sucker have been documented in Jackfish River. Four of those seven species were captured by RAMP in 2012 and 2013 as well as two additional species (longnose dace and trout-perch) not previously documented. These studies used a variety of capture techniques and reach lengths across multiple seasons, which may explain the discrepancy in species composition.

2013 Result Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints were within the inner tolerance limits for the range of *baseline* variability at *test* reaches SUC-F1 and JAR-F1, with the exception of ATI, which was below the inner tolerance limit for the 5th percentile (Figure 5.10-35).

Mean values of CPUE and abundance at *test* reaches SAC-F1, UNC-F2, and UNC-F3, and *baseline* reach BRC-F1 were lower than the inner tolerance limit for the 5th percentile of regional *baseline* conditions (Figure 5.10-36). In addition, richness and diversity were lower than the inner tolerance limit for the 5th percentile of regional *baseline* conditions at *test* reaches SAC-F1 and UNC-F2 (Figure 5.10-36).

Classification of Results Differences in measurement endpoints of fish assemblages for erosional *test* reaches SUC-F1 and JAR-F1 on tributaries of Christina Lake were classified as **Negligible-Low** compared to regional *baseline* conditions, with almost all measurement endpoints within the range of *baseline* variability, and lower ATI values reflecting a greater proportion of sensitive fish species. Differences in measurement endpoints of fish assemblages for depositional *test* reaches SAC-F1, UNC-F2, and UNC-F3 on tributaries of Christina Lake were classified as **High** because almost all measurement endpoints were lower than the range of variability for *baseline* depositional reaches (i.e., CPUE and abundance at all three; in addition to diversity and richness at SAC-F1 and UNC-F2). In addition, only one fish was captured at *test* reach UNC-F2 and no fish were captured at *test* reach SAC-F1. It should be noted that these reaches have a large proportion of deep-water habitat, resulting in poor capture efficiency and spatial coverage. In future years of monitoring, an effort will be made to sample in better fish habitat to assess fish assemblages in these creeks.

5.10.5.2 Christina Lake Fish Tissue Monitoring

A fish tissue program to assess mercury in sportfish (lake whitefish, northern pike, and walleye) was conducted in fall 2013 in Christina Lake as part of AESRD's Fall Walleye Index Netting (FWIN) Program. Christina Lake is located south of Fort McMurray in the Christina River Watershed and in close proximity to oil sands development (e.g., Devon, MEG Energy, Cenovus). The lake is primarily used for recreational angling. Christina Lake has a total area of 21.3 km^2 and is approximately 32.9 m deep in the deepest portion of the lake. Fish tissue samples have been previously collected and analyzed at this lake in 2003 as part of the annual Regional Lakes Fish Tissue program undertaken by RAMP (RAMP 2004).

This section includes 2013 results from Christina Lake as well as comparisons to results from surveys conducted in 2003; results from other lakes/rivers sampled by RAMP and AESRD in the RAMP RSA from 2002 to 2013; and results from other studies in Alberta (1975 to 2003).

Whole-Organism Metrics

In 2013, a total of ten lake whitefish (five female, four male, and one unsexed), 14 northern pike (ten female, three male, and one unsexed), and 20 walleye (12 female, seven male, and one unsexed) from Christina Lake were sampled for fish tissue (muscle) analysis of mercury (Table 5.10-45). The fork lengths of fish sampled were as follows:

1. Lake whitefish – fork length ranged from a 198 mm unsexed fish to a 418 mm mature male. On average, male lake whitefish (mean fork length: 357 mm) were larger than female fish (mean fork length: 268 mm). The mean length of all sampled fish was 297 mm.
2. Northern pike – fork length ranged from a 404 mm immature female to a 709 mm mature female. On average, male northern pike (mean fork length: 545 mm) were larger than female fish (mean fork length: 531 mm). The mean length of all sampled fish was 540 mm.

3. Walleye – fork length ranged from a 97 mm immature female to a 602 mm mature female. On average, female walleye (mean fork length: 354 mm) were larger than male fish (mean fork length: 343 mm). The mean length of all sampled fish was 361 mm.

Mercury Concentrations

Concentrations of mercury in muscle of individual lake whitefish, northern pike, and walleye collected from Christina Lake in 2013 are presented in Table 5.10-45:

1. The mean mercury concentration in lake whitefish was 0.074 mg/kg and ranged from 0.058 mg/kg in a 227 mm immature male to 0.091 mg/kg in a 253 mm immature female.
2. The mean mercury concentration in northern pike was 0.237 mg/kg and ranged from 0.033 mg/kg in a 429 mm mature male to 0.699 mg/kg in a 618 mm unsexed fish.
3. The mean mercury concentration in walleye was 0.277 mg/kg and ranged from 0.119 mg/kg in 241 mm immature male to 0.733 mg/kg in a 575 mm unsexed mature fish.

Regressions between mercury concentration ($\log_{10}$-transformed) and fork length were not statistically significant for lake whitefish ($p=0.70$; $r^2=0.02$) indicating that there was no difference in mercury concentrations across varying length of fish. Mercury was significantly different across fork lengths for northern pike ($p<0.001$, $r^2=0.80$) and walleye ($p<0.001$, $r^2=0.58$), 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

A summary of 2013 lake whitefish, northern pike, and walleye muscle mercury concentrations from Christina Lake relative to Health Canada fish consumption guidelines is as follows:

Lake Whitefish Mercury concentrations in all lake whitefish captured from Christina 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 in lake whitefish in 2013 were similar to those recorded in 2003 at Christina Lake (Figure 5.10-37).

Northern Pike Mercury concentrations in five northern pike fish captured from Christina Lake were above the Health Canada guideline for subsistence fishers (0.2 mg/kg), two of which were above the guideline for general consumers (0.5 mg/kg). The mercury concentrations for 2013 were similar to those recorded in 2003 at Christina Lake (Figure 5.10-38).

Walleye Mercury concentrations in ten walleye captured from Christina Lake were above the Health Canada guideline for subsistence fishers (0.2 mg/kg), three of which were above the guideline for general consumers (0.5 mg/kg). The mercury concentrations for 2013 were similar to those recorded in 2003 at Christina Lake (Figure 5.10-39). The Government of Alberta has established waterbody-specific consumption guidelines for some lakes (see Table 3.2-10). The guideline for consumption is based on body weight of captured fish given that mercury bioaccumulates in fish as they get bigger. There were two walleye captured that were greater than 1,816 g in weight (Table 5.10-45), indicating that there are consumption limits for adults, women (child-bearing or pregnant), and children in the amount of fish that can be consumed on a weekly basis (i.e., 8 servings/week for women and two to four servings/week for children).

Additional exceedances of USEPA mercury consumption guidelines are outlined in Table 5.10-45.

Temporal and Spatial Comparisons

Christina Lake Temporal comparisons were made across two years of sampling (2003 and 2013) in Christina Lake (Figure 5.10-37, Figure 5.10-38, and Figure 5.10-39). Lake whitefish and northern pike captured in 2013 were generally smaller than those caught in 2003. It should be noted that the sample size in 2003 was lower than 2013 and not representative of all size classes. An analysis of covariance (ANCOVA) on ranked-transformed (Conover and Ima 1982) data indicated that differences in mercury concentrations in fish tissue relative to length were not statistically significant across years for walleye (p=0.42). Differences in mercury concentrations in northern pike and lake whitefish fish tissue relative to length could not be evaluated between years because the slopes were significantly different (p=0.01) (Figure 5.10-38).

Lakes in the RAMP RSA This section compares 2013 results from Christina Lake to other lakes/rivers sampled by RAMP and AESRD in the RAMP RSA from 2002 to 2013, and results from other studies in Alberta (1975 to 2003).

Length-normalized concentrations of mercury in lake whitefish, northern pike, and walleye sampled from lakes by RAMP and AESRD between 2002 and 2013 are provided in Figure 5.10-40 to Figure 5.10-42. Most of the sampled lakes were in the southern portion (i.e., Gregoire Lake, Christina Lake, and Winefred Lake) and northern portion of the RAMP RSA (i.e., Jackson, Net, and Brutus lakes), while some are on the western border of the RAMP RSA (Big Island, Gardiner, and Namur lakes) and Lake Claire is in the Athabasca River Delta (RAMP 2009b).

Mercury concentrations in lake whitefish, northern pike, and walleye from Christina Lake were within the range of mercury concentrations recorded from other lakes within the RAMP RSA. In general, the highest concentrations of mercury in fish were recorded from Net Lake in 2010 and the lowest were recorded from Big Island Lake in 2008.

Spatial comparisons using an ANCOVA for each species indicated that there were significant differences in mercury concentrations in fish across lakes ($p<0.001$) for lake whitefish and northern pike. Differences in mercury concentrations in walleye relative to fork length across lakes could not be evaluated because of the significant difference in slopes between fork length and lakes ($p<0.001$).

There are several factors that could influence the concentration of mercury in fish, including 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) (e.g., Christina Lake). 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).

On a local scale, wetlands and land clearing are potential sources of mercury to surface waterbodies. Wetlands are an important source of methylmercury production in boreal ecosystems (St. Louis et al. 1996; Grigal 2002). 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. 1996). 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 2002).

Information for these lakes including water quality and physical characteristics were not available and; therefore, could not be included in the analyses. In addition, ageing data for fish captured in 2013 were not available to determine whether older (and larger fish) had higher concentrations of mercury in tissue.

Lakes in Alberta To provide a regional context for the results from the 2013 Regional Lakes Fish Tissue program, Figure 5.10-43 to Figure 5.10-45 provide length-standardized mercury concentrations in fish sampled from lakes in northern Alberta against human consumption guidelines (see Section 3.2.4.2) (AOSERP 1977; Grey et al. 1995; NRBS 1996; RAMP 2003; RAMP 2004; RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2012; RAMP 2013).

Mean mercury concentrations in lake whitefish were standardized to mean fork length of fish from all samples (386 mm). Standardized mean mercury concentrations ranged from 0.01 mg/kg (Primrose Lake 1983) to 0.15 mg/kg (Lake Athabasca 1975) (Figure 5.10-43). In all waterbodies 100% of length-standardized mean mercury concentrations in lake whitefish were below Health Canada subsistence fisher guidelines (0.2 mg/kg) and below general consumer guidelines (0.5 mg/kg).

Mean mercury concentrations in northern pike were standardized to mean fork length of fish from all samples (596 mm). Standardized mean mercury concentrations ranged from 0.052 mg/kg (Reita Lake in 1981) to 0.71 mg/kg (Helena Lake in 1974) (Figure 5.10-44). In waterbodies sampled for northern pike, 50% of length-standardized mean mercury concentrations were below Health Canada subsistence fisher guidelines (0.2 mg/kg), 43% were above subsistence guidelines and below general consumer guidelines (0.5 mg/kg), and 7% were above general consumer guidelines. With the exception of Net Lake, the lakes for which length-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 (1974 to 1981). Mercury concentrations exceeded Health Canada general consumer guidelines in northern pike in Net Lake in 2010, located approximately 150 km north of Fort McMurray.

Mean mercury concentrations in walleye were standardized to mean fork length across all samples (439.1 mm). Standardized mean mercury concentrations ranged from 0.018 mg/kg (Graham Lake 1981a) to 0.83 mg/kg (Ironwood Lake 1982a) (Figure 5.10-45). In waterbodies sampled for walleye, 46% of standardized mean mercury concentrations were below the Health Canada subsistence fisher guideline (0.2 mg/kg), 38% 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. With the exception of Net Lake, 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 observed during years prior to focal project development (1974 to 1981).

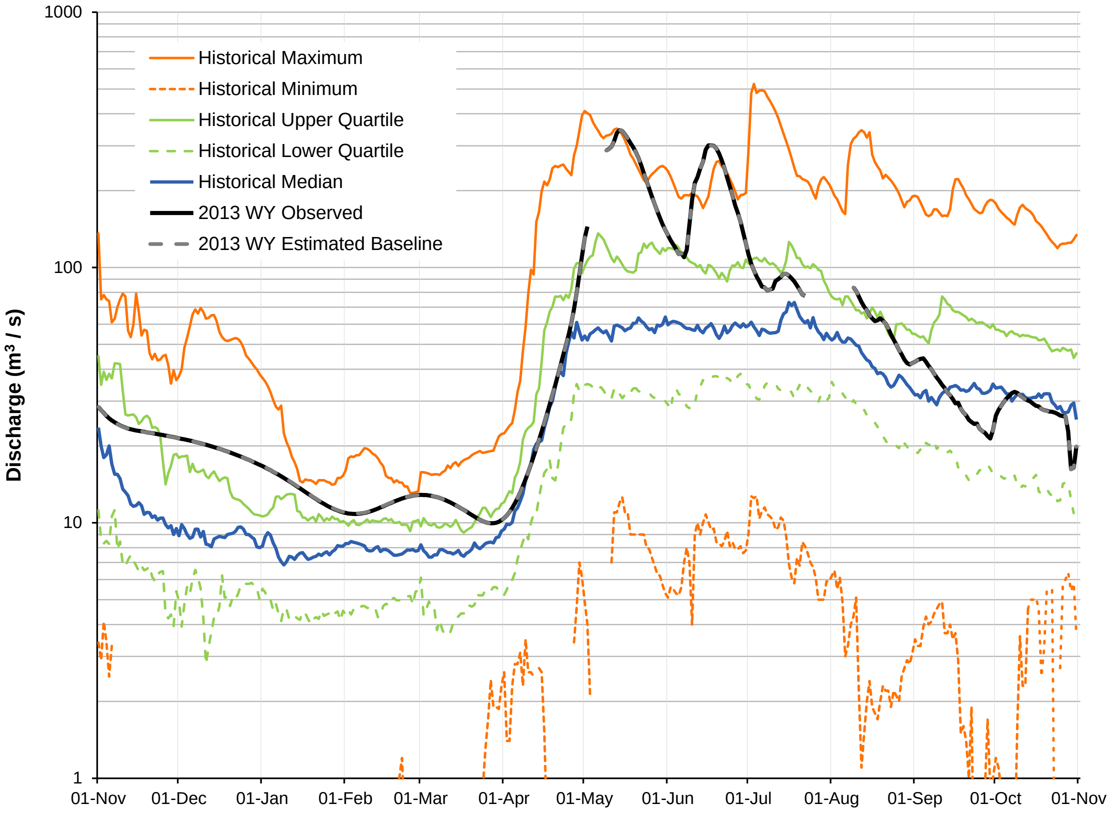
An exceedance of the Health Canada general consumer guideline for the standardized mean mercury concentration in walleye was measured in Lake Athabasca in 1977 (Figure 5.10-45), which is located within the RAMP RSA and downstream of focal project activities. Since then, the standardized mean mercury concentration in walleye in Lake Athabasca has been below the Health Canada general consumer guideline (Figure 5.10-45).

Classification of Results

Mercury concentrations in lake whitefish from Christina Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in northern pike and walleye from Christina Lake in 2013 were above Health Canada consumption subsistence guidelines indicating a **High** risk to the health of subsistence fishers consuming northern pike and walleye. Given that all northern pike and most walleye exceeded the guideline for subsistence fishers, there was a **Moderate** risk to general consumers of northern pike and walleye, dependent on the quantity of fish consumed.

Mercury concentrations in fish from Christina Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes. There were no significant increases in mercury concentrations in lake whitefish, northern pike, or walleye in Christina Lake between 2003 and 2013 and between lakes within 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. An 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 ($p<0.001$) in mercury concentrations in walleye and lake whitefish based on analyses conducted on samples from 1984 to 2011 as well as from 2002 to 2011 in the Steepbank and Muskeg reaches of the Athabasca River. Mercury concentrations in northern pike in western Lake Athabasca were also found to have decreased between 1981 and 2009, while walleye and lake trout showed no changes. Overall, the 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.

Figure 5.10-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the mouth of the Christina River in the 2013 WY, compared to historical values.



Note: The observed 2013 WY hydrograph was based on Christina River near the mouth, Station S47A, 2013 provisional data. The upstream drainage area is 13,038 km². Historical data included estimated values from 1967 to 2011 and recorded data in 2012. The estimated historical data from 1967 to 2011 were calculated from the difference between the measured flow at Clearwater River above Christina River, WSC Station 07CD005 and Clearwater River above Draper, WSC Station 07CD001. The historical data calculated were calculated based on 43 years of record (1967 to 2011) from March to October, and 21 years of record for November to February (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 were negligible.

Table 5.10-2 Estimated water balance for the mouth of the Christina River, 2013 WY.

Component	Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus Other Oil Sands Developments	
Observed *test* hydrograph (total discharge)	**1,781.208**	**1,781.208**	**Observed discharge at Christina River near the mouth, RAMP S47A**
Closed-circuited area water loss from the calculated *test* hydrograph	-1.834	-1.834	Estimated 13.4 km^2 of the Christina River watershed is closed-circuited from focal projects or from focal projects plus other oil sands developments as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+2.887	+2.984	Estimated 105.7 km^2 and 109.3 km^2 of the Christina River watershed with land change from focal projects and from focal projects plus other oil sands developments as of 2013, respectively, that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Christina River watershed from projects	-0.436	-0.436	Approximately 0.44 million m^3 of water withdrawn by Nexen, ConocoPhillips, MEG Energy, Canadian Natural, Cenovus, 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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**1,780.592**	**1,780.494**	**Estimated *baseline* discharge at Christina River near the mouth, RAMP Station S47A**
Incremental flow (change in total annual discharge)	+0.616	+0.714	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**+0.03%**	**+0.04%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Based on Christina River near the mouth, RAMP Station S47A, 2013 WY provisional data.

Table 5.10-3 Calculated change in hydrologic measurement endpoints for the mouth of the Christina River, 2013 WY.

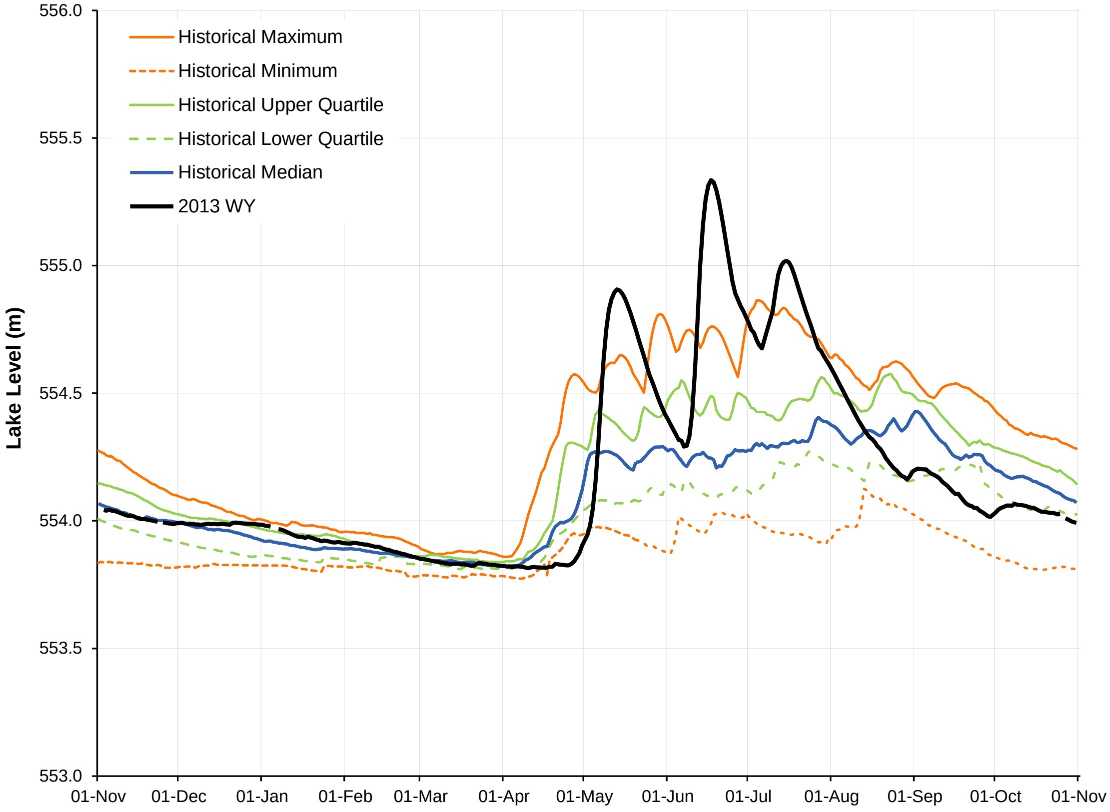
Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)		Relative Change	
		Focal Projects	Focal Projects Plus Other Oil Sands Developments	Focal Projects	Focal Projects Plus Other Oil Sands Developments
Mean open-water season discharge	106.775	106.725	106.719	+0.05%	+0.05%
Mean winter discharge	15.955	15.965	15.964	-0.06%	-0.06%
Annual maximum daily discharge	345.259	345.075	345.056	+0.05%	+0.06%
Open-water season minimum daily discharge	16.223	16.213	16.213	+0.06%	+0.06%

Note: Based on Christina River near the mouth, RAMP Station S47A, 2013 WY provisional data.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and two decimal places, respectively.

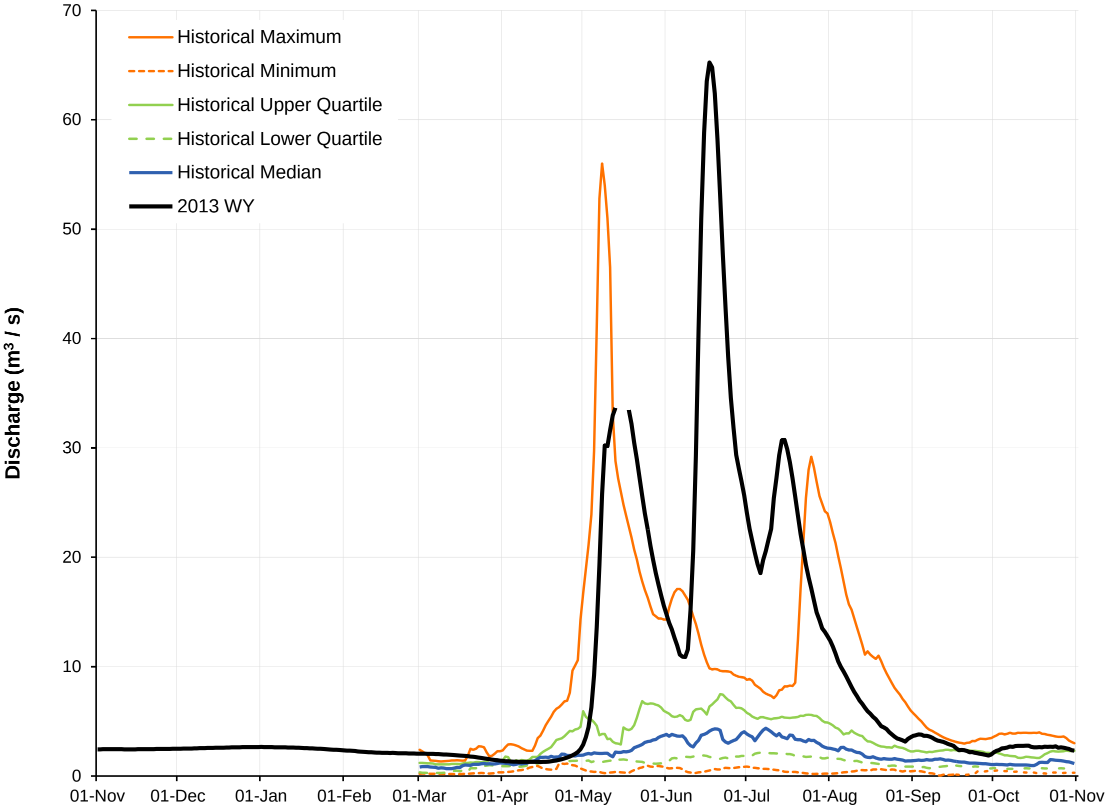
Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Figure 5.10-4 Observed lake levels for Christina Lake near Winfred Lake in the 2013 WY, compared to historical values.



Note: Based on provisional 2013 WY data recorded at Christina Lake near Winfred Lake WSC Station 07CE906. Historical values were calculated for the period 2001 to 2012.

Figure 5.10-5 **Hydrograph for Jackfish River below Christina Lake for the 2013 WY, compared to historical values.**



Note: Based on provisional 2013 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 and RAMP Station S56 for 2012.

Table 5.10-4 Concentrations of water quality measurement endpoints, mouth of Christina River (*test* station CHR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	11	8.1	8.3	8.4
Total suspended solids	mg/L	-	28	11	<3	26	123
Conductivity	µS/cm	-	303	11	210	291	375
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.024	11	0.017	0.023	**0.054**
Total nitrogen	mg/L	1	0.83	11	0.60	1.00	**1.80**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	19.6	11	14.0	19.8	25.3
Ions							
Sodium	mg/L	-	23.0	11	12.8	25.0	34.0
Calcium	mg/L	-	30.9	11	22.0	26.5	30.2
Magnesium	mg/L	-	8.89	11	6.96	8.00	9.42
Chloride	mg/L	120	22.0	11	9.5	24.0	41.0
Sulphate	mg/L	270	6.44	11	2.20	6.80	8.49
Total dissolved solids	mg/L	-	195	11	140	190	250
Total alkalinity	mg/L	-	114	11	86	110	120
Selected metals							
Total aluminum	mg/L	0.1	**1.39**	11	**0.24**	**0.62**	**3.23**
Dissolved aluminum	mg/L	0.1	0.015	11	0.007	0.010	0.029
Total arsenic	mg/L	0.005	0.0014	11	0.0007	0.0011	0.0018
Total boron	mg/L	1.2	0.057	11	0.027	0.054	0.074
Total molybdenum	mg/L	0.073	0.00044	11	0.00016	0.00038	0.00040
Total mercury (ultra-trace)	ng/L	5, 13	2.2	10	<1.2	<1.3	**6.0**
Total strontium	mg/L	-	0.13	11	0.08	0.12	0.15
Total hydrocarbons							
BTEX	mg/L	-	<0.10	2	<0.10	<0.10	0.10
Fraction 1 (C6-C10)	mg/L	-	<0.10	2	<0.10	<0.10	0.10
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	0.25
Naphthenic Acids	mg/L	-	0.33	2	<0.02	0.03	0.03
Oilsands Extractable	mg/L	-	0.48	2	0.37	0.74	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.2	2	<8.8	<11.4	<14.1
Retene	ng/L	-	3.44	2	<2.07	2.76	3.44
Total dibenzothiophenes	ng/L	-	16.3	2	6.0	29.1	52.1
Total PAHs	ng/L	-	148	2	155	235	316
Total Parent PAHs	ng/L	-	23.5	2	19.5	19.9	20.4
Total Alkylated PAHs	ng/L	-	125	2	135	216	296
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**1.04**	11	0.26	**0.38**	**0.96**
Sulphide	mg/L	0.002	**0.003**	11	<0.002	**0.005**	**0.011**
Total iron	mg/L	0.3	**2.17**	11	**0.78**	**1.49**	**3.81**
Total phenols	mg/L	0.004	**0.0046**	11	<0.0010	**0.0054**	**0.0140**
Total phosphorus	mg/L	0.05	**0.089**	11	0.049	**0.064**	**0.149**
Total chromium	mg/L	0.001	**0.0013**	11	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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.22	11	7.90	8.20	8.35
Total suspended solids	mg/L	-	7	11	<3	8	30
Conductivity	µS/cm	-	228	11	125	205	268
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.065**	11	0.016	0.033	**0.053**
Total nitrogen	mg/L	1	0.681	11	0.600	0.901	**1.400**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	19.3	11	13.0	18.0	29.2
Ions							
Sodium	mg/L	-	6.6	11	2.9	6.0	10.0
Calcium	mg/L	-	30.6	11	16.3	27.4	35.1
Magnesium	mg/L	-	8.2	11	4.6	8.0	10.6
Chloride	mg/L	120	<0.5	11	<0.5	1.0	2.0
Sulphate	mg/L	270	5.8	11	0.5	4.4	9.6
Total dissolved solids	mg/L	-	217	11	120	140	240
Total alkalinity	mg/L		113	11	59	102	138
Selected metals							
Total aluminum	mg/L	0.1	0.09	10	0.05	**0.21**	**0.51**
Dissolved aluminum	mg/L	0.1	0.014	10	0.003	0.010	0.019
Total arsenic	mg/L	0.005	0.0016	10	0.0007	0.0011	0.0016
Total boron	mg/L	1.2	0.039	10	0.022	0.031	0.051
Total molybdenum	mg/L	0.073	0.0006	10	0.0003	0.0004	0.0007
Total mercury (ultra-trace)	ng/L	5, 13	1.3	10	<0.6	<1.2	4.9
Total strontium	mg/L	-	0.13	10	0.06	0.10	0.16
Total hydrocarbons							
BTEX	mg/L	-	<0.10	2	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	-	<0.10	2	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.37	2	0.06	0.16	0.25
Oilsands Extractable	mg/L	-	0.61	2	0.40	0.61	0.82
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.2	2	<8.8	<11.4	<14.1
Retene	ng/L	-	<1.69	2	<2.07	2.92	3.76
Total dibenzothiophenes	ng/L	-	6.67	2	5.84	20.62	35.40
Total PAHs	ng/L	-	103	2	154	182	211
Total Parent PAHs	ng/L	-	22.9	2	18.5	20.1	21.8
Total Alkylated PAHs	ng/L	-	80	2	132	162	192
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**2.71**	10	**0.68**	**1.42**	**2.64**
Dissolved iron	mg/L	0.3	**1.96**	10	0.03	**0.62**	**1.41**
Total phenols	mg/L	0.004	**0.009**	11	<0.001	**0.009**	**0.019**
sulphide	mg/L	0.002	**0.005**	11	<0.002	**0.006**	**0.040**
Total phosphorus	mg/L	0.05	**0.089**	11	0.040	**0.068**	**0.128**

[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, Christina River upstream of Jackfish River (*test* station CHR-3), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.24
Total suspended solids	mg/L	-	<3.00
Conductivity	µS/cm	-	233
Nutrients			
Total dissolved phosphorus	mg/L	0.05	**0.090**
Total nitrogen	mg/L	1	0.641
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	22.50
Ions			
Sodium	mg/L	-	7.50
Calcium	mg/L	-	33.5
Magnesium	mg/L	-	9.37
Chloride	mg/L	120	<0.50
Sulphate	mg/L	270	5.96
Total dissolved solids	mg/L	-	187
Total alkalinity	mg/L		126
Selected metals			
Total aluminum	mg/L	0.1	0.057
Dissolved aluminum	mg/L	0.1	0.019
Total arsenic	mg/L	0.005	0.002
Total boron	mg/L	1.2	0.045
Total molybdenum	mg/L	0.073	0.00087
Total mercury (ultra-trace)	ng/L	5, 13	1.50
Total strontium	mg/L	-	0.144
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	-	0.31
Oilsands Extractable	mg/L	-	0.49
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	1.050
Total dibenzothiophenes	ng/L	-	6.672
Total PAHs	ng/L	-	102.5
Total Parent PAHs	ng/L	-	22.44
Total Alkylated PAHs	ng/L	-	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Dissolved iron	mg/L	0.3	**2.87**
Total iron	mg/L	0.3	**4.15**
Total phosphorus	mg/L	0.05	**0.131**
Sulphide	mg/L	0.002	**0.007**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-7 Concentrations of water quality measurement endpoints, Christina River upstream of development (*baseline* station CHR-4), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.1
Total suspended solids	mg/L	-	18.0
Conductivity	µS/cm	-	221
Nutrients			
Total dissolved phosphorus	mg/L	0.05	**0.118**
Total nitrogen	mg/L	1	0.869
Nitrate+nitrite	mg/L	3	0.079
Dissolved organic carbon	mg/L	-	26.1
Ions			
Sodium	mg/L	-	3.50
Calcium	mg/L	-	34.6
Magnesium	mg/L	-	8.21
Chloride	mg/L	120	<0.50
Sulphate	mg/L	270	2.36
Total dissolved solids	mg/L	-	186
Total alkalinity	mg/L		114
Selected metals			
Total aluminum	mg/L	0.1	**0.227**
Dissolved aluminum	mg/L	0.1	0.027
Total arsenic	mg/L	0.005	0.003
Total boron	mg/L	1.2	0.026
Total molybdenum	mg/L	0.073	0.0006
Total mercury (ultra-trace)	ng/L	5, 13	2.30
Total strontium	mg/L	-	0.124
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	-	0.38
Oilsands Extractable	mg/L	-	0.48
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	11.00
Total dibenzothiophenes	ng/L	-	6.672
Total PAHs	ng/L	-	114.1
Total Parent PAHs	ng/L	-	22.44
Total Alkylated PAHs	ng/L	-	91.65
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Dissolved iron	mg/L	0.3	**6.44**
Total iron	mg/L	0.3	**10.6**
Total phosphorus	mg/L	0.05	**0.303**
Sulphide	mg/L	0.002	**0.0048**

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

Table 5.10-8 Concentrations of water quality measurement endpoints, Christina Lake (*test* station CHL-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	September 2012
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.2	8.1
Total suspended solids	mg/L	-	5	15
Conductivity	µS/cm	-	166	206
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.009	0.004
Total nitrogen	mg/L	1	0.721	0.631
Nitrate+nitrite	mg/L	3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	16.3	13.4
Ions				
Sodium	mg/L	-	4.5	6.1
Calcium	mg/L	-	22.3	23.6
Magnesium	mg/L	-	6.75	7.21
Chloride	mg/L	120	1.09	1.04
Sulphate	mg/L	270	0.87	1.01
Total dissolved solids	mg/L	-	140	141
Total alkalinity	mg/L		86.4	105.0
Selected metals				
Total aluminum	mg/L	0.1	0.0142	0.0298
Dissolved aluminum	mg/L	0.1	0.005	<0.001
Total arsenic	mg/L	0.005	0.0007	0.0005
Total boron	mg/L	1.2	0.0213	0.0262
Total molybdenum	mg/L	0.073	0.00021	0.00023
Total mercury (ultra-trace)	ng/L	5, 13	1.3	1.2
Total strontium	mg/L	-	0.061	0.074
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.29	0.11
Oilsands Extractable	mg/L	-	0.55	0.12
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<15.16	<8.76
Retene	ng/L	-	0.905	<0.509
Total dibenzothiophenes	ng/L	-	6.67	35.30
Total PAHs	ng/L	-	103.3	225.2
Total Parent PAHs	ng/L	-	23.25	23.74
Total Alkylated PAHs	ng/L	-	80.05	201.43
Other variables that exceeded CCME/AESRD guidelines in fall 2013				
Total phenols	mg/L	0.004	**0.0048**	**0.0052**

[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, Sawbones Creek (*test* station SAC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	September 2012
			Value	**Value**
Physical variables				
pH	pH units	6.5-9.0	7.7	7.7
Total suspended solids	mg/L	-	<3.0	<3.0
Conductivity	µS/cm	-	143	95
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.032	0.024
Total nitrogen	mg/L	1	0.681	0.701
Nitrate+nitrite	mg/L	3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	26.4	19.8
Ions				
Sodium	mg/L	-	2.70	2.50
Calcium	mg/L	-	20.2	12.1
Magnesium	mg/L	-	6.01	3.72
Chloride	mg/L	120	<0.50	<0.50
Sulphate	mg/L	270	<0.50	<0.50
Total dissolved solids	mg/L	-	149	101
Total alkalinity	mg/L		71.2	47.8
Selected metals				
Total aluminum	mg/L	0.1	0.022	0.046
Dissolved aluminum	mg/L	0.1	0.008	0.006
Total arsenic	mg/L	0.005	0.0012	0.0007
Total boron	mg/L	1.2	0.011	0.019
Total molybdenum	mg/L	0.073	<0.0001	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	1.0	1.1
Total strontium	mg/L	-	0.059	0.037
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	-	0.29	0.05
Oilsands Extractable	mg/L	-	0.81	0.30
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<15.16	<8.756
Retene	ng/L	-	<0.669	<0.509
Total dibenzothiophenes	ng/L	-	6.7	35.3
Total PAHs	ng/L	-	102.5	203.4
Total Parent PAHs	ng/L	-	22.50	16.42
Total Alkylated PAHs	ng/L	-	80	187
Other variables that exceeded CCME/AESRD guidelines in fall 2013				
Dissolved iron	mg/L	0.3	**0.475**	0.244
Total phenols	mg/L	0.004	**0.007**	**0.009**
Total iron	mg/L	0.3	**0.792**	**0.400**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-10 Concentrations of water quality measurement endpoints, Jackfish River (*test* station JAR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	September 2012
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.1	8.0
Total suspended solids	mg/L	-	<3.0	<3.0
Conductivity	µS/cm	-	175	207
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.015	0.010
Total nitrogen	mg/L	1	0.691	0.501
Nitrate+nitrite	mg/L	3	<0.071	<0.071
Dissolved organic carbon	mg/L	-	15.9	16.1
Ions				
Sodium	mg/L	-	4.6	5.5
Calcium	mg/L	-	22.5	24.5
Magnesium	mg/L	-	6.67	7.29
Chloride	mg/L	120	1.06	1.05
Sulphate	mg/L	270	0.95	1.01
Total dissolved solids	mg/L	-	173	129
Total alkalinity	mg/L		89.3	107.0
Selected metals				
Total aluminum	mg/L	0.1	0.022	0.008
Dissolved aluminum	mg/L	0.1	0.005	0.001
Total arsenic	mg/L	0.005	0.0007	0.0005
Total boron	mg/L	1.2	0.022	0.030
Total molybdenum	mg/L	0.073	0.00023	0.00022
Total mercury (ultra-trace)	ng/L	5, 13	1.0	<0.6
Total strontium	mg/L	-	0.066	0.075
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	-	0.23	0.04
Oilsands Extractable	mg/L	-	0.54	0.36
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	15.2	<8.76
Retene	ng/L	-	1.140	0.916
Total dibenzothiophenes	ng/L	-	6.67	35.30
Total PAHs	ng/L	-	106	206
Total Parent PAHs	ng/L	-	22.96	16.59
Total Alkylated PAHs	ng/L	-	83.0	189.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013				
Total phenols	mg/L	0.004	**0.0087**	0.0035

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-11 Concentrations of water quality measurement endpoints, lower Sunday Creek (*test* station SUC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	September 2012
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.2	8.2
Total suspended solids	mg/L	-	<3.0	8.0
Conductivity	µS/cm	-	310	267
Nutrients				
Total dissolved phosphorus	mg/L	0.05	0.031	0.019
Total nitrogen	mg/L	1	0.503	0.571
Nitrate+nitrite	mg/L	3	0.073	<0.071
Dissolved organic carbon	mg/L	-	18.0	14.4
Ions				
Sodium	mg/L	-	12.5	6.8
Calcium	mg/L	-	38.8	33.4
Magnesium	mg/L	-	11.2	10.4
Chloride	mg/L	120	<6.3	3.86
Sulphate	mg/L	270	<15.1	1.1
Total dissolved solids	mg/L	-	223	157
Total alkalinity	mg/L		142	135
Selected metals				
Total aluminum	mg/L	0.1	**0.142**	**0.239**
Dissolved aluminum	mg/L	0.1	0.007	0.004
Total arsenic	mg/L	0.005	0.0010	0.0009
Total boron	mg/L	1.2	0.034	0.027
Total molybdenum	mg/L	0.073	0.0006	0.0003
Total mercury (ultra-trace)	ng/L	5, 13	1.2	1.9
Total strontium	mg/L	-	0.116	0.085
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	-	0.20	0.28
Oilsands Extractable	mg/L	-	0.75	0.65
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	-	<15.16	<8.76
Retene	ng/L	-	2.63	2.07
Total dibenzothiophenes	ng/L	-	6.67	35.30
Total PAHs	ng/L	-	103	206
Total Parent PAHs	ng/L	-	22.5	16.5
Total Alkylated PAHs	ng/L	-	80.6	189.3
Other variables that exceeded CCME/AESRD guidelines in fall 2013				
Total iron	mg/L	0.3	**0.548**	**0.949**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-12 Concentrations of water quality measurement endpoints, upper Sunday Creek (*baseline* station SUC-2), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.0
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	227
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.018
Total nitrogen	mg/L	1	0.381
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	14.4
Ions			
Sodium	mg/L	-	3.0
Calcium	mg/L	-	34.3
Magnesium	mg/L	-	9.8
Chloride	mg/L	120	1.0
Sulphate	mg/L	270	0.54
Total dissolved solids	mg/L	-	144
Total alkalinity	mg/L		125
Selected metals			
Total aluminum	mg/L	0.1	0.068
Dissolved aluminum	mg/L	0.1	0.006
Total arsenic	mg/L	0.005	0.0009
Total boron	mg/L	1.2	0.015
Total molybdenum	mg/L	0.073	0.00027
Total mercury (ultra-trace)	ng/L	5, 13	0.94
Total strontium	mg/L	-	0.069
Total hydrocarbons			
BTEX	mg/L	-	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25
Naphthenic Acids	mg/L	-	0.17
Oilsands Extractable	mg/L	-	0.43
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	1.47
Total dibenzothiophenes	ng/L	-	6.67
Total PAHs	ng/L	-	103
Total Parent PAHs	ng/L	-	22.5
Total Alkylated PAHs	ng/L	-	80.5
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Total phenols	mg/L	0.004	**0.004**
Total iron	mg/L	0.3	**0.457**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-13 Concentrations of water quality measurement endpoints, Birch Creek (*baseline* station BRC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.48
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	341
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.032
Total nitrogen	mg/L	1	0.421
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	10.8
Ions			
Sodium	mg/L	-	13.6
Calcium	mg/L	-	45.9
Magnesium	mg/L	-	12.6
Chloride	mg/L	120	<0.500
Sulphate	mg/L	270	4.95
Total dissolved solids	mg/L	-	197
Total alkalinity	mg/L		184
Selected metals			
Total aluminum	mg/L	0.1	0.079
Dissolved aluminum	mg/L	0.1	0.006
Total arsenic	mg/L	0.005	0.0016
Total boron	mg/L	1.2	0.0496
Total molybdenum	mg/L	0.073	0.0010
Total mercury (ultra-trace)	ng/L	5, 13	0.800
Total strontium	mg/L	-	0.140
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	-	0.19
Oilsands Extractable	mg/L	-	0.45
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	<0.669
Total dibenzothiophenes	ng/L	-	6.67
Total PAHs	ng/L	-	105.57
Total Parent PAHs	ng/L	-	25.53
Total Alkylated PAHs	ng/L	-	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Total iron	mg/L	0.3	**1.46**
Total phosphorus	mg/L	0.05	**0.079**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-14 Concentrations of water quality measurement endpoints, Unnamed Creek, east of Christina Lake (*test* station UNC-2), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	7.91
Total suspended solids	mg/L	-	<5.0
Conductivity	µS/cm	-	136
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.022
Total nitrogen	mg/L	1	0.891
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	21.0
Ions			
Sodium	mg/L	-	2.60
Calcium	mg/L	-	18.8
Magnesium	mg/L	-	5.61
Chloride	mg/L	120	0.57
Sulphate	mg/L	270	<0.500
Total dissolved solids	mg/L	-	141
Total alkalinity	mg/L		68.4
Selected metals			
Total aluminum	mg/L	0.1	0.058
Dissolved aluminum	mg/L	0.1	0.006
Total arsenic	mg/L	0.005	0.0008
Total boron	mg/L	1.2	0.015
Total molybdenum	mg/L	0.073	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	1.10
Total strontium	mg/L	-	0.050
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	-	0.35
Oilsands Extractable	mg/L	-	0.76
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	0.803
Total dibenzothiophenes	ng/L	-	6.672
Total PAHs	ng/L	-	105.6
Total Parent PAHs	ng/L	-	25.53
Total Alkylated PAHs	ng/L	-	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Dissolved iron	mg/L	0.3	**0.329**
Sulphide	mg/L	0.002	**0.0024**
Total iron	mg/L	0.3	**0.512**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Table 5.10-15 Concentrations of water quality measurement endpoints, Unnamed Creek south of Christina Lake (*test* station UNC-3), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.11
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	227
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.040
Total nitrogen	mg/L	1	0.591
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	18.0
Ions			
Sodium	mg/L	-	6.60
Calcium	mg/L	-	31.1
Magnesium	mg/L	-	9.29
Chloride	mg/L	120	<0.50
Sulphate	mg/L	270	<0.50
Total dissolved solids	mg/L	-	179
Total alkalinity	mg/L		127
Selected metals			
Total aluminum	mg/L	0.1	0.092
Dissolved aluminum	mg/L	0.1	0.009
Total arsenic	mg/L	0.005	0.0011
Total boron	mg/L	1.2	0.027
Total molybdenum	mg/L	0.073	<0.0002
Total mercury (ultra-trace)	ng/L	5, 13	0.950
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	-	0.22
Oilsands Extractable	mg/L	-	0.94
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	<0.669
Total dibenzothiophenes	ng/L	-	6.672
Total PAHs	ng/L	-	105.6
Total Parent PAHs	ng/L	-	25.53
Total Alkylated PAHs	ng/L	-	80.05
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Dissolved iron	mg/L	0.3	**0.365**
Total iron	mg/L	0.3	**0.577**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Figure 5.10-6 Piper diagram of fall ion concentrations in the mainstem stations (*test* stations CHR-1, CHR-2, CHR-3, and *baseline* station CHR-4) of the Christina River.

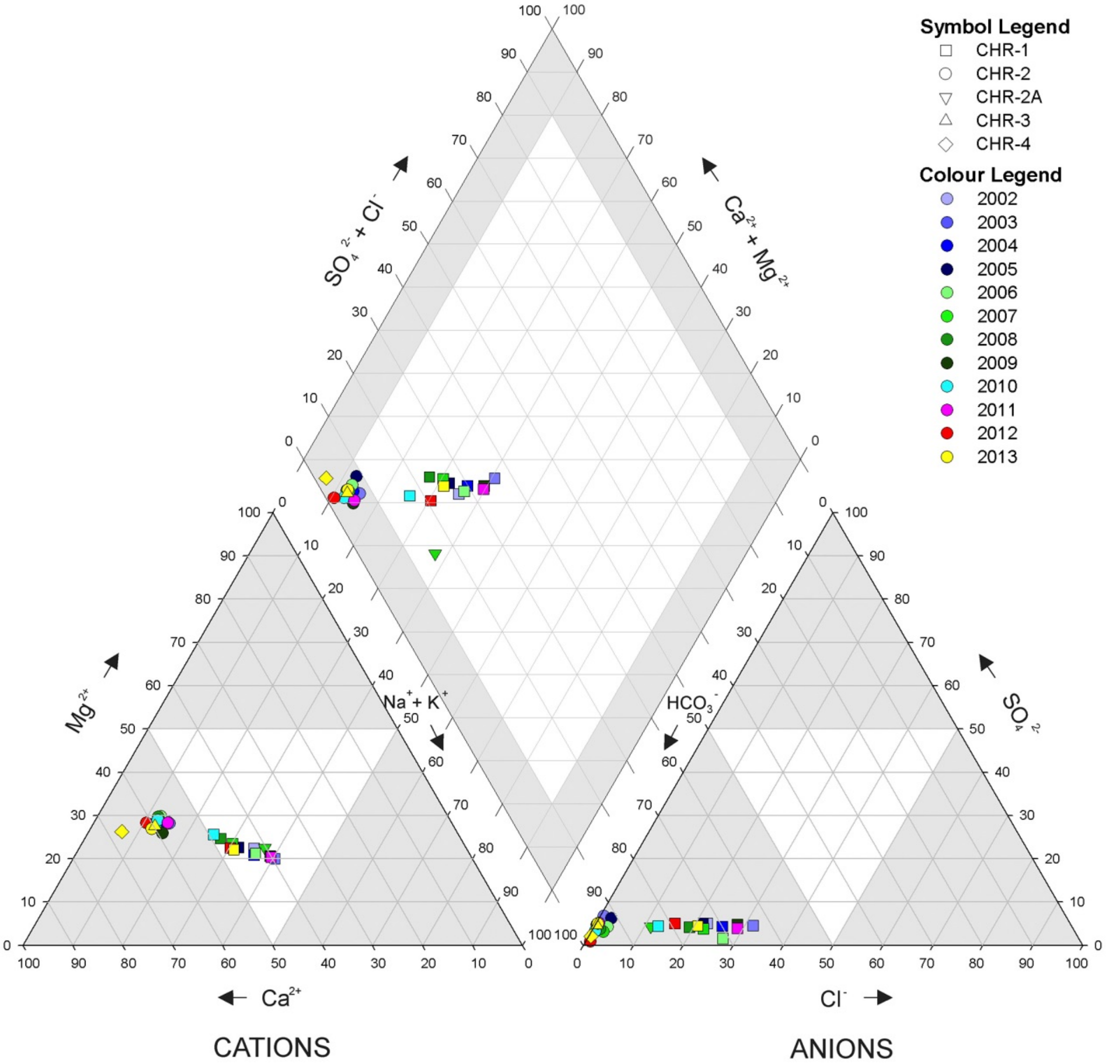


Figure 5.10-7 Piper diagram of fall ion concentrations in tributary stations (*test* stations JAR-1, SAC-1, SUC-1, UNC-2, UNC-3 and *baseline* stations BRC-1, SUC-2) of the Christina River watershed.

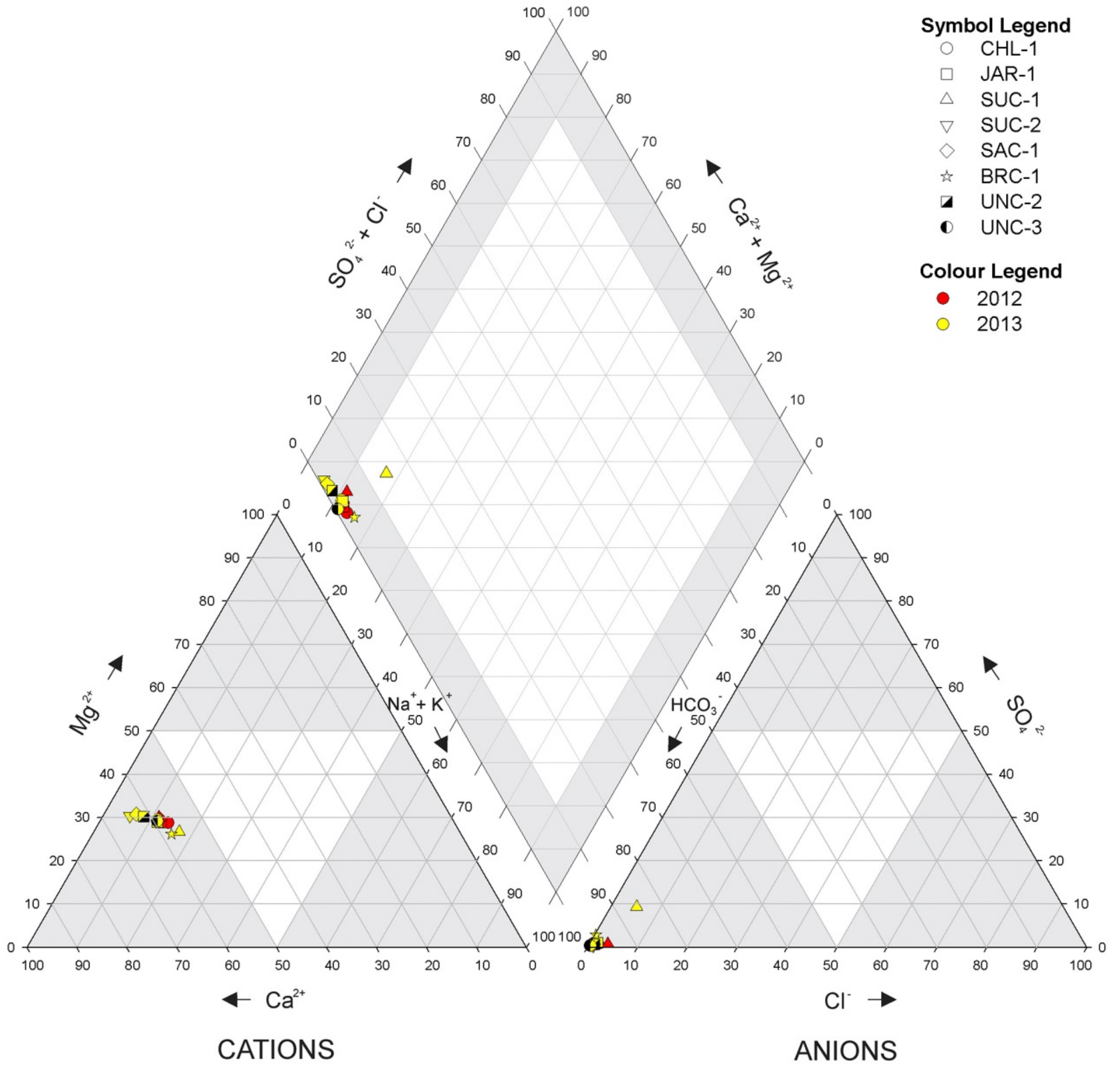


Table 5.10-16 Water quality guideline exceedances, Christina River watershed, 2013.

Variable	Units	Guideline[a]	BRC-1	CHR-1	CHR-2	CHR-3	CHR-4	CHL-1	JAR-1	SAC-1	SUC-1	SUC-2	UNC-2	UNC-3
Winter														
Dissolved iron	mg/L	0.3	-	0.72	ns	1.49	3.00	-	-	2.84	2.46	0.33	2.46	0.33
Dissolved phosphorous	mg/L	0.05	-	-	ns	-	-	-	-	0.08	-	-	-	-
Sulphide	mg/L	0.002	-	-	ns	-	-	-	-	0.0022	-	-	-	-
Total aluminum	mg/L	0.1	-	0.61	ns	-	-	-	-	-	-	0.13	-	0.13
Total iron	mg/L	0.3	1.03	1.62	ns	3.00	5.24	-	-	3.45	2.83	0.64	2.83	0.64
Total nitrogen	mg/L	1	-	-	ns	-	-	-	-	1.381	1.721	-	1.721	-
Total phenols	mg/L	0.004	-	-	ns	0.0060	0.0066	-	0.0043	0.0078	0.0114	0.0045	0.0114	0.0045
Total phosphorus	mg/L	0.05	0.0509	0.0741	ns	0.1660	0.1160	-	-	0.1090	-	-	-	-
Spring														
Dissolved aluminum	mg/L	0.1	-	0.101	ns	-	-	-	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	0.306	0.683	ns	0.429	0.565	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	0.0078	0.0189	ns	0.0053	0.0055	-	-	0.0034	-	-	0.0038	0.0023
Total aluminum	mg/L	0.1	3.30	16.70	ns	3.20	0.88	-	0.15	1.13	0.34	0.50	0.38	0.45
Total chromium	mg/L	0.001	0.00441	0.01740	ns	0.00289	0.00118	-	-	0.00155	-	-	-	-
Total copper	mg/L	0.002[b]	-	0.00956	ns	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	7.35	14.60	ns	3.41	2.51	-	0.34	1.21	0.51	0.75	0.49	0.53
Total lead	mg/L	0.0015[b]	-	0.0119	ns	-	-	-	-	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5	6.5	-	ns	6.1	6.3	-	-	-	-	-	-	-
Total nitrogen	mg/L	1	1.091	1.901	ns	-	-	-	-	-	-	-	-	-
Total phenols	mg/L	0.004	0.0055	0.0065	ns	0.008	0.0121	-	0.0041	0.0076	0.0060	0.0052	0.0084	0.0078
Total phosphorus	mg/L	0.05	0.333	0.859	ns	0.160	0.120	-	-	-	0.059	-	-	-
Total silver	mg/L	0.0001	0.000112	0.000170	ns	0.000109	0.000117	-	-	-	0.000104	-	0.000126	-
Total zinc	mg/L	0.03	-	0.034	ns	-	-	-	-	-	-	-	-	-
Summer														
Dissolved iron	mg/L	0.3	0.60	0.71	ns	2.03	3.32	-	-	1.11	-	-	0.38	-
Dissolved phosphorous	mg/L	0.05	-	-	ns	0.0825	0.0910	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	0.0043	0.0160	ns	0.0088	0.0089	0.0031	0.0029	0.0029	0.0029	0.0025	0.0031	0.0044
Total aluminum	mg/L	0.1	1.05	23.40	ns	2.54	0.59	-	-	-	0.29	-	0.14	0.53
Total chromium	mg/L	0.001	-	0.0158	ns	0.0019	-	-	-	-	-	-	-	-
Total copper	mg/L	0.0001[b]	-	0.0101	ns	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	1.98	18.40	ns	4.39	8.84	-	-	1.91	0.66	0.32	0.79	0.71
Total lead	mg/L	0.0028[b]	-	0.0136	ns	-	-	-	-	-	-	-	-	-
Total mercury (ultra-trace)	ng/L	5	-	10	ns	-	-	-	-	-	-	-	-	-
Total nitrogen	mg/L	1	-	2.421	ns	1.071	1.371	1.081	-	-	-	-	-	-
Total phenols	mg/L	0.004	0.0045	0.0079	ns	0.0100	0.0129	0.0060	0.0064	0.0091	0.0060	0.0055	0.0090	0.0066
Total phosphorus	mg/L	0.05	0.114	0.846	ns	0.178	0.179	-	-	0.080	-	-	-	0.051
Total silver	mg/L	0.0001	-	0.000159	ns	-	-	-	-	-	-	-	-	-
Total zinc	mg/L	0.03	-	0.0345	ns	-	-	-	-	-	-	-	-	-
Fall														
Dissolved iron	mg/L	0.3	-	1.04	1.96	2.87	6.44	-	-	0.48	-	-	0.33	0.37
Dissolved phosphorous	mg/L	0.05	-	-	0.0651	0.0903	0.1180	-	-	-	-	-	-	-
Sulphide	mg/L	0.002	-	0.0029	0.0048	0.0068	0.0048	-	-	-	-	-	0.0024	-
Total aluminum	mg/L	0.1	-	1.400	-	-	0.227	-	-	-	0.142	-	-	-
Total chromium	mg/L	0.001	-	0.00131	-	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	1.46	2.17	2.71	4.15	10.60	-	-	0.79	0.55	0.46	0.51	0.58
Total phenols	mg/L	0.004	-	0.0046	0.0085	-	-	0.0048	0.0087	0.0067	-	0.0041	-	-
Total phosphorus	mg/L	0.05	0.0793	0.0888	0.0885	0.1310	0.3030	-	-	-	-	-	-	-

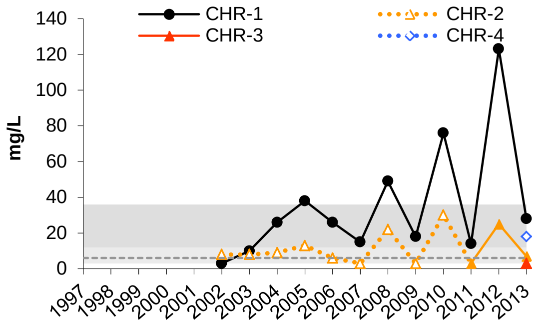
[a] Sources for all guidelines are outlined in Table 3.2-5.

[b] Guideline is hardness-dependent. See Table 3.2-5 for equation.

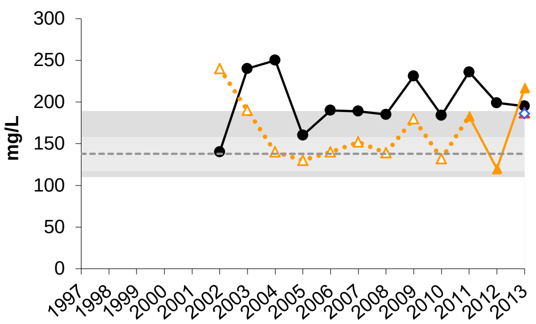
ns = not sampled; underline denotes *baseline* stations.

Figure 5.10-8 Concentrations of selected water quality measurement endpoints in the mainstem stations (*test* stations CHR-1, CHR-2, CHR-3, and *baseline* station CHR-4) of the Christina River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

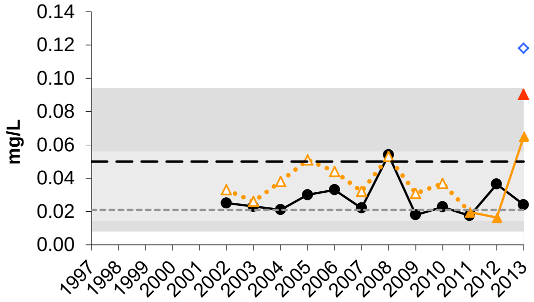
Total Suspended Solids (TSS)



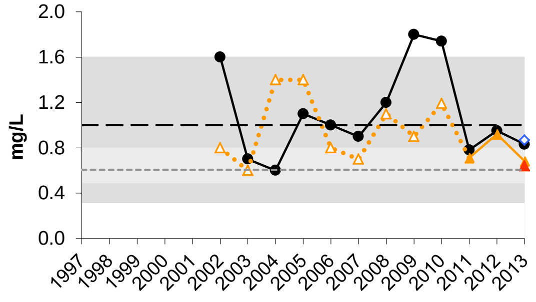
Total Dissolved Solids (TDS)



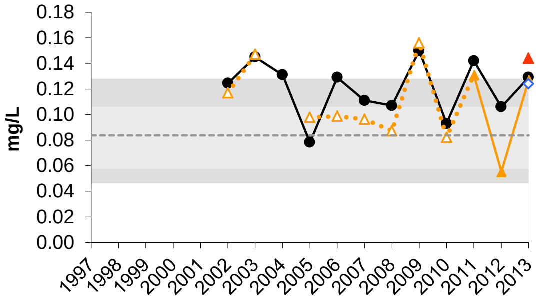
Dissolved Phosphorus



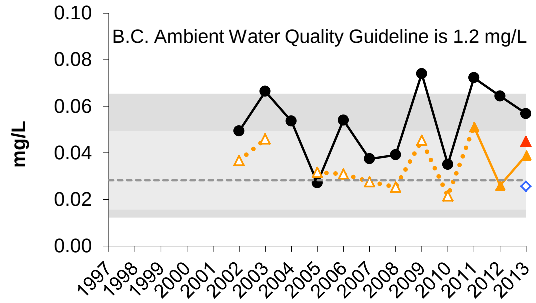
Total Nitrogen



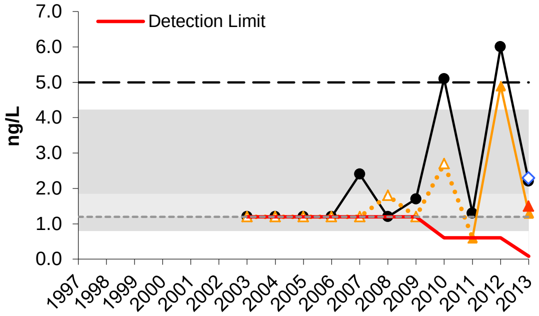
Total Strontium



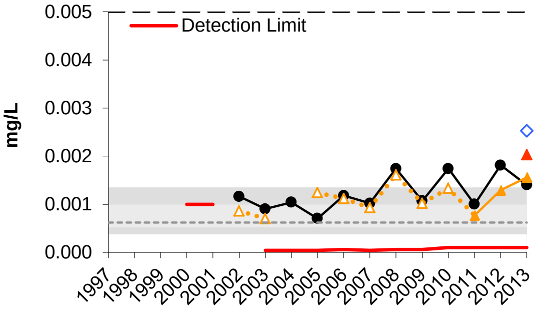
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



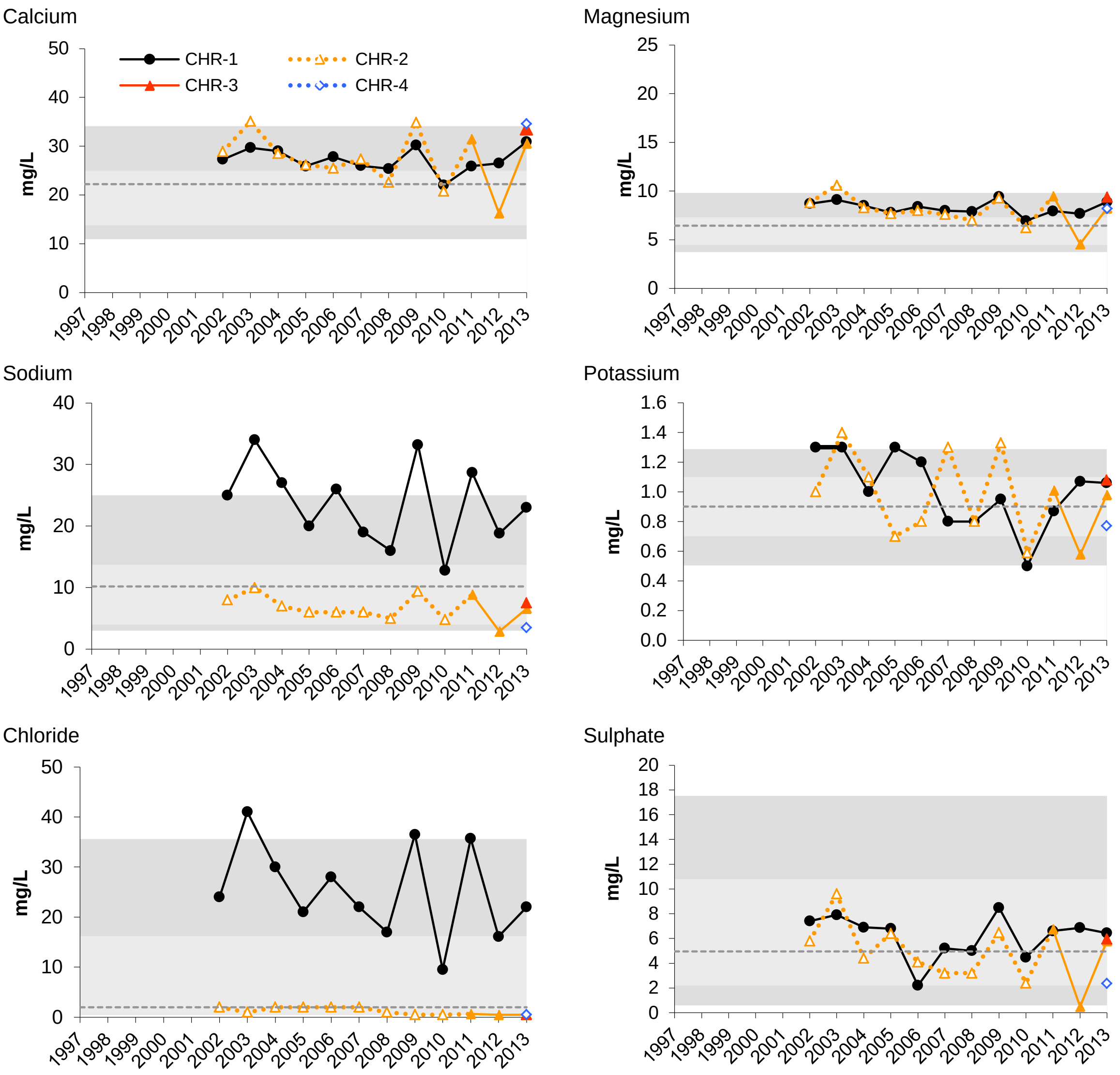
Non-detectable values are shown at the detection limit.

- - - - - 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 3.2.2.2 for a discussion of this approach.

Figure 5.10-8 (Cont'd.)



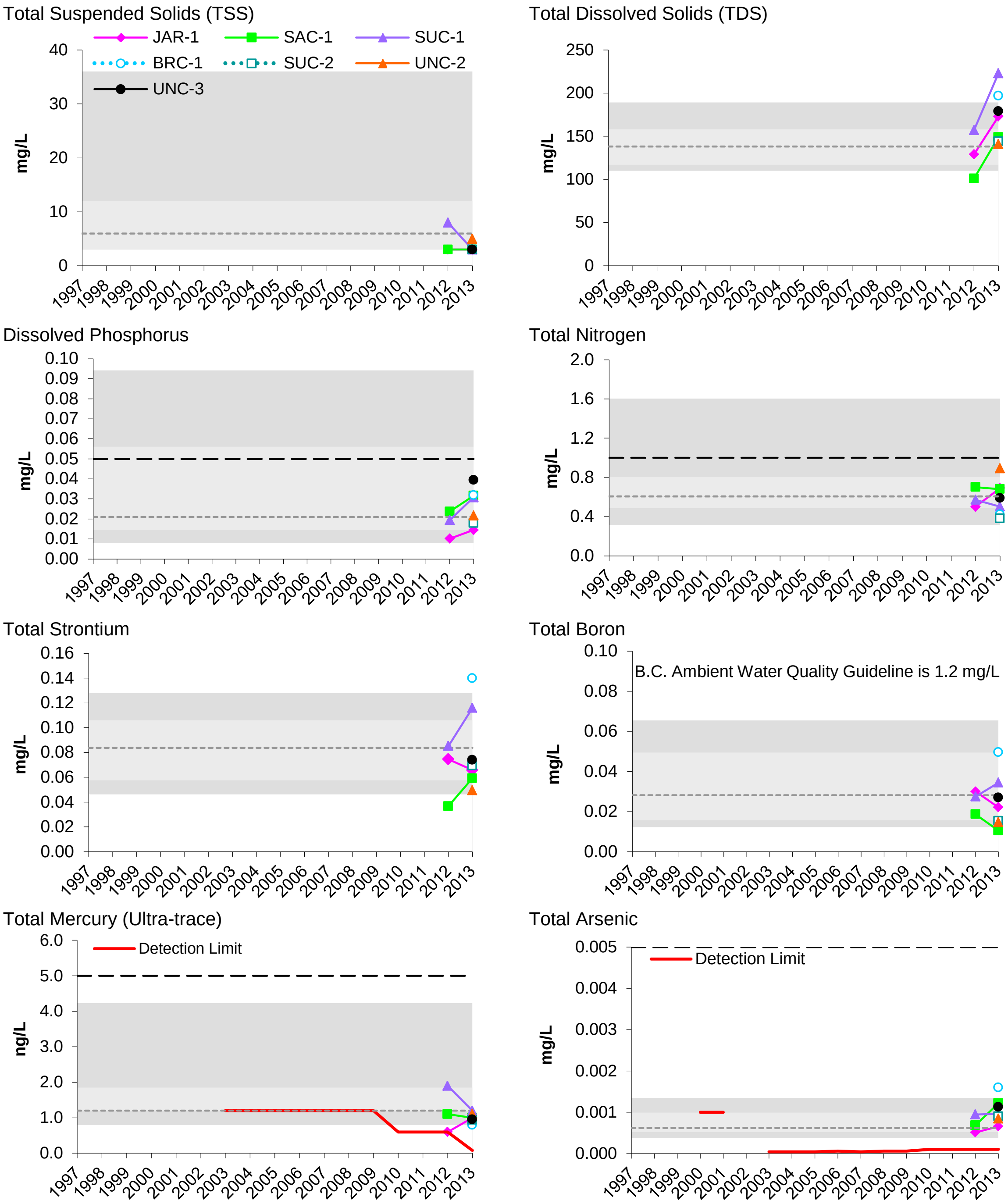
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.10-9 Concentrations of selected water quality measurement endpoints in the tributary stations (*test* stations JAR-1, SAC-1, SUC-1, UNC-2, UNC-3 and *baseline* stations BRC-1, SUC-2) of the Christina River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



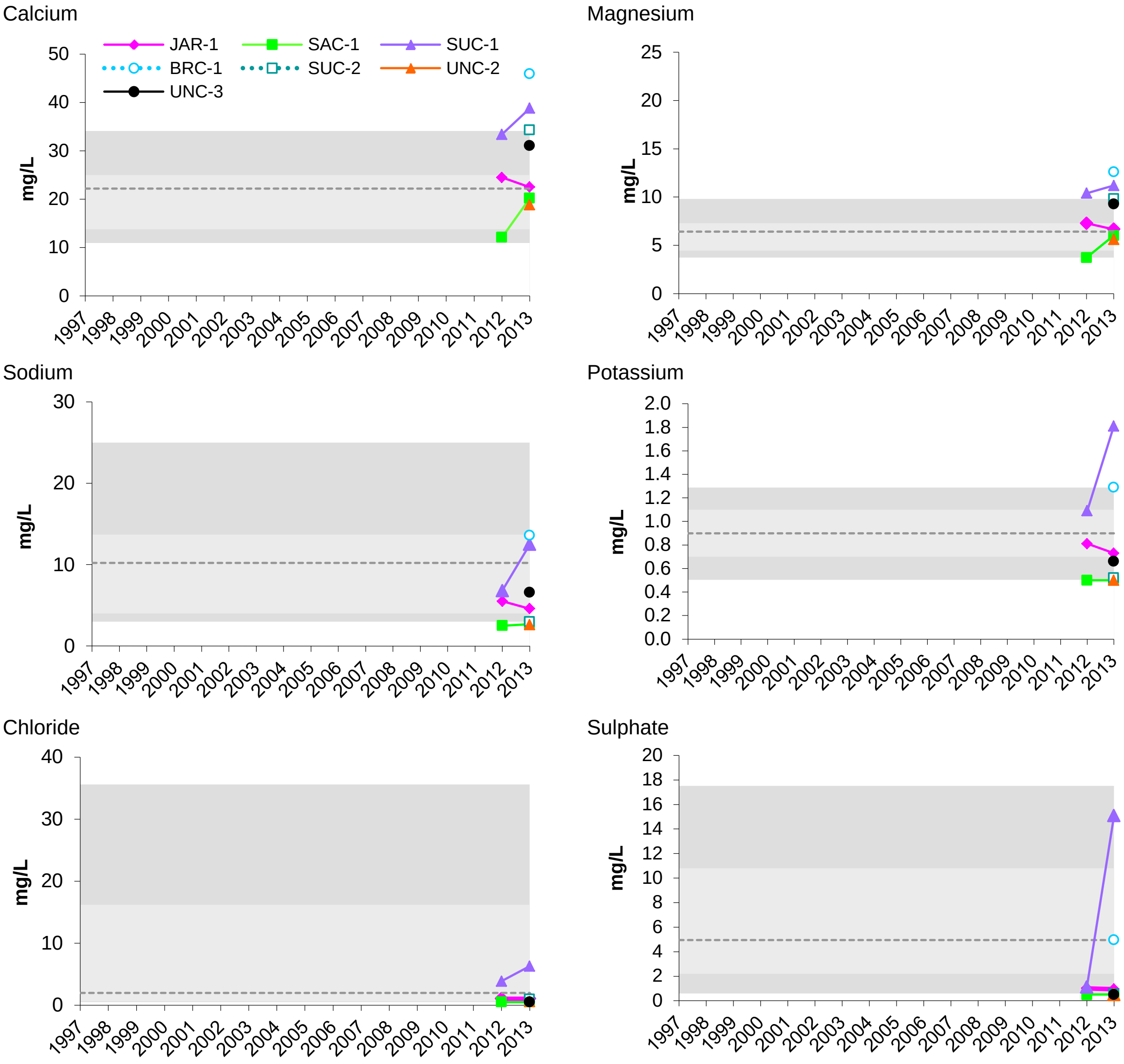
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

Figure 5.10-9 (Cont'd.)



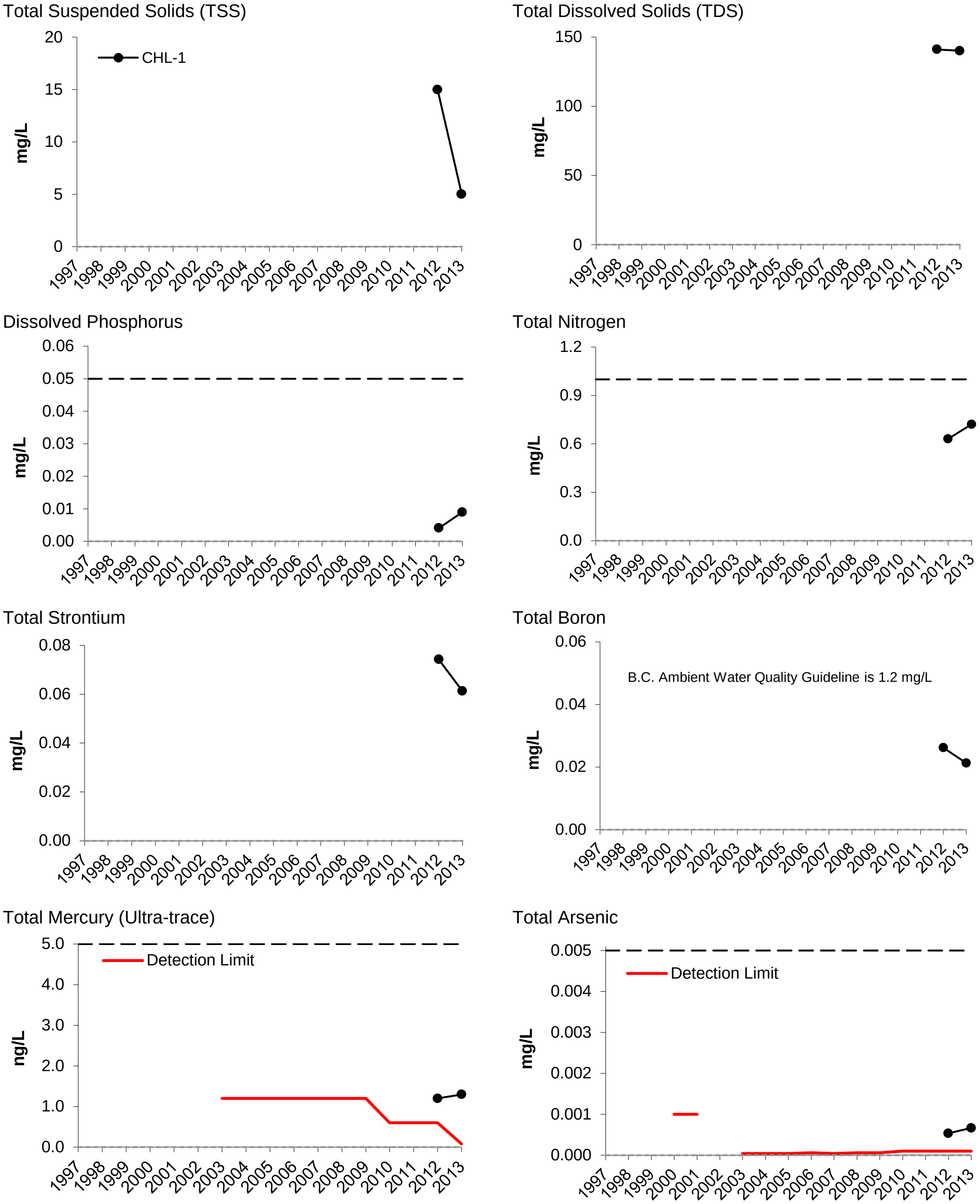
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

Figure 5.10-10 Concentrations of selected water quality measurement endpoints in Christina Lake (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



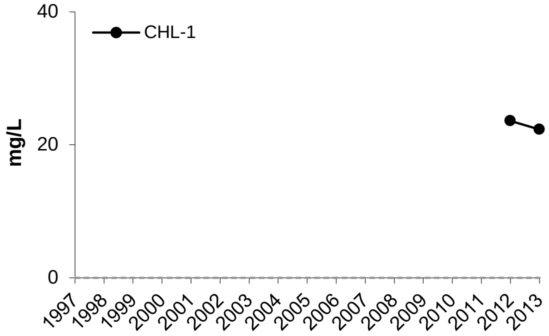
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

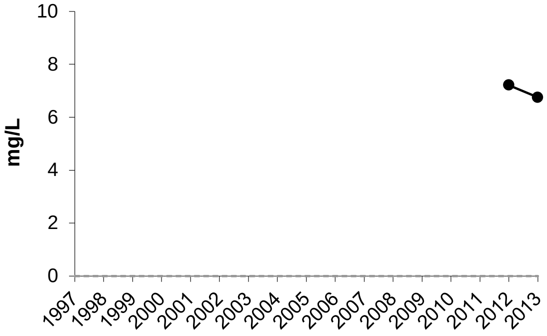
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Figure 5.10-10 (Cont'd.)

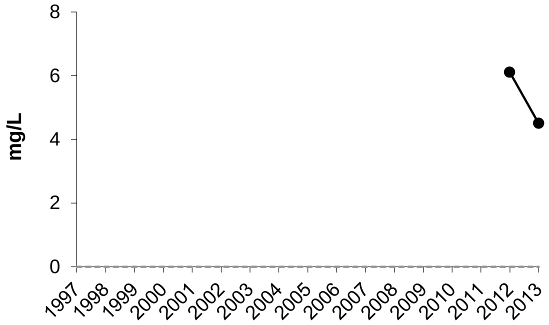
Calcium



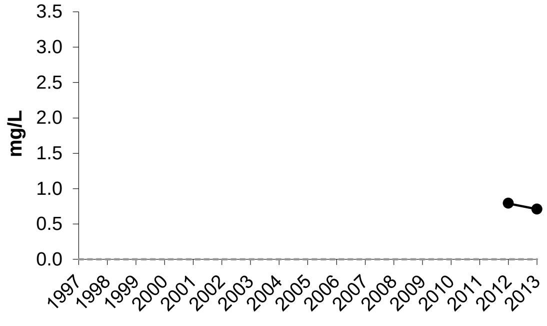
Magnesium



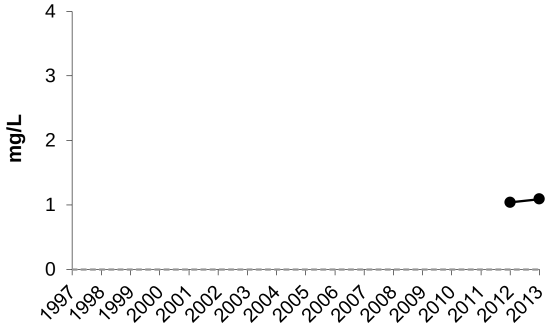
Sodium



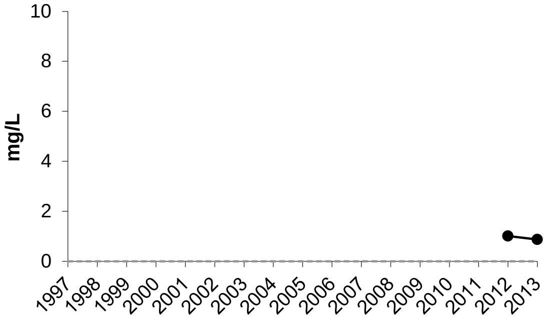
Potassium



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 5.10-17 Water quality index (fall 2013) for stations in the Christina River watershed.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
CHR-1	Christina River, near the mouth	*test*	87.4	Negligible-Low
CHR-2	Christina River, upstream of Janvier	*test*	92.1	Negligible-Low
CHR-3	Christina River, upstream of Jackfish River	*test*	81.7	Negligible-Low
CHR-4	Christina River, upstream of development	*baseline*	71.4	Moderate
BRC-1	Birch Creek	*baseline*	75.9	Moderate
JAR-1	Jackfish River	*test*	100.0	Negligible-Low
SAC-1	Sawbones Creek	*test*	96.2	Negligible-Low
SUC-1	Sunday Creek	*test*	87.4	Negligible-Low
SUC-2	Sunday Creek	*baseline*	95.0	Negligible-Low
UNC-2	Unnamed Creek east of Christina Lake	*test*	100.0	Negligible-Low
UNC-3	Unnamed Creek south of Christina Lake	*test*	97.5	Negligible-Low

Table 5.10-18 Monthly water quality measurement endpoints, Christina River near the mouth (*test* station CHR-1), January to December, 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	12	7.73	(January)	7.91	8.33	(September)
Total suspended solids	mg/L	-	12	<3	(January)	16	1110	(July)
Conductivity	µS/cm	-	12	135	(May)	416	676	(November)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	12	0.004	(January)	0.024	0.050	(July)
Total nitrogen	mg/L	1.0	12	0.711	(October)	0.920	**2.421**	(July)
Nitrate+nitrite	mg/L	3	12	<0.070	(May)	<0.071	0.349	(April)
Dissolved organic carbon	mg/L	-	12	7.6	(March)	17.8	24.4	(July)
Ions								
Sodium	mg/L	-	12	7.4	(May)	37.4	71.2	(November)
Calcium	mg/L	-	12	15.7	(May)	35.9	44.8	(April)
Magnesium	mg/L	-	12	4.1	(May)	10.2	14.1	(April)
Chloride	mg/L	120	12	3.19	(May)	40.25	107.00	(November)
Sulphate	mg/L	410	12	3.9	(August)	10.9	17.1	(November)
Total dissolved solids	mg/L	-	12	171	(May)	265	395	(November)
Total alkalinity	mg/L	-	12	56.1	(May)	140.5	177.0	(April)
Selected metals								
Total aluminum	mg/L	0.1	12	0.05	(November)	**0.76**	**23.40**	(July)
Dissolved aluminum	mg/L	0.1	12	0.006	(April)	0.016	0.101	(May)
Total arsenic	mg/L	0.005	12	0.0008	(January)	0.0010	0.0026	(May)
Total boron	mg/L	1.2	12	0.038	(August)	0.074	0.098	(April)
Total molybdenum	mg/L	0.073	12	<0.00010	(July)	0.00038	0.00618	(April)
Total mercury (ultra-trace)	ng/L	5, 13	12	<0.76	(December)	1.30	**10.00**	(June/July)
Total strontium	mg/L	-	12	0.079	(May)	0.175	0.240	(November)
Total hydrocarbons								
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	0.41	(July)
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	12	0.12	(February)	0.23	0.63	(July)
Oilsands Extractable	mg/L	-	12	0.17	(October)	0.42	1.69	(July)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	12	<15.16	-	<15.16	19.70	(February)
Retene	ng/L	-	11	0.68	(December)	1.80	106.00	(May)
Total dibenzothiophenes	ng/L	-	12	6.67	(December)	19.54	1347.56	(May)
Total PAHs	ng/L	-	12	103.6	(December)	183.1	6026.3	(May)
Total Parent PAHs	ng/L	-	12	22.56	(October)	24.47	232.26	(May)
Total Alkylated PAHs	ng/L	-	12	80.8	(December)	157.0	5794.0	(May)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	6	0.003	(March)	0.004	**0.010**	(May)
Sulphide	mg/L	0.002	11	<0.002	(March)	**0.004**	**0.020**	(May)
Total phosphorus	mg/L	0.05	12	**0.0542**	(November)	**0.0758**	**0.8600**	(July)
Total Kjeldahl Nitrogen	mg/L	1.0	3	0.46	(March)	0.76	**2.35**	(July)
Total iron	mg/L	0.3	12	**1.200**	(December)	**1.740**	**18.400**	(July)
Dissolved iron	mg/L	0.3	12	**0.428**	(April)	**0.696**	**1.070**	(August)
Total chromium	mg/L	0.001	6	0.00031	(January)	**0.00110**	**0.01740**	(May)
Total copper	mg/L	0.0018-0.0027[2]	2	0.0006	(November)	0.0008	**0.0101**	(July)
Total silver	mg/L	0.0001	2	<0.00001	-	<0.00001	**0.00017**	(May)
Total titanium	mg/L	0.1	1	0.003	(November)	0.017	**0.171**	(May)
Total zinc	mg/L	0.03	2	0.001	(January)	0.003	**0.041**	(November)

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

[1] n value refers to number of exceedances in 2013.

[2] Guideline is hardness dependent based on equation: $(e^{0.8545(\ln(\text{hardness}))-1.465})*0.2]/1000$ mg/L. Minimum guideline value = 0.002 mg/L.

Table 5.10-19 Monthly water quality guideline exceedances, Christina River near the mouth (*test* station CHR-1), January to December 2013.

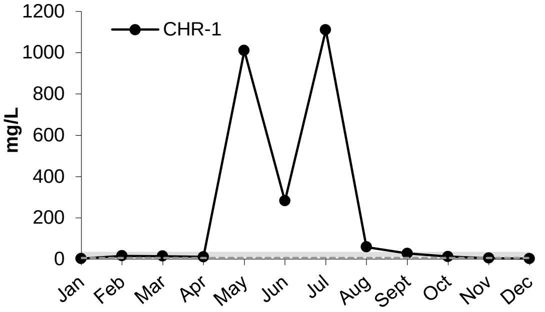
Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0056	-	-	-	0.0100	-	0.0079	0.0050	0.0046	-	0.0057	-
Sulphide	mg/L	0.002	0.0036	0.0037	-	0.0034	0.0200	0.0073	0.0160	0.0071	0.0029	0.0038	0.0025	0.0023
Dissolved phosphorus	mg/L	0.05	-	-	-	-	-	-	-	-	-	-	0.076	-
Total phosphorus	mg/L	0.05	0.066	0.078	0.074	0.074	0.860	0.214	0.846	0.125	0.089	0.064	0.025	0.059
Total nitrogen	mg/L	1.0	1.121	-	-	-	1.900	1.211	2.421	-	-	-	-	-
Total aluminum	mg/L	0.1	0.311	0.628	0.609	0.531	16.700	7.820	23.400	1.660	1.390	0.891	-	0.242
Dissolved aluminum	mg/L	0.1	-	-	-	-	0.1010	0.0797	0.0733	-	-	-	-	-
Total iron	mg/L	0.3	1.56	1.73	1.62	1.75	14.60	6.96	18.40	3.26	2.17	1.69	1.31	1.20
Dissolved iron	mg/L	0.3000	0.945	0.736	0.717	0.428	0.683	0.479	0.708	1.070	1.040	0.662	0.541	0.498
Total chromium	mg/L	0.001	-	-	-	0.0016	0.0174	0.0069	0.0158	0.0020	0.0013	-	-	-
Total copper	mg/L	0.0018-0.0027[1]	-	-	-	-	0.0096	-	0.0101	-	-	-	-	-
Total mercury (ultra-trace)	mg/L	5, 13	-	-	-	-	-	10.0	10.0	-	-	-	-	-
Total silver	mg/L	0.0001	-	-	-	-	0.00017	-	0.00016	-	-	-	-	-
Total titanium	mg/L	0.1	-	-	-	-	0.171	-	-	-	-	-	-	-
Total zinc	mg/L	0.03	-	-	-	-	0.0340	-	0.0345	-	-	-	0.0406	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

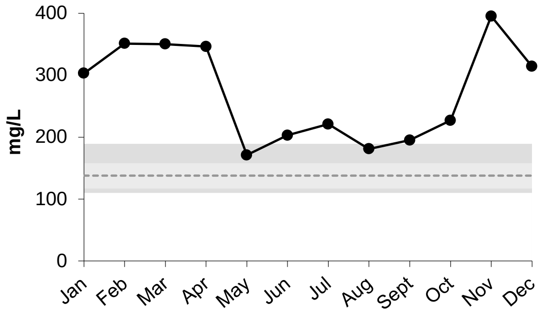
[1] Guideline is hardness dependent based on equation: $(e^{0.8545(\ln(hardness))-1.465})$*0.2]/1000 mg/L. Minimum guideline value = 0.002 mg/L.

Figure 5.10-11 Concentrations of selected water quality measurement endpoints in the Christina River near the mouth (monthly data) relative to regional *baseline* fall concentrations.

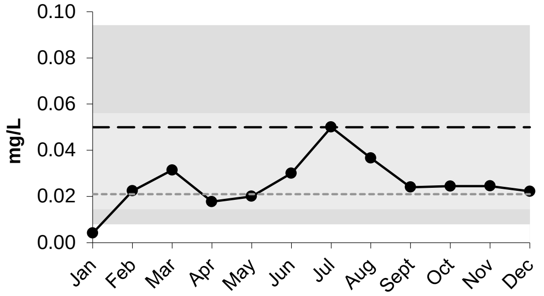
Total Suspended Solids (TSS)



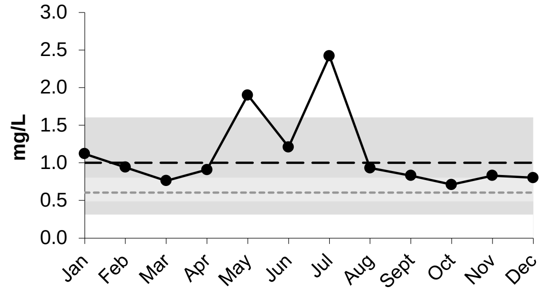
Total Dissolved Solids (TDS)



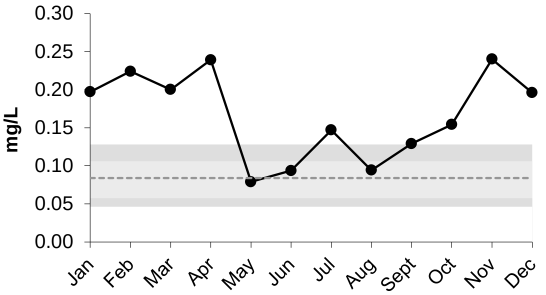
Dissolved Phosphorus



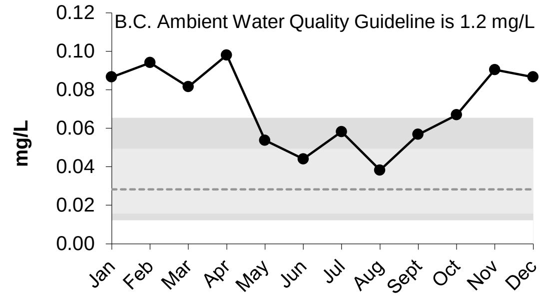
Total Nitrogen



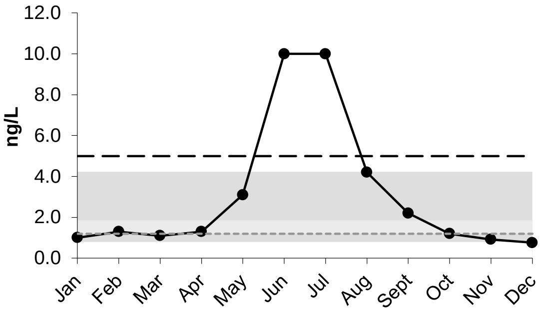
Total Strontium



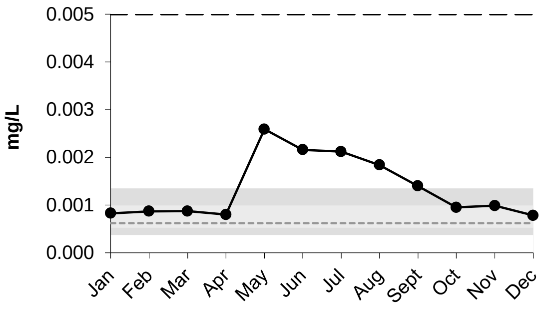
Total Boron


B.C. Ambient Water Quality Guideline is 1.2 mg/L

Total Mercury (Ultra-trace)



Total Arsenic



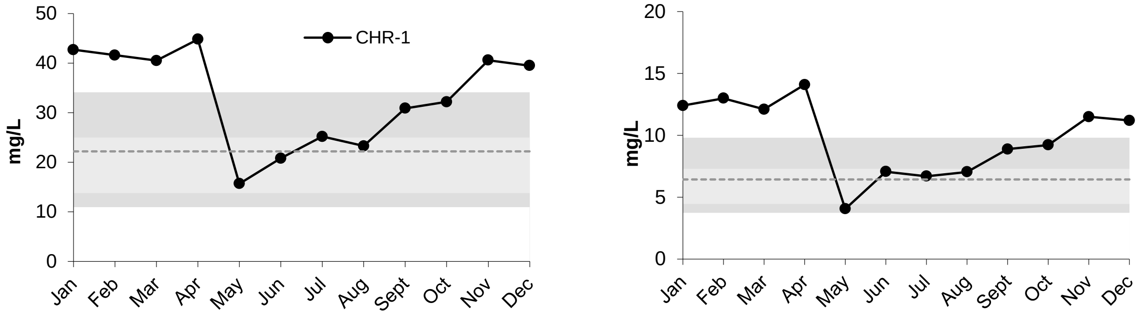
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

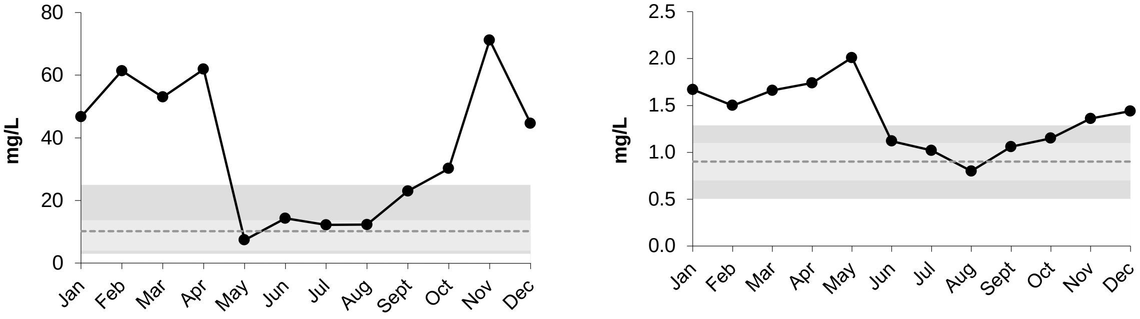
○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling in fall. See sections 3.2.2.2 for a discussion of this approach.

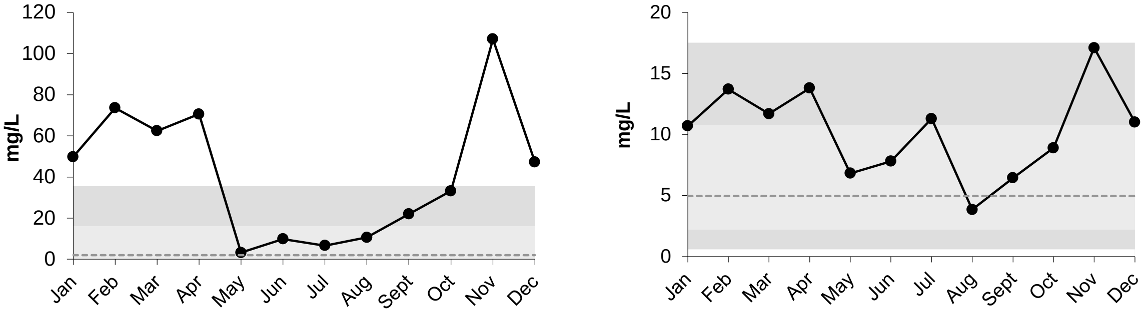
Figure 5.10-11 (Cont’d.)


Calcium

Magnesium


Sodium

Potassium


Chloride

Sulphate

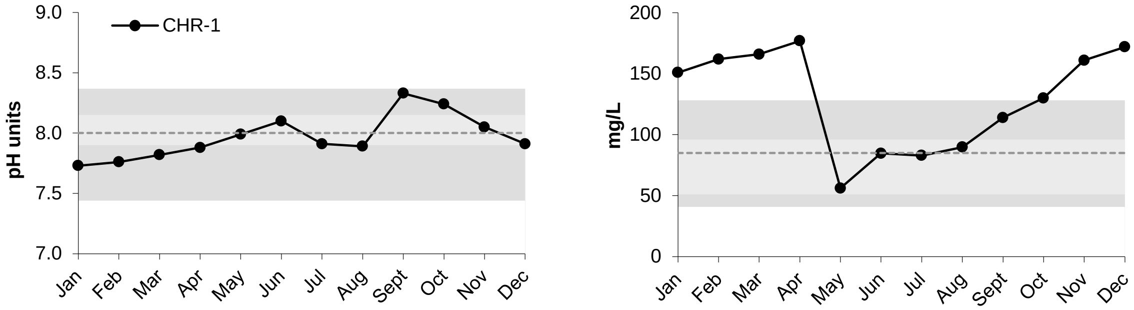
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

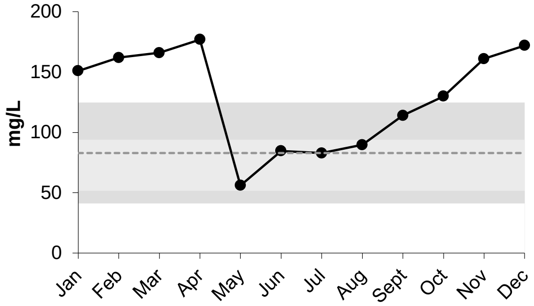
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling in fall. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.10-11 (Cont'd.)


pH

Total Alkalinity

Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 in fall. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.10-12 Piper diagram of monthly ion concentrations in the Christina River near the mouth (*test* station CHR-1).

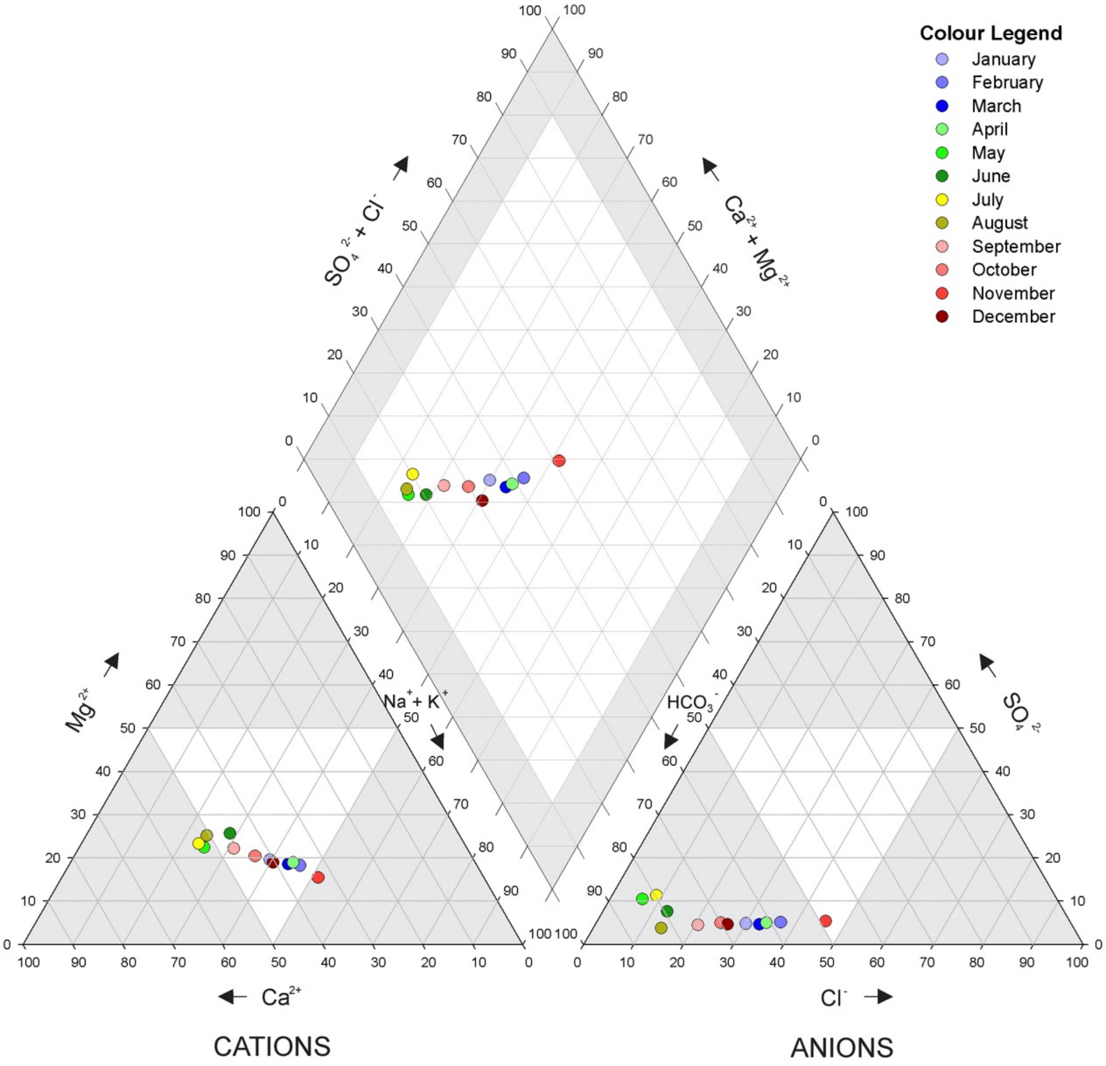
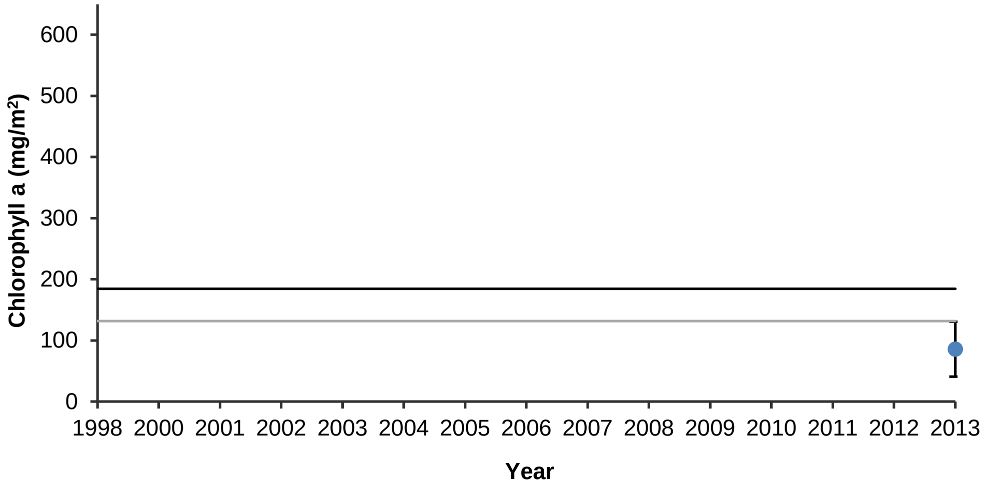


Table 5.10-20 Average habitat characteristics of benthic invertebrate community sampling locations in the Christina River, fall 2013.

Variable	Units	CHR-E3 Middle *Test* Reach of the Christina River	CHR-D4 Upper *Baseline* Reach of the Christina River
Sample date	-	Sept 8, 2013	Sept 8, 2013
Habitat	-	Erosional	Depositional
Water depth	m	0.3	0.5
Current velocity	m/s	0.46	0.30
Field Water Quality			
Dissolved oxygen	mg/L	8.8	6.8
Conductivity	µS/cm	236	244
pH	pH units	8.2	7.1
Water temperature	°C	16.7	14.8
Sediment Composition			
Sand	%	-	88
Silt	%	-	7
Clay	%	-	5
Total Organic Carbon	%	-	0.53
Sand/Silt/Clay	%	21	-
Small Gravel	%	4	-
Large Gravel	%	14	-
Small Cobble	%	2	-
Large Cobble	%	27	-
Boulder	%	15	-
Bedrock	%	0	-

Figure 5.10-13 Periphyton chlorophyll *a* biomass at *test* reach CHR-E3 of the Christina River.

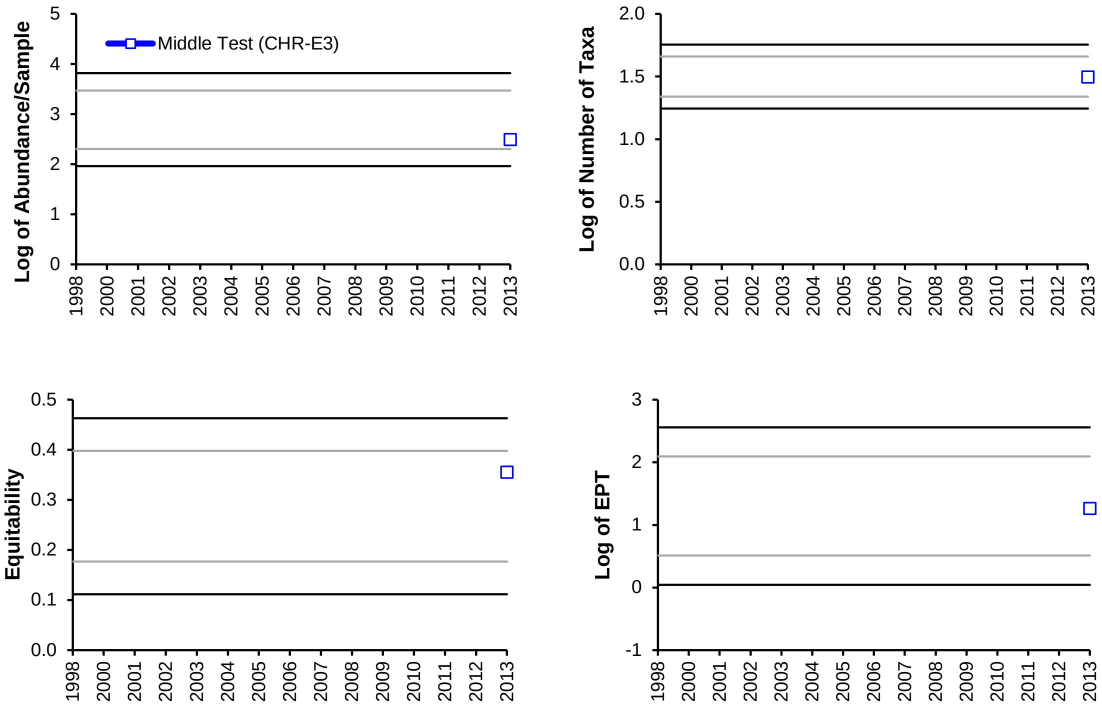


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2012.

Table 5.10-21 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at reaches of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test **Reach CHR-E3**	***Baseline*** **Reach CHR-D4**
	2013	**2013**
Nematoda	7	3
Oligochaeta	<1	<1
Naididae	5	1
Tubificidae	<1	6
Enchytraeidae	1	<1
Hirudinea	-	<1
Hydracarina	1	5
Gastropoda	-	<1
Bivalvia	<1	1
Ceratopogonidae	1	3
Chironomidae	64	79
Diptera (misc)	<1	<1
Coleoptera	1	<1
Ephemeroptera	8	<1
Odonata	<1	-
Plecoptera	5	-
Trichoptera	6	<1
Benthic Invertebrate Community Measurement Endpoints		
Abundance (mean per replicate samples)	440	124
Richness	31	15
Equitability	0.36	0.37
% EPT	21	1

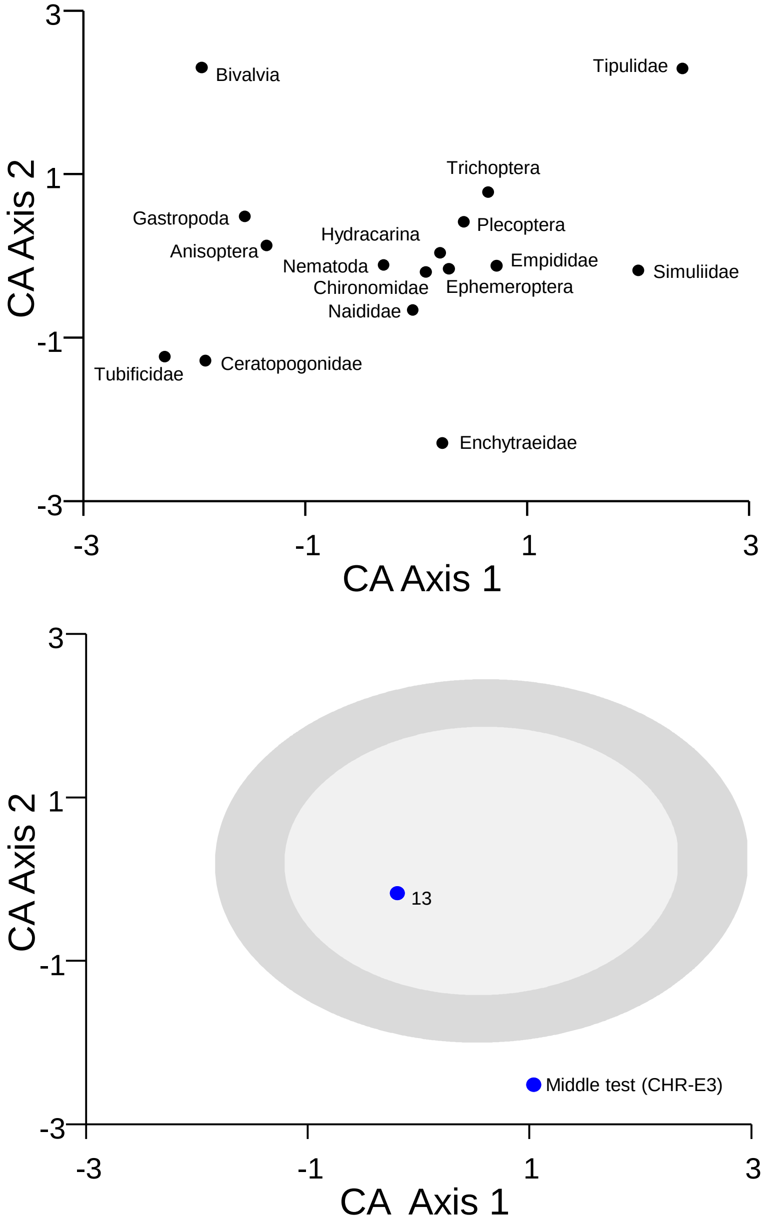
Figure 5.10-14 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-E3 of the Christina River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2012.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-15 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing *test* reach CHR-E3.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for regional *baseline* erosional reaches.

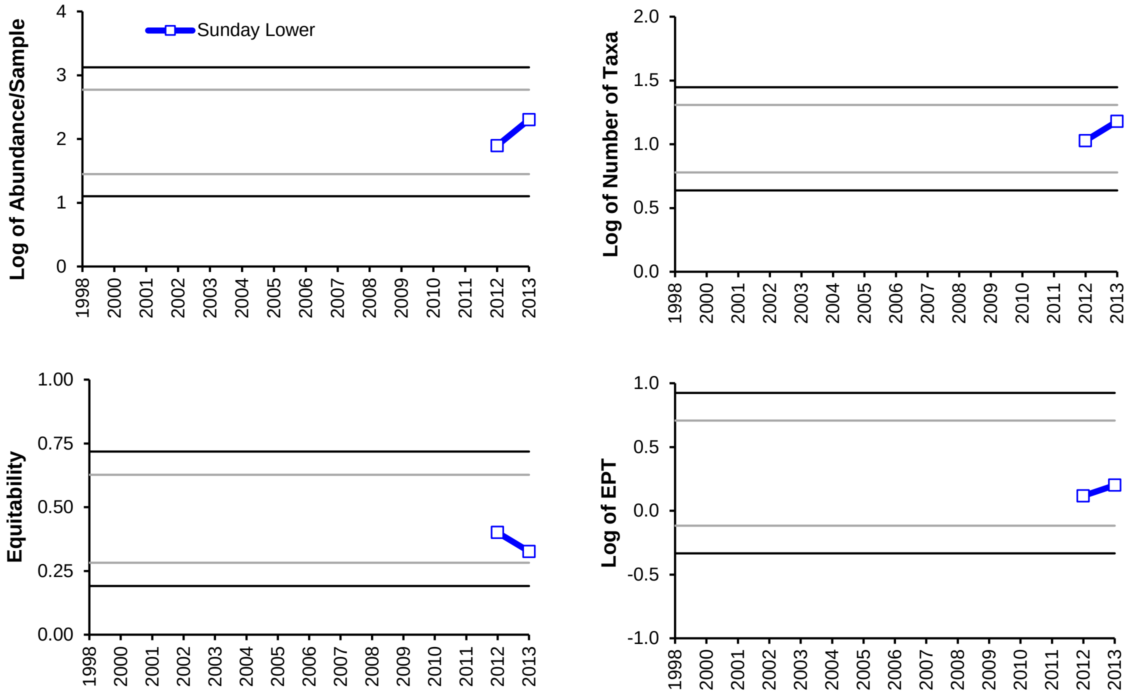
Table 5.10-22 Average habitat characteristics of benthic invertebrate community sampling locations in Sunday Creek, fall 2013.

Variable	Units	SUC-D1 Lower *Test* Reach of Sunday Creek	SUC-D2 Upper *Baseline* Reach of Sunday Creek
Sample date	-	Sept 9, 2013	Sept 5, 2013
Habitat	-	Depositional	Depositional
Water depth	m	0.6	0.3
Current velocity	m/s	0.34	0.15
Field Water Quality			
Dissolved oxygen	mg/L	8.1	8.2
Conductivity	µS/cm	310	203
pH	pH units	7.6	7.5
Water temperature	°C	15.6	14.6
Sediment Composition			
Sand	%	96	98
Silt	%	3	1
Clay	%	1	1
Total Organic Carbon	%	0.29	0.05

Table 5.10-23 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Sunday Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach SUC-D1		*Baseline* Reach SUC-D2
	2012	**2013**	**2013**
Nematoda	<1	3	3
Oligochaeta	<1	-	<1
Naididae	2	1	4
Tubificidae	2	<1	2
Enchytraeidae	-	<1	<1
Hydracarina	<1	<1	1
Gastropoda	<1	<1	<1
Ostracoda			
Cladocera			
Copepoda			
Bivalvia	2	2	1
Ceratopogonidae	2	4	7
Chironomidae	80	87	78
Diptera (misc)	7	3	1
Coleoptera		-	<1
Ephemeroptera	<1	<1	2
Odonata	<1	<1	<1
Plecoptera		<1	-
Trichoptera	<1	<1	1
Heteroptera		<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	168	258	1,429
Richness	14	16	26
Equitability	0.39	0.33	0.23
% EPT	<1	1	3

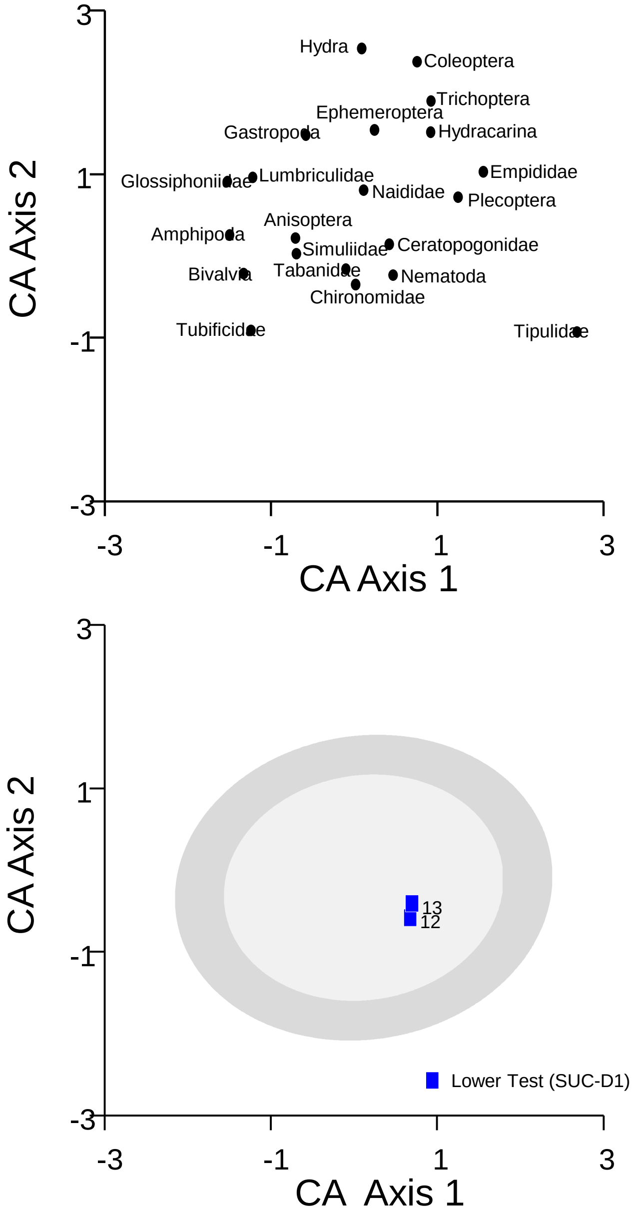
Figure 5.10-16 Variation in benthic invertebrate community measurement endpoints in Sunday Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2012.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-17 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reach SUC-D1.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Table 5.10-24 Average habitat characteristics of benthic invertebrate community sampling locations at tributary *test* reaches SAC-D1, UNC-D2, UNC-D3, and *baseline* reach BRC-D1 of the Christina River watershed, fall 2013.

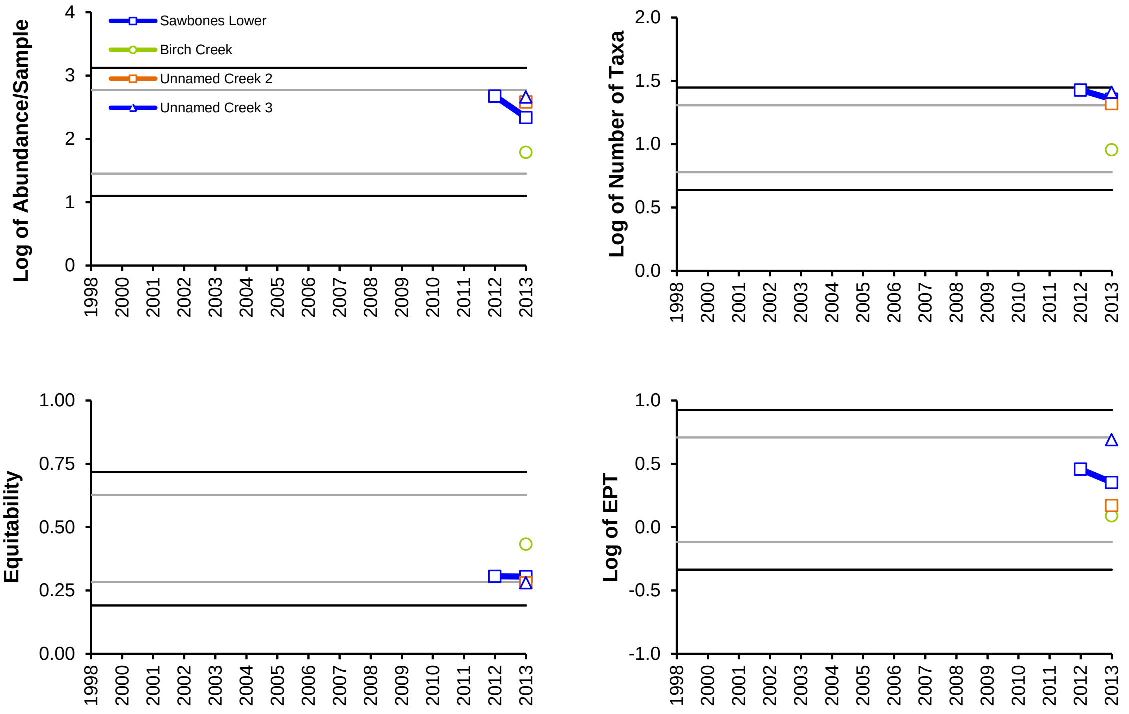
Variable	Units	SAC-D1 Lower *Test* Reach of Sawbones Creek	BRC-D1 Lower *Baseline* Reach of Birch Creek	UNC-D2 *Test* Reach of Unnamed Creek (east of CHL)	UNC-D3 *Test* Reach of Unnamed Creek (south of CHL)
Sample date	**-**	Sept 9, 2013	Sept 5, 2013	Sept 6, 2013	Sept. 9, 2013
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	1.1	0.5	0.6	0.7
Current velocity	m/s	0.11	0.38	-	0.12
Field Water Quality					
Dissolved oxygen	mg/L	6.4	7.4	7.2	7.7
Conductivity	µS/cm	120	304	122	222
pH	pH units	6.7	8.0	7.9	7.2
Water temperature	°C	16.2	13.6	18.7	15.6
Sediment Composition					
Sand	%	87	94	75	96
Silt	%	10	4	21	3
Clay	%	3	2	5	1
Total Organic Carbon	%	2.04	0.34	4.6	0.59

CHL = Christina Lake

Table 5.10-25 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities at depositional reaches on tributaries of the Christina River watershed.

Taxon	Percent Major Taxa Enumerated in Each Year				
	Test Reach SAC-D1		*Test* Reach UNC-D2	*Test* Reach UNC-D3	*Baseline* Reach BRC-D1
	2012	2013	2013	2013	2013
Hydra	<1	<1	-	-	-
Nematoda	3	4	4	1	1
Naididae	2	1	1	1	1
Enchytraeidae	-	<1	-	-	-
Tubificidae	2	3	3	1	1
Lumbriculidae	<1	<1	-	-	-
Erpobdellidae	<1	-	-	-	-
Glossiphoniidae	<1	-	-	-	-
Hirudinea	-	-	-	<1	<1
Enchytraeidae	-	-	<1	-	-
Hydracarina	1	1	2	<1	<1
Amphipoda	<1	<1	<1	<1	<1
Gastropoda	1	<1	<1	<1	<1
Bivalvia	1	2	3	1	1
Ceratopogonidae	5	7	9	8	8
Chironomidae	68	77	77	75	75
Diptera (misc.)	<1	2	1	5	5
Coleoptera	<1	<1	-	-	-
Ephemeroptera	2	1	<1	2	2
Odonata	<1	-	-	<1	<1
Plecoptera	-	-	<1	2	2
Trichoptera	<1	<1	<1	3	3
Benthic Invertebrate Community Measurement Endpoints					
Abundance (mean per replicate samples)	780	346	513	595	209
Richness	31	22	21	26	9
Equitability	0.3	0.3	0.28	0.28	0.43
% EPT	2	2	1	8	1

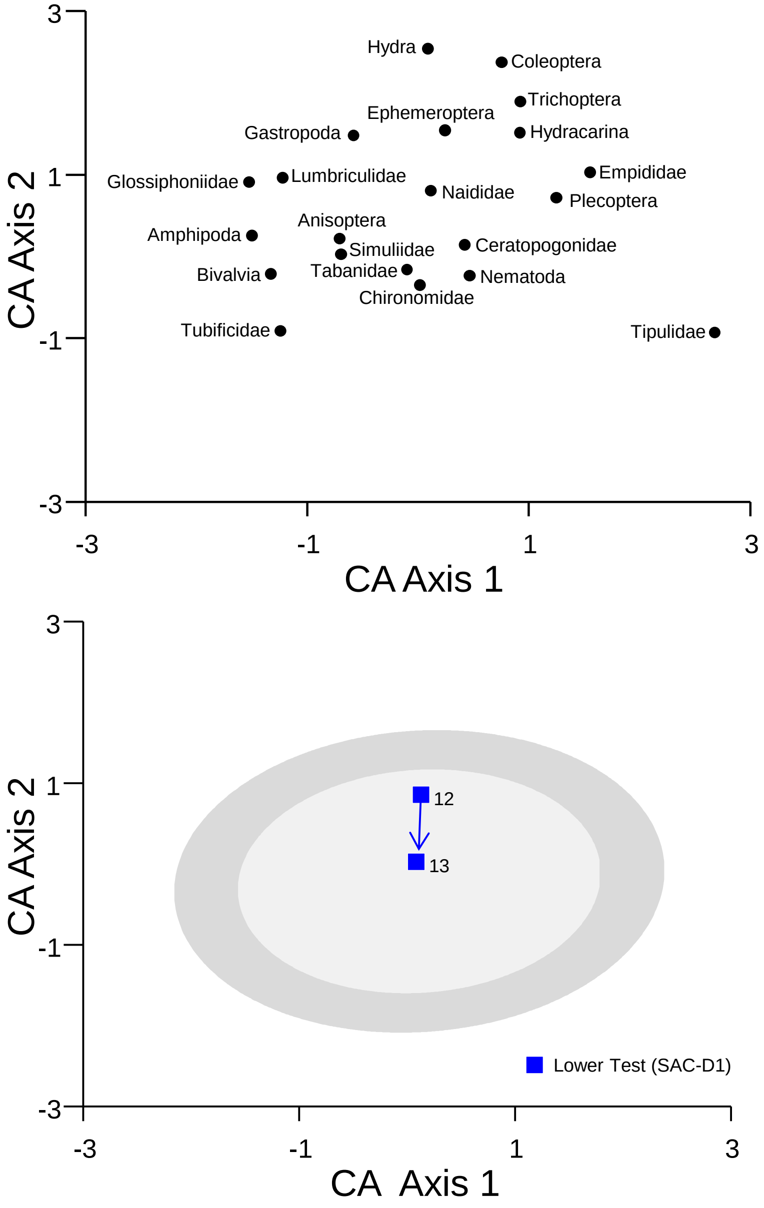
Figure 5.10-18 Variation in benthic invertebrate community measurement endpoints in Sawbones Creek, Unnamed Creeks 2 and 3, and Birch Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches (1998 to 2012).

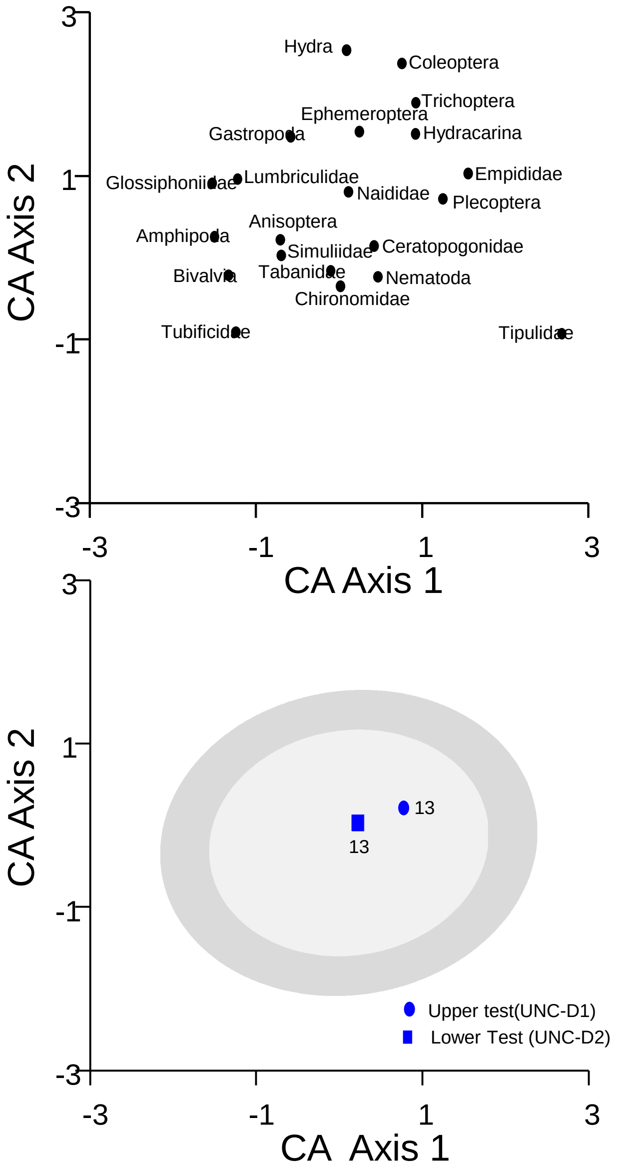
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-19 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reach SAC-D1.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Figure 5.10-20 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reaches UNC-D2 and UNC-D3.

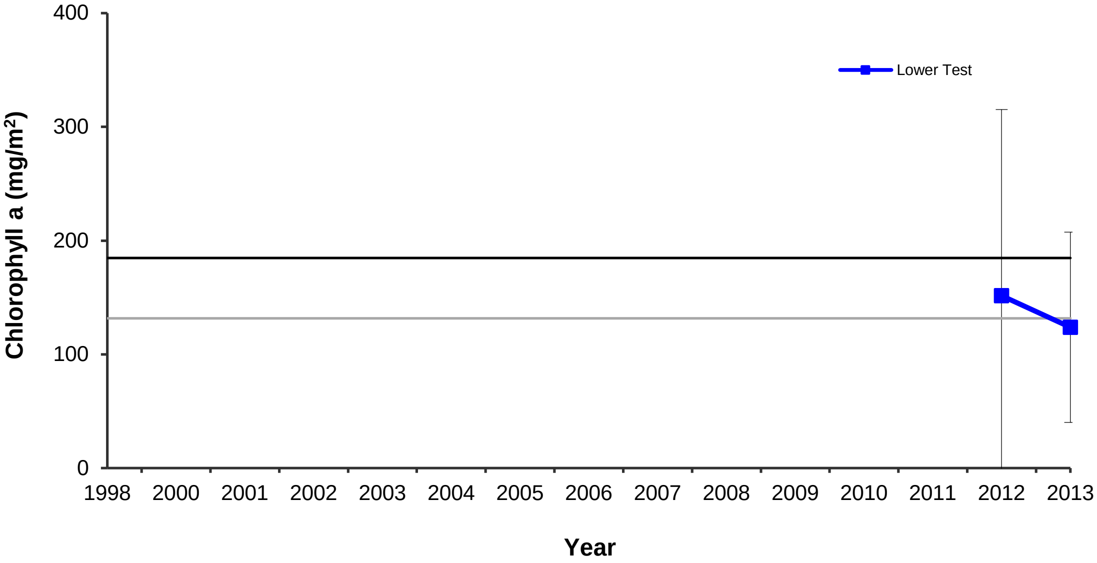


Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Table 5.10-26 Average habitat characteristics of benthic invertebrate community sampling locations at *test* reach JAR-E1 of Jackfish River, fall 2013.

Variable	Units	JAR-E1 Lower *Test* Reach of Jackfish River
Sample date	-	Sept 6, 2013
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	0.66
Field Water Quality		
Dissolved oxygen	mg/L	8.3
Conductivity	µS/cm	144
pH	pH units	7.9
Water temperature	°C	17.5
Sediment Composition		
Sand/Silt/Clay	%	4
Small Gravel	%	18
Large Gravel	%	29
Small Cobble	%	30
Large Cobble	%	10
Boulder	%	10
Bedrock	%	0

Figure 5.10-21 Periphyton chlorophyll *a* biomass at *test* reach JAR-E1 of Jackfish River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2012.

Table 5.10-27 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community of Jackfish River.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Reach JAR-E1	
	2012	**2013**
Nematoda	1	5
Naididae	2	4
Tubificidae	<1	1
Enchytraeidae	<1	1
Lumbriculidae	<1	
Erpobdellidae	<1	
Hydracarina	11	8
Amphipoda	<1	<1
Gastropoda	1	1
Bivalvia	<1	1
Ceratopogonidae	<1	
Chironomidae	23	33
Diptera (misc.)	2	4
Coleoptera	<1	2
Ephemeroptera	29	29
Odonata	<1	<1
Plecoptera	<1	<1
Trichoptera	19	11
Benthic Invertebrate Community Measurement Endpoints		
Abundance (mean per replicate samples)	3,823	4,448
Richness	38	39
Equitability	0.28	0.28
% EPT	48	42

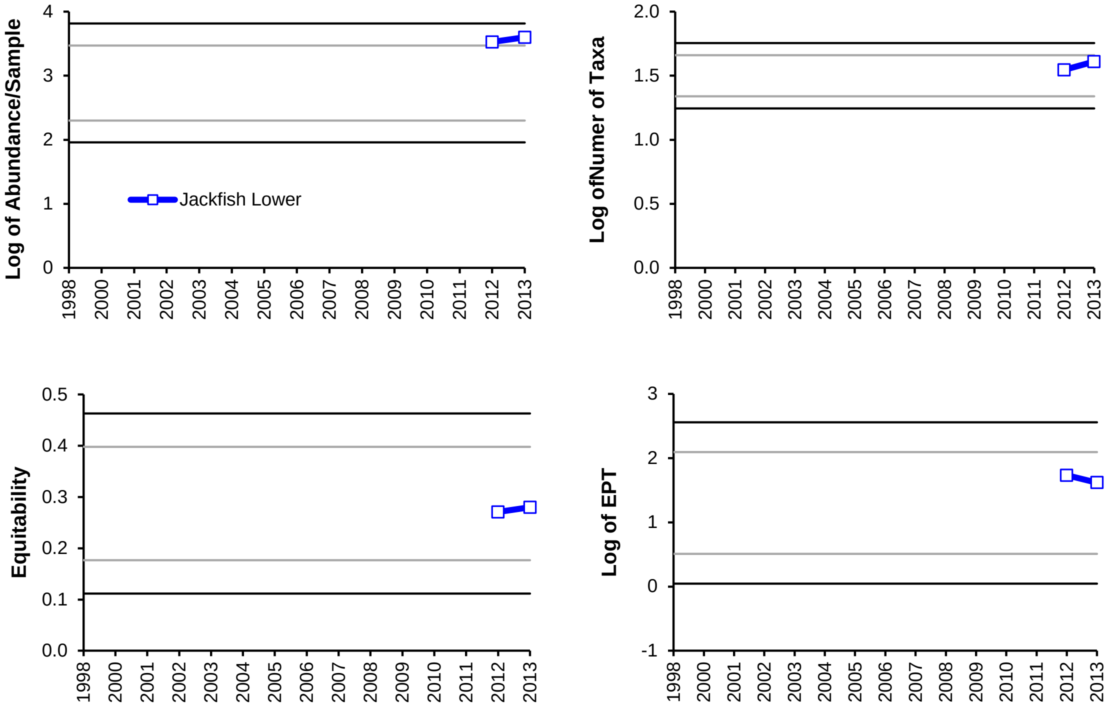
Table 5.10-28 Results of ANOVA testing for differences in benthic invertebrate community endpoints in the lower Jackfish River (JAR-E1).

Measurement Endpoint	P-value	Nature of Change(s)
	2013 vs. 2012	
Log of Abundance	0.434	No change.
Log of Richness	0.089	No change.
Equitability	0.780	No change.
Log of EPT	**0.015**	Lower in 2013 than 2012.
CA Axis 1	0.607	No change.
CA Axis 2	0.099	No change.

Bold values indicate significant difference ($p<0.05$).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

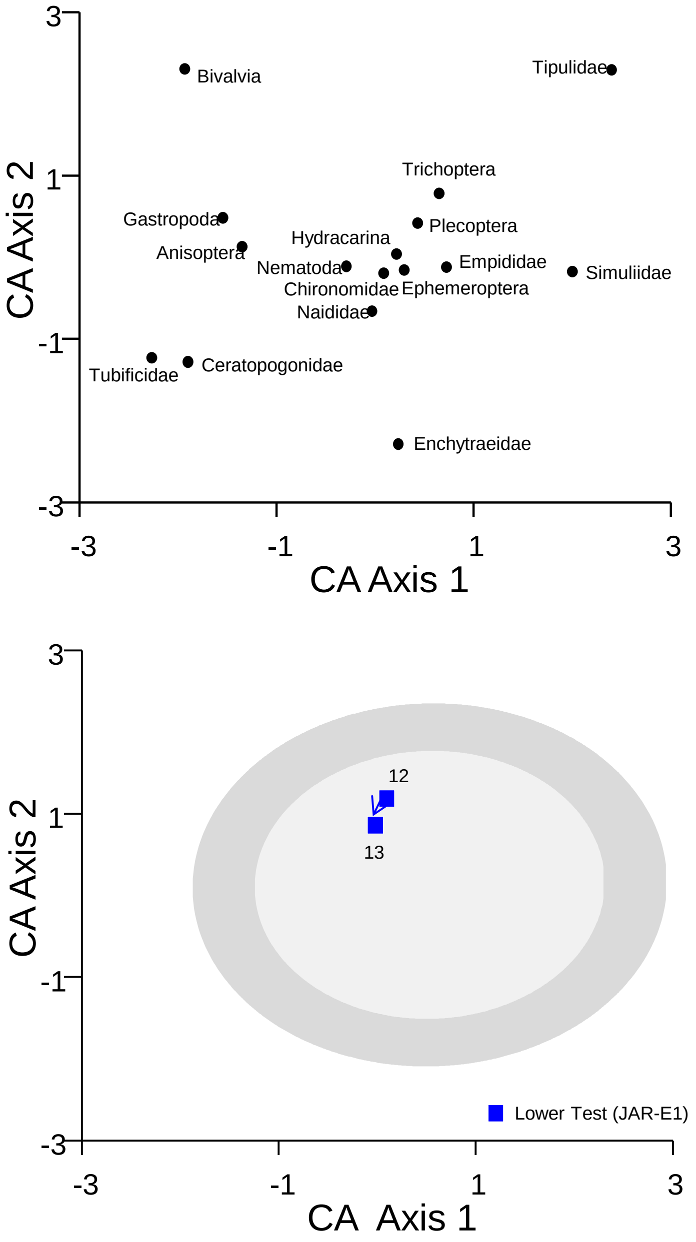
Figure 5.10-22 Variation in benthic invertebrate community measurement endpoints in Jackfish River.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* erosional reaches.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-23 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing *test* reach JAR-E1.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

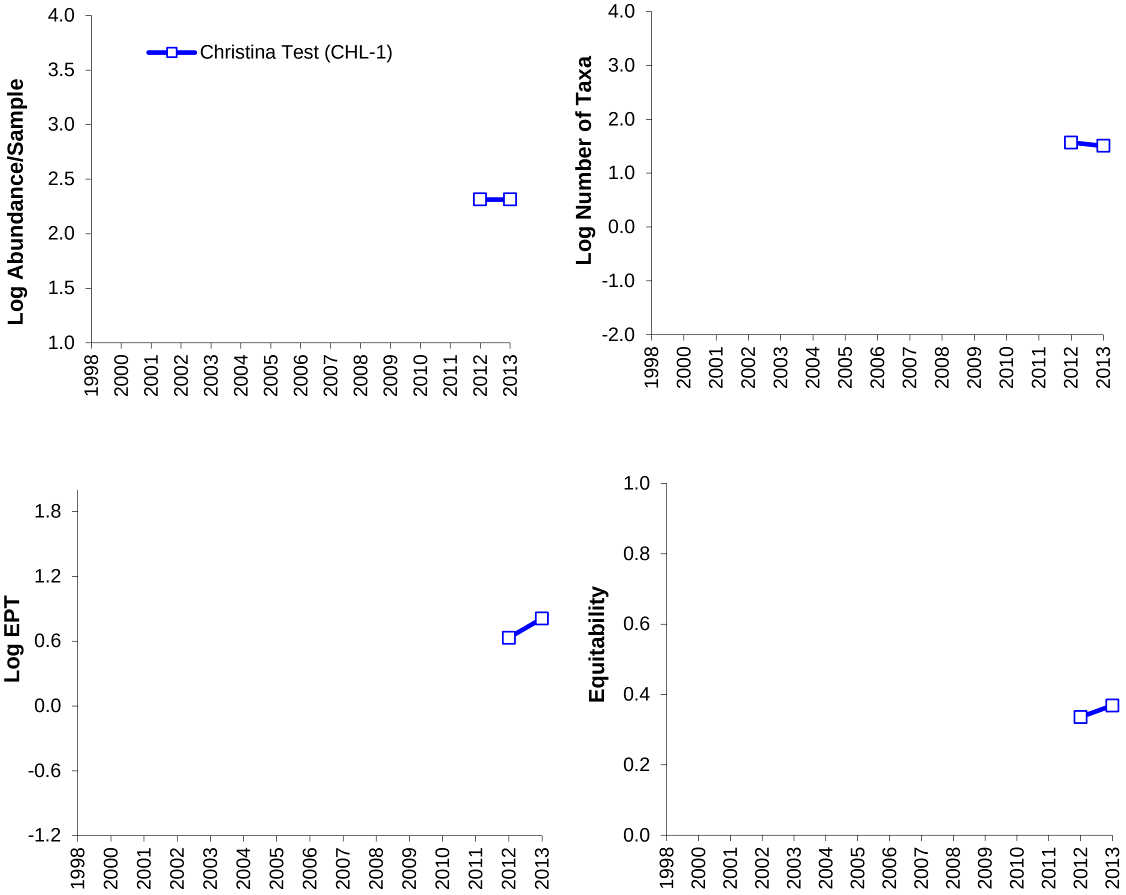
Table 5.10-29 Average habitat characteristics of benthic invertebrate sampling locations in Christina Lake, fall 2013.

Variable	Units	Christina Lake
Sample date	-	Sept 6, 2013
Habitat	-	Depositional
Water depth	m	1.3
Field Water Quality		
Dissolved oxygen	mg/L	8.0
Conductivity	µS/cm	134
pH	pH units	8.3
Water temperature	°C	18.2
Sediment Composition		
Sand	%	98
Silt	%	1
Clay	%	<1
Total Organic Carbon	%	0.34

Table 5.10-30 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Christina Lake.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Christina Lake	
	2012	2013
Nematoda	11	12
Hirudinea	<1	<1
Naididae	5	1
Tubificidae	<1	2
Enchytraeidae	2	1
Lumbriculidae	<1	-
Hydracarina	2	1
Amphipoda	11	11
Gastropoda	3	1
Bivalvia	4	1
Ceratopogonidae	1	3
Diptera (misc)	<1	-
Chironomidae	31	61
Coleoptera	-	<1
Ephemeroptera	2	6
Odonata	<1	<1
Trichoptera	1	<1
Benthic Invertebrate Community Measurement Endpoints		
Abundance (mean per replicate samples)	638	593
Richness	33	27
Equitability	0.28	0.32
% EPT	3	8

Figure 5.10-24 Variation in benthic invertebrate community measurement endpoints in Christina Lake.



Note: Values have been adjusted to a common depth of 2 m.

Note: Abundance, richness, and %EPT data were $\log_{10}$(x+1) transformed.

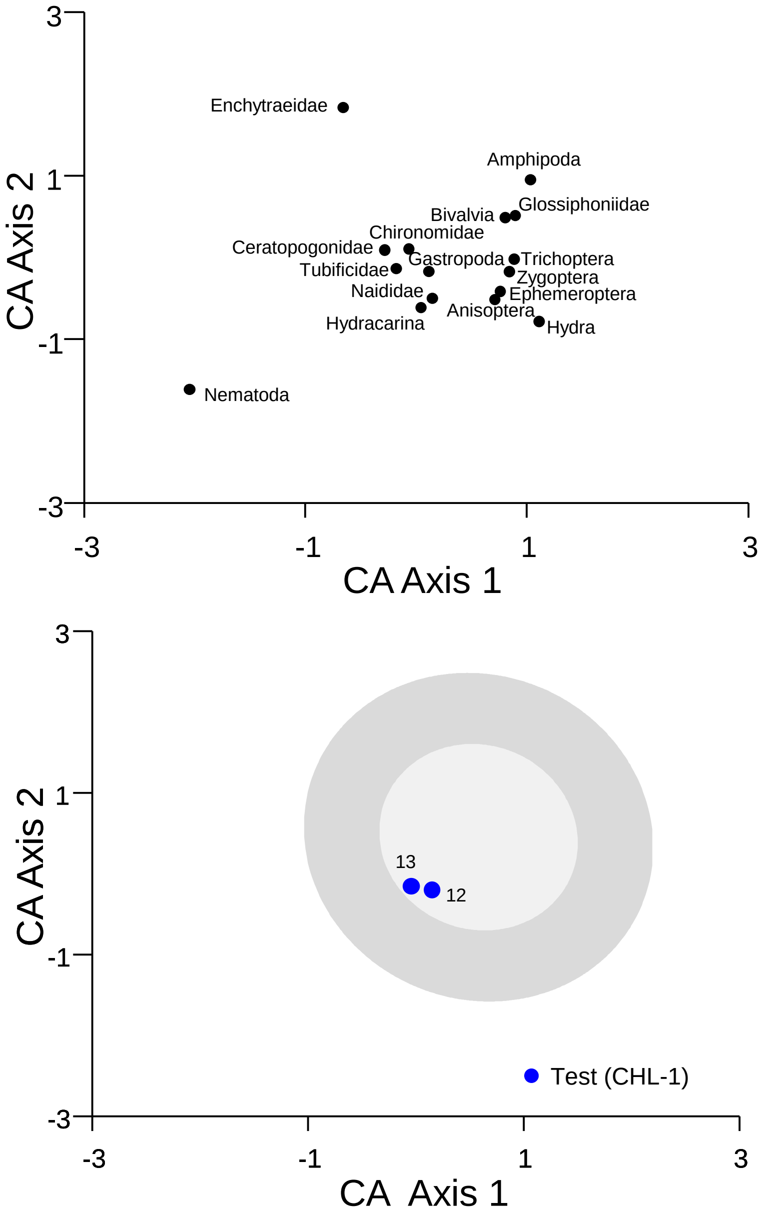


Figure 5.10-25 Ordination (Correspondence Analysis) of benthic invertebrate communities in RAMP lakes, showing Christina Lake.

Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for previous years.

Table 5.10-31 Concentrations of selected sediment measurement endpoints, Christina River (*baseline* station CHR-D4), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**
			Value
Physical variables			
Clay	%	-	13.0
Silt	%	-	30.0
Sand	%	-	57.0
Total organic carbon	%	-	1.60
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]	0.0010
Retene	mg/kg	-	0.0001
Total dibenzothiophenes	mg/kg	-	0.002
Total PAHs	mg/kg	-	0.025
Total Parent PAHs	mg/kg	-	0.002
Total Alkylated PAHs	mg/kg	-	0.022
Predicted PAH toxicity[3]	H.I.	1.0	0.11
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	5.0
Chironomus growth - 10d	mg/organism	-	4.30
Hyalella survival - 14d	# surviving	-	10.0
Hyalella growth - 14d	mg/organism	-	0.11

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-32 Concentrations of selected sediment measurement endpoints, Sawbones Creek (*test* station SAC-D1), fall 2013.

Variables	Units	Guideline	September 2013	September 2012
			Value	Value
Physical variables				
Clay[4]	%	-	5.4	6.0
Silt[4]	%	-	26.9	36.3
Sand[4]	%	-	67.7	57.8
Total organic carbon	%	-	4.08	5.95
Total hydrocarbons				
BTEX	mg/kg	-	<20	<30
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	<30
Fraction 2 (C10-C16)	mg/kg	150[1]	33	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	101	249
Fraction 4 (C34-C50)	mg/kg	2,800[1]	51	145
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0012	0.0012
Retene	mg/kg	-	1.200	0.280
Total dibenzothiophenes	mg/kg	-	0.015	0.017
Total PAHs	mg/kg	-	1.384	0.498
Total Parent PAHs	mg/kg	-	0.025	0.026
Total Alkylated PAHs	mg/kg	-	1.359	0.473
Predicted PAH toxicity[3]	H.I.	1.0	**2.43**	0.36
Metals that exceeded CCME guidelines in 2013				
none	mg/kg	-		
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	5.6	9.0
Chironomus growth - 10d	mg/organism	-	2.58	2.26
Hyalella survival - 14d	# surviving	-	9.8	9.6
Hyalella growth - 14d	mg/organism	-	0.15	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 5.10-33 Concentrations of selected sediment measurement endpoints, Sunday Creek (*test* station SUC-D1), fall 2013.

Variables	Units	Guideline	September 2013	September 2012
			Value	Value
Physical variables				
Clay	%	-	3.1	1.1
Silt	%	-	9.6	0.6
Sand	%	-	87.4	98.3
Total organic carbon	%	-	0.71	0.13
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	28	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	22	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0005	0.0002
Retene	mg/kg	-	0.013	0.001
Total dibenzothiophenes	mg/kg	-	0.007	0.002
Total PAHs	mg/kg	-	0.081	0.028
Total Parent PAHs	mg/kg	-	0.008	0.002
Total Alkylated PAHs	mg/kg	-	0.073	0.025
Predicted PAH toxicity[3]	H.I.	1.0	0.33	0.13
Metals that exceeded CCME guidelines in 2013				
none	mg/kg	-		
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	5.4	7.0
Chironomus growth - 10d	mg/organism	-	3.88	0.90
Hyalella survival - 14d	# surviving	-	8.6	8.6
Hyalella growth - 14d	mg/organism	-	0.50	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 5.10-34 Concentrations of selected sediment measurement endpoints, Sunday Creek (*baseline* station SUC-D2), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**
			Value
Physical variables			
Clay	%	-	3.6
Silt	%	-	<1.0
Sand	%	-	95.6
Total organic carbon	%	-	0.12
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]	0.0014
Retene	mg/kg	-	0.142
Total dibenzothiophenes	mg/kg	-	0.002
Total PAHs	mg/kg	-	0.173
Total Parent PAHs	mg/kg	-	0.003
Total Alkylated PAHs	mg/kg	-	0.170
Predicted PAH toxicity[3]	H.I.	1.0	0.93
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	7.6
Chironomus growth - 10d	mg/organism	-	5.50
Hyalella survival - 14d	# surviving	-	9.8
Hyalella growth - 14d	mg/organism	-	0.74

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-35 Concentrations of selected sediment measurement endpoints, Christina Lake (*test* station CHL-1), fall 2013.

Variables	Units	Guideline	September 2013	September 2012
			Value	Value
Physical variables				
Clay[4]	%	-	1.0	0.9
Silt[4]	%	-	2.5	0.9
Sand[4]	%	-	97.0	98.2
Total organic carbon	%	-	0.22	0.22
Total hydrocarbons				
BTEX	mg/kg	-	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0007	0.0003
Retene	mg/kg	-	0.005	0.003
Total dibenzothiophenes	mg/kg	-	0.003	0.002
Total PAHs	mg/kg	-	0.029	0.039
Total Parent PAHs	mg/kg	-	0.002	0.006
Total Alkylated PAHs	mg/kg	-	0.026	0.033
Predicted PAH toxicity[3]	H.I.	1.0	0.13	0.18
Metals that exceeded CCME guidelines in 2013				
none	mg/kg	-		
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	7.4	8.4
Chironomus growth - 10d	mg/organism	-	5.63	2.77
Hyalella survival - 14d	# surviving	-	9.8	10.0
Hyalella growth - 14d	mg/organism	-	0.94	0.33

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 5.10-36 Concentrations of selected sediment measurement endpoints, Birch Creek (*baseline* station BRC-D1), fall 2013.

Variables	Units	Guideline	September 2013
			Value
Physical variables			
Clay	%	-	10.0
Silt	%	-	20.0
Sand	%	-	70.0
Total organic carbon	%	-	1.50
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]	56
Fraction 4 (C34-C50)	mg/kg	2,800[1]	23
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0016
Retene	mg/kg	-	0.011
Total dibenzothiophenes	mg/kg	-	0.006
Total PAHs	mg/kg	-	0.091
Total Parent PAHs	mg/kg	-	0.018
Total Alkylated PAHs	mg/kg	-	0.073
Predicted PAH toxicity[3]	H.I.	1.0	0.25
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	6.2
Chironomus growth - 10d	mg/organism	-	3.15
Hyalella survival - 14d	# surviving	-	9.2
Hyalella growth - 14d	mg/organism	-	0.32

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-37 Concentrations of selected sediment measurement endpoints, Unnamed Creek (*test* station UNC-D2), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**
			Value
Physical variables			
Clay	%	-	5.2
Silt	%	-	32.6
Sand	%	-	62.2
Total organic carbon	%	-	6.40
Total hydrocarbons			
BTEX	mg/kg	-	<60
Fraction 1 (C6-C10)	mg/kg	30[1]	<60
Fraction 2 (C10-C16)	mg/kg	150[1]	39
Fraction 3 (C16-C34)	mg/kg	300[1]	**374**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	188
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0039
Retene	mg/kg	-	0.637
Total dibenzothiophenes	mg/kg	-	0.018
Total PAHs	mg/kg	-	0.963
Total Parent PAHs	mg/kg	-	0.046
Total Alkylated PAHs	mg/kg	-	0.918
Predicted PAH toxicity[3]	H.I.	1.0	0.50
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	6.2
Chironomus growth - 10d	mg/organism	-	1.85
Hyalella survival - 14d	# surviving	-	8.4
Hyalella growth - 14d	mg/organism	-	0.25

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.10-38 Concentrations of selected sediment measurement endpoints, Unnamed Creek (*test* station UNC-D3), fall 2013.

Variables	Units	Guideline	September 2013
			Value
Physical variables			
Clay	%	-	1.0
Silt	%	-	<2.0
Sand	%	-	97.0
Total organic carbon	%	-	0.29
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]	0.0004
Retene	mg/kg	-	0.004
Total dibenzothiophenes	mg/kg	-	0.002
Total PAHs	mg/kg	-	0.020
Total Parent PAHs	mg/kg	-	0.002
Total Alkylated PAHs	mg/kg	-	0.018
Predicted PAH toxicity[3]	H.I.	1.0	0.09
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	6.2
Chironomus growth - 10d	mg/organism	-	3.58
Hyalella survival - 14d	# surviving	-	9.0
Hyalella growth - 14d	mg/organism	-	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).

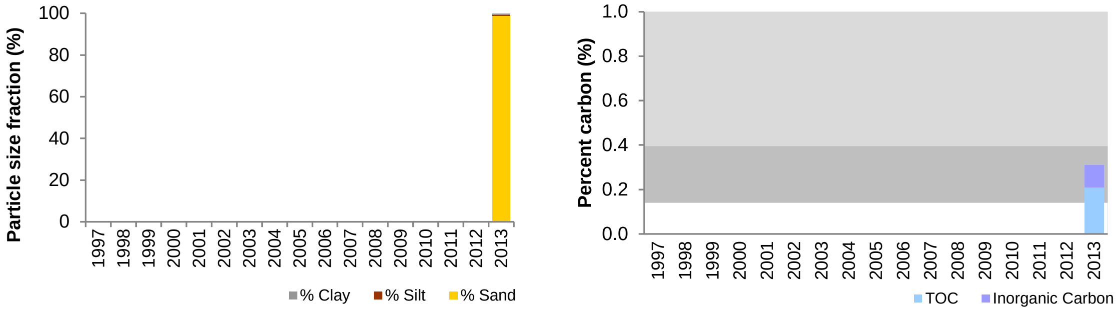
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.10-26 Variation in sediment quality measurement endpoints in the Christina River, *baseline* station CHR-D4.

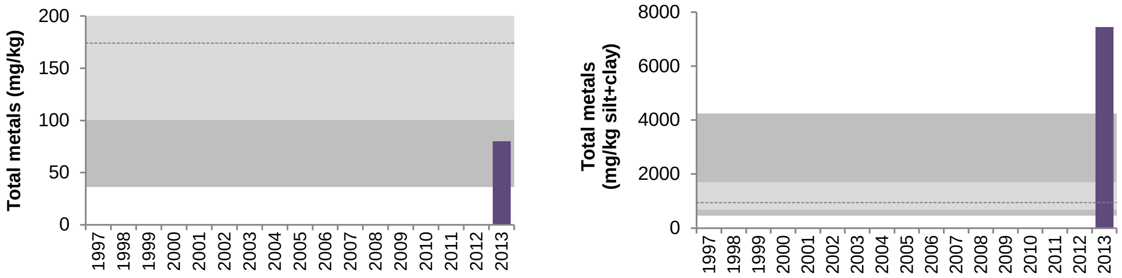
Particle size distribution

Carbon Content[1]



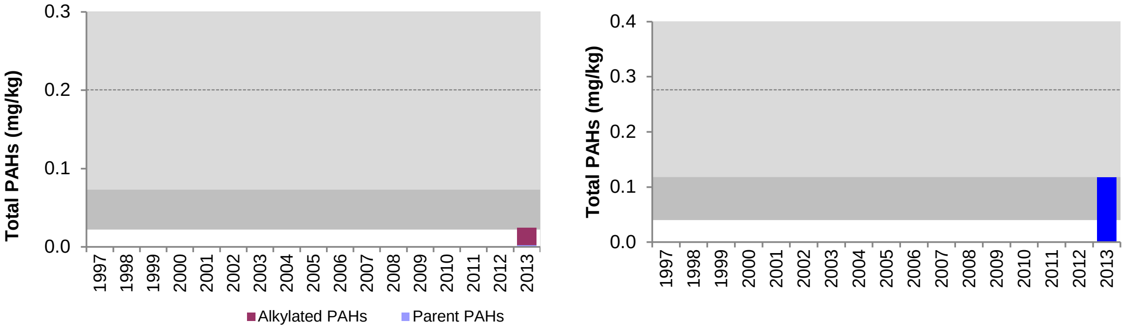
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



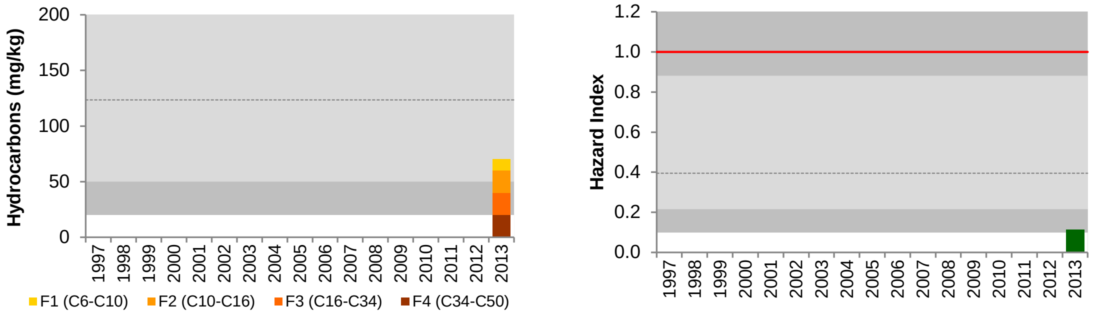
Total PAHs

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 (1997-2013).

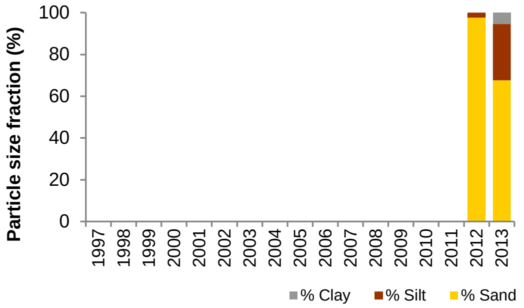
[1] Regional *baseline* values represent "total" values for multi-variable data.

[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).

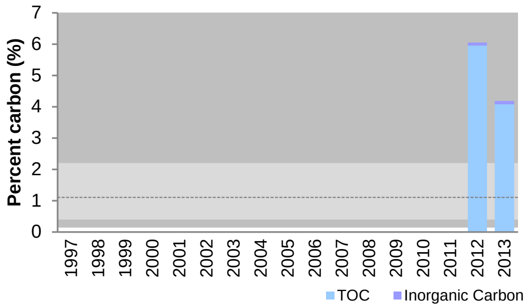
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-27 Variation in sediment quality measurement endpoints in Sawbones Creek, *test* station SAC-D1.

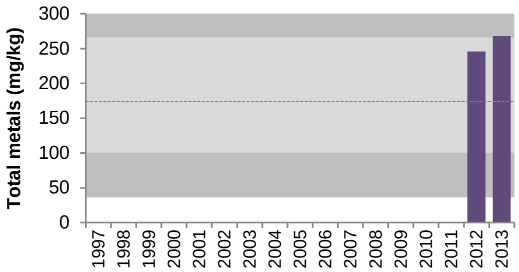
Particle size distribution



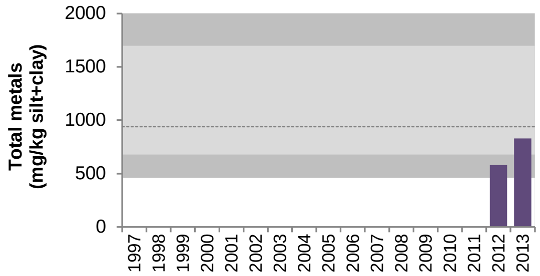
Carbon Content[1]



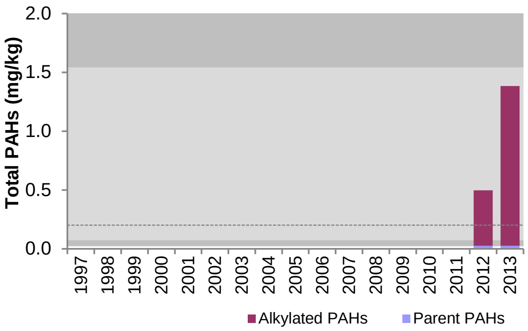
Total Metals[2]



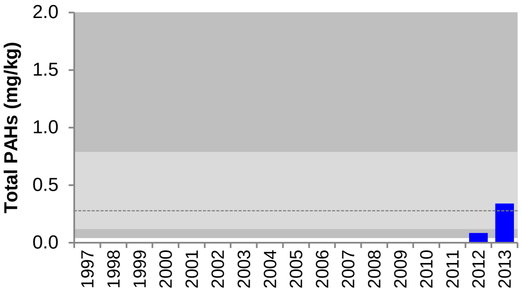
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



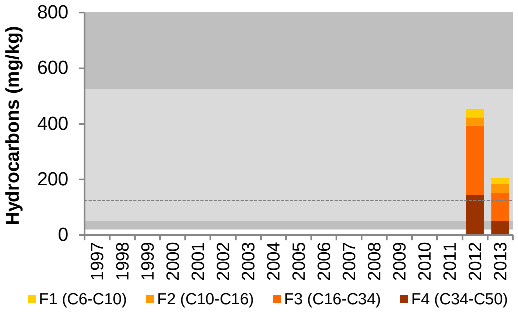
Total PAHs



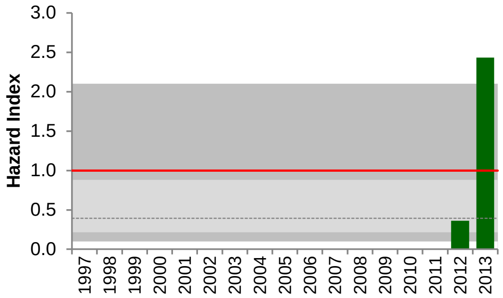
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



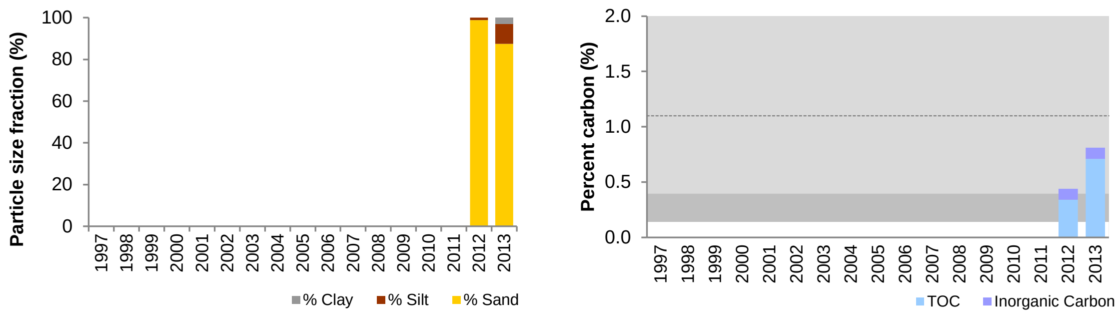
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

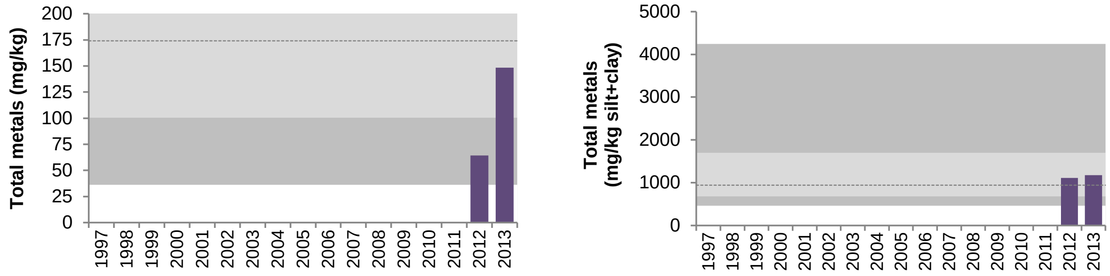
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

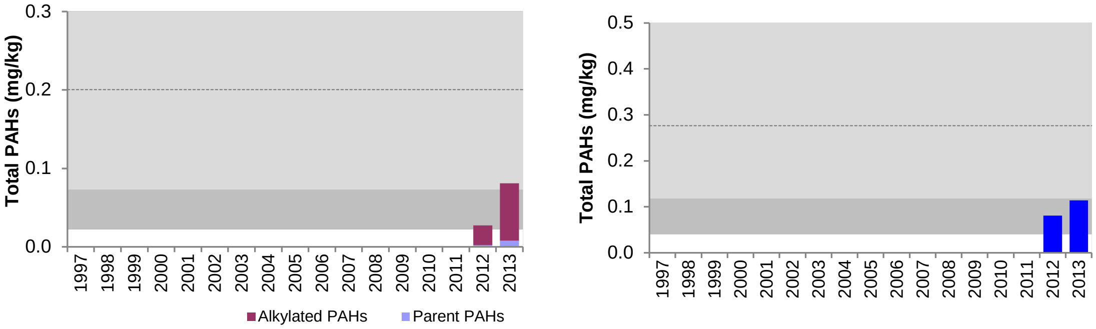
Figure 5.10-28 Variation in sediment quality measurement endpoints in Sunday Creek, *test* station SUC-D1.


Particle size distribution

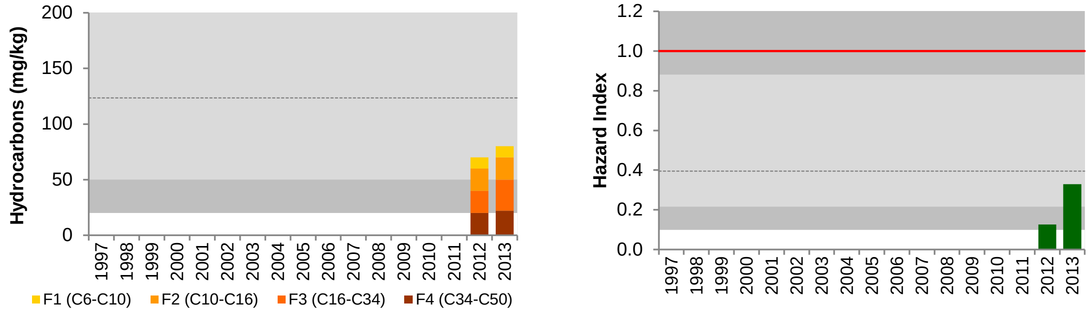
Carbon Content[1]


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 (1997-2013).

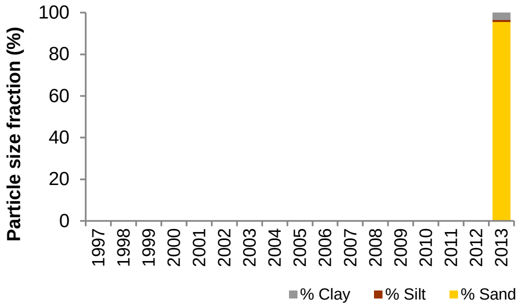
[1] Regional *baseline* values represent "total" values for multi-variable data.

[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).

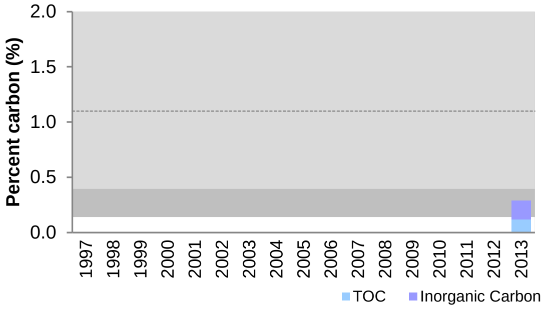
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-29 Variation in sediment quality measurement endpoints in Sunday Creek, *baseline* station SUC-D2.

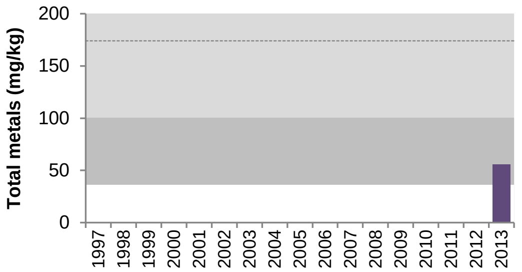
Particle size distribution



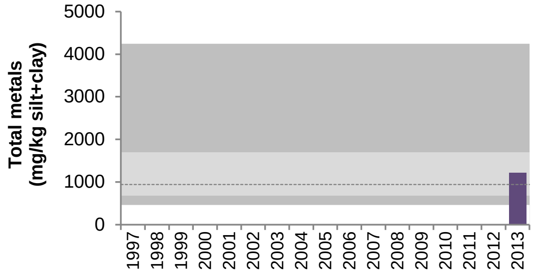
Carbon Content[1]



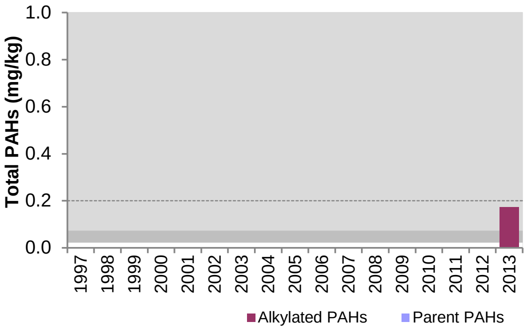
Total Metals[2]



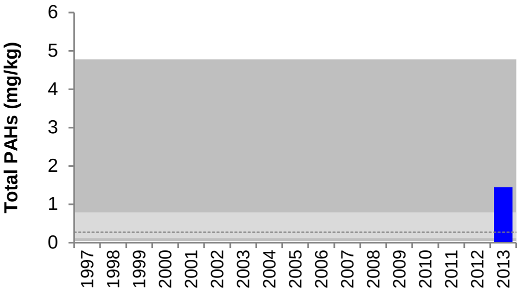
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



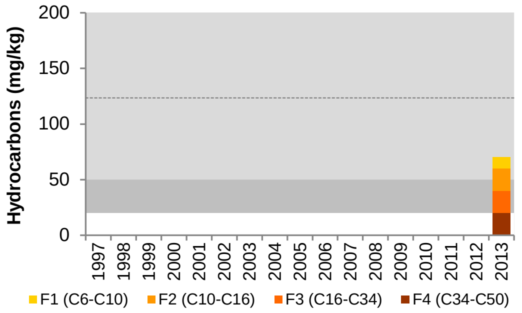
Total PAHs



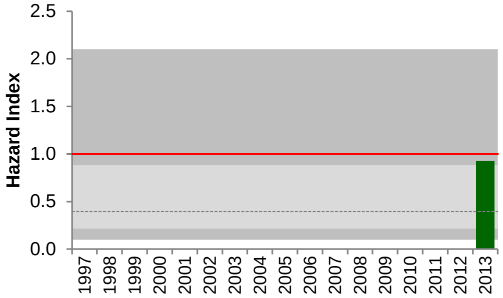
Total PAHs normalized to 1% TOC



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 (1997-2013).

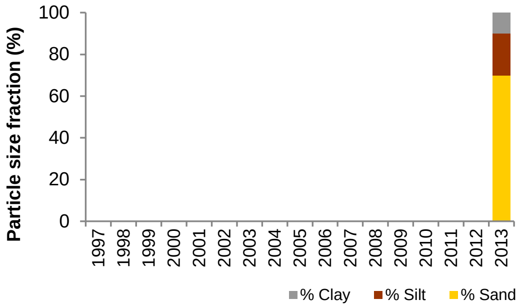
[1] Regional *baseline* values represent "total" values for multi-variable data.

[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).

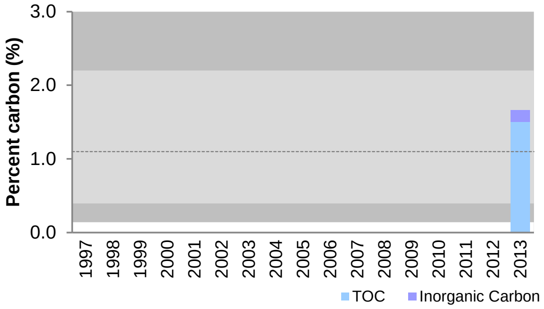
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-30 Variation in sediment quality measurement endpoints in Birch Creek, *baseline* station BRC-D1.

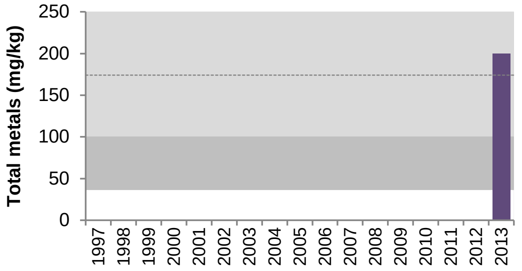
Particle size distribution



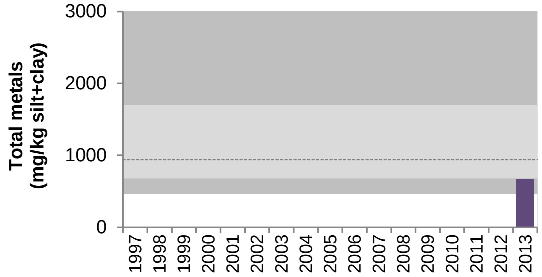
Carbon Content[1]



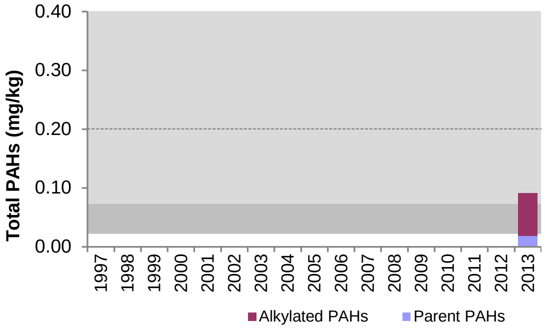
Total Metals[2]



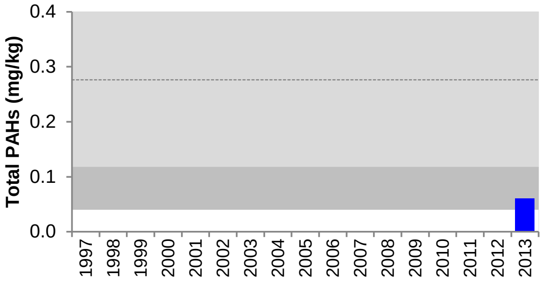
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



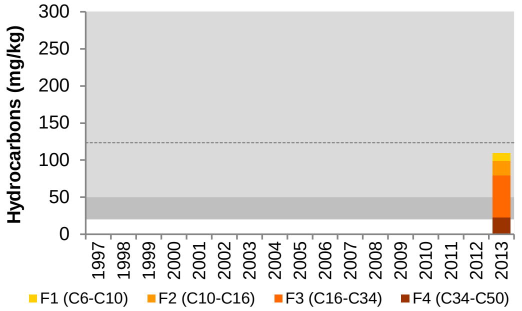
Total PAHs



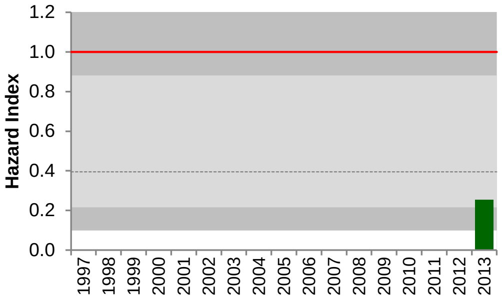
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



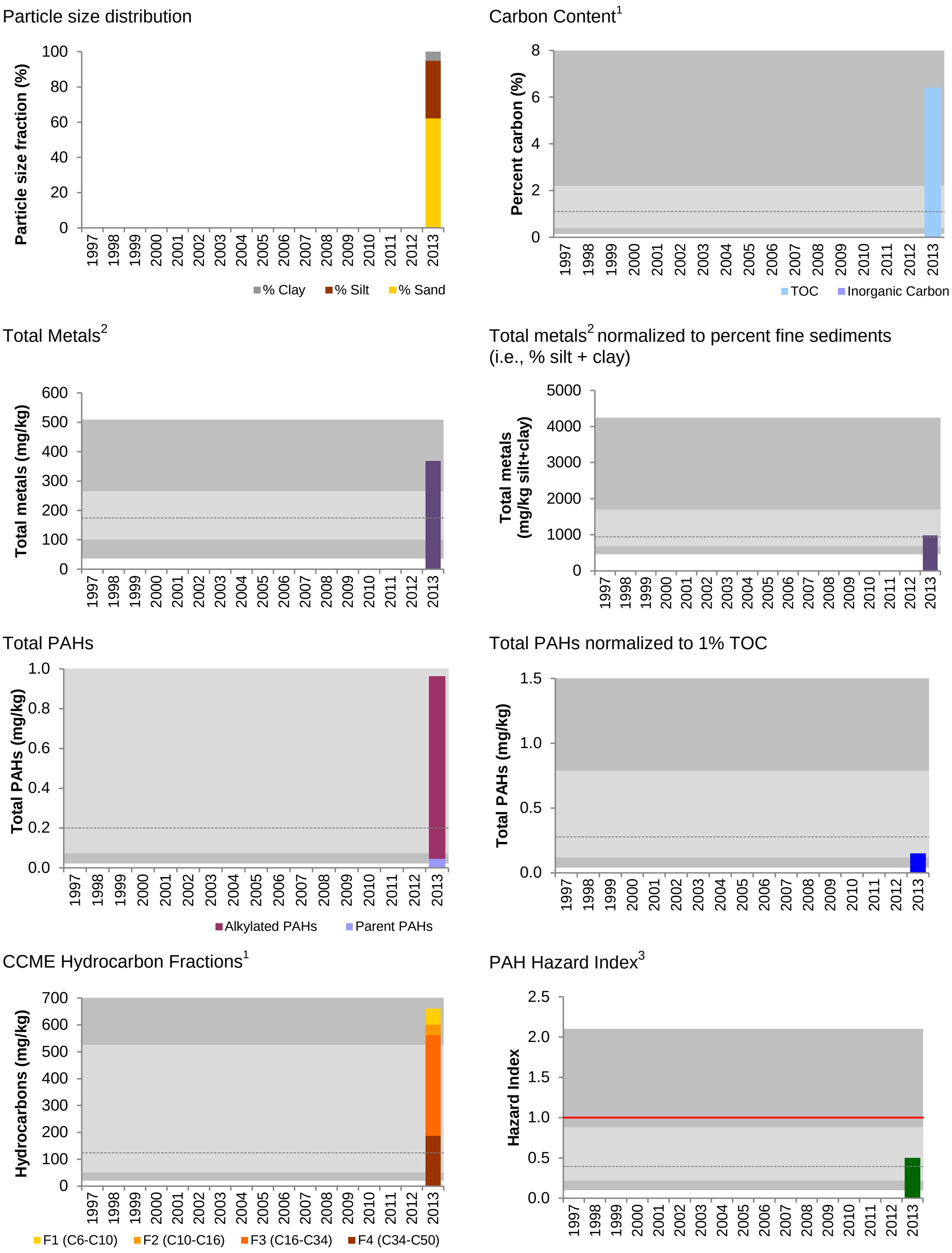
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2013).

[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 5.10-31 Variation in sediment quality measurement endpoints in Unnamed Creek, *test* station UNC-D2.


Particle size distribution

Carbon Content[1]

Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)

Total PAHs

Total PAHs normalized to 1% TOC

CCME Hydrocarbon Fractions[1]

PAH Hazard Index[3]

Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2013).

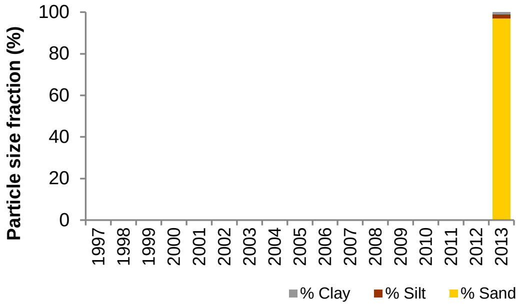
[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

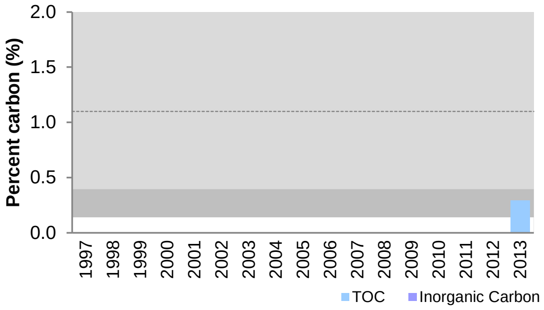
[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.10-32 Variation in sediment quality measurement endpoints in Unnamed Creek, *test* station UNC-D3.

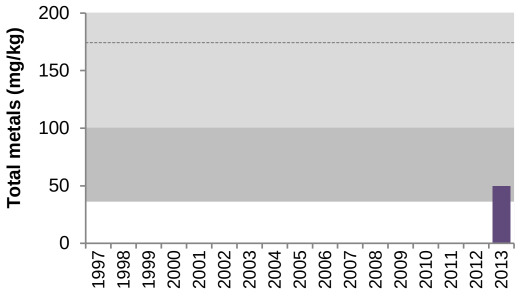
Particle size distribution



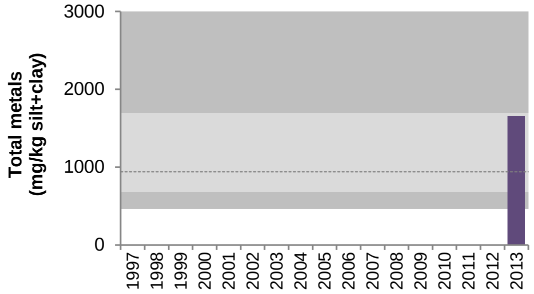
Carbon Content[1]



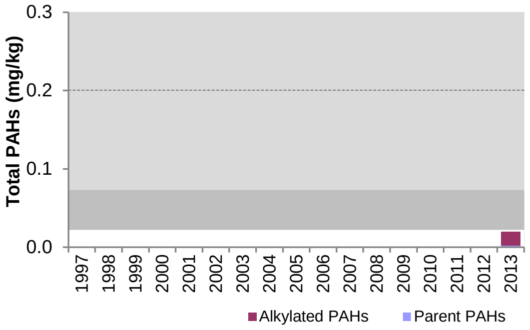
Total Metals[2]



Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)

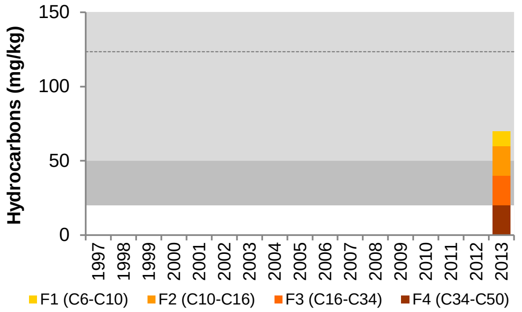


Total PAHs

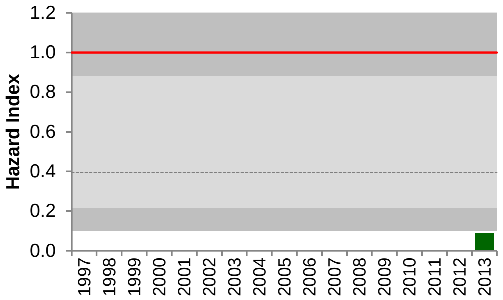


Total PAHs normalized to 1% TOC

CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



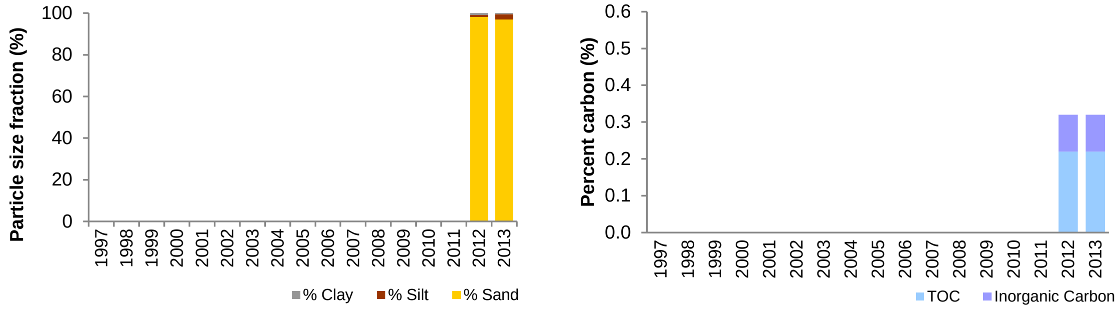
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

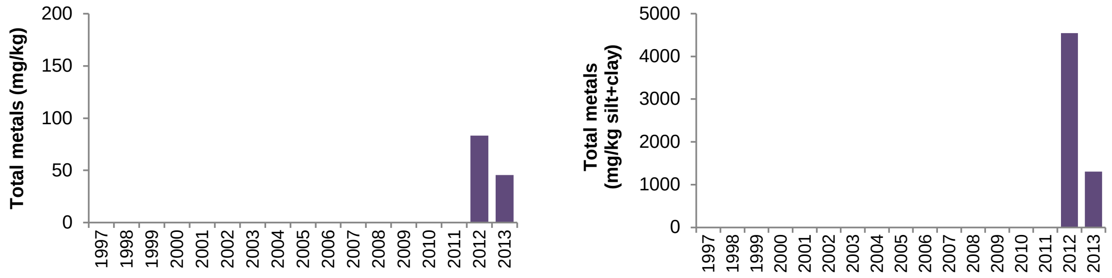
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

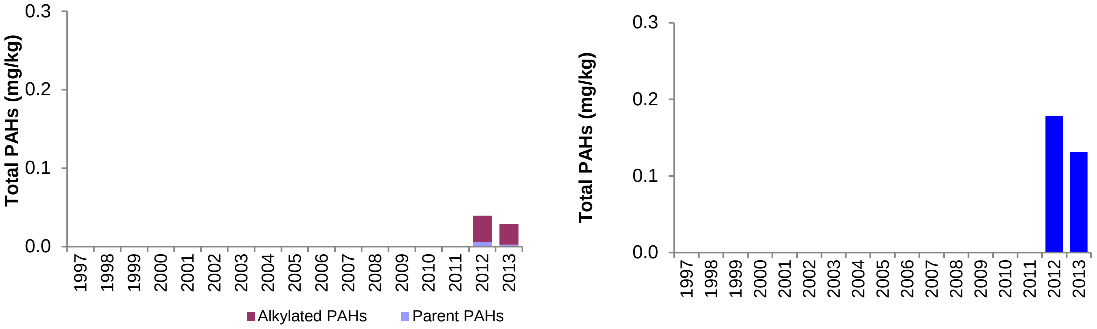
Figure 5.10-33 Variation in sediment quality measurement endpoints in Christina Lake, *test* station CHL-1.


Particle size distribution

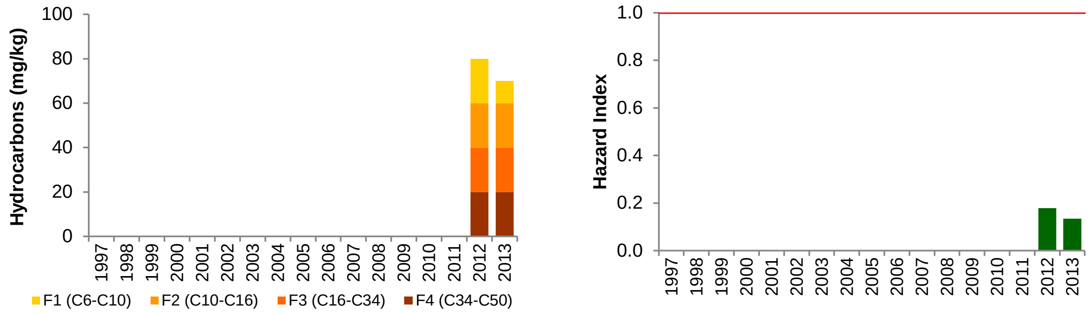
Carbon Content


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[1]

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 5.10-39 Sediment quality index (fall 2013) for stations in the Christina River watershed.

Station Identifier	Location	2013 Designation	Sediment Quality Index	Classification
CHR-D4	Upper Christina River	*baseline*	98.8	Negligible-Low
BRC-D1	Birch Creek	*baseline*	100.0	Negligible-Low
SAC-D1	Sawbones Creek	*test*	98.6	Negligible-Low
SUC-D1	Sunday Creek	*test*	98.9	Negligible-Low
SUC-D2	Sunday Creek	*baseline*	97.8	Negligible-Low
UNC-D2	Unnamed Creek, east of Christina Lake	*test*	95.6	Negligible-Low
UNC-D3	Unnamed Creek, south of Christina Lake	*test*	100.0	Negligible-Low

Table 5.10-40 Average habitat characteristics of fish assemblage monitoring locations in the Christina River, fall 2013.

Variable	Units	CHR-F3 *Test* Reach of the Christina River	CHR-F4 *Baseline* Reach of the Christina River
Sample date	-	Sept 7, 2013	Sept 7, 2013
Habitat type	-	riffle/run	run
Maximum depth	m	0.75	1.02
Mean depth	m	0.42	0.72
Bankfull channel width	m	50.5	19.5
Wetted channel width	m	47.6	18.3
Substrate			
Dominant	-	cobble	fines
Subdominant	-	coarse gravel, fines	-
Instream cover			
Dominant	-	boulders	undercut banks, boulders
Subdominant	-	small woody debris, filamentous algae	overhanging vegetation, small woody debris
Field water quality			
Dissolved oxygen	mg/L	8.0	7.2
Conductivity	µS/cm	191	173
pH	pH units	7.89	7.52
Water temperature	^{0}C	14.2	14.4
Water velocity			
Left bank velocity	m/s	0.35	0.20
Left bank water depth	m	0.42	0.60
Centre of channel velocity	m/s	0.62	0.39
Centre of channel water depth	m	0.60	0.70
Right bank velocity	m/s	0.33	0.39
Right bank water depth	m	0.69	1.02
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	overhanging vegetation
Subdominant	-	overhanging vegetation	woody shrubs and saplings

Table 5.10-41 Total number and percent composition of all fish species captured at reaches of the Christina River, 2013.

Common Name	Code	Total Species				Percent of Total Catch			
		Test Reach CHR-F1	*Test* Reach CHR-F2	*Test* Reach CHR-F3	*Baseline* Reach CHR-F4	*Test* Reach CHR-F1	*Test* Reach CHR-F2	*Test* Reach CHR-F3	*Baseline* Reach CHR-F4
		2012	**2012**	**2013**	**2013**	**2012**	**2012**	**2013**	**2013**
Arctic grayling	ARGR	-	2	-	-	-	3.7	-	-
brook stickleback	BRST	-	-	-	-	-	-	-	-
burbot	BURB	-	-	13	-	-	-	33.3	-
flathead chub	FLCH	1	-	-	-	3.8	-	-	-
fathead minnow	FTMN	-	-	-	-	-	-	-	-
finescale dace	FNDC	-	-	-	-	-	-	-	-
goldeye	GOLD	7	-	-	-	26.9	-	-	-
lake chub	LKCH	5	3	-	1	19.2	5.6	-	1.9
lake whitefish	LKWH	-	-	-	-	-	-	-	-
longnose dace	LNDC	-	-	3	-	-	-	7.7	-
longnose sucker	LNSC	1	1	1	3	3.8	1.9	2.6	5.6
northern pike	NRPK	2	-	2	-	7.7	-	5.1	-
northern redbelly dace	NRDC	-	1	-	-	-	1.9	-	-
pearl dace	PRDC	-	1	1	35	-	1.9	2.6	64.8
slimy sculpin	SLSC	3	-	17	-	11.5	-	43.6	-
spoonhead sculpin	SPSC	-	-	-	-	-	-	-	-
spottail shiner	SPSH	-	-	-	-	-	-	-	-
trout-perch	TRPR	4	45	-	-	15.4	83.3	-	-
walleye	WALL	3	-	-	-	11.5	-	-	-
white sucker	WHSC	-	1	1	1	-	1.9	2.6	1.9
yellow perch	YLPR	-	-	-	-	-	-	-	-
sucker sp. *		-	-	1	14	-	-	2.6	25.9
Total		**26**	**54**	**39**	**54**	**100**	**100**	**100**	**100**
Total Species Richness		**8**	**7**	**7**	**4**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,448**	**2,010**	**2,541**	**2,327**	-	-	-	-

* Unknown sucker species not included in species richness count.

Note: *Test* reaches CHR-F1 and CHR-F2 not sampled in 2013.

Table 5.10-42 Summary of fish assemblage measurement endpoints for reaches of the Christina River watershed, 2013.

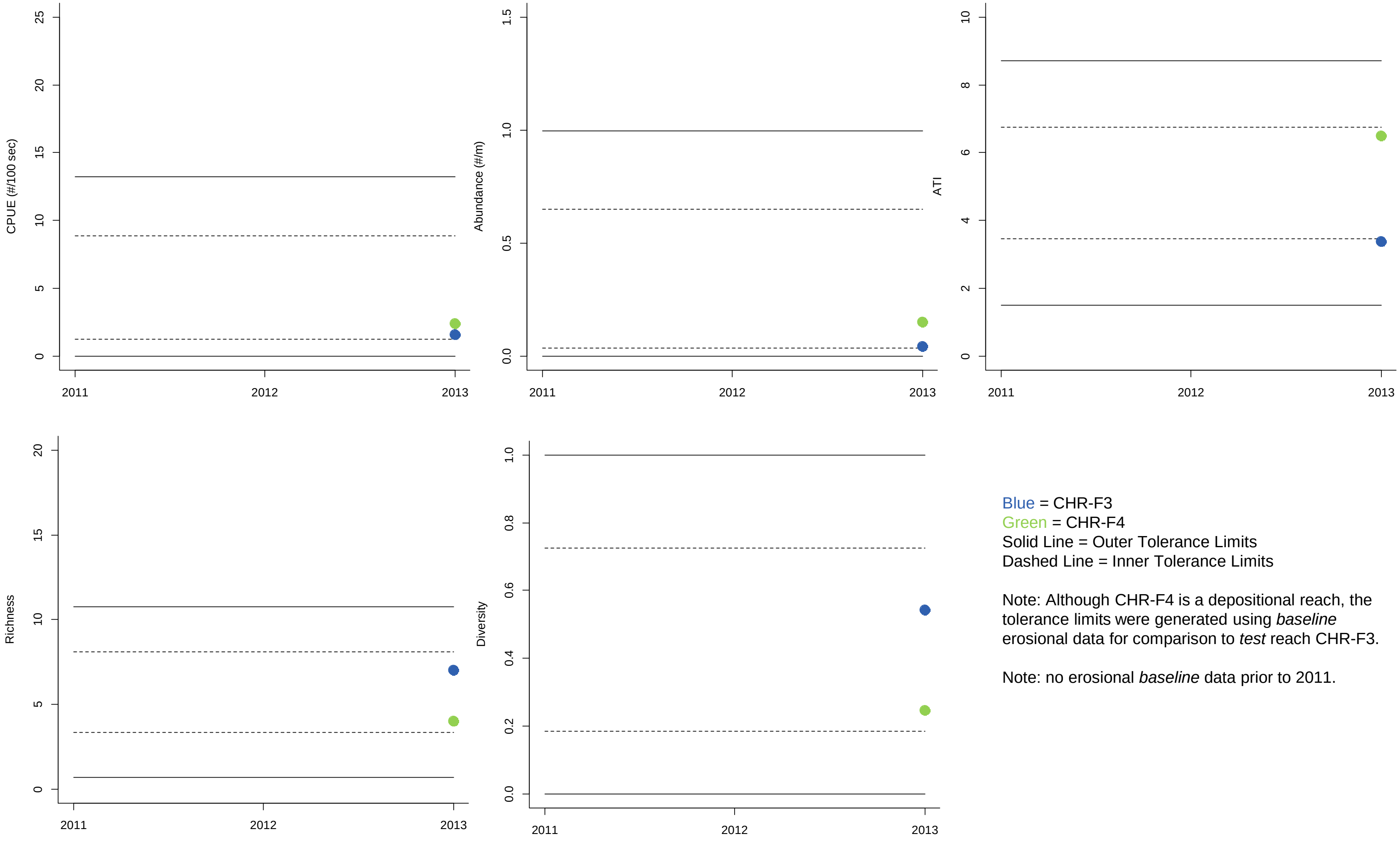
Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CHR-F1	2012	0.01	0.01	8	3	1.79	0.61	0.15	7.50	1.19	1.73	1.38
CHR-F2	2012	0.02	0.01	7	3	0.84	0.33	0.19	7.43	1.22	2.58	1.45
CHR-F3	2013	0.04	0.02	7	3	1.22	0.58	0.14	3.37	0.59	1.57	0.63
CHR-F4	2013	0.15	0.11	4	1	0.00	0.25	0.10	6.48	0.19	2.38	1.84
JAR-F1	2012	0.08	0.03	6	3	0.84	0.55	0.09	3.69	1.28	1.38	0.54
	2013	0.11	0.03	5	4	0.89	0.50	0.14	2.88	0.44	3.41	0.99
SAC-F1	2012	0.01	0.01	1	0	0.00	0.00	0.00	7.80	0.00	0.06	0.14
	2013	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUC-F1	2012	0.18	0.14	7	2	0.55	0.25	0.15	3.33	0.39	2.40	1.95
	2013	0.12	0.06	3	2	0.55	0.46	0.04	4.39	0.14	2.68	1.45
SUC-F2	2013	0.12	0.05	5	3	0.89	0.49	0.05	5.58	1.74	2.88	1.19
UNC-F2	2013	0.00	0.01	1	0	0.45	0.00	0.00	7.60	-	0.08	0.19
UNC-F3	2013	0.02	0.02	3	1	1.00	0.20	0.27	7.23	0.90	0.37	0.37
BRC-F1	2013	0.03	0.04	1	1	0.55	0.00	0.00	7.60	-	0.50	0.56

* Unknown species not included in analysis.

SD = standard deviation across sub-reaches within a reach.

Diversity was zero at BRC-F1 given there was only one species captured.

Figure 5.10-34 **Variation in fish assemblage measurement endpoints at reaches of the Christina River in 2013, relative to regional *baseline* conditions.**



Blue = CHR-F3
Green = CHR-F4
Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

Note: Although CHR-F4 is a depositional reach, the tolerance limits were generated using *baseline* erosional data for comparison to *test* reach CHR-F3.

Note: no erosional *baseline* data prior to 2011.

Table 5.10-43 Average habitat characteristics of fish assemblage monitoring locations in tributaries of Christina Lake, fall 2013.

Variable	Units	SUC-F1 Lower *Test* Reach of Sunday Creek	SUC-F2 Upper *Baseline* Reach of Sunday Creek	SAC-F1 *Test* Reach of Sawbones Creek	UNC-F2 Lower *Test* Reach of Unnamed Creek (east of CHL)	UNC-F3 Lower *Test* Reach of Unnamed Creek (south of CHL)	BRC-F1 *Baseline* Reach of Birch Creek	JAR-F1 *Test* Reach of Jackfish River
Sample date	-	Sept 6, 2013	Sept 8, 2013	Sept 5, 2013	Sept 9, 2013	Sept 9, 2013	Oct 7, 2013	Sept 8, 2013
Habitat type	-	run	run	run	run	run	run	riffle/run
Maximum depth	m	0.85	0.94	1.48	1.91	1.3	0.9	0.61
Mean depth	m	0.56	0.71	1.16	0.56	0.52	0.80	0.53
Bankfull channel width	m	12.5	7.0	4.0	5.0	5.2	8.4	32.5
Wetted channel width	m	9.9	6.2	4.0	5.0	4.1	6.4	30.0
Substrate								
Dominant	-	sand	sand / fines	fines	fines	sand	sand	gravel
Subdominant	-	cobble	small boulder	-	sand	fines	small boulders	cobble
Instream cover								
Dominant	-	boulders	macrophytes, small woody debris, overhanging vegetation, boulders	macrophytes, small woody debris	macrophytes	macrophytes	live trees and roots	boulders
Subdominant	-	macrophytes, small woody debris, overhanging vegetation, undercut banks	undercut banks, large woody debris, filamentous algae	overhanging vegetation, undercut banks	undercut banks	undercut banks	macrophytes, small woody debris, overhanging vegetation, undercut banks	filamentous algae, macrophytes, small woody debris
Field water quality								
Dissolved oxygen	mg/L	8.6	8.1	4.6	7.4	6.5	9.4	9.0
Conductivity	µS/cm	226	192	111	127	198	302	138
pH	pH units	8.16	7.88	7.58	7.87	8.02	8.22	8.38
Water temperature	^{0}C	17.1	13.1	18.2	17.2	15.2	5.9	18.9
Water velocity								
Left bank velocity	m/s	0.11	0.02	0.05	0.44	0.10	0.05	0.22
Left bank water depth	m	0.38	0.59	0.92	0.56	0.34	0.71	0.51
Centre of channel velocity	m/s	0.24	0.04	0.09	0.56	0.12	0.06	0.42
Centre of channel water depth	m	0.62	0.84	1.45	0.67	0.48	0.82	0.56
Right bank velocity	m/s	0.32	0.01	0.05	-	0.19	0.09	0.42
Right bank water depth	m	0.69	0.71	1.10	-	0.73	1.01	0.51
Riparian cover – understory (<5 m)								
Dominant	-	woody shrubs and saplings	overhanging vegetation	woody shrubs and saplings	overhanging vegetation	overhanging vegetation	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	woody shrubs and saplings	overhanging vegetation	-	woody shrubs and saplings	Overhanging vegetation	overhanging vegetation

Note: too deep to cross channel at UNC-F2 to collect depth and flow measurements.

CHL = Christina Lake

Table 5.10-44 Total number and percent composition of all fish species captured at fish assemblage monitoring locations in tributaries of Christina Lake, fall 2013.

Common Name	Code	Total Species											Percent of Total Catch										
		SUC-F1		SUC-F2	SAC-F1		UNC-F2	UNC-F3	BRC-F1	JAR-F1		SUC-F1		SUC-F2	SAC-F1		UNC-F2	UNC-F3	BRC-F1	JAR-F1	
		2012	2013	2013	2012	2013	2013	2013	2013	2012	2013	2012	2013	2013	2012	2013	2013	2013	2013	2012	2013
Arctic grayling	ARGR	1	-	-	-	-	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-
brook stickleback	BRST	-	-	2	-	-	-	-	-	-	-	-	-	5.6	-	-	-	-	-	-	-
burbot	BURB	-	-	-	-	-	-	-	-	12	47	-	-	-	-	-	-	-	-	48.0	61.0
flathead chub	FLCH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
fathead minnow	FTMN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
finescale dace	FNDC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
goldeye	GOLD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iowa darter	IWDR	-	-	1	-	-	-	-	-	-	-	-	-	2.8	-	-	-	-	-	-	-
lake chub	LKCH	2	-	-	-	-	-	-	-	-	-	4.5	-	-	-	-	-	-	-	-	-
lake whitefish	LKWH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
longnose dace	LNDC	-	-	-	-	-	-	-	-	2	8	-	-	-	-	-	-	-	-	8.0	10.4
longnose sucker	LNSC	1	-	-	-	-	-	1	-	1	4	2.3	-	-	-	-	-	20.0	-	4.0	5.2
northern pike	NRPK	2	-	1	1	-	-	3	-	1	-	4.5	-	2.8	100.0	-	-	60.0	-	4.0	-
northern redbelly dace	NRDC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pearl dace	PRDC	1	12	-	-	-	-	-	-	-	-	2.3	20.0	-	-	-	-	-	-	-	-
slimy sculpin	SLSC	36	39	18	-	-	-	-	-	6	17	81.8	65.0	50.0	-	-	-	-	-	24.0	22.1
spoonhead sculpin	SPSC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
spottail shiner	SPSH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
trout-perch	TRPR	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1.3
walleye	WALL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
white sucker	WHSC	-	8	14	-	-	1	1	6	3	-	-	13.3	38.9	-	-	100.0	20.0	75	12.0	-
yellow perch	YLPR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
dace sp.*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
sucker sp. *		1	1	-	-	-	-	-	2	-	-	2.3	1.7	-	-	-	-	-	25	-	-
Total		**44**	**60**	**36**	**1**	**0**	**1**	**5**	**8**	**25**	**77**	**100**	**100**	**100**	**100**	**0**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**3**	**5**	**1**	**0**	**1**	**3**	**1**	**6**	**5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,784**	**1,252**	**2,246**	**1,635**	**1,328**	**1,334**	**1,224**	**2,006**	**1,803**	**2,265**	-	-	-	-	-	-	-	-	-	-

* Unknown sucker species not included in species richness count.

Figure 5.10-35 Variation in fish assemblage measurement endpoints in erosional tributaries of the Christina River (*test* reaches SUC-F1, JAR-F1 and *baseline* station SUC-F2) in 2013, relative to regional *baseline* conditions.

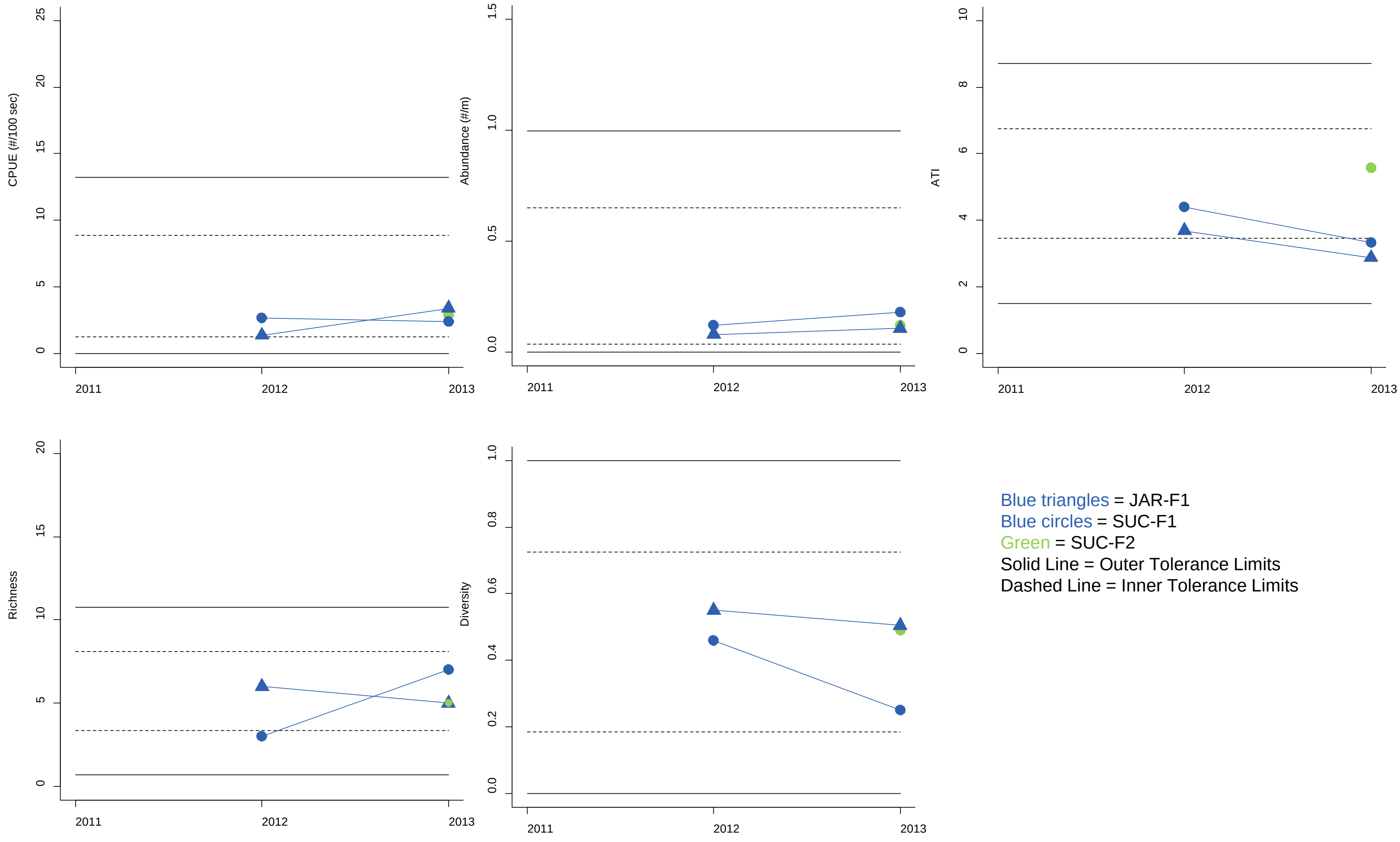


Figure 5.10-36 Variation in fish assemblage measurement endpoints in depositional tributaries of the Christina River (*test* reaches UNC-F2, UNC-F3, SAC-F1, and *baseline* station BRC-1) in 2013, relative to regional *baseline* conditions.

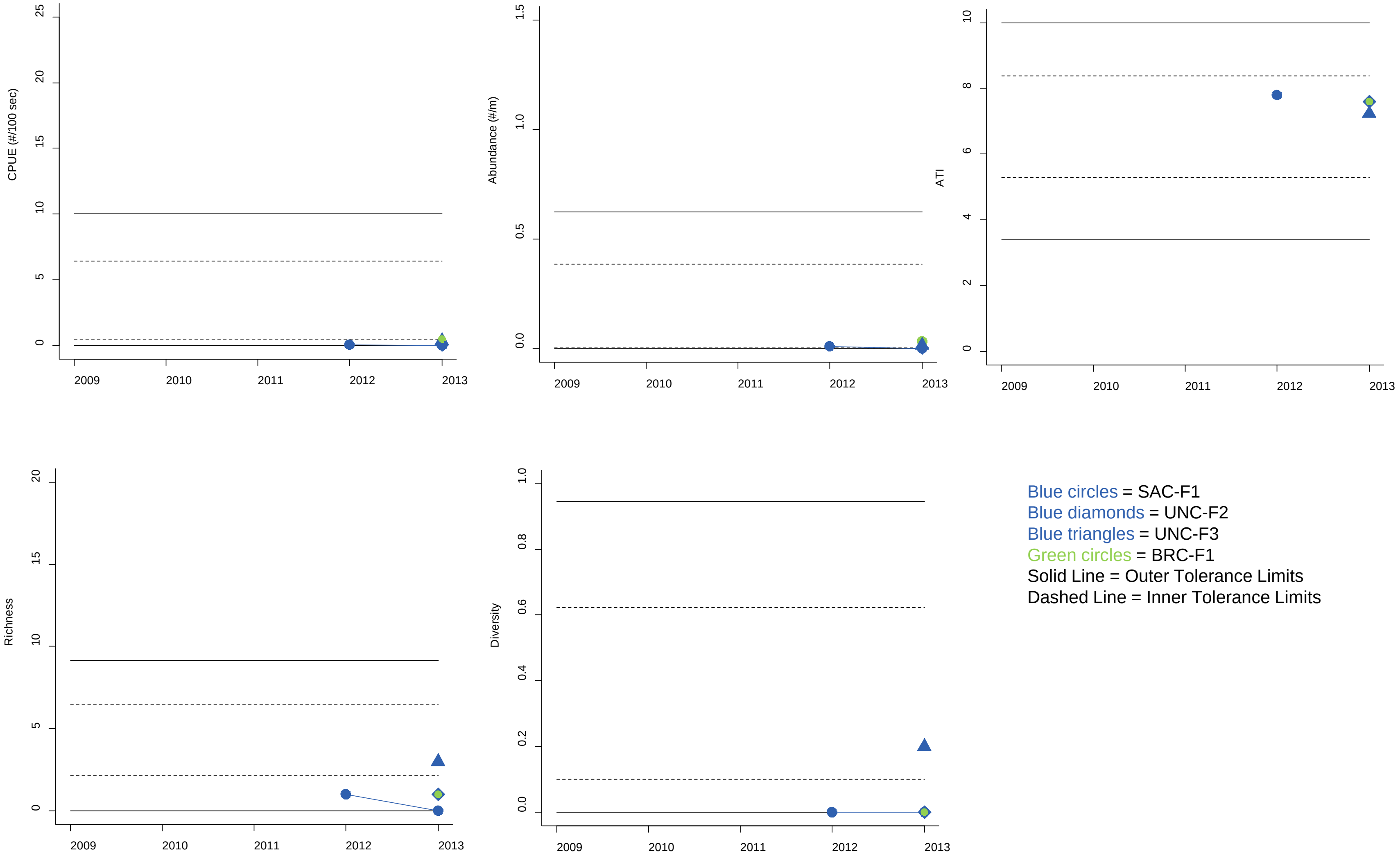


Table 5.10-45 Metrics and mercury concentrations in lake whitefish, northern pike, and walleye collected from Christina Lake, fall 2013, relative to fish consumption criteria for the protection of human health.

Species	Sample ID	Sex	Fork Length (mm)	Weight (g)	Hg (mg/kg)
Lake whitefish	CL-02	F	360	580	0.062
	CL-04	M	385	675	0.063
	CL-27	F	213	104	0.060
	CL-36	U	198	93	0.079
	CL-37	F	261	208	0.083
	CL-38	M	418	1,055	0.086
	CL-39	M	227	150	0.058
	CL-40	F	253	194	0.075
	CL-41	F	253	181	0.091
	CL-44	M	398	858	0.082
Northern pike	CL-18	F	645	1,725	0.405
	CL-19	F	576	1,453	0.175
	CL-20	F	404	468	0.094
	CL-21	F	563	1,303	0.225
	CL-22	U	618	1,765	**0.699**
	CL-23	M	429	599	0.033
	CL-24	F	563	1,225	0.173
	CL-25	F	653	1,948	0.323
	CL-26	M	496	820	0.184
	CL-28	M	472	712	0.092
	CL-31	F	492	744	0.104
	CL-32	F	490	782	0.134
	CL-34	F	709	2,193	**0.614**
	CL-42	F	453	632	0.057
Walleye	CL-01	F	602	2,646	**0.636**
	CL-03	M	324	364	0.301
	CL-05	M	374	541	0.284
	CL-06	U	575	2,028	**0.733**
	CL-07	F	209	94	0.121
	CL-08	F	422	693	0.164
	CL-09	F	388	635	0.156
	CL-10	F	383	604	0.348
	CL-11	F	548	1,882	**0.529**
	CL-12	F	97	74	0.222
	CL-13	M	355	453	0.195
	CL-14	F	347	431	0.311
	CL-15	F	234	130	0.120
	CL-16	M	228	120	0.130
	CL-17	F	366	507	0.154
	CL-29	M	474	110	**0.458**
	CL-30	F	261	192	0.166
	CL-33	M	404	1,043	0.222
	CL-35	M	241	140	0.119
	CL-43	F	388	551	0.164

M-Male; F-Female; U-Undetermined

Shading denotes exceedance of Health Canada guideline for subsistence fishers (0.20 mg/kg)

Shading denotes exceedance of Health Canada guideline for general consumers (0.50 mg/kg)

Bolded value denotes exceedance of USEPA guideline for recreational fishers (0.4 mg/kg)

Underlined value denotes exceedance of USEPA guideline for subsistence fishers (0.049 mg/kg)

* Fork length calculated from total length based on correlation equation.

Figure 5.10-37 **Temporal comparison of the relationship between rank-transformed fork length and mercury concentrations in the tissue of lake whitefish from Christina Lake, 2002 and 2013.**

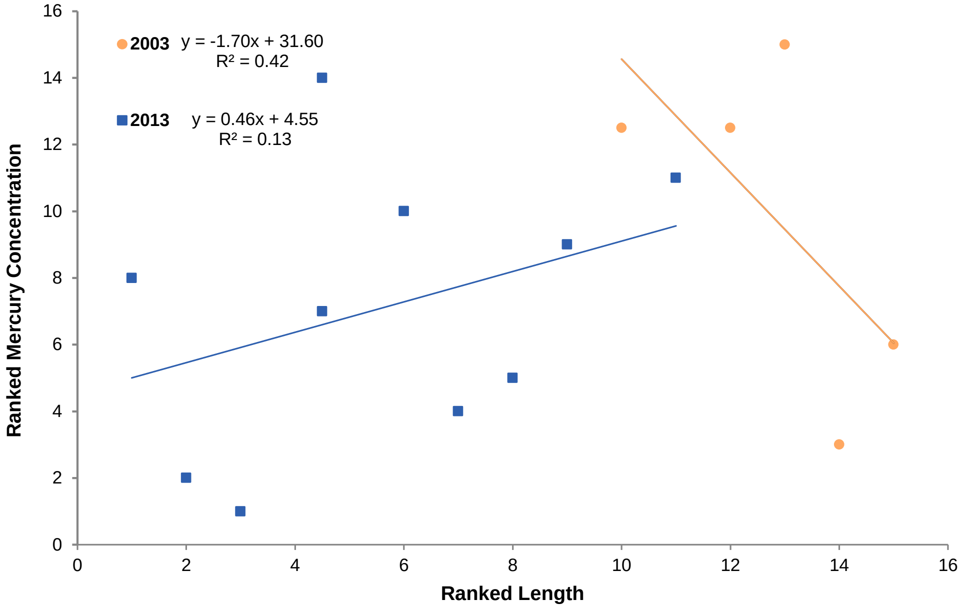


Figure 5.10-38 **Temporal comparison of the relationship between rank-transformed fork length and mercury concentrations in the tissue of northern pike from Christina Lake, 2003 and 2013.**

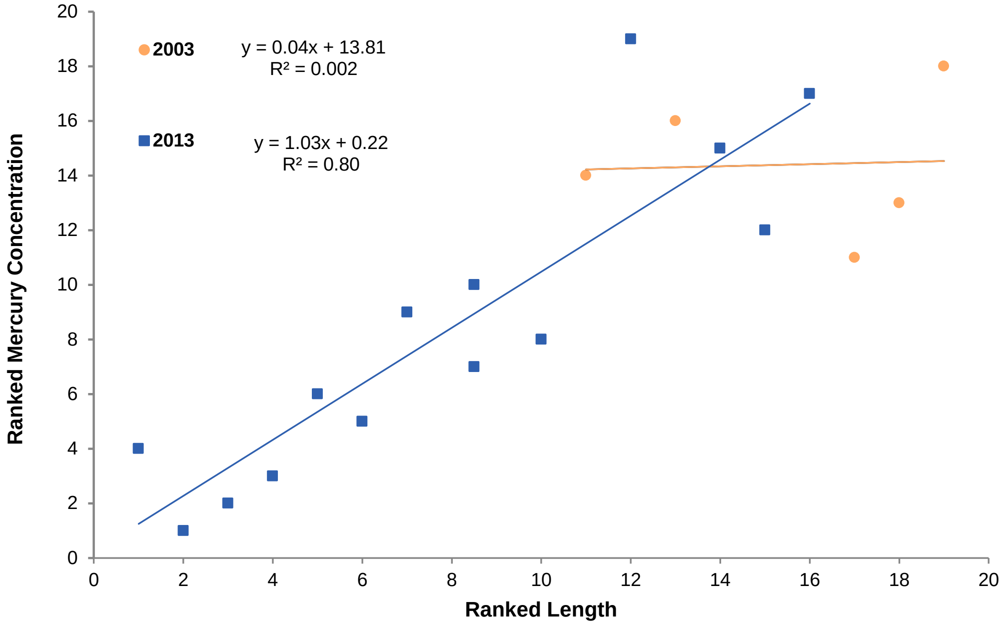


Figure 5.10-39 Temporal comparison of the relationship between rank-transformed fork length and mercury concentrations in the tissue of walleye from Christina Lake, 2003 and 2013.

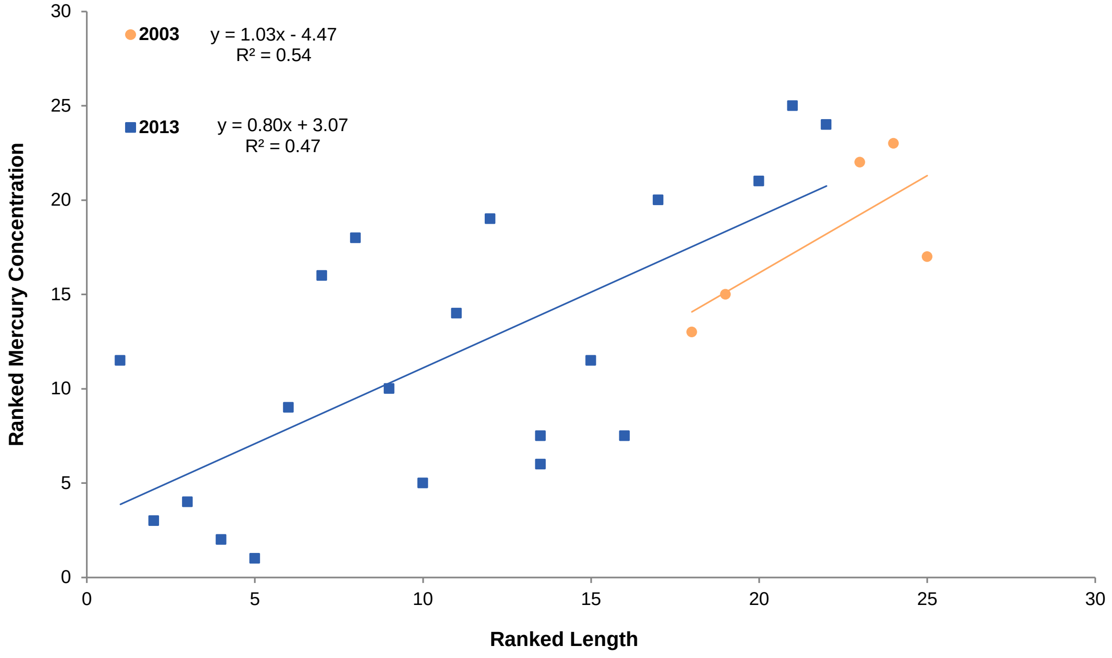
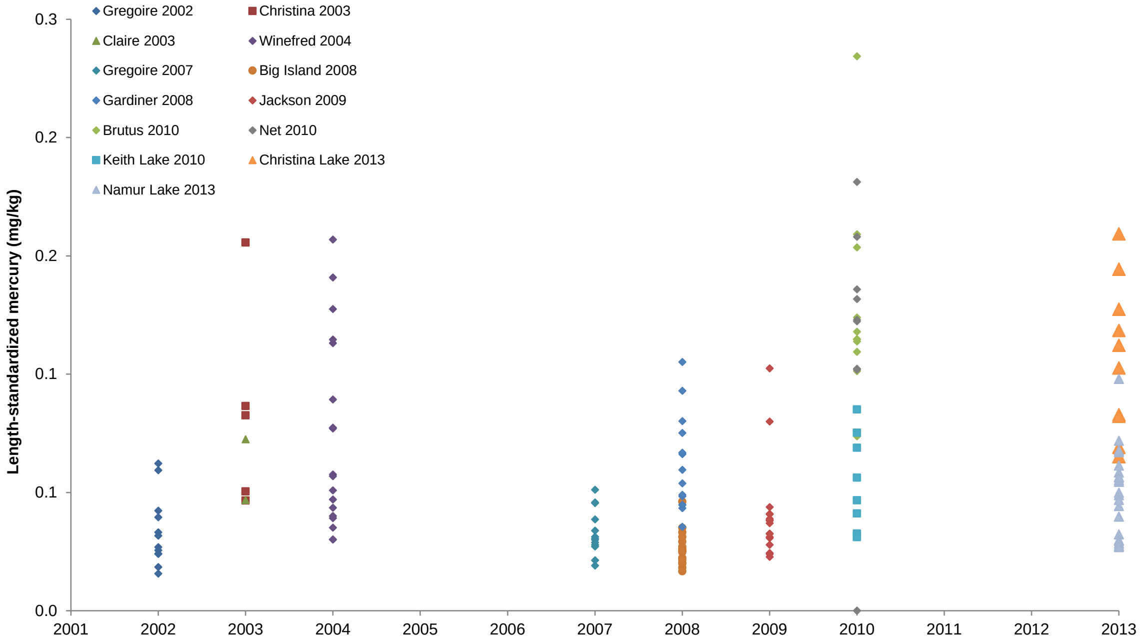
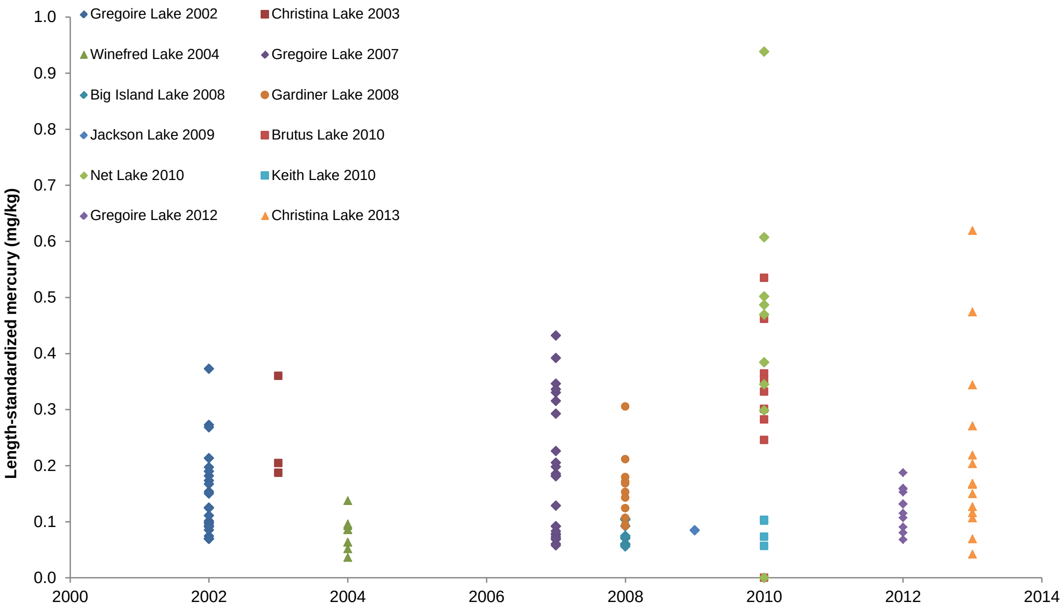


Figure 5.10-40 Regional comparison of mean length-normalized concentrations of mercury in lake whitefish in lakes sampled by RAMP and AESRD, 2002 to 2013.



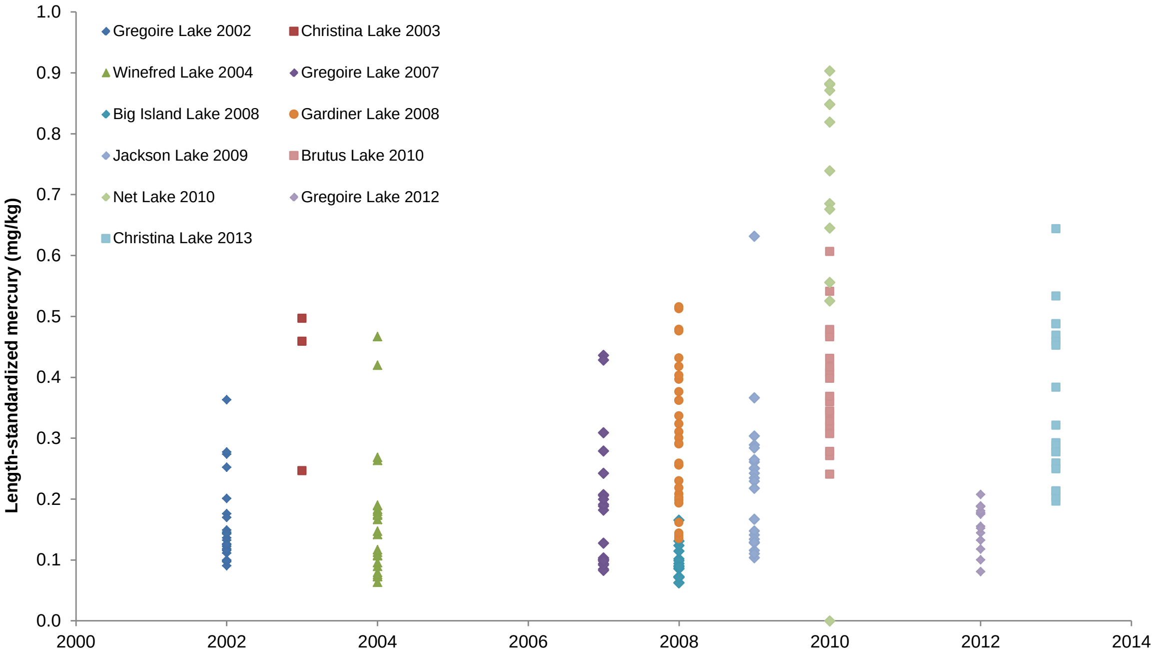
Sources: RAMP 2003; 2004; 2008, 2009a; 2010; and 2011.

Figure 5.10-41 Regional comparison of mean length-standardized concentrations of mercury in northern pike across lakes sampled by RAMP/AESRD, 2002 to 2013.



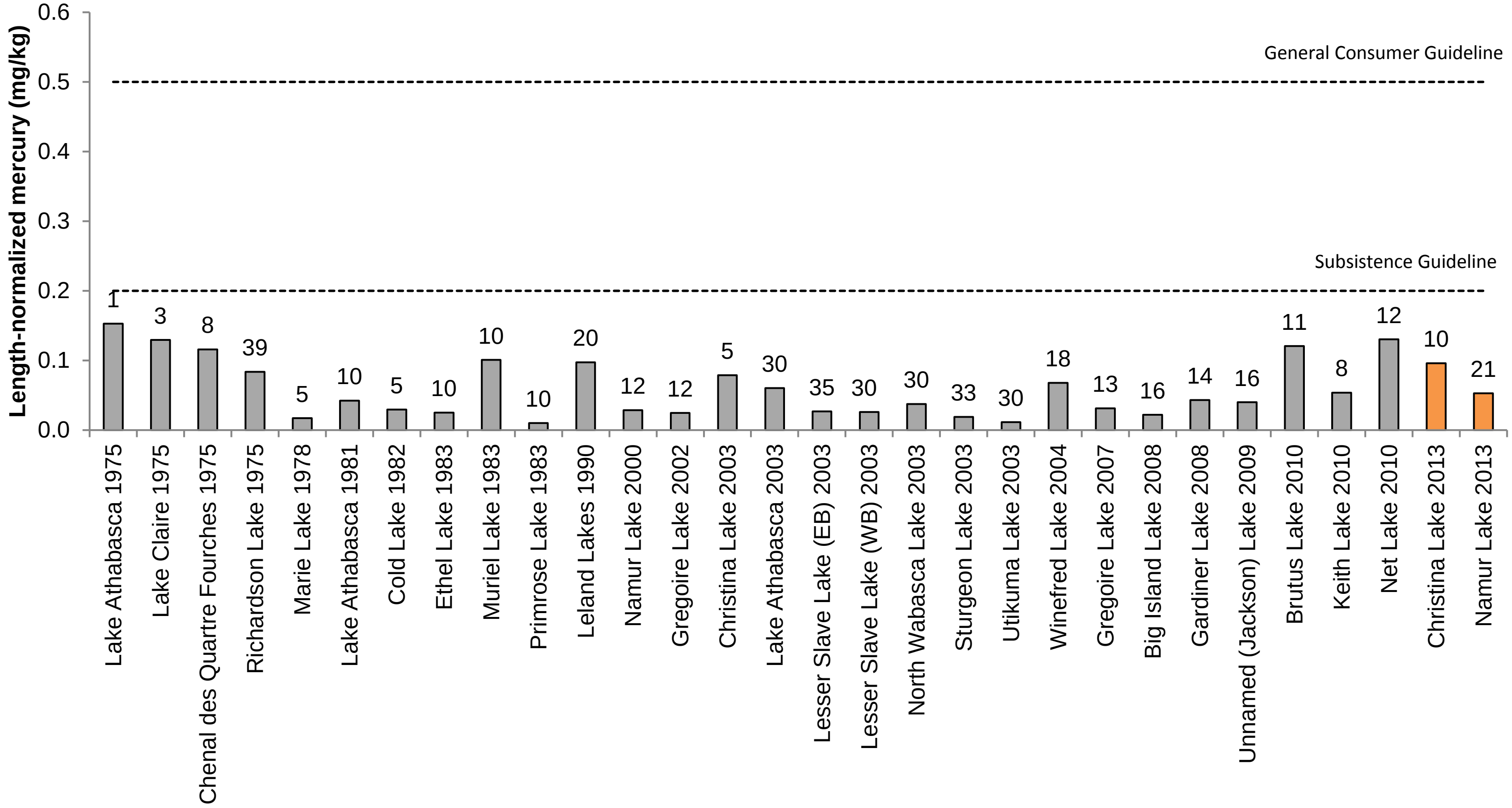
Sources: RAMP 2003; 2004; 2008, 2009a; 2010; and 2011.

Figure 5.10-42 Regional comparison of mean length-standardized concentrations of mercury in walleye across lakes sampled by RAMP/AESRD, 2002 to 2013.



Sources: RAMP 2003; 2004; 2008, 2009a; 2010; and 2011.

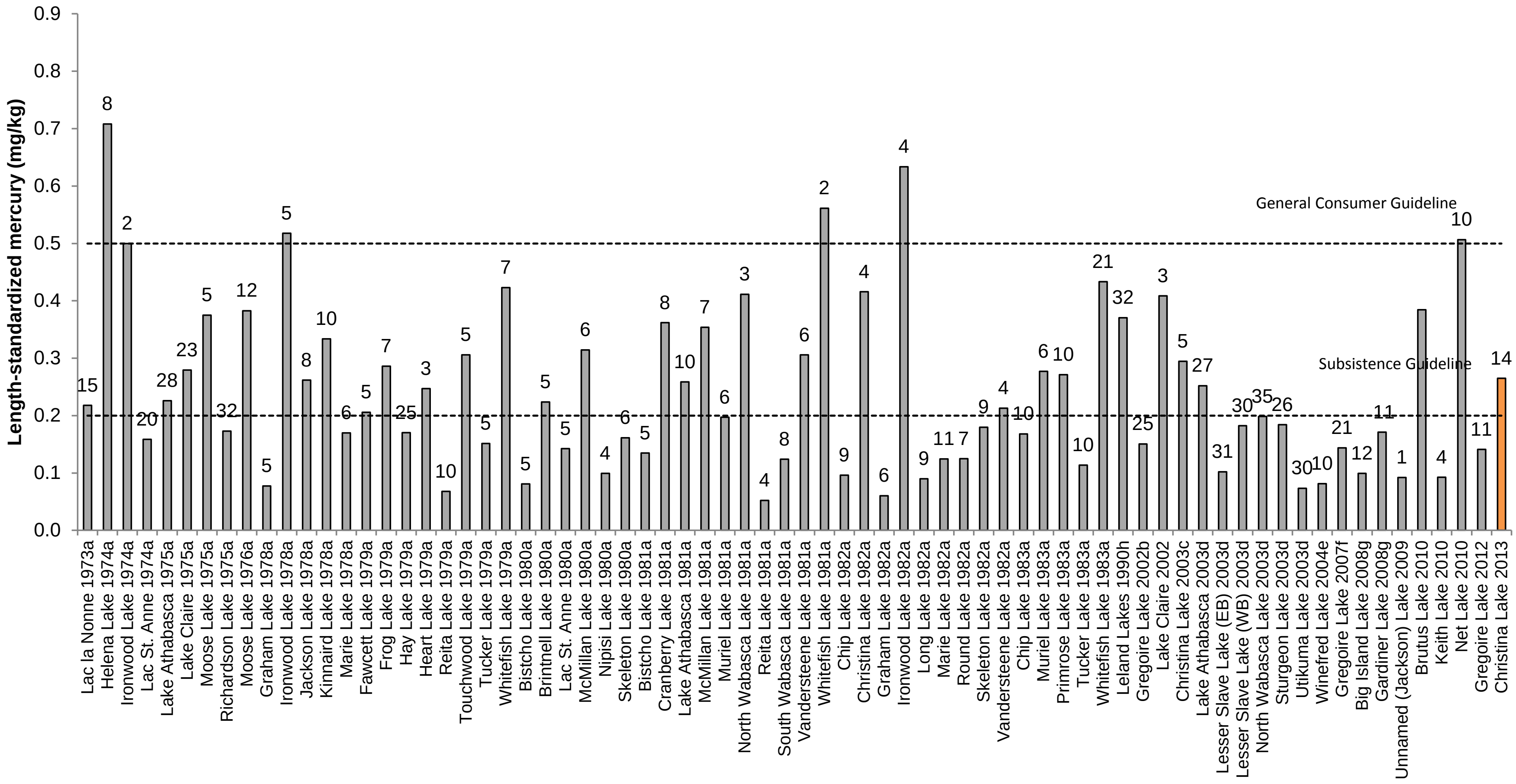
Figure 5.10-43 **Comparison of mean length-normalized concentrations of mercury in lake whitefish from lakes in Alberta, 1973 to 2013.**



Note: orange shading denotes results from current sampling year; sample size represented by number above each bar.

Sources: AOSERP 1977; RAMP 2003; 2004 2005; 2008; 2009a; 2010; 2011; Grey et al. 1995.

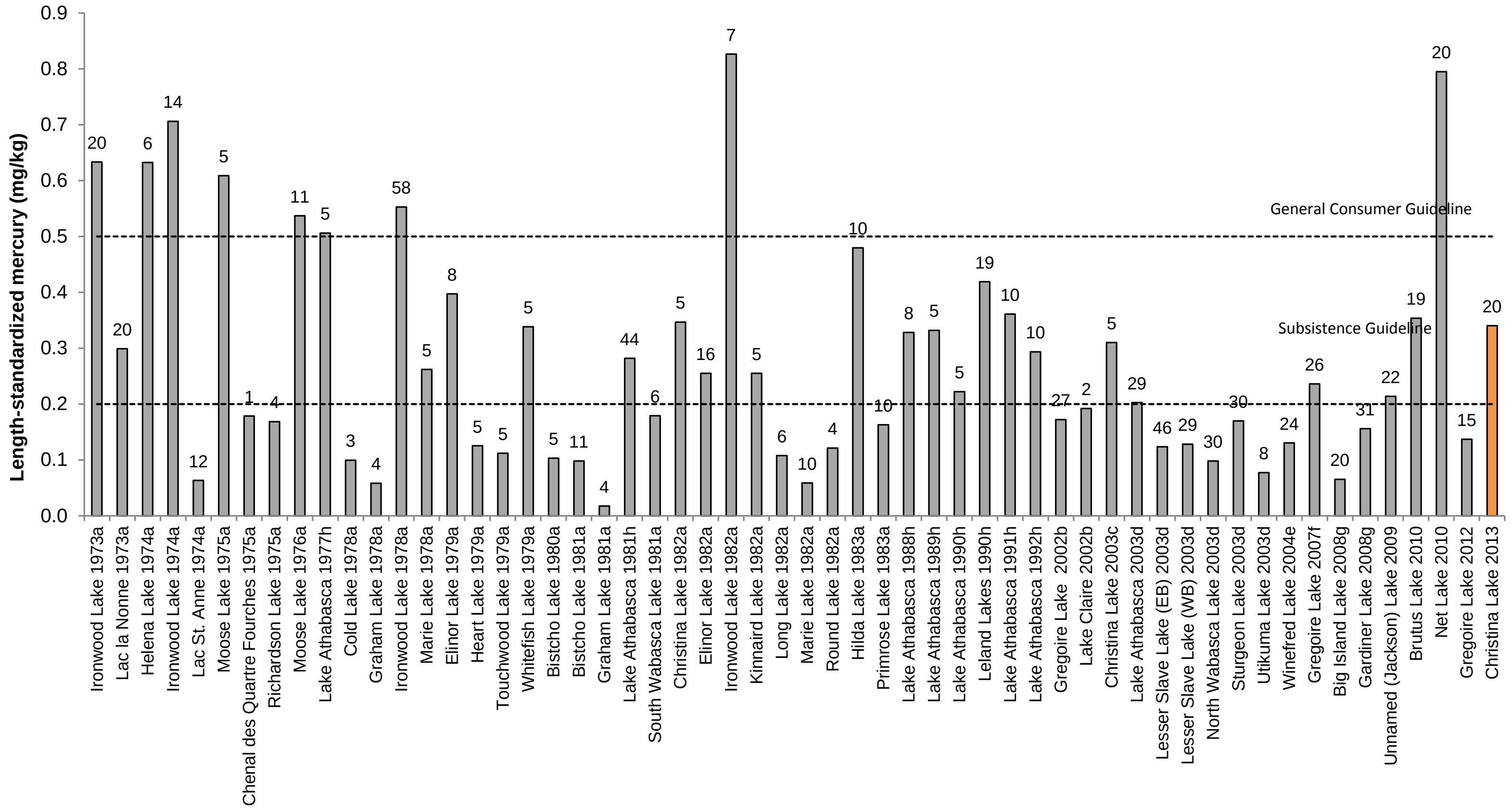
Figure 5.10-44 **Comparison of mean length-standardized concentrations of mercury in northern pike from lakes in Alberta, 1973 and 2013.**



Note: orange shading denotes results from current sampling year; sample size represented by number above each bar.

Sources: AOSERP 1977; RAMP 2003; 2004 2005; 2008; 2009a; 2010; 2011; Grey et al. 1995.

Figure 5.10-45 Comparison of mean length-standardized concentrations of mercury in walleye from lakes in Alberta, 1973 and 2013.



Note: orange shading denotes results from current sampling year; sample size represented by number above each bar.

Sources: AOSERP 1977; RAMP 2003; 2004 2005; 2008; 2009a; 2010; 2011; Grey et al. 1995.

5.11 HANGINGSTONE RIVER WATERSHED

Table 5.11-1 Summary of results for the Hangingstone River watershed.

Hangingstone River Watershed	Summary of 2013 Conditions	
Climate and Hydrology		
Criteria	**WSC 07CD004,** Hangingstone River at Fort McMurray	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	**HAR-1** upstream of Fort McMurray	**HAR-1A** at the mouth
Water Quality Index	🟤	🟤
Benthic Invertebrate Communities and Sediment Quality		
No Benthic Invertebrate Communities and Sediment Quality component activities conducted in 2013		
Fish Populations		
No Fish Populations component activities conducted in 2013		

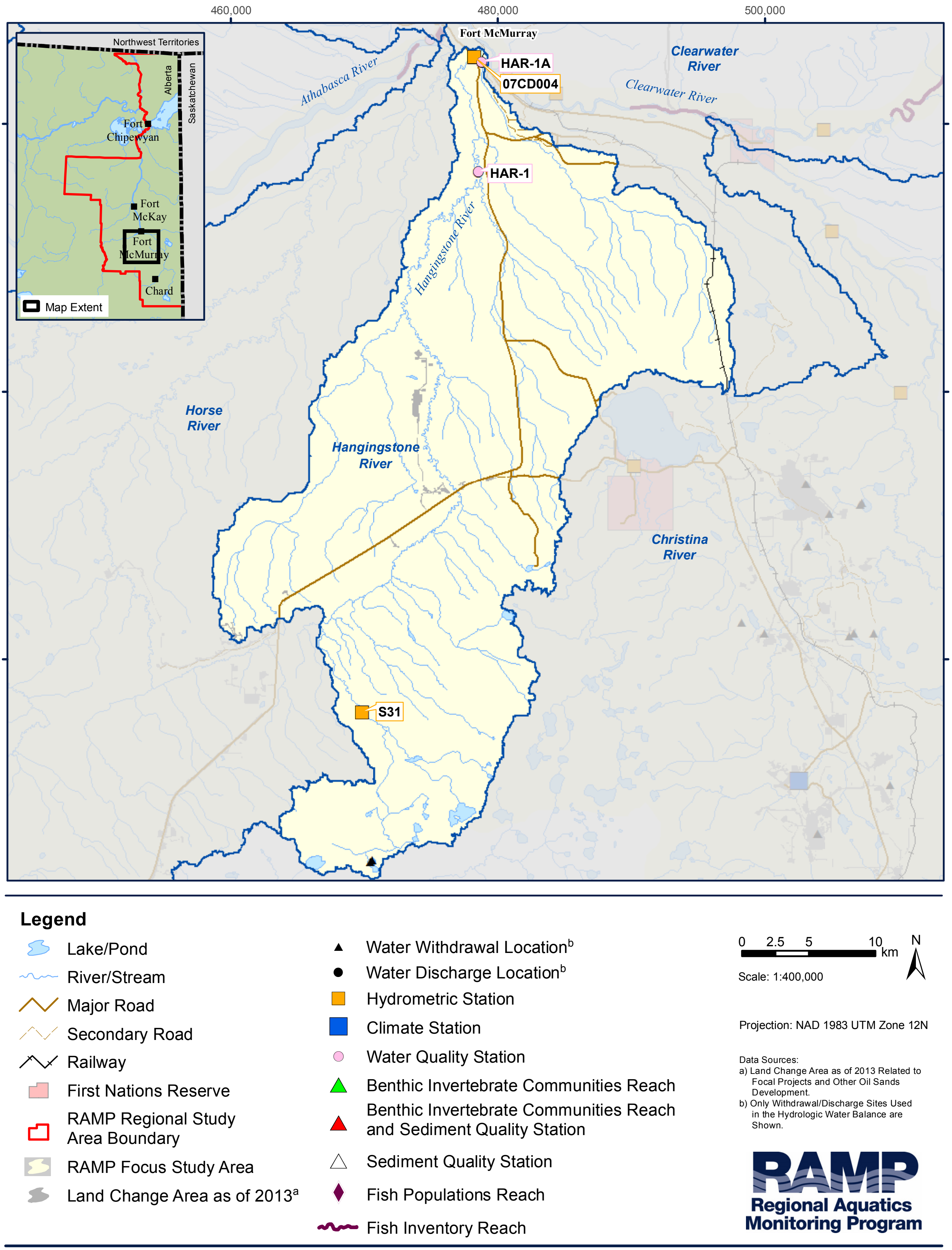
Legend and Notes

🟡 Negligible-Low
🟠 Moderate
🟤 High
baseline
test

Hydrology: Measurement endpoints calculated on differences between observed hydrograph and estimated hydrographs that would have been observed in the absence of oil sands developments in the watershed: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Figure 5.11-1 Hangingstone River watershed.



Data Sources:
a) Land Change Area as of 2013 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\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K11_Hangingstone_20140224_ss.mxd

Figure 5.11-2 Representative monitoring stations of the Hangingstone River, fall 2013.

Water Quality Station HAR-1:
Right Downstream Bank, facing downstream

Water Quality Station HAR-1A:
Right Downstream Bank, facing upstream

5.11.1 Summary of 2013 Conditions

Approximately 0.40% (434 ha) of the Hangingstone River watershed had undergone land change as of 2013 from focal projects, which was an increase from 2012 (Table 2.5-2). Land change has occurred in the upper portion of the watershed related to the JACOS Hangingstone project.

Monitoring activities were conducted for the Climate and Hydrology and Water Quality components of RAMP in the Hangingstone River watershed in 2013. Table 5.11-1 is a summary of the 2013 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 2013 in the Hangingstone River watershed. Figure 5.11-2 contains fall 2013 photos of the water quality monitoring stations in the watershed.

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and 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 2013 between *test* stations HAR-1 and HAR-1A and the regional *baseline* fall conditions were classified as **High**. Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative the regional *baseline* concentrations. Concentrations for select water quality measurement endpoints were generally outside of their historical range (2004 to 2008) for *test* station HAR-1. Despite higher concentrations of dissolved ions than previously observed, the ionic composition at *test* station HAR-1 in 2013 was similar to previous years.

5.11.2 Hydrologic Conditions: 2013 Water Year

Hydrometric monitoring for the Hangingstone River watershed was conducted at 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 209 million m^3. This value was 122% higher than the historical mean open-water runoff volume. Flows increased during freshet in April and early May 2013 to a peak flow of 67.2 m^3/s on May 7, which was 117% higher than the historical maximum daily flow on this date (Figure 5.11-3). Following the spring freshet, flows decreased to below historical upper quartile values from late May to early June. Rainfall events in early to mid-June caused an increase in flow to above the historical upper quartile value and exceeded the historical maximum daily flow from June 10 to June 16, 2013. The peak flow of 182 m^3/s on June 11 was the highest flow recorded in the 2013 WY, and was 362% higher than the historical mean open-water maximum daily flow. Following this peak, flows generally decreased until late September, with the exception of a slight increase in late July in response to rainfall events. The minimum open-water daily flow of 0.57 m^3/s was recorded on September 14 and was 40% lower than the historical mean minimum daily flow of 0.94 m^3/s for the open-water period (Figure 5.11-3).

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The estimated water balance at WSC Station 07CD004, for January 1 to October 31, 2013 is provided in Table 5.11-2 and described as follows:

1. The closed-circuited land area from focal projects as of 2013 in the Hangingstone River watershed was estimated to be 0.32 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 0.072 million m^3.

2. As of 2013, the area of land change in the Hangingstone watershed from focal projects that was not closed-circuited was estimated to be 4.0 km^2 (Table 2.5-1). The increase in flow to the Hangingstone River that would not have otherwise occurred was estimated at 0.182 million m^3.

3. In the 2013 WY, Nexen withdrew approximately 13,660 m^3 of water from two locations in the Hangingstone River watershed to support drilling and construction activities.

The estimated cumulative effect of oil sands development was an increase in flow of 0.096 million m^3 to the Hangingstone River. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.11-3. The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% higher 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).

5.11.3 Water Quality

In fall 2013, water quality samples were taken from:

- the Hangingstone River upstream of Fort McMurray (*test* station HAR-1), sampled in 2004 to 2008 and 2013; and

- the Hangingstone River near the mouth (*test* station HAR-1A), sampled for the first time in 2013.

Temporal Trends Trends over time could not be assessed at these stations because there were not enough available historical data.

2013 Results Relative to Historical Concentrations Historical comparisons were not possible at *test* station HAR-1A given that sampling was initiated in 2013. Fall 2013 concentrations of many variables, especially ions, dissolved solids, and metals were outside of previously-measured concentrations (2004 to 2008) at *test* station HAR-1 (Table 5.11-4), including:

- pH, conductivity, sodium, calcium, magnesium, chloride, sulphate, total dissolved solids, total alkalinity, total molybdenum, total boron, and total strontium, with concentrations that exceeded previously-measured maximum concentrations; and
- dissolved phosphorus, total nitrogen, total aluminum, and dissolved aluminum, with concentrations below previously-measured minimum concentrations.

Ion Balance The ionic composition of water at *test* stations HAR-1 and HAR-1A in fall 2013 was generally similar, and dominated by calcium and bicarbonate (Figure 5.11-4). The ionic composition at *test* station HAR-1 in fall 2013 was similar to previous years.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of most water quality measurement endpoints measured at *test* stations HAR-1 and HAR-1A were below water quality guidelines in fall 2013, with the exception of total aluminum at both stations (Table 5.11-4 and Table 5.11-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in the Hangingstone River (Table 5.11-6):

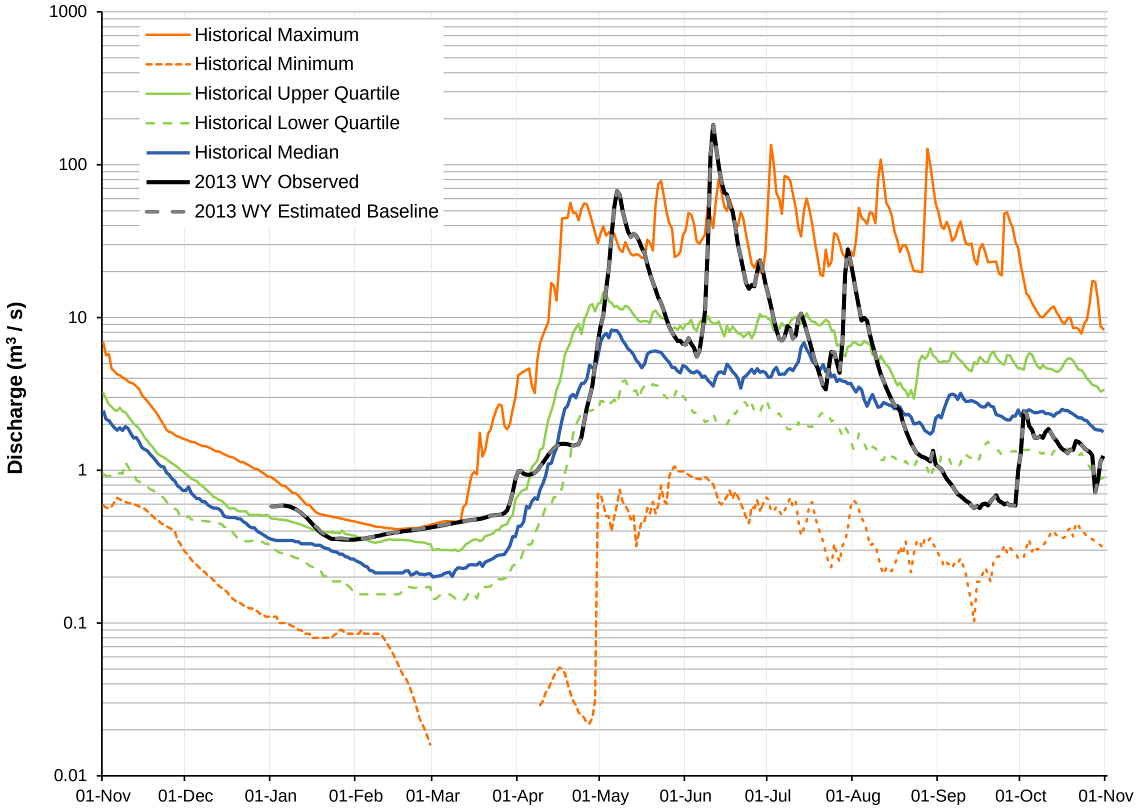
- sulphide, total iron, total phenols, and total phosphorus at *test* station HAR-1; and
- total iron and total phenols at *test* station HAR-1A.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of water quality measurement endpoints at *test* stations HAR-1 and HAR-1A were within regional *baseline* concentrations, with the exception of total dissolved solids, total strontium, total boron, total arsenic, calcium, magnesium, sodium, potassium, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at both stations (Figure 5.11-5).

Water Quality Index The WQI values for *test* stations HAR-1 (56.8) and HAR-1A (56.3) indicated **High** differences from regional *baseline* water quality conditions. These differences can primarily be attributed to higher levels of dissolved ions and metals.

Classification of Results Differences in water quality in fall 2013 between *test* stations HAR-1 and HAR-1A and the regional *baseline* fall conditions were classified as **High** (Table 5.11-1). Differences were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River, relative the regional *baseline* concentrations. Concentrations for select water quality measurement endpoints were generally outside of their historical range (2004 to 2008) for *test* station HAR-1. Despite higher concentrations of dissolved ions than previously observed, the ionic composition at *test* station HAR-1 in 2013 was similar to previous years.

Figure 5.11-3 **The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Hangingstone River in the 2013 WY, compared to historical values.**



Note: Observed 2013 WY hydrograph based on Hangingstone River at Fort McMurray, WSC Station 07CD004, provisional data for January 1 to October 31, 2013. The upstream drainage area of WSC Station 07CD004 is 962 km^2, which is 10% smaller than the size of the entire Hangingstone River watershed (1,066 km^2). Historical values from March 1 to October 31 were calculated for the period from 1965 to 2012, and historical values for other months were calculated for the period from 1970 to 1987.

Note: Historical minimum daily flows were zero from March 1 to April 8, and were not plotted due to the logarithmic axis used in the graph.

Table 5.11-2 Estimated water balance at WSC Station 07CD004, Hangingstone River at Fort McMurray, 2013 WY.

Component	Volume (million m³)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**217.360**	**Observed discharge, obtained from Hangingstone River at Fort McMurray, WSC Station 07CD004**
Closed-circuited area water loss from the observed hydrograph	-0.072	Estimated 0.32 km² of Hangingstone River watershed closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.182	Estimated 4.0 km² of Hangingstone River watershed with land change from focal projects as of 2013 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Hangingstone River watershed from focal projects	-0.014	13,660 m³ withdrawn from sources in the Hangingstone River watershed for drilling and construction activities
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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**217.264**	**Estimated discharge at Hangingstone River at Fort McMurray, WSC Station 07CD004**
Incremental flow (change in total discharge)	0.096	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	**+0.04%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data for January 1 to October 31, 2013 for Hangingstone River at Fort McMurray, WSC Station 07CD004.

Table 5.11-3 Estimated change in hydrologic measurement endpoints for the Hangingstone River watershed, 2013 WY.

Measurement Endpoint	**Value from *Baseline* Hydrograph (m^3/s)**	**Value from *Test* Hydrograph (m^3/s)**	**Relative Change**
Mean open-water period discharge	13.157	13.164	+0.05%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	181.908	182.000	+0.05%
Open-water period minimum daily discharge	0.565	0.565	+0.05%

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: Values were calculated from provisional data for January 1 to October 31, 2013 for Hangingstone River at Fort McMurray, WSC Station 07CD004.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and two decimal places, respectively.

Note: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

Table 5.11-4 Concentrations of water quality measurement endpoints, Hangingstone River, above Fort McMurray (*test* station HAR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2004-2008 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.48	5	8.00	8.20	8.30
Total suspended solids	mg/L	-	<3.0	5	<3.0	9.0	12.0
Conductivity	µS/cm	-	487	5	231	232	278
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.034	5	0.038	0.046	0.049
Total nitrogen	mg/L	1	0.601	5	0.700	0.900	1.00
Nitrate+nitrite	mg/L	3	<0.071	5	<0.100	<0.100	<0.100
Dissolved organic carbon	mg/L	-	20.7	5	17.0	28.0	34.0
Ions							
Sodium	mg/L	-	41.7	5	17.0	18.0	25.0
Calcium	mg/L	-	50.2	5	22.3	25.7	31.5
Magnesium	mg/L	-	14.2	5	7.2	7.4	8.3
Chloride	mg/L	120	18.6	5	9.0	13.0	13.0
Sulphate	mg/L	410	42.0	5	9.60	10.4	29.3
Total dissolved solids	mg/L	-	315	5	167	190	290
Total alkalinity	mg/L		190	5	88	94	119
Selected metals							
Total aluminum	mg/L	0.1	**0.142**	5	**0.166**	**0.421**	**0.499**
Dissolved aluminum	mg/L	0.1	0.009	5	0.011	0.017	0.037
Total arsenic	mg/L	0.005	0.0017	5	0.0012	0.0014	0.0017
Total boron	mg/L	1.2	0.183	5	0.054	0.061	0.087
Total molybdenum	mg/L	0.073	0.0029	5	0.0007	0.0009	0.0016
Total mercury (ultra-trace)	ng/L	5, 13	1.50	5	<1.20	<1.20	2.30
Total strontium	mg/L	-	0.291	5	0.121	0.123	0.179
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	-	0.33	-	-	-	-
Oilsands Extractable	mg/L	-	0.42	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	-	-	-	-
Retene	ng/L	-	0.678	-	-	-	-
Total dibenzothiophenes	ng/L	-	8.425	-	-	-	-
Total PAHs	ng/L	-	113.5	-	-	-	-
Total Parent PAHs	ng/L	-	22.96	-	-	-	-
Total Alkylated PAHs	ng/L	-	90.56	-	-	-	-
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.003**	5	**0.003**	**0.008**	**0.018**
Total iron	mg/L	0.3	**1.14**	5	**1.13**	**1.38**	**1.57**
Total phenols	mg/L	0.004	**0.007**	5	**0.008**	**0.011**	**0.012**
Total phosphorus	mg/L	0.05	**0.060**	5	**0.059**	**0.068**	**0.075**

[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 5.11-5 Concentrations of water quality measurement endpoints, Hangingstone River near the mouth (*test* station HAR-1A), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013
			Value
Physical variables			
pH	pH units	6.5-9.0	8.52
Total suspended solids	mg/L	-	<3.0
Conductivity	µS/cm	-	553
Nutrients			
Total dissolved phosphorus	mg/L	0.05	0.025
Total nitrogen	mg/L	1	0.601
Nitrate+nitrite	mg/L	3	<0.071
Dissolved organic carbon	mg/L	-	22.1
Ions			
Sodium	mg/L	-	49.4
Calcium	mg/L	-	54.3
Magnesium	mg/L	-	16.7
Chloride	mg/L	120	27.6
Sulphate	mg/L	410	49.5
Total dissolved solids	mg/L	-	357
Total alkalinity	mg/L		202
Selected metals			
Total aluminum	mg/L	0.1	**0.317**
Dissolved aluminum	mg/L	0.1	0.007
Total arsenic	mg/L	0.005	0.0016
Total boron	mg/L	1.2	0.197
Total molybdenum	mg/L	0.073	0.0026
Total mercury (ultra-trace)	ng/L	5, 13	1.70
Total strontium	mg/L	-	0.32
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	-	0.50
Oilsands Extractable	mg/L	-	0.56
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	-	<15.16
Retene	ng/L	-	1.640
Total dibenzothiophenes	ng/L	-	71.68
Total PAHs	ng/L	-	328.6
Total Parent PAHs	ng/L	-	33.71
Total Alkylated PAHs	ng/L	-	294.9
Other variables that exceeded CCME/AESRD guidelines in fall 2013			
Total iron	mg/L	0.3	**1.01**
Total phenols	mg/L	0.004	**0.007**

[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 5.11-4 Piper diagram of fall ion concentrations in Hangingstone River watershed.

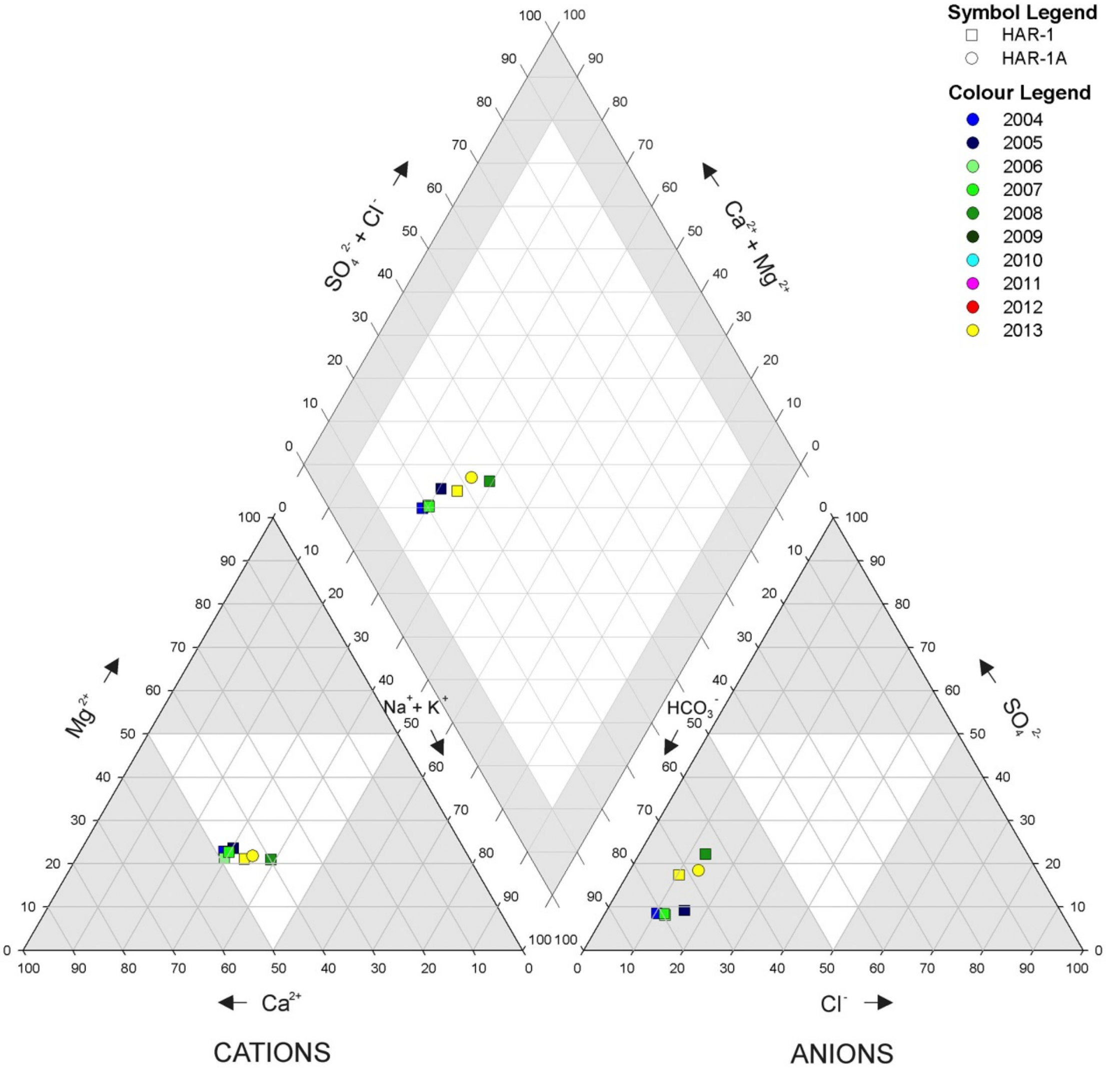
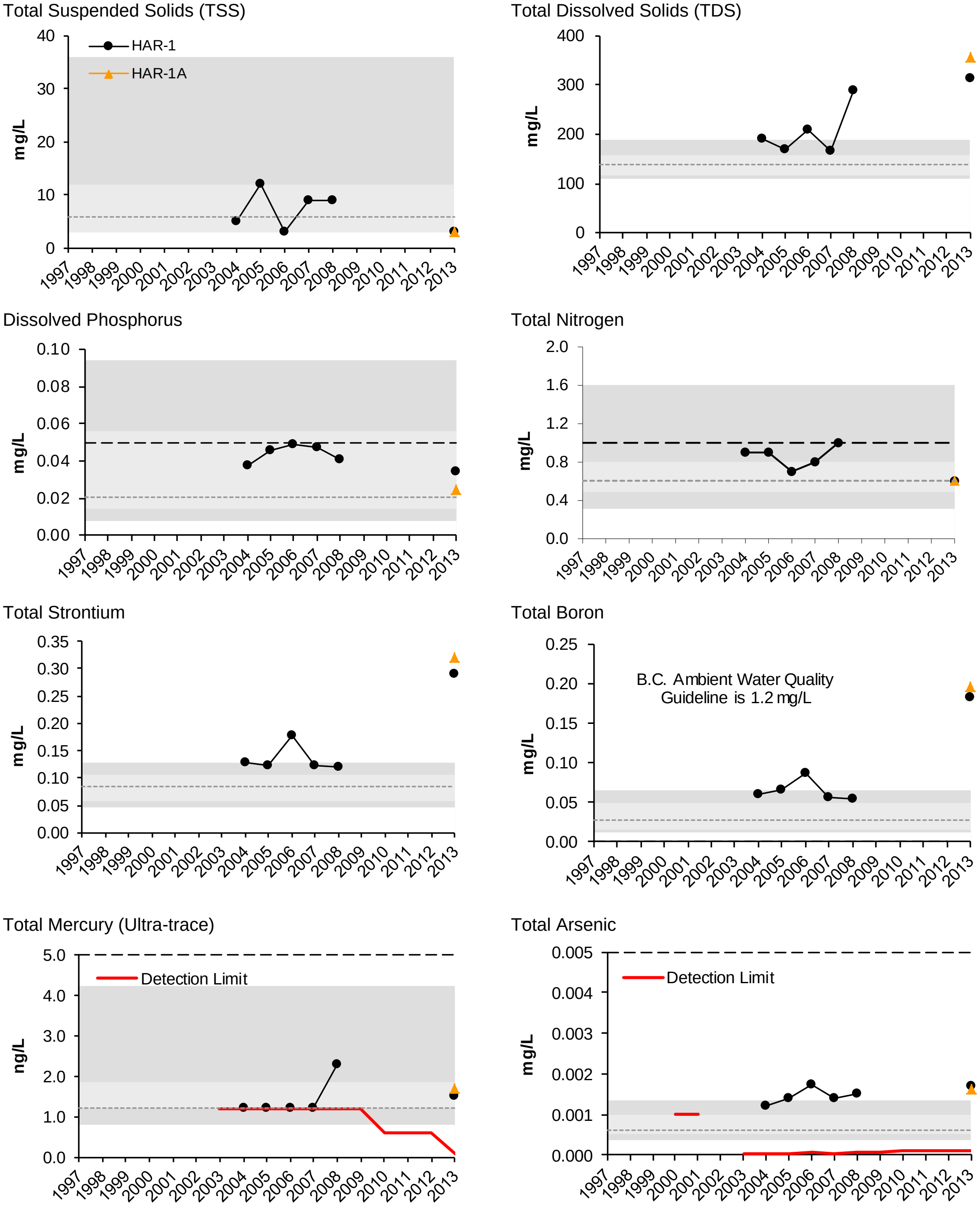


Table 5.11-6 Water quality guideline exceedances for the Hangingstone River watershed, fall 2013.

Variable	Units	Guideline[a]	HAR-1	HAR-1A
Sulphide	mg/L	0.002	0.0031	-
Total aluminum	mg/L	0.1	0.142	0.317
Total iron	mg/L	0.3	1.14	1.01
Total phenols	mg/L	0.004	0.007	0.007
Total phosphorus	mg/L	0.05	0.060	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.11-5 Concentrations of selected water quality measurement endpoints in the Hangingstone River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

Total Arsenic

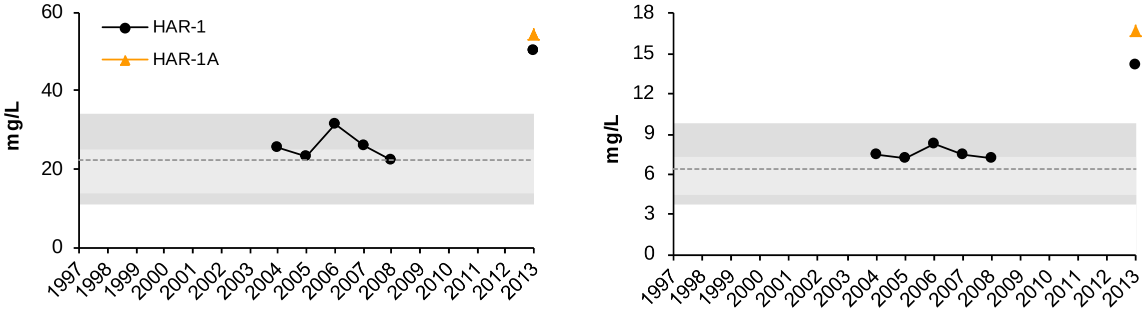
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

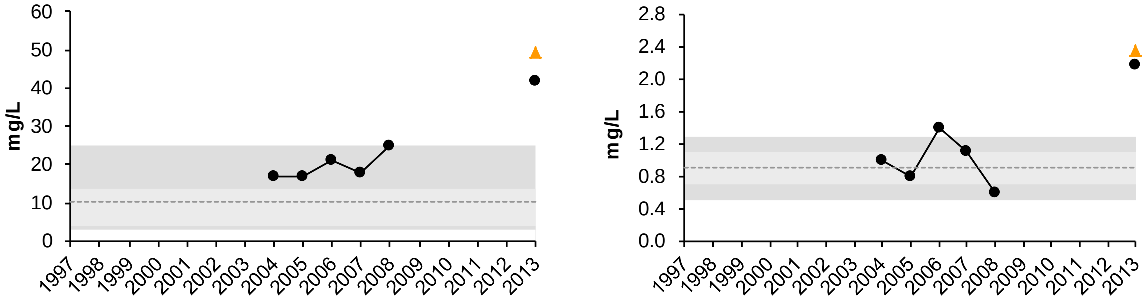
○······○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

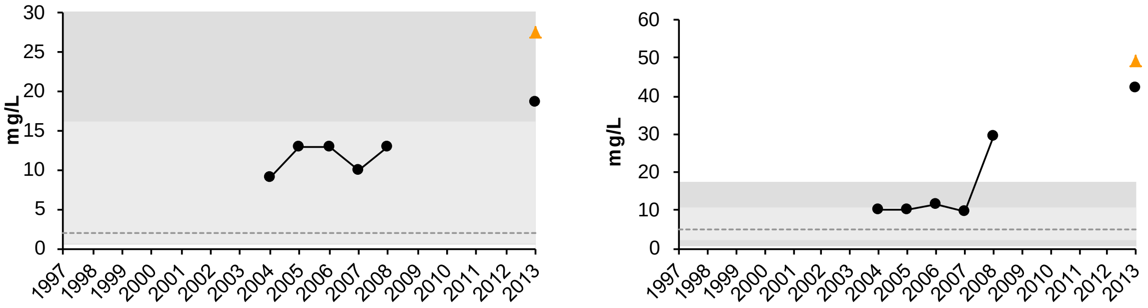
Figure 5.11-5 (Cont'd.)


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 3.2.2.2 for a discussion of this approach.

5.12 PIERRE RIVER AREA

Table 5.12-1 Summary of results for watersheds in the Pierre River area.

Pierre River Area	Summary of 2013 Conditions			
Climate and Hydrology				
Criteria	**S48** Big Creek near the mouth	**S44** Pierre River near Fort McKay	**S50A** Red Clay Creek	**S49** Eymundson Creek near the mouth
Mean open-water season discharge	not measured			
Mean winter discharge	not measured			
Annual maximum daily discharge	not measured			
Minimum open-water season discharge	not measured			
Water Quality				
Criteria	**BIC-1** Big Creek at the mouth	**PIR-1** Pierre River at the mouth	**RCC-1** Red Clay Creek at the mouth	**EYC-1** Eymundson Creek at the mouth
Water Quality Index	🟡	🟡	🟡	🟠
Benthic Invertebrate Communities and Sediment Quality				
Criteria	**BIC-D1** Big Creek at the mouth	**PIR-D1** Pierre River at the mouth	**RCC-E1** Red Clay Creek at the mouth	**EYC-D1** Eymundson Creek at the mouth
Benthic Invertebrate Communities	n/a	n/a	n/a	n/a
Sediment Quality	🟡	🟡	not sampled	🟡
Fish Populations				
Criteria	**BIC-F1** Big Creek at the mouth	**PIR-F1** Pierre River at the mouth	**RCC-F1** Red Clay Creek at the mouth	**EYC-F1** Eymundson Creek at the mouth
Fish Assemblages	n/a	n/a	n/a	n/a

Legend and Notes

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

n/a - not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

Hydrology: The open-water season refers to the time period between May 1 and October 31 and the winter season refers to the time period between November 1 and March 31.

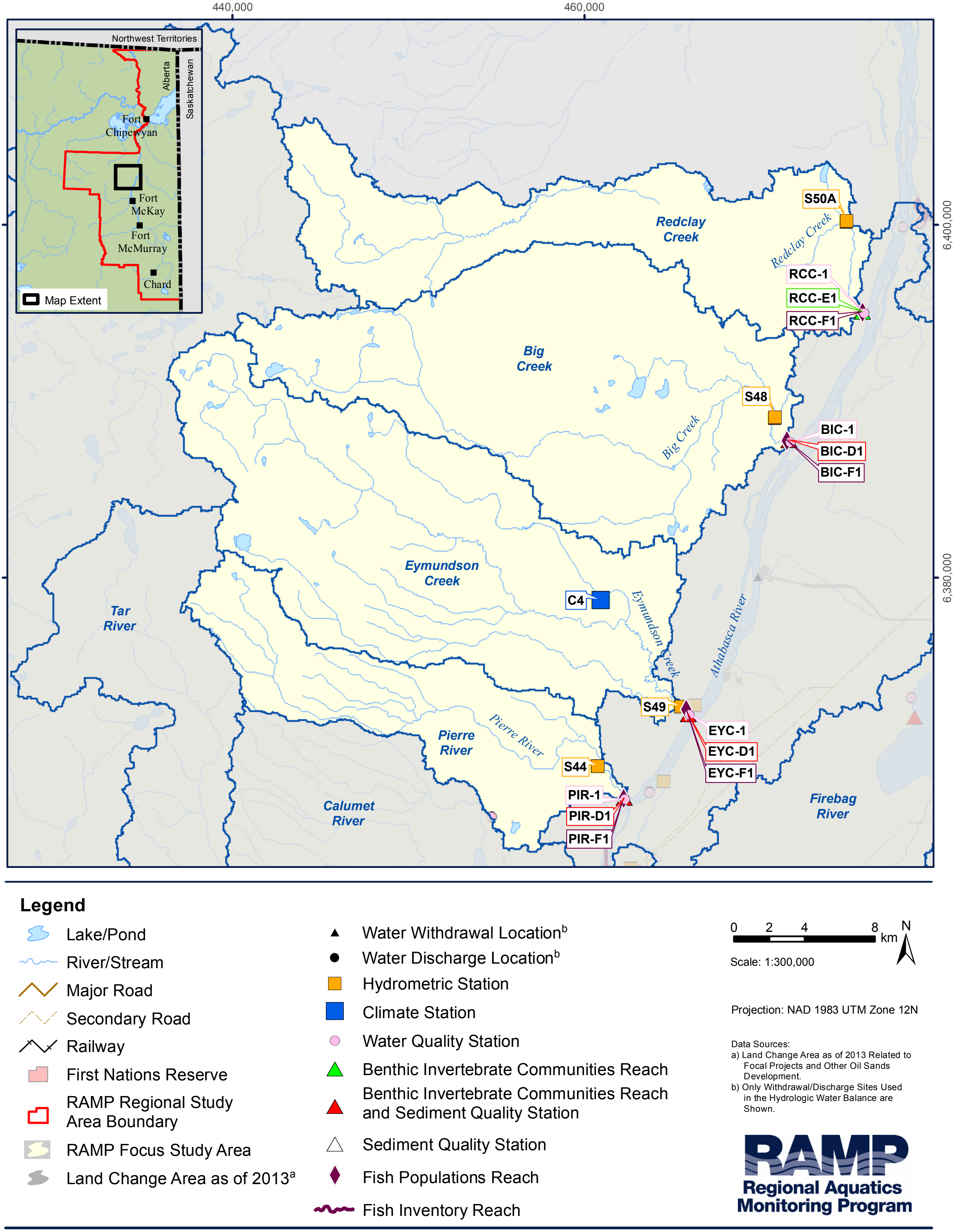
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.12-1 Pierre River area watersheds.



Data Sources:
a) Land Change Area as of 2013 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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K12_PierreArea_20140224_ss.mxd

Figure 5.12-2 Representative monitoring stations of the watersheds in the Pierre River area, fall 2013.

Hydrology Station S44: Pierre River

Hydrology Station S50: Red Clay Creek

Water Quality Station EYC-1 (Eymundson Creek): Left Downstream Bank, facing downstream

Benthic Invertebrate Reach RCC-E1 (Red Clay Creek): Left Downstream Bank, facing downstream

Water Quality Station BIC-1 (Big Creek): Left Downstream Bank, facing downstream

Water Quality Station PIR-1 (Pierre River): Centre of Channel, facing downstream

5.12.1 Summary of 2013 Conditions

As of 2013, there has been no land change in watersheds of the Pierre River area from focal projects and other oil sands developments. This section includes 2013 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, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components in watersheds of the Pierre River area in 2013. Monitoring in these watersheds was in advance of development activities for the Shell Pierre River Mine project and the Teck Frontier project. Hydrometric data have been collected to develop hydrographs for each watershed; however, water balances were not completed given that there was no development. Details for each hydrology station can be found in Appendix C.

Table 5.12-1 is a summary of the 2013 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 2013 photos of various monitoring stations located in watersheds in the Pierre River area.

Water Quality Differences in water quality in fall 2013 between *baseline* stations BIC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low**. Differences in water quality in fall 2013 between *baseline* station EYC-1 and regional *baseline* fall conditions were classified as **Moderate** as a result of several guideline exceedances and high concentrations of total arsenic, total suspended solids, total mercury (ultra-trace), etc. *Baseline* station EYC-1 differed from the other stations (BIC-1, PIR-1, and RCC-1) in this area in its ionic composition, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station. *Baseline* station EYC-1 also had a higher concentration of total suspended solids than the other stations.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1, and PIR-D1 were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; and a low percentage of EPT taxa. The benthic invertebrate community at *baseline* reach RCC-E1 was indicative of good water quality, with a lower abundance of worms and a high percentage of EPT taxa. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the RAMP FSA.

All stations of the Pierre River area had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions. No concentrations of sediment quality measurement endpoints exceeded the sediment or soil quality guidelines at *baseline* station BIC-D1, while only total arsenic exceeded the guideline at *baseline* station EYC-D1. *Baseline* Station PIR-D1 had many guideline exceedances, including CCME F3 hydrocarbons, total arsenic, chrysene, and phenanthrene. Survival of the midge *Chironomus* was fairly low at all stations (ranging from 46% to 64%) and the predicted PAH toxicity values exceeded the chronic toxicity threshold at EYC-D1 and PIR-D1. No trend analysis or historical comparisons were conducted at these stations due to sediment quality sampling being initiated in these locations in fall 2013.

Fish Populations (fish assemblages) The fish assemblages at *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 were similar to other *baseline* reaches in the area, and with each other. As with other reaches near the confluence to the Athabasca River, there was a high proportion of juvenile burbot captured at these reaches in fall 2013. Burbot is a sensitive species and likely contributed to the low ATI values at most of these reaches, which were outside the lower tolerance limits of regional *baseline* conditions.

5.12.2 Water Quality

In fall 2013, water quality samples were collected from:

- Big Creek (*baseline* station BIC-1), sampled since 2011;
- Eymundson Creek (*baseline* station EYC-1), sampled since 2011;
- Pierre River (*baseline* station PIR-1), sampled since 2011; and
- Red Clay Creek (*baseline* station RCC-1), sampled since 2011.

Water quality samples were also collected seasonally in an effort to obtain three years of seasonal *baseline* data at each station, including sampling during winter at *baseline* station BIC-1, and spring, and summer at all stations. Winter samples were not collected at stations EYC-1, PIR-1, and RCC-1 given these watercourses were frozen to depth.

Temporal Trends Trends in concentrations of water quality measurement endpoints were not assessed at these stations because there were only three years of data.

2013 Results Relative to Historical Concentrations Historical comparisons were not conducted at these stations because sampling was only initiated in 2011 (Table 5.12-2 to Table 5.12-5).

Ion Balance The ionic composition of water at *baseline* stations BIC-1, PIR-1, and RCC-1 in fall 2013 was generally similar, and dominated by calcium and bicarbonate. Water at *baseline* station EYC-1 was less dominated by bicarbonate and showed a greater influence of sulphate. The ionic composition has remained consistent between sampling years at all stations (Figure 5.12-3).

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of most water quality measurement endpoints measured at *baseline* stations BIC-1, PIR-1, RCC-1, and EYC-1 were below water quality guidelines in fall 2013, with the exception of (Table 5.12-2 to Table 5.12-5):

- total aluminum, dissolved phosphorus, and total mercury (ultra-trace) at *baseline* station BIC-1;
- total aluminum and total mercury (ultra-trace) at *baseline* station EYC-1; and
- total aluminum at *baseline* station PIR-1.

There were no guideline exceedances of water quality measurement endpoints in fall 2013 at *baseline* station RCC-1.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured at these *baseline* stations (Table 5.12-6):

- sulphide, total aluminum, total iron, total nitrogen, total phenols, and total phosphorus at *baseline* station BIC-1 in winter;
- dissolved iron, sulphide, total aluminum, total chromium, total iron, total mercury (ultra-trace), total nitrogen, total phenols, and total phosphorus at *baseline* station BIC-1 in spring;

- dissolved iron, dissolved phosphorus, sulphide, total aluminum, total iron, total nitrogen, total phenols, and total phosphorus at *baseline* station BIC-1 in summer;
- total and dissolved iron, total phenols, sulphide, total chromium, and total phosphorus at *baseline* station BIC-1 in fall;
- dissolved aluminum, dissolved copper, sulphide, total aluminum, total cadmium, total chromium, total copper, total iron, total lead, total nitrogen, total phenols, total phosphorus, total silver, total thallium, and total zinc at *baseline* station EYC-1 in spring;
- dissolved iron, sulphide, total aluminum, total cadmium, total chromium, total copper, total iron, total lead, total nitrogen, total phenols, total phosphorus, total silver, and total zinc at *baseline* station EYC-1 in summer;
- total chromium, total iron, total phenols, and total phosphorus at *baseline* station EYC-1 in fall;
- dissolved iron, sulphide, total aluminum, total cadmium, total chromium, total copper, total iron, total lead, total mercury (ultra-trace), total nitrogen, total phenols, total phosphorus, total silver, and total zinc at *baseline* station PIR-1 in spring;
- dissolved iron, dissolved phosphorus, sulphide, total aluminum, total chromium, total iron, total nitrogen, total phenols, and total phosphorus at *baseline* station PIR-1 in summer;
- sulphide, total chromium, total iron, total phenols, and total phosphorus at *baseline* station PIR-1 in fall;
- sulphide, total aluminum, total phosphorus, total phenols, and total iron at *baseline* station RCC-1 in spring;
- total iron and sulphide at *baseline* station RCC-1 in summer; and
- total iron at *baseline* station RCC-1 in fall.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, concentrations of water quality measurement endpoints at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 were within regional *baseline* concentrations, with the exception of (Figure 5.12-4):

- total arsenic, sulphate, total suspended solids, total mercury (ultra-trace), and calcium, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station EYC-1; and
- total arsenic, with a concentration that was below 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 (91.2), and RCC-1 (93.7) indicated **Negligible-Low** differences, while the WQI value at *baseline* station EYC-1 (61.2) indicated a **Moderate** difference from regional *baseline* water quality conditions (Table 5.12-7).

Classification of Results Differences in water quality in fall 2013 between *baseline* stations BIC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low**. Differences in water quality in fall 2013 between *baseline* station EYC-1 and regional *baseline* fall conditions were classified as **Moderate** as a result of several guideline exceedances and high concentrations of total arsenic, total suspended solids, total mercury (ultra-trace), etc. *Baseline* station EYC-1 differed from the other stations

(BIC-1, PIR-1, and RCC-1) in this area in its ionic composition, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station. *Baseline* station EYC-1 also had a higher concentration of total suspended solids than the other stations.

5.12.3 Benthic Invertebrate Communities and Sediment Quality

5.12.3.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled for the first time in fall 2013 at:

- depositional *baseline* reach BIC-D1 of Big Creek;
- depositional *baseline* reach EYC-D1 of Eymundson Creek;
- depositional *baseline* reach PIR-D1 of the Pierre River; and
- erosional *baseline* reach RCC-E1 of Red Clay Creek.

2013 Habitat Conditions Water at *baseline* reach BIC-D1 in fall 2013 was 0.5 m deep, slightly alkaline (pH: 7.9), with a moderate velocity (0.4 m/s), high dissolved oxygen (9.5 mg/L), and moderate conductivity (375 µS/cm) (Table 5.12-8). The substrate consisted almost entirely of sand, with low total organic carbon (0.5%) (Table 5.12-8).

Water at *baseline* reach EYC-D1 in fall 2013 was shallow (0.2 m), basic (pH: 8.8), with a moderate velocity (0.4 m/s), high dissolved oxygen (8.8 mg/L), and high conductivity (602 µS/cm) (Table 5.12-8). The substrate was dominated by sand, with low total organic carbon (0.7%) (Table 5.12-8).

Water at *baseline* reach PIR-D1 in fall 2013 was shallow (0.2 m), alkaline (pH: 8.3), with a slow velocity (0.21 m/s), high dissolved oxygen (9.2 mg/L), and high conductivity (443 µS/cm) (Table 5.12-8). The substrate consisted almost entirely of sand, with small amounts of silt and clay, and low total organic carbon (~2%) (Table 5.12-8).

Water at *baseline* reach RCC-E1 in fall 2013 was shallow (0.2 m), slightly alkaline (pH: 7.9), with a moderate velocity (0.4 m/s), high dissolved oxygen (8.6 mg/L), and high conductivity (477 µS/cm) (Table 5.12-8). The substrate consisted primarily of large cobble, small gravel, and sand/silt/clay (Table 5.12-8). Periphyton biomass averaged 91.7 mg/m^2, which was within the range of variation of the means of *baseline* reaches from previous sampling years (Figure 5.12-5).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *baseline* reach BIC-D1 was dominated by chironomids (68%), with subdominant taxa consisting of tubificids (11%) and gastropods (Lymnaeidae; 10%) (Table 5.12-9). Dominant chironomids included *Rheosmittia*, *Paracladopelma*, and *Tanytarsus*. One Ephemeroptera (Leptophlebiidae) was found at this reach.

The benthic invertebrate community at *baseline* reach EYC-D1 was dominated by chironomids (65%), with subdominant taxa consisting of tubificid worms (14%) and miscellaneous Diptera (12%; Table 5.12-9). Dominant chironomids included *Rheosmittia, Heterotrissocladius*, and *Tanytarsus*. Miscellaneous Diptera included Simuliidae, Tipulidae, and Empididae. One Baetidae mayfly was found at this reach.

The benthic invertebrate community at *baseline* reach PIR-D1 was dominated by chironomids (57%), with subdominant taxa consisting of tubificid worms (22%) and nematodes (17%) (Table 5.12-9). Dominant chironomids included *Microspectra/*

Tanytarsus, Paratanytarsus, Paralauterborniella, Paracladopelma, and *Cryptochironomus.* Ephemeroptera (*Caenis* and Leptophlebiidae) and Bivalvia (*Pisidium/Sphaerium*) were present in low relative abundances.

The benthic invertebrate community at *baseline* reach RCC-E1 was diverse and dominated by chironomids (*Tvetnia, Microspectra/Tanytarsus, Rheotanytarsus*, and *Polypedilum*) (Table 5.12-9). Trichoptera were relatively abundant and diverse with 13 taxa present; with *Hydropsyche* and *Brachycentrus* as the most abundant. Ephemeroptera (*Baetis, Leptophlebia*, and *Heptagenia*) were present as well as permanent aquatic forms including amphipods, bivalve clams (*Pisidium/Sphaerium*), and gastropods (*Physa*) in low relative abundances (<1%). Many other groups were present in low relative abundances (Table 5.12-9).

Comparison to Published Literature The benthic invertebrate community at b*aseline* reach BIC-D1 contained a benthic fauna typical of a shifting habitat of sandy-bottomed rivers. Chirinomids and worms were in relatively high abundance and tubificids, known to be tolerant of poor water quality conditions, were the dominant type of worm (Pennak 1989) (Table 5.12-9). The chironomids that were present were only moderately tolerant of poor water quality (Mandeville 2002).

The benthic invertebrate community at *baseline* reach EYC-D1 contained a community typical of sandy-bottomed riverine environments. Chironomids were dominant as well as worms. Dominant forms of Chironomidae are known to be moderately tolerant of poor water quality conditions (Mandeville 2002). The percentage of EPT taxa and taxa richness were low (Table 5.12-9); which is common of sandy-bottomed rivers.

The benthic invertebrate community at *baseline* reach PIR-D1 was representative of generally poor water quality, with a high abundance of chrionomids, which are known to be tolerant of poor water quality conditions (Table 5.12-9) (Mandeville 2002). The higher relative abundance of tubificids also suggested degraded water quality (Pennak 1989). Additionally, an unusually high abundance of nematodes was observed at *baseline* reach PIR-E1 in 2013.

The benthic invertebrate community at *baseline* reach RCC-E1 contained a benthic fauna representative of good overall water quality conditions. Chironomids were dominant and known to be moderately tolerant of poor water quality (Mandeville 2002); however, the total abundance of worms was low (< 6%) indicating good habitat quality. Several forms of flying insects (EPT taxa: mayflies, stoneflies, and caddisflies) were present at *baseline* reach RCC-E1, which are indicative a good habitat conditions (Table 5.12-9).

Comparison to Regional *Baseline* Conditions Given that all benthic invertebrate communities reaches in the Pierre River area were *baseline*, the data collected contributed to the regional *baseline* conditions for comparisons to *test* reaches in the RAMP FSA. Therefore, comparisons between these reaches and regional *baseline* conditions were not conducted.

Classification of Results The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1, and PIR-D1 were typical of sand-bottomed rivers and had a high abundance of chironomids and worms, which are indicative of poor water quality conditions; and a low percentage of EPT taxa. The benthic invertebrate community at *baseline* reach RCC-E1 was indicative of good water quality, with a lower abundance of worms and a high percentage of EPT taxa. The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the RAMP FSA.

5.12.3.2 Sediment Quality

In fall 2013, sediment quality samples were collected for the first time from:

- Big Creek (*baseline* station BIC-D1);
- Eymundson Creek (*baseline* station EYC-D1); and
- Pierre River (*baseline* station PIR-D1).

Temporal Trends No trend analysis on sediment quality measurement endpoints was possible for any of the stations, given they were first sampled in 2013.

2013 Results In fall 2013, sediments for *baseline* stations PIR-D1, BIC-D1, and EYC-D1 were all dominated by sand; however, *baseline* station EYC-D1 also contained high concentrations of silt and clay relative to the other stations. Concentrations of low-molecular-weight hydrocarbons (CCME F1 and BTEX) were below detection limits at all stations. Heavier hydrocarbon fractions (CCME F3 and F4) were high at *baseline* station PIR-D1 and above detection limits at *test* stations BIC-D1 and EYC-D1 (Table 5.12-10 to Table 5.12-12).

Direct tests of sediment toxicity showed high rates of survival in the amphipod *Hyalella* ranging from 82% to 92% survival at all stations (Table 5.12-10 to Table 5.12-12). Rates of survival for the midge *Chironomus* showed poor survival rates at *baseline* stations PIR-D1 (56%), EYC-D1 (46%), and BIC-D1 (64%). *Baseline* stations PIR-D1 and EYC-D1 had predicted PAH toxicity that exceeded the chronic toxicity threshold value of 1.0 (Table 5.12-10 and Table 5.12-12).

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 2013 at *baseline* station BIC-D1. At *baseline* station EYC-D1, the guideline for total arsenic and the potential chronic toxicity threshold were exceeded in fall 2013. At *baseline* station PIR-D1, the guidelines for F3 hydrocarbons, total arsenic, chrysene, and phenanthrene were exceeded. The predicted PAH toxicity also exceeded the potential chronic toxicity threshold of 1.0 at *baseline* station PIR-D1.

2013 Results Relative Regional *Baseline* Concentrations In fall 2013, concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *baseline* stations PIR-D1 and BIC-D1 (Figure 5.12-6 and Figure 5.12-7). At *baseline* station EYC-D1, the concentration of total metals and the PAH hazard index exceeded the 95th percentile of the regional *baseline* concentrations; however, total metals normalized to percent fines were within regional *baseline* concentrations (Figure 5.12-8).

Sediment Quality Index The SQI values calculated for *baseline* stations BIC-D1 (100), EYC-D1 (86.8), and PIR-D1 (84.2) indicated **Negligible-Low** differences from regional *baseline* conditions.

Classification of Results All stations of the Pierre River area had a sediment quality index value indicating **Negligible-Low** differences from regional *baseline* conditions. No concentrations of sediment quality measurement endpoints exceeded the sediment or soil quality guidelines at *baseline* station BIC-D1, while only total arsenic exceeded the guideline at *baseline* station EYC-D1. *Baseline* Station PIR-D1 had many guideline exceedances, including CCME F3 hydrocarbons, total arsenic, chrysene, and phenanthrene. Survival of the midge *Chironomus* was fairly low at all stations (ranging from 46% to 64%) and the predicted PAH toxicity values exceeded the chronic toxicity threshold at EYC-D1 and PIR-D1. No trend analysis or historical comparisons were conducted at these stations due to sediment quality sampling being initiated in these locations in fall 2013.

5.12.4 Fish Populations

Fish assemblages were sampled for the first time in fall 2013 at:

- depositional *baseline* reach BIC-F1, near the mouth of Big Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach BIC-D1);
- depositional *baseline* reach EYC-F1, near the mouth of Eymundson Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach EYC-D1);
- depositional *baseline* reach PIR-F1, near the mouth of the Pierre River (this reach is at the same location as the benthic invertebrate community *baseline* reach PIR-D1); and
- erosional *baseline* reach RCC-F1, near the mouth of Red Clay Creek (this reach is at the same location as the benthic invertebrate community *baseline* reach (RCC-E1).

2013 Habitat Conditions *Baseline* reach BIC-F1 was comprised of shallow (maximum depth: 0.38 m) run habitat with a wetted width of 7.8 m and bankfull width of 10.9 m (Table 5.12-13). The substrate was dominated by sand and fine material. Water at *baseline* reach BIC-F1 in fall 2013 had a mean depth of 0.27 m and a moderate velocity (0.26 m/s), was alkaline (pH: 8.25), with moderate conductivity (354 µS/cm), high dissolved oxygen (8.8 mg/L), and a temperature of 12.9ºC. There was diverse instream cover comprised of woody debris, algae, boulders, and overhanging vegetation.

Baseline reach EYC-F1 was comprised of shallow riffle habitat with a wetted width of 8.7 m and bankfull width of 14.5 m (Table 5.12-13). The substrate was dominated by sand and silt. Water at *baseline* reach EYC-F1 in fall 2013 was shallow (mean depth: 0.17 m), with a moderate velocity (0.26 m/s), was alkaline (pH: 8.11), with high conductivity (475 µS/cm), moderate dissolved oxygen (8.2 mg/L), and a temperature of 11.9ºC. Instream cover was comprised of small and large woody debris.

Baseline reach PIR-F1 was comprised of shallow run and riffle habitat with a wetted width of 2.3 m and a bankfull width of 8.5 m (Table 5.12-13). The substrate was dominated by fine material with patches of embedded coarse gravel. Water at *baseline* reach PIR-F1 in fall 2013 was shallow (mean depth: 0.14 m), with a slow velocity (0.23 m/s), was alkaline (pH: 8.15), with high conductivity (470 µS/cm), and a temperature of 12.8˚C. Instream cover was comprised primarily of filamentous algae with small amounts of small woody debris (Table 5.12-13).

Baseline reach RCC-F1 was comprised of run and riffle habitat with a wetted width of 7.8 m and bankfull width of 10.9 m (Table 5.12-13). The substrate was dominated by cobble with some sand. Water at *baseline* reach RCC-F1 in fall 2013 was shallow (mean depth: 0.22 m), with a moderate velocity (0.32 m/s), was alkaline (pH: 8.03), with high conductivity (480 µS/cm), moderate dissolved oxygen (7.6 mg/L), and a temperature of 12.1ºC. Instream cover was comprised of algae and boulders, with smaller proportions of small woody debris, overhanging vegetation, and macrophytes.

Relative Abundance of Fish Species The fish assemblage at *baseline* reach BIC-F1 was dominated by burbot (38%) and white sucker (42%) (Table 5.12-14). The fish assemblage at *baseline* reach EYC-F1 was dominated by lake chub (73%) (Table 5.12-14). The fish assemblage at *baseline* reach PIR-F1 was dominated by lake chub (58%), with burbot (12%), longnose sucker (12%), and white sucker (13%) as the subdominant species (Table 5.12-14). The fish assemblage at *baseline* reach RCC-F1 was dominated by burbot (38%), with longnose sucker as the subdominant species (19%) (Table 5.12-14).

Temporal and Spatial Comparisons Sampling at *baseline* reaches of the Pierre River area (BIC-F1, EYC-F1, PIR-F1, and RCC-F1) was added to the RAMP Fish Assemblage Program in 2013; therefore, temporal and spatial comparisons were not conducted.

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the oil sands region, which can be used as a baseline to compare results of subsequent investigations as many of the studies cited in Golder (2004) are prior to major expansion in the oil sands. Golder (2004) referenced Big Creek as Unnamed Tributary 47. Information on Big Creek in Golder (2004) was limited to one previous study in 1979 that found lake chub and sucker fry (species not specified) in the creek; however, additional data were collected as part of the baseline program for the Shell Pierre River Mine Application (Shell 2007). A total of ten species have been recorded in Big Creek, including one sportfish (burbot), two sucker species, and seven small-bodied fish species (Shell 2007). One additional small-bodied fish species (brook stickleback) was found in tributaries to Big Creek. Five species were documented during the RAMP survey, all of which have previously been reported in Big Creek (Table 5.12-14).

Information on Eymundson Creek was limited to one previous study in 1973 that documented flathead chub (Golder 2004). Eleven species were documented by Shell (2007), including two sportfish species, two sucker species, and seven small-bodied fish species. Five species were documented by RAMP, including walleye, which has not previously been reported in Eymundson Creek (Table 5.12-14).

Shell (2007) documented 17 species in the Pierre River, mostly within 3 km of the mouth and included five sport fish, two large-bodied species, and ten small-bodied fish species. Nine species were documented by RAMP, including finescale dace, which has not previously been reported (Table 5.12-14).

Information on Red Clay Creek was limited to one previous study in 1973 that found Arctic grayling Golder (2004); 14 species were documented were documented by Shell (2007), including four sportfish, two sucker species, and eight small-bodied fish species. Nine species were documented by RAMP in 2013, including spoonhead sculpin, which has not previously been reported (Table 5.12-14). Sampling by Shell (2007) was multi-season using a variety of techniques 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.

Shell (2007) has documented similar habitat conditions where *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 are located, consisting of shallow run and riffle habitat, with some flat habitat of beaver ponds (Big and Eymundson creeks); low gradient, run habitat with silt and sand substrate (Pierre River); and run habitat with sandy substrate and areas of cobble and gravel that would be suitable for spawning (Red Clay Creek).

Shell (2007) reported that these rivers have potential for small-bodied fish habitat and seasonal use by sportfish species (including potential spawning habitat), but limited overwintering conditions.

2013 Results Relative to Regional *Baseline* Conditions Mean values of CPUE and richness at *baseline* reach PIR-F1 exceeded the inner tolerance limit of the 95th percentile of regional *baseline* conditions for depositional reaches; and the mean value of ATI at *baseline* reaches BIC-F1, EYC-F1, and PIR-F1 were below the 5th percentile of regional baseline conditions (Figure 5.12-9). The lower ATI value was likely due to the high proportion of burbot captured at each of these reaches, which is a sensitive species (Whittier et al. 2007). Mean values of all measurement endpoints in fall 2013 at *baseline* reach RCC-F1 were within the inner tolerance limits of regional *baseline* conditions for erosional reaches, with the exception of richness, which was higher than regional *baseline* variability (Table 5.12-15 and Figure 5.12-9).

Classification of Results The fish assemblages at *baseline* reaches BIC-F1, EYC-F1, PIR-F1, and RCC-F1 were similar to other *baseline* reaches in the area, and with each other. As with other reaches near the confluence to the Athabasca River, there was a high proportion of juvenile burbot captured at these reaches in fall 2013. Burbot is a sensitive species and likely contributed to the low ATI values at most of these reaches, which were outside the lower tolerance limits of regional *baseline* conditions.

Table 5.12-2 Concentrations of water quality measurement endpoints, Big Creek (*baseline* station BIC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.1	8.2	8.4
Total suspended solids	mg/L	-	59.0	2	9.0	12.0	15.0
Conductivity	µS/cm	-	387.0	2	391.0	418.5	446.0
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.082**	2	0.023	0.024	0.025
Total nitrogen	mg/L	1	0.891	2	0.891	0.901	0.911
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	22.1	2	21.0	24.2	27.3
Ions							
Sodium	mg/L	-	13.6	2	10.4	10.8	11.1
Calcium	mg/L	-	53.6	2	52.5	53.9	55.2
Magnesium	mg/L	-	13.6	2	12.4	13.8	15.1
Chloride	mg/L	120	<0.50	2	0.630	0.680	0.730
Sulphate	mg/L	410	11.0	2	8.26	14.9	21.5
Total dissolved solids	mg/L	-	275	2	265	286	307
Total alkalinity	mg/L		199	2	203	213	223
Selected metals							
Total aluminum	mg/L	0.1	**1.74**	2	**0.179**	**0.298**	**0.417**
Dissolved aluminum	mg/L	0.1	0.009	2	0.003	0.004	0.004
Total arsenic	mg/L	0.005	0.0017	2	0.0010	0.0010	0.0010
Total boron	mg/L	1.2	0.058	2	0.060	0.065	0.069
Total molybdenum	mg/L	0.073	0.00037	2	0.00031	0.00037	0.00042
Total mercury (ultra-trace)	ng/L	5, 13	**6.10**	2	0.60	1.30	2.00
Total strontium	mg/L	-	0.168	2	0.147	0.176	0.204
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.6	2	0.1	0.2	0.4
Oilsands Extractable	mg/L	-	0.7	2	0.3	1.1	1.8
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	4.2	2	1.1	2.3	3.5
Total dibenzothiophenes	ng/L	-	10.5	2	9.0	22.1	35.3
Total PAHs	ng/L	-	125.4	2	168.6	187.5	206.5
Total Parent PAHs	ng/L	-	23.6	2	16.4	18.3	20.1
Total Alkylated PAHs	ng/L	-	101.7	2	148.5	169.3	190.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.858**	2	0.043	**0.309**	**0.575**
Total Chromium	mg/L	0.001	**0.0017**	2	0.0004	0.0005	0.0005
Total iron	mg/L	0.3	**4.76**	2	**1.25**	**1.36**	**1.46**
Total phenols	mg/L	0.004	**0.0065**	2	**0.0043**	**0.0058**	**0.0073**
Total phosphorous	mg/L	0.05	**0.210**	2	**0.071**	**0.078**	**0.085**
Sulphide	mg/L	0.002	**0.006**	2	<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.

Table 5.12-3 Concentrations of water quality measurement endpoints, Eymundson Creek (*baseline* station EYC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	2	8.0	8.1	8.3
Total suspended solids	mg/L	-	180	2	54.0	99.0	144
Conductivity	µS/cm	-	596	2	318	425	531
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.019	2	0.009	0.017	0.025
Total nitrogen	mg/L	1	0.981	2	0.971	**1.04**	**1.10**
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	23.0	2	26.1	28.7	31.2
Ions							
Sodium	mg/L	-	26.5	2	11.6	17.1	22.5
Calcium	mg/L	-	76.5	2	35.5	46.4	57.2
Magnesium	mg/L	-	22.3	2	9.94	13.6	17.3
Chloride	mg/L	120	3.62	2	1.52	2.57	3.61
Sulphate	mg/L	410	137	2	58.6	88.8	119
Total dissolved solids	mg/L	-	425	2	258	329	400
Total alkalinity	mg/L		177	2	98.7	125	151
Selected metals							
Total aluminum	mg/L	0.1	**5.13**	2	**1.78**	**3.01**	**4.24**
Dissolved aluminum	mg/L	0.1	0.013	2	0.022	0.052	0.082
Total arsenic	mg/L	0.005	0.0036	2	0.0023	0.0031	0.0038
Total boron	mg/L	1.2	0.113	2	0.074	0.090	0.106
Total molybdenum	mg/L	0.073	0.0020	2	0.0013	0.0019	0.0025
Total mercury (ultra-trace)	ng/L	5, 13	**21.0**	2	**9.20**	**11.1**	**13.0**
Total strontium	mg/L	-	0.225	2	0.114	0.170	0.226
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.51	2	0.10	0.32	0.54
Oilsands Extractable	mg/L	-	1.36	2	0.51	0.95	1.39
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	9.05	2	4.70	9.15	13.6
Total dibenzothiophenes	ng/L	-	226	2	37.1	58.5	79.9
Total PAHs	ng/L	-	730	2	278	349	419
Total Parent PAHs	ng/L	-	36.5	2	23.7	24.1	24.5
Total Alkylated PAHs	ng/L	-	693	2	254	325	395
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total chromium	mg/L	0.001	**0.0049**	2	**0.0031**	**0.0046**	**0.0062**
Total iron	mg/L	0.3	**8.27**	2	**4.09**	**5.78**	**7.46**
Total phenols	mg/L	0.004	**0.0098**	2	**0.0070**	**0.0079**	**0.0087**
Total phosphorous	mg/L	0.05	**0.270**	2	**0.140**	**0.621**	**1.10**

[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, Pierre River (*baseline* station PIR-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	2	8.1	8.2	8.3
Total suspended solids	mg/L	-	41.0	2	21.0	47.5	74.0
Conductivity	µS/cm	-	554	2	387	433	478
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.029	2	**0.060**	**0.062**	**0.064**
Total nitrogen	mg/L	1	0.931	2	**1.08**	**1.25**	**1.42**
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	28.3	2	31.7	36.5	41.3
Ions							
Sodium	mg/L	-	28.6	2	20.2	22.5	24.7
Calcium	mg/L	-	70.5	2	41.8	46.4	51.0
Magnesium	mg/L	-	20.1	2	12.1	13.7	15.2
Chloride	mg/L	120	8.70	2	5.46	6.47	7.48
Sulphate	mg/L	410	28.5	2	23.0	29.0	34.9
Total dissolved solids	mg/L	-	396	2	303	342	380
Total alkalinity	mg/L		265	2	173	190	206
Selected metals							
Total aluminum	mg/L	0.1	**1.50**	2	**0.476**	**0.928**	**1.38**
Dissolved aluminum	mg/L	0.1	0.008	2	0.008	0.015	0.022
Total arsenic	mg/L	0.005	0.0025	2	0.0024	0.0025	0.0026
Total boron	mg/L	1.2	0.122	2	0.100	0.106	0.113
Total molybdenum	mg/L	0.073	0.00145	2	0.00099	0.00109	0.00118
Total mercury (ultra-trace)	ng/L	5, 13	4.60	2	3.80	4.35	4.90
Total strontium	mg/L	-	0.258	2	0.164	0.194	0.223
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.01	2	0.060	0.285	0.510
Oilsands Extractable	mg/L	-	1.08	2	0.460	1.18	1.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	15.2	2	8.76	11.4	14.1
Retene	ng/L	-	5.91	2	2.35	3.43	4.50
Total dibenzothiophenes	ng/L	-	238	2	43.4	47.3	51.3
Total PAHs	ng/L	-	764	2	260	285	310
Total Parent PAHs	ng/L	-	32.8	2	18.3	21.2	24.1
Total Alkylated PAHs	ng/L	-	731	2	242	264	285
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.006**	2	**0.017**	**0.018**	**0.018**
Total chromium	mg/L	0.001	**0.0018**	2	**0.0011**	**0.0015**	**0.0019**
Total iron	mg/L	0.3	**2.90**	2	**2.78**	**2.84**	**2.89**
Total phenols	mg/L	0.004	**0.0062**	2	**0.0068**	**0.0084**	**0.0099**
Total phosphorous	mg/L	0.05	**0.144**	2	**0.122**	**0.136**	**0.15**

[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, Red Clay Creek (*baseline* station RCC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2011-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.38	2	8.07	8.19	8.30
Total suspended solids	mg/L	-	<3.0	2	<3.0	5.0	7.0
Conductivity	µS/cm	-	522	2	480	500	519
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.018	2	0.010	0.013	0.015
Total nitrogen	mg/L	1	0.551	2	0.501	0.511	0.521
Nitrate+nitrite	mg/L	3	<0.071	2	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	13.8	2	12.9	14.3	15.7
Ions							
Sodium	mg/L	-	15.7	2	10.6	12.1	13.5
Calcium	mg/L	-	72.0	2	63.4	66.0	68.6
Magnesium	mg/L	-	21.3	2	16.5	17.9	19.3
Chloride	mg/L	120	1.46	2	1.62	1.63	1.64
Sulphate	mg/L	410	54.6	2	35.9	40.6	45.2
Total dissolved solids	mg/L	-	337	2	317	327	337
Total alkalinity	mg/L		269	2	225	230	235
Selected metals							
Total aluminum	mg/L	0.1	0.033	2	0.058	**0.180**	**0.303**
Dissolved aluminum	mg/L	0.1	0.0030	2	0.0012	0.0014	0.0015
Total arsenic	mg/L	0.005	0.00016	2	0.00019	0.00022	0.00026
Total boron	mg/L	1.2	0.115	2	0.083	0.084	0.085
Total molybdenum	mg/L	0.073	0.00014	2	0.00010	0.00011	0.00012
Total mercury (ultra-trace)	ng/L	5, 13	0.610	2	1.00	1.10	1.20
Total strontium	mg/L	-	0.268	2	0.192	0.223	0.254
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.49	2	0.09	0.15	0.20
Oilsands Extractable	mg/L	-	0.93	2	0.48	1.20	1.91
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	0.6694	2	0.5140	1.292	<2.07
Total dibenzothiophenes	ng/L	-	6.672	2	6.221	20.76	35.30
Total PAHs	ng/L	-	103.3	2	151.5	186.2	220.8
Total Parent PAHs	ng/L	-	22.86	2	16.44	17.83	19.23
Total Alkylated PAHs	ng/L	-	80.41	2	132.3	168.3	204.4
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.397**	2	**0.305**	**0.445**	**0.584**

[a] Sources for all guidelines are outlined in Table 3.2-5.

Values in **bold** are above the guideline.

Figure 5.12-3 Piper diagram of ion balance in Big Creek, Eymundson Creek, Pierre River, and Red Clay Creek.

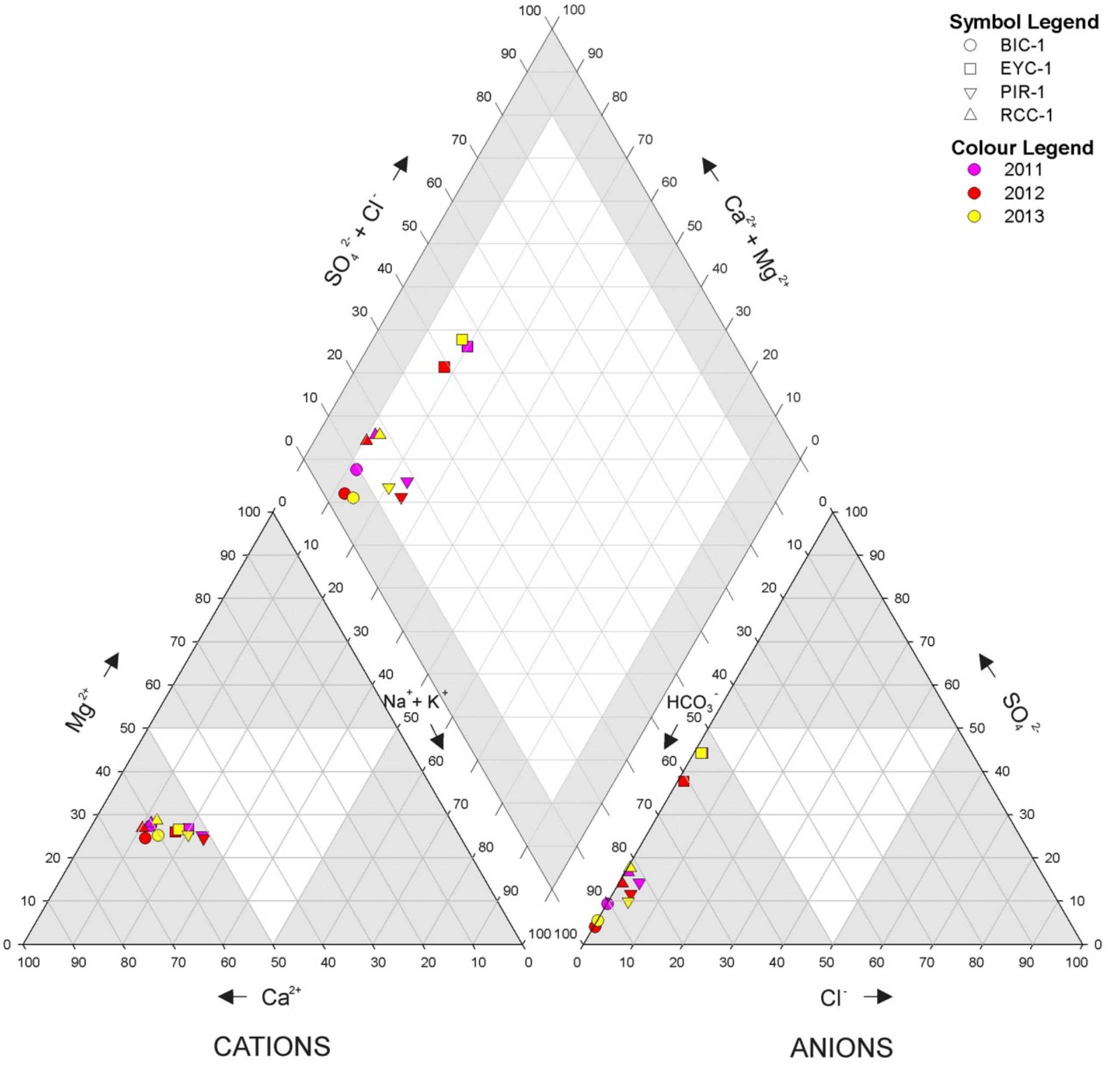


Table 5.12-6 Water quality guideline exceedances at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1, 2013.

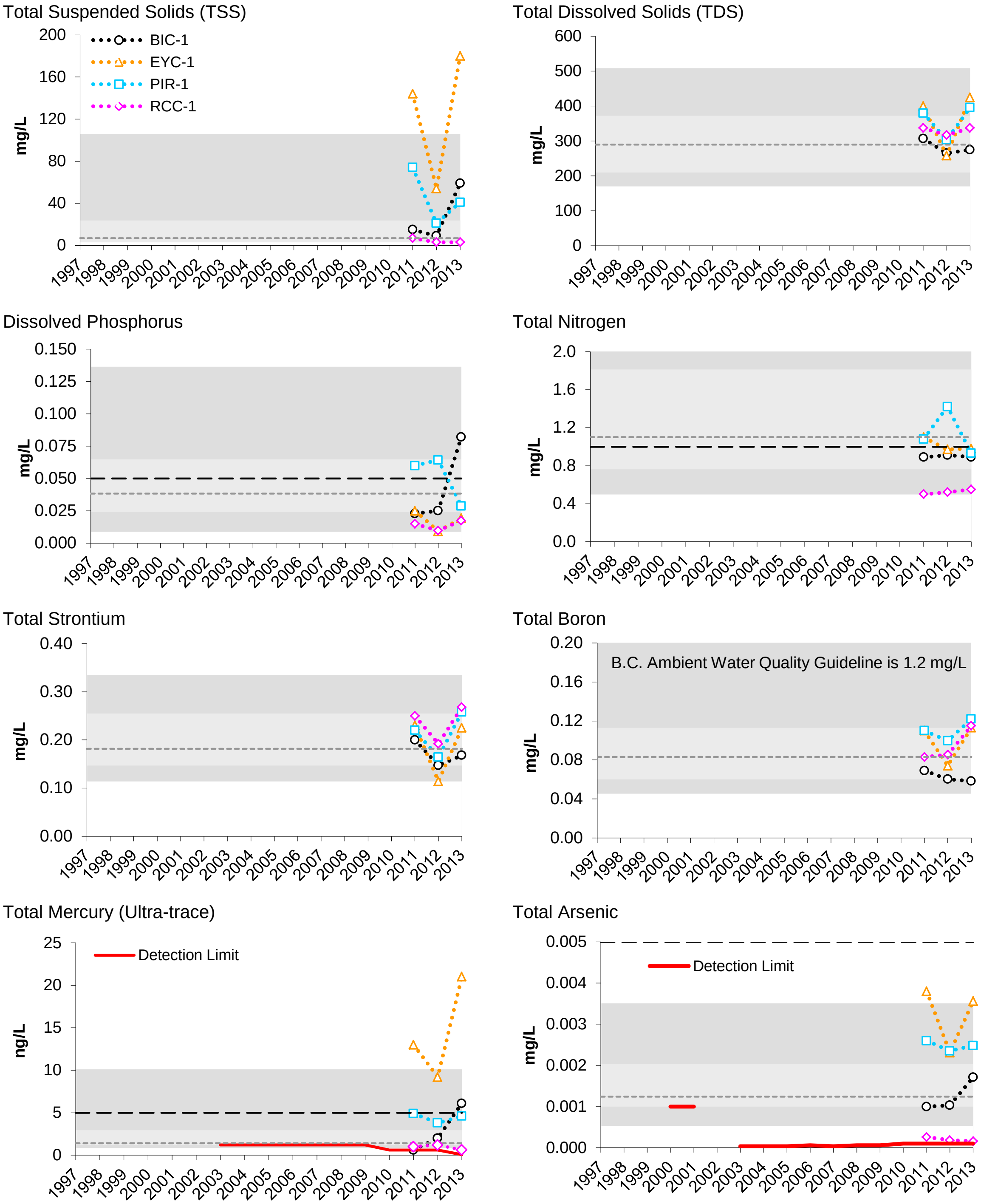
Variable	Units	Guideline[a]	BIC-1	EYC-1	PIR-1	RCC-1
Winter						
Sulphide	mg/L	0.002	0.006	ns	ns	ns
Total aluminum	mg/L	0.1	0.123	ns	ns	ns
Total iron	mg/L	0.3	1.05	ns	ns	ns
Total nitrogen	mg/L	1.0	1.07	ns	ns	ns
Total phenols	mg/L	0.004	0.0041	ns	ns	ns
Total phosphorus	mg/L	0.05	0.075	ns	ns	ns
Spring						
Dissolved aluminum	mg/L	0.1	-	0.101	-	-
Dissolved copper	mg/L	0.002[b]	-	0.005	-	-
Dissolved iron	mg/L	0.3	0.794	-	0.399	-
Sulphide	mg/L	0.002	0.038	0.237	0.064	0.011
Total aluminum	mg/L	0.1	5.22	26.7	7.22	0.231
Total cadmium	mg/L	0.00014-0.00021[b]	-	0.00386	0.00046	-
Total chromium	mg/L	0.001	0.005	0.024	0.008	-
Total copper	mg/L	0.002[b]	-	0.017	0.008	-
Total iron	mg/L	0.3	10.40	46.50	11.90	3.31
Total lead	mg/L	0.0017-0.0026[b]	-	0.063	0.007	-
Total mercury (ultra-trace)	ng/L	5, 13	9.60	-	11.80	-
Total nitrogen	mg/L	1.0	1.23	9.31	1.62	-
Total phenols	mg/L	0.004	0.007	0.010	0.006	0.005
Total phosphorus	mg/L	0.05	0.381	3.36	0.582	0.146
Total silver	mg/L	0.0001	-	0.00067	0.00012	-
Total thallium	mg/L	0.0008	-	0.0018	-	-
Total zinc	mg/L	0.03	-	0.062	0.044	-
Summer						
Dissolved iron	mg/L	0.3	1.04	1.05	2.46	-
Dissolved phosphorus	mg/L	0.05	0.058	-	0.0865	-
Sulphide	mg/L	0.002	0.036	0.052	0.0422	0.0029
Total aluminum	mg/L	0.1	0.92	17.40	0.86	-
Total cadmium	mg/L	0.00027[b]	-	0.00056	-	-
Total chromium	mg/L	0.001	-	0.015	0.00108	-
Total copper	mg/L	0.0039[b]	-	0.0117	-	-
Total iron	mg/L	0.3	2.50	23.60	4.19	0.44
Total lead	mg/L	0.0067[b]	-	0.0136	-	-
Total nitrogen	mg/L	1.0	1.43	2.73	1.67	-
Total phenols	mg/L	0.004	0.0093	0.0092	0.0117	-
Total phosphorus	mg/L	0.05	0.152	0.672	0.216	-
Total silver	mg/L	0.0001	-	0.00011	-	-
Total zinc	mg/L	0.03	-	0.0507	-	-
Fall						
Dissolved iron	mg/L	0.3	0.858	-	-	-
Dissolved phosphorus	mg/L	0.05	0.0822	-	-	-
Sulphide	mg/L	0.002	0.0060	-	0.0058	-
Total aluminum	mg/L	0.1	1.74	5.13	1.50	-
Total chromium	mg/L	0.001	0.0017	0.0049	0.0018	-
Total iron	mg/L	0.3	4.76	8.27	2.90	0.40
Total mercury (ultra-trace)	ng/L	5, 13	6.1	21	-	-
Total phenols	mg/L	0.004	0.0065	0.0098	0.0062	-
Total phosphorus	mg/L	0.05	0.210	0.270	0.144	-

[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, EYC-1, PIR-1, and RCC-1 (fall data) relative to regional *baseline* fall concentrations.**



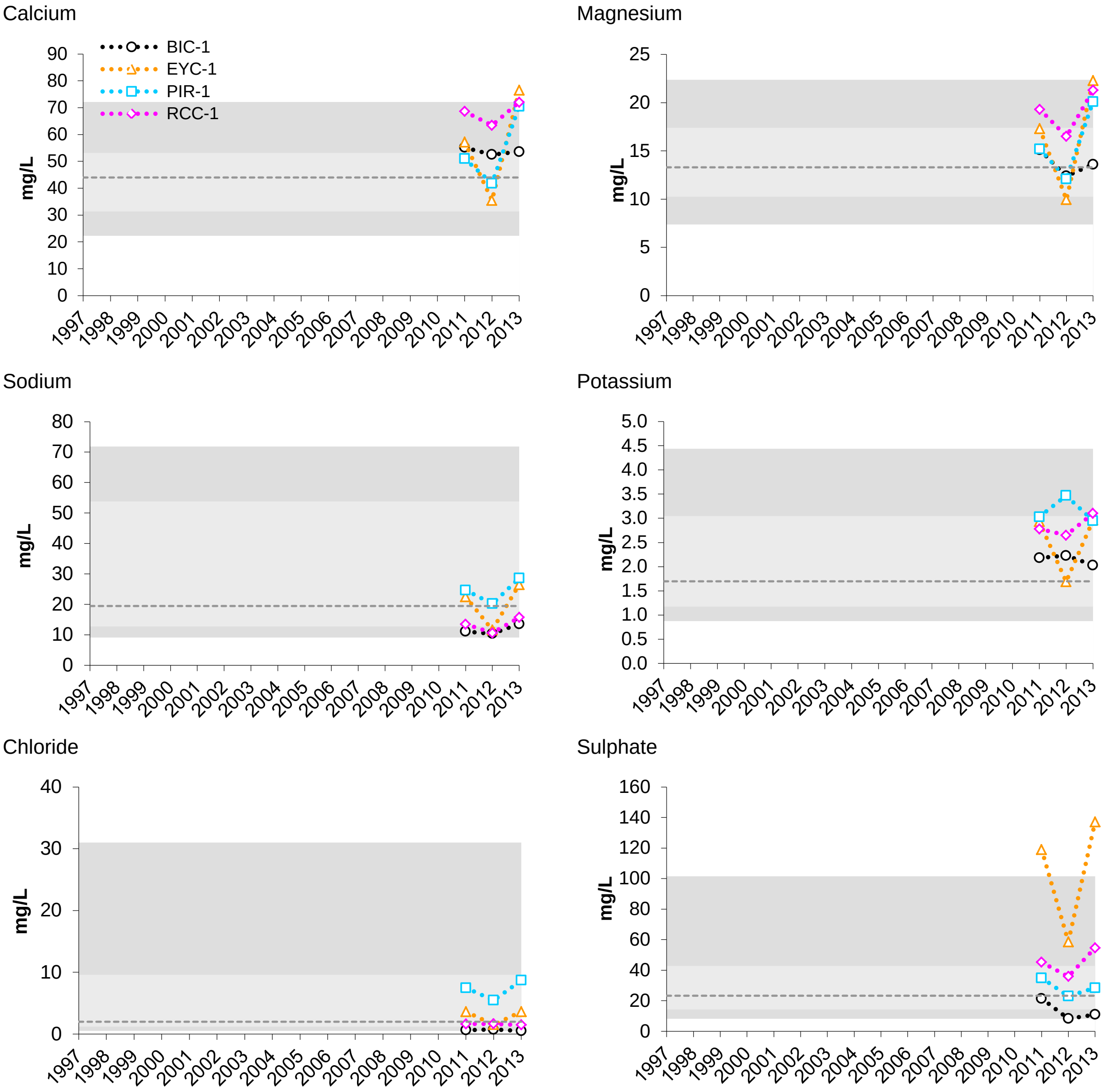
Non-detectable values are shown at the detection limit.

– – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

Figure 5.12-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

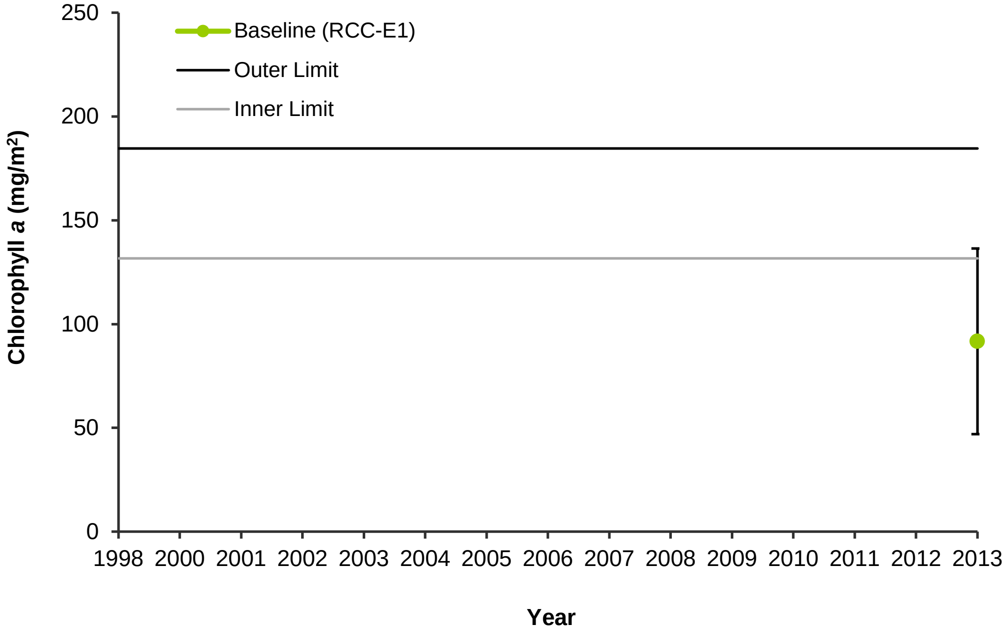
Table 5.12-7 Water quality index (fall 2013) for the watersheds in the Pierre River area.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
BIC-1	near the mouth of Big Creek	*baseline*	98.7	Negligible-Low
EYC-1	near the mouth of Eymundson Creek	*baseline*	61.2	Moderate
PIR-1	near the mouth of Pierre River	*baseline*	91.2	Negligible-Low
RCC-1	near the mouth of Red Clay Creek	*baseline*	93.7	Negligible-Low

Table 5.12-8 **Average habitat characteristics of benthic invertebrate community sampling locations in the Pierre River area, fall 2013.**

Variable	**Units**	**BIC-D1 *Baseline* Reach of Big Creek**	**PIR-E1 *Baseline* Reach of the Pierre River**	**RCC-E1 *Baseline* Reach of Red Clay Creek**	**EYC-D1 *Baseline* Reach of Eymundson Creek**
Sample date	-	Sept 11, 2013	Sept 7, 2013	Sept 12, 2013	Sept 12, 2013
Habitat	-	Depositional	Depositional	Erosional	Depositional
Water depth	m	0.5	0.2	0.2	0.2
Current velocity	m/s	0.43	0.21	0.4	0.42
Field Water Quality					
Dissolved oxygen	mg/L	9.5	9.2	8.6	8.8
Conductivity	µS/cm	375	443	477	602
pH	pH units	7.9	8.3	7.9	7.9
Water temperature	°C	11.2	10.6	11.9	11
Sediment Composition					
Sand	%	96	86	-	86
Silt	%	3	9	-	10
Clay	%	1	5	-	4
Sand/Silt/Clay	%	-	-	20	-
Small Gravel	%	-	-	6	-
Large Gravel	%	-	-	14	-
Small Cobble	%	-	-	26	-
Large Cobble	%	-	-	28	-
Boulder	%	-	-	7	-
Bedrock	%	-	-	0	-
Total Organic Carbon	%	0.46	1.8	-	0.67

Figure 5.12-5 Periphyton chlorophyll *a* biomass at *baseline* reach RCC-E1 of Red Clay Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* reaches for years up to and including 2012.

Table 5.12-9 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in the Pierre River area.

Taxon	Percent Major Taxa Enumerated in Each Year			
	Red Clay Creek (RCC-E1)	Pierre River (PIR-D1)	Eymundson Creek (EYC-D1)	Big Creek (BIC-D1)
	2013	2013	2013	2013
Hydra	<1	-	-	-
Nematoda	1	17	2	5
Oligochaeta	<1	-	-	-
Naididae	3	<1	6	2
Tubificidae	3	22	14	11
Enchytraeidae	<1	<1	<1	2
Lumbriculidae	-	-	-	<1
Hirudinea	-	<1	-	-
Hydracarina	3	<1	-	-
Amphipoda	<1	-	-	-
Gastropoda	<1	-	-	10
Bivalvia	<1	<1	-	1
Ceratopogonidae	<1	1	1	<1
Chironomidae	73	57	65	68
Diptera (misc)	5	<1	12	2
Coleoptera	<1	-	-	-
Ephemeroptera	2	2	<1	<1
Odonata	<1	-	-	-
Neuroptera	<1	-	-	-
Plecoptera	<1	-	-	-
Trichoptera	8	-	-	-
Benthic Invertebrate Community Measurement Endpoints				
Abundance (mean per replicate samples)	3,514	326	15	14
Richness	31	11	4	4
Equitability	0.27	0.46	0.72	0.75
% EPT	11	2	<1	<1

Table 5.12-10 Concentrations of selected sediment quality measurement endpoints in Pierre River (*baseline* station PIR-D1), fall 2013.

Variables	Units	Guideline	September 2013
			Value
Physical variables			
Clay	%	-	7.7
Silt	%	-	12.3
Sand	%	-	80.0
Total organic carbon	%	-	5.04
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	95
Fraction 3 (C16-C34)	mg/kg	300[1]	**1,130**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	972
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0026
Retene	mg/kg	-	0.099
Total dibenzothiophenes	mg/kg	-	4.083
Total PAHs	mg/kg	-	11.95
Total Parent PAHs	mg/kg	-	0.245
Total Alkylated PAHs	mg/kg	-	11.71
Predicted PAH toxicity[3]	H.I.	1.0	**1.56**
Metals that exceeded CCME guidelines in 2013			
Total arsenic	mg/kg	5.9	**5.93**
Other analytes that exceeded CCME guidelines in 2013			
Chrysene	mg/kg	0.0571	**0.0732**
Phenanthrene	mg/kg	0.0419	**0.0438**
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	5.6
Chironomus growth - 10d	mg/organism	-	2.99
Hyalella survival - 14d	# surviving	-	8.4
Hyalella growth - 14d	mg/organism	-	0.24

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.12-11 Concentrations of selected sediment quality measurement endpoints in Big Creek (*baseline* station BIC-D1), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**
			Value
Physical variables			
Clay	%	-	2.0
Silt	%	-	6.6
Sand	%	-	91.4
Total organic carbon	%	-	0.40
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]	63
Fraction 4 (C34-C50)	mg/kg	2,800[1]	86
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0005
Retene	mg/kg	-	0.007
Total dibenzothiophenes	mg/kg	-	0.028
Total PAHs	mg/kg	-	0.179
Total Parent PAHs	mg/kg	-	0.011
Total Alkylated PAHs	mg/kg	-	0.168
Predicted PAH toxicity[3]	H.I.	1.0	0.29
Metals that exceeded CCME guidelines in 2013			
none	mg/kg	-	
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	6.4
Chironomus growth - 10d	mg/organism	-	2.60
Hyalella survival - 14d	# surviving	-	9.2
Hyalella growth - 14d	mg/organism	-	0.30

Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.12-12 Concentrations of selected sediment quality measurement endpoints in Eymundson Creek (*baseline* station EYC-D1), fall 2013.

Variables	Units	Guideline	September 2013
			Value
Physical variables			
Clay	%	-	19.3
Silt	%	-	31.4
Sand	%	-	49.3
Total organic carbon	%	-	1.67
Total hydrocarbons			
BTEX	mg/kg	-	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	25
Fraction 3 (C16-C34)	mg/kg	300[1]	161
Fraction 4 (C34-C50)	mg/kg	2,800[1]	97
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[2]	0.0014
Retene	mg/kg	-	0.057
Total dibenzothiophenes	mg/kg	-	0.889
Total PAHs	mg/kg	-	2.979
Total Parent PAHs	mg/kg	-	0.102
Total Alkylated PAHs	mg/kg	-	2.876
Predicted PAH toxicity[3]	H.I.	1.0	**3.04**
Metals that exceeded CCME guidelines in 2013			
Arsenic (As)	mg/kg	5.9	14.6
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	4.6
Chironomus growth - 10d	mg/organism	-	3.91
Hyalella survival - 14d	# surviving	-	8.2
Hyalella growth - 14d	mg/organism	-	0.23

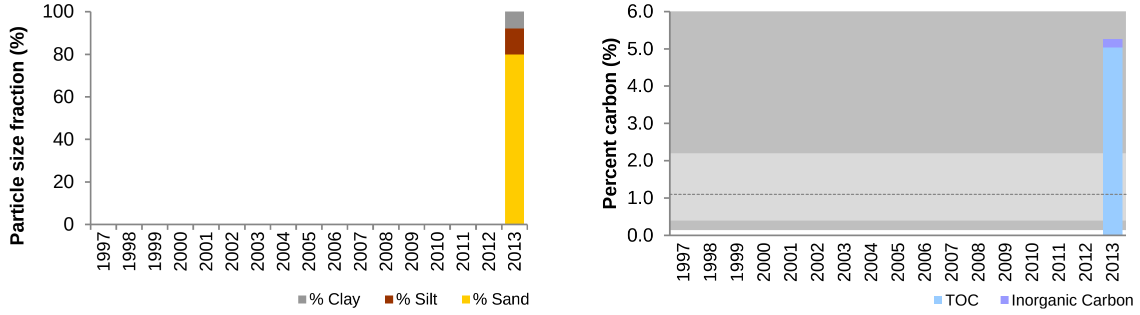
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

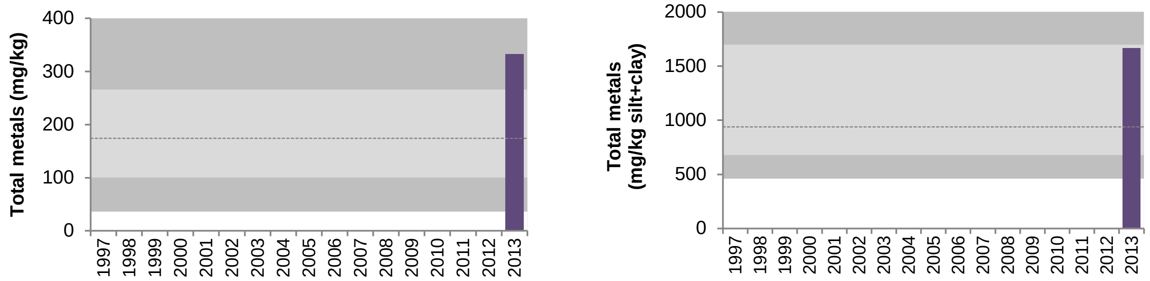
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

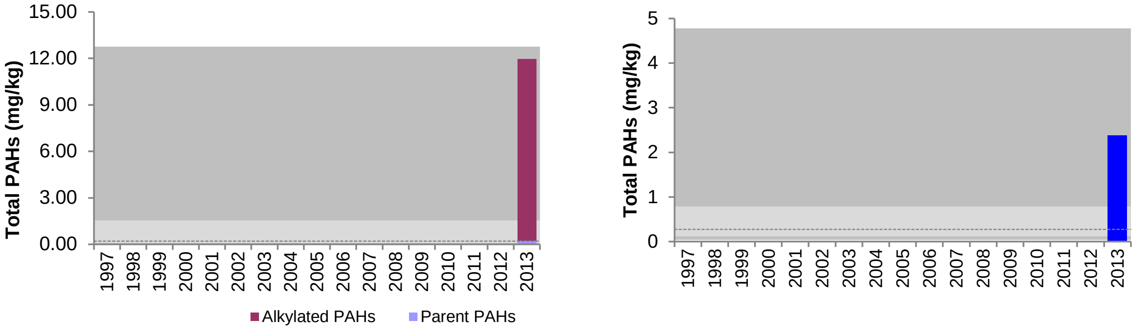
Figure 5.12-6 Variation in sediment quality measurement endpoints in Pierre River, *baseline* station PIR-D1.


Particle size distribution

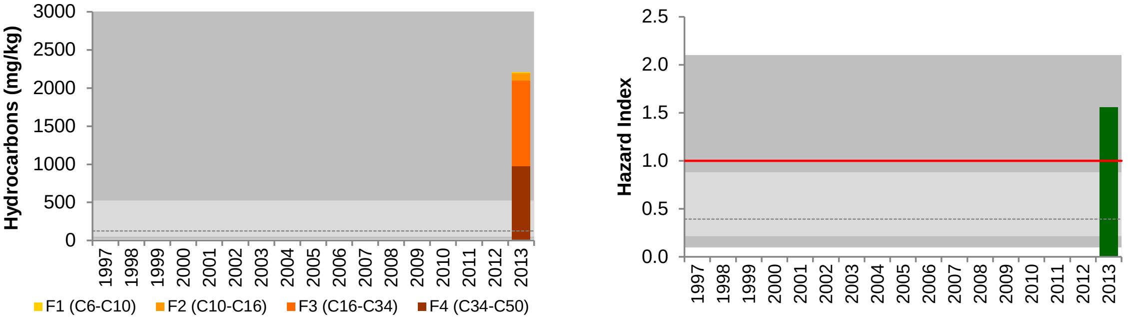
Carbon Content[1]


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 2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

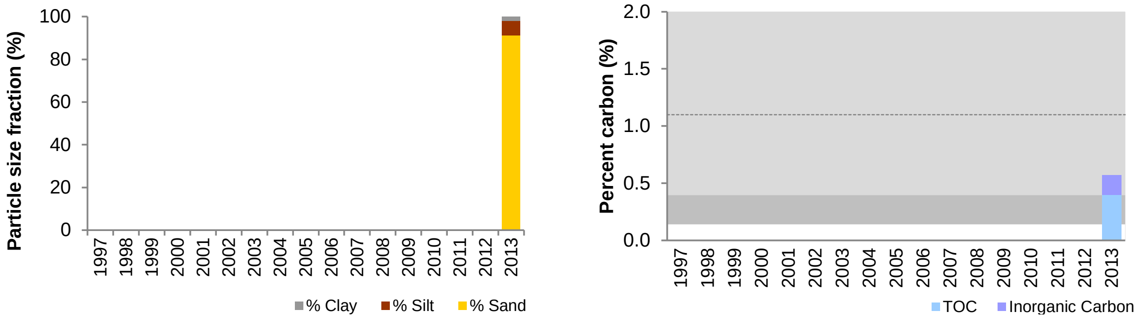
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.12-7 Variation in sediment quality measurement endpoints in Big Creek, *baseline* station BIC-D1.

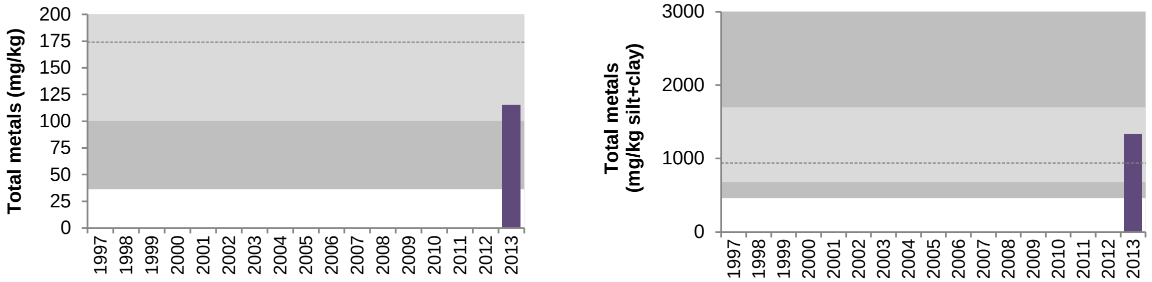
Particle size distribution

Carbon Content[1]



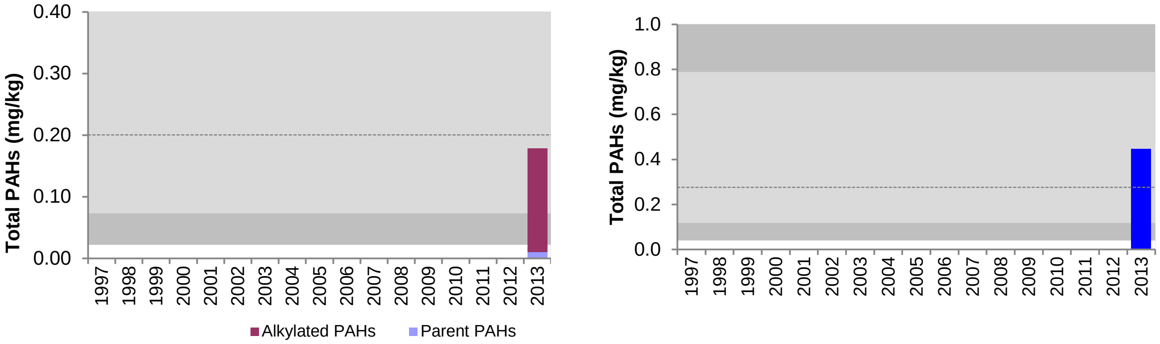
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



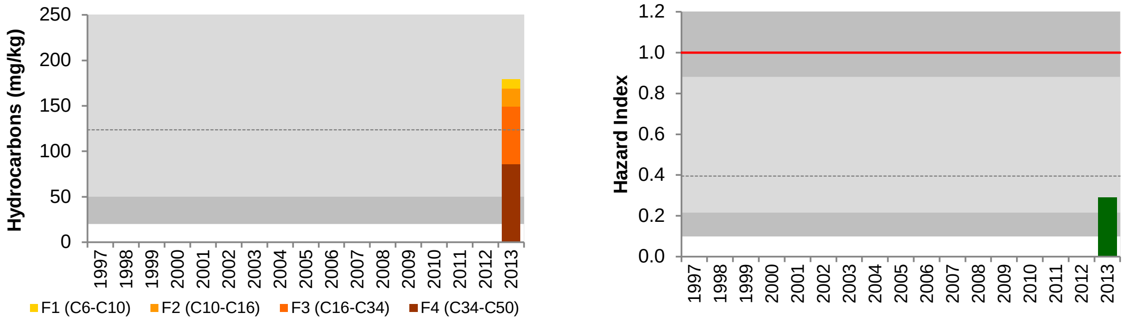
Total PAHs

Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]

PAH Hazard Index[3]



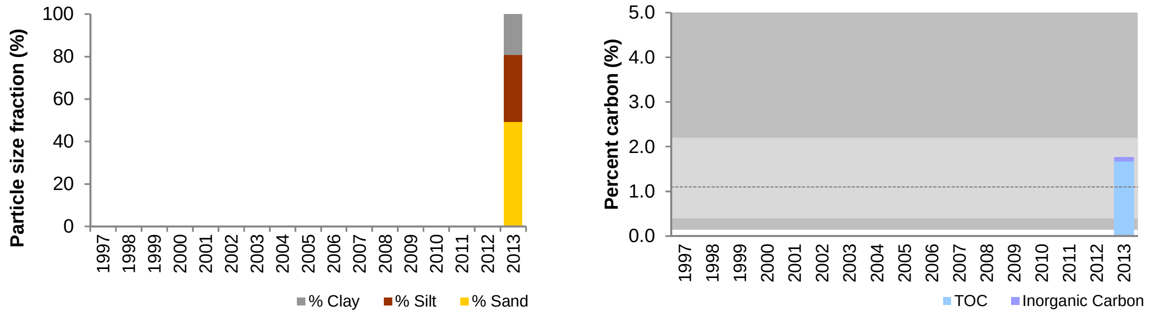
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

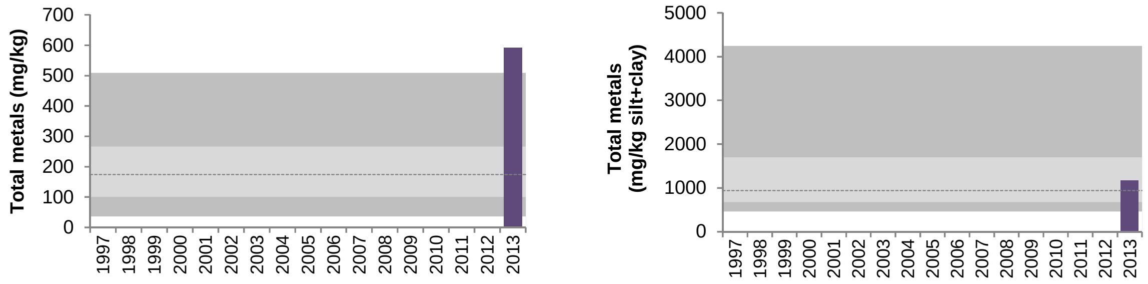
[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

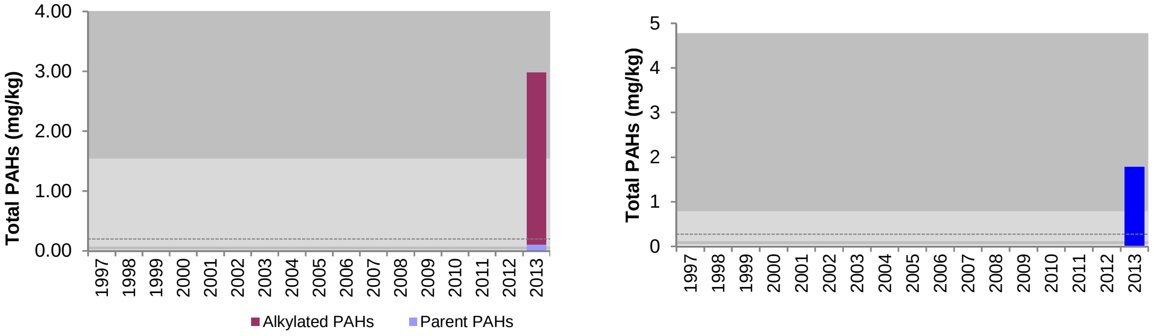
Figure 5.12-8 Variation in sediment quality measurement endpoints in Eymundson Creek, *baseline* station EYC-D1.


Particle size distribution

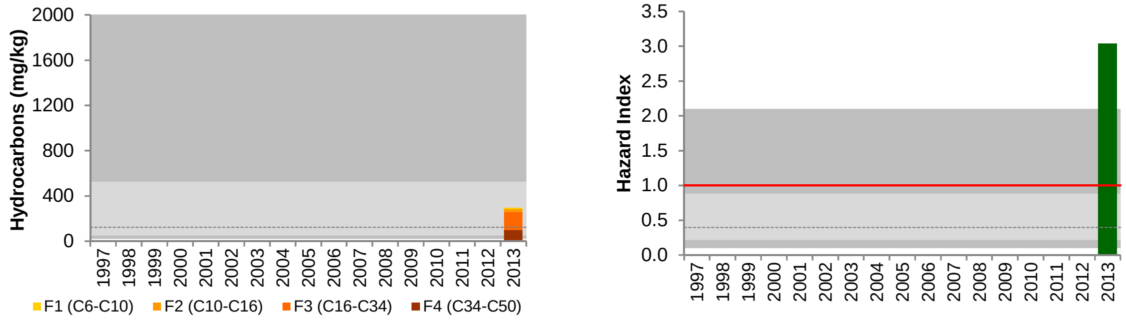
Carbon Content[1]


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 2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.12-13 Average habitat characteristics of fish assemblage monitoring locations in the Pierre River area.

Variable	**Units**	**BIC-F1 *Baseline* Reach of Big Creek**	**EYC-F1 *Baseline* Reach of Eymundson Creek**	**PIR-F1 *Baseline* Reach of the Pierre River**	**RCC-F1 *Baseline* Reach of Red Clay Creek**
Sample date		Sept 10, 2013	Sept 10, 2013	Sept 10, 2013	Sept 10, 2013
Habitat type	-	run	run	riffle/run	run/riffle
Maximum depth	m	0.38	0.25	0.30	0.38
Mean depth	m	0.27	0.17	0.14	0.22
Bankfull channel width	m	10.0	14.5	8.5	10.9
Wetted channel width	m	7.1	8.7	2.3	7.8
Substrate					
Dominant	-	sand	sand/fines	sand/fines	cobble
Subdominant	-	fines	-	gravel	sand
Instream cover					
Dominant	-	filamentous algae, small woody debris, overhanging vegetation, boulders	large woody debris, small woody debris	filamentous algae	filamentous algae, boulders
Subdominant	-	-	-	small woody debris	macrophytes, small woody debris, overhanging vegetation
Field water quality					
Dissolved oxygen	mg/L	8.8	8.2	N/A	7.6
Conductivity	µS/cm	354	475	470	480
pH	pH units	8.25	8.11	8.15	8.00
Water temperature	^{0}C	12.9	11.9	12.8	12.1
Water velocity					
Left bank velocity	m/s	0.21	0.23	0.25	0.24
Left bank water depth	m	0.18	0.16	0.10	0.12
Centre of channel velocity	m/s	0.33	0.29	0.23	0.35
Centre of channel water depth	m	0.27	0.18	0.18	0.20
Right bank velocity	m/s	0.32	0.26	0.22	0.32
Right bank water depth	m	0.37	0.18	0.13	0.34
Riparian cover – understory (<5 m)					
Dominant	-	woody shrubs and saplings, overhanging vegetation	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	-	-	overhanging vegetation	-

Table 5.12-14 Total number and percent composition of fish species captured in the Pierre River area, 2013.

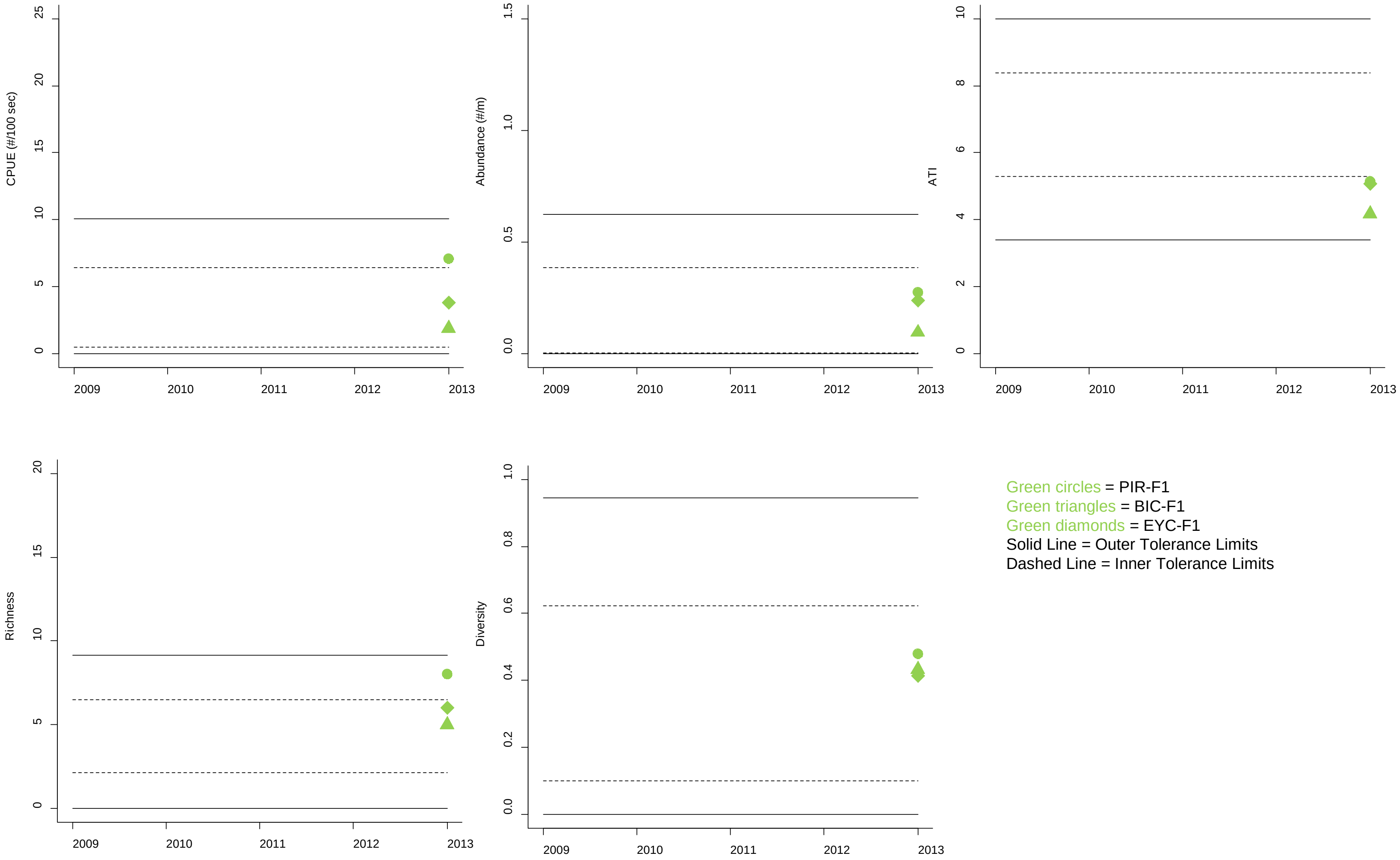
Common Name	Code	Total Species Catch				Percent of Total Catch			
		BIC-F1	EYC-F1	PIR-F1	RCC-F1	BIC-F1	EYC-F1	PIR-F1	RCC-F1
brook stickleback	BRST	-	-	-	9	0	0	0	12.2
burbot	BURB	9	9	10	28	37.5	15	12.2	37.8
finescale dace	FNDC	-	-	2	-	0	0	2.4	0
flathead chub	FLCH	-	2	-	-	0	3.3	0	0
lake chub	LKCH	2	44	44	2	8.3	73.3	53.7	2.7
longnose sucker	LNSC	-	3	10	14	0	5	12.2	18.9
northern pike	NRPK	-	-	1	-	0	0	1.2	0
slimy sculpin	SLSC	1	-	2	11	4.2	0	2.4	14.9
spoonhead sculpin	SPSC	2	-	-	2	8.3	0	0	2.7
walleye	WALL	-	1	-	1	0	1.7	0	1.4
white sucker	WHSC	10	1	11	11	41.7	1.7	13.4	14.9
yellow perch	YLPR	-	-	2	1	0	0	2.4	1.4
Total Count		**24**	**60**	**82**	**74**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**6**	**8**	**9**	**-**	**-**	**-**	**-**
Electrofishing effort (secs)		**1,278**	**1,557**	**1,154**	**1,277**	**-**	**-**	**-**	**-**

Table 5.12-15 Summary of fish assemblage measurement endpoints for reaches of the Pierre River area, fall 2013.

Reach	Abundance (#/m^2)		Richness			Diversity		ATI		CPUE (#/100 secs)	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BIC-F1	0.10	0.06	5	3	1.14	0.43	0.28	4.17	1.56	1.88	1.09
EYC-F1	0.24	0.09	6	3	0.84	0.41	0.07	5.06	0.34	3.84	1.42
PIR-F1	0.27	0.18	8	4	2.17	0.48	0.31	5.13	0.95	7.08	4.79
RCC-F1	0.32	0.09	9	5	1.82	0.72	0.10	4.57	1.27	6.19	1.79

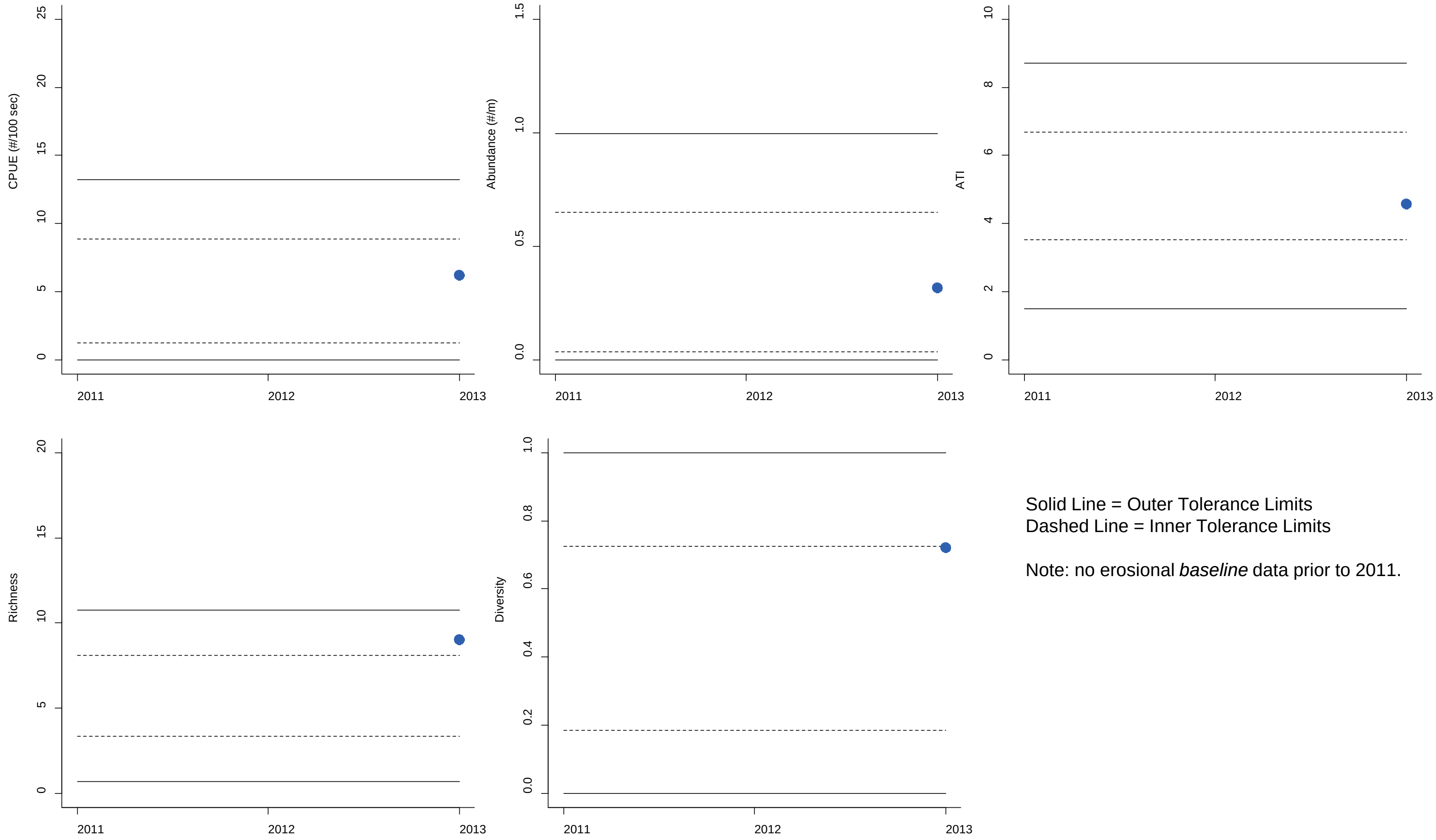
SD=standard deviation across sub-reaches within a reach.

Figure 5.12-9 Variation in fish assemblage measurement endpoints at depositional *baseline* reaches (PIR-F1, EYC-F1, and BIC-F1) of the Pierre River area, fall 2013.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

Figure 5.12-10 Variation in fish assemblage measurement endpoints at erosional *baseline* reach RCC-F1 of Red Clay Creek, fall 2013.



Solid Line = Outer Tolerance Limits
Dashed Line = Inner Tolerance Limits

Note: no erosional *baseline* data prior to 2011.

Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* erosional reaches.

5.13 MISCELLANEOUS AQUATIC SYSTEMS

Table 5.13-1 Summary of results for the miscellaneous aquatic systems.

Miscellaneous Aquatic Systems	Summary of 2013 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
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.

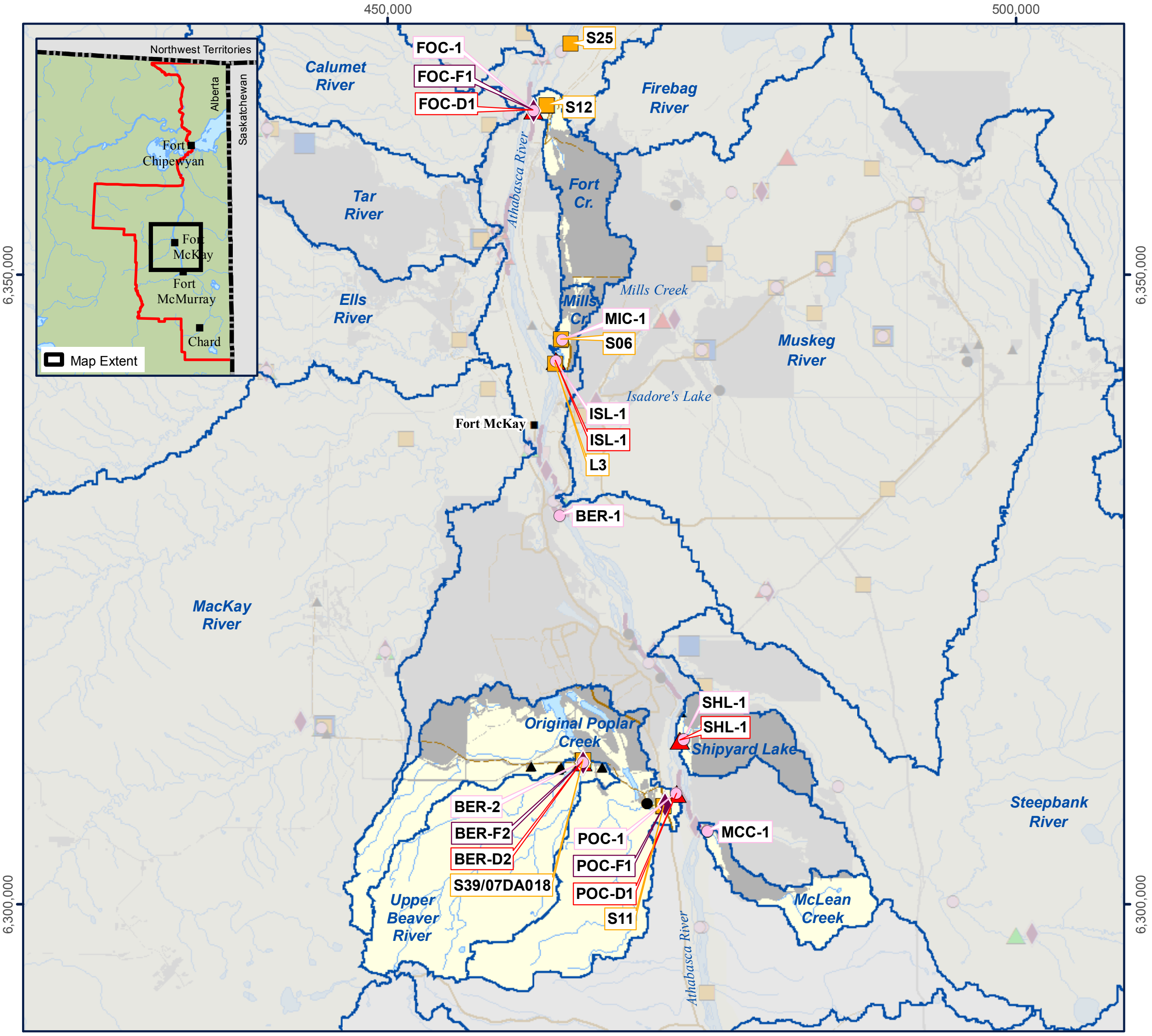
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional baseline 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 (fish assemblages): Classification based on differences in measurement endpoints from the range of variation in regional *baseline* conditions; see Section 3.2.4.4 for a description of the classification methodology.

Figure 5.13-1 Miscellaneous aquatic systems.



Legend

- Lake/Pond
- River/Stream
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- 🟥 RAMP Regional Study Area Boundary
- RAMP Focus Study Area
- Land Change Area as of 2013[a]
- ▲ Water Withdrawal Location[b]
- ● Water Discharge Location[b]
- 🟧 Hydrometric Station
- 🟦 Climate Station
- ● Water Quality Station
- ▲ Benthic Invertebrate Communities Reach
- ▲ Benthic Invertebrate Communities Reach and Sediment Quality Station
- △ Sediment Quality Station
- ♦ Fish Populations Reach
- Fish Inventory Reach

0 2.5 5 10 km

N

Scale: 1:500,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2013 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

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_K13_Misc_20140224_ss.mxd

Figure 5.13-2 Representative monitoring stations of miscellaneous aquatic systems, fall 2013.

Water Quality Station BER-2 (Beaver River): Centre of Channel, facing upstream

Water Quality Station FOC-1 (Fort Creek): Downstream

Water Quality Station MCC-1 (McLean Creek) Near the Mouth

Water Quality Station POC-1 (Poplar Creek): Centre of Channel, facing upstream

Water Quality Station ISL-1 (Isadore's Lake): Aerial View

Water Quality Station SHL-1 (Shipyard Lake): Aerial View

5.13.1 Summary of 2013 Conditions

This section includes 2013 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 2013 comprised approximately 18.9% (5,357 ha) of the original Poplar Creek watershed, 82.3% (5,463 ha) of the Fort Creek watershed, 27.2% (1,262 ha) of the McLean Creek watershed, approximately 63.7% (908 ha) of the Mills Creek watershed, 90.1% (4,643 ha) of the original watershed draining into Shipyard Lake, and approximately 0.1% (119 ha) of the Upper Beaver River watershed (Table 2.5-1).

Table 5.13-1 is a summary of the 2013 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 2013. Figure 5.13-2 contains 2013 photos of various monitoring stations located in the miscellaneous aquatic systems in the RAMP FSA.

Isadore's Lake and Mills Creek The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 1.63 million m^3 to Mills Creek. The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge were 56.5% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

In the 2013 WY, lake levels of Isadore's Lake decreased from November to December 2012 and remained near historical minimum values until mid-March 2013. Lake levels exceeded the historical maximum values from May 1 to May 8. Following this peak, lake levels decreased sharply until the lowest open-water lake level of 233.674 masl on June 4. Rainfall events in early to mid-June increased lake levels to above historical values by June 13, and remained between the historical upper quartile and maximum values until mid-October 2013.

Differences in water quality in fall 2013 between Mills Creek and regional *baseline* fall conditions were classified as **High** due to relatively high concentrations of many ions and other dissolved species that exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water at *test* stations ISL-1 and MIC-1 showed many similarities, supporting the idea that historical changes in water quality at Isadore's Lake may have occurred as a result of receiving water from Mills Creek.

Differences in measurement endpoints of the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because the significant increases in richness and percent EPT were indicative of positive changes in the lake. The percentage of the fauna as EPT taxa has always been <1% (normally EPT taxa are absent); however, in 2013, EPT taxa accounted for 3% of the benthic invertebrate community. CA Axis 1 and 2 scores were higher in 2013; however, this was due to a minor shift in taxa composition. All measurement endpoints were within the tolerance limits of historical variability in the lake. Isadore's Lake, historically, has had low diversity and a high abundance of nematodes making it unique compared to other lakes monitored by RAMP. In 2013, the relative abundance of nematodes was still high; however, other aspects of the benthic invertebrate community such as the percentage of the fauna as EPT taxa and richness have increased making the lake more consistent to other RAMP lakes.

Sediment quality measurement endpoints were generally within the range of previously-measured concentrations at *test* station ISL-1, with the exception of PAHs, which exceeded previously-measured concentrations except when normalized to %TOC. Concentrations of total arsenic, CCME F3 hydrocarbons, and dibenz(a,h)anthracene exceeded sediment quality guidelines in fall 2013. A SQI was not calculated for *test* station ISL-1 because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2013 at *test* station SHL-1 were within previously-measured concentrations, with the exception of some ions and metals. The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the watershed (90% of the Shipyard Lake watershed has been disturbed). A WQI was not calculated for lakes in 2013 due to potential ecological differences in regional water quality characteristics between lakes and rivers.

Differences in measurement endpoints for benthic invertebrate communities in Shipyard Lake in 2013 were classified as **Negligible-Low**. The significant increases in abundance and taxa richness were strong and implied that the observed changes were not caused by degradation of 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.

In fall 2013, most sediment quality measurement endpoints were within the range of previously-measured concentrations at *test* station SHL-1. Concentrations of total arsenic, F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, Dibenz(a,h)anthracene, and phenanthrene) exceeded sediment quality guidelines. Increasing trends were apparent for total alkylated PAHs, and F3 and F4 hydrocarbons. *Test* station SHL-1 was not compared to regional *baseline* conditions due to ecological differences between lakes and rivers.

Poplar Creek and Beaver River The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 248%, 77.0%, 18.6%, and 27.6% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

Concentrations of several water quality measurement endpoints, primarily ions, 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 2013 between *test* station POC-1 and *baseline* station BER-2 and regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of most water quality measurement endpoints exhibited some variability throughout the year at *test* station POC-1, which were more apparent in the ionic composition of water and showed seasonal variability. Generally the highest concentrations of ions and metals occurred in December. Guideline exceedances occurred most frequently in April, May, and July; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

Differences in measurement endpoints of the benthic invertebrate community at *test* station POC-Dl were classified as **Moderate** because of the significant and large differences in abundance, equitability, percentage of fauna as EPT taxa, and CA axis scores compared to *baseline* reach BER-D2. Richness and abundance have been decreasing since 2001 at *test* reach POC-D1 and EPT taxa, which were increasing until 2012, have decreased in 2013. The lower equitability, which was outside of the inner tolerance limit for the 5th percentile of regional *baseline* conditions, did not denote a negative change, but suggested that *test* reach POC-D1 was becoming more diverse. The benthic invertebrate community at *test* reach POC-D1 was typical of a sand-bottom creek and dominated by worms and chironomids.

Differences in sediment quality observed in fall 2013 between *test* station POC-D1, *baseline* station BER-D2, and regional *baseline* conditions were classified as **Negligible-Low** with nearly all sediment quality measurement endpoints within the range of previously-measured concentrations. Some sediment and soil quality guidelines were exceeded at *test* station POC-D1, including chrysene and F3 hydrocarbons.

Differences in measurement endpoints of the fish assemblage at *test* reach POC-F1 were classified as **Negligible-Low** because the significant increases in richness, diversity, CPUE were not indicative of a negative change in the fish assemblage. In addition, the lower ATI value and the higher diversity compared to the range of regional *baseline* variability indicated that the fish assemblage had a greater number of species and a greater proportion of more sensitive species (e.g., burbot).

McLean Creek Concentrations of water quality measurement endpoints at *test* station MCC-1 were generally within the regional *baseline* concentrations, and within the range of previously-measured concentrations in fall 2013. The Water Quality Index value indicated **Negligible-Low** differences between *test* station MCC-1 and regional *baseline* concentrations. Despite generally being within regional *baseline* variability, fall concentrations of total dissolved solids and several ions have shown consistent increases since 2009.

Fort Creek The 2013 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum daily discharge were 16.6% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**. The difference in measurement endpoints between the 2013 WY and previous years was due to the updated watershed areas and changes in land disturbance from focal project activities. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed.

Differences in water quality in fall 2013 between *test* station FOC-1 and regional *baseline* conditions were classified as **Moderate**. Relatively high concentrations of several water quality measurement endpoints, primarily ions, were observed in fall 2013. Many of these measurement endpoints were outside of the range of previously-measured concentrations and contributed to the lower WQI value observed in 2013.

Differences in measurement endpoints of benthic invertebrate communities at *test* reach FOC-Dl were classified as **Negligible-Low** because the higher richness and CA Axis 2 scores in 2013 compared to previous years were not indicative of degradation; abundance and diversity (i.e., equitability) have been increasing over the last three years; and the number of EPT taxa was generally higher in more recent years compared to the *baseline* period. The increase in CA Axis 2 scores reflected higher relative abundances of mayflies and caddisflies, which was also consistent with improved conditions.

Differences in sediment quality observed in fall 2013 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.

Differences in measurement endpoints of the fish assemblage at *test* reach FOC-F1 were classified as **Moderate** because there was a significant decrease in abundance, which could be indicative of a potential negative change in the fish assemblage. In addition, there were also decreases, although not statistically significant, in CPUE, richness, and diversity. The ATI value was lower than the regional range of *baseline* variability; however, reflecting a greater proportion of sensitive fish species in 2013 compared to previous years.

5.13.2 Mills Creek and Isadore's Lake

Monitoring was conducted in 2013 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: 2013 Water Year

Mills Creek

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.

Continuous hydrometric data during the open-water season (May to October) have been collected at RAMP Station S6 from 1997 to 2013, with annual data collected from 2006 to 2013. The 2013 WY annual runoff volume of 1.25 million m^3 was 65% higher than the historical mean annual runoff volume of 0.758 million m^3. The open-water (May to October) runoff volume of 1.01 million m^3 was 49% higher than the historical mean open-water runoff volume of 0.681 million m^3. Flows decreased from November 2012 to early March 2013, with flows from mid-January to March below the historical minimum values (Figure 5.13-3). Flows increased in April and early May to above the historical upper quartile values and exceeded the historical maximum daily flow on April 12. Following the spring freshet, flows generally decreased until the lowest open-water flow of 0.006 m^3/s on May 28. This value was 62% lower than the historical mean open-water minimum daily flow. Flows increased sharply in response to rainfall events in early June, exceeding the historical maximum flows from June 8 to June 19. The maximum recorded daily flow of 0.181 m^3/s on June 10 was 12% higher than the historical mean open-water maximum daily flow. Flows recorded from mid-June to the end of the 2013 WY varied between the historical upper quartile and the historical maximum values, with the exception of flows from August 18 to August 24, which were below the historical median values and flows in early-October, which exceeded the historical maximum flow for that period.

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 2013 in the Mills Creek watershed was estimated to be 5.6 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 1.78 million m^3. Approximately 1.06 km^2 of closed-circuited land was located downstream of S6, and was not included in the loss of flow estimate to Mills Creek.

2. As of 2013, the area of land change in the Mills Creek watershed from focal projects that was not closed-circuited was estimated to be 2.44 km^2 (Table 2.5-1). The increase in flow to Mills Creek that would not have otherwise occurred was estimated at 0.156 million m^3.

The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 1.63 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 56.5% 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).

Isadore's Lake

Continuous lake level data for Isadore's Lake have been collected at Station L3 since February 2000. In the 2013 WY, lake levels decreased from November to December 2012 and remained near historical minimum values until mid-March 2013 (Figure 5.13-4). Lake levels increased during freshet in April and early May, exceeding the historical maximum lake levels from May 1 to May 8. The maximum lake level of 234.233 masl recorded on May 2 was 0.219 m higher than the historical mean maximum lake level and the second-highest lake level recorded at this station (this maximum lake level of 234.517 masl was recorded on July 12, 2011). Following this peak, lake levels decreased sharply until the lowest open-water lake level of 233.674 masl on June 4. Rainfall events in early to mid-June increased lake levels to above historical values by June 13, and remained between the historical upper quartile and maximum values until mid-October 2013.

5.13.2.2 Water Quality

In fall 2013, water quality samples were taken from:

- Isadore's Lake (*test* station ISL-1), sampled in 2000, 2001, and annually since 2004; and
- Mills Creek (*test* station MIC-1), sampled since 2010.

Water quality monitoring was initiated in Mills Creek in fall 2010 to assess the potential influence of water quality entering Isadore's Lake. Monitoring of Mills Creek was prompted by changes that had been observed in the ionic characteristics of water in Isadore's Lake in recent years.

Temporal Trends Significant increasing trends (α=0.05) in fall concentrations of water quality measurement endpoints were detected for total dissolved solids, sulphate, chloride, sodium, total strontium, and total boron at *test* station ISL-1. Trend analysis was not performed for *test* station MIC-1 because only four years of data were available.

2013 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within the range of historical concentrations in fall 2013 at *test* stations ISL-1 and MIC-1, with the exception of (Table 5.13-4 and Table 5.13-5):

- total alkalinity, with a concentration below the previously-measured minimum concentration at *test* station ISL-1;
- conductivity, sodium, calcium, chloride, sulphate, total dissolved solids, total boron, and total strontium, with concentrations that exceeded previously-measured maximum concentrations at *test* station ISL;

- pH, total nitrogen, total alkalinity, and total mercury (ultra-trace), with concentrations below previously-measured minimum concentrations at *test* station MIC-1; and
- conductivity, sodium, calcium, magnesium, chloride, sulphate, total dissolved solids, total boron, and total strontium, with concentrations that exceeded previously-measured maximum concentrations at *test* station MIC-1.

Ion Balance In the first two years of sampling (2000 and 2001), the ionic composition of water at *test* station ISL-1 was dominated by calcium and bicarbonate. Since 2004, the anion composition has shifted to a greater proportion of sulphate, while calcium and magnesium continued to dominate the cation composition. In fall 2013, the anion composition shifted from previous years by being even more dominated by sulphate and, to a lesser extent, by chloride (Figure 5.13-5). The ionic composition of water in fall 2010 to 2013 at *test* station MIC-1 was consistent with that of *test* station ISL-1, but with a slightly lower relative concentration of magnesium. The consistent ionic composition between Mills Creek and Isadore's Lake supported the hypothesis that flows from Mills Creek have been responsible for 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 at *test* station ISL-1 in fall 2013 (Table 5.13-4). The concentration of sulphate exceeded the guideline at *test* station MIC-1 in fall 2013 (Table 5.13-5).

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were observed in fall 2013 (Table 5.13-6):

- sulphide and total phenols at *test* station ISL-1; and
- sulphide and total iron at *test* station MIC-1.

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, 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, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations; and
- dissolved phosphorus, total nitrogen, and total mercury (ultra-trace), with concentrations 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 2013 was 59.1, indicating a **High** difference in water quality compared to regional *baseline* conditions (Table 5.13-7). The low WQI was 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 are not compared to regional *baseline* concentrations, there was no WQI for *test* station ISL-1; however, due to similar water quality between Isadore's Lake and Mills Creek, it would be expected that similar exceedances of regional *baseline* concentrations would likely be observed.

Classification of Results Differences in water quality in fall 2013 between Mills Creek and regional *baseline* fall conditions were classified as **High**, due to relatively high concentrations of many ions and other dissolved species that exceeded 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 2013 in Isadore's lake at depositional *test* station ISL-1 (sampled since 2006).

2013 Habitat Conditions Water in Isadore's Lake in fall 2013 was slightly alkaline (pH: 7.83) with high conductivity (634 µS/cm). The substrate was dominated by silt (79%), with relatively high total organic carbon content (~10%) (Table 5.13-8).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Isadore's Lake in fall 2013 was dominated by chironomids (60%), with subdominant taxa consisting of nematodes (18%) (Table 5.13-9). Chironomids were principally of the genera *Einfeldia*, *Chironomus*, *Ablabesmyia*, and *Dicrotendipes* all of which are commonly distributed in north-temperate lakes (Wiederholm 1983). Ephemeroptera (*Caenis*), the damselfly, *Enallagma*, and two families of dragonflies (Aeshnidae and Libellulidae) were found in low relative abundances. Gastropods were diverse and included *Lymnaea*, *Physa*, *Gyraulus*, *Helisoma*, *Menetus cooperi*, and *Valvata tricarinata*. Amphipods (*Hyalella azteca*) were found in low relative abundances.

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 2013 values and the mean of all previous years.

Richness significantly increased over time and was higher in 2013 than the mean of all previous years (2009 to 2012) (Table 5.13-10). These changes accounted for 23% and 50% of the variance in annual means, respectively.

The percentage of the fauna as EPT taxa was significantly higher in 2013 than the mean of previous years, accounting for 39% of the variance in annual means (Table 5.13-10, Figure 5.13-8).

CA Axis 1 scores were higher in 2013 than the means of all previous years, accounting for 22% of the variance in annual means (Table 5.13-10). The increase in CA Axis 1 scores reflected an increase in the relative abundance of gastropods over time (Figure 5.13-9).

CA Axis 2 scores increased over time and were higher in 2013 than the mean of all previous years, likely due to an increase in the relative abundance of ceratopogonid over time (Figure 5.13-9). These changes accounted for 33% and 25% of the variance in annual means, respectively (Table 5.13-10).

Comparison to Published Literature The benthic invertebrate community in Isadore's Lake has shown some improvement since 2012. The relative abundance of "tolerant" nematodes in 2013 was still high possibly indicating poor water quality (Pennak 1989); however, gastropods were diverse and chironomids were abundant. Several flying insects were found at Isadore's Lake including *Caenis* mayflies and several types of dragonfly suggesting that conditions have improved.

2013 Results Relative to Historical Conditions All measurement endpoints were within the inner tolerance limits of the normal range for means of previous years from Isadore's Lake (Figure 5.13-8).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* station ISL-1 were classified as **Negligible-Low** because the significant increases in richness and percent EPT were indicative of positive changes in the lake. The percentage of the fauna as EPT taxa has always been <1% (normally EPT taxa are absent); however, in 2013, EPT taxa accounted for 3% of the benthic invertebrate community. CA Axis 1 and 2 scores were higher in 2013; however, this was due to a minor shift in taxa composition. All measurement endpoints were within the tolerance limits of historical variability in the lake. Isadore's Lake, historically, has had low diversity and a high abundance of nematodes making it unique compared to other lakes monitored by RAMP. In 2013, the relative abundance of nematodes was still high; however, other aspects of the benthic invertebrate community such as the percentage of the fauna as EPT taxa and richness have increased making the lake more consistent to other RAMP lakes.

Sediment Quality

Sediment quality in fall 2013 was sampled in Isadore's Lake (*test* station ISL-1, sampled in 2001 and continuously from 2006 to 2013) at the same location where sampling for benthic invertebrate communities was conducted.

Temporal Trends No significant trends (α=0.05) in concentrations of any sediment quality measurement endpoints were detected at *test* station ISL-1 from 2001 to 2013.

2013 Results Relative to Historical Concentrations In fall 2013, sediments for *test* station ISL-1 were dominated by sand, with higher proportions of sand and lower proportions of silt than previously measured (Table 5.13-11, Figure 5.13-10). Concentrations of low-molecular-weight hydrocarbons (F1, BTEX, and F2) were below detection limits, while concentrations of heavier hydrocarbon fractions (F3 and F4) were within the range of previously-measured concentrations. Concentrations of PAHs generally exceeded previously-measured concentrations in 2013, with the exception of carbon-normalized concentrations of PAHs (Table 5.13-11, Figure 5.13-10). Total organic carbon was relatively high at *test* station ISL-1 in 2013.

Growth of the amphipod *Hyalella* and survival of the midge *Chironomus* were within the range of previously-measured values (Table 5.13-11). *Chironomus* growth exceeded the previously-measured maximum value and *Hyalella* survival was lower in 2013 than the previously-measured minimum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines No sediment quality measurement endpoints exceeded sediment or soil quality guidelines in fall 2013, with the exception of total arsenic, F3 hydrocarbons, and dibenz(a,h)anthracene.

2013 Results Relative Regional *Baseline* Concentrations No comparisons were made in fall 2013 between *test* station ISL-1 and regional *baseline* concentrations given that lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers.

Sediment Quality Index A *baseline*-referenced SQI was not calculated for *test* station ISL-1 because lakes were not included in the regional *baseline* conditions given potential ecological differences between lakes and rivers and the lack of *baseline* data for lakes in the region.

Classification of Results Sediment quality measurement endpoints were generally within the range of previously-measured concentrations at *test* station ISL-1, with the exception of PAHs, which exceeded previously-measured concentrations except when normalized to %TOC. Concentrations of total arsenic, CCME F3 hydrocarbons, and dibenz(a,h)anthracene exceeded sediment quality guidelines in fall 2013. An SQI was not calculated for *test* station ISL-1 because lakes were not included in regional *baseline* conditions given ecological differences between lakes and rivers.

5.13.3 Shipyard Lake

Monitoring was conducted in Shipyard Lake in fall 2013 for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.3.1 Water Quality

Water quality samples were taken from Shipyard Lake in fall 2013 at *test* station SHL-1 (sampled annually from 1998 to 2013).

Temporal Trends Temporal Trends The following significant trends ($\alpha=0.05$) in fall concentrations of water quality measurement endpoints were detected:

- A decreasing concentration of sulphate (although the fall 2013 value was historically high); and
- Increasing concentrations of chloride, potassium, sodium, and total boron.

2013 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints at *test* station SHL-1 in fall 2013 were within previously-measured concentrations (Table 5.13-12), with the exception of:

- calcium and alkalinity, with concentrations below previously-measured minimum concentrations; and
- pH, sodium, chloride, sulphate, total arsenic, and total boron, with concentrations that exceeded previously-measured maximum concentrations.

Ion Balance The ionic composition of water at *test* station SHL-1 in fall 2013 continued a 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 catchment area.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentration of all measurement endpoints at *test* station SHL-1 in fall 2013 were below published guidelines (Table 5.13-12).

Other Water Quality Guideline Exceedances Concentrations of sulphide, total iron, and total phenols exceeded water quality guidelines in fall 2013 at *test* station SHL-1 (Table 5.13-6).

Classification of Results Concentrations of most water quality measurement endpoints in fall 2013 at *test* station SHL-1 were within previously-measured concentrations, with the exception of some ions and metals. The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the watershed (90% of the Shipyard Lake watershed has been disturbed; see Table 2.5-2). The WQI was not calculated for lakes in 2013 due to potential ecological differences in regional water quality characteristics between lakes and rivers.

5.13.3.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 in Shipyard Lake at depositional *test* station SHL-1 (sampled since 2000).

2013 Habitat Conditions Water in Shipyard Lake was alkaline (pH: 8.3) and had moderate conductivity (~ 360 µS/cm) (Table 5.13-13). The substrate of Shipyard Lake in fall 2013 was primarily composed of silt (62%), with some clay (35%), and a small amount of sand (3%) and relatively high total organic carbon (~15%) (Table 5.13-13).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Shipyard Lake at *test* station SHL-1 in fall 2013 was dominated by chironomids (40%), gastropods (28%), and nematodes (21%) (Table 5.13-14). Dominant chironomids included *Einfeldia*, *Chironomus,* and *Paratanytarsus* all of which are commonly distributed in north temperate regions (Wiederholm 1983). Ephemeroptera (*Caenis*), the damselfly, *Enallagma*, and two caddisfly genera (*Mystacides* and *Polycentropus*) were found at *test* station SHL-1 in 2013. Bivalves (*Pisidium/Sphaerium*) were present and gastropods were well represented and abundant with five species present. Other permanent aquatic forms (amphipods, *Hyalella azteca*) were also present.

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 2013 values and the mean of all previous sampling years.

Abundance, richness, and equitability significantly increased over time, accounting for 20%, 39%, and 20% of the variance in annual means, respectively (Table 5.13-15, Figure 5.13-11).

CA Axis 2 scores significantly decreased over time due to an increase in gastropods, accounting for 25% of the variance in annual means (Table 5.13-15, Figure 5.13-12).

Comparison to Published Literature The benthic invertebrate community of Shipyard Lake contained a fauna in 2013 that was typical for a lake benthic community in the oil sands region (Parsons et al. 2010). The benthic invertebrate community contained several permanent aquatic forms such as fingernail clams (Bivalvia: Sphaeriidae), snails

(Gastropoda), and amphipods (*Hyalella azteca*). Larger flying insects (Ephemeroptera and Trichoptera), which were absent in 2012, were present in 2013 in low relative abundances. The relative abundance of worms was low indicating good aquatic health.

2013 Results Relative to Historical Conditions Mean values of measurement endpoints for benthic invertebrate communities in 2013 were within the inner tolerance limits for the normal range of variation for means from previous years for *test* station SHL-1 (Figure 5.13-11).

Classification of Results Differences in measurement endpoints for benthic invertebrate communities in Shipyard Lake in 2013 were classified as **Negligible-Low**. The significant increases in abundance and taxa richness were strong (explaining > 20% of the total variation in annual means) and implied that the observed changes were not caused by degradation of 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 2013 was sampled in Shipyard Lake (*test* station SHL-1), which has been sampled from 2001 to 2004 and 2006 to 2013, in the same location where sampling for benthic invertebrate communities was conducted.

Temporal Trends Significant increasing trends (α=0.05) in concentrations of sediment quality measurement endpoints from 2001 to 2013 were detected at *test* station SHL-1 in total alkylated PAHs, and F3 and F4 hydrocarbons.

2013 Results Relative to Historical Concentrations Sediments at *test* station SHL-1 in fall 2013 contained a high proportion of silt, and low proportions of clay and sand (Table 5.13-16, Figure 5.13-13). Concentrations of all sediment quality measurement endpoints in fall 2013 were within the range of previously-measured concentrations (Table 5.13-16). Growth of the midge *Chironomus* exceeded the previously-measured maximum value, while survival of the amphipod *Hyalella* was lower than previously measured.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints that exceeded sediment or soil quality guidelines in fall 2013 included total arsenic, F3 hydrocarbons, and the PAHs benz[a]anthracene, benz[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene (Table 5.13-16).

2013 Results Relative Regional *Baseline* Concentrations No comparisons could be made in fall 2013 between Shipyard Lake and regional *baseline* concentrations, given that lakes are not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers

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 In fall 2013, most sediment quality measurement endpoints were within the range of previously-measured concentrations at *test* station SHL-1. Concentrations of total arsenic, F3 hydrocarbons, and several PAHs (benz[a]anthracene, benz[a]pyrene, chrysene, Dibenz(a,h)anthracene, and phenanthrene) exceeded sediment or soil quality guidelines. Increasing trends were apparent for total alkylated PAHs, and F3 and F4 hydrocarbons. SHL-1 was not compared to the regional *baseline* condition due to ecological differences between lakes and rivers.

5.13.4 Poplar Creek and Beaver River

Monitoring was conducted in the Poplar Creek and Beaver River watersheds in 2013 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.4.1 Hydrologic Conditions: 2013 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 WSC Station 07DA018 (RAMP S39), Beaver River above Syncrude. Details for this station can be found in Appendix C.

The 2013 WY was the first year since the 1973 to 1986 monitoring period with continuous annual data collection for RAMP Station S11 (WSC 07DA007). Continuous hydrometric data during the open-water (May to October) period have been collected for RAMP Station S11 (WSC 07DA007) from 1973 to 1986 and from 1996 to 2012. Flows decreased from November 2012 to February 2013, with flows from early December to February exceeding the historical maximum values calculated from 1973 to 1986 (Figure 5.13-16). Flows increased during spring freshet in April and early May to a peak of 10.6 m^3/s on May 9. Following the freshet peak, flows decreased until early June and then increased to above the historical maximum daily flow from June 10 to June 19 due to rainfall events in early to mid-June. The annual peak flow of 21.9 m^3/s on June 12 was 123% higher than the annual historical maximum daily flow. Following this peak, flows steadily decreased until late July, with flows remaining above the historical upper quartile values. Rainfall events in late July increased flows before decreasing again until monitoring ceased on August 19. Flows were observed to be still decreasing when monitoring resumed on September 22 to below the historical lower quartile value in late September. Flows increased in October to above historical median values due to the rainfall events in late September and early October.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph
The 2013 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 2013 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 0.47 million m^3.
2. As of 2013, the area of land change from focal projects in the Poplar Creek watershed that was not closed-circuited was estimated to be 1.9 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 0.06 million m^3.
3. Syncrude reported a total discharge of 50.7 million m^3 of water to Poplar Creek via the Poplar Creek spillway. The discharge from the spillway into Poplar Creek in 2013 was the second highest release since 1984 as reported by Syncrude's annual compliance report to AESRD.

The estimated cumulative effect of oil sands development in the 2013 WY was an increase in flow of 50.3 million m^3 at RAMP Station S11 (WSC 07DA007). The observed *test* and estimated *baseline* hydrographs for Station S11 (WSC 07DA007), Poplar Creek at Highway 63 are presented in Figure 5.13-14. The 2013 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 248%, 77%, 18.6%, and 27.6% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-17). These differences were classified as **High** (Table 5.13-1).

5.13.4.2 Water Quality

In fall 2013, water quality samples were taken from:

- the Beaver River near its mouth (*test* station BER-1), sampled from 2003 to 2013;
- Poplar Creek near its mouth (*test* station POC-1), sampled from 2000 to 2013; and
- the upper Beaver River upstream of all focal project developments (*baseline* station BER-2), sampled from 2008 to 2013.

Monthly water quality sampling was also conducted at *test* station POC-1 in 2013.

The upper Beaver River flows via the Poplar Creek Reservoir to Poplar Creek (i.e., it is hydrologically connected to *test* station POC-1) rather than to the lower Beaver River, where *test* station BER-1 is located. The lower Beaver River was isolated from the upper Beaver River watershed in the early 1970s through the development of Syncrude's Mildred Lake project. The lower Beaver River is downstream of a seepage-collection pond located downstream of the dam of the Mildred Lake tailings facility (seepage collected in this pond is pumped back into the tailings facility).

Temporal Trends There were no statistically significant ($\alpha=0.05$) 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. Trend analyses could not be completed for *baseline* station BER-2 due to an insufficient length of time series data for this station.

2013 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were within previously-measured concentrations at *test* station POC-1 in fall 2013 (Table 5.13-19). Concentrations of water quality measurement endpoints were within the range of previously-measured concentrations at *test* station BER-1 and *baseline* station BER-2, with the following exceptions (Table 5.13-20, Table 5.13-21):

- total suspended solids, calcium, magnesium, sulphate, total aluminum, and total alkalinity, with concentrations that exceeded previously-measured maximum concentrations at *test* station BER-1; and
- dissolved phosphorus and total arsenic, with concentrations that exceeded previously-measured maximum concentrations at *baseline* station BER-2.

Ion Balance The ionic composition of water at *test* stations POC-1, BER-1, and *baseline* station BER-2 have been highly variable across sampling years; however, data from fall 2013 were within the range of historical concentrations (Figure 5.13-15). In 2011 and 2012 there was a greater influence of sodium at *baseline* station BER-2; however, in 2013 the ionic balance exhibited similarities to earlier historical observations.

Comparison of Fall Water Quality Measurement Endpoints to Published Guidelines Concentrations of the following water quality measurement endpoints exceeded water quality guidelines in fall 2013 (Table 5.13-19 to Table 5.13-21):

- total nitrogen and total aluminum at *test* station POC-1;

- total chloride, total aluminum, and total mercury (ultra-trace) at *test* station BER-1; and
- total aluminum, total nitrogen, and dissolved phosphorus at *baseline* station BER-2.

Other Water Quality Guideline Exceedances The following other water quality guideline exceedances were measured in fall 2013 (Table 5.13-6):

- total and dissolved iron, sulphide, and total phenols at *test* station POC-1;
- total chromium, total iron, sulphide, total phosphorus, and total phenols at *test* station BER-1; and
- total and dissolved iron, sulphide, total chromium, total phenols, and total phosphorous at *baseline* station BER-2.

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of several water quality measurement endpoints in fall 2013 at *test* station BER-1 exceeded regional *baseline* concentrations, while only one measurement endpoint at *baseline* station BER-2 and *test* station POC-1 that exceeded regional *baseline* concentrations (Figure 5.13-16):

- chloride, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *test* station POC-1;
- total suspended solids, total dissolved solids, total strontium, calcium, magnesium, sodium, chloride, and sulphate, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations at *test* station BER-1;
- dissolved phosphorus, with a concentration below the 5th percentile of regional *baseline* concentrations at *test* station BER-1; and
- total boron, with a concentration that exceeded the 95th percentile of regional *baseline* concentrations at *baseline* station BER-2.

Water Quality Index The WQI values for fall 2013 for *test* station POC-1 (98.0) and *baseline* station BER-2 (92.4) indicated **Negligible-Low** differences from regional *baseline* concentrations (Table 5.13-7). The WQI value for *test* station BER-1 was 69.4, indicating a **Moderate** difference from regional *baseline* concentrations. Differences from regional *baseline* concentrations can be attributed to high ion concentrations at *test* station BER-1.

Monthly Water Quality Results Water quality sampling was also conducted monthly in 2013 at *test* station POC-1. Generally the highest ion concentrations were observed in December and the highest concentrations of PAHs were found in May (Table 5.13-22).

Monthly Water Quality Guideline Exceedances Water quality guideline exceedances that were measured in 2013 at *test* station POC-1 include (Table 5.13-23):

- total nitrogen in February to April, July to September, and December;
- dissolved iron in February to May and July to December;
- total phosphorus and total chromium in April, May, and July;
- total aluminum in April to October, and December;
- dissolved aluminum in May;
- chloride in December;

- sulphide and total iron for all months; and
- total phenols in all months, with the exception of December.

2013 Monthly Results Relative to Regional *Baseline* Fall Concentrations In 2013 most monthly data collected at *test* station POC-1 were within regional *baseline* fall concentrations, with the following exceptions (Figure 5.13-17):

- total suspended solids, which exceeded the 95th percentile of regional *baseline* fall concentrations in May (yearly maximum);
- total dissolved solids, sodium, and total strontium, which exceeded the 95th percentile of the regional *baseline* fall concentrations in December (yearly maximum);
- dissolved phosphorus, with a concentration below the 5th percentile of regional *baseline* fall concentrations in January (yearly minimum);
- total mercury (ultra-trace), with a concentration below the 5th percentile of regional *baseline* fall concentrations in January and February; and
- chloride, with concentrations that exceeded the 95th percentile of regional *baseline* concentrations in April, September, and December (yearly maximum).

Monthly Ion Balance The ionic composition of water at *test* station POC-1 remained generally consistent across months in 2013 (Figure 5.13-18). Slight differences in seasons were apparent, with generally more chloride dominance from January to April and calcium dominance in the remaining months (e.g., open-water season). The anion composition showed high variability, particularly during September and December where chloride was much more dominant than observed in any other months.

Classification of Fall Results Concentrations of several water quality measurement endpoints, primarily ions, 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 2013 between *test* station POC-1, *baseline* station BER-2 and regional *baseline* conditions were classified as **Negligible-Low**.

Summary of Monthly Results Concentrations of most water quality measurement endpoints exhibited some variability throughout the year at *test* station POC-1, which were more apparent in the ionic composition of water and showed seasonal variability. Generally the highest concentrations of ions and metals occurred in December. Guideline exceedances occurred most frequently in April, May, and July; however, most monthly concentrations of water quality measurement endpoints were within the range of the regional *baseline* fall conditions.

5.13.4.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at:

- depositional *test* reach POC-D1, sampled since 2008; and
- depositional *baseline* reach BER-D2, sampled since 2008. This reach was used as *baseline* for comparison to *test* reach POC-D1.

2013 Habitat Conditions Water at *test* reach POC-D1 in fall 2013 was shallow (0.3 m) and alkaline (pH: 8.5), with high conductivity (459 µS/cm). The substrate was primarily composed of sand (78%), with some silt (16%) (Table 5.13-24).

Water at *baseline* reach BER-D2 in fall 2013 was moderately deep (0.4 m) and weakly alkaline (pH: 7.4), with moderate conductivity (366 µS/cm). The substrate was dominated by sand (87%) (Table 5.13-24).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach POC-D1 was dominated by chironomids (38%) and tubificid worms (22%) (Table 5.13-25). Dominant chironomid genera consisted primarily of Microspectra, Polypedilm, and Paralauterborniella, all of which are common in north-temperate waters (Wiederholm 1983). Ephemeroptera (Caenis, Heptagenia, and Tricorythodes) were present in low relative abundances. Bivalves (Pisidium/Sphaerium) were also noted in low relative abundances.

The benthic invertebrate community at *baseline* reach BER-D2 was dominated by chironomids (44%) and tubificid worms (24%), with subdominant taxa consisting of Ceratopogonidae (5%), nematodes (4%), and naidid worms (4%) (Table 5.13-25). Ephemeroptera (Caenis, Hexagenia limbata, and Leptophlebiidae) and Trichoptera (Phryganeidae) were found in low relative abundances. Dominant chironomid genera consisted of Polypedilum, Phaenopsectra, and Paratanytarsus all of which are common (Wiederholm 1983). A single fingernail clam was found along with the gastropod Gyraulus cooperi in 2013.

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 2008, Hypothesis 1, Section 3.2.3.1); and
- changes in 2013 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 2, Section 3.2.3.1);
- differences between 2013 values and the mean of all available *baseline* data; and
- differences from *baseline* reach BER-D2 in 2013 values.

Abundance was significantly higher at *test* reach POC-D1 compared to *baseline* reach BER-D2, explaining greater than 20% of the variance in annual reach means (Table 5.13-26).

Equitability, the percentage of the fauna as EPT taxa, and CA Axis 1 and 2 scores were significantly higher at *baseline* reach BER-D2 than *test* reach POC-D1 and the percentage of EPT taxa was lower in 2013 than the mean of *baseline* years at BER-D2. These differences explained a relatively large amount (>20%) of variance in annual reach means (Table 5.13-26, Figure 5.13-19). The difference in axis scores was due to a difference in taxa composition between the *baseline* and *test* reaches, with the *baseline* reach containing a community with higher relative abundances of water mites, beetles, and gastropods and a lower relative abundance of tubificid worms (Figure 5.13-20).

Comparison to Published Literature The benthic invertebrate community at *test* reach POC-D1 in fall 2013 was typical for a sand-based creek, with a higher percentage of the fauna as worms (~25%) but also with a high percentage of chironomids (38%) (Table 5.13-25) (Hynes 1960; Griffiths 1998). The benthic invertebrate community at *test* reach POC-D1 also included permanent aquatic forms such as fingernail clams and flying insects (mayflies) but in low relative abundances relative to what might be expected in a baseline condition (e.g., Hynes 1960; Griffiths 1993).

2013 Results Relative to Historical or Baseline Conditions *Test* reach POC-D1 and *baseline* reach BER-D2 have less than eight years of data; therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using regional *baseline* data for depositional reaches. Values of all measurement endpoints for benthic invertebrate communities at *test* reach POC-D1 and *baseline* reach BER-D1 were within the inner tolerance limits of the normal range of variation for means from the regional *baseline* depositional reaches, with the exception of equitability at *test* reach POC-D1 (Figure 5.13-19, Figure 5.13-20). Equitability at *test* reach POC-D1 in 2013 was slightly lower than the inner tolerance limit of the 5th percentile of regional *baseline* conditions (Figure 5.13-19).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* reach POC-Dl were classified as **Moderate** because of the significant and large differences in abundance, equitability, percentage of fauna as EPT taxa, and CA axis scores compared to *baseline* reach BER-D2. Richness and abundance have been decreasing since 2001 at *test* reach POC-D1 and EPT taxa, which were increasing until 2012, have decreased in 2013. The lower equitability, which was outside of the inner tolerance limit for the 5th percentile of regional *baseline* conditions, does not denote a negative change, but suggested that *test* reach POC-D1 was becoming more diverse. The benthic invertebrate community at *test* reach POC-D1 was typical of a sand-bottom creek and dominated by worms and chironomids.

Sediment Quality

Sediment quality was sampled in fall 2013, in the same locations as benthic invertebrate communities, at:

- *test* station POC-D1 (sampled in 1997, 2002, 2004, and 2008 to 2013); and
- *baseline* station BER-D2 (sampled from 2008 to 2013).

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station POC-D1 in fall 2013, with the exception of an increasing PAH hazard index value. Trend analysis could not be conducted for *baseline* station BER-D2 due to the insufficient data record for this station (n=6).

2013 Results Relative to Historical Concentrations Sediment at *test* station POC-D1 was dominated by sand in fall 2013 (Table 5.13-27, Figure 5.13-21). Sediment at *baseline* station BER-D2 was dominated by sand, with a higher proportion of sand and lower proportion of silt than previously observed at this station (Table 5.13-28, Figure 5.13-22). Total organic carbon was within the range of previously-measured concentrations at *test* station POC-D1 and *baseline* station BER-D2. Concentrations of all measured total hydrocarbon fractions, with the exception of F3 and F4 hydrocarbons, were undetectable in sediments collected in fall 2013 at both stations (Table 5.13-27, Table 5.13-28). 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 at *baseline* station BER-D2, which was lower than the previously-measured minimum concentration. The predicted PAH toxicity value was within the range of previously-measured values at both stations.

Direct tests of sediment toxicity to invertebrates at *test* station POC-D1 and *baseline* station BER-D2 showed higher growth and lower survival in 2013 for the midge *Chironomus* compared to the range of previously-measured values (Table 5.13-27, Table 5.13-28). The 14-day growth of the amphipod *Hyalella* was higher at *baseline* station BER-D2 than previously measured (Table 5.13-28).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Sediment quality measurement endpoints with concentrations that exceeded sediment quality guidelines in fall 2013 at *test* station POC-D1 included chrysene, F3 hydrocarbons, and predicted PAH toxicity (Hazard Index) of sediments, which exceeded the potential effect threshold of 1.0 (Table 5.13-27).

2013 Results Relative Regional *Baseline* Concentrations In fall 2013, concentrations of total PAHs normalized to 1% TOC exceeded the 95th percentile of regional *baseline* concentrations at *test* station POC-D1 (Figure 5.13-21). Concentrations of all sediment quality measurement endpoints were within the range of regional *baseline* concentrations at *baseline* station BER-D2 (Figure 5.13-22).

Sediment Quality Index The SQI values for *test* station POC-D1 and b*aseline* station BER-D2 were 89.0 and 98.9, respectively (Table 5.13-29) indicating **Negligible-Low** differences in sediment quality conditions compared to regional *baseline* conditions.

Classification of Results Differences in sediment quality observed in fall 2013 between *test* station POC-D1, *baseline* station BER-D2, and regional *baseline* conditions were classified as **Negligible-Low** with nearly all sediment quality measurement endpoints falling within the range of previously-measured concentrations. Some sediment and soil quality guidelines were exceeded at *test* station POC-D1, including chrysene and F3 hydrocarbons.

5.13.4.4 Fish Populations

Fish assemblages were sampled in fall 2013 at:

- depositional *test* reach POC-F1, also sampled in 2009, 2011, and 2012 (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, 2011, and 2012 (this reach is in the same location as the benthic invertebrate community *baseline* reach BER-D2).

2013 Habitat Conditions *Test* reach POC-F1 was comprised of riffle and run habitat with a wetted width of 10.1 m and a bankfull width of 11.4 m (Table 5.13-30). The substrate consisted of a mixture of cobble and sand. Water at *test* reach POC-F1 in fall 2013 had a mean depth of 0.23 m, a slow velocity (0.10 m/s), was slightly alkaline (pH: 8.34), with high conductivity (600 µS/cm), high dissolved oxygen (9.4 mg/L), and a temperature of 13.6˚C (Table 5.13-30). Instream cover was dominated by boulders, with smaller amounts of algae and small woody debris (Table 5.13-30).

Baseline reach BER-F2 was comprised of run habitat, with a wetted width of 5.7 m and a bankfull width of 10.9 m (Table 5.13-30). The substrate consisted almost entirely of sand with some cobble. Water at *baseline* reach BER-F2 had a mean depth of 0.12 m, a moderate velocity (0.33 m/s), was slightly alkaline (pH: 7.87), with moderate conductivity (369 µS/cm), moderate to high dissolved oxygen (8.4 mg/L), and a temperature of 18.3°C. Instream cover was dominated by small woody debris with some large woody debris and undercut banks (Table 5.13-30).

Relative Abundance of Fish Species The abundance of fish species at *test* reach POC-F1 was higher than previous sampling years and dominated by lake chub (nearly 50% of the total catch) (Table 5.13-31). Burbot were captured at *test* reach POC-F1 for the first time in fall 2013 and comprised nearly 25% of the total catch (Table 5.13-31). Burbot were common near the mouths of many of the tributaries to the Athabasca River in fall 2013 and were caught in numbers not previously seen during the RAMP program. The increase in catch in fall 2013 was primarily due to the shift in reach location to an area of the river that had suitable fish habitat and a water depth that was wadeable. In previous years, fish sampling was conducted in deeper waters where the capture efficiency was lower.

The abundance of fish also increased at *baseline* reach BER-F2, with nearly twice as many fish in 2013 compared to 2012 (Table 5.13-31), likely due to a decrease in water depth, thereby increasing the wadeable area of the river. Consistent with previous sampling years, total catch was dominated by lake chub, brook stickleback, and fathead minnow (Table 5.13-31).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach POC-F1 included testing for changes over time in measurement endpoints (2009 to 2013, Hypothesis 1, Section 3.2.4.4). Spatial comparisons for *test* reach POC-F1 included testing for differences from *baseline* reach BER-F2 over time (Hypothesis 2, Section 3.2.4.4).

There were significant increases in richness (p=0.002), diversity (p=0.027), and total CPUE (p=0.045) over time at *test* reach POC-F1, explaining greater than 20% in the variance of annual means (Table 5.13-32, Table 5.13-33). As a result of the high proportion of burbot, which is considered a sensitive species, the assemblage tolerance index at *test* reach POC-F1 was also the lowest recorded (Table 5.13-32) but showed no significant trend over time. There was a slight decrease in species richness and an increase in ATI at *baseline* reach BER-F2 in 2013 compared to 2012 (Table 5.13-32).

There were no significant differences in any measurement endpoints between *test* reach POC-F1 and *baseline* reach BER-F2 (Table 5.13-33).

Comparison to Published Literature Golder (2004) summarized results of historical fish inventory studies conducted within watersheds of the 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. After four sampling events across five years, 13 fish species have been documented by RAMP in Poplar Creek, including two small-bodied species and one sportfish species (walleye) not previously recorded in Golder (2004). A total of nine species have been found at *baseline* reach BER-F2 over the same period, including three small-bodied species not previously recorded. The higher species richness in studies cited in Golder (2004) were from multi-season sampling events using a variety of fishing techniques that were able to capture fish in all lifestages compared to the backpack electrofishing method used by RAMP that targets smaller fish. A comparison of the RAMP results to one of the intensive studies (Golder 2004) found that the species composition documented by RAMP was similar to that found in previous studies using similar methodology.

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 was located, was documented as limited for feeding and overwintering activities (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 and sand substrate (Golder 2004). Habitat of the upper Beaver River where *baseline* reach BER-F2 is located was characterized as having low habitat diversity and poor fish habitat (Golder 2004).

2013 Results Relative to Regional *Baseline* Conditions The mean value of ATI at *test* reach POC-F1 was below the inner tolerance limit of the 5th percentile and diversity was higher than the inner tolerance limit for the 95th percentile of the normal range of depositional *baseline* conditions, respectively (Figure 5.13-23). Mean values of all measurement endpoints at *baseline* reach BER-F2 were within the normal range of depositional *baseline* conditions (Figure 5.13-23).

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach POC-F1 were classified as **Negligible-Low** because the significant increases in richness, diversity, CPUE were not indicative of a negative change in the fish assemblage. In addition, the lower ATI value and the higher diversity compared to the range of regional *baseline* variability indicated that the fish assemblage had a greater number of species and a greater proportion of more sensitive species (e.g., burbot).

5.13.5 McLean Creek

Monitoring was conducted in the McLean Creek watershed in 2013 for the Water Quality component.

5.13.5.1 Water Quality

Water quality samples were collected in fall 2013 near the mouth of McLean Creek at *test* station MCC-1 (sampled from 1999 to 2013).

Temporal Trends There were no significant trends (α=0.05) observed at *test* station MCC-1 from 1997 to 2013. However, since 2009, concentrations of total dissolved solids and several ions and dissolved metals (e.g., strontium and boron) have shown consistent year-to-year increases.

2013 Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints at *test* station MCC-1 in fall 2013 were within previously-measured concentrations, with the exception of dissolved aluminum and total molybdenum, with concentrations that exceeded previously-measured maximum concentrations (Table 5.13-34).

Ion Balance The ionic composition of water at *test* station MCC-1 in fall 2013 was in similar proportions to values measured in previous years and dominated by calcium bicarbonate (Figure 5.13-24).

Comparison of Water Quality Measurement Endpoints to Published Guidelines All measurement endpoints were within water quality guidelines at *test* station MCC-1 in fall 2013, with the exception of total aluminum (Table 5.13-34).

Other Water Quality Guideline Exceedances Concentrations of total iron, sulphide, total phosphorus, and total phenols exceeded relevant water quality guidelines at *test* station MCC-1 in fall 2013 (Table 5.13-6).

2013 Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints that exceeded the 95th percentile of regional *baseline* concentrations at *test* station MCC-1 in fall 2013 included total dissolved solids, sodium, and chloride (Figure 5.13-25).

Water Quality Index The WQI value of 94.8 for *test* station MCC-1 in fall 2013 indicated **Negligible-Low** differences from regional *baseline* conditions (Table 5.13-7).

Classification of Results Concentrations of water quality measurement endpoints at *test* station MCC-1 were generally within the regional *baseline* concentrations, and within the range of previously-measured concentrations in fall 2013. The Water Quality Index value indicated **Negligible-Low** differences between *test* station MCC-1 and regional *baseline* concentrations. Despite generally being within regional *baseline* variability, fall concentrations of total dissolved solids and several ions have shown consistent increases since 2009.

5.13.6 Fort Creek

Monitoring was conducted in the Fort Creek watershed in 2013 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components.

5.13.6.1 Hydrologic Conditions: 2013 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 in 2013.

Hydrometric data have been collected during the open-water period (May to October) at RAMP Station S12 from 2000 to 2001 and 2006 to 2013. The 2013 WY open-water runoff volume was 2.87 million m^3, which was 100% higher than the historical mean open-water runoff volume of 1.44 million m^3. Flows increased after monitoring began on April 29 to a peak of 0.504 m^3/s on May 5, and then decreased steadily until early June (Figure 5.13-25). Flows then increased in response to rainfall events in mid-June, reaching a maximum open-water daily flow of 0.671 m^3/s on June 11. This value was 55% higher than the historical mean open-water maximum daily flow of 0.432 m^3/s. Following this peak, flows decreased through July and August until the lowest open-water flow of 0.027 m^3/s on September 16, which was 23% higher than the historical mean open-water minimum daily flow. Flows increased again in response to rainfall events in late September and early October, with values from early to mid-October were similar to the historical maximum values.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at RAMP Station S12 is presented in Table 5.13-35 and described below:

1. The closed-circuited land area from focal projects as of 2013 in the Fort Creek watershed was estimated to be 17.9 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 0.989 million m^3.
2. As of 2013, the area of land change from focal projects in the Fort Creek watershed that was not closed-circuited was estimated to be 36.7 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 0.405 million m^3.

The estimated cumulative effect of oil sands development in the 2013 WY was a loss of flow of 0.584 million m^3 to Fort Creek. The resulting observed *test* and estimated *baseline* hydrographs are presented in Figure 5.13-25. The 2013 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum daily discharge were 16.6% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.13-36). These differences were classified as **High** (Table 5.13-1). The difference in measurement endpoint values between the 2013 WY and previous years was due to the updated watershed areas (see Appendix C) and changes in land disturbance from focal project activities. In addition to changes in flow volume, variability in daily flow has also increased due to focal project activity in the watershed.

5.13.6.2 Water Quality

In fall 2013, water quality samples were taken from the mouth of Fort Creek at *test* station FOC-1 (sampled intermittently from 2000 to 2013, designated as *baseline* until 2003).

Temporal Trends The following significant temporal trends (α=0.05) in concentrations of water quality measurement endpoints were detected at *test* station FOC-1 from 2000 to 2013:

- Decreasing concentrations of total dissolved phosphorus, total nitrogen, and total arsenic; and
- Increasing concentrations of calcium, magnesium, potassium, sulphate, and total dissolved solids.

2013 Results Relative to Historical Concentrations In fall 2013, concentrations of water quality measurement endpoints were within previously-measured concentrations with the exception of (Table 5.13-37):

- conductivity, calcium, magnesium, sulphate, total dissolved solids, and total strontium, with concentrations that exceeded previously-measured maximum concentrations; and
- total arsenic, with a concentration below the previously-measured minimum concentration.

Ion Balance The ionic composition of water at *test* station FOC-1 in fall 2013 showed a continued shift over time towards a greater influence of sulphate, with no changes in cation composition (Figure 5.13-24).

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 2013 (Table 5.13-37).

Other Water Quality Guideline Exceedances The concentration of total iron exceeded the water quality guideline at *test* station FOC-1 in fall 2013 (Table 5.13-6).

2013 Results Relative to Regional *Baseline* Concentrations In fall 2013, 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, total strontium, calcium, magnesium, potassium, and sulphate , with concentrations that exceeded the 95th percentile of regional *baseline* concentrations; and
- total nitrogen, total mercury (ultra-trace), and total arsenic, with concentrations below the 5th percentile of regional *baseline* concentrations.

Water Quality Index The WQI value for *test* station FOC-1 (76.4) indicated **Moderate** differences from regional *baseline* water quality conditions in fall 2013 (Table 5.13-7).

Classification of Results Differences in water quality in fall 2013 between *test* station FOC-1 and regional *baseline* conditions were classified as **Moderate**. Relatively high concentrations of several water quality measurement endpoints, primarily ions, were observed in fall 2013. Many of these measurement endpoints were outside of the range of previously-measured concentrations and contributed to the lower WQI value observed in 2013.

5.13.6.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2013 at depositional *test* reach FOC-D1 (designated as *baseline* from 2001 to 2003 and *test* from 2004 to 2012).

2013 Habitat Conditions Water at *test* reach FOC-D1 in fall 2013 was alkaline (pH: 8.4), with high dissolved oxygen (9.9 mg/L), high conductivity (673 µS/cm), a shallow depth (0.2 m), and slow velocity (0.21 m/s) (Table 5.13-38). The substrate was dominated by sand (95%), with low amounts of organic carbon (2.7%) (Table 5.13-38).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach FOC-Dl was dominated by chironomids (55%), with subdominant taxa consisting of tubificid worms (23%) and Diptera (14%) (Table 5.13-39). Gastropods were present in low abundances (Table 5.13-39). A small number of flying insects (Ephemeroptera: *Baetis*, and Trichoptera: *Apatania, Brachycentrus*) were present at *test* reach FOC-D1 in 2013. Chironomids were diverse and primarily consisted of *Microspectra/Tanytarsus* and *Parametriocnemus* (Table 5.13-39).

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 1, Section 3.2.3.1);
- changes over time during the *test* period (i.e., since 2002, Hypothesis 2, Section 3.2.3.1);
- changes between 2013 values and the mean of all *baseline* years (2001 to 2003); and
- changes between 2013 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, accounting for >20% of the variance in annual means (Table 5.13-40).

Richness and CA Axis 2 scores were significantly higher in 2013 than the mean of previous years during the *test* period, explaining 23%and 50% of the variance in annual means, respectively (Table 5.13-40). Changes in CA Axis 2 scores reflected higher relative abundances of mayflies and caddisflies, and a somewhat lower relative abundance of chironomids relative to what was observed in previous years (Figure 5.13-28).

Equitability was higher during the *test* period explaining a large portion of the variance in annual means (24%) (Table 5.13-40).

Comparison to Published Literature The benthic invertebrate community at *test* reach FOC-D1 was typical of a sandy-bottomed river and represented by low diversity and high relative abundance of chironomids and tubificid worms (64% and 17%, respectively). Flying insects (mayflies, caddisflies) were sparse, which is typical of sandy-bottomed rivers. An individual gastropod was the only permanent (non-worm) aquatic form found at this reach. Diversity and richness have been increasing over the past three years (Figure 5.13-28; 2011 to 2013) while the percentage of the fauna as EPT taxa has been decreasing over the past three years.

2013 Results Relative to Historical or *Baseline* Conditions *Test* reach FOC-D1 has more than eight years of data (2001 to 2013); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* conditions were evaluated. Mean values of richness and CA Axis 2 scores were outside the inner tolerance limits for the normal range of variation for means from previous years at *test* reach FOC-D1 (Figure 5.13-27, Figure 5.13-28).

When compared to regional *baseline* conditions, richness and CA Axis 2 scores were within the normal range of variability. The number of taxa observed across regional *baseline* depositional reaches varied between six and 20 taxa and richness at *test* reach FOC-D1 in 2013 was 14 taxa.

Classification of Results Differences in measurement endpoints of benthic invertebrate communities at *test* reach FOC-Dl were classified as **Negligible-Low** because the higher richness and CA Axis 2 scores in 2013 compared to previous years were not indicative of degradation and abundance and diversity (i.e., equitability) have been increasing over the last three years and the number of EPT taxa was generally higher in more recent years compared to the *baseline* period (Figure 5.13-28). The increase in CA Axis 2 scores reflected higher relative abundances of mayflies and caddisflies, which was also consistent with improved conditions.

Sediment Quality

Sediment quality was sampled in fall 2013 at *test* station FOC-D1 in the same location as the benthic invertebrate communities were collected. *Test* reach FOC-D1 was designated as *baseline* in 2000 and 2002 and as *test* from 2006 to 2008 and 2010 to 2013.

Temporal Trends No significant trends (α=0.05) in concentrations of sediment quality measurement endpoints were detected for *test* station FOC-D1 in fall 2013, with the exception of decreasing trends in concentrations of total metals and total arsenic.

2013 Results Relative to Historical Concentrations Sediments at *test* station FOC-D1 were dominated by sand, with sand, silt, and clay proportions all within the range of previously-measured values (Table 5.13-41). Concentrations of low-molecular-weight hydrocarbons (F1+BTEX) were below detection limits at *test* station FOC-D1 in fall 2013, while concentrations of heavier F3 and F4 hydrocarbons exceeded previously-measured maximum concentrations. Total PAHs at *test* station FOC-D1 were comprised almost exclusively of alkylated species, indicating a petrogenic origin of these compounds. Total metals and total PAHs were within the range of previously-measured concentrations (Table 5.13-41).

Direct tests of sediment toxicity to invertebrates at *test* station FOC-D1 showed higher growth and lower survival of the midge *Chironomus* than previously measured. Survival and growth for the amphipod *Hyalella* were within previously-measured values (Table 5.13-41).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines In fall 2013, concentrations of all sediment quality measurement endpoints at *test* station FOC-D1 were within sediment quality guidelines, with the exception of F3 hydrocarbons, dibenz(a,h)anthracene, and chrysene (Table 5.13-41).

2013 Results Relative Regional *Baseline* Concentrations In fall 2013, total PAHs normalized to 1% TOC exceeded the 95th percentile of regional *baseline* concentration at *test* station FOC-D1. All other sediment quality measurement endpoints were within the range of regional *baseline* concentrations, including the concentration of total PAHs before being carbon normalized (Figure 5.13-29).

Sediment Quality Index A SQI value of 89.7 was calculated for *test* station FOC-D1 for fall 2013 indicating **Negligible-Low** differences from regional *baseline* conditions (Table 5.13-7). The SQI values for *test* station FOC-D1 have been variable since sediment quality monitoring began in 2000, ranging from 59.8 to 100 (n=9).

Classification of Results Differences in sediment quality observed in fall 2013 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.

5.13.6.4 Fish Populations

Fish assemblages were sampled in fall 2013 at depositional *test* reach FOC-F1, which was sampled for the first time in 2011 and is at the same location as benthic invertebrate community *test* reach FOC-D1.

2013 Habitat Conditions *Test* reach FOC-F1 was comprised of run and riffle habitat, with a wetted width of 1.7 m and a bankfull width of 4.0 m (Table 5.13-42). The substrate was dominated entirely by sand and fine gravel. Water at *test* reach FOC-F1 in fall 2013 had a mean depth of 0.24 m, with a slow velocity (0.18 m/s), was alkaline (pH: 8.36), with high conductivity (673 µ/cm), high dissolved oxygen (9.75 mg/L), and a temperature of 10.3˚C. Instream cover consisted of large woody debris with small portions of small woody debris (Table 5.13-42).

Relative Abundance of Fish Species The abundance of fish species at *test* reach FOC-F1 decreased from previous years and was dominated by burbot, comprising over 60% of the catch; burbot have not been documented in previous years (Table 5.13-43). The large abundance of burbot was comparable to other reaches located near the confluence to the Athabasca River in 2013 (e.g., Tar River, Pierre River, Eymundson Creek, etc.). With the exception of burbot as well as the presence of juvenile northern pike, the fish species composition in Fort Creek in 2013 was similar to previous sampling years (Table 5.13-43).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach FOC-F1 included testing for changes over time in measurement endpoints (2011 to 2013, Hypothesis 1, Section 3.2.4.4). There was no upstream *baseline* reach to make spatial comparisons to *test* reach FOC-F1.

There were significant decreases in abundance (p=0.010) and ATI (p=0.004) at *test* reach FOC-F1 (Table 5.13-44, Table 5.13-45). The decrease in the ATI value was indicative of the presence of more sensitive species including the large proportion of burbot captured in 2013.

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 documented in Fort Creek. Between 2011 and 2013, RAMP found a total of 13 species and has captured all but one species (spoonhead sculpin) that have been found in previous studies (Golder 2004). The increase in the number of fish species documented by RAMP was likely the result of increased fishing effort by RAMP at *test* reach FOC-F1. The methods reported in Golder (2004) for Fort Creek were similar to those for RAMP with respect to sampling method (backpack electrofishing) and fishing effort (1,212 seconds in one study); however, RAMP has sampled across multiple years whereas previous surveys are typically for only one year.

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.

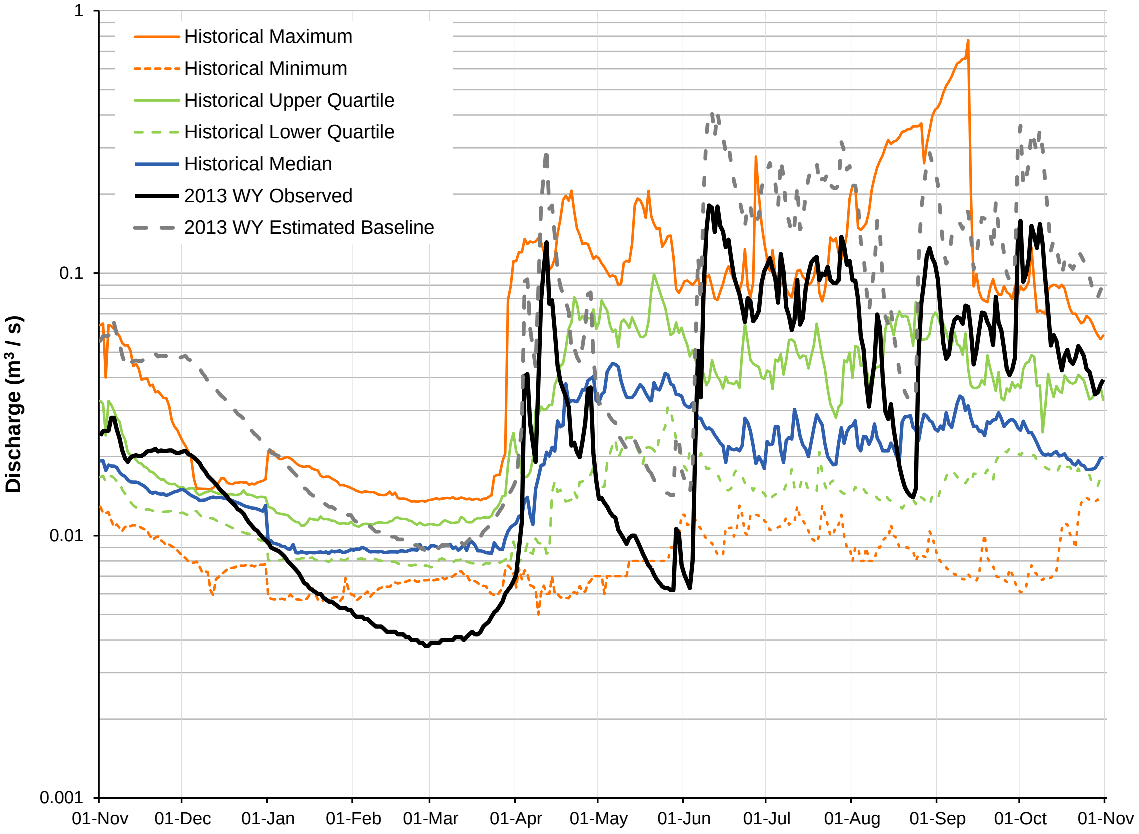
2013 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints in fall 2013 at *test* reach FOC-F1 were within the normal range of depositional *baseline* conditions, with the exception of the ATI value, which was below the outer tolerance limit for the 5th percentile of regional *baseline* conditions (Figure 5.13-30). The decrease in ATI; however, was not in a direction of a negative change in the fish assemblage given a lower ATI was reflective of a greater proportion of sensitive fish species present.

Classification of Results Differences in measurement endpoints of the fish assemblage at *test* reach FOC-F1 were classified as **Moderate** because there was a significant decrease in abundance, which could be indicative of a potential negative change in the fish assemblage. In addition, there were also decreases, although not statistically significant, in CPUE, richness, and diversity. The ATI value was lower than the regional range of *baseline* variability; however, which indicated a greater proportion of sensitive fish species in 2013 compared to previous years.

5.13.7 Susan Lake Outlet

Monitoring was conducted at the Susan Lake outlet in 2012 for the Climate and Hydrology component. Due to equipment malfunctions, water level data were not collected between May 5 and July 11, 2013; therefore, a hydrograph was not completed for this station. Details for this station can be found in Appendix C.

Figure 5.13-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Mills Creek in the 2013 WY, compared to historical values.



Note: Based on the provisional 2013 WY data from Mills Creek at Highway 63, S6. Historical values from May to October were calculated from data collected from 1997 to 2012 and from 2006 to 2012 for other months. The upstream drainage area is 9 km².

Note: The closed-circuited land area from focal projects as of 2013 in the Mills Creek watershed was estimated to be 5.6 km², which was more than 60% of the entire Mills creek watershed (9 km²). This resulted in a loss of flow to Mills Creek that would have otherwise occurred from this land area, and resulted in estimated *baseline* values to be higher than the observed values for a number of days in the 2013 WY.

Table 5.13-2 Estimated water balance at Station S6, Mills Creek at Highway 63, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**1.252**	**Observed discharge, obtained from Mills Creek at Highway 63, RAMP Station S6**
Closed-circuited area water loss from the observed *test* hydrograph	-1.784	Estimated 5.6 km^2 of the Mills Creek watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.156	Estimated 2.4 km^2 of the Mills Creek watershed with land change from focal projects as of 2013, 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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**2.879**	**Estimated *baseline* discharge at RAMP Station S6, Mills Creek at Highway 63**
Incremental flow (change in total discharge)	-1.628	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**-56.5%**	**Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph**

Note: Definitions and assumptions were discussed in Section 3.2.1.4.

Note: The observed discharge volume was calculated from 2013 WY provisional data for Mills Creek at Highway 63, RAMP Station S6.

Note: Approximately 1.06 km² land downstream of S6 was closed-circuited, and this area was not included in the loss of flow estimation to Mills Creek.

Table 5.13-3 Calculated change in hydrologic measurement endpoints for the Mills Creek watershed, 2013 WY.

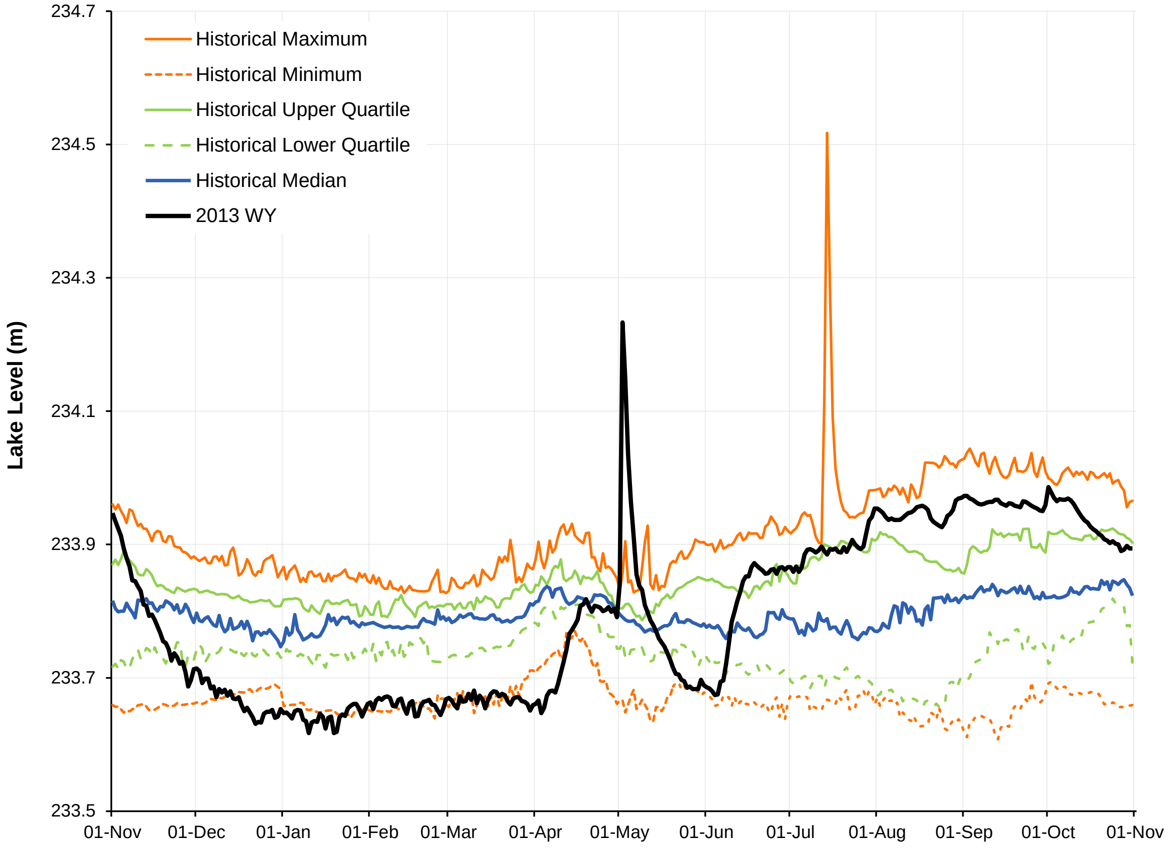
Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.147	0.064	-56.5%
Mean winter discharge	0.024	0.011	-56.5%
Annual maximum daily discharge	0.416	0.181	-56.5%
Open-water season minimum daily discharge	0.014	0.006	-56.5%

Note: Values were calculated from 2013 WY provisional data for Mills Creek at Highway 63, RAMP Station S6.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values 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.

Figure 5.13-4 **Observed water level for Isadore's Lake for the 2013 WY, compared to historical values.**



Note: Based on provisional 2013 WY data recorded at Isadore's Lake, RAMP Station L3. Historical values were calculated for the period of 2000 to 2012.

Table 5.13-4 Concentrations of water quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	11	7.7	8.2	8.3
Total suspended solids	mg/L	-	7.0	11	<3.0	6.0	10
Conductivity	µS/cm	-	769	11	353	553	672
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.010	11	0.003	0.007	**0.067**
Total nitrogen	mg/L	1	0.701	11	0.300	**1.08**	**1.25**
Nitrate+nitrite	mg/L	3	<0.071	11	<0.050	<0.100	0.300
Dissolved organic carbon	mg/L	-	9.90	11	8.00	11.0	12.9
Ions							
Sodium	mg/L	-	16.4	11	6.00	11.0	13.0
Calcium	mg/L	-	90.4	11	37.0	60.2	85.4
Magnesium	mg/L	-	33.3	11	25.0	29.2	36.0
Chloride	mg/L	120	35.2	11	4.0	16.0	23.3
Sulphate	mg/L	410	243	11	63.9	109	148
Total dissolved solids	mg/L	-	591	11	250	375	456
Total alkalinity	mg/L		116	11	122	158	227
Selected metals							
Total aluminum	mg/L	0.1	0.076	11	0.006	0.017	**0.182**
Dissolved aluminum	mg/L	0.1	0.003	11	<0.001	<0.001	0.020
Total arsenic	mg/L	0.005	0.00058	11	0.00046	0.00078	0.00116
Total boron	mg/L	1.2	0.061	11	0.035	0.043	0.055
Total molybdenum	mg/L	0.073	<0.00010	11	<0.00001	0.00010	0.00013
Total mercury (ultra-trace)	ng/L	5, 13	0.53	9	1.0	<1.2	1.6
Total strontium	mg/L	-	0.319	11	0.162	0.233	0.277
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.45	2	0.07	0.10	0.13
Oilsands Extractable	mg/L	-	0.67	2	0.38	0.84	1.29
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	0.717	2	<0.509	<1.290	<2.071
Total dibenzothiophenes	ng/L	-	8.089	2	6.020	20.74	35.45
Total PAHs	ng/L	-	107.2	2	176.7	242.4	308.2
Total Parent PAHs	ng/L	-	23.37	2	18.04	19.90	21.75
Total Alkylated PAHs	ng/L	-	83.88	2	155.0	222.5	290.1
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.004	**0.0511**	11	<0.002	**0.0080**	**0.0878**
Total phenols	mg/L	0.004	**0.0052**	11	<0.001	**0.0050**	**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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	2010-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.06	3	8.13	8.14	8.19
Total suspended solids	mg/L	-	<3.0	3	<3.0	<3.0	5.0
Conductivity	µS/cm	-	1,290	3	859	898	910
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.002	3	<0.001	0.001	0.005
Total nitrogen	mg/L	1	0.281	3	0.301	0.301	0.451
Nitrate+nitrite	mg/L	3	<0.071	3	<0.071	<0.071	<0.071
Dissolved organic carbon	mg/L	-	7.20	3	6.40	7.20	8.40
Ions							
Sodium	mg/L	-	14.8	3	9.30	9.40	10.5
Calcium	mg/L	-	235	3	135	138	139
Magnesium	mg/L	-	52.1	3	33.4	35.9	36.1
Chloride	mg/L	120	50.2	3	19.4	21.1	21.2
Sulphate	mg/L	410	**443**	3	169	192	212
Total dissolved solids	mg/L	-	1,020	3	598	607	617
Total alkalinity	mg/L		246	3	254	277	313
Selected metals							
Total aluminum	mg/L	0.1	0.0036	3	<0.0030	0.0043	0.0107
Dissolved aluminum	mg/L	0.1	0.0013	3	<0.0010	<0.0010	0.0024
Total arsenic	mg/L	0.005	0.00030	3	0.00029	0.00031	0.00037
Total boron	mg/L	1.2	0.0532	3	0.0360	0.0419	0.0489
Total molybdenum	mg/L	0.073	<0.0001	3	<0.0001	<0.0001	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13	0.36	3	<0.60	0.60	0.60
Total strontium	mg/L	-	0.483	3	0.299	0.318	0.392
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.51	2	0.06	0.07	0.07
Oilsands Extractable	mg/L	-	0.94	2	0.32	0.82	0.82
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.76	<11.44	<14.13
Retene	ng/L	-	<0.669	2	<0.51	<1.29	<2.07
Total dibenzothiophenes	ng/L	-	6.672	2	6.814	21.06	35.303
Total PAHs	ng/L	-	102.5	2	177.753	191.7	205.739
Total Parent PAHs	ng/L	-	22.44	2	16.406	20.29	24.182
Total Alkylated PAHs	ng/L	-	80.05	2	153.571	171.5	189.333
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.321**	3	**0.321**	**0.520**	**1.04**
Total Sulphide	mg/L	0.002	**0.0033**	3	<0.0020	<0.0020	<0.0020

[a] Sources for all guidelines are outlined in Table 3.2-5

Values in **bold** are above the guideline; underlined values are outside of historical range.

Figure 5.13-5 Piper diagram of fall ion balance in Isadore's Lake, Mills Creek, and Shipyard Lake.

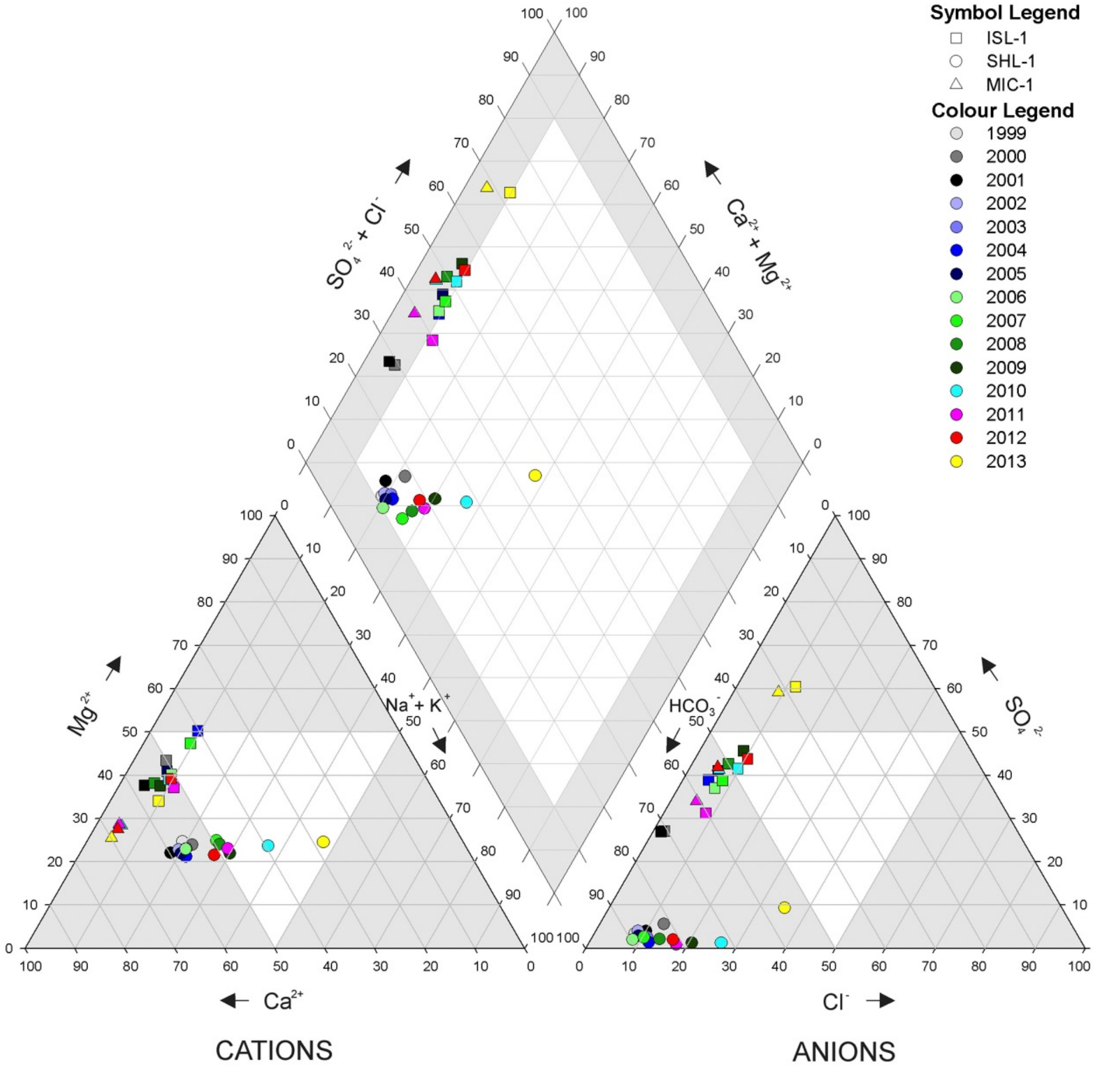


Table 5.13-6 Water quality guideline exceedances at *test* station BER-1, *baseline* station BER-2, *test* station POC-1, *test* station MCC-1, *test* station ISL-1, *test* station SHL-1, *test* station MIC-1, and *test* station FOC-1, fall 2013.

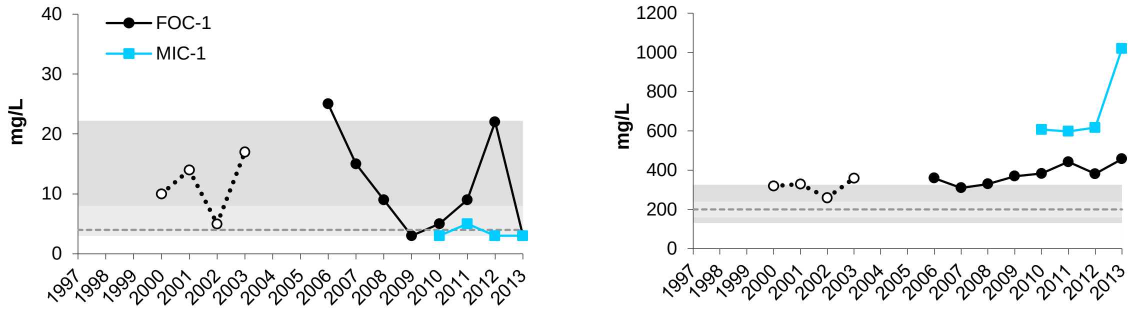
Variable	Units	Guideline[a]	POC-1	BER-1	BER-2	MCC-1	ISL-1	SHL-1	MIC-1	FOC-1
Winter										
Dissolved iron	mg/L	0.3	0.658	ns	ns	ns	ns	ns	ns	ns
Sulphide	mg/L	0.002	0.004	ns	ns	ns	ns	ns	ns	ns
Total iron	mg/L	0.3	0.800	ns	ns	ns	ns	ns	ns	ns
Total nitrogen	mg/L	1	1.04	ns	ns	ns	ns	ns	ns	ns
Total phenols	mg/L	0.004	0.006	ns	ns	ns	ns	ns	ns	ns
Spring										
Dissolved iron	mg/L	0.3	0.465	ns	ns	ns	ns	ns	ns	ns
Sulphide	mg/L	0.002	0.015	ns	ns	ns	ns	ns	ns	ns
Total aluminum	mg/L	0.1	3.99	ns	ns	ns	ns	ns	ns	ns
Total chromium	mg/L	0.001	0.004	ns	ns	ns	ns	ns	ns	ns
Total iron	mg/L	0.3	2.62	ns	ns	ns	ns	ns	ns	ns
Total phenols	mg/L	0.004	0.006	ns	ns	ns	ns	ns	ns	ns
Total phosphorus	mg/L	0.05	0.087	ns	ns	ns	ns	ns	ns	ns
Summer										
Dissolved iron	mg/L	0.3	0.492	ns	ns	ns	ns	ns	ns	ns
Sulphide	mg/L	0.002	0.020	ns	ns	ns	ns	ns	ns	ns
Total aluminum	mg/L	0.1	1.17	ns	ns	ns	ns	ns	ns	ns
Total chromium	mg/L	0.001	0.0012	ns	ns	ns	ns	ns	ns	ns
Total iron	mg/L	0.3	1.14	ns	ns	ns	ns	ns	ns	ns
Total nitrogen	mg/L	1	1.40	ns	ns	ns	ns	ns	ns	ns
Total phenols	mg/L	0.004	0.010	ns	ns	ns	ns	ns	ns	ns
Total phosphorus	mg/L	0.05	0.0501	ns	ns	ns	ns	ns	ns	ns
Fall										
Chloride	mg/L	120	-	189	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	0.93	-	1.70	-	-	-	-	-
Sulphate	mg/L	410	-	-	-	-	-	-	443	-
Sulphide	mg/L	0.002	0.0079	0.004	0.0115	0.0040	0.051	0.0043	0.0033	-
Total aluminum	mg/L	0.1	0.24	5.32	0.95	0.65	-	-	-	-
Total chromium	mg/L	0.001	-	0.0038	0.0010	-	-	-	-	-
Total iron	mg/L	0.3	1.37	5.56	2.89	0.65	-	0.51	0.32	0.54
Total mercury	ug/L	5	-	6.19	-	-	-	-	-	-
Total nitrogen	mg/L	1	1.05	-	1.021	-	-	-	-	-
Total phenols	mg/L	0.004	0.0086	0.0052	0.0070	0.0070	0.0052	0.0087	-	-
Total phosphorus	mg/L	0.05	-	0.1400	0.1710	0.0554	-	-	-	-

[a] Sources for all guidelines are outlined in Table 3.2-5.

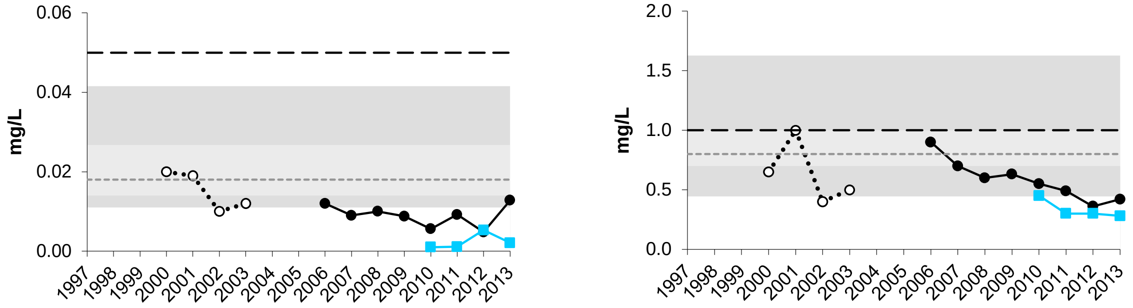
Underline denotes *baseline* station.

ns = not sampled

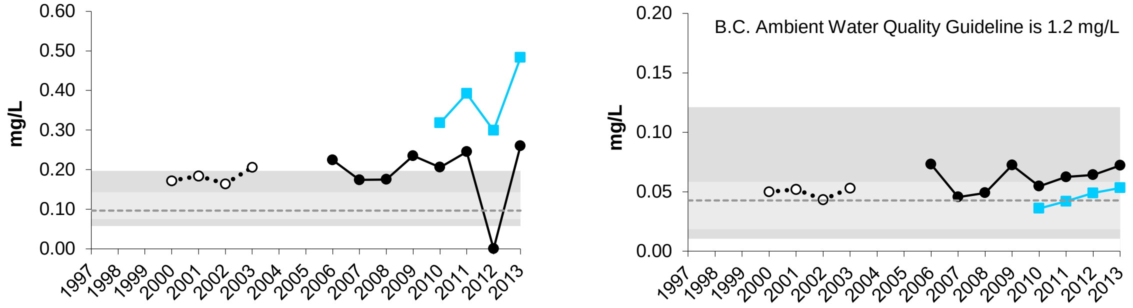
Figure 5.13-6 Concentrations of selected fall water quality measurement endpoints, Mills Creek (*test* station MIC-1) and Fort Creek (*test* station FOC-1) (fall data), relative to historical concentrations and regional *baseline* fall concentrations.


Total Suspended Solids (TSS)

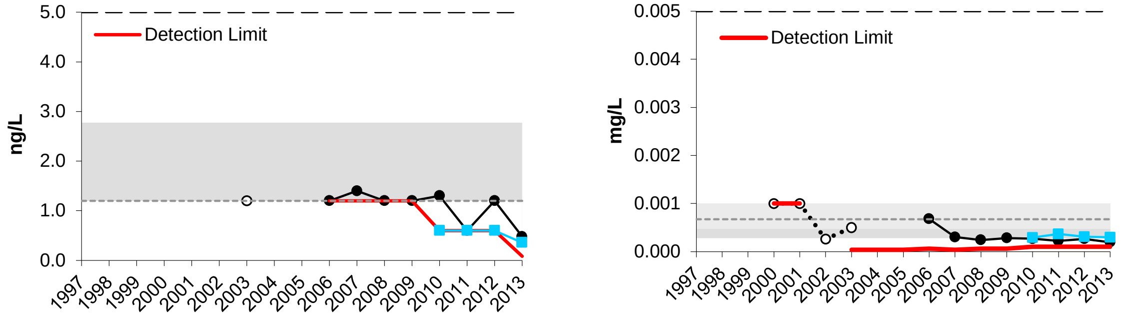
Total Dissolved Solids (TDS)


Dissolved Phosphorus

Total Nitrogen


Total Strontium

Total Boron


Total Mercury (Ultra-trace)

Total Arsenic

Non-detectable values are shown at the detection limit.

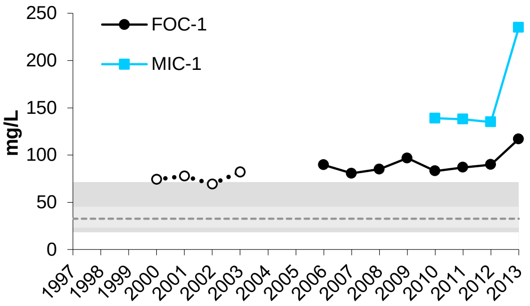
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

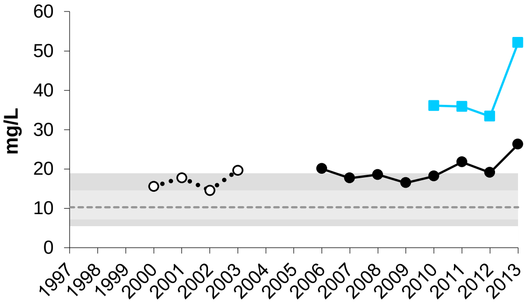
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.13-6 (Cont'd.)

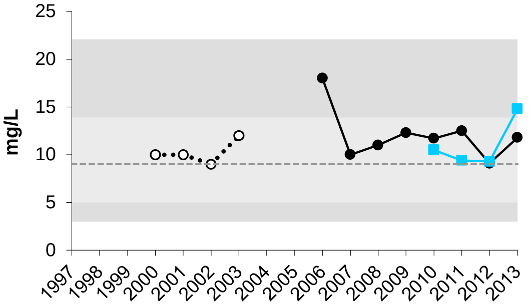
Calcium



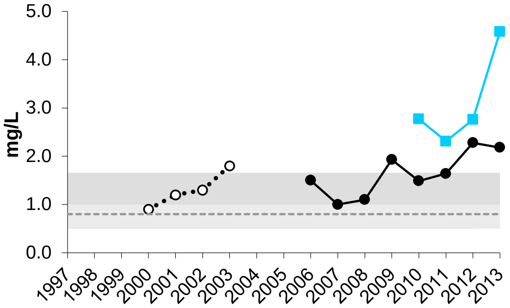
Magnesium



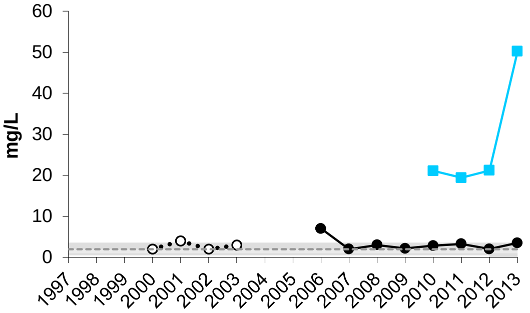
Sodium



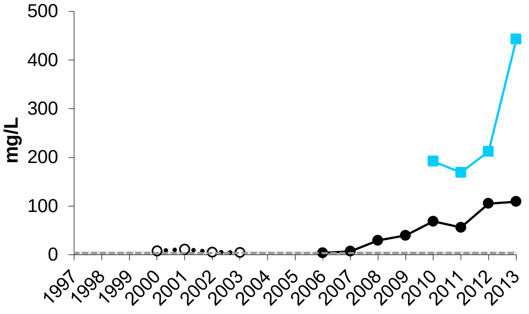
Potassium



Chloride



Sulphate



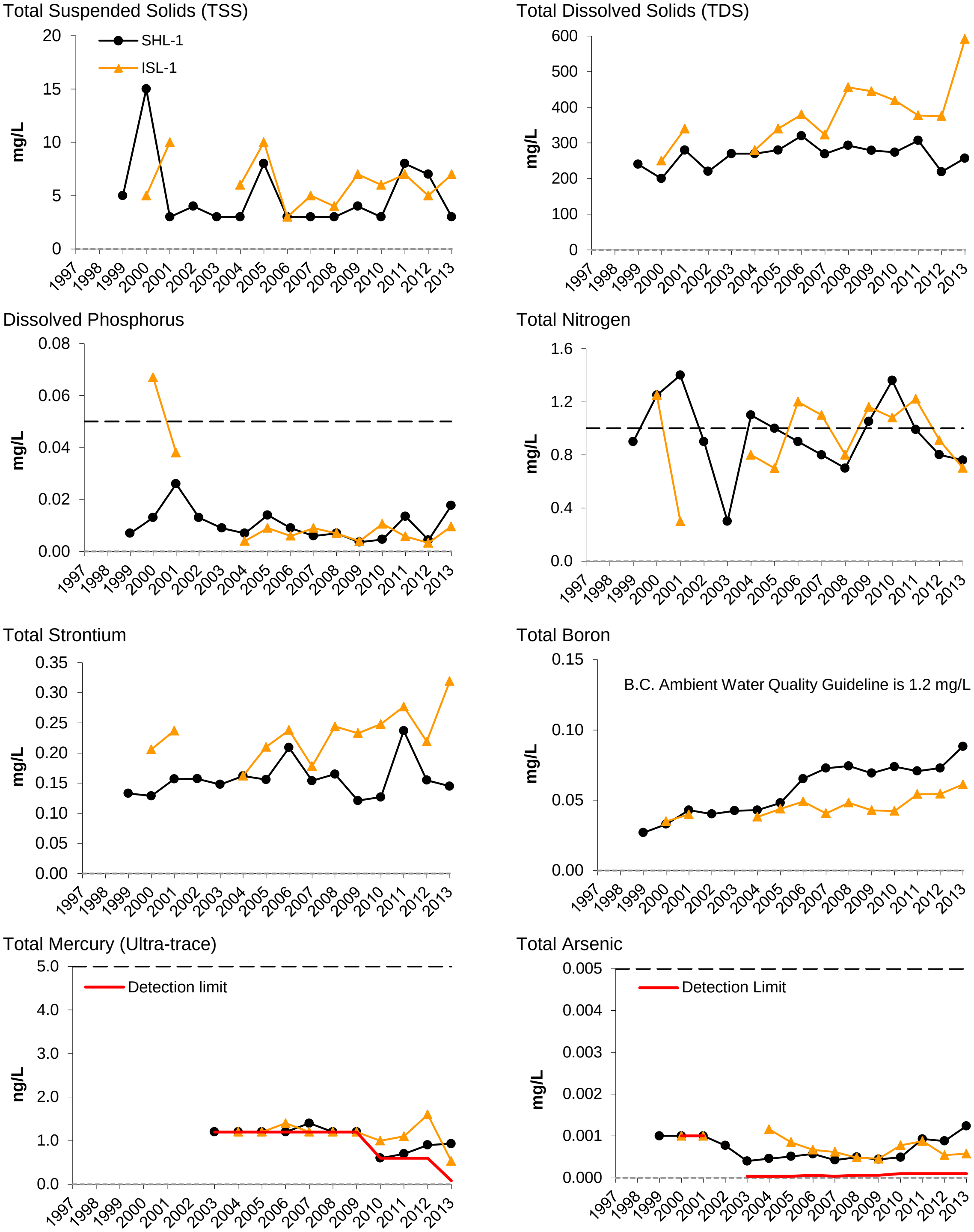
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.13-7 Concentrations of selected fall water quality measurement endpoints, Isadore's Lake (*test* station ISL-1) and Shipyard Lake (*test* station SHL-1) (fall data), relative to historical concentrations.



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)

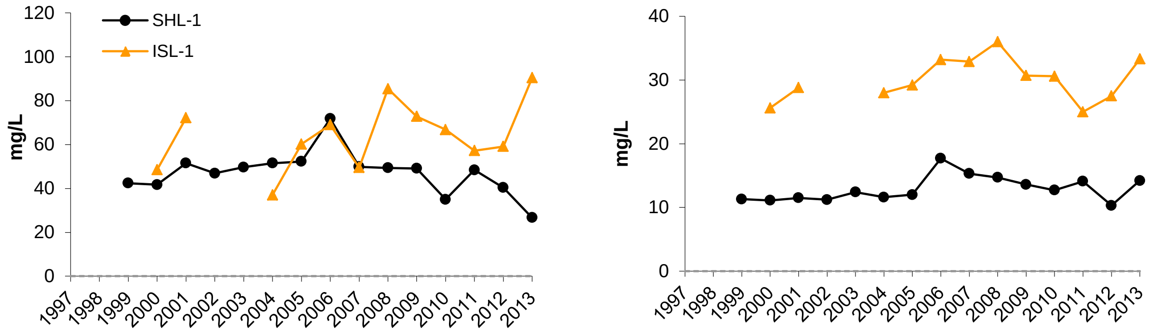
Total Arsenic

Non-detectable values are shown at the detection limit.

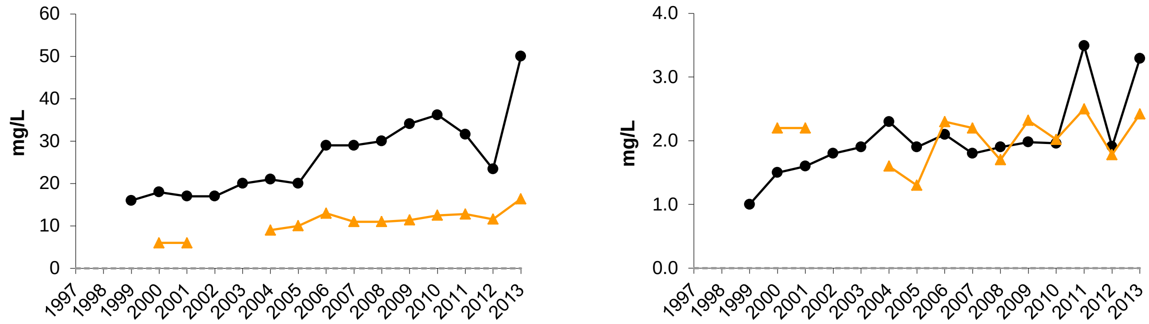
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

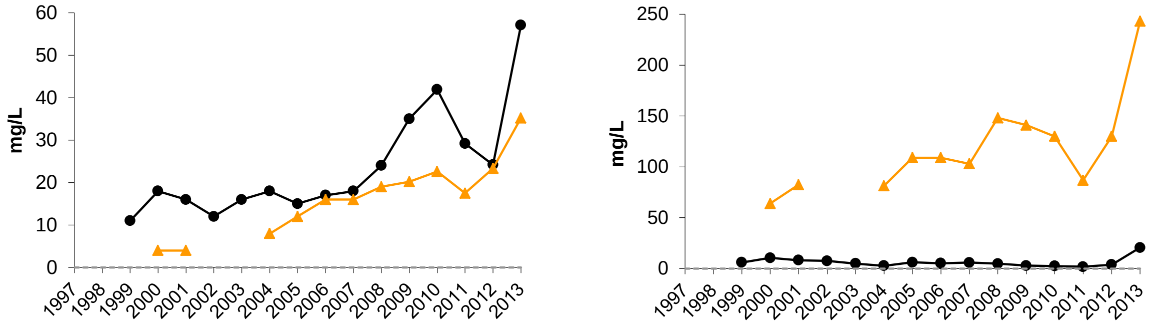
Figure 5.13-7 (Cont'd.)


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.

O·······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Table 5.13-7 Water quality index (fall 2013) for miscellaneous watershed stations.

Station Identifier	Location	2013 Designation	Water Quality Index	Classification
POC-1	near the mouth of Poplar Creek	*test*	98.0	Negligible-Low
FOC-1	near the mouth of Fort Creek	*test*	76.4	Moderate
BER-1	near the mouth of Beaver River	*test*	69.4	Moderate
BER-2	upper Beaver River	*baseline*	92.4	Negligible-Low
MCC-1	near the mouth of McLean Creek	*test*	94.8	Negligible-Low
MIC-1	Mills Creek	*test*	59.1	High

Table 5.13-8 Average habitat characteristics of benthic invertebrate sampling locations in Isadore's Lake, fall 2013.

Variable	Units	Isadore's Lake
Sample date	-	Sept 6, 2013
Habitat	-	Depositional
Water depth	m	2.0
Field Water Quality		
Dissolved oxygen	mg/L	10.9
Conductivity	µS/cm	634
pH	pH units	7.83
Water temperature	°C	21.4
Sediment Composition		
Sand	%	2
Silt	%	79
Clay	%	19
Total Organic Carbon	%	9.9

Table 5.13-9 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Isadore's Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Station ISL-1		
	2006	2007 to 2012	2013
Nematoda	72	12 to 69	18
Hirudinea		0 to <1	<1
Naididae	4	0 to 8	6
Tubificidae		0 to <1	2
Hydracarina		0 to 8	1
Amphipoda	<1	0 to <1	1
Gastropoda		0 to <1	4
Bivalvia		0 to <1	
Ceratopogonidae	<1	0 to <1	4
Diptera (misc)	<1	0 to <1	
Chironomidae	2	7 to 57	60
Ephemeroptera		0 to 1	3
Odonata		0 to <1	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	282	288	211
Richness	10	5 to 10	9
Equitability	0.23	0.36 to 0.57	0.51
% EPT	0	0 to 1	3

Table 5.13-10 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Isadore's Lake (ISL-1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs. Previous Years	
Log of Abundance	0.386	0.426	7	6	No change.
Log of Richness	**0.043**	**0.004**	23	50	Increasing over time; higher in 2013 than mean of previous years.
Equitability	0.165	0.766	15	1	No change.
Log of EPT	0.434	**0.007**	3	39	Higher in 2013 than mean of previous years.
CA Axis 1	0.913	**0.015**	0	22	Higher in 2013 than mean of previous years.
CA Axis 2	**0.008**	**0.019**	33	25	Increasing over time; higher in 2013 than mean of previous years.

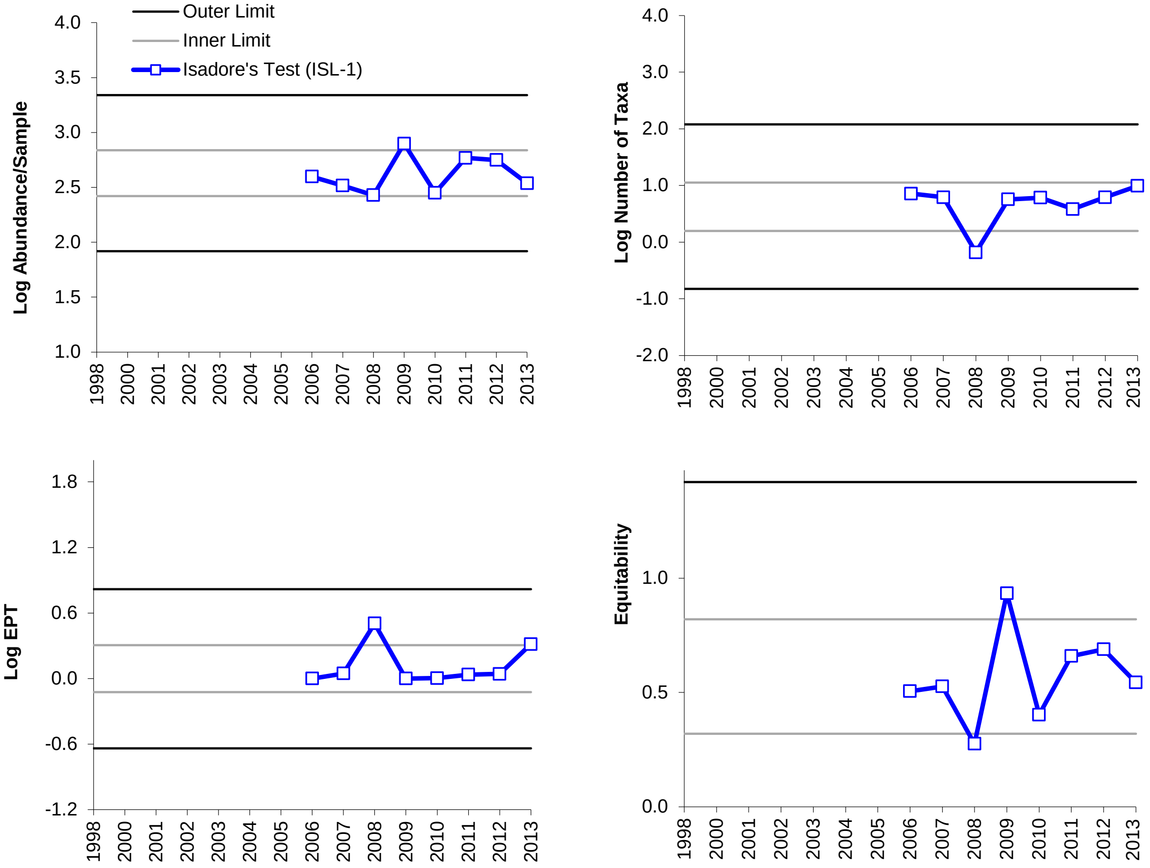
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-8 Variation in benthic invertebrate community measurement endpoints in Isadore's Lake (*test* station ISL-1).

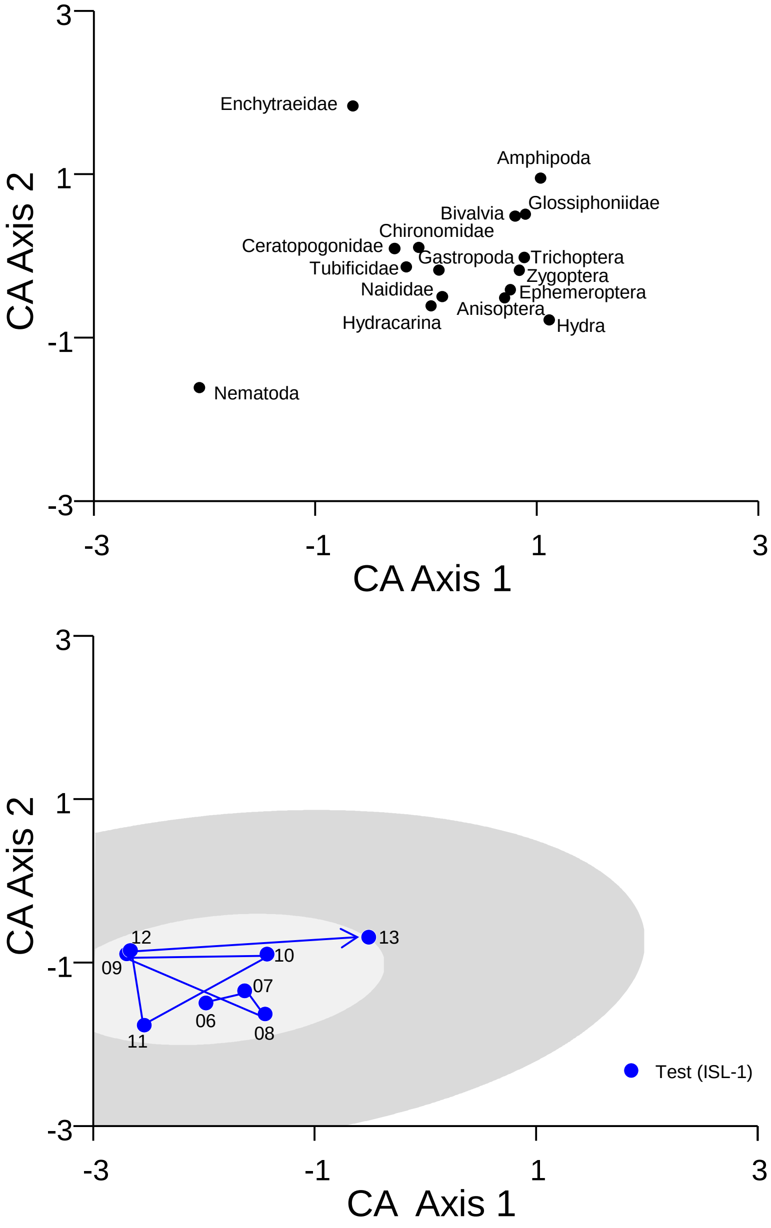


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2006 to 2012.

Note: Values shown have been adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-9 Ordination (Correspondence Analysis) of benthic invertebrate communities in RAMP lakes, showing Isadore's Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.13-11 Concentrations of sediment quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	21.5	8	11.3	26.0	57.0
Silt	%	-	0.7	8	39.0	61.4	85.5
Sand	%	-	77.8	8	1.6	11.1	35.0
Total organic carbon	%	-	8.34	8	1.30	4.59	18.80
Total hydrocarbons							
BTEX	mg/kg	-	<130	7	<5	<10	<100
Fraction 1 (C6-C10)	mg/kg	30[1]	<130	7	<5	<10	<100
Fraction 2 (C10-C16)	mg/kg	150[1]	<126	7	<5	25	91
Fraction 3 (C16-C34)	mg/kg	300[1]	**945**	7	150	**323**	**4,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	576	7	89	252	**3,500**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0119	8	0.0051	0.0066	0.0110
Retene	mg/kg	-	0.320	8	0.037	0.053	0.071
Total dibenzothiophenes	mg/kg	-	0.689	8	0.115	0.172	0.261
Total PAHs	mg/kg	-	3.534	8	0.779	1.450	2.056
Total Parent PAHs	mg/kg	-	0.256	8	0.068	0.143	0.175
Total Alkylated PAHs	mg/kg	-	3.278	8	0.711	1.338	1.881
Predicted PAH toxicity[3]	H.I.	1.0	0.60	8	0.07	0.58	**1.29**
Metals that exceeded CCME guidelines in 2013							
Total Arsenic	mg/kg	5.9	**6.79**	8	3.58	**6.255**	**7.40**
Other analytes that exceeded CCME guidelines in 2013							
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.00687**	8	0.00173	0.00293	**0.00790**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8.0	5	6.4	7.0	9.0
Chironomus growth - 10d	mg/organism	-	2.99	5	1.06	2.43	2.63
Hyalella survival - 14d	# surviving	-	6.4	5	7.6	9.2	9.8
Hyalella growth - 14d	mg/organism	-	0.34	5	0.20	0.32	0.44

Values in **bold** indicate concentrations exceeding guidelines.

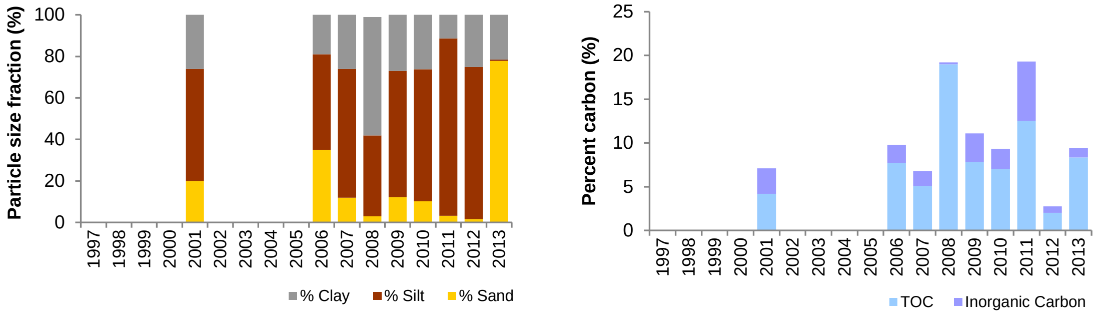
Values underlined indicate concentrations outside the range of historic observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

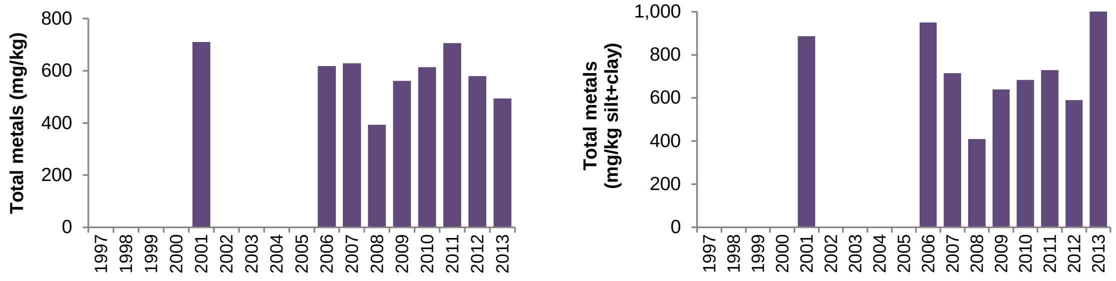
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-10 Variation in sediment quality measurement endpoints in Isadore's Lake, *test* station ISL-1.



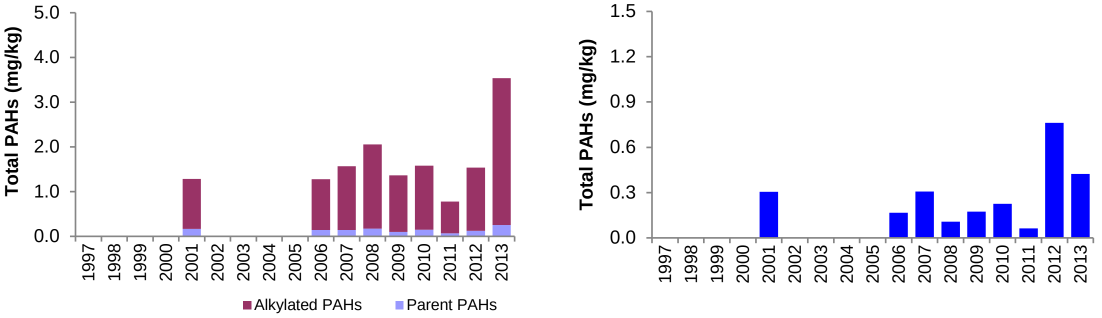
Particle size distribution

Carbon Content



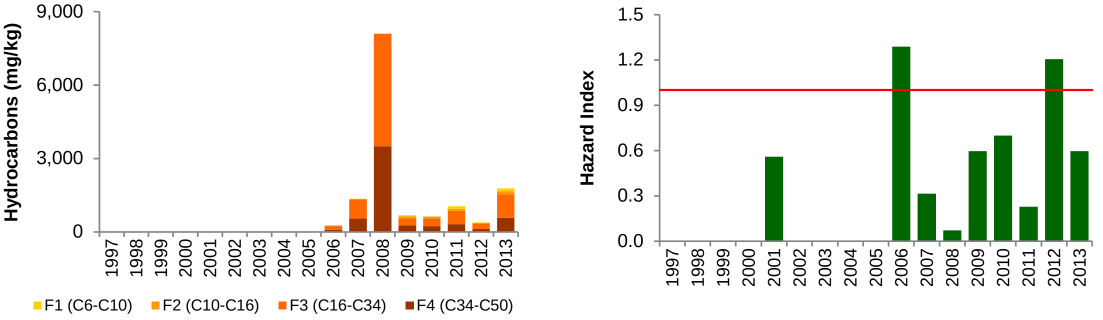
Total Metals[1]

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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.25	14	7.7	8.1	8.20
Total suspended solids	mg/L	-	<3.0	14	<3.0	3.5	15
Conductivity	µS/cm	-	466	14	358	411	509
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.018	14	0.004	0.008	0.026
Total nitrogen	mg/L	1	0.761	14	0.300	0.946	**1.40**
Nitrate+nitrite	mg/L	3	<0.071	14	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	18.3	14	16.7	19.2	24.0
Ions							
Sodium	mg/L	-	50.0	14	16.0	22.2	36.2
Calcium	mg/L	-	26.7	14	35.0	49.3	71.8
Magnesium	mg/L	-	14.2	14	10.3	12.2	17.7
Chloride	mg/L	120	57.1	14	11.0	18.0	41.9
Sulphate	mg/L	270	20.6	14	1.87	5.15	10.5
Total dissolved solids	mg/L	-	257	14	200	272	320
Total alkalinity	mg/L		126	14	159	184	251
Selected metals							
Total aluminum	mg/L	0.1	0.025	14	<0.002	0.012	**0.190**
Dissolved aluminum	mg/L	0.1	0.0044	14	<0.0010	0.0017	<0.0100
Total arsenic	mg/L	0.005	0.0012	14	0.0004	0.0005	0.0010
Total boron	mg/L	1.2	0.088	14	0.027	0.057	0.074
Total molybdenum	mg/L	0.073	0.00017	14	0.00002	0.00009	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	0.93	10	<0.6	<1.2	1.4
Total strontium	mg/L	-	0.145	14	0.121	0.156	0.237
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.2	2	0.17	0.53	0.88
Oilsands Extractable	mg/L	-	0.59	2	0.69	1.61	2.52
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	<0.669	2	0.559	1.31	<2.07
Total dibenzothiophenes	ng/L	-	10.48	2	8.427	22.46	36.50
Total PAHs	ng/L	-	110.0	2	163.3	194.0	224.8
Total Parent PAHs	ng/L	-	23.45	2	17.81	19.57	21.32
Total Alkylated PAHs	ng/L	-	86.52	2	142.0	174.5	207.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.004**	14	<0.003	**0.008**	**0.014**
Total iron	mg/L	0.3	**0.508**	14	0.270	**0.510**	**1.54**
Total phenols	mg/L	0.004	**0.009**	14	<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 2013.**

Variable	Units	Shipyard Lake
Sample date	-	Sept 4, 2013
Habitat	-	Depositional
Water depth	m	1
Field Water Quality		
Dissolved oxygen	mg/L	8.5
Conductivity	µS/cm	360
pH	pH units	8.3
Water temperature	°C	18.2
Sediment Composition		
Sand	%	3
Silt	%	62
Clay	%	35
Total Organic Carbon	%	15.4

Table 5.13-14 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community of Shipyard Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Station SHL-1		
	2000	2001 to 2012	2013
Hydra		0 to <1	
Nematoda		0 to 5	21
Hirudinea		0 to 1	<1
Naididae	8	0 to 33	<1
Tubificidae	1	0 to 7	<1
Enchytraeidae		0 to 7	
Lumbriculidae		0 to <1	
Hydracarina		0 to 4	3
Amphipoda	7	0 to 3	2
Gastropoda	18	<1 to 17	28
Bivalvia	7	<1 to 8	4
Ceratopogonidae		0 to 6	<1
Diptera (misc)	3	0 to 53	<1
Chironomidae	25	3 to 48	40
Ephemeroptera	16	0 to 6	<1
Odonata	3	0 to 1	<1
Trichoptera	2	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	95	28 to 1,254	181
Richness	13	4 to 27	13
Equitability	0.56	0.16 to 0.75	0.44
% EPT	19	<1 to 5	<1

Table 5.13-15 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Shipyard Lake (SHL-1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2013 vs. Previous Years	Time Trend	2013 vs. Previous Years	
Log of Abundance	**<0.001**	**0.037**	20	4	Abundance increased over time and was higher in 2013 than the mean of prior years.
Log of Richness	**<0.001**	0.085	39	2	Increasing over time.
Equitability	**<0.001**	0.701	20	0	Increasing over time.
Log of EPT	**0.019**	**0.005**	4	5	Decreasing over time; lower in 2013 than mean of previous years.
CA Axis 1	**0.003**	0.859	7	0	Increasing over time.
CA Axis 2	**<0.001**	**0.025**	25	3	Decreasing over time; lower in 2013 than mean of previous years.

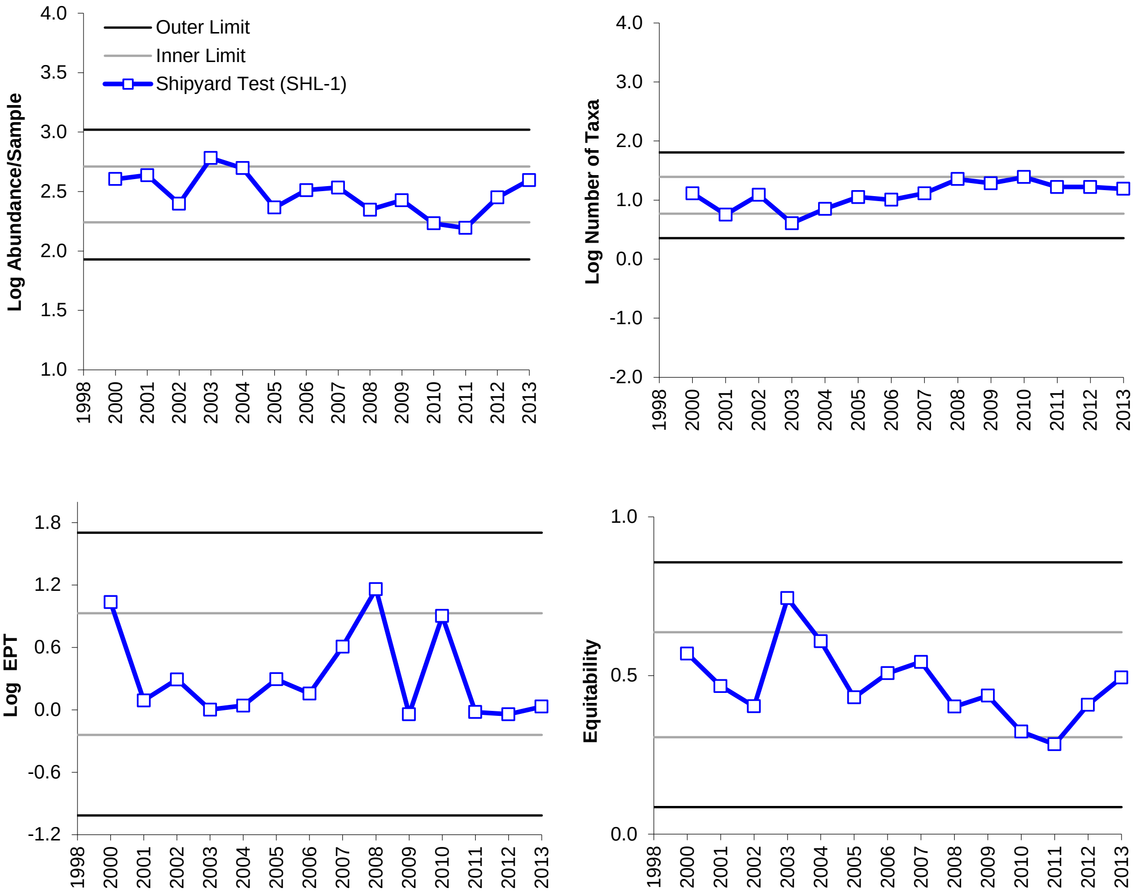
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-11 Variation in benthic invertebrate community measurement endpoints in Shipyard Lake (*test* station SHL-1).

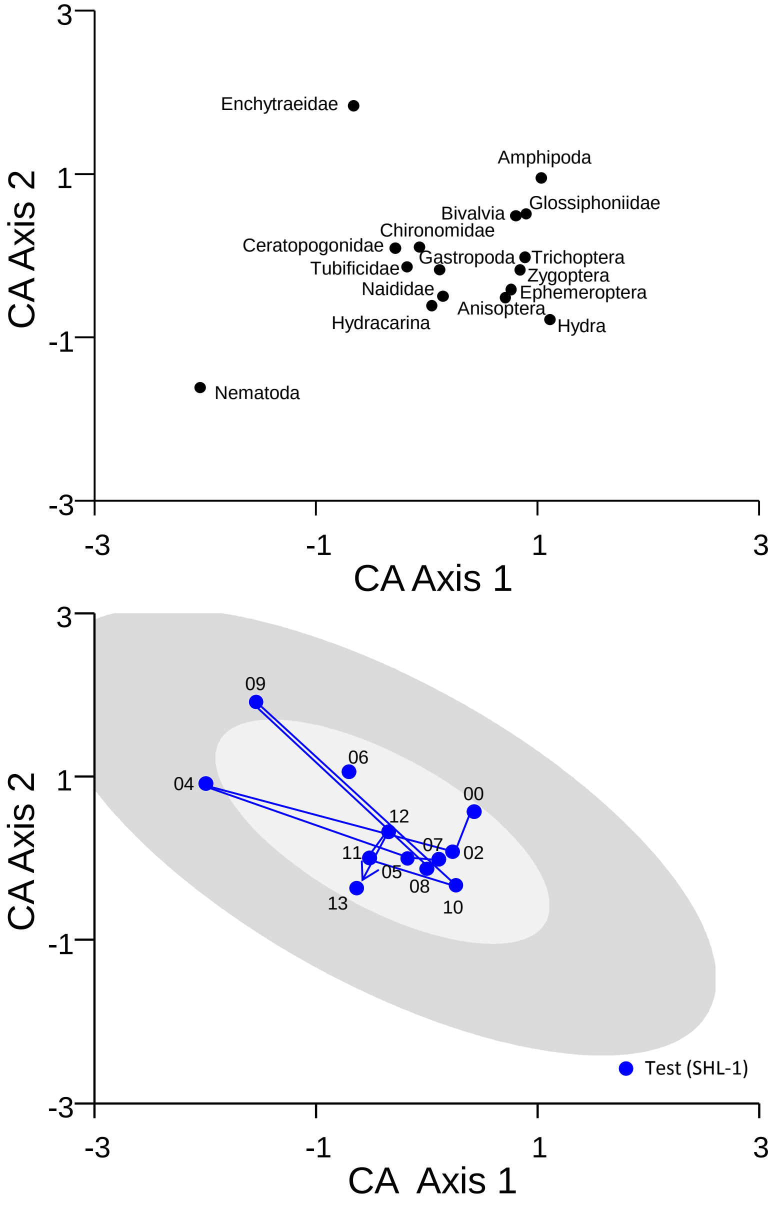


Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from 2000 to 2012.

Note: Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-12 Ordination (Correspondence Analysis) of benthic invertebrate communities in RAMP lakes, showing Shipyard Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Table 5.13-16 Concentrations of sediment quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2013.

Variables	**Units**	**Guideline**	**September 2013**	**2001-2012 (fall data only)**			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	36.0	10	12.8	33.7	60.0
Silt	%	-	48.0	10	36.0	41.4	86.2
Sand	%	-	16.0	10	1.0	4.5	40.8
Total organic carbon	%	-	9.68	11	5.50	13.40	19.60
Total hydrocarbons							
BTEX	mg/kg	-	<100	8	<5	<35	<240
Fraction 1 (C6-C10)	mg/kg	30[1]	<100	8	<5	<35	<240
Fraction 2 (C10-C16)	mg/kg	150[1]	<102	8	<5	114	**<313**
Fraction 3 (C16-C34)	mg/kg	300[1]	**896**	8	290	**1,190**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	496	8	<5	365	1,180
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0258	9	0.0108	0.0186	0.0306
Retene	mg/kg	-	0.078	11	0.046	0.082	0.199
Total dibenzothiophenes	mg/kg	-	1.241	11	0.265	0.682	2.622
Total PAHs	mg/kg	-	6.312	11	2.276	5.436	10.718
Total Parent PAHs	mg/kg	-	0.480	11	0.231	0.289	0.672
Total Alkylated PAHs	mg/kg	-	5.832	11	2.020	5.191	10.106
Predicted PAH toxicity[3]	H.I.	1.0	1.19	11	0.10	0.70	**3.79**
Metals that exceeded CCME guidelines in 2013							
Total Arsenic	mg/kg	5.9	**7.97**	11	5.50	**6.7**	**7.80**
Other analytes that exceeded CCME guidelines in 2013							
Benz[a]anthracene	mg/kg	0.0317	**0.048**	11	0.010	0.021	**0.064**
Benzo[a]pyrene	mg/kg	0.0319	**0.050**	11	0.013	0.027	**0.079**
Chrysene	mg/kg	0.0571	**0.106**	11	0.033	0.052	**0.163**
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.0172**	11	0.0041	**0.0102**	**0.0273**
Phenanthrene	mg/kg	0.0419	**0.0497**	11	0.0258	0.0370	**0.0678**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.4	7	5.6	7.6	8.8
Chironomus growth - 10d	mg/organism	-	4.04	7	1.25	2.00	2.56
Hyalella survival - 14d	# surviving	-	4.0	7	6.0	8.2	8.4
Hyalella growth - 14d	mg/organism	-	0.38	7	0.10	0.26	0.45

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historic observations.

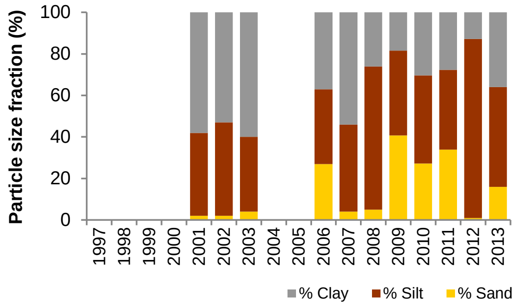
[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

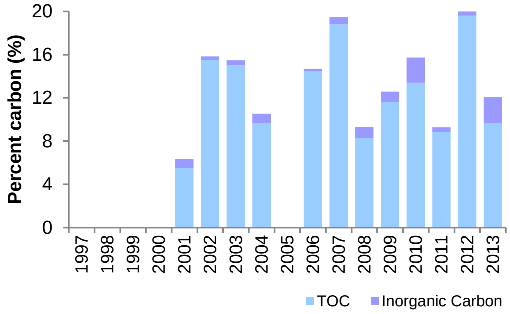
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-13 Variation in sediment quality measurement endpoints in Shipyard Lake, *test* station SHL-1.

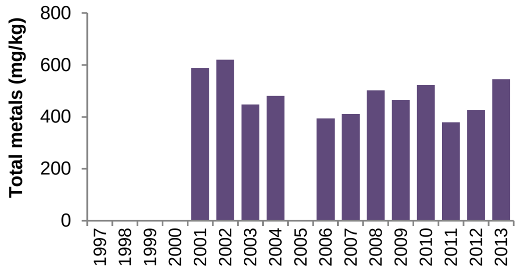
Particle size distribution



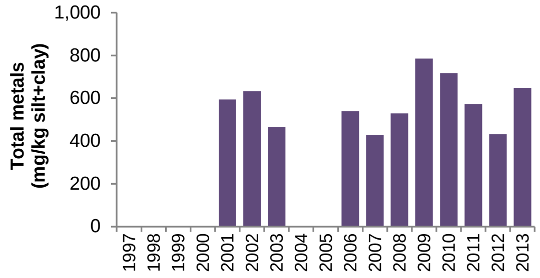
Carbon Content



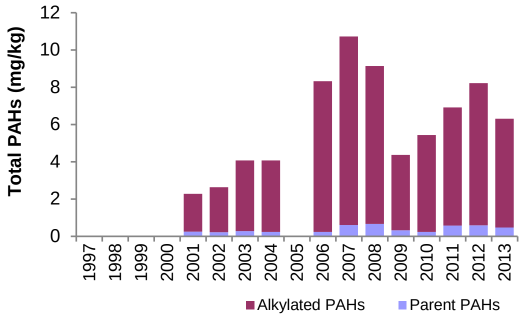
Total Metals[1]



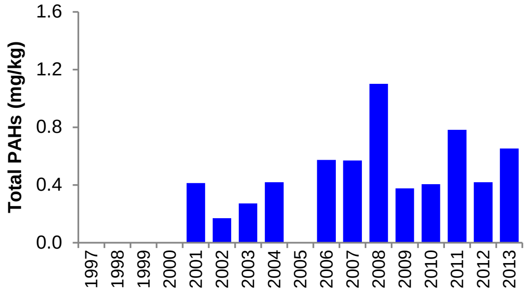
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



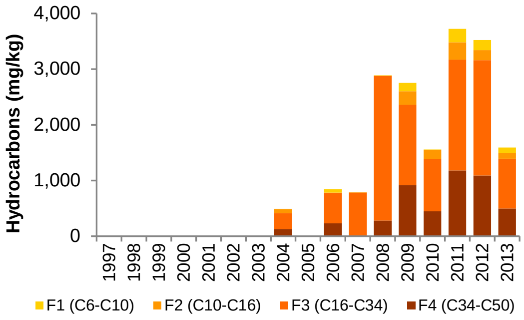
Total PAHs



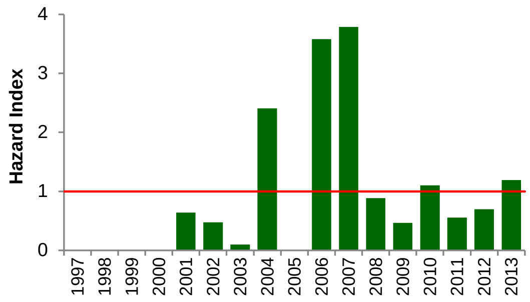
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



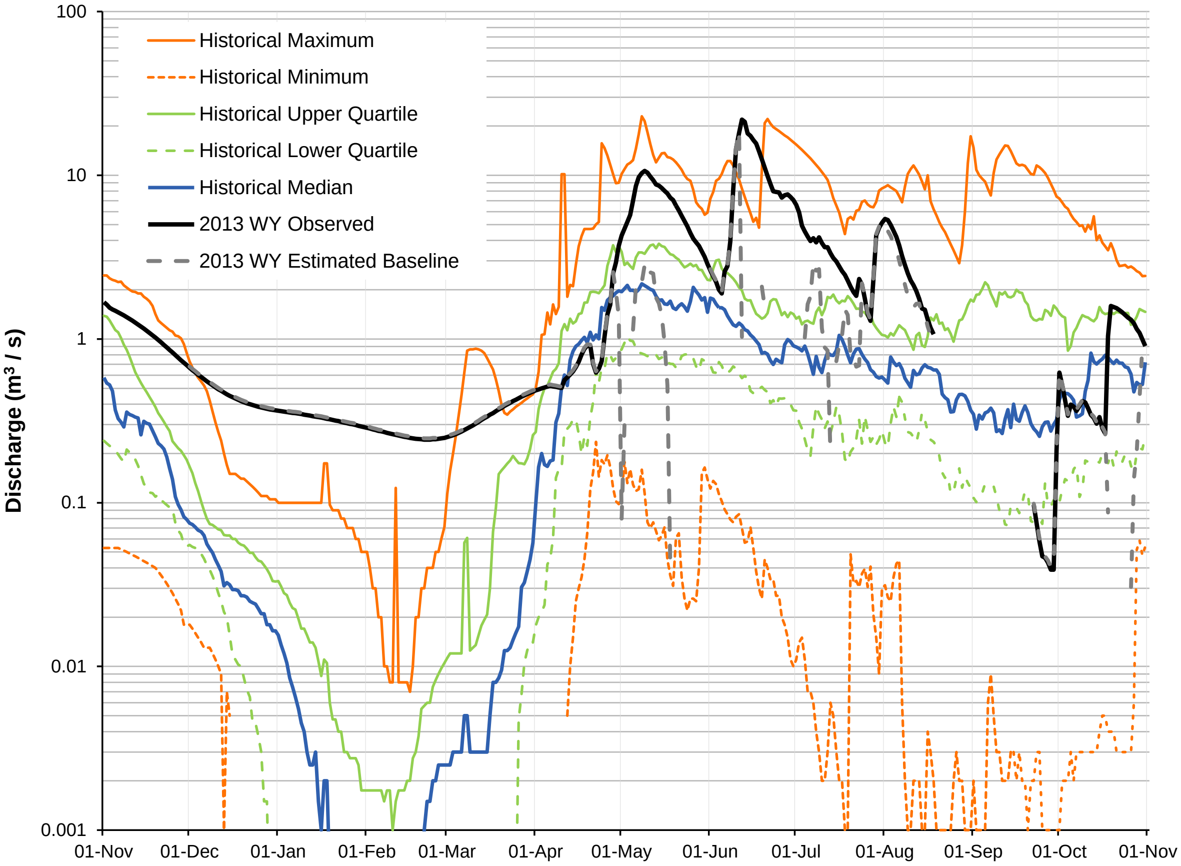
PAH Hazard Index[2]



[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 2013, compared to historical values.



Note: The 2013 WY observed values were calculated from provisional data for November 1, 2013 to October 31, 2013 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 2012, and from 1973 to 1986 for other months.

Note: Some differences were calculated between observed flows at Station S11 and water releases from the Poplar Creek Spillway that resulted in estimated *baseline* values to be negative for a number of days in the 2013 WY. *Baseline* values on these days were set to zero, in accordance with previous reports (e.g., RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012), 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, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**67.506**	**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	-0.473	Estimated 3.1 km^2 of the Poplar Creek watershed is closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.058	Estimated 1.9 km^2 of the Poplar Creek watershed with land change from focal projects as of 2013 that is not closed-circuited (Table 2.5-1)
Water withdrawals from the Poplar Creek watershed from focal projects	-0.003	-Water withdrawals by Suncor (daily values provided)
Water releases into the Poplar Creek watershed from focal projects	0	None reported
Diversions into or out of the watershed	+50.678	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	Not applicable
Estimated *baseline* hydrograph (total discharge)	**22.747**	**Estimated *baseline* discharge at Poplar Creek at Highway 63, WSC Station 07DA007 (RAMP Station S11).**
Incremental flow (change in total discharge)	+50.260	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge)	**+196.8%**	**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 were calculated from provisional data for November 1, 2012 to October 31, 2013 for Poplar Creek at Highway 63, Station S11 (WSC 07DA007). The upstream drainage area is 151 km^2.

Note: Some differences were calculated between observed flows at Station S11 and water releases from the Poplar Creek Spillway that resulted in estimated *baseline* values to be negative for a number of days in the 2013 WY. *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 RAMP 2012).

Table 5.13-18 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed, 2013 WY.

Measurement Endpoint	**Value from *Baseline* Hydrograph (m^3/s)**	**Value from *Test* Hydrograph (m^3/s)**	**Relative Change**
Mean open-water season discharge	1.056	3.673	+248%
Mean winter discharge	0.289	0.511	+77.0%
Annual maximum daily discharge	18.474	21.904	+18.6%
Open-water season minimum daily discharge	0.031	0.039	+27.6%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Values were calculated from provisional data for November 1, 2012 to October 31, 2013 for Poplar Creek at Highway 63, Station S11 (WSC 07DA007). The upstream drainage area is 151 km^2.

Note: Some differences were calculated between observed flows at Station S11 and water releases from the Poplar Creek Spillway that resulted in estimated *baseline* values to be negative for a number of days in the 2013 WY. *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 RAMP 2012).

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and 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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	13	8.2	8.3	8.4
Total suspended solids	mg/L	-	4.0	13	4.0	10	61
Conductivity	µS/cm	-	606	13	308	459	1,590
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.021	13	0.007	0.013	0.027
Total nitrogen	mg/L	1	**1.05**	13	0.300	**1.10**	**2.11**
Nitrate+nitrite	mg/L	3	<0.071	13	<0.050	0.100	0.100
Dissolved organic carbon	mg/L	-	31.8	13	4.70	24.0	32.0
Ions							
Sodium	mg/L	-	64.5	13	10.0	46.8	238
Calcium	mg/L	-	42.3	13	28.2	39.0	74.4
Magnesium	mg/L	-	15.3	13	9.70	13.5	29.3
Chloride	mg/L	120	66.3	13	2.00	20.0	**321**
Sulphate	mg/L	270	27.5	13	7.8	14.7	44.2
Total dissolved solids	mg/L	-	403	13	200	306	890
Total alkalinity	mg/L		181	13	135	198	304
Selected metals							
Total aluminum	mg/L	0.1	**0.241**	13	0.050	**0.320**	**1.44**
Dissolved aluminum	mg/L	0.1	0.014	13	0.002	0.007	<0.090
Total arsenic	mg/L	0.005	0.0012	13	0.0008	0.0011	0.0023
Total boron	mg/L	1.2	0.156	13	0.039	0.124	0.179
Total molybdenum	mg/L	0.073	0.00030	13	0.00010	0.00025	0.00072
Total mercury (ultra-trace)	ng/L	5, 13	2.00	10	0.800	1.20	2.00
Total strontium	mg/L	-	0.276	13	0.149	0.202	0.513
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.59	2	0.19	0.50	0.81
Oilsands Extractable	mg/L	-	1.98	2	0.51	1.16	1.81
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	1.990	2	1.300	1.735	2.170
Total dibenzothiophenes	ng/L	-	20.22	2	16.96	34.32	51.68
Total PAHs	ng/L	-	149.4	2	184.6	233.2	281.8
Total Parent PAHs	ng/L	-	24.45	2	18.16	19.29	20.41
Total Alkylated PAHs	ng/L	-	124.9	2	164.2	213.9	263.7
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**0.929**	13	0.050	0.249	**2.32**
Sulphide	mg/L	0.002	**0.0079**	13	<0.003	**0.0062**	**0.0102**
Total iron	mg/L	0.3	**1.37**	13	**0.70**	**1.08**	**3.63**
Total phenols	mg/L	0.004	**0.009**	13	<0.001	**0.007**	**0.019**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	10	8.0	8.2	8.4
Total suspended solids	mg/L	-	150	10	<3	12	77
Conductivity	µS/cm	-	1,450	10	566	970.5	1,930
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.006	10	0.004	0.008	0.022
Total nitrogen	mg/L	1	0.881	10	0.700	**1.01**	**1.68**
Nitrate+nitrite	mg/L	3	<0.071	10	<0.071	<0.100	<0.100
Dissolved organic carbon	mg/L	-	18.0	10	15.0	28.5	52.0
Ions							
Sodium	mg/L	-	164	10	53.0	97.5	267
Calcium	mg/L	-	116	10	49.1	71.6	91.5
Magnesium	mg/L	-	34.1	10	15.5	20.4	28.1
Chloride	mg/L	120	**189**	10	55	99.5	**364**
Sulphate	mg/L	410	128	10	50.7	70.8	117
Total dissolved solids	mg/L	-	873	10	450	652	1110
Total alkalinity	mg/L	-	363	10	158	253	349
Selected metals							
Total aluminum	mg/L	0.1	**5.32**	10	0.03	**0.29**	**5.13**
Dissolved aluminum	mg/L	0.1	0.003	10	0.002	0.006	0.045
Total arsenic	mg/L	0.005	0.0021	10	0.0007	0.0010	0.0021
Total boron	mg/L	1.2	0.17	10	0.09	0.14	0.24
Total molybdenum	mg/L	0.073	0.00031	10	0.00019	0.00033	0.00066
Total mercury (ultratrace)	ng/L	5, 13	**6.19**	10	<1.2	1.6	**8.1**
Total strontium	mg/L	-	0.40	10	0.23	0.30	0.63
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	3.79	2	1.26	4.26	7.26
Oilsands Extractable	mg/L	-	3.47	2	0.960	5.150	9.34
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	12.23	15.70
Retene	ng/L	-	57.10	2	5.030	6.645	8.260
Total dibenzothiophenes	ng/L	-	42.03	2	39.94	44.79	49.63
Total PAHs	ng/L	-	334.7	2	363.4	367.8	372.3
Total Parent PAHs	ng/L	-	33.47	2	25.11	27.71	30.31
Total Alkylated PAHs	ng/L	-	301.2	2	338.3	340.1	342.0
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total chromium	mg/L	0.001	**0.0038**	10	0.0004	**0.0011**	**0.0075**
Total iron	mg/L	0.3	**5.56**	10	**1.79**	**2.94**	**6.97**
Total phenols	mg/L	0.004	**0.0052**	9	0.0020	**0.0082**	**0.0147**
Total phosphorus	mg/L	0.05	**0.140**	10	0.016	0.031	**0.128**
Sulphide	mg/L	0.002	**0.0038**	10	0.0020	**0.0180**	**0.0380**

[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 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	5	7.8	8.2	8.4
Total suspended solids	mg/L	-	9.0	5	6.0	9.0	93
Conductivity	µS/cm	-	413	5	255	445	511
Nutrients							
Total dissolved phosphorus	mg/L	0.05	**0.105**	5	0.037	**0.064**	**0.074**
Total nitrogen	mg/L	1	**1.02**	5	**0.891**	**1.30**	**2.44**
Nitrate+nitrite	mg/L	3	<0.071	5	<0.071	<0.071	<0.100
Dissolved organic carbon	mg/L	-	26.3	5	20.5	26.3	34.0
Ions							
Sodium	mg/L	-	44.6	5	20.9	53.5	67.7
Calcium	mg/L	-	34.2	5	22.5	29.7	35.8
Magnesium	mg/L	-	12.2	5	7.52	10.4	12.2
Chloride	mg/L	120	1.66	5	0.680	1.35	2.00
Sulphate	mg/L	270	15.3	5	12.5	14.6	15.3
Total dissolved solids	mg/L	-	333	5	210	324	348
Total alkalinity	mg/L		214	5	118	225	266
Selected metals							
Total aluminum	mg/L	0.1	**0.950**	5	**0.266**	**0.431**	**2.17**
Dissolved aluminum	mg/L	0.1	0.031	5	0.012	0.023	0.034
Total arsenic	mg/L	0.005	0.0019	5	0.0014	0.0016	0.0018
Total boron	mg/L	1.2	0.266	5	0.089	0.218	0.424
Total molybdenum	mg/L	0.073	0.00052	5	0.00020	0.00045	0.00063
Total mercury (ultra-trace)	ng/L	5, 13	2.80	5	0.90	1.90	**10.6**
Total strontium	mg/L	-	0.213	5	0.146	0.175	0.267
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.32	2	0.37	0.41	0.44
Oilsands Extractable	mg/L	-	0.27	2	0.87	0.88	0.88
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	9.58	11.86	<14.13
Retene	ng/L	-	1.85	2	1.26	2.06	2.86
Total dibenzothiophenes	ng/L	-	6.695	2	5.844	20.57	35.31
Total PAHs	ng/L	-	103.9	2	151.1	178.1	205.1
Total Parent PAHs	ng/L	-	22.44	2	17.69	18.44	19.20
Total Alkylated PAHs	ng/L	-	81.44	2	131.9	159.7	187.4
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Dissolved iron	mg/L	0.3	**1.70**	5	**0.737**	**0.857**	**1.16**
Sulphide	mg/L	0.002	**0.012**	5	**0.006**	**0.011**	**0.017**
total chromium	mg/L	0.001	**0.0010**	5	0.0006	0.0007	**0.0036**
Total iron	mg/L	0.3	**2.89**	5	**1.79**	**1.86**	**3.23**
Total phenols	mg/L	0.004	**0.007**	5	**0.005**	**0.008**	**0.010**
Total phosphorus	mg/L	0.05	**0.171**	5	**0.102**	**0.133**	**0.147**

[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 2013.

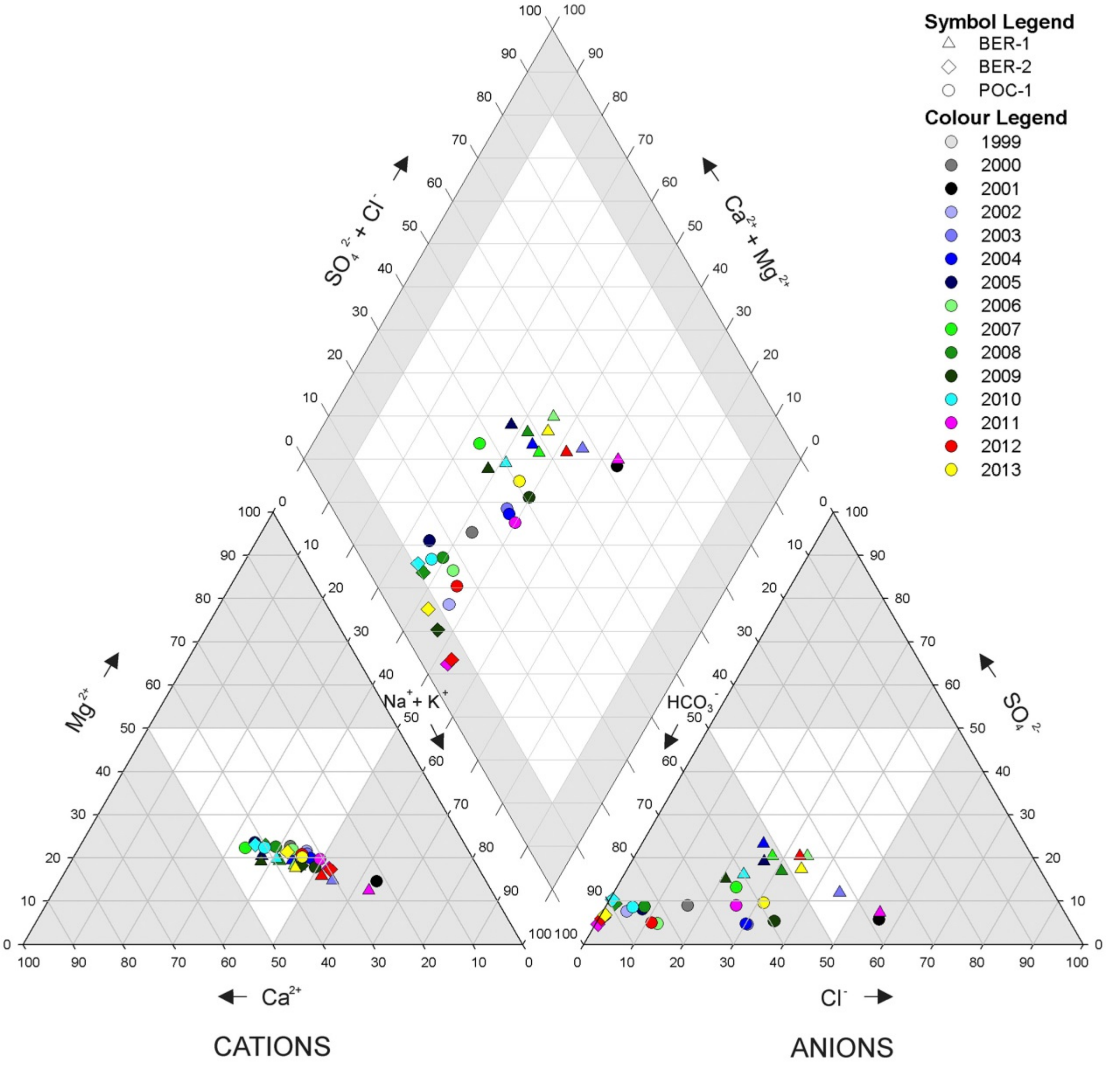
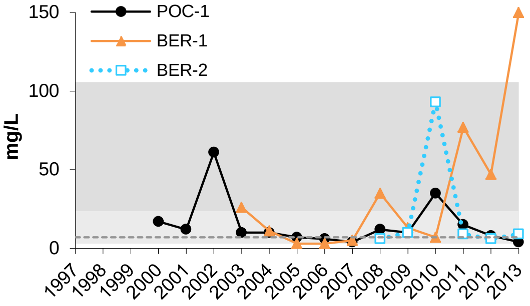
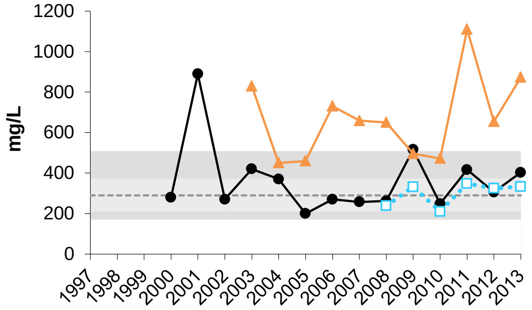


Figure 5.13-16 Concentrations of selected water quality measurement endpoints in *test* station BER-1, *test* station POC-1, and *baseline* station BER-2 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

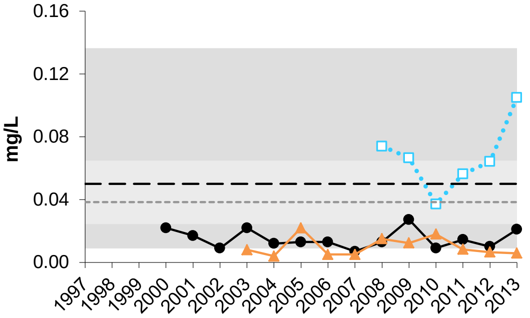
Total Suspended Solids (TSS)



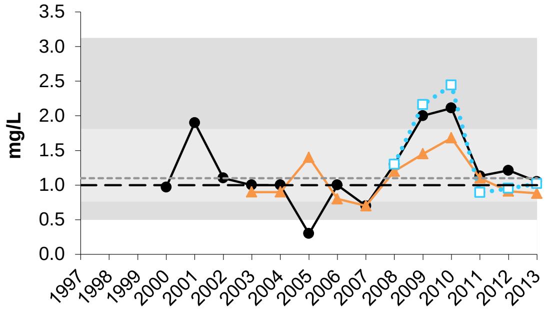
Total Dissolved Solids (TDS)



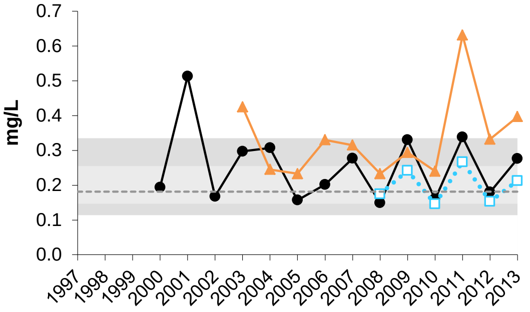
Dissolved Phosphorus



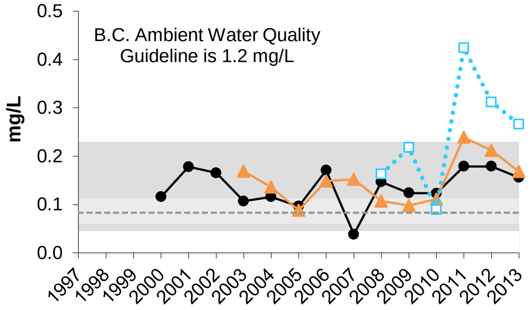
Total Nitrogen



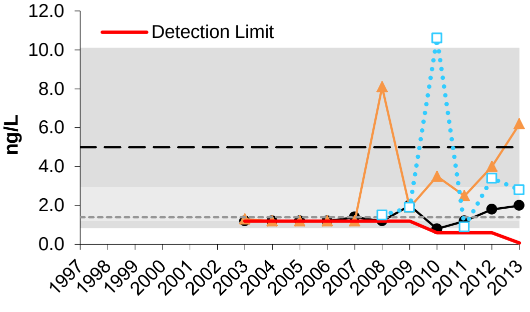
Total Strontium



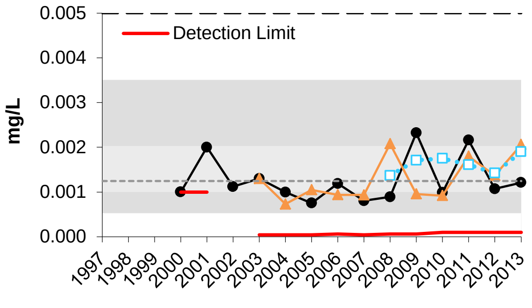
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



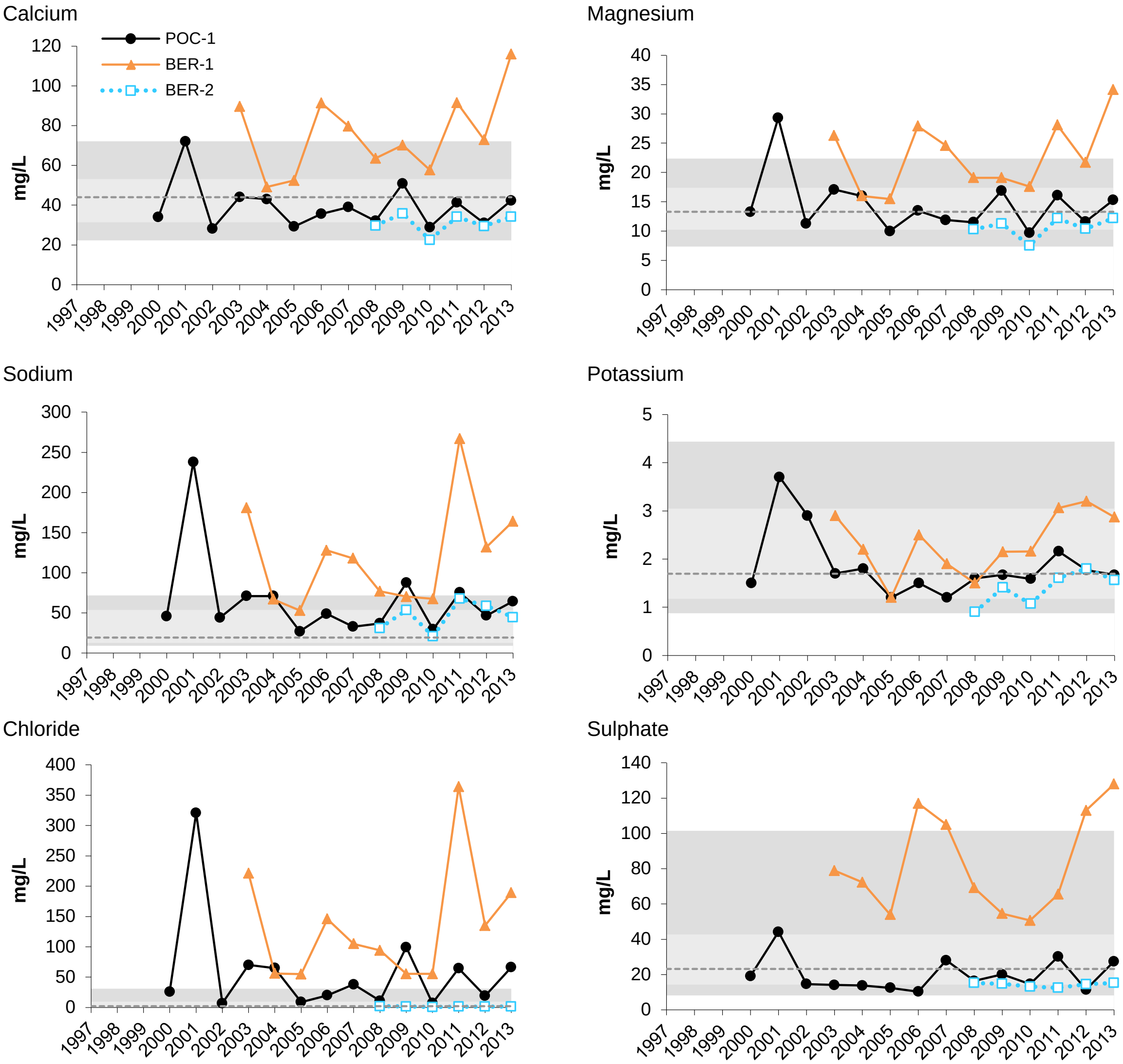
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 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 3.2.2.2 for a discussion of this approach.

Table 5.13-22 Monthly water quality measurement endpoints, Poplar Creek (*test* station POC-1), January to December, 2013.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality data and month of occurrence					
			n	Min		Median	Max	
Physical variables								
pH	pH units	6.5-9.0	12	7.85	(July)	8.12	8.37	(September)
Total suspended solids	mg/L	-	12	<3	-	4	147	(May)
Conductivity	µS/cm	-	12	247	(July)	457	899	(December)
Nutrients								
Total dissolved phosphorus	mg/L	0.05	12	0.004	(January)	0.018	0.028	(April/July)
Total nitrogen	mg/L	1.0	12	0.801	(October)	**1.045**	**1.401**	(July)
Nitrate+nitrite	mg/L	3	12	<0.070	-	<0.071	0.208	(February)
Dissolved organic carbon	mg/L	-	12	21.1	(May)	26.3	33.8	(August)
Ions								
Sodium	mg/L	-	12	20.1	(July)	44.8	111.0	(December)
Calcium	mg/L	-	12	23.8	(May)	32.8	49.8	(December)
Magnesium	mg/L	-	12	8.2	(May)	12.2	20.1	(December)
Chloride	mg/L	120	12	5.0	(July)	26.1	**127.0**	(December)
Sulphate	mg/L	410	12	17.2	(July)	21.7	30.4	(December)
Total dissolved solids	mg/L	-	12	217	(June)	311	546	(December)
Total alkalinity	mg/L	-	12	99	(July)	167	246	(December)
Selected metals								
Total aluminum	mg/L	0.1	12	0.043	(March)	**0.171**	**3.99**	(May)
Dissolved aluminum	mg/L	0.1	12	0.003	(January)	0.014	0.057	(May)
Total arsenic	mg/L	0.005	12	0.0007	(January)	0.0007	0.0012	(September)
Total boron	mg/L	1.2	12	0.088	(October)	0.126	0.189	(January)
Total molybdenum	mg/L	0.073	12	0.00019	(October)	0.00026	0.00321	(April)
Total mercury (ultra-trace)	ng/L	5, 13	12	<0.60	(January/February)	1.29	5.00	(May)
Total strontium	mg/L	-	12	0.127	(May)	0.205	0.368	(December)
Total hydrocarbons								
BTEX	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 1 (C6-C10)	mg/L	-	12	<0.1	-	<0.1	<0.1	-
Fraction 2 (C10-C16)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 3 (C16-C34)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	12	<0.25	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	-	12	0.09	(December)	0.43	0.62	(January)
Oilsands Extractable	mg/L	-	12	0.28	(March)	0.60	1.98	(September)
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	12	<15.16	-	<15.16	23.90	(February)
Retene	ng/L	-	12	<0.67	(March)	1.60	29.20	(May)
Total dibenzothiophenes	ng/L	-	12	11.40	(March)	24.91	1115.00	(May)
Total PAHs	ng/L	-	12	133.7	(December)	182.4	3614.8	(May)
Total Parent PAHs	ng/L	-	12	22.50	(March)	26.03	125.28	(May)
Total Alkylated PAHs	ng/L	-	12	108.5	(January)	158.6	3489.5	(May)
Other variables that exceeded CCME/AESRD guidelines in 2013[1]								
Total phenols	mg/L	0.004	11	0.003	(December)	0.007	**0.010**	(May)
Sulphide	mg/L	0.002	12	0.0027	(January)	**0.008**	**0.020**	(July)
Total phosphorus	mg/L	0.05	3	**0.0207**	(October)	**0.0309**	**0.1290**	(April)
Total Kjeldahl Nitrogen	mg/L	1.0	3	0.73	(October)	0.95	**1.33**	(July)
Total iron	mg/L	0.3	12	**0.477**	(January)	**0.913**	**2.620**	(May)
Dissolved iron	mg/L	0.3	10	**0.255**	(January)	**0.517**	**1.520**	(December)
Total chromium	mg/L	0.001	3	<0.00030	-	**0.00069**	**0.00381**	(May)

[a] Sources for all guidelines are outlined in Table 3.2-5.
Values in **bold** are above the guideline.

[1] n value refers to number of exceedances in 2013.

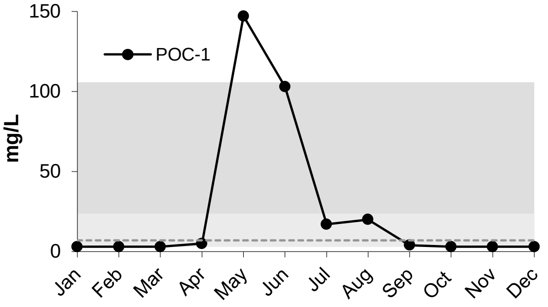
Table 5.13-23 Monthly water quality guideline exceedances, Poplar Creek (*test* station POC-1), January to December, 2013.

Variable	Units	Guideline[a]	January	February	March	April	May	June	July	August	September	October	November	December
Total phenols	mg/L	0.004	0.0051	0.0065	0.0064	0.0074	0.0100	0.0046	0.0102	0.0087	0.0086	0.0046	0.0065	-
Chloride	mg/L	120	-	-	-	-	-	-	-	-	-	-	-	127
Sulphide	mg/L	0.002	0.0027	0.0077	0.0036	0.0028	0.0100	0.0100	0.0199	0.0157	0.0079	0.0076	0.0077	0.0027
Total phosphorus	mg/L	0.05	-	-	-	0.013	0.090	-	0.050	-	-	-	-	-
Total nitrogen	mg/L	1.0	-	1.248	1.039	1.050	-	-	1.401	1.371	1.051	-	-	1.051
Total aluminum	mg/L	0.1	-	-	-	0.171	3.990	0.673	1.170	0.307	0.241	0.170	-	0.144
Dissolved aluminum	mg/L	0.1	-	-	-	-	0.0573	-	-	-	-	-	-	-
Total iron	mg/L	0.3	0.48	0.58	0.80	1.11	2.62	0.70	1.14	0.84	1.37	0.99	0.81	1.98
Dissolved iron	mg/L	0.3000	-	0.373	0.658	0.542	0.465	-	0.492	0.354	0.929	0.754	0.561	1.520
Total chromium	mg/L	0.001	-	-	-	0.0011	0.0038	-	0.0012	-	-	-	-	-

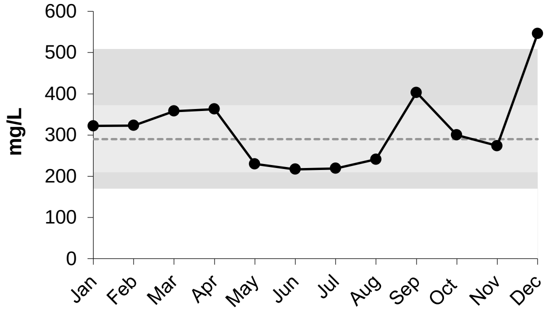
[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 5.13-17 Concentrations of selected water quality measurement endpoints in Poplar Creek (monthly data) relative to regional *baseline* fall concentrations.

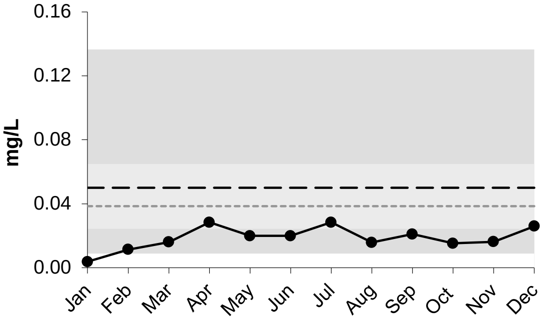
Total Suspended Solids (TSS)



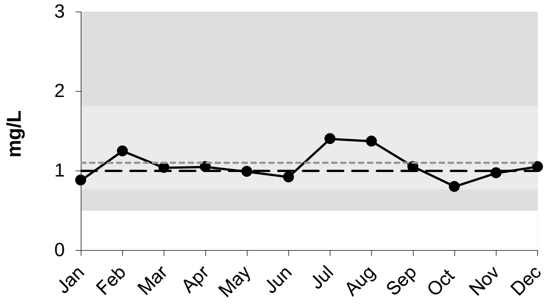
Total Dissolved Solids (TDS)



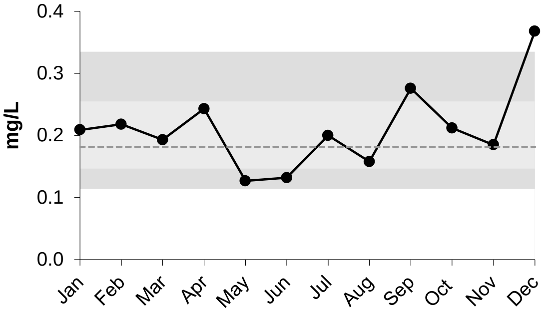
Dissolved Phosphorus



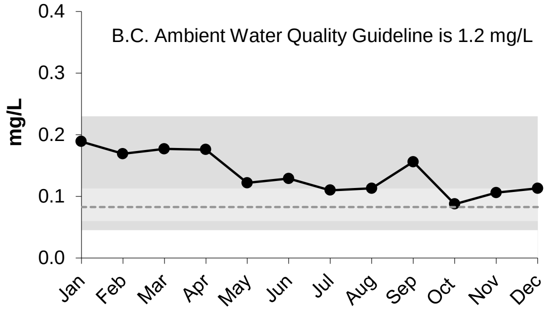
Total Nitrogen



Total Strontium

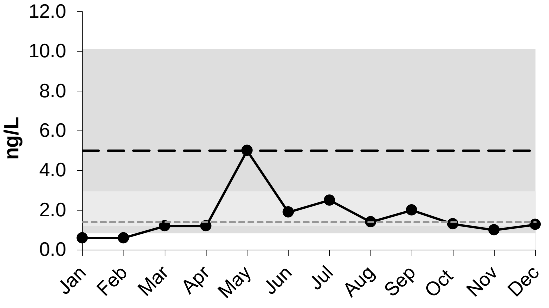


Total Boron

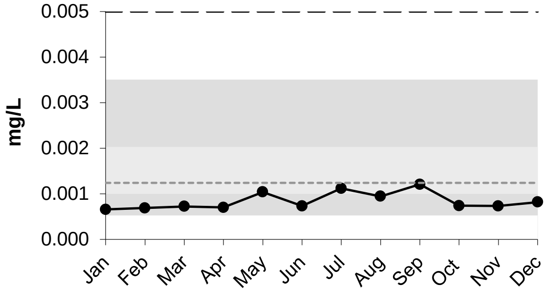


B.C. Ambient Water Quality Guideline is 1.2 mg/L

Total Mercury (Ultra-trace)



Total Arsenic



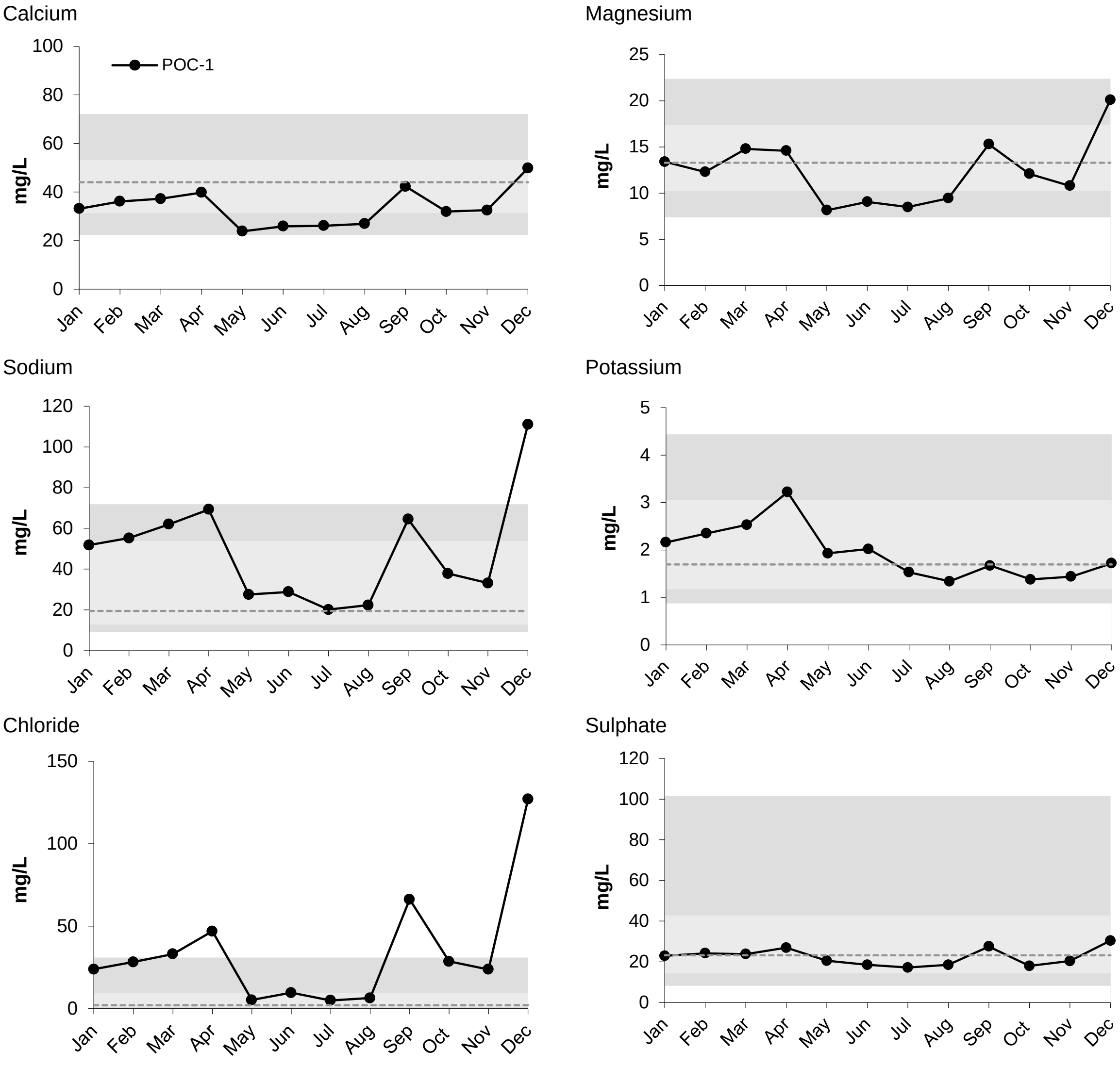
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.13-17 (Cont'd.)



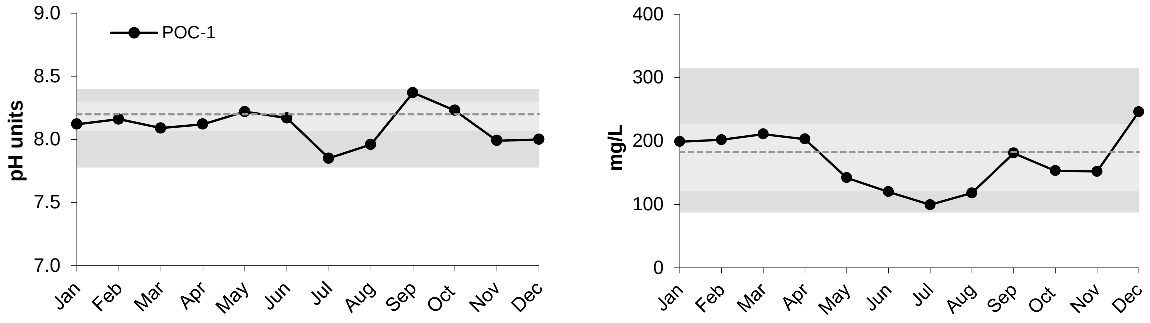
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○······○ 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 3.2.2.2 for a discussion of this approach.

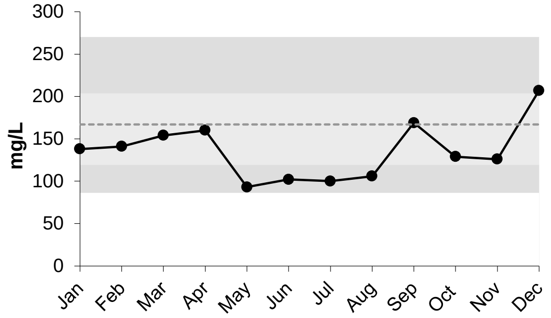
Figure 5.13-17 (Cont'd.)



pH

Total Alkalinity

Hardness (as $CaCO_3$)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ 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 3.2.2.2 for a discussion of this approach.

Figure 5.13-18 Piper diagram of monthly ion concentrations in Poplar Creek (*test* station POC-1).

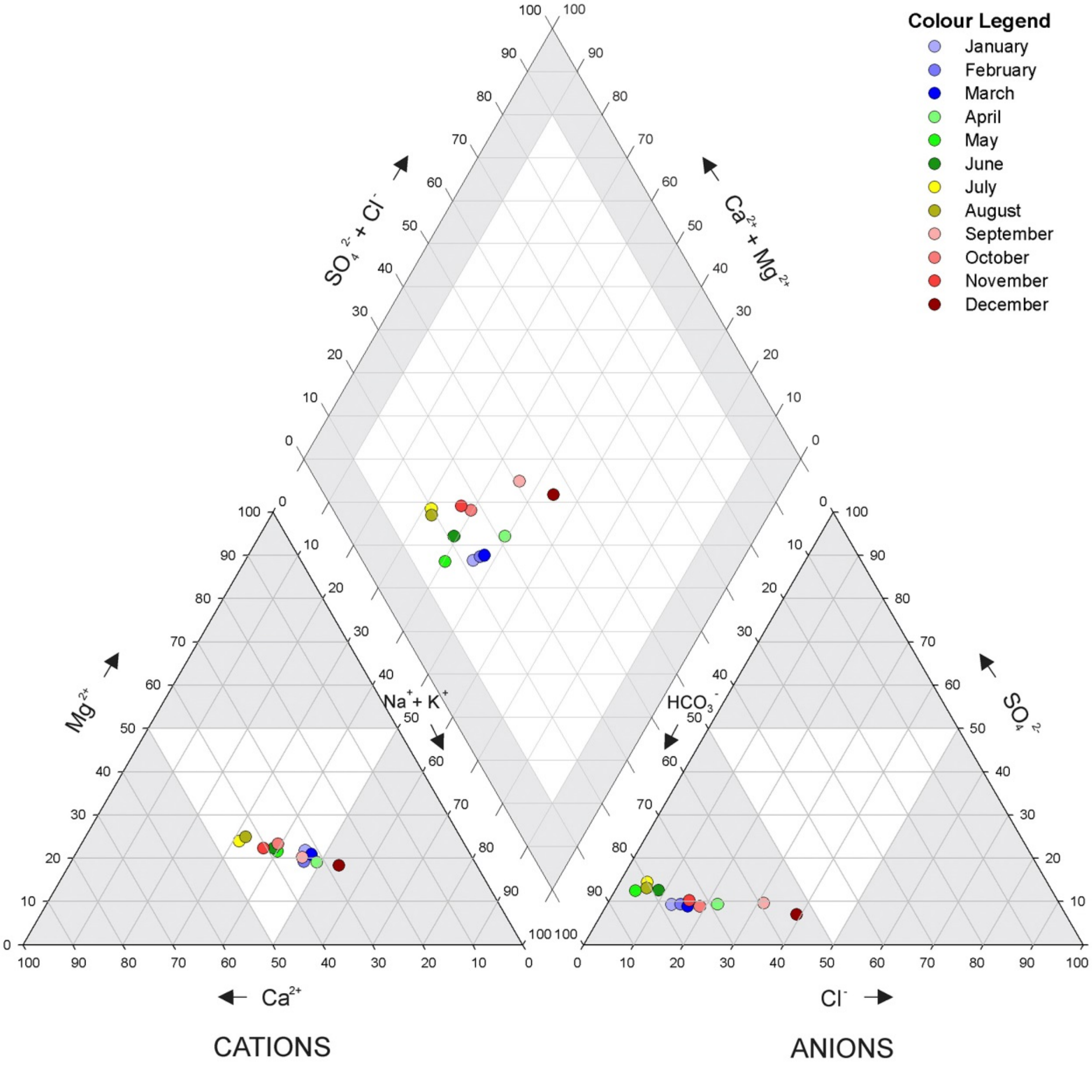


Table 5.13-24 Average habitat characteristics of benthic invertebrate sampling locations in the Beaver River and Poplar Creek, fall 2013.

Variable	**Units**	**POC-D1** **Lower *Test* Reach of Poplar Creek**	**BER-D2** **Upper *Baseline* Reach of the Beaver River**
Sample date	-	Sept 10, 2013	Sept 3, 2013
Habitat	-	Depositional	Depositional
Water depth	m	0.3	0.4
Current velocity	m/s	0.14	0.17
Field Water Quality			
Dissolved oxygen	mg/L	7.8	7.9
Conductivity	µS/cm	459	366
pH	pH units	8.5	7.4
Water temperature	°C	16.9	15.2
Sediment Composition			
Sand	%	78	87
Silt	%	16	9
Clay	%	6	5
Total Organic Carbon	%	2.1	0.63

Table 5.13-25 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate communities at the upper Beaver River and lower Poplar Creek.

Taxon	Percent Major Taxa Enumerated in Each Year					
	***Baseline* Reach BER-D2**			***Test* Reach POC-D1**		
	2008	**2009 to 2012**	**2013**	**2008**	**2009 to 2012**	**2013**
Hydra		0 to <1			0 to <1	
Nematoda	1	<1	4	2	1 to 5	1
Oligochaeta		0 to <1	2		0 to <1	<1
Naididae	<1	4 to 8	4	<1	<1 to 2	2
Tubificidae	1	2 to 36	24	72	13 to 22	22
Enchytraeidae	<1	0 to <1	3		0 to 17	
Erpobdellidae		<1				
Hirudinea	<1	0 to <1	<1		0 to <1	
Hydracarina	1	<1 to 8	<1		0 to <1	<1
Amphipoda		<1	<1		0 to <1	<1
Gastropoda	<1	<1 to 3	<1		<1	
Bivalvia	1	<1	<1	1	4 to 13	<1
Ceratopogonidae	6	3 to 11	5	2	0 to 5	2
Chironomidae	84	32 to 71	44	21	20 to 64	38
Dixidae		<1				
Dolichopodidae		<1				
Diptera (misc.)	1	0 to 1	3	<1	0 to <1	<1
Coleoptera		2 to 10	<1	<1	<1 to 2	<1
Ephemeroptera	4	2 to 6	3	<1	<1	<1
Odonata		<1			0 to <1	<1
Plecoptera		0 to <1				
Neuroptera		<1				
Trichoptera	<1	0 to <1	<1	<1	<1	
Lepidoptera		0 to <1				
Benthic Invertebrate Community Measurement Endpoints						
Abundance (mean per replicate samples)	174	101 to 672	126	185	364 to 1,054	835
Richness	13	8 to 26	17	8	18 to 25	14
Equitability	0.38	0.26 to 0.63	0.46	0.4	0.26 to 0.77	0.26
% EPT	3	<1 to 4	3	<1	0 to <1	<1

Table 5.13-26 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in *test* reach POC-D1 and *baseline* reach BER-D2.

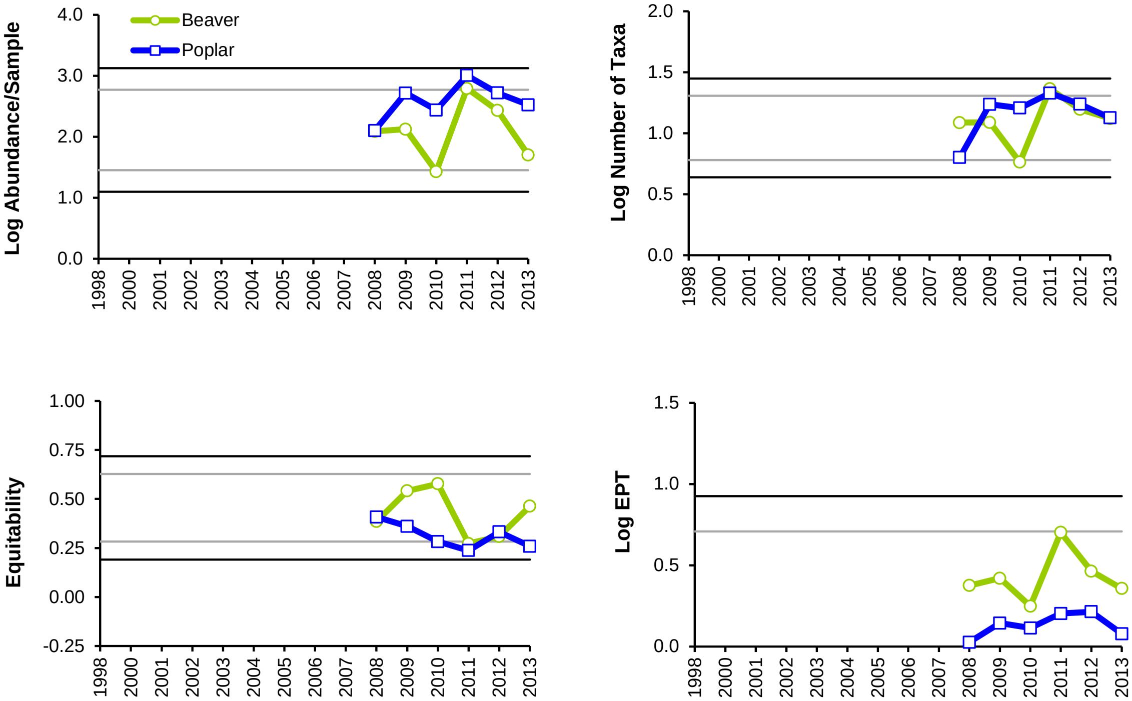
Measurement Endpoint	**P-value**					**Variance Explained (%)**					**Nature of Change(s)**
	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*Test* Period)**	**Difference between *Baseline* and *Test* Reaches (Time Trend)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Reach vs. *Test* Reach**	**Time Trend (*Test* Period)**	**Difference between *Baseline* and *Test* Reaches (Time Trend)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log of Abundance	**<0.001**	0.134	0.248	**0.017**	0.690	29	3	2	7	0	Higher at *test* reach; higher in 2013 at *test* reach than mean of the *baseline* reach.
Log of Richness	0.250	**0.004**	0.488	0.782	0.681	2	16	1	0	0	Increasing over time at *test* reach.
Equitability	**0.002**	**0.043**	0.718	**0.011**	0.323	27	11	0	18	3	Higher at *baseline* reach; decreasing over time at *test* reach; lower in 2013 at *test* reach than mean of the *baseline* reach.
Log of EPT	**<0.001**	0.417	0.959	**0.003**	0.597	66	2	0	27	1	Higher at *baseline* reach; lower in 2013 at *test* reach than mean of *baseline* reach.
CA Axis 1	**<0.001**	0.483	0.261	**0.002**	0.634	42	1	2	16	0	Higher at *baseline* reach; lower in 2013 than mean of *baseline* years.
CA Axis 2	**0.005**	0.348	0.059	**0.050**	0.631	21	2	9	10	1	Higher at *baseline* reach; lower in 2013 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).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

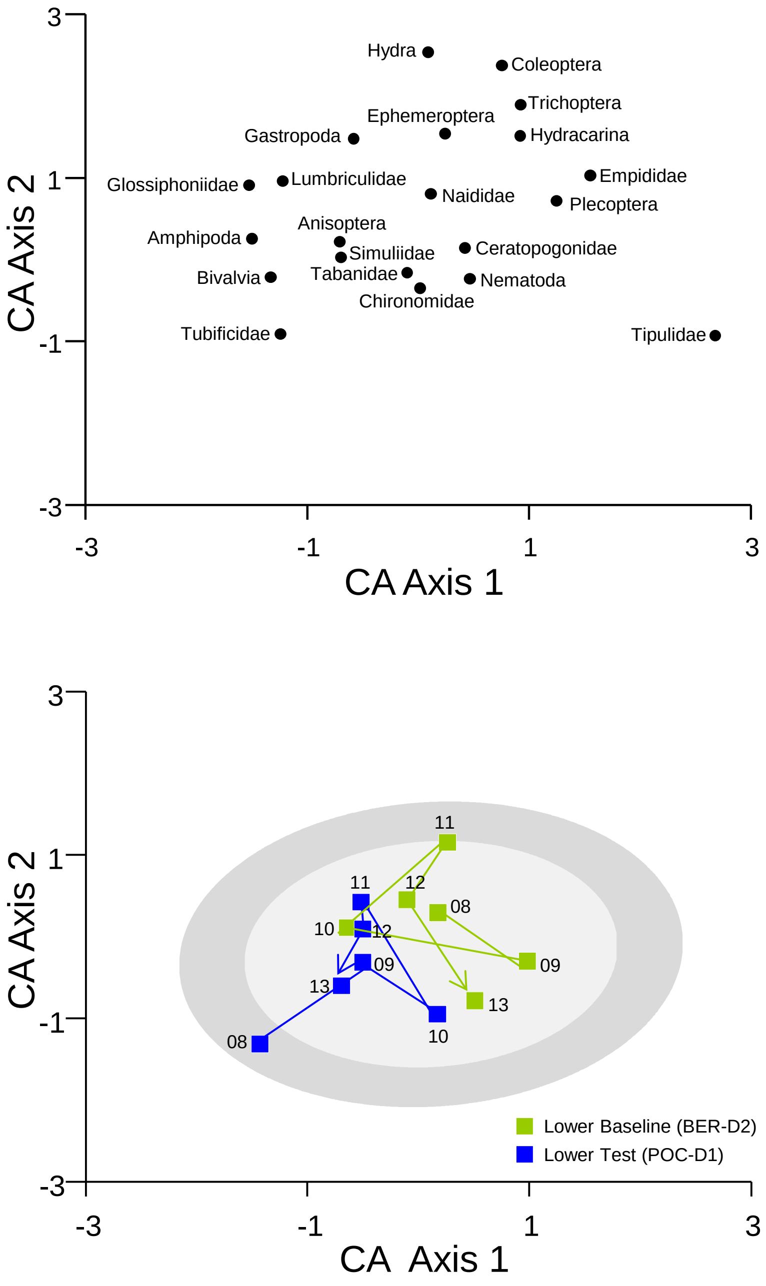
Figure 5.13-19 Variation in benthic invertebrate community measurement endpoints in Beaver River and Poplar Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-20 **Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing reaches of Poplar Creek and the Beaver River.**



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches in the RAMP FSA.

Table 5.13-27 Concentrations of sediment quality measurement endpoints, lower Poplar Creek (*test* station POC-D1), fall 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>8.3</u>	8	10.0	19.9	35.0
Silt	%	-	23.3	8	13.3	35.8	68.3
Sand	%	-	68.5	8	0.9	48.8	73.0
Total organic carbon	%	-	2.41	8	1.07	2.15	2.53
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]	<83	6	<5	30	143
Fraction 3 (C16-C34)	mg/kg	300[1]	**908**	6	170	**576**	**2,830**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	838	6	54	569	**2,820**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0017	8	0.0019	0.0088	0.0205
Retene	mg/kg	-	0.124	7	0.048	0.108	0.167
Total dibenzothiophenes	mg/kg	-	3.984	8	0.249	0.790	3.90
Total PAHs	mg/kg	-	11.95	8	1.75	2.97	13.3
Total Parent PAHs	mg/kg	-	0.244	8	0.122	0.195	0.440
Total Alkylated PAHs	mg/kg	-	11.71	8	1.61	2.81	12.8
Predicted PAH toxicity[3]	H.I.	1.0	**1.89**	8	0.16	0.95	**4.15**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Other analytes that exceeded CCME guidelines in 2013							
Chrysene	mg/kg	0.0571	**0.0727**	7	0.0181	0.0347	**0.1310**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>4.2</u>	6	6.8	7.9	9.2
Chironomus growth - 10d	mg/organism	-	<u>3.85</u>	6	1.61	1.72	2.45
Hyalella survival - 14d	# surviving	-	9.2	7	8.0	8.6	9.6
Hyalella growth - 14d	mg/organism	-	0.20	7	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).

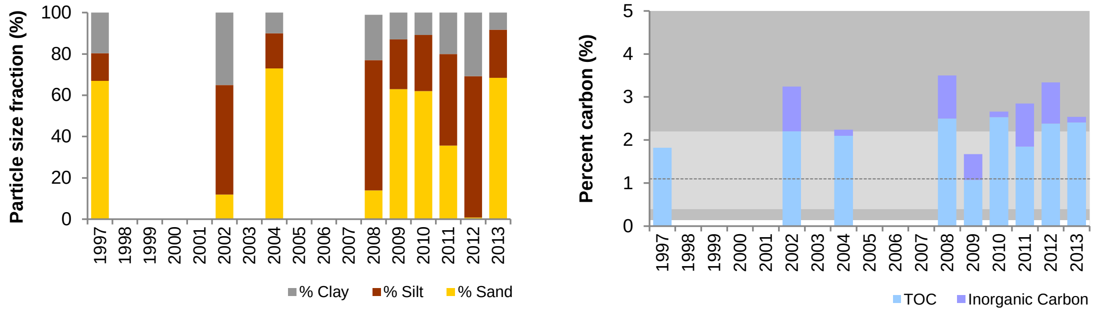
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.13-21 Variation in sediment quality measurement endpoints at *test* station POC-D1.

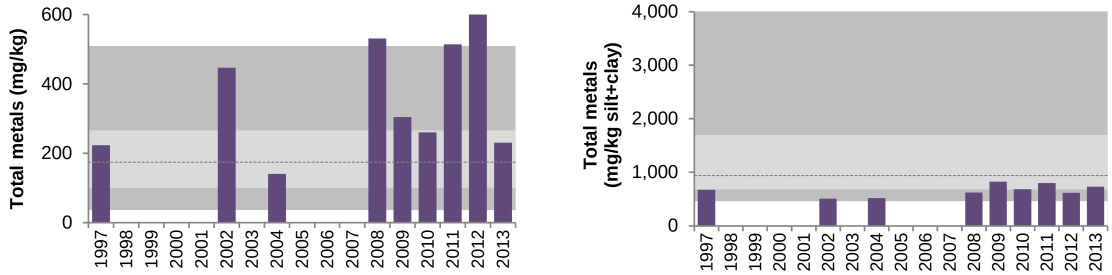
Particle size distribution

Carbon Content[1]



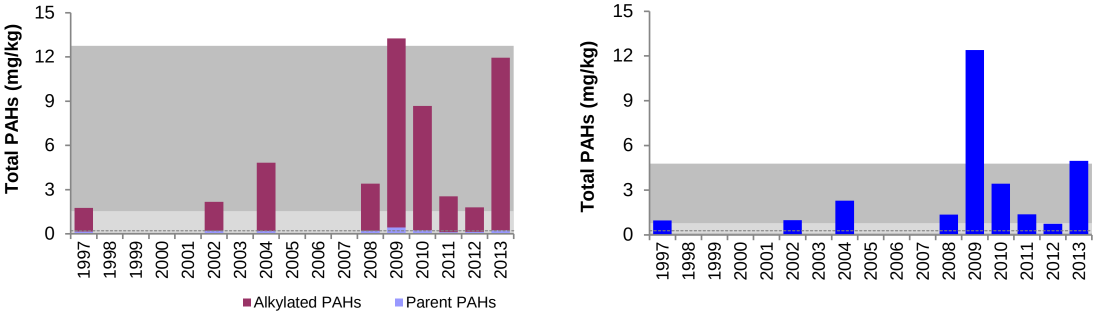
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



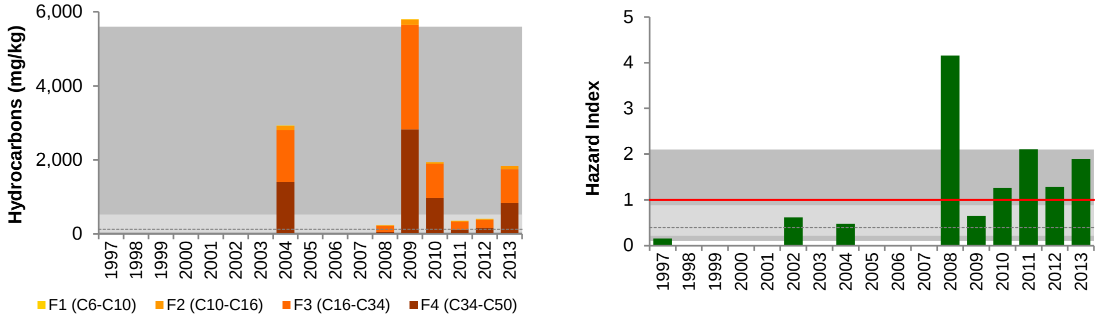
Total PAHs

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 (1997-2013).

[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 5.13-28 Concentrations of sediment quality measurement endpoints, upper Beaver River (*baseline* station BER-D2), fall 2013.

Variables	Units	Guideline	September 2013	2008-2013 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.0	5	2.4	5.8	9.0
Silt	%	-	<1.0	5	1.0	6.6	21.0
Sand	%	-	95.6	5	70.0	87.4	95.3
Total organic carbon	%	-	0.3	5	<0.1	0.4	2.0
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<10	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<10	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	4	<20	<20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	20	4	<20	<21	119
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	4	<20	<20	94
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0010	5	0.0003	0.0010	0.0030
Retene	mg/kg	-	0.001	5	0.005	0.011	0.520
Total dibenzothiophenes	mg/kg	-	0.003	5	0.001	0.004	0.015
Total PAHs	mg/kg	-	0.029	5	0.018	0.077	0.704
Total Parent PAHs	mg/kg	-	0.004	5	0.004	0.007	0.017
Total Alkylated PAHs	mg/kg	-	0.025	5	0.014	0.070	0.686
Predicted PAH toxicity[3]	H.I.	1.0	0.12	4	0.16	0.42	0.88
Metals that exceed CCME guidelines in 2013							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6.80	5	7.40	8.00	8.80
Chironomus growth - 10d	mg/organism	-	3.93	5	1.60	2.09	2.63
Hyalella survival - 14d	# surviving	-	9.00	5	6.60	8.60	9.60
Hyalella growth - 14d	mg/organism	-	0.45	5	0.17	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).

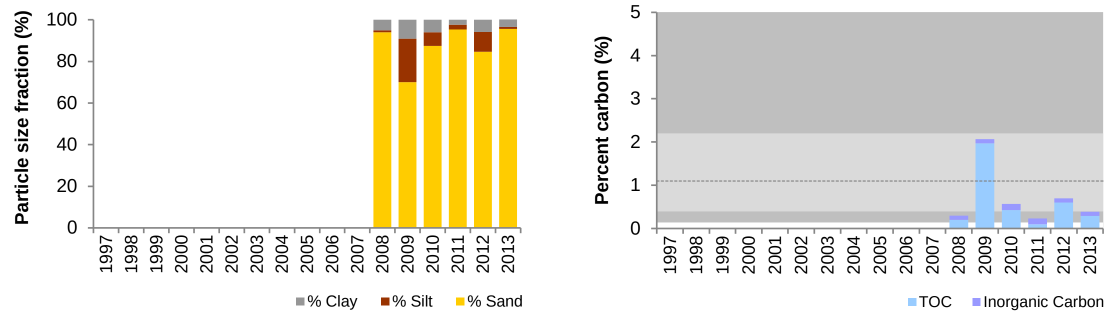
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.13-22 Variation in sediment quality measurement endpoints at *test* station BER-D2.

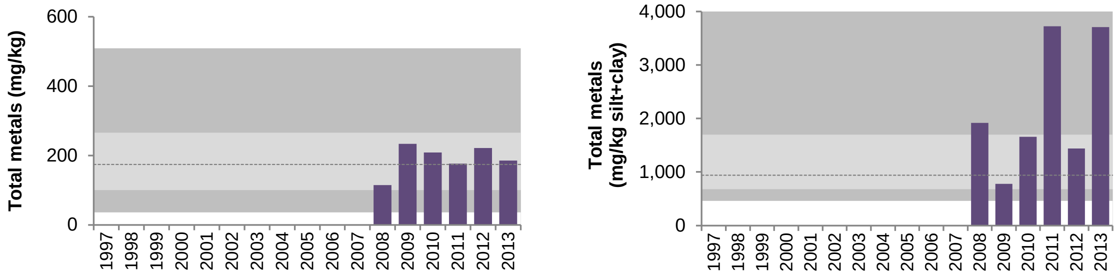
Particle size distribution

Carbon Content[1]



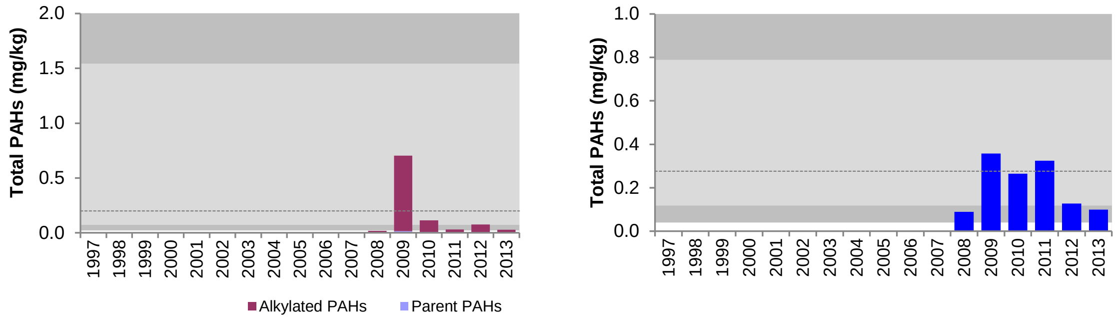
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



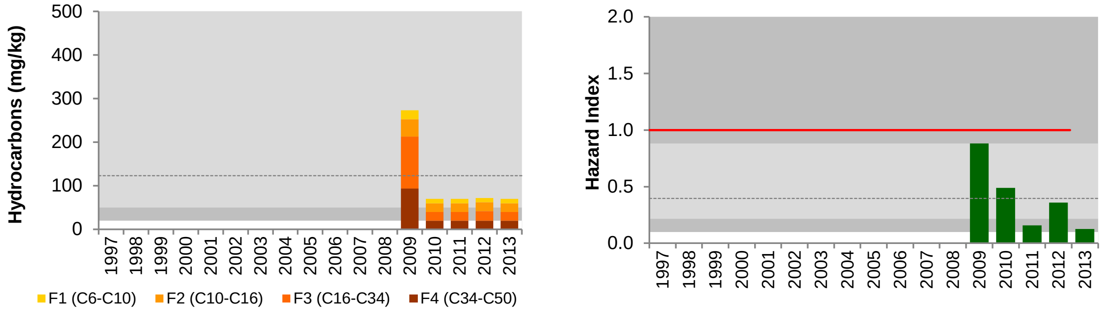
Total PAHs

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 (1997-2013).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-29 Sediment quality index (fall 2013) for miscellaneous watershed stations.

Station Identifier	Location	2013 Designation	Sediment Quality Index	Classification
POC-D1	mouth of Poplar Creek	*test*	89.0	Negligible-Low
FOC-D1	mouth of Fort Creek	*test*	89.7	Negligible-Low
BER-D2	upper Beaver River	*baseline*	98.9	Negligible-Low

Table 5.13-30 Average habitat characteristics of fish assemblage monitoring locations of Poplar Creek and upper Beaver River, fall 2013.

Variable	Units	POC-F1 Lower *Test* Reach of Poplar Creek	BER-F2 Upper *Baseline* Reach of the Beaver River
Sample date	-	Sept 14, 2013	Sept 4, 2013
Habitat type	-	riffle/run	run
Maximum depth	m	0.36	0.55
Mean depth	m	0.23	0.12
Bankfull channel width	m	11.4	10.9
Wetted channel width	m	10.1	5.7
Substrate			
Dominant	-	cobble	sand
Subdominant	-	sand	cobble
Instream cover			
Dominant	-	boulders	small woody debris
Subdominant	-	filamentous algae, small woody debris	large woody debris, undercut banks
Field water quality			
Dissolved oxygen	mg/L	9.0	8.2
Conductivity	µS/cm	600	369
pH	pH units	8.34	7.87
Water temperature	^{0}C	14.8	18.3
Water velocity			
Left bank velocity	m/s	0.07	0.20
Left bank water depth	m	0.24	0.17
Centre of channel velocity	m/s	0.20	0.33
Centre of channel water depth	m	0.19	0.12
Right bank velocity	m/s	0.04	0.47
Right bank water depth	m	0.27	0.07
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	-	overhanging vegetation

Table 5.13-31 Total number and percent composition of fish species captured at reaches of Poplar Creek and the upper Beaver River, 2009 to 2013.

		Total Species								**Percent of Total Catch**							
Common Name	**Code**	***Baseline* Reach BER-F2**				***Test* Reach POC-F1**				***Baseline* Reach BER-F2**				***Test* Reach POC-F1**			
		2009	**2011**	**2012**	**2013**	**2009**	**2011**	**2012**	**2013**	**2009**	**2011**	**2012**	**2013**	**2009**	**2011**	**2012**	**2013**
brook stickleback	BRST	1	2	8	18	4	-	-	-	3.3	6.1	19.0	24.7	20.0	0.0	0	0
burbot	BURB	-	-	-	-	-	-	-	18	0	0	0	0	0	0	0	22.5
fathead minnow	FTMN	2	2	4	15	-	-	2	-	7	6.1	9.5	20.5	0	0	11.1	0
finescale dace	FNDC	-	-	-	2	-	2	-	-	0	0	0.0	2.7	0	7.7	0	0
lake chub	LKCH	10	-	20	26	1	-	9	37	33.3	0	47.6	35.6	5.0	0	50.0	46.3
longnose sucker	LNSC	-	-	1	-	-	15	4	15	0	0	2.4	0	0	57.7	22.2	18.8
northern pike	NRPK	-	-	-	-	1	-	-	2	0	0	0	0	5.0	0	0	2.5
pearl dace	PRDC	-	28	2	-	-	4	-	-	0	84.8	4.8	0	0	15.4	0	0
spoonhead sculpin	SPSC	-	-	-	-	1	-	-	-	0	0	0	0	5.0	0	0	0
trout-perch	TRPR	2	-	-	-	5	-	-	-	6.7	0	0	0	25.0	0	0	0
walleye	WALL	-	-	-	-	4	-	-	1	0	0	0	0	20.0	0	0	1.3
white sucker	WHSC	15	-	5	8	4	5	2	7	50.0	0	11.9	11.0	20.0	19.2	11.1	8.8
yellow perch	YLPR	-	-	-	-	-	-	1	-	0	0	0	0	0	0	5.6	0
sucker sp. *		-	1	1	4	-	-	-	-	0	3.0	2.4	5.5	0	0	0	0
Total Count		**30**	**33**	**42**	**73**	**20**	**26**	**18**	**80**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**3**	**7**	**6**	**7**	**4**	**5**	**6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Electrofishing Effort (secs)		**1,678**	**1,412**	**1,618**	**1,192**	**1,534**	**1,003**	**1,535**	**1,312**	-	-	-	-	-	-	-	-

* Unknown species not included in total count.

Table 5.13-32 Summary of fish assemblage measurement endpoints in reaches of the Beaver River and Poplar Creek, 2009 and 2013.

Site	Year	Abundance		Richness*			Diversity*		ATI*		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BER-F2	2009	0.10	-	5	5	-	0.62	-	7.04	-	1.96	-
	2011	0.22	0.39	4	1	0.84	0.13	0.22	7.74	3.63	3.05	5.27
	2012	0.19	0.13	7	3	1.10	0.58	0.11	6.45	0.96	2.53	1.70
	2013	0.29	0.30	5	3	1.14	0.60	0.11	7.22	0.50	6.04	5.91
POC-F1	2009	0.07	-	7	7	-	0.81	-	8.29	-	1.19	-
	2011	0.17	0.22	4	1	1.34	0.30	0.28	6.01	3.33	1.91	2.63
	2012	0.09	0.09	6	2	1.23	0.43	0.24	6.41	1.10	1.16	1.13
	2013	0.27	0.17	6	4	0.84	0.64	0.08	4.78	0.52	6.21	3.93

* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach.

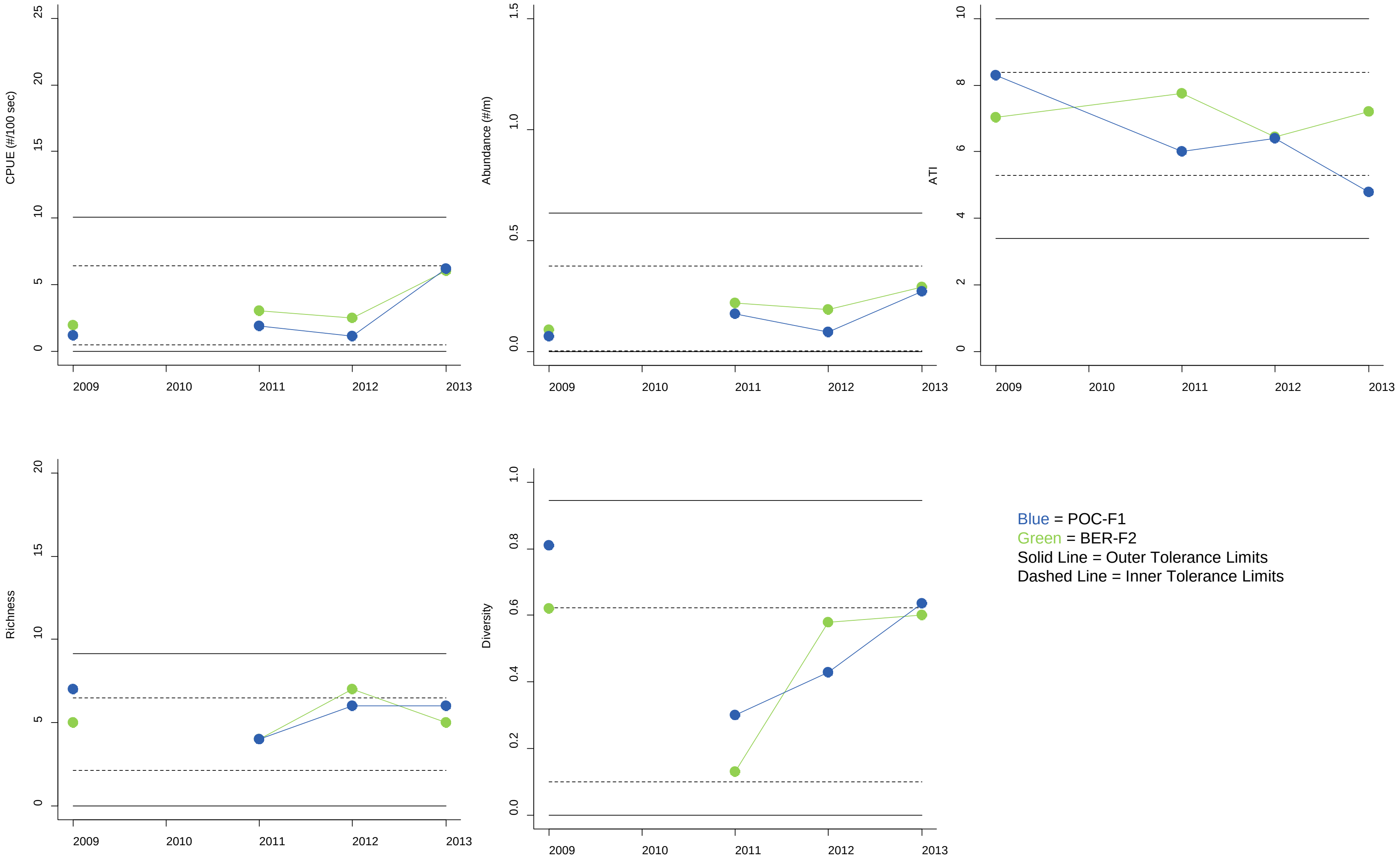
Table 5.13-33 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in Poplar Creek.

Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*test* reach)	*Baseline* Reach vs. *Test* Reach	Time Trend (*test* reach)	*Baseline* Reach vs. *Test* Reach	
Abundance	0.394	0.785	5.6	1.0	No change.
Richness	**0.002**	0.663	57.6	1.0	Increasing over time.
Diversity	**0.027**	0.542	32.6	1.0	Increasing over time.
ATI	0.062	0.285	30.7	5.0	No change.
CPUE (No./100 sec)	**0.045**	0.628	27.4	1.0	Increasing over time.

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 3.2-17).

Figure 5.13-23 Variation in fish assemblage measurement endpoints in Poplar Creek and the upper Beaver River, 2009 to 2013.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

Table 5.13-34 Concentrations of water quality measurement endpoints, McLean Creek (*test* station MCC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	14	8.0	8.3	8.6
Total suspended solids	mg/L	-	4.0	14	<3.0	12.5	83
Conductivity	µS/cm	-	760	14	289	405	1,220
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.034	14	0.005	0.015	0.048
Total nitrogen	mg/L	1	0.941	14	0.700	**1.17**	**1.52**
Nitrate+nitrite	mg/L	3	<0.071	14	<0.050	<0.100	<1.00
Dissolved organic carbon	mg/L	-	26.2	14	4.90	25.3	35.0
Ions							
Sodium	mg/L	-	87.6	14	10.3	33.0	182
Calcium	mg/L	-	65.0	14	37.9	47.8	81.7
Magnesium	mg/L	-	17.6	14	10.3	13.4	21.0
Chloride	mg/L	120	54.4	14	4.75	30.5	**220**
Sulphate	mg/L	410	67.2	14	3.17	13.7	76.4
Total dissolved solids	mg/L	-	516	14	218	310	743
Total alkalinity	mg/L		252	14	141	175	319
Selected metals							
Total aluminum	mg/L	0.1	**0.650**	14	0.070	**0.349**	**2.58**
Dissolved aluminum	mg/L	0.1	0.020	14	0.003	0.008	0.016
Total arsenic	mg/L	0.005	0.0012	14	0.0006	0.0009	0.0014
Total boron	mg/L	1.2	0.165	14	0.024	0.057	0.220
Total molybdenum	mg/L	0.073	0.00092	14	0.00012	0.00020	0.00085
Total mercury (ultra-trace)	ng/L	5, 13	1.70	10	<1.20	1.25	4.10
Total strontium	mg/L	-	0.259	14	0.110	0.165	0.331
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1.33	2	0.700	4.32	7.94
Oilsands Extractable	mg/L	-	2.32	2	1.19	6.55	11.9
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	1.140	2	<2.071	3.585	5.100
Total dibenzothiophenes	ng/L	-	23.57	2	32.28	86.40	140.5
Total PAHs	ng/L	-	163.3	2	302.3	465.7	629.1
Total Parent PAHs	ng/L	-	24.53	2	25.58	26.15	26.71
Total Alkylated PAHs	ng/L	-	138.8	2	276.7	439.5	602.4
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Sulphide	mg/L	0.002	**0.004**	14	**0.002**	**0.009**	**0.025**
Total iron	mg/L	0.3	**0.647**	14	**0.360**	**0.688**	**3.46**
Total phenols	mg/L	0.004	**0.007**	14	0.001	**0.007**	**0.012**
Total phosphorus	mg/L	0.05	**0.055**	14	0.008	0.038	**0.072**

[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 5.13-24 Piper diagram of ion balance in McLean Creek and Fort Creek.

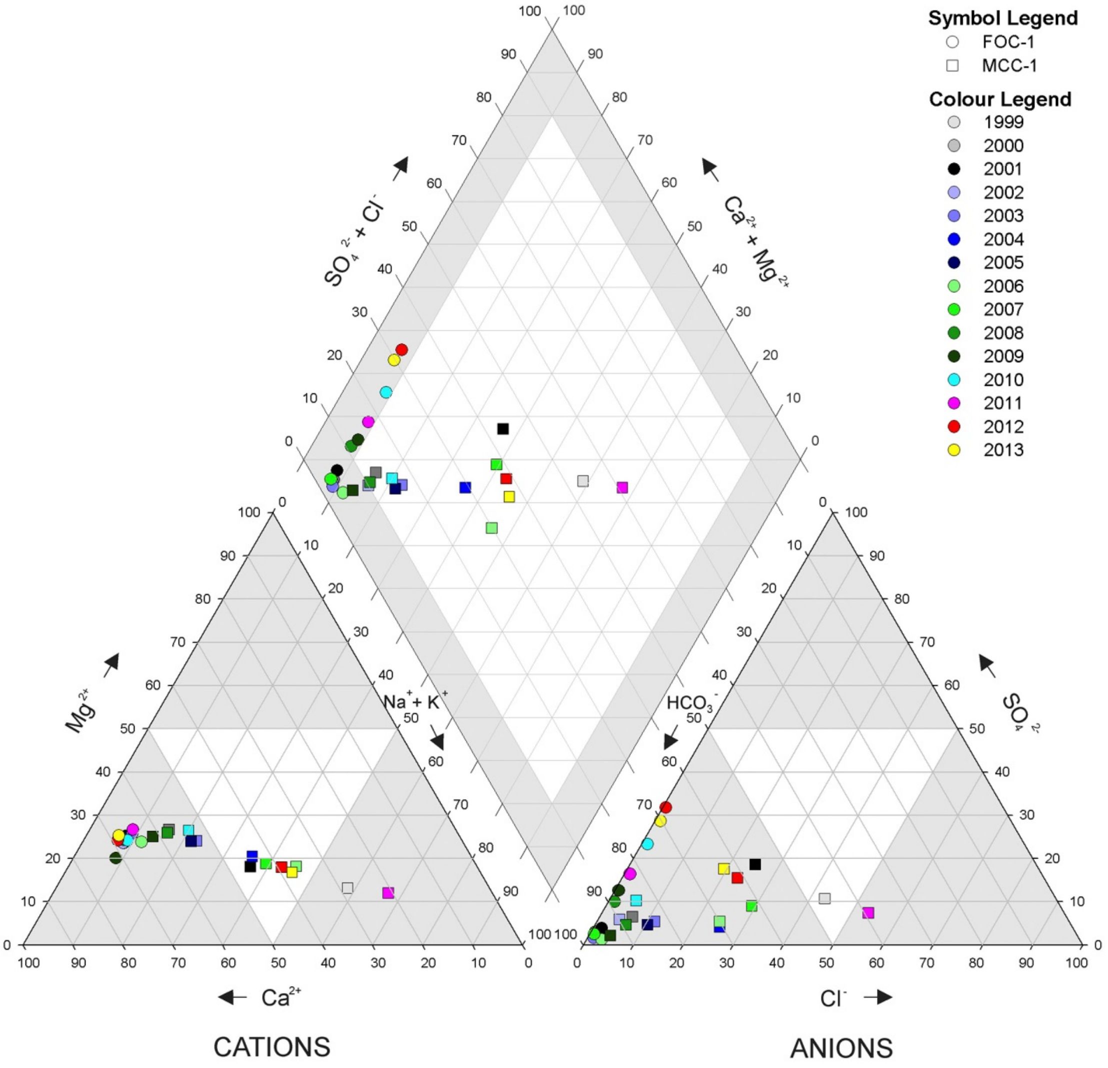
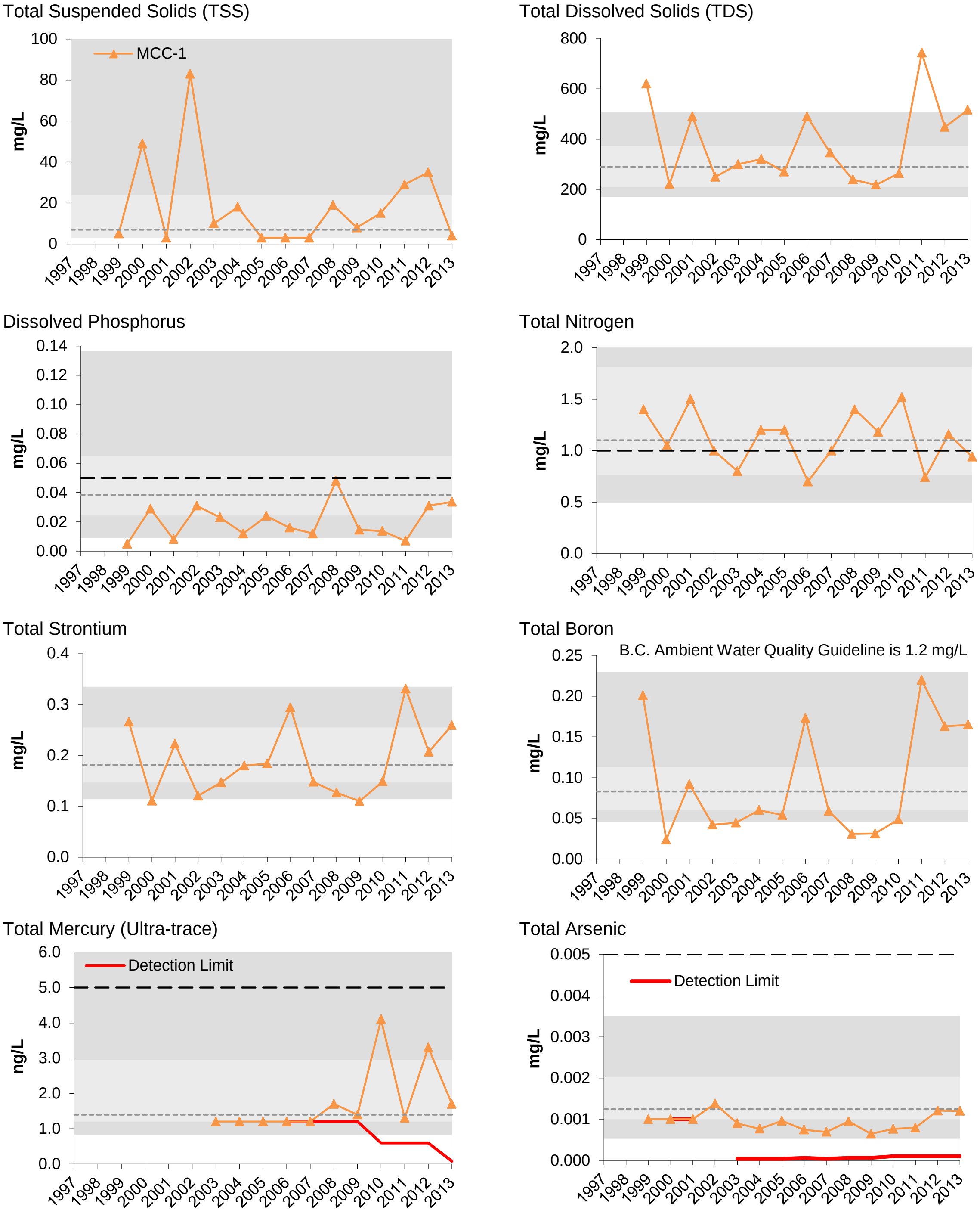


Figure 5.13-25 Concentrations of selected water quality measurement endpoints in McLean Creek (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



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.

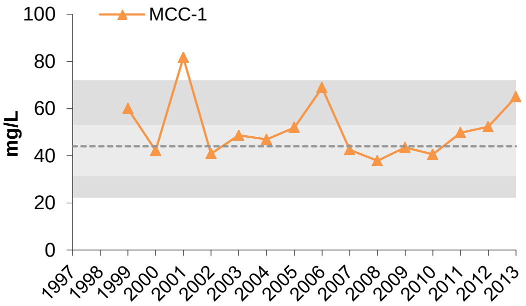
– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

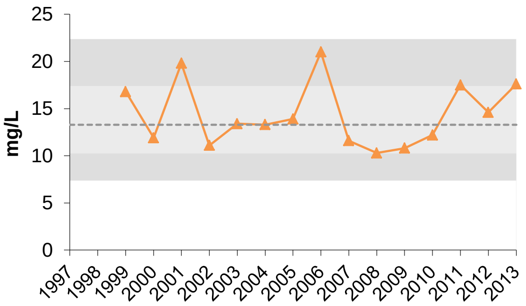
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of RAMP sampling. See sections 3.2.2.2 for a discussion of this approach.

Figure 5.13-25 (Cont'd.)

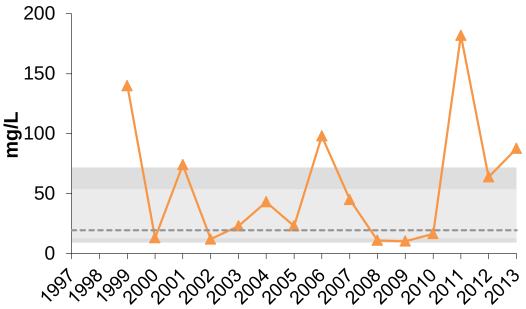
Calcium



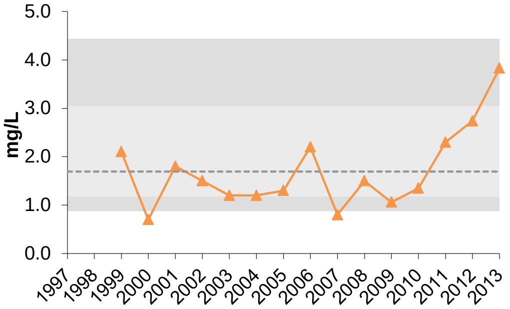
Magnesium



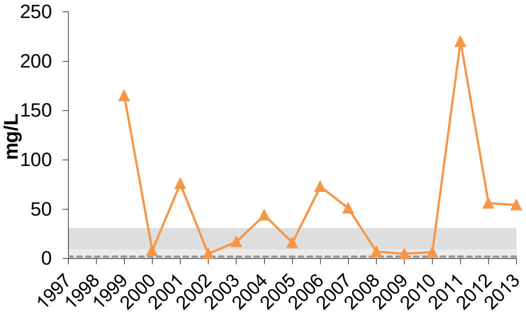
Sodium



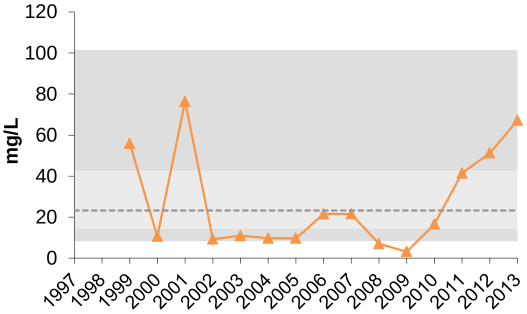
Potassium



Chloride



Sulphate



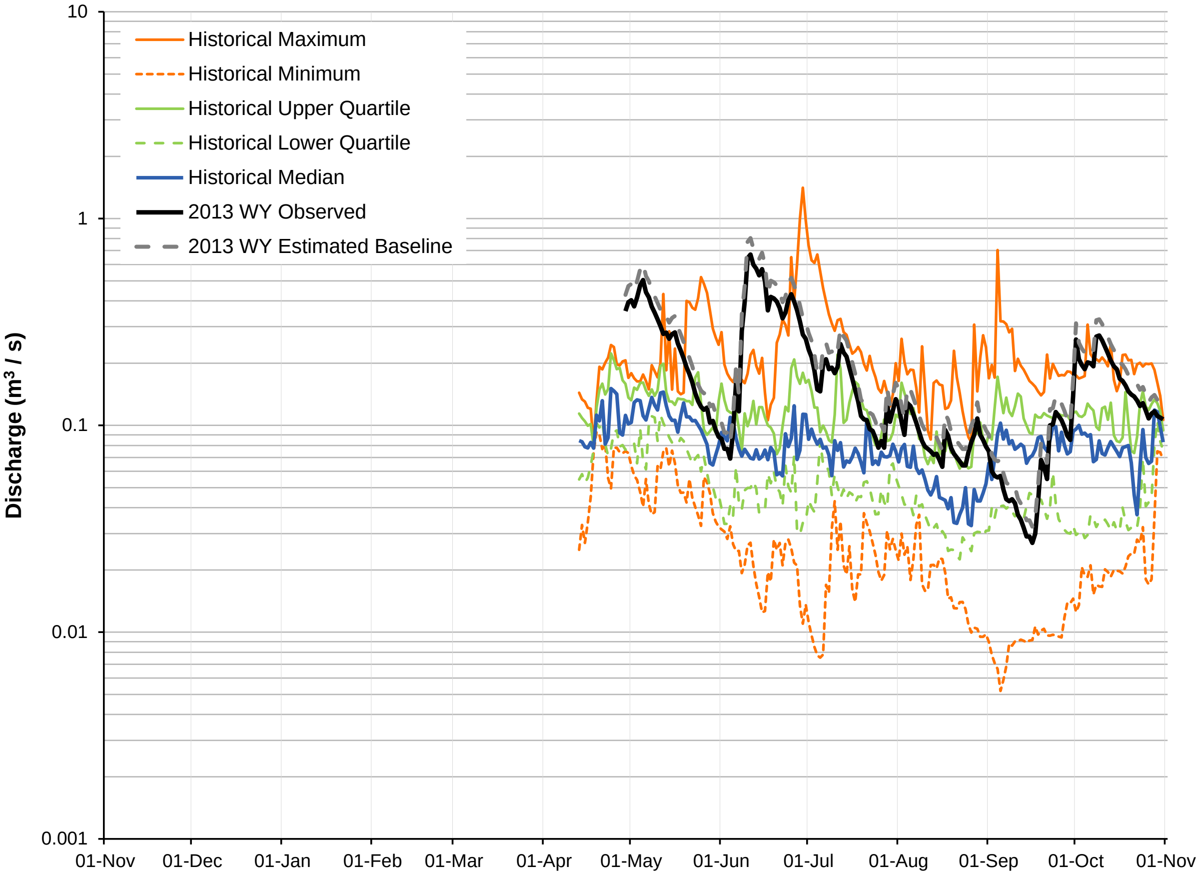
Non-detectable values are shown at the detection limit.

– – – – – 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 3.2.2.2 for a discussion of this approach.

Figure 5.13-26 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Fort Creek in the 2013 WY, compared to historical values.



Note: Observed 2013 WY hydrograph based on Fort Creek at Highway 63, RAMP Station S12, 2013 WY provisional data from April 29 to October 31. The upstream drainage area is 63.8 km^2. Historical values from April 22 to October 31 were calculated using data collected from 2000 to 2002 and from 2006 to 2012.

Table 5.13-35 Estimated water balance at Station S12, Fort Creek at Highway 63, 2013 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* discharge	2.937	**Observed *test* discharge, obtained from Fort Creek at Highway 63, RAMP Station S12.**
Closed-circuited area water loss from the observed *test* discharge	-0.989	Estimated 17.9 km^2 of Fort Creek watershed closed-circuited by focal projects as of 2013 (Table 2.5-1)
Incremental runoff from land clearing (not closed-circuited area)	+0.405	Estimated 36.7 km^2 of Fort Creek watershed with land change from focal projects as of 2013 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	Not applicable
Estimated *baseline* discharge	3.521	**Estimated *baseline* discharge at Fort Creek at Highway 63, RAMP Station S12.**
Incremental flow (change in total discharge)	-0.584	Total discharge from observed *test* volume less total discharge of estimated *baseline* volume
Incremental flow (% of total discharge)	**+16.6%**	**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 was calculated from provisional data from April 29 to October 31, 2013 for Fort Creek at Highway 63 RAMP Station S12.

Table 5.13-36 Calculated change in hydrologic measurement endpoints for the Fort Creek at Highway 63, 2013 WY.

Measurement Endpoint	**Value from *Baseline* Hydrograph (m^3/s)**	**Value from *Test* Hydrograph (m^3/s)**	**Relative Change**
Mean open-water season discharge	0.217	0.181	-16.6%
Mean winter discharge	-	-	-
Annual maximum daily discharge	0.804	0.671	-16.6%
Open-water season minimum daily discharge	0.032	0.027	-16.6%

Note: Definitions and assumptions are discussed in Section 3.2.1.4.

Note: Observed discharge volume was calculated from provisional data from April 29 to October 31, 2013 for Fort Creek at Highway 63 RAMP Station S12. The upstream drainage area is 60.8 km^2.

Note: The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three and 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 5.13-37 Concentrations of water quality measurement endpoints, Fort Creek (*test* station FOC-1), fall 2013.

Measurement Endpoint	Units	Guideline[a]	September 2013	1997-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	11	8.1	8.3	8.4
Total suspended solids	mg/L	-	<3.0	11	<3.0	14.0	35.5
Conductivity	µS/cm	-	694	11	432	562	649
Nutrients							
Total dissolved phosphorus	mg/L	0.05	0.013	11	0.005	0.010	0.019
Total nitrogen	mg/L	1	0.421	11	0.361	0.551	1.00
Nitrate+nitrite	mg/L	3	<0.071	11	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	10.0	11	10.0	13.0	14.0
Ions							
Sodium	mg/L	-	11.8	11	9.0	11.0	18.0
Calcium	mg/L	-	117	11	69.4	83.1	96.8
Magnesium	mg/L	-	26.3	11	14.6	18.2	21.8
Chloride	mg/L	120	3.52	11	2.00	2.84	7.00
Sulphate	mg/L	410	109	11	3.7	11.2	105
Total dissolved solids	mg/L	-	458	11	260	360	443
Total alkalinity	mg/L		280	11	231	277	309
Selected metals							
Total aluminum	mg/L	0.1	0.062	11	0.031	0.084	**0.850**
Dissolved aluminum	mg/L	0.1	0.0016	11	<0.0010	0.0015	0.0500
Total arsenic	mg/L	0.005	0.00020	11	0.00023	0.00028	<0.0010
Total boron	mg/L	1.2	0.072	11	0.038	0.053	0.073
Total molybdenum	mg/L	0.073	<0.00010	10	<0.00001	0.00009	0.00010
Total mercury (ultra-trace)	ng/L	5, 13	0.480	8	0.600	<1.20	1.40
Total strontium	mg/L	-	0.260	11	<0.00001	0.184	0.245
Total hydrocarbons							
BTEX	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	-	<0.1	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0.90	2	0.25	0.33	0.40
Oilsands Extractable	mg/L	-	1.64	2	0.58	1.25	1.92
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<15.16	2	<8.756	<11.44	<14.13
Retene	ng/L	-	0.958	2	<2.071	5.430	8.790
Total dibenzothiophenes	ng/L	-	52.33	2	42.54	243.9	445.2
Total PAHs	ng/L	-	233.6	2	298.1	913.4	1529
Total Parent PAHs	ng/L	-	24.99	2	22.55	29.42	36.29
Total Alkylated PAHs	ng/L	-	208.6	2	275.6	884.0	1492
Other variables that exceeded CCME/AESRD guidelines in fall 2013							
Total iron	mg/L	0.3	**0.543**	11	0.065	**0.689**	**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 5.13-38 Average habitat characteristics of benthic invertebrate sampling locations in Fort Creek, fall 2013.

Variable	**Units**	**FOC-D1** **Lower *Test* Reach of Fort Creek**
Sample date	-	Sept 15, 2013
Habitat	-	Depositional
Water depth	m	0.2
Current velocity	m/s	0.21
Field Water Quality		
Dissolved oxygen	mg/L	9.9
Conductivity	µS/cm	673
pH	pH units	8.4
Water temperature	°C	10.6
Sediment Composition		
Sand	%	95
Silt	%	3
Clay	%	2
Total Organic Carbon	%	2.7

Table 5.13-39 Summary of major taxa abundances and measurement endpoints of the benthic invertebrate community in Fort Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach FOC-D1		
	2001	**2002 to 2012**	**2013**
Nematoda	2	1 to 24	1
Oligochatea		0 to 2	<1
Naididae	1	0 to 2	3
Tubificidae		<1 to 66	23
Enchytraeidae	1	0 to 2	<1
Lumbricidae		7	
Erpobdellidae		0 to <1	
Glossiphoniidae		0 to <1	
Hydracarina	<1	0 to 2	
Gastropoda	<1	0 to 3	<1
Bivalvia	5	0 to 8	
Ceratopogonidae	<1	0 to 8	<1
Chironomidae	80	18 to 95	55
Diptera (misc.)	9	0 to 3	14
Ephemeroptera	<1	0 to 1	<1
Odonata			<1
Plecoptera		0 to 7	
Trichoptera		0 to <1	<1
Heteroptera		0 to <1	
Benthic Invertebrate Community Measurement Endpoints			
Abundance (mean per replicate samples)	91	13 to 1,603	72
Richness	15	4 to 13	14
Equitability	0.50	0.30 to 0.80	0.45
% EPT	<1	0 to 9	1

Table 5.13-40 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in lower Fort Creek (*test* reach FOC-D1).

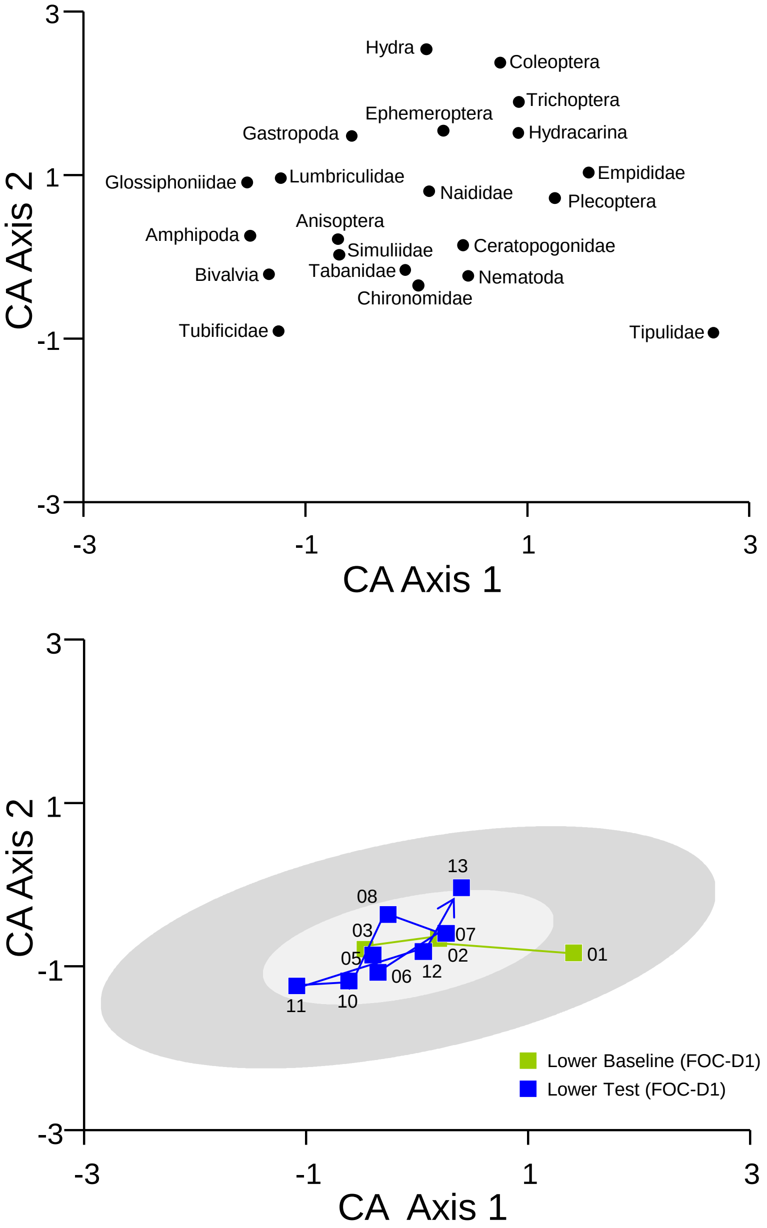
Measurement Endpoint	**P-value**				**Variance Explained (%)**				**Nature of Change(s)**
	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	***Baseline* Period vs. *Test* Period**	**Time trend (*test* period)**	**2013 vs. *Baseline* Years**	**2013 vs. Previous Years**	
Log of Abundance	**0.002**	0.661	0.255	0.581	39	1	5	1	Higher during *baseline* period.
Log of Richness	**0.003**	0.474	0.480	**0.010**	32	2	2	23	Higher during *baseline* period; higher in 2013 than mean of all previous years.
Equitability	**0.014**	0.560	0.594	0.398	24	1	1	3	Higher during *test* period.
Log of EPT	0.462	0.419	0.339	0.472	6	7	10	5	No change.
CA Axis 1	0.095	0.763	0.974	0.206	20	1	0	11	No change.
CA Axis 2	0.961	0.479	0.061	0.021	0	4	33	50	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate or High (Table 3.2-6).

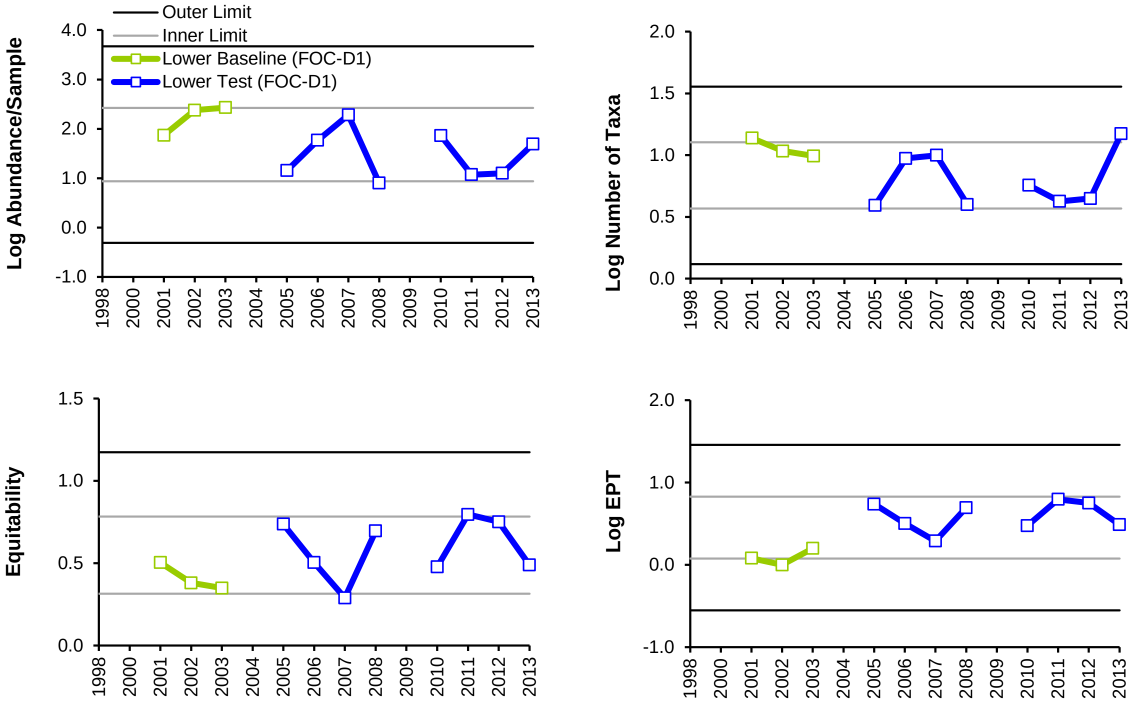
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-27 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Fort Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner 5th and outer 95th percentiles for previous years at *test* reach FOC-D1.

Figure 5.13-28 Variation in benthic invertebrate community measurement endpoints in Fort Creek.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years (2001 to 2012).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.13-41 Concentrations of sediment quality measurement endpoints, Fort Creek (*test* station FOC-D1), fall 2013.

Variables	Units	Guideline	September 2013	2001-2012 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1.9	6	1.0	3.9	15.0
Silt	%	-	3.2	6	1.0	5.9	29.0
Sand	%	-	94.8	6	56.0	89.7	97.9
Total organic carbon	%	-	1.90	8	1.48	3.06	7.10
Total hydrocarbons							
BTEX	mg/kg	-	<10	5	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	5	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	127	5	16	93	**311**
Fraction 3 (C16-C34)	mg/kg	300[1]	**2,930**	5	**440**	**2,020**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	2,330	5	450	1,500	2,140
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0008	8	0.0006	0.0054	0.0170
Retene	mg/kg	-	0.069	8	0.033	0.089	0.679
Total dibenzothiophenes	mg/kg	-	1.85	8	0.16	2.01	3.22
Total PAHs	mg/kg	-	9.69	8	1.85	8.77	14.26
Total Parent PAHs	mg/kg	-	0.274	8	0.159	0.250	0.874
Total Alkylated PAHs	mg/kg	-	9.42	8	1.69	8.53	13.38
Predicted PAH toxicity[3]	H.I.	1.0	0.51	7	0.42	0.73	**1.50**
Metals that exceeded CCME guidelines in 2013							
none	mg/kg	-					
Other analytes that exceeded CCME guidelines in 2013							
Chrysene	mg/kg	0.0571	**0.098**	8	0.018	**0.086**	**0.230**
Dibenz(a,h)anthracene	mg/kg	0.00622	**0.0120**	8	0.0039	**0.0131**	**0.0680**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	3.2	7	6.8	9.0	10.0
Chironomus growth - 10d	mg/organism	-	3.30	7	1.24	1.89	2.98
Hyalella survival - 14d	# surviving	-	9.3	7	6.0	8.8	9.6
Hyalella growth - 14d	mg/organism	-	0.16	7	0.10	0.20	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).

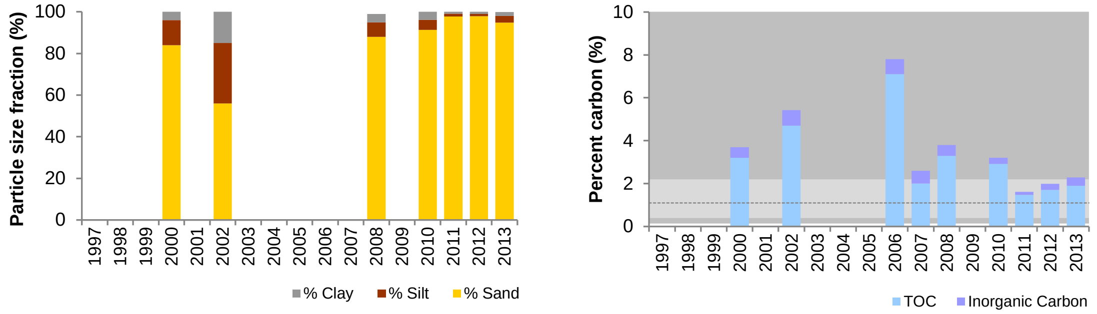
[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[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 5.13-29 Variation in sediment quality measurement endpoints in Fort Creek, *test* station FOC-D1.

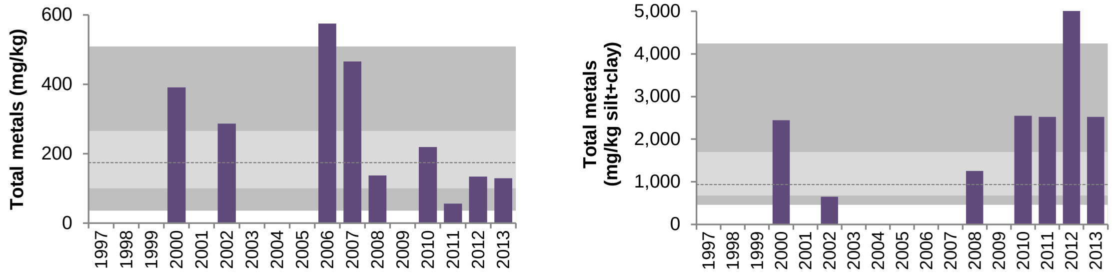
Particle size distribution

Carbon Content[1]



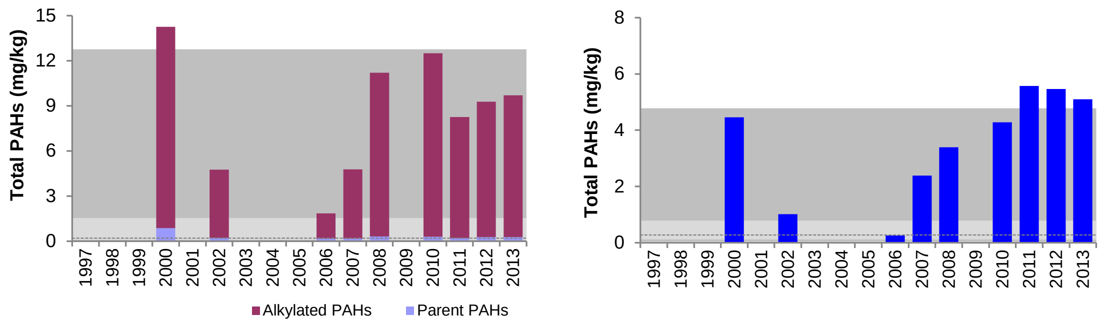
Total Metals[2]

Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



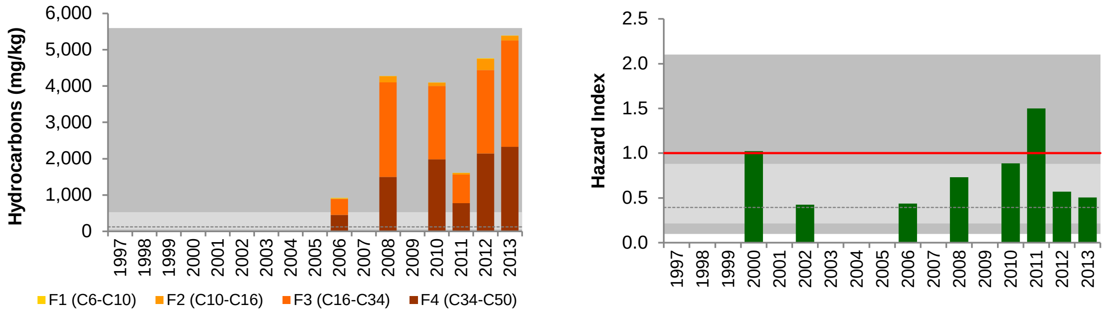
Total PAHs

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 5.13-42 Average habitat characteristics of fish assemblage monitoring locations in Fort Creek, fall 2013.

Variable	Units	FOC-F1 Lower *Test* Reach of Fort Creek
Sample date	-	Sept 15, 2013
Habitat type	-	riffle/run
Maximum depth	m	0.30
Mean depth	m	0.24
Bankfull channel width	m	4.0
Wetted channel width	m	1.7
Substrate		
Dominant	-	sand
Subdominant	-	fine gravel
Instream cover		
Dominant	-	large woody debris
Subdominant	-	small woody debris
Field water quality		
Dissolved oxygen	mg/L	9.75
Conductivity	µS/cm	673
pH	pH units	8.36
Water temperature	^{0}C	10.3
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	-	-

Table 5.13-43 Total number and percent composition of fish species captured at *test* reach FOC-F1 of Fort Creek, 2011 to 2013.

Common Name	**Code**	**Total Species**			**Percent of Total Catch**		
		2011	**2012**	**2013**	**2011**	**2012**	**2013**
brook stickleback	BRST	8	-	-	9.8	0	0
burbot	BURB	-	-	18	0	0	62.1
fathead minnow	FTMN	-	4	-	0	6.6	0
finescale dace	FNDC	23	-	-	28.0	0	0
lake chub	LKCH	33	1	3	40.2	1.6	10.3
longnose sucker	LNSC	16	15	5	19.5	24.6	17.2
northern pike	NRPK	-	-	2	0	0	6.9
northern redbelly dace	NRDC	-	22	1	0	36.1	3.4
pearl dace	PRDC	-	7	-	0	11.5	0
slimy sculpin	SLSC	1	2	-	1.2	3.3	0
spottail shiner	SPSH	-	7	-	0	11.5	0
trout-perch	TRPR	-	1	-	0	1.6	0
white sucker	WHSC	1	2	-	1.2	3.3	0
Total		**82**	**61**	**29**	**100**	**100**	**100**
Total Species Richness		**6**	**9**	**5**	**-**	**-**	**-**

Table 5.13-44 Summary of fish assemblage measurement endpoints in reaches of Fort Creek, 2011 to 2013.

Year	**Abundance**		**Richness**			**Diversity**		**ATI**		**CPUE**	
	Mean	**SD**	**Total**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
2011	0.67	0.36	6	3	1.14	0.52	0.16	6.44	1.07	7.59	4.92
2012	0.41	0.25	9	4	2.28	0.50	0.29	6.70	0.70	4.82	2.98
2013	0.15	0.07	5	3	1.29	0.39	0.26	3.27	0.89	3.46	1.52

SD = standard deviation across sub-reaches within a reach.

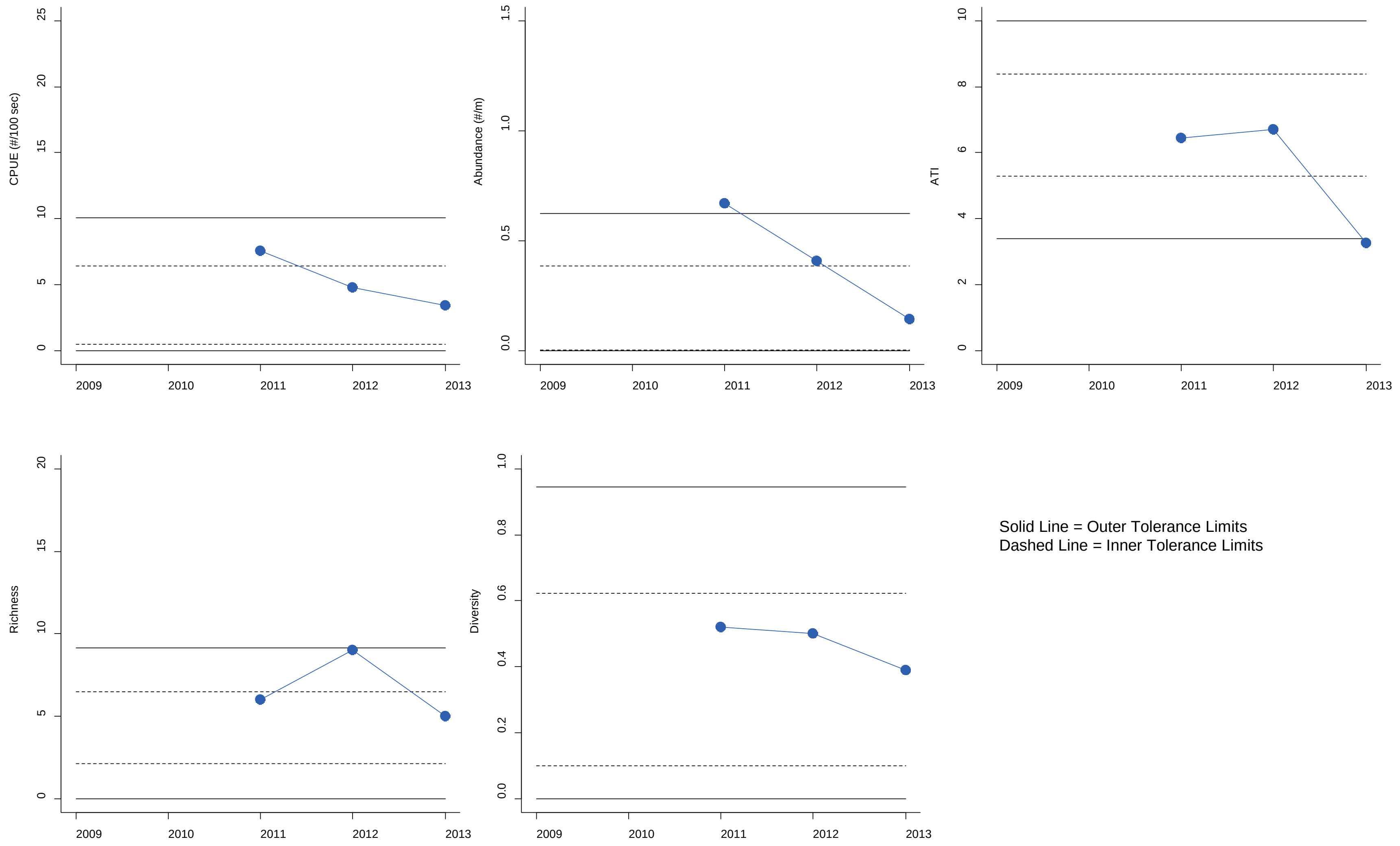
Table 5.13-45 Results of analysis of variance (ANOVA) testing for differences in fish assemblage measurement endpoints in For Creek.

Variable	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**0.010**	43.4	Decreasing over time.
Richness	0.470	4.4	No change.
Diversity	0.441	5.1	No change.
ATI	**0.004**	50.8	Decreasing over time.
CPUE (No./100 sec)	0.094	21.6	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 3.2-17).

Figure 5.13-30 Variation in fish assemblage measurement endpoints in Fort Creek, 2011 to 2013.



Note: Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

5.14 ACID-SENSITIVE LAKES

This section presents the results of the Acid-Sensitive Lakes (ASL) component of RAMP for 2013.

5.14.1 General Characteristics of the RAMP ASL Component Lakes in 2013

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 depth of only 1.83 m (Table 5.14-1). Given the shallow depth of these lakes, a large proportion of the water volume in many of the lakes freezes to depth each winter. Freezing to depth results in large changes in lake chemistry (e.g., anoxia, decrease in pH, increase in alkalinity) that reverse when melting occurs in spring (See Appendix H in RAMP 2008).

The water chemistry variables measured in the 50 RAMP lakes from 1999 to 2013 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 6.83. The median pH in 2013 was 7.04, slightly higher than the historical median but slightly lower than the median pH of 7.24 recorded in 2012. Gran alkalinity in the RAMP lakes has historically ranged from negative values to 2,023 µeq/L, with a median value of 206 µeq/L (Table 5.14-2). The median Gran alkalinity in 2013 was 235 µeq/L, which was slightly higher than more recent sampling years, with the exception of 2012 (262 µeq/L). The highest value of Gran alkalinity ever measured in the RAMP lakes was recorded in Kearl Lake in 2012 (2,023 µeq/L), but was considerably lower in 2013 (1,629 µeq/L) and similar to the historical mean for this lake (1,684 µeq/L).

Conductivity in the RAMP lakes has historically ranged from 8.4 µS/cm to 196 µS/cm, with a median of 33.5 µS/cm. The median conductivity in 2013 was identical to the historical median but was slightly lower than the 2012 median value (38.8 µS/cm). Consistent with Gran alkalinity, the highest conductivity recorded in the RAMP lakes (196 µS/cm) was observed in Kearl Lake in 2012 but was considerably lower in 2013 (162 µeq/L).

In 2012, total dissolved solids (TDS) and most of the base cations (i.e., calcium, magnesium, and potassium) were unusually high in concentration and, in some cases, were the highest values recorded across all monitoring years. These high concentrations were attributed to hydrologic conditions, in particular low precipitation and runoff in summer 2012. In 2013, median concentrations of these variables were considerably lower (with the exception of sodium) and similar to their historical median values. Historically, the concentration of sulphate has been relatively low in the RAMP lakes, ranging from non-detectable to 19.0 mg/L, with a median concentration of 1.15 mg/L. The median sulphate concentration in 2013 was 0.72 mg/L, which was considerably lower than the median concentration in 2012 (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 21.7 mg/L (Kortelainen et al. 1989; Forsius et al. 1992; Driscoll et al. 1991). In 2013, the median DOC concentration was 23.9 mg/L, which was slightly higher than the historical median concentration. Some of the highest concentrations of DOC observed in 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 2013, the concentration of DOC in these lakes was considerably lower (i.e., 36.9 mg/L and 36.8 mg/L in Lake 185 and Lake 209, respectively) and more consistent with historical concentrations.

In general, concentrations of nitrates in the RAMP lakes have historically been quite low, ranging from non-detectable to 733 mg/L, with a median of 3.2 µg/L, although individual lakes may have nitrate concentrations 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.

The concentration of total phosphorus in the RAMP lakes ranged from 3 µg/L to 341 µg/L, with a historical median of 39 µg/L. Using phosphorus as a guide, the RAMP lakes; therefore, cover the range of nutrient conditions from oligotrophic to eutrophic (Wetzel 2001). The median concentration of total phosphorus in 2013 was 34.5 µg/L. Lower historical concentrations of dissolved phosphorus (historical median: 11 µg/L) indicated that a large fraction of the phosphorus is bound to suspended particulates (e.g., higher DOC in 2013).

Lakes having "unusual" water chemistry were identified in the 2013 monitoring data as those below or above the 5th and 95th percentile for three measurement endpoints including pH, Gran alkalinity, and DOC (Table 5.14-3). Generally, these were the same lakes identified in previous years as having "unusual" water chemistry. Four lakes (168/SM10, 169/SM9, 172/WF3, and Clayton Lake/BM7) had very low levels of pH and Gran alkalinity and were the most poorly buffered of the RAMP lakes. These lakes are found in organic soils in upland regions including the Stony and Birch Mountains subregions, with the exception of Lake 172/WF3, which is located in the West of Fort McMurray subregion. The highest pH and Gran alkalinity concentrations were found in lakes 270/NE9, 271/NE10 and Kearl Lake/NE11, all located in mineral soils in the Northeast of Fort McMurray subregion. 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 lakes 223/WF4, 226/WF6 and 227/WF7 located in the West of Fort McMurray subregion.

The lowest levels of Gran alkalinity and pH were 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).

The water 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

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 and potassium among years; these changes 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. The significant differences with an interaction term accounted for more than 5% of the variability included nitrates and DOC in Case 1 (all RAMP lakes); Gran alkalinity, conductivity, potassium, calcium, and sulphate in Case 2 (*baseline* lakes); and 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 2013, which is an 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, indicated 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 from 2002 to 2013. Similar to pH, an increase in Gran alkalinity is inconsistent with an acidification scenario. Given that both *baseline* and *test* lakes showed significant increases in Gran alkalinity likely indicated that factors other than the deposition of acidifying emissions are causing the increases in Gran alkalinity.

There were no significant changes in sulphate in the RAMP lakes from 2002 to 2013. Sulphate is the principal acidifying agent in oil sands emissions.

There were no significant changes in nitrates in all three cases. Concentrations of nitrates appeared to be decreasing (negative slope) in the *test* lakes (Case 3) from 2002 to 2013, although these changes were not statistically significant. The decreasing concentration of nitrates in Case 3 was supported by the one-way ANOVA results that showed a significant decrease in nitrates in all lakes from 2002 to 2013.

There were no significant changes in DOC across sampling years. The concentration of DOC appeared to be increasing (positive slope) in the *test* lakes, although these changes were not statistically significant.

There was a significant increase in the sum of base cations (SBC) from 2002 to 2013 in the *baseline* lakes (Case 2). Given that the *baseline* lakes are remote from the main sources of acidifying emissions and the increase in SBC was not accompanied by decreases in Gran alkalinity or pH, indicated that factors other than acidifying emissions may be causing the increase in SBC in the *baseline* lakes.

There was no significant change in the concentration of dissolved aluminum across sampling years for all three cases.

Similar to historical data, there were significant changes in the ionic characteristics of the RAMP lakes. Significant increases over time were observed in:

- TDS (Case 1 and Case 2);
- conductivity (Case 2);
- sodium (Case 2);
- potassium (Case 1 and Case 2); and
- magnesium (Case 1).

In 2012, significant increases were observed in 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) (RAMP 2013). These changes were observed after a dry summer and were attributed to long-term changes in hydrologic conditions that 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. Changes in the ionic characteristics of the RAMP lakes were less evident in 2013 and likely reflected hydrologic conditions that are more consistent with historical conditions.

5.14.3 Critical Loads of Acidity and Critical Load Exceedances

The critical loads of acidity (CL) were calculated for each RAMP lake for 2002 to 2013 using the Henriksen steady state water chemistry model modified to include the contribution of organic anions as both strong acids and weak organic buffers (WRS 2006; RAMP 2005). The critical load (CL) is an inherent property of each lake that defines the greatest load of acidifying substances that will not cause ecological damage to the lake. 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. In 2013, calculations of CL included calculation of the original base cation concentrations from the current base cation concentrations using the F factor of Brakke et al. (1990) (See Section 3.2.5.3).

The runoff value to each lake, an influential term in the Henriksen model, 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; therefore, the acid sensitivity of a lake will vary depending on the hydrologic regime.

Table 5.14-5 provides estimates of the critical loads of acidity for each individual RAMP lake between 2002 and 2013; summary statistics are provided in Table 5.14-6. In 2013, critical loads ranged from -0.761 keq H^+/ha/yr to 3.613 keq H^+/ha/yr, with a median CL of 0.457 keq H^+/ha/y. The median and mean critical loads were lower in 2013 than 2012; however, critical loads in the RAMP lakes generally appeared to be increasing over time as a result of increases in lake buffering capacity (Gran alkalinity) noted in Section 5.14.2.2.

Mean critical loads in 2013 in the six subregions are presented in Table 5.14-7. Similar to previous years, the lowest critical loads are found in lakes in the Stony Mountains subregion, followed by lakes in the Birch Mountains and West of Fort McMurray 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 3.5.5.3). 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 Potential Acid Input (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 these lakes ranged from a low of 18.4 % (9 of 49 lakes) in 2005 to a high of 39.1 % (18 of 46 lakes) in 2007. In 2013, twelve (24%) of the fifty lakes had a Net PAI greater than the critical load. Differences between years reflect differences in the runoff and the export of alkalinity to each lake.

The percentage of RAMP lakes in which the modeled Net PAI is greater than the critical load (18.4% to 39.1%) was 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 represented 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 with 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 (seven of twelve) are found in the Stony Mountains subregion.

5.14.5 Mann-Kendall Trend Analysis on Measurement Endpoints

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 in a direction indicative of acidification was detected in at least one variable. It is important to note that the Mann-Kendall test is a non-parametric test that subtracts successive values and ranks the differences as negative or positive. Small consistent increases or decreases in a variable that may not be 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 for those lakes where significant changes occurred in a direction indicative of acidification (Figure 5.14-2). The control charts examine changes in a variable in a particular lake in relation to its historical variability, which avoids the false conclusions that may arise from the Mann-Kendall analysis.

In 2013, there were fewer significant trends detected in values of measurement endpoints than previous years and include (Table 5.14-9):

1. Only one lake (270/NE9) had a significant decrease in pH suggestive of acidification. This is a highly buffered lake (Gran alkalinity: 1027 µeq/L) located in mineral soils in the Northeast of Fort McMurray subregion. Given that this decrease in pH was not associated with a decrease in Gran alkalinity or an increase in sulphate, indicates that factors other than acidification may be causing the decrease in pH. Figure 5.14-2 shows that the pH in Lake 270/NE9 has not deviated by more than 0.40 pH units, with a standard deviation of 0.21 pH units over the 12 years of monitoring and has remained relatively constant in the last five years.

   Significant increases in pH were observed in lakes 171/WF2, 227/WF7, 436/BM2, 442/BM9, 444/BM1, 146/CM1, and 152/CM2. An increase in pH is the opposite effect expected from an acidification scenario. Many of the lakes showing an increasing trend in pH in 2013 were also identified in 2012. An increase in pH over time was also detected using an ANOVA (Section 5.12.2) of *baseline* and *test* lakes. The increase in pH appeared to be a regional phenomenon and is likely the result of changing hydrologic conditions in the RAMP lakes.

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 seven 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 indication of acidification (See Section 5.14.5). An increase in Gran alkalinity over time was also detected using an ANOVA (Section 5.12.2) of *baseline* and *test* lakes. Similar to pH, changing hydrologic conditions were likely responsible for the observed increases in Gran alkalinity.

3. A significant increase in the concentration of sulphate was detected over time in Lake 223/WF4 in the West of Fort McMurray subregion, with an exceedance of the 2SD limit in 2013 (Figure 5.14-2). This lake is highly buffered with a mean Gran alkalinity of 722 µeq/L and there were no significant changes in any of the other measurement endpoints for this lake (including pH and Gran alkalinity) to suggest that acidification may be occurring.

4. A significant increase in the concentration of sulphate was detected over time in Lake 146/CM 1 in the Caribou Mountains subregion. A significant trend was also evident in the control chart in which the 2SD limit was exceeded in two consecutive years (2012 and 2013). This increase in sulphate in Lake 146/CM1 was small (<1.5 mg/L from the long-term mean) 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 development and based on current emissions modeling, unaffected by acidic emissions.

The increase in sulphate was likely attributed to other sources of acidification. Lake 146/CM1 will be monitored in future years to determine whether this trend continues.

5. A significant increase in the concentration of nitrates over time was detected in Lake 289/SM3 in the Stony Mountains subregion, Lake 209/NE1 located in the Northeast of Fort McMurray subregion, and Lake 442/BM9 in the Birch Mountains subregion. The control charts for Lakes 289/SM3 and 442/BM9 indicated that the concentration of nitrates in these lakes was extremely low and variable, with a mean concentration of approximately 2 µg/L (Figure 5.14-2). These lakes provide examples of small, relatively consistent increases in the concentration of nitrates that are likely ecologically insignificant, or within the range of analytical error. While the concentration of nitrates exceeded the 2SD limit on one occasion in both lakes (i.e., 2011 for Lake 289/SM3 and 2001 for Lake 442/BM9), concentrations in the year following the exceedance returned to near the historical mean concentration. The control charts indicated that there was no significant trend in nitrates occurring in either of these lakes. In addition, Gran alkalinity and pH significantly increased (rather than decreased) in lakes 289 and 442. Lake 209/NE8 is a small pond with an area of only 0.1 km^2 and a catchment area of 0.8 km^2. With a mean concentration of approximately 8 µg/L, this pond has generally higher concentrations of nitrates and greater variability than the other lakes 289/SM3 and 442/BM9. There was a significant increase in the concentration of nitrates in Lake 209/NE8, with an exceedance of the 2SD limit in 2013 (Figure 5.14-2), which was associated with a significant increase (rather than decrease) in Gran alkalinity. The high variability of nitrates and the limitations of its use as a measurement endpoint were noted in previous reports (e.g., RAMP 2012).

6. Significant decreases in DOC over time were detected in lakes 342/SM2, 354/SM1, and Lake 354/SM1 in the Stony Mountains subregion and Lake 270/NE9 in the Northeast of Fort McMurray subregion. However, there were no significant decreases in pH or Gran alkalinity associated with the decrease in DOC in all three lakes, with the exception of Lake 270/NE9 which showed a significant decrease in pH. The control charts provided no supporting evidence that a significant trend in DOC was occurring in any of these three lakes (Figure 5.14-2). The changes in DOC were likely attributed to factors other than acidification, but will be monitored in future years.

7. Significant increases in the sum of base cation (SBC) concentrations over time were detected in lakes 171/WF2 and 227/WF7, located in the West of Fort McMurray subregion; Lake 209/NE8 and Kearl Lake (418/NE11), located in the Northeast of Fort McMurray subregion; Namur Lake (436/BM2) and Lake 444/BM1 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 reduces (rather than increases) Gran alkalinity and pH, indicating that acidification is occurring. For these nine lakes that showed an increase in SBC, there were no significant decreases in pH or Gran alkalinity indicative of acidification. Seven of the nine lakes actually had significant increases in pH and/or Gran alkalinity. The control charts indicated that a

significant increasing trend in SBC was only occurring in lakes 152/CM2 and 146/CM4. In Lake 152/CM2, the SBC has continuously increased for seven consecutive years. In both lakes, two consecutive exceedances of the 2SD limit were observed in the same direction (Figure 5.14-2) (a single exceedance of the 2SD limit is not considered an indication of a trend). However, lakes 152/CM2 and 146/CM1 showed significant increases in pH and Gran alkalinity and are *baseline* lakes found in the Canadian Shield, remote from acidifying emissions. The increases in SBC in these two lakes and the other seven lakes can be attributed to increased loadings of alkalinity (calcium and magnesium bicarbonates) from their catchments rather than calcium and magnesium sulphate.

8. A significant increase in dissolved aluminum was detected in Lake 452/NE1, located in the Northeast of Fort McMurray subregion. Similar to nitrates, dissolved aluminum in the RAMP lakes is highly variable both between lakes and among years within each lake. The increase in dissolved aluminum in this lake was not associated with significant decreases in pH and Gran alkalinity or increases in sulphate and/or nitrates, indicative of acidification. The significant increasing trend was also evident in the control chart for Lake 452/NE1, with an exceedance of the 3SD limit in 2013 (Figure 5.14-2). Lake 452/NE1 will be tracked in future years to determine whether the observed increasing trend in dissolved aluminum continues.

The results of the Mann-Kendall trend analyses did not indicate that acidification is occurring in any of the RAMP lakes. Changes in measurement endpoints were noted but were inconsistent with an acidification scenario and likely reflected hydrologic changes in the RAMP lakes. Monitoring of measurement endpoints should be maintained, particularly in Lakes 152/CM2, 146/CM1, and 452/NE1 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 the risk of acidification. These ten lakes are scattered throughout the oil sands region and 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 (where sufficient data are available) are presented in Figure 5.14-3 to Figure 5.14-9. Similar to previous years, the control charts for all of the measurement endpoints showed isolated exceedances beyond ±2SD during the monitoring period. Some of these exceedances were in a direction consistent with acidification, while other exceedances were not. According to the rules of interpretation of these control charts, two consecutive exceedances of the 2SD limit in a direction consistent with acidification are required to indicate a significant trend.

The following measurement endpoints/lakes showed exceedances in a direction consistent with acidification (i.e., decrease in pH, DOC, Gran alkalinity; increase in SBC, sulphate, nitrates, dissolved aluminum) at some point during the RAMP data record:

- pH in lakes 167 (1999), 290 (2005), and 448 (1999);
- SBC in lakes 170 (1999), 290 (2003), and 448 (2011);

- Sulphate in lakes 167 (1999), 168 (1999), 287 (2007), and 447 (1999);
- DOC in lakes 170 (2000), 172 (2001), and 447 (2010);
- Nitrates in lakes 168 (1999), 290 (2011), and 172 (2010);
- Gran alkalinity in lakes 170 (2005), 287 (2005), 290 (2005), and 447 (2005); and
- Dissolved aluminum in Lake 167 (2010), 168 (2003), 169 (2013), and 290 (2003).

In all cases prior to 2013, concentrations of these measurement endpoints returned to values within the 2SD limits in the following year.

There were no exceedances of the 2SD limits in 2013 that were consistent with acidification, with the exception of dissolved aluminum in Lake 169/SM9 in the Stony Mountains. This lake will be monitored to determine whether dissolved aluminum returns to values normal for this variable. 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 2013 compared to historical data suggest that there were no significant changes in the overall water chemistry of the lakes across years that were attributable to acidification. Significant increases in pH, Gran alkalinity, TDS, conductivity, and selected base cations were observed; however, these changes appeared to be the result of factors other than acidifying emissions (e.g., hydrology). Concentrations of nitrates appeared to be unusually variable both between lakes and between years within individual lakes.

A summary of the state of the RAMP lakes in 2013, with respect to the potential for acidification, was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In general, there was a greater number of exceedances of the 2SD criterion in 2013 than in 2011 and 2012. The highest number of exceedances (6) occurred in lakes in the Northeast of Fort McMurray subregion. Four of these exceedances were attributed to high concentrations of dissolved aluminum, which exceeded the 2SD criterion in two lakes in the Stony Mountain subregion and two lakes in the Birch Mountain subregion. The reasons for the high concentrations of aluminum in 2013 are unknown, although they are likely related to hydrologic changes. Exceedances were also observed in base cation concentrations in two lakes (one in the Caribou Mountains subregion and one in the West of Fort McMurray subregion), which were also likely due to factors other than acidification. Taking into account these factors, five of the subregions were classified as having a **Negligible-Low** indication of incipient acidification while the Northeast of Fort McMurray subregion was classified as having a **Moderate** indication of incipient acidification due to relatively high concentrations of nitrates in one lake.

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 chemical characteristics of the RAMP acid-sensitive lakes.

Variable	Mean		Median		Minimum		Maximum		5th percentile 2013	95th percentile 2013
	1999 to 2013	2013	1999 to 2013	2013	1999 to 2013	2013	1999 to 2013	2013		
Lab pH	6.65	6.78	6.83	7.04	3.97	4.38	9.46	8.03	5.00	7.88
Total alkalinity (µeq/L)	335	360	226	258	0	20	2032	1643	20.0	965
Gran alkalinity (µeq/L)	320	336	206	235	-57.2	-41.2	2023	1629	11.43	943
Specific conductivity (µS/cm)	45.2	43.9	33.5	33.5	8.4	8.4	196	162	10.5	111
Total dissolved solids (mg/L)	69.4	65.1	61.9	57	0.02	20	219	162.5	25.5	149
Turbidity (NTU)	4.33	3.97	2.2	2.855	0.01	0.584	53	24.4	0.942	10.7
Total suspended solids (mg/L)	7.36	3.16	2.64	0.5	0	0	175	50	0.025	13.8
Colour (TCU)	155	199	124	187	8	12.6	948	532	37.5	426
Sodium (mg/L)	2.05	1.84	1.37	1.285	0.02	0.02	12.35	10.07	0.07	6.52
Potassium (mg/L)	0.53	0.62	0.43	0.425	0.00	0.05	2.45	1.9	0.15	1.41
Calcium (mg/L)	5.83	6.11	4.76	5.21	0.0015	0.01	32.2	19.8	0.79	15.1
Magnesium (mg/L)	1.89	1.98	1.49	1.54	0.005	0.15	13.64	7.32	0.28	4.93
Bicarbonate (mg/L)	20.30	21.95	13.81	15.76	0.00	1.25	124	100	1.25	58.9
Chloride (mg/L)	0.33	0.26	0.16	0.11	0.015	0.015	2.64	2.24	0.03	1.09
Sulphate (mg/L)	2.35	1.93	1.15	0.72	0.02	0.02	19.0	17.3	0.02	7.7
Total dissolved nitrogen (µg/L)	831	883	699	806	105	343	2891	2024	433	1724
Ammonia (µg/L)	35.7	29.8	15.2	13	0.35	1.5	1509	637	2.175	64.1
Nitrate + Nitrite (µg/L)	19.2	14.8	3.2	5	0.02	1	733	253	1	43.3
Total phosphorus (µg/L)	54.4	49.7	39	34.5	3	4	341	248	11.5	137
Dissolved phosphorous (µg/L)	20.8	23.6	11	12	1	2	181	181	2.90	75.2
Dissolved inorganic carbon (mg/L)	3.41	3.22	2.1	1.9	0.027	0.2	21.6	16.7	0.2	10.3
Dissolved organic carbon (mg/L)	23.3	25.2	21.72	23.9	6.82	7.2	92.2	52.3	10.3	41.8
Chlorophyll *a* (µg/L)	21.2	24.4	9.7	13.0	0.1	0.1	371	137	0.1	95.6
Iron (mg/L)	0.406	0.521	0.185	0.255	0.001	0.01	3.88	3.02	0.01	1.72
Total nitrogen (µg/L)	1198	1100	953	886	274	378	6558	3788	530	2153
Total Kjeldahl nitrogen (µg/L)	1178	1085	930	874	273	378	6552	3776	528	2149
Sum base cations (µeq/L)	549	564	440	460	38	47	2411	2054	86	1372
Dissolved aluminum (µg/L)	72.6	94.0	24.7	35.7	0.1	2.67	850	850	3.9545	454.15

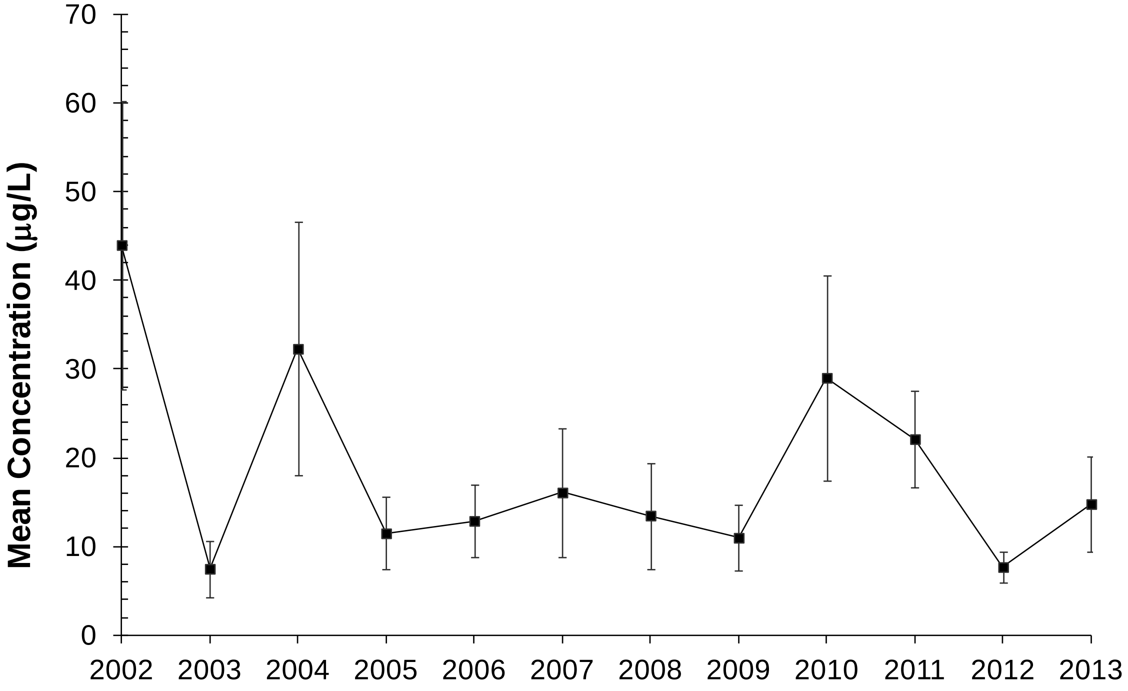
Grey shading denotes measurement endpoints for the ASL program. Yellow shading denotes values that are less than the detection limit with values equal to one half the detection limit.

Table 5.14-3 RAMP acid-sensitive lakes with chemical characteristics either below the 5th or above the 95th percentile in 2013.

Lake	Subregion	pH	Gran Alkalinity (μeq/L)	DOC (mg/L)
5th percentile 2013		5.00	11.4	10.29
95th percentile 2013		7.88	943.3	41.83
118/S1/Weekes L.	Canadian Shield	7.67	479	9.30
168/SM10	Stony Mountains	5.01	10.8	20.40
169 /SM9	Stony Mountains	4.76	-5.4	24.70
172/WF3	West of Fort McMurray	5.00	27.6	37.40
223/WF4	West of Fort McMurray	7.24	666	52.30
226/WF6	West of Fort McMurray	6.95	389	46.50
227/WF7	West of Fort McMurray	7.61	809.8	42.10
270/NE9	Northeast of Fort McMurray	7.96	1,027	23.40
271/NE10	Northeast of Fort McMurray	8.03	1,256	23.80
418/NE11/Kearl L.	Northeast of Fort McMurray	8.02	1,629	27.0
436/BM2/Namur L.	Birch Mountains	7.79	447	7.20
444/BM1/Legend L.	Birch Mountains	7.23	244	9.30
448/BM7/Clayton L.	Birch Mountains	4.38	-41.2	24.00

Yellow shading denotes values below the 5th percentile in 2013.
Green shading denotes values above the 95th percentile in 2013.

Figure 5.14-1 Mean concentration of nitrates (± 1SE) in all 50 RAMP acid-sensitive lakes combined, 2002 to 2013.



Note: Error bars represent one standard error of the mean.

Table 5.14-4 Results of the one-way ANOVA and the GLM for all 50 RAMP acid-sensitive lakes, *baseline* lakes, and *test* lakes.

Variable	1-Way ANOVA All Lakes	GLM Case 1 - All Lakes			GLM Case 2 - *Baseline* Lakes			GLM Case 3 - *Test* Lakes		
	Significance	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term
pH	NS	S	Positive	NS	S	Positive	NS	S	Positive	NS
Gran alkalinity	NS	S	Positive	S (1.44%)	S	Positive	S (5.26%)	S	Positive	S (1.30%)
Conductivity	NS	NS	Positive	S (1.51%)	S	Positive	S (6.93%)	NS	Negative	S (1.31%)
TDS	S	S	Positive	NS	S	Positive	NS	NS	Positive	NS
Colour	NS	S	Positive	NS	NS	Positive	NS	S	Positive	NS
Sodium	NS	NS	Positive	NS	S	Positive	NS	NS	Positive	NS
Potassium	S	S	Positive	S (3.77%)	S	Positive	S (5.63%)	NS	Positive	NS
Calcium	NS	NS	Positive	NS	NS	Positive	S (6.84%)	NS	Negative	NS
Magnesium	NS	S	Positive	NS	NS	Positive	NS	NS	Positive	S (1.53%)
Chloride	NS	S	Negative	S (2.71%)	NS	Negative	S (2.38%)	S	Negative	NS
Sulphate	NS	NS	Negative	NS	NS	Positive	S (7.91%)	NS	Negative	NS
Nitrates	S	NS	Negative	S (26.4%)	NS	Positive	NS	NS	Negative	S (26.5%)
DOC	NS	NS	Positive	S (5.36%)	NS	Negative	NS	NS	Positive	S (5.64%)
Sum Base Cations	NS	NS	Positive	S (1.59%)	S	Positive	NS	NS	Positive	S (1.46%)
Dissolved aluminum	NS	NS	Positive	NS	NS	Positive	S (4.77%)	NS	Positive	NS

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. Kruskal Wallis non-parametric test was used in the one-way ANOVA when the variances were significantly different.

Table 5.14-5 Critical loads[1] of acidity in the RAMP acid-sensitive lakes, 2002 to 2013

NO_xSO_x GIS No.	Original RAMP Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y) using F to calculate BC_0												
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Net PAI
Stony Mountains Subregion																
168	A21	SM10	18.2	-0.071	-0.082	-0.099	-0.131	-0.101	-0.052	-0.117	-0.101	-0.140	-0.121	-0.121	-0.145	0.134
169	A24	SM9	8.3	-0.184	-0.141	-0.394	-0.519	-0.257	-0.078	-0.234	-0.206	-0.258	-0.422	-0.326	-0.383	0.121
170	A26	SM6	13.1	-0.016	-0.019	-0.029	-0.052	-0.042	-0.009	0.002	-0.026	-0.049	-0.035	-0.046	-0.060	0.125
167	A29	SM5	3.7	-0.078	-0.055	-0.014	0.004	0.090	-0.010	-0.257	0.042	-0.283	-0.096	-0.122	-0.281	0.105
166	A86	SM7	6.9	0.064	0.141	0.182	0.249	0.193	0.144	0.472	0.511	0.316	0.041	0.280	0.277	0.043
287	25	SM8	9.6	-0.092	-0.135	-0.198	-0.284	-0.201	-0.026	-0.166	-0.215	-0.266	-0.199	-0.212	-0.265	0.120
289	27	SM3	7.4	0.034	0.071	0.079	0.126	0.076	0.088	0.092	0.115	0.001	0.057	0.115	0.066	0.118
290	28	SM4	11.7	0.001	0.019	-0.004	-0.005	0.006	-0.007	0.001	0.000	-0.033	-0.007	-0.015	-0.022	0.115
342	82	SM2	15.4	0.064	0.059	0.117	0.155	0.118	0.012	0.115	0.139	0.140	0.095	0.107	0.096	0.027
354	94	SM10	9.6	0.707	0.676	0.803	1.033	0.426	0.152	1.394	1.413	1.022	0.727	0.823	0.772	0.043
West of Fort McMurray Subregion																
165	A42	WF1	10.4	0.382	0.883	1.378	2.112	0.964	0.727	2.110	2.252	1.858	1.352	1.167	1.380	0.044
171	A47	WF2	4.3	0.104	0.170	0.126	0.468	0.150		0.792	0.390	0.169	0.239	0.318	0.291	0.082
172	A59	WF3	51.6	0.006	0.000	-0.001	-0.019	-0.027	-0.018	0.035	0.021	0.010	0.011	-0.013	-0.027	0.049
223	P94	WF4	1.8	0.112	0.090	0.117	1.199	0.194	0.087	0.330	0.318	0.155	0.262	0.306	0.296	0.151
225	P96	WF5	5.0	0.123	0.264	0.229	1.469	0.383	0.202	0.413	0.451	0.553	0.868	0.703	0.443	0.172
226	P97	WF6	4.2	0.088	0.340	0.202	2.655	0.192	0.166	0.287	0.391	0.464	0.374	0.358	0.470	0.240
227	P98	WF7	1.6	0.288	1.131	0.576	0.835	0.947	0.460	1.058	1.451	1.645	1.245	1.365	1.324	0.209
267	1	WF8	23.1	0.197	0.400	0.349	0.934	0.415	0.147		0.758	0.348	0.517	0.522	0.410	0.161
Northeast of Fort McMurray Subregion																
452	L4	NE1	16.8	0.092	0.092	0.069	0.262	0.087	0.064	0.243	0.125	0.078	0.202	0.243	0.165	0.188
470	L7	NE2	15.1	0.171	0.141	0.074	0.312	0.745	0.156	0.228	0.201	0.208	0.285	0.356	0.232	0.166
471	L8	NE3	24.0	0.341	0.601	0.431	1.107	0.604	0.226	0.445	0.486	0.424	0.572	0.802	0.598	0.145
400	L39	NE4	3.2	1.069	0.913	0.715	0.654	1.473	0.723	1.344	1.347	0.796	1.239	1.143	0.913	0.059
268	E15	NE5	7.3	1.349	2.186	1.478	2.291	0.257	0.409	1.976	2.842	2.286	2.031	2.357	0.329	0.163
182	P23	NE6	8.3	0.352	1.251	1.443	4.085	0.347	2.000	0.065	2.360	3.172	2.817	2.570	1.426	0.251
185	P27	NE7	5.9	0.037	0.015	-0.072	0.279	-0.029	0.031	0.047	0.016	0.046	0.088	-0.146	-0.004	0.189

Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2011) or CEMA (2010b) representing emissions from industrial sources that include all the existing sources and approved sources from 2008. The PAI is the net PAI after correction for nitrogen uptake by plants in the catchment (eutrophication). Runoff in all CL measurements estimated using the IMB method from data provided by Gibson et al. (pers. comms.).

Table 5.14-5 (Cont'd.)

NO_xSO_x GIS No.	Original RAMP Designation	Current AESRD Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y) using F to calculate BC_0												
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Net PAI
Northeast of Fort McMurray Subregion (Cont'd.)																
209	P7	NE8	0.8	0.852	0.781	0.348	0.600	0.416	0.413	2.472	0.836	1.267	0.945	0.705	1.611	0.178
270	4	NE9	11.2	3.371	4.488	4.986	8.031	4.567	1.331	3.932	6.714	5.356	4.528	4.236	3.414	0.137
271	6	NE10	17.1	2.446	2.659	6.395	7.347	3.557	2.317	3.067	4.905	3.638	3.994	3.901	3.486	0.064
418	Kearl L.	NE11	77.2		2.759	2.316	5.097	1.715	0.801	2.588	2.739	2.046	2.984	3.169	2.624	0.618
Birch Mountains Subregion																
436	L18	BM2	165.5	1.382	2.067	1.715	2.194	1.726	1.077	2.356	2.283	2.185	2.056	2.093	2.104	0.066
442	L23	BM9	33.3	0.260	0.353	0.267	0.362	0.308	0.295	0.427	0.437	0.233	0.113	0.394	0.427	0.056
444	L25	BM1	58.7	0.491	0.819	0.772	0.854	0.901	0.560	1.092	1.301	0.847	0.933	1.177	1.231	0.067
447	L28	BM6	13.7	-0.123	-0.179	-0.012	-0.340	-0.242	-0.017	0.001	-0.184	0.115	-0.084	-0.080	-0.204	0.050
448	L29	BM7	4.7	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.312	-1.015	-0.761	0.046
454	L46	BM8	32.5	0.433	0.590	0.351	0.855	0.409	0.328	0.514	0.618	0.348	0.517	0.607	0.492	0.053
455	L47	BM4	37.3	0.572	0.735	1.640	1.436	0.807	0.406	0.854	1.321	0.871	1.086	1.003	1.117	0.054
457	L49	BM5	30.6	0.457	0.664	0.417	0.883	0.501	0.227	0.565	0.714	0.438	0.414	0.638	0.533	0.052
464	L60	BM3	29.8	0.336	0.634	0.490	0.736	0.375	0.237	0.549	0.579	0.436	0.570	0.789	0.579	0.055
175	P13	BM10	5.2	0.393	0.345	0.662	1.455	0.618	0.298	0.813	2.806	0.520	0.932	0.972	0.655	0.084
199	P49	BM11	0.6	0.110	0.150	0.168	0.196	0.209	0.079	0.139	0.143	0.103	0.152	1.830	0.124	0.086
Canadian Shield Subregion																
473	A301	S4	114.6	0.105	0.130	0.102	0.327	0.165		0.213	0.196	0.147	0.196	0.218	0.191	0.014
118	L107	S1	13.4	2.042	2.265	1.785	2.679	1.998	1.431	2.706	2.156	2.228	2.290	2.383	2.335	0.007
84	L109	S2	112.6	0.181	0.208	0.147	0.333	0.156		0.244	0.318	0.165	0.278	0.308	0.265	0.014
88	O-10	S5	4.5	0.273	0.312	0.204		0.282		0.400	0.544	0.209	0.328	0.375	0.374	0.014
90	R1	S3	37.9	0.346	0.479	0.351	0.550	0.444	0.547	0.608	0.587	0.460	0.544	0.590	0.581	0.014
Caribou Mountains Subregion																
146	E52	CM1	24.1	1.049	1.332	0.986	2.344	1.801	2.065	3.763	3.048	3.497	2.898	3.399	3.613	0.027
152	E59	CM2	46.8	0.486	0.593	0.434	0.956	0.604	0.578	0.791	1.005	0.999	0.909	1.075	1.162	0.027
89	E68	CM3	28.0	0.468	0.458	0.258	1.275	0.729	0.538	0.432	0.664	0.706	0.638	0.901	0.678	0.027
97	O-2 E67	CM4	38.1	0.532	0.563	0.298	0.187	0.300	0.338	0.436	0.351	0.904	0.697	0.854	0.779	0.027
91	O-1/E55	CM5	2.8	0.093	0.138	0.115	8.728	0.895	0.323	0.407	0.743	0.260	1.051	0.531	0.480	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 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 2013.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
No. of lakes	49	50	50	49	50	46	49	50	50	50	50	50
Minimum CL	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.422	-1.015	-0.761
Maximum CL	3.371	4.488	6.395	8.728	4.567	2.317	3.932	6.714	5.356	4.528	4.236	3.613
Average CL	0.429	0.637	0.645	1.339	0.597	0.428	0.809	0.984	0.803	0.816	0.872	0.724
Median CL	0.260	0.349	0.262	0.736	0.361	0.232	0.432	0.527	0.386	0.517	0.598	0.457
No. of lakes in which the PAI is greater than the CL	15	14	15	9	13	18	12	12	11	12	11	12
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	24.0	22.0	24.0	22.0	24.0

Table 5.14-7 Mean critical loads for each subregion in 2013.

Subregion	Critical Load keq H^+/ha/y
Stony Mountains	0.005
West of Fort McMurray	0.573
Northeast of Fort McMurray	1.345
Birch Mountains	0.572
Canadian Shield	0.749
Caribou Mountains	1.343

Table 5.14-8 Chemical characteristics of the RAMP acid-sensitive lakes having the modeled PAI greater than the critical load in 2013.

NO_xSO_x GIS No.	AESRD Designation	Subregion	pH	Gran Alkalinity (µeq/L)	Conductivity (µS/cm)	DOC (mg/L)	Lake Area (km^2)
168	A21/SM10	Stony Mts.	5.01	10.8	10.3	20.4	1.38
169	A24/SM9	Stony Mts.	4.76	-5.4	12.0	24.7	1.45
170	A26/SM6	Stony Mts.	5.32	23.4	8.4	16.8	0.71
167	A29/SM5	Stony Mts.	5.73	32.8	10.7	14.2	1.05
287	25/SM8	Stony Mts.	5.09	12.2	9.2	15.4	2.18
289	27/SM3	Stony Mts.	6.72	85.2	15.3	13.4	1.83
290	28/SM4	Stony Mts.	5.62	43.8	11.3	21.3	0.54
172	A59/WF3	West Ft. Mc.	5.00	27.6	21.9	37.4	2.06
185	P27/NE7	N.E. Ft. Mc.	5.37	65.0	22.0	36.9	0.09
452	L4/NE1	N.E. Ft. Mc.	6.11	123.6	24.9	33.1	0.61
447	L28/BM6	Birch Mts.	5.12	32.4	20.3	30.6	1.30
448	L29/BM7	Birch Mts.	4.38	-41.2	18.4	24.0	0.65

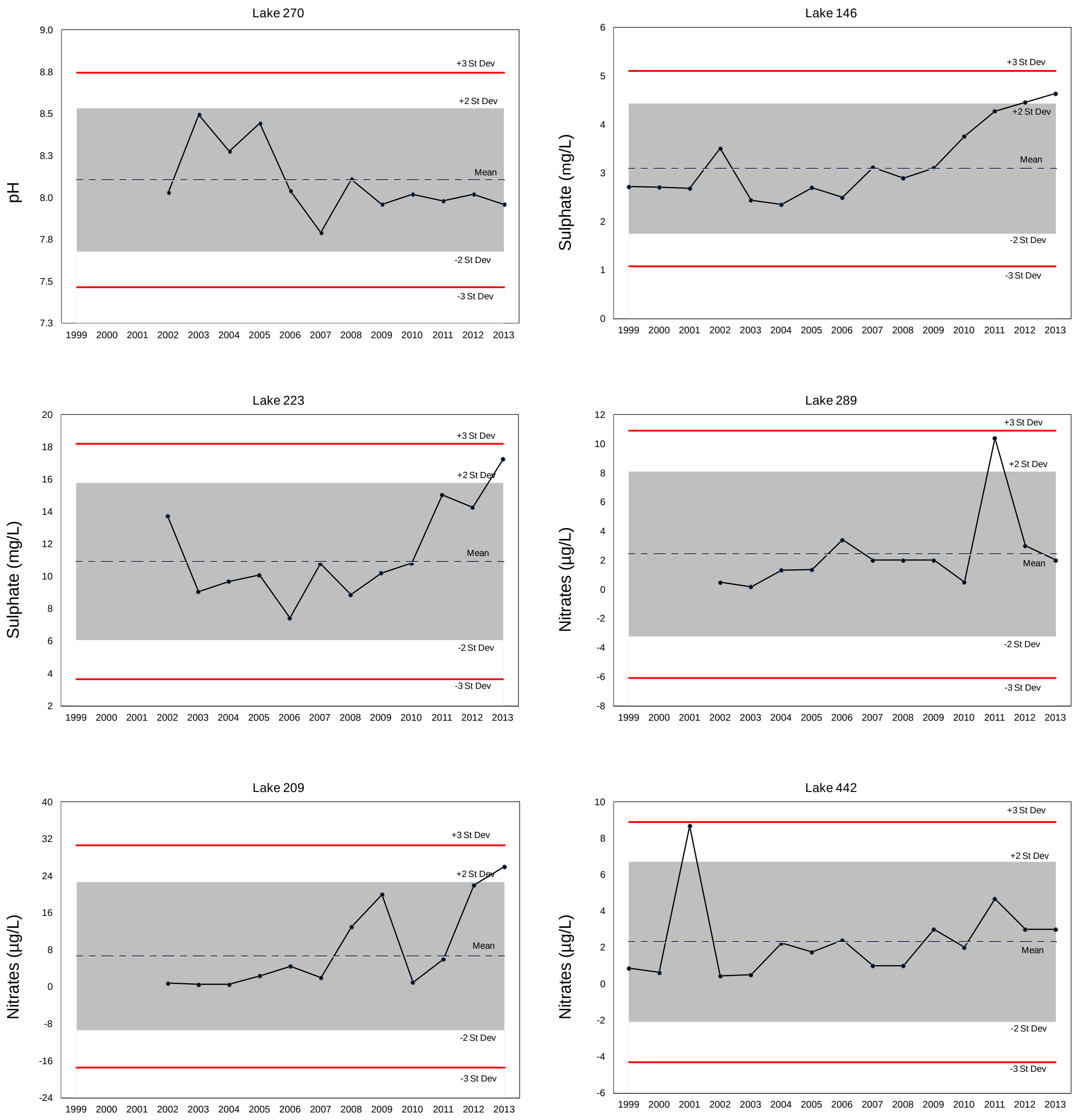
Table 5.14-9 Results of Mann-Kendall trend analyses on measurement endpoints for the RAMP acid-sensitive lakes, 2013.

Lake ID	AESRD Designation	pH	Gran alkalinity (mg/L as $CaCO_3$)	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*	Z	
289	SM3	1.71	1.99	-0.206	2.03	0.206	-0.48		0	0.118
342	SM2	-0.69	-1.37	-2.73	-0.415	-2.13	-2.95		-0.894	0.027
354	SM1	1.23	-1.30	-0.962	0.069	-1.99	-2.13		0.270	0.043
171	WF2	2.08	1.86	-0.396	-0.594	0.248	2.08		-1.07	0.082
223	WF4	-1.37	-1.92	2.13	-0.842	0.891	0.07	16		0.151
227	WF7	2.40	1.71	-1.71	0.137	0.480	2.67	3		0.209
452	NE1	1.69	1.86	0.297	0.297	1.19	1.68	26		0.188
209	NE8	1.65	2.40	0.000	2.89	0.480	1.99	10		0.178
270	NE9	-2.00	-1.44	-1.03	0.421	-2.20	-1.71		1.43	0.137
418	NE11	1.02	1.71	-1.87	0.551	1.56	2.18	19		0.618
436	BM2	3.12	3.72	1.83	-0.886	-1.54	2.28		0.894	0.066
442	BM9	2.77	1.70	-1.39	2.09	-0.495	-0.99		0.894	0.056
444	BM1	2.82	2.63	-0.347	0.055	-0.743	2.38		0	0.067
146	CM1	2.57	3.83	2.67	-0.396	-0.495	3.37	-14		0.027
152	CM2	2.77	3.50	-3.66	-0.496	1.19	3.46	-2		0.027
97	CM4	1.64	1.81	1.29	0.198	2.28	3.56	6		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.

Note: Shaded values are statistically significant – red in a direction consistent with an acidification scenario, green in a direction inconsistent with acidification.

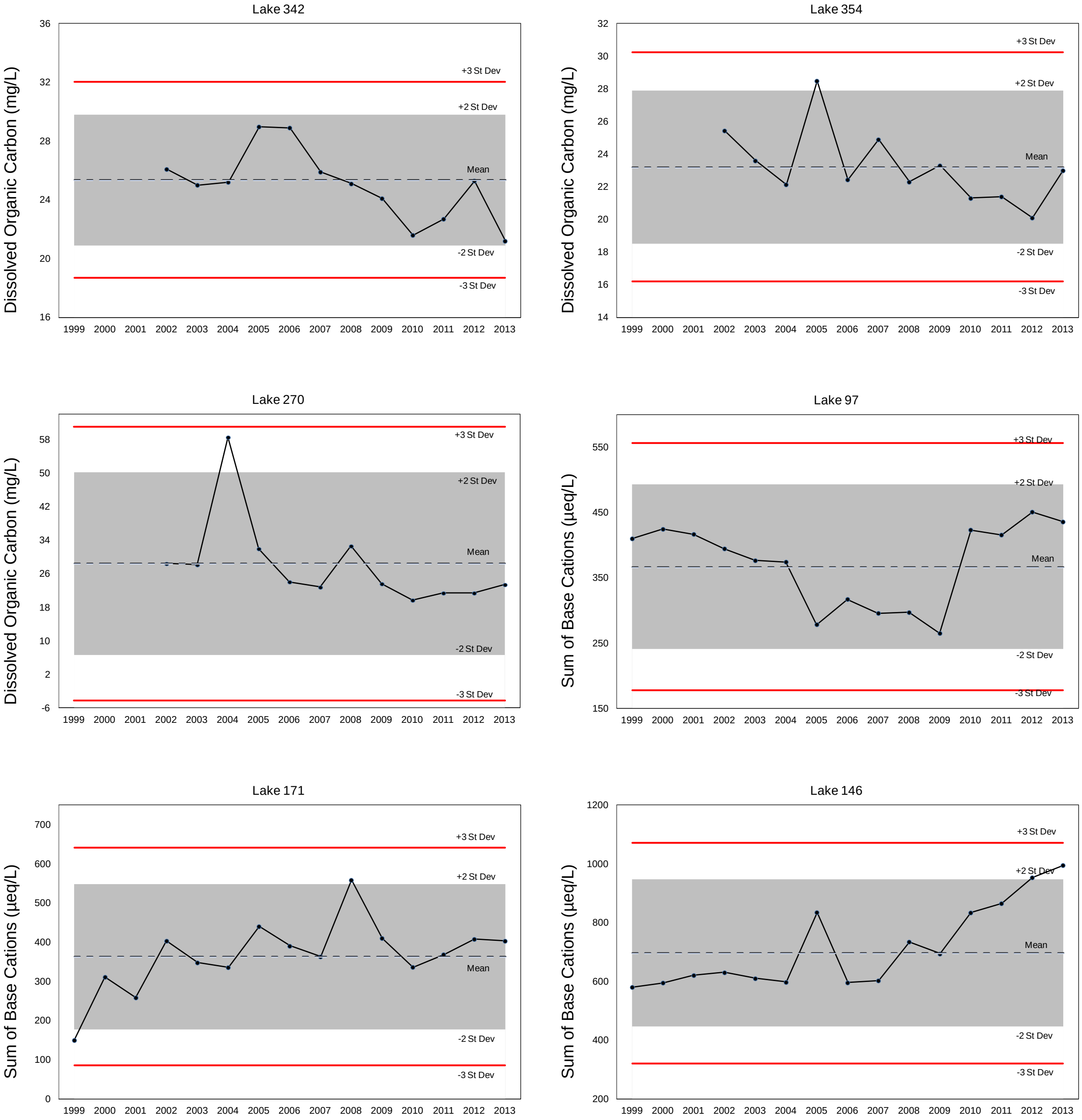
Figure 5.14-2 Control charts for acid-sensitive lakes showing significant trends in measurement endpoints using Mann-Kendall trend analysis.



Note: Only significant trends in a direction indicative of acidification are presented.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

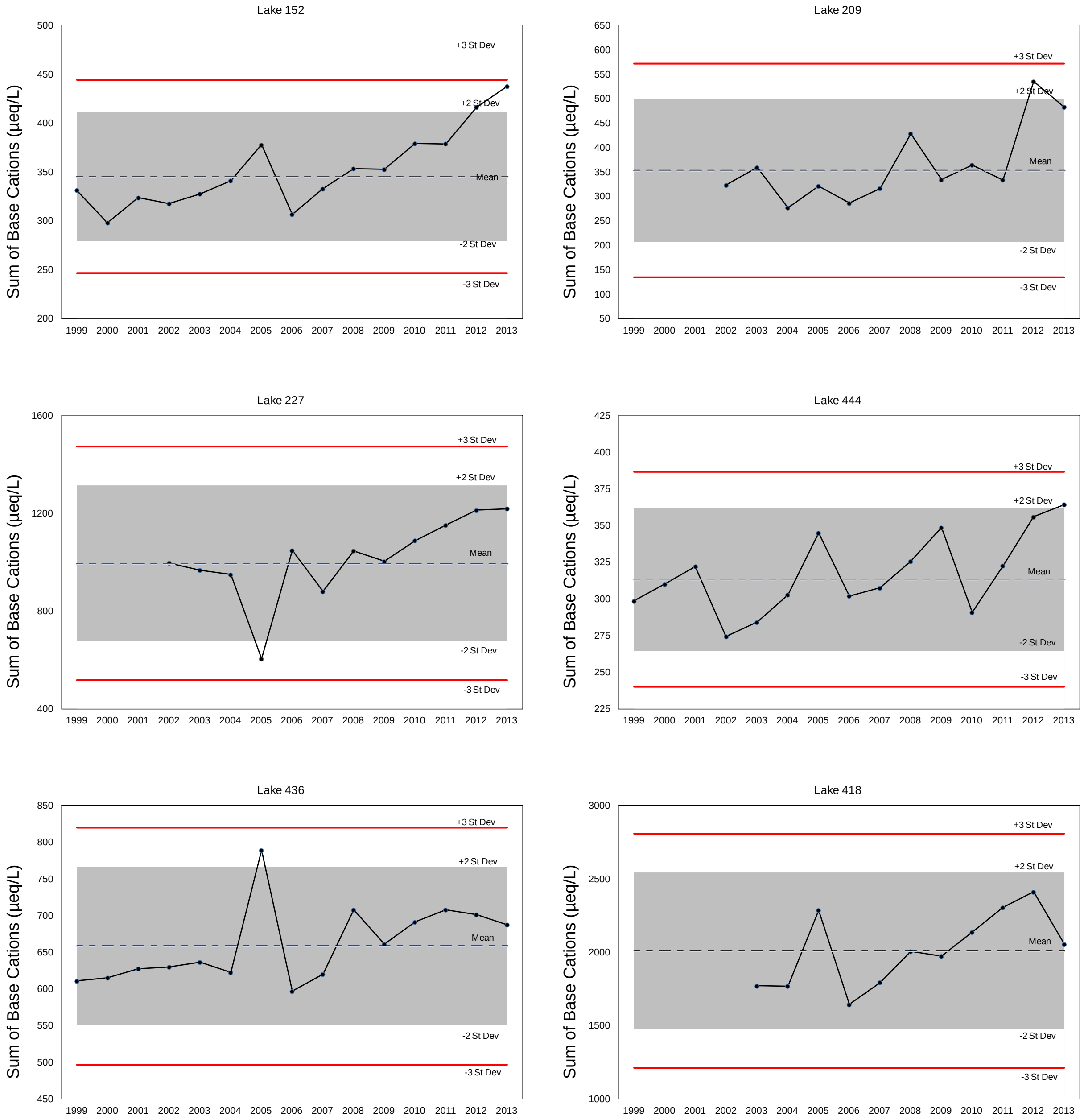
Figure 5.14-2 (Cont'd.)



Note: Only significant trends in a direction indicative of acidification are presented.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

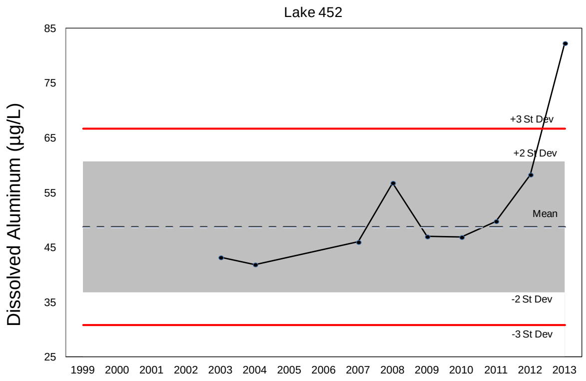
Figure 5.14-2 (Cont'd.)



Note: Only significant trends in a direction indicative of acidification are presented.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Figure 5.14-2 (Cont'd.)



Note: Only significant trends in a direction indicative of acidification are presented.

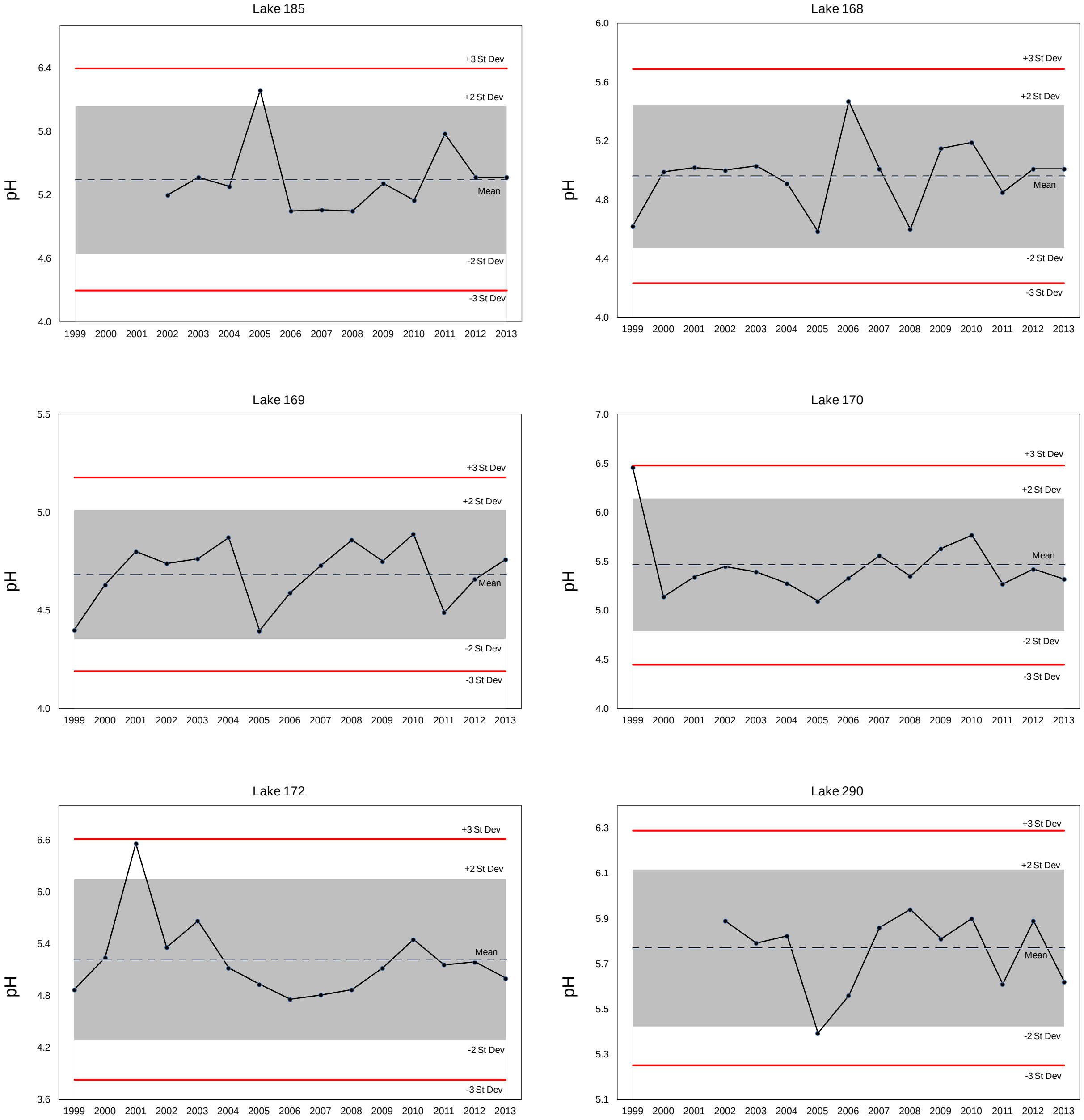
Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Table 5.14-10 Acidification risk factor for individual 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	SM10	Stony Mountains	-0.145	0.134	134
169	A24	SM9	Stony Mountains	-0.383	0.121	121
170	A26	SM6	Stony Mountains	-0.060	0.125	125
167	A29	SM5	Stony Mountains	-0.281	0.105	105
166	A86	SM7	Stony Mountains	0.277	0.043	0.155
287	25	SM8	Stony Mountains	-0.265	0.120	120
289	27	SM3	Stony Mountains	0.066	0.118	1.768
290	28	SM4	Stony Mountains	-0.022	0.115	115
342	82	SM2	Stony Mountains	0.096	0.027	0.281
354	94	SM1	Stony Mountains	0.772	0.043	0.056
165	A42	WF1	West of Fort McMurray	1.380	0.044	0.032
171	A47	WF2	West of Fort McMurray	0.291	0.082	0.282
172	A59	WF3	West of Fort McMurray	-0.027	0.049	49.0
223	P94	WF4	West of Fort McMurray	0.296	0.151	0.509
225	P96	WF5	West of Fort McMurray	0.443	0.172	0.388
226	P97	WF6	West of Fort McMurray	0.470	0.240	0.510
227	P98	WF7	West of Fort McMurray	1.324	0.209	0.158
267	1	WF8	West of Fort McMurray	0.410	0.161	0.392
452	L4	NE1	Northeast of Fort McMurray	0.180	0.188	1.044
470	L7	NE2	Northeast of Fort McMurray	0.217	0.166	0.763
471	L8	NE3	Northeast of Fort McMurray	0.603	0.145	0.240
400	L39	NE4	Northeast of Fort McMurray	0.907	0.059	0.065
268	E15	NE5	Northeast of Fort McMurray	0.305	0.163	0.534
182	P23	NE6	Northeast of Fort McMurray	1.426	0.251	0.176
185	P27	NE7	Northeast of Fort McMurray	-0.004	0.189	189
209	P7	NE8	Northeast of Fort McMurray	1.611	0.178	0.111
270	4	NE9	Northeast of Fort McMurray	3.414	0.137	0.040
271	6	NE10	Northeast of Fort McMurray	3.415	0.064	0.019
418	Kearl L.	NE11	Northeast of Fort McMurray	2.700	0.618	0.229
436	L18	BM2	Birch Mountains	2.104	0.066	0.032
442	L23	BM9	Birch Mountains	0.427	0.056	0.132
444	L25	BM1	Birch Mountains	1.231	0.067	0.054
447	L28	BM6	Birch Mountains	-0.204	0.050	50.2
448	L29	BM7	Birch Mountains	-0.761	0.046	46.1
454	L46	BM8	Birch Mountains	0.492	0.053	0.108
455	L47	BM4	Birch Mountains	1.117	0.054	0.048
457	L49	BM5	Birch Mountains	0.533	0.052	0.097
464	L60	BM3	Birch Mountains	0.579	0.055	0.096
175	P13	BM10	Birch Mountains	0.655	0.084	0.128
199	P49	BM11	Birch Mountains	0.124	0.086	0.691
473	A301	S4	Canadian Shield	0.191	0.014	0.073
118	L107	S1	Canadian Shield	2.335	0.007	0.003
84	L109	S2	Canadian Shield	0.265	0.014	0.053
88	O-10	S5	Canadian Shield	0.374	0.014	0.037
90	R1	S3	Canadian Shield	0.581	0.014	0.024
146	E52	CM1	Caribou Mountains	3.613	0.027	0.007
152	E59	CM2	Caribou Mountains	1.127	0.027	0.024
89	E68	CM3	Caribou Mountains	0.708	0.027	0.038
97	O-2 E67	CM4	Caribou Mountains	0.797	0.027	0.034
91	O-1/E55	CM5	Caribou Mountains	0.443	0.027	0.061

Shading denotes those lakes most at risk to acidification.

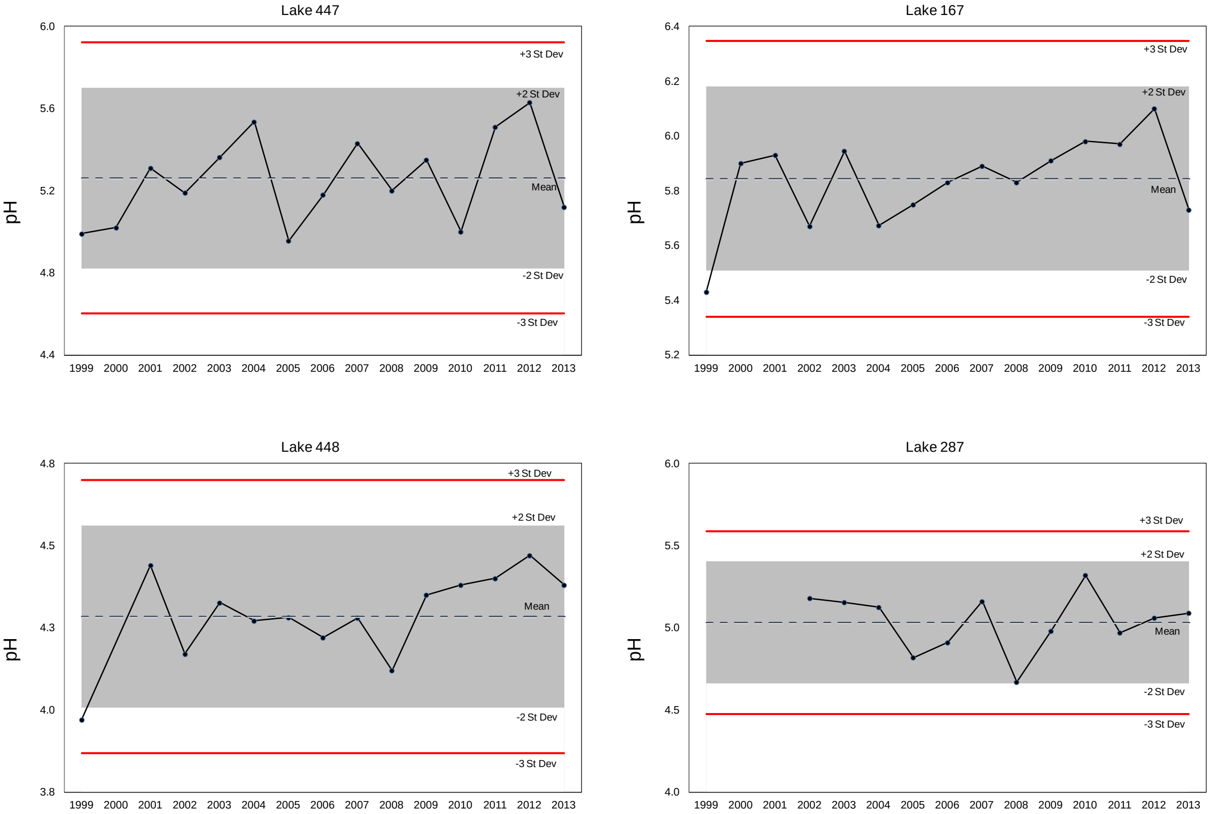
Figure 5.14-3 Control charts of pH in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

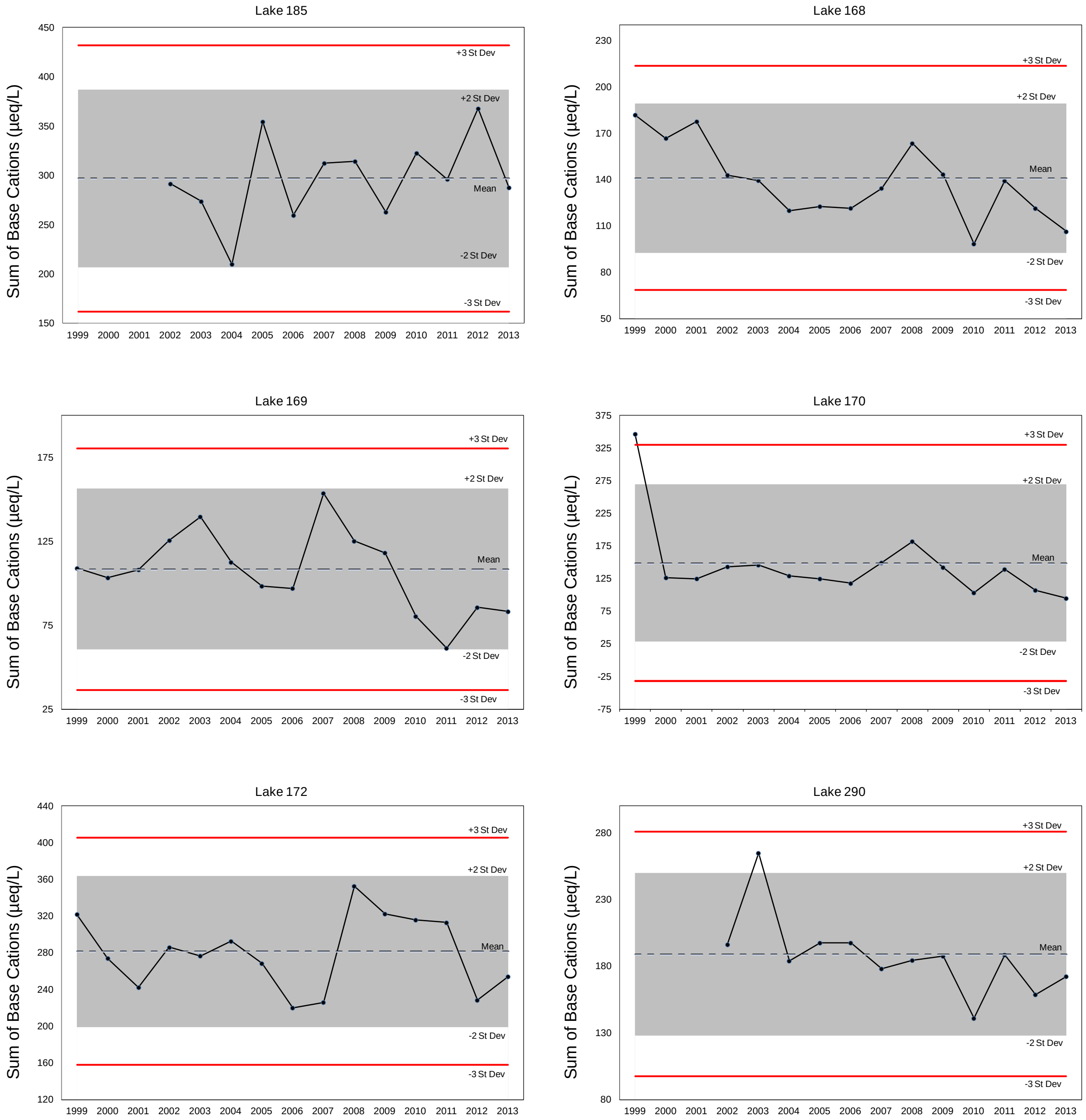
Figure 5.14-3 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

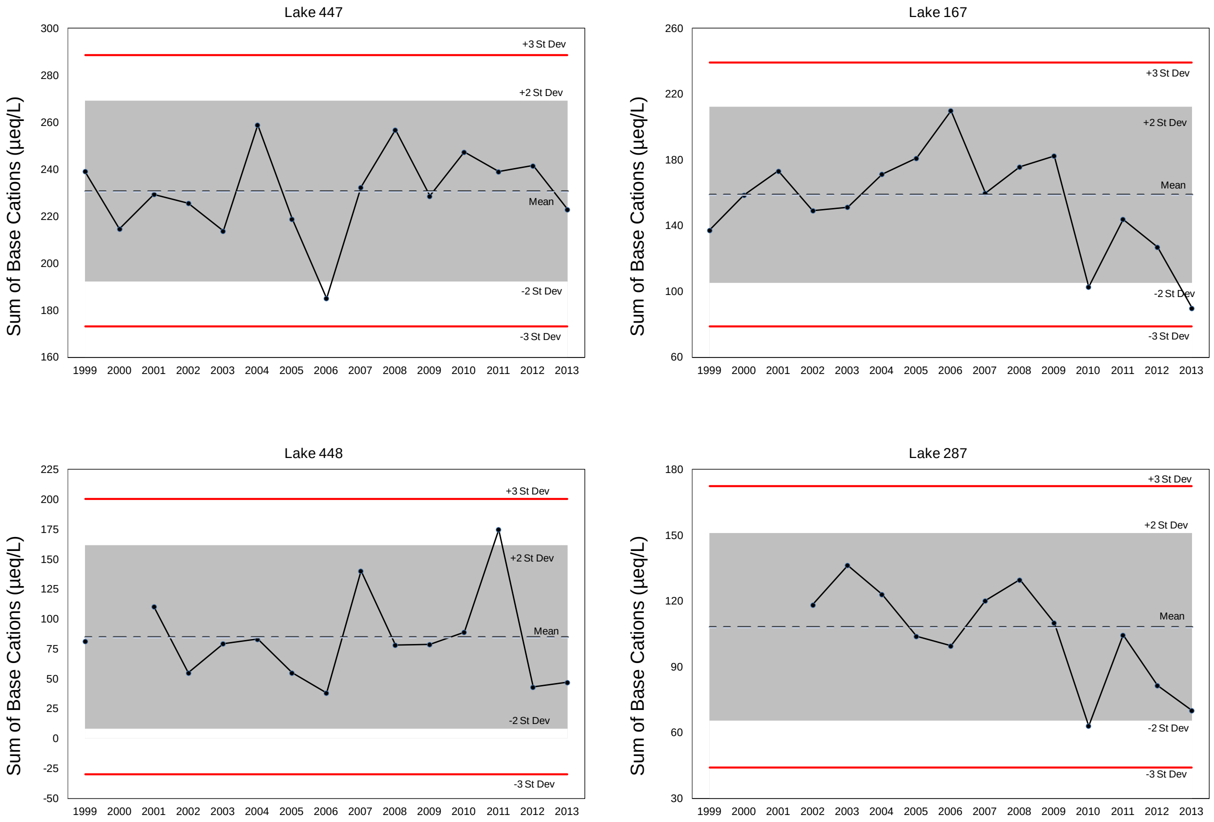
Figure 5.14-4 Control charts of the sum of base cations in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

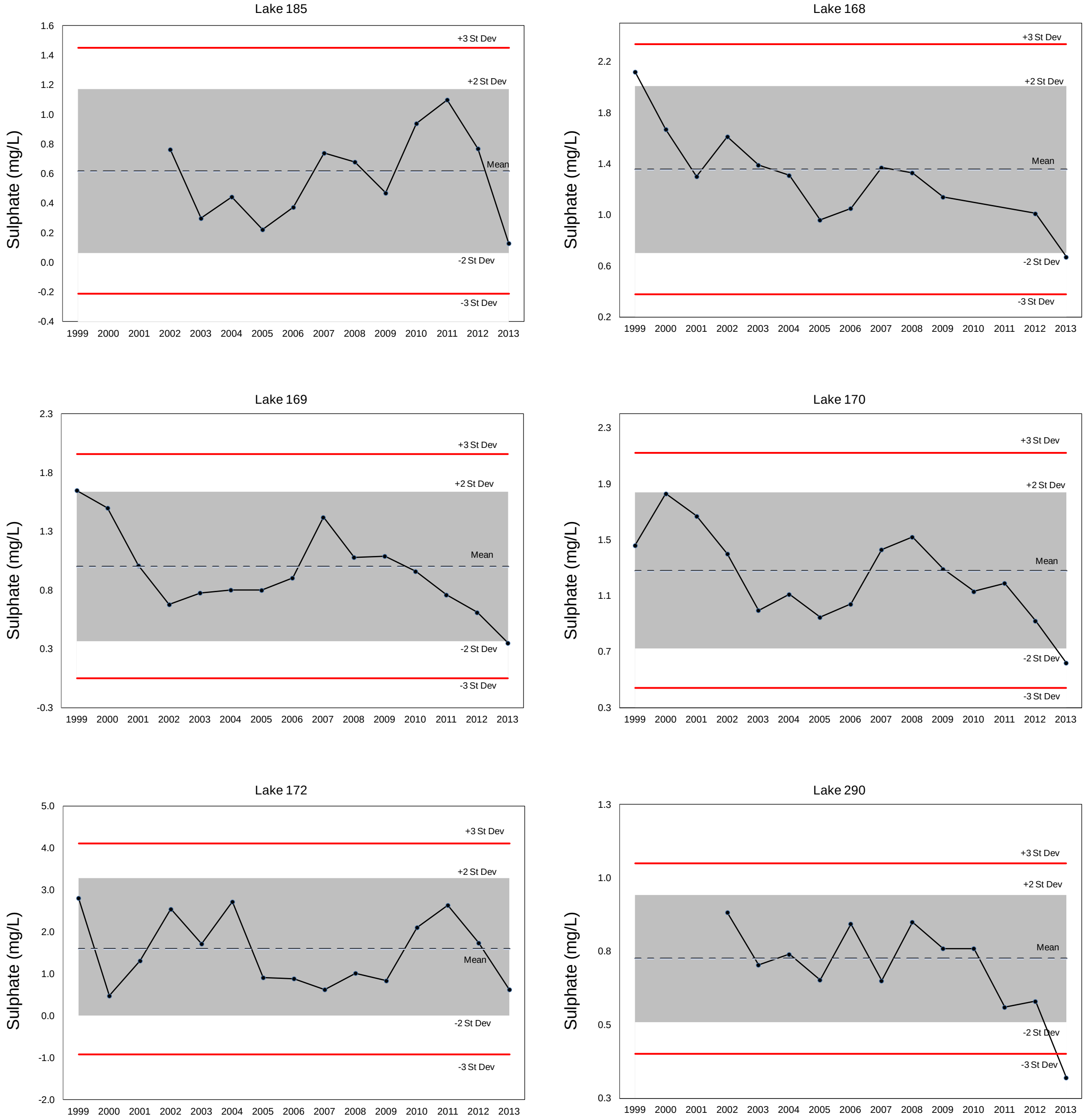
Figure 5.14-4 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

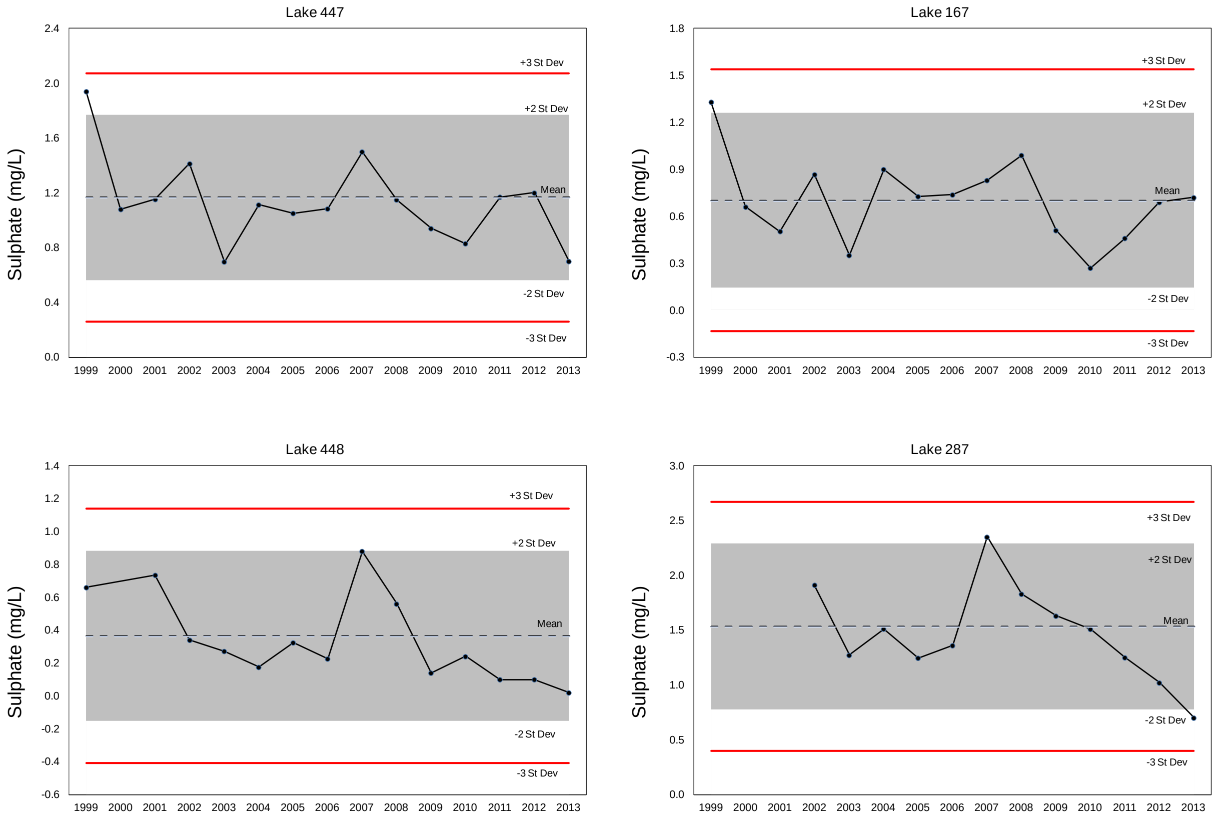
Figure 5.14-5 Control charts of sulphate in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

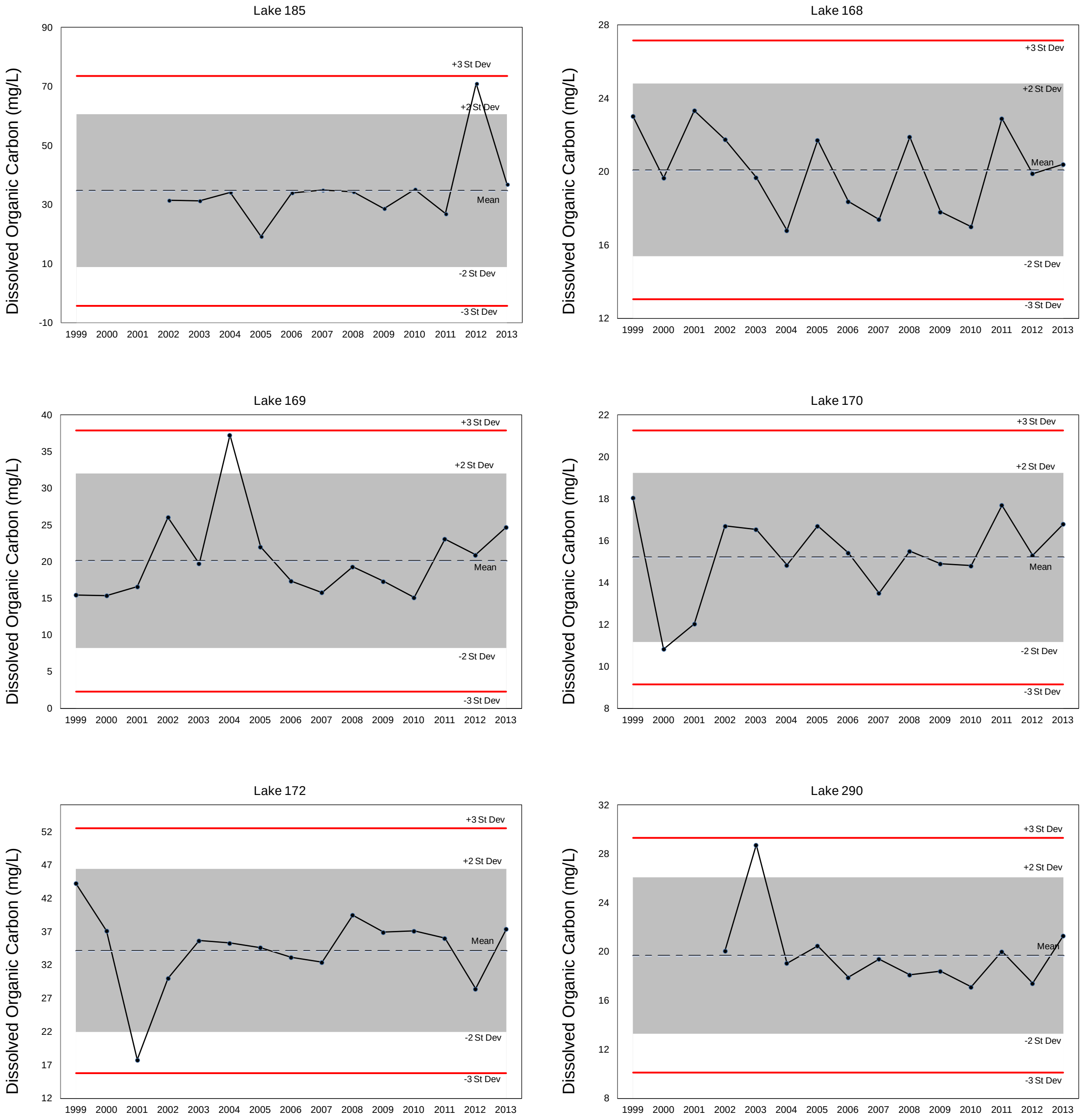
Figure 5.14-5 (Cont’d.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

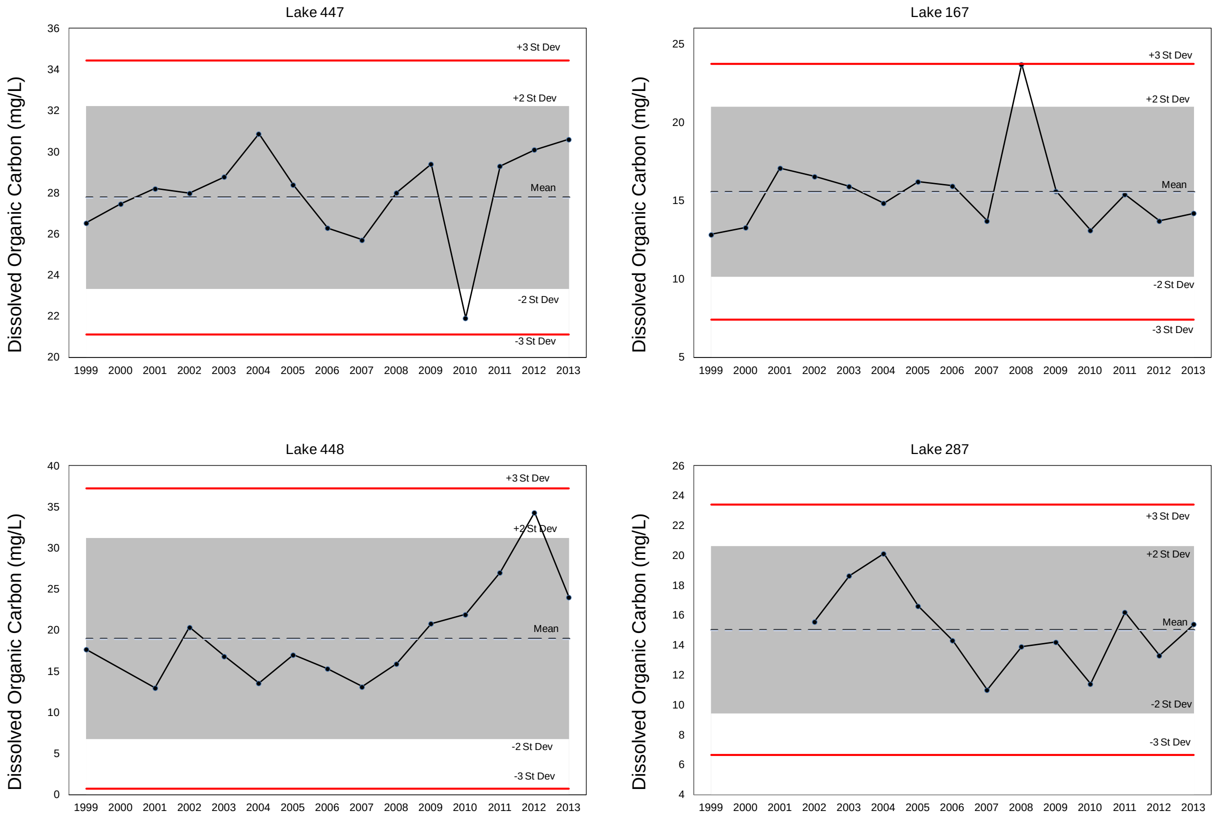
Figure 5.14-6 Control charts of dissolved organic carbon in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

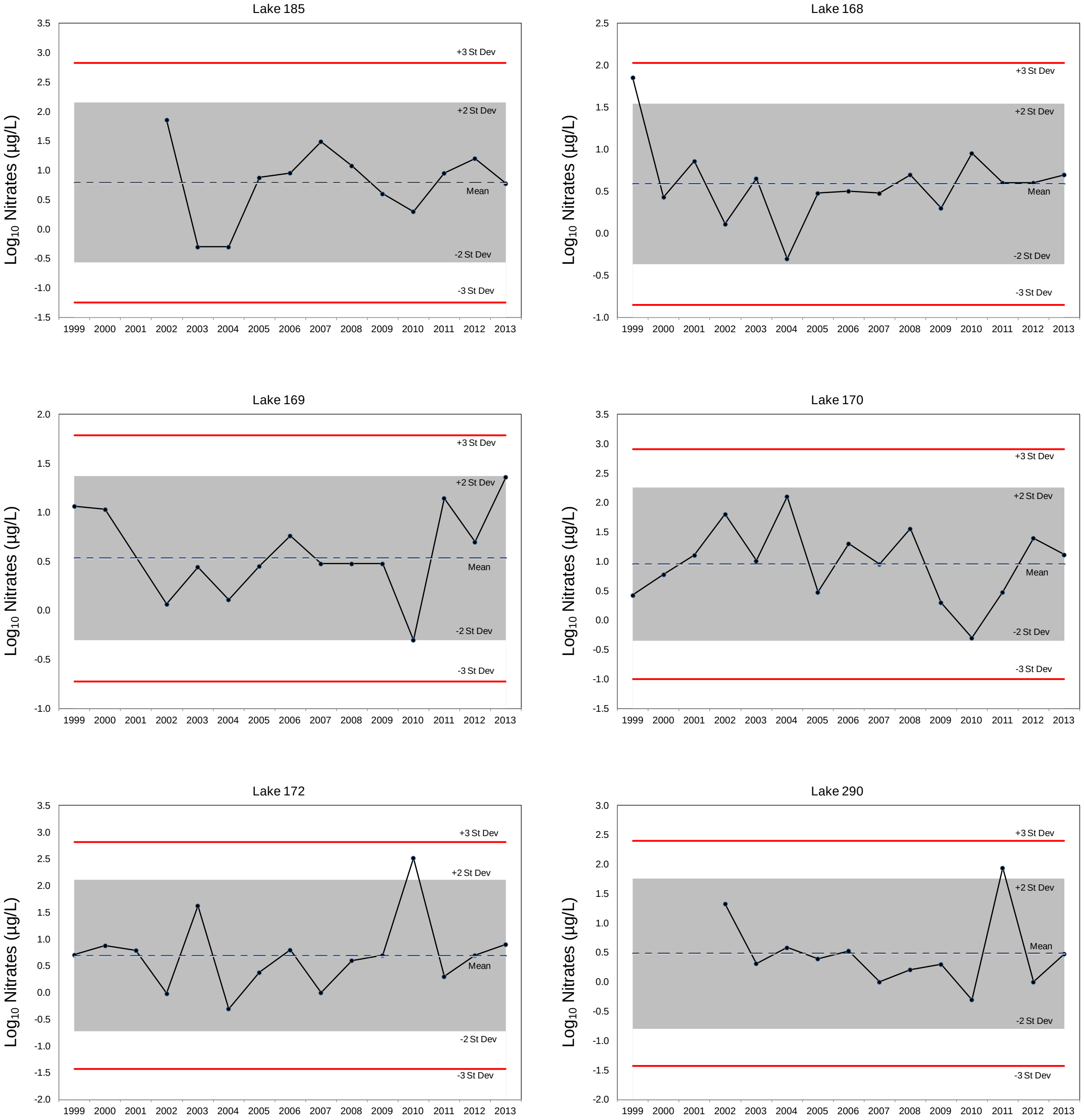
Figure 5.14-6 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

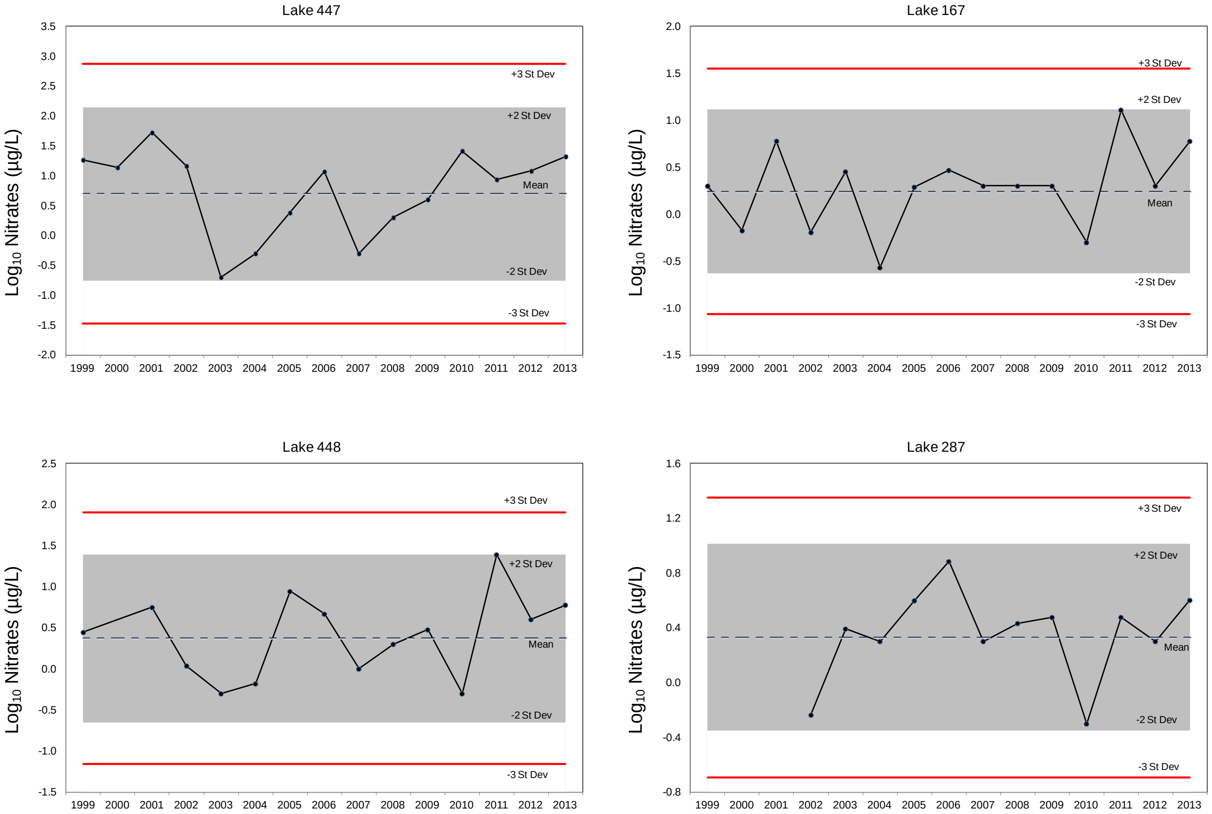
Figure 5.14-7 Control charts of nitrates in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

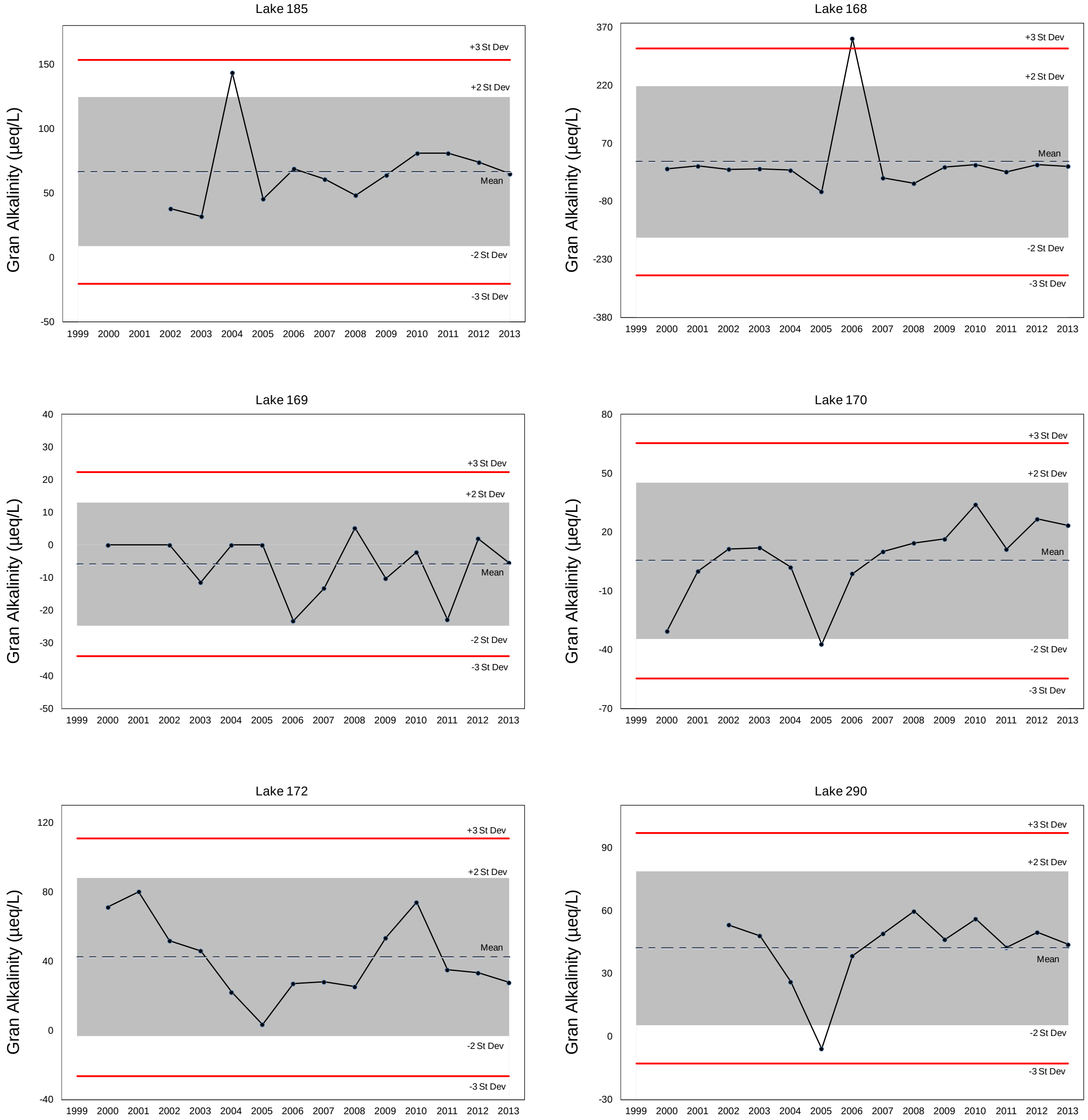
Figure 5.14-7 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

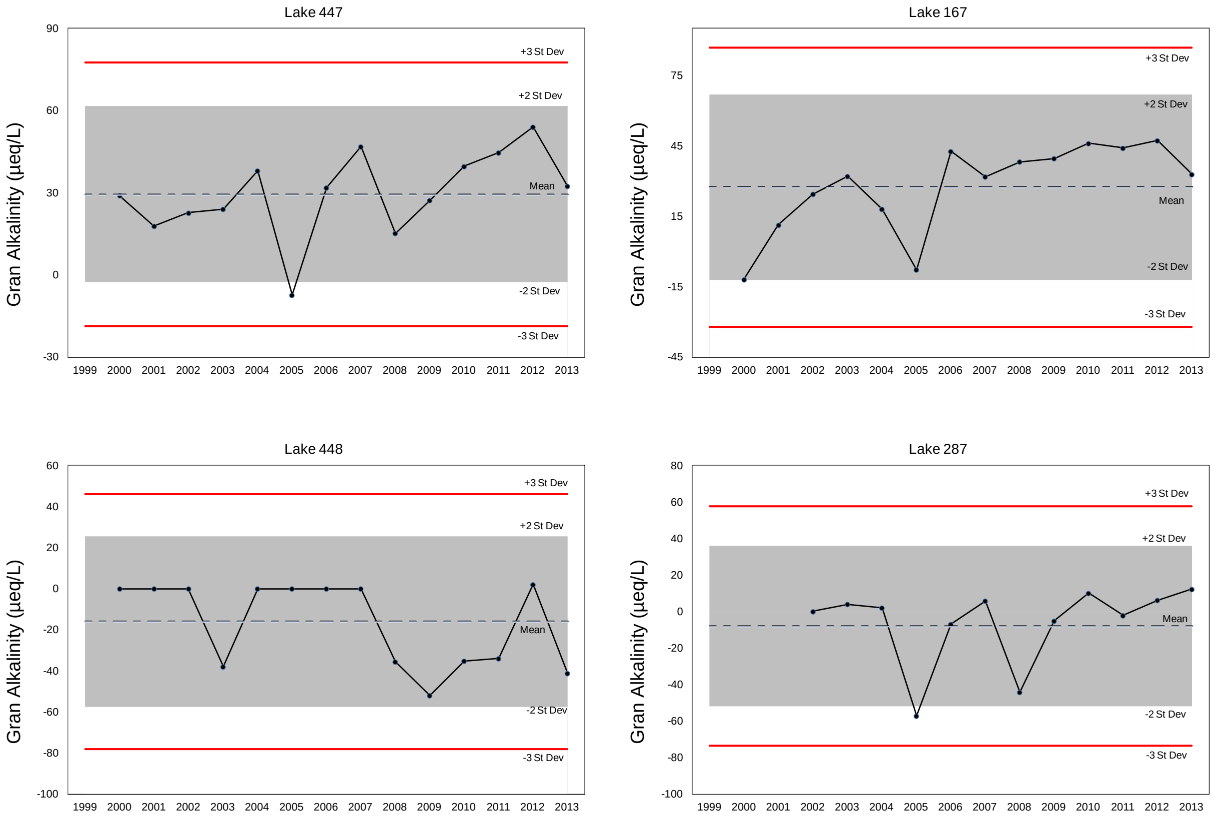
Figure 5.14-8 Control charts of Gran alkalinity in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

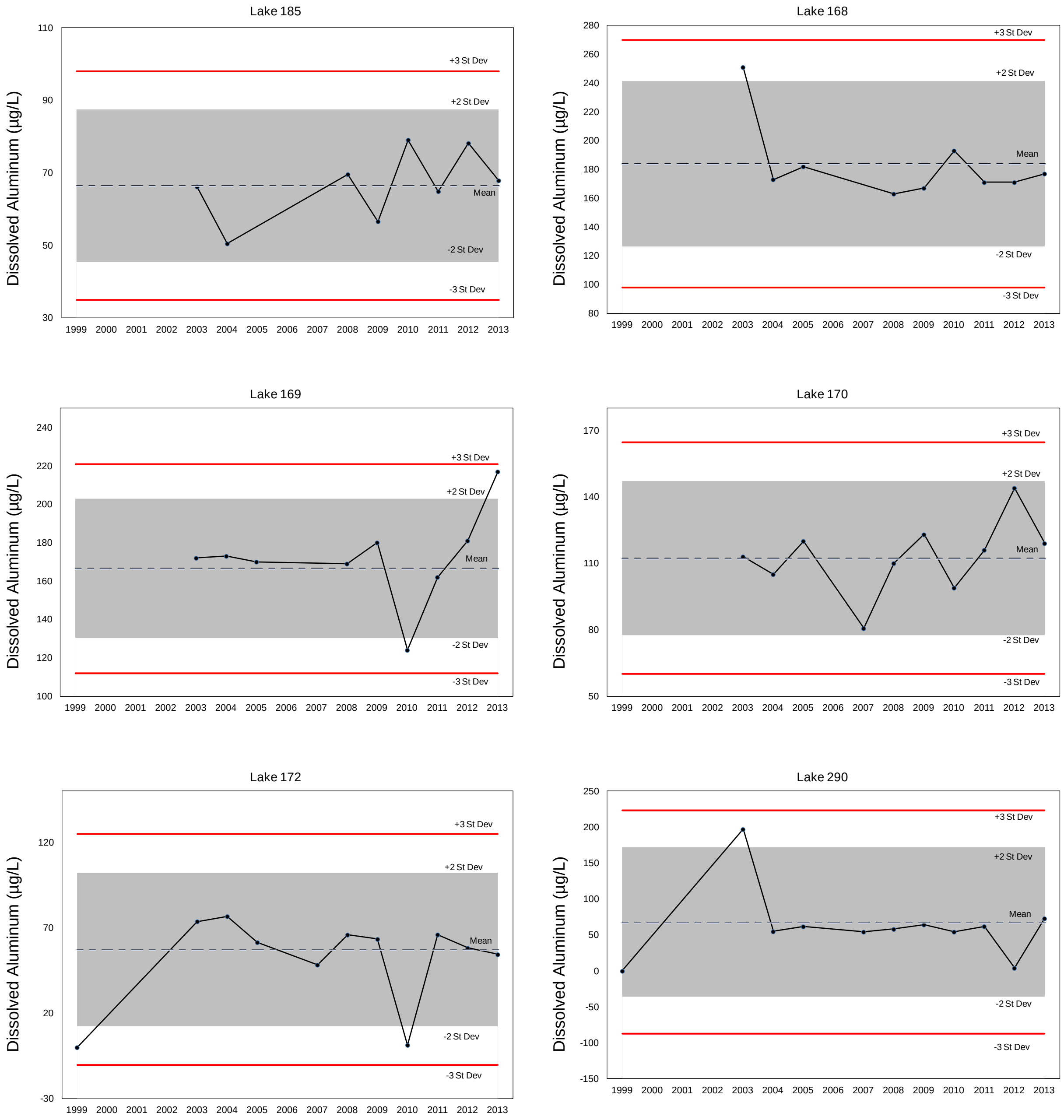
Figure 5.14-8 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

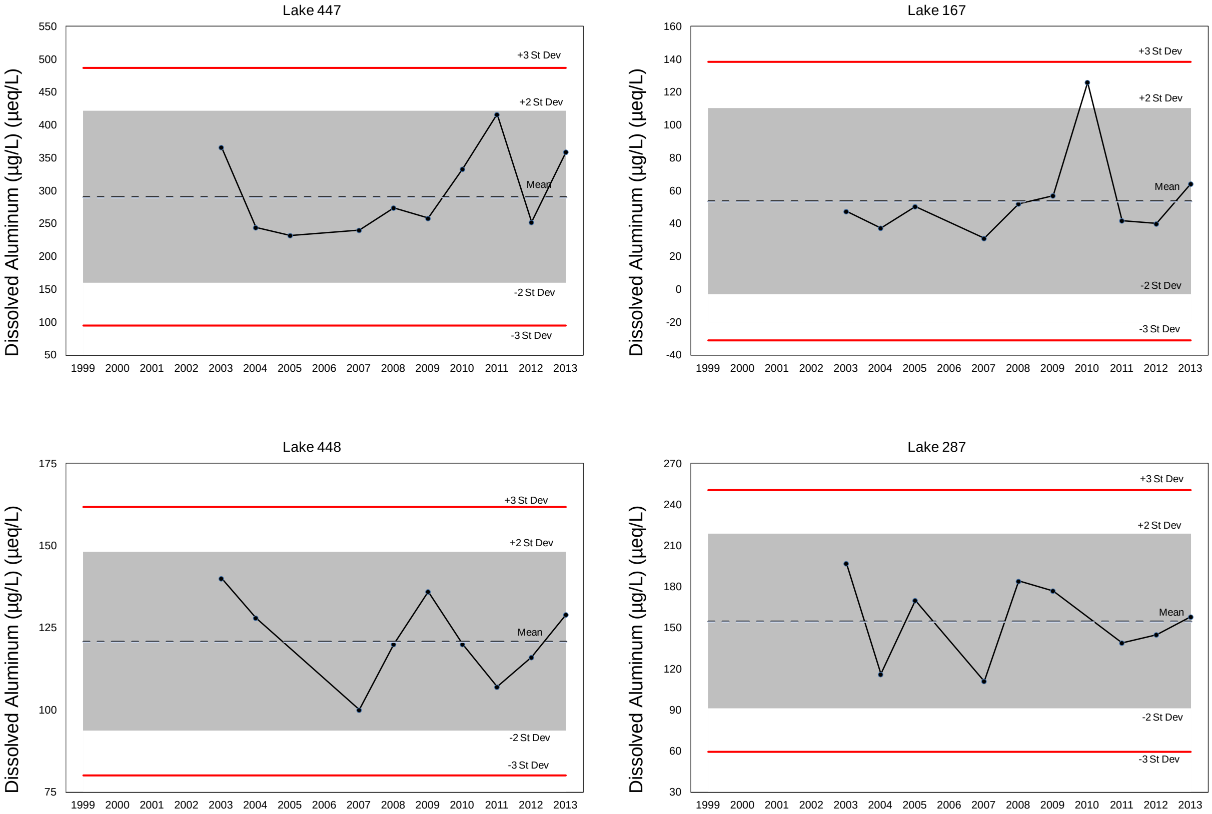
Figure 5.14-9 Control charts of dissolved aluminum in ten RAMP acid-sensitive lakes most at risk to acidification.



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

Figure 5.14-9 (Cont'd.)



Grey shading: ±2 standard deviations; Red lines: ± 3 standard deviations; dotted line – mean.

Note: See Section 3.2.5.2 for a description of the interpretation of control charts.

6.0 SPECIAL STUDIES

This part of the RAMP 2013 Technical Report presents results from special studies that were conducted in 2013, but were not part of the core monitoring program that is described in Section 3. These assessments were conducted to evaluate any specific events that occurred during the 2013 monitoring year that help to explain the monitoring results, and document non-core monitoring activities.

In 2013, there were two studies conducted by RAMP that were not part of the core monitoring program: an analysis of the flooding events that occurred in the region in June 2013 and the reporting of water quality results for a subset of lakes in the Nexen Lakes Wetland Monitoring Program (Hatfield 2014).

6.1 ANALYSIS OF SPRING 2013 FLOOD

In June 2013, the oil sands region experienced flooding that exceeded the historical mean conditions and in some areas, the historical maximum conditions. This section provides a description and quantification of precipitation patterns in the region beginning in fall 2012 that lead to the flood events in June 2013. In addition, a flood-frequency analysis (FFA) was conducted on seven rivers in the region to relate the magnitude of the flooding to their corresponding frequency of occurrence and help describe the variability of the flood events in the region. To provide context for interpretation of the spring 2013 flood event, a discussion of intensity-duration-frequency statistics (IDF statistics) for the Environment Canada (EC) Fort McMurray station was also included in the analysis.

6.1.1 Magnitude and Spatial Patterns of Precipitation

Regional patterns of precipitation, snowpack volumes, and snow melt rates from fall 2012 to June 2013 were analyzed in order to characterize antecedent conditions prior to the flood event.

6.1.1.1 Precipitation in the 2012 WY

The mean annual precipitation measured at Fort McMurray since 1945 is 433.9 mm. During the 2012 water year (WY), the Fort McMurray climate station recorded 460.1 mm of precipitation (Figure 6.1-1). The 2012 WY was characterized by below average winter and spring precipitation, with the majority of precipitation in July, September, and October. Precipitation from July to October 2012 accounted for almost 71% of the annual total precipitation. This regional pattern was observed at ten climate stations, with little spatial variability in the 2012 WY and resulted in wet soil conditions at the start of winter in late October 2012. The 2012 WY hydrograph for the Muskeg River at the Water Survey of Canada (WSC) station 07DA008 showed that the discharge was above the upper quartile at the end of October 2012 (Figure 6.1-2). This pattern of high discharge at the start of winter was observed at most hydrometric stations in the region in fall 2012.

Figure 6.1-1 Cumulative total precipitation measured at climate stations in the Athabasca oil sands region in the 2012 WY (November 1, 2011 to October 31, 2012).

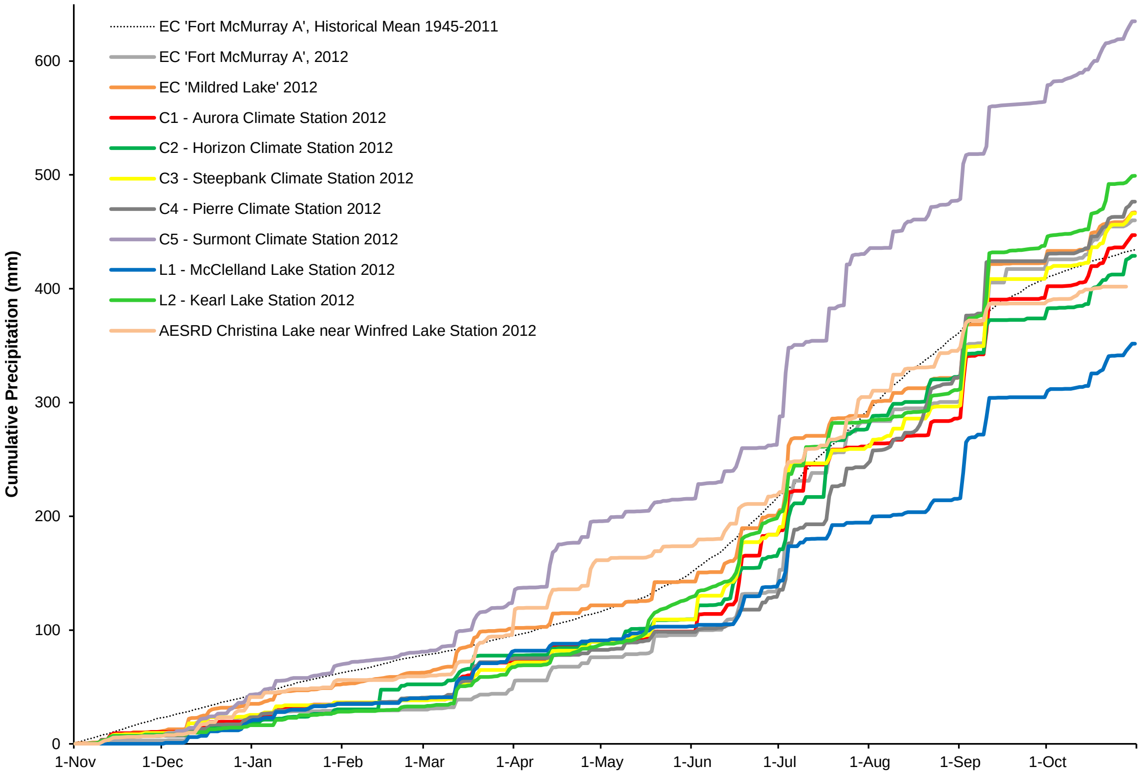
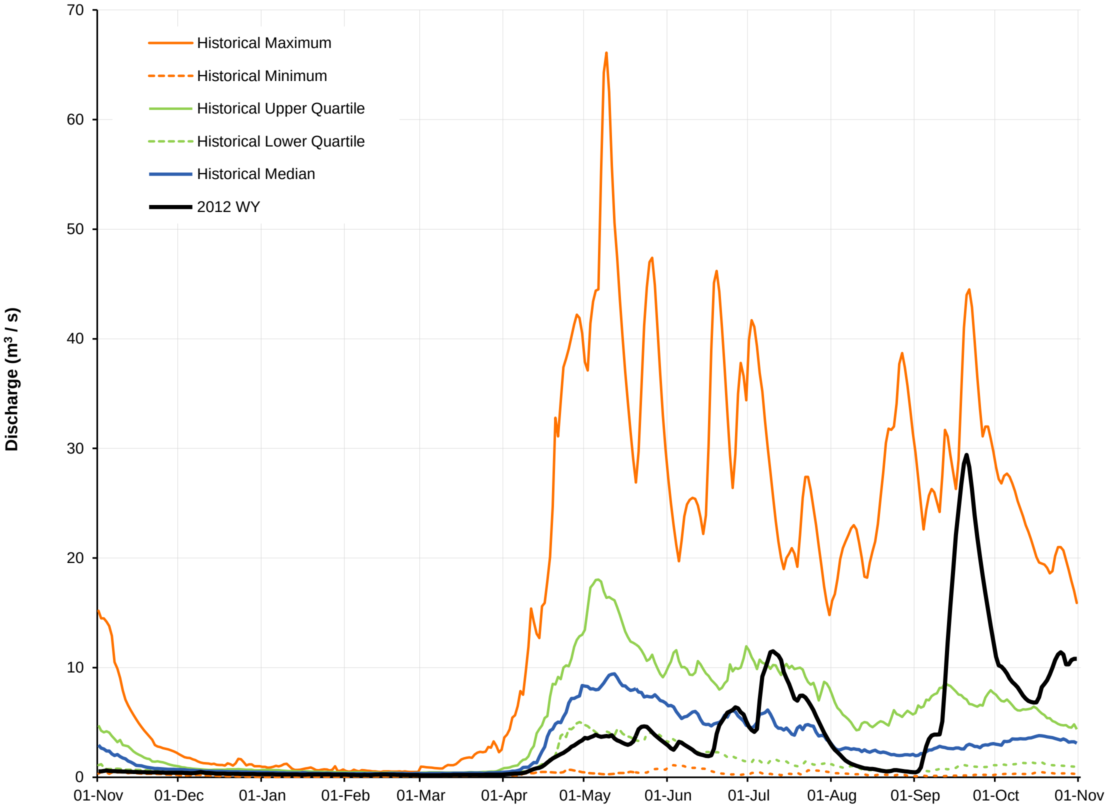


Figure 6.1-2 **The 2012 WY hydrograph for the Muskeg River near Fort McKay (WSC station 07DA008) compared to historical values.**



6.1.1.2 Snowpack and Melt in Winter 2012/2013

The snowpack in the Fort McMurray area during the 2012/2013 winter was above the historical mean in all land cover types (i.e., jackpine, mixed deciduous, flat low-lying, and open land) (Figure 6.1-3). Snowpack snow water equivalent (SWE) for the land cover categories of jackpine, mixed deciduous, and flat low-lying terrains ranged from 72% to 89% above the mean of the previous eight years of record. Snowpack snow water equivalent (SWE) for open land/lake terrain recorded an increase of only 12% from the historical mean.

Continuous snow depth observations, measured at five RAMP climate stations, showed that snow melted approximately two weeks later in 2013 than 2012; 2012 was considered an average year for snow melt (Figure 6.1-4). Snow had predominantly melted by mid-April in 2012 while roughly 25% of the snow depth at RAMP climate stations C4 and C5 was still present on May 1, 2013.

The duration of snowmelt in 2013 was also shorter than in average years. Moderate Resolution Imaging Spectroradiometer MODIS imagery of the Fort McMurray area for spring 2012 and 2013 indicated that on a regional scale, the landscape in 2012 took approximately 24 days to reach snow-free conditions while in 2013 snow melt occurred in approximately ten days (Figure 6.1-5). Snow accumulation in 2013 was not only greater but also melted substantially faster than in an average year.

Figure 6.1-3 Maximum measured snowpack amounts in the Athabasca oil sands region, 2004 to 2013.

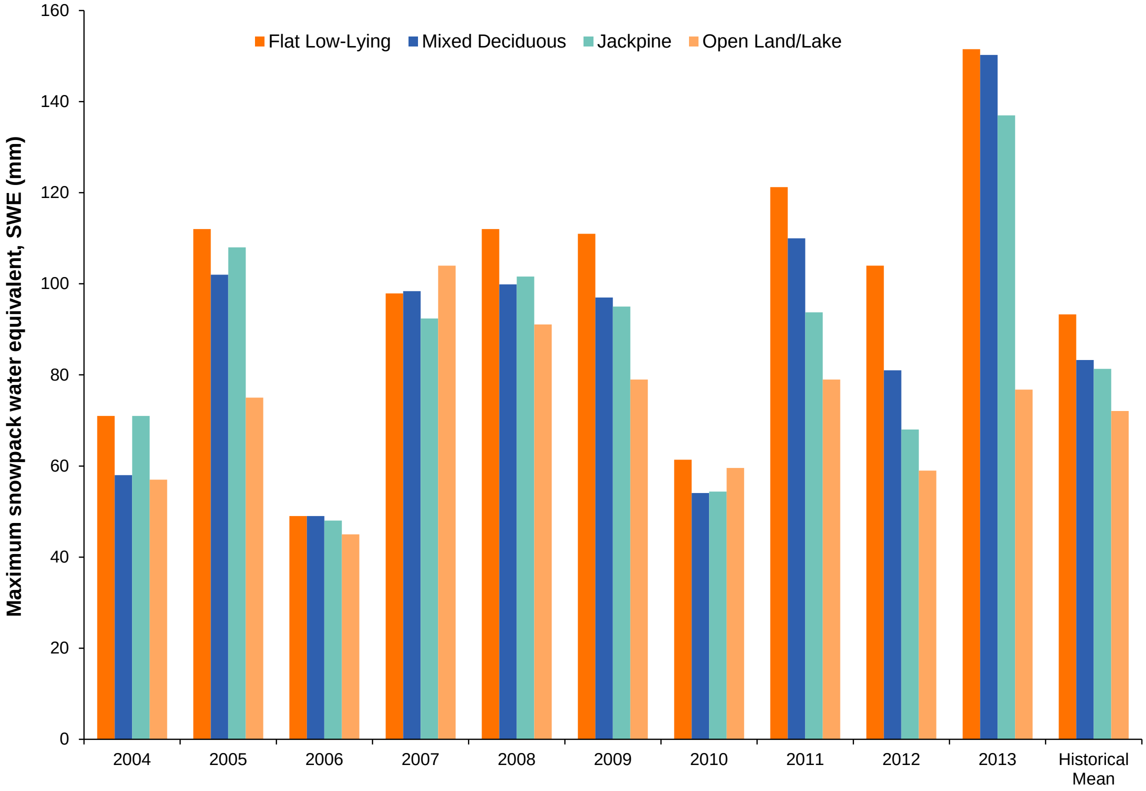


Figure 6.1-4 Measured snow depth (cm) at five climate stations in 2012 and 2013.

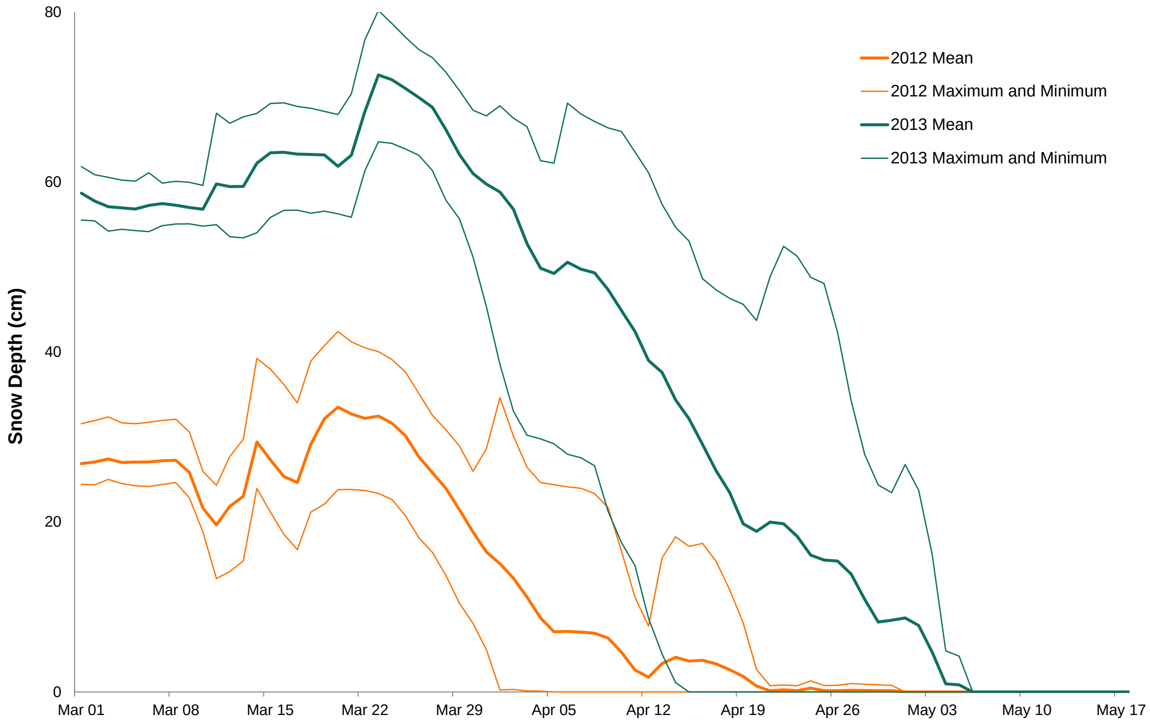
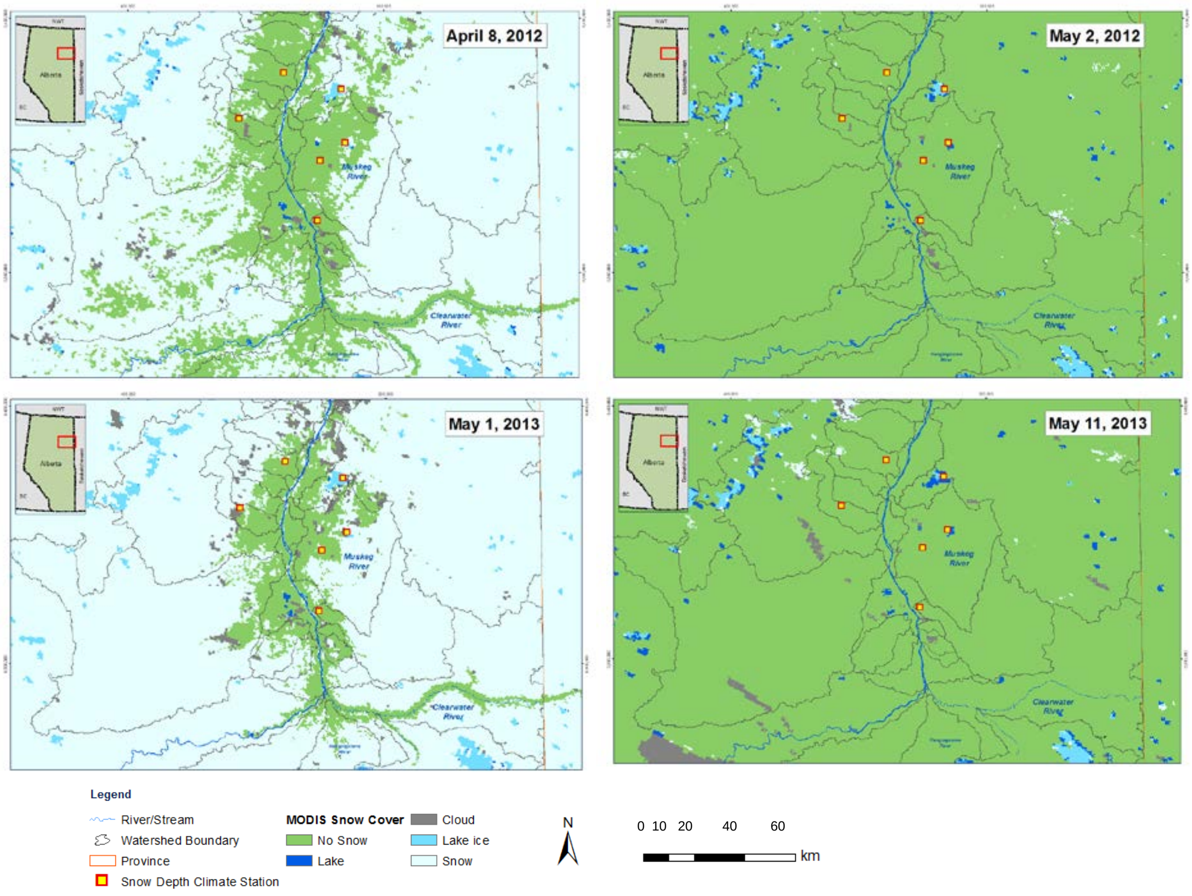


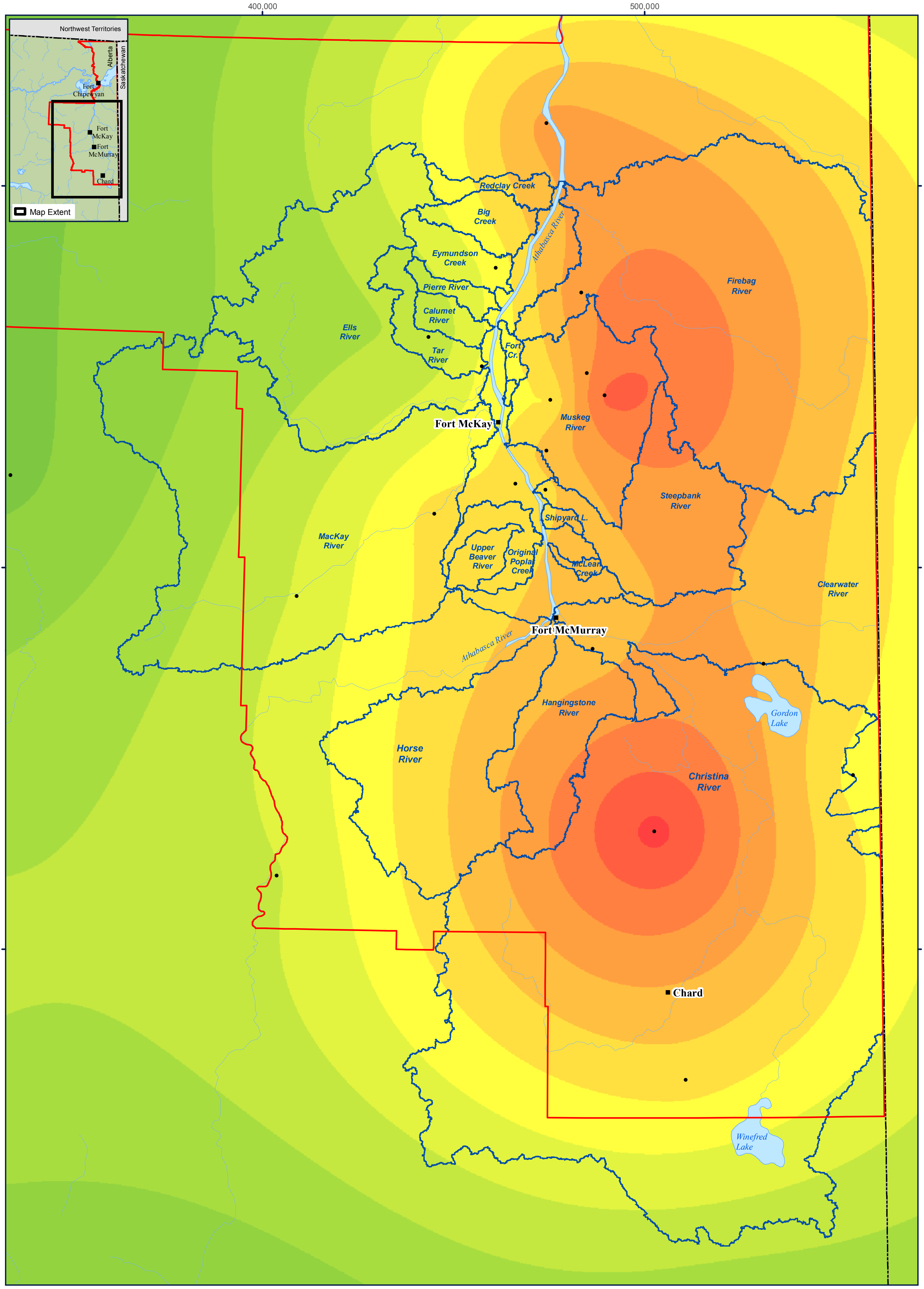
Figure 6.1-5 MODIS imagery depicting snow cover and melt in spring 2012 and 2013.



6.1.1.3 Precipitation in Spring 2013

The Fort McMurray climate station in June 2013 recorded 165.9 mm of precipitation, which was almost 40% of the historical annual mean. The highest intensity of rainfall leading up to the peak flooding occurred from June 5 to June 11, 2013. Total precipitation measured at 29 regional stations ranged from 23 to 144 mm during that seven-day period (Appendix C, Figure 6.1-6). The regional distribution of rainfall suggested that areas to the east of the Athabasca River and south of Fort McMurray received the highest amount of precipitation, specifically, the Firebag, Muskeg, Steepbank, Christina, and Hangingstone watersheds.

Figure 6.1-6 Spatial distribution of total rainfall from June 5 to June 11, 2013 in the Regional Municipality of Wood Buffalo.



Legend

- ⬚ Province Boundary
- ▭ Regional Municipality of Wood Buffalo
- Watershed Boundary
- ● Precipitation Monitoring Station

Event Precipitation Data

7 Day Total (mm)

- 🟩 < 30
- 🟩 30 - 40
- 🟩 40 - 50
- 🟩 50 - 60
- 🟩 60 - 70
- 🟨 70 - 80
- 🟨 80 - 90
- 🟨 90 - 100
- 🟧 100 - 110
- 🟧 110 - 120
- 🟧 120 - 130
- 🟥 130 - 140
- 🟥 140 - 150

Data Sources:
a) Lake and River at 1:2,000,000 from the Atlas of Canada.
b) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.

0 5 10 20 km

Scale: 1:1,000,000

Projection: NAD 1983 UTM Zone 12N

N

Regional Aquatics Monitoring Program

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_N_Rainfall_20140213_ss.mxd

6.1.1.4 Comparison to Fort McMurray Intensity-Duration-Frequency (IDF) Statistics

Introduction

The hydrologic response to a rain event is partly controlled by the amount of rain that falls (depth) and the rate at which it falls (intensity). These two factors are commonly expressed by intensity-duration-frequency (IDF) relationships (often referred to as IDF curves or IDF statistics), which relate rainfall intensity to rainfall duration for a range of probabilistic reoccurrence intervals. IDF statistics are commonly expressed as the depth of rainfall (mm) that falls in a given time period (typically 5, 10, 15, 30 minutes and 1, 2, 6, 12, 24 hours) for a certain return period (years). The return period is the average length of time between precipitation events that equals or exceeds a given rainfall depth.

For example, a 5-year, 24-hour storm for a hypothetical climate station has a rainfall depth of 50 mm, which indicates on average, that every 5 years this location is likely to experience a rain event in which ≥50 mm of rain will fall in a 24-hour period. A 100-year, 24-hour storm for the same location has a rainfall depth of 90 mm, and although the 100-year event is much more severe than the 5-year event (in terms of rainfall amount), it is only likely to occur once in 100 years.

To develop IDF statistics, frequency analysis is applied to historical rainfall records. IDF statistics can; therefore, be developed for any climate station with a rainfall record. However, to produce statistically robust IDF statistics, relatively long precipitation records with a high logging interval are required. Environment Canada (EC) provides IDF statistics for locations across Canada with a minimum of ten years of rate-of-rainfall observations (Environment Canada 2012).

Application of IDF Statistics to the June 2013 Precipitation Event

IDF statistics for the EC Fort McMurray climate station ('Fort McMurray A', station ID 3062693) were used to help interpret the June 2013 rain event. The Fort McMurray IDF statistics for the 24-hour event duration are presented in Table 6.1-1.

Table 6.1-1 Return-period rainfall amounts (mm) for a 24-hour event duration for the Fort McMurray climate station ('Fort McMurray A', station ID 3062693).

	Return Intervals for the Environment Canada Climate Station Fort McMurray A (Station 3062693)					
Duration	**2 year**	**5 year**	**10 year**	**25 year**	**50 year**	**100 year**
24 hours	39.3	53.8	63.4	75.6	84.6	93.5

Source: Environment Canada Short Duration Rainfall Intensity-Duration-Frequency Data (Environment Canada 2012). IDF statistics developed using data from 1966 to 1995.

An important caveat in interpreting the IDF statistics for the Fort McMurray climate station is that it represents point measurements of rainfall, which may not be directly applicable over large areas, due to the potential for spatial variability in rainfall intensity, duration, and frequency. The magnitude of the June 2013 rain event was spatially variable, as indicated in Figure 6.1-6. Therefore, return-period rainfall amounts for the EC Fort McMurray climate station are presented for the purpose of general comparisons to the regional stations and should not be interpreted as locally specific values for each regional station. It should also be noted that the Fort McMurray IDF curve does not incorporate any projected future trends in precipitation, nor any trends since the year of the most recent data used to produce the curve (i.e., data used in the development of the curve for the Fort McMurray station were from 1966 to 1995).

To compare precipitation values for the regional climate stations to the return-period rainfall amounts for Fort McMurray, daily total precipitation was converted to 24-hour total precipitation. Daily total precipitation represents a fixed 24-hour interval (e.g., from midnight of one day to midnight of the next day). Consequently, daily total precipitation may under-represent the maximum precipitation that accumulated in any 24-hour period. For example, a rain event that totaled 10 mm from 11 pm to 1 am would be under-represented by daily data with a cutoff of midnight (i.e., each day would have a total rainfall of 5 mm), whereas the same event would be accurately represented by 24-hour rainfall totals calculated on a rolling basis (i.e., a 24-hour period including the rain event would correctly indicate the event as 10 mm). Daily total rainfall values for the regional climate stations were converted to 24-hour total values by applying the standard empirically-derived conversion factor of 1.13 developed by the United States National Weather Service (e.g., Herschfield 1961; Miller et al. 1973; Bonnin et al. 2011). Daily total rainfall and converted 24-hour total rainfall for the 29 regional climate stations during the period from June 5 to 11, 2013 are provided in Appendix C.

Compared to the Fort McMurray IDF 24-hour event return period estimates (Table 6.1-1), 24-hour rainfall totals for regional climate stations during the June 2013 precipitation event were generally average or below average (i.e., equal to or less than the 2-year, 24-hour event return-period amount of 39.3 mm for Fort McMurray). Exceedances of the Fort McMurray 2-year return period estimate occurred at 14 of the 29 regional climate stations, for one or two 24-hour periods during the seven-day event. The 14 stations that experienced above-average rainfall in comparison to the Fort McMurray 24-hour return-period amounts are provided in Table 6.1-2.

Table 6.1-2 Regional climate stations with 24-hour rainfall totals exceeding the 2-year, 24-hour event for Fort McMurray for the period June 5 to 11, 2013.

	RAMP C4	RAMP C5	RAMP L1	RAMP L2	EC Fort McMurray	EC Mildred Lake	AESRD Christina Lake	RAMP S3	RAMP S40	AESRD Gordon Lake Lookout	WBEA JP104	WBEA JP107	WBEA JP213	WBEA JP316
Date	**24-hour Total Rainfall (mm)[a]**													
June 5	4.3	9.5	1.8	5.1	3.7	10.1	8.5	6.2	12.6	0.2	0.0	0.1	0.0	0.0
June 6	9.2	9.5	15.4	27.6	13.9	9.6	1.0	27.3	8.9	16.0	10.0	2.2	0.0	0.0
June 7	0.0	5.2	0.0	0.2	3.4	1.7	7.2	0.3	4.6	0.9	15.6	7.4	3.3	8.5
June 8	18.6	54.0	26.7	34.1	39.9	29.4	19.2	34.0	17.2	40.3	0.5	0.4	0.0	1.8
June 9	49.3	55.5	77.9	46.3	45.3	42.7	44.0	61.5	49.9	47.1	37.3	15.6	26.7	29.1
June 10	8.0	28.6	10.4	12.9	4.6	3.3	23.3	14.1	4.3	16.7	48.5	83.0	50.1	42.5
June 11	5.0	0.0	1.2	7.5	7.2	8.8	2.6	6.3	8.3	1.4	7.2	20.0	13.8	14.9
Total	94.4	162.3	133.3	133.7	118.1	105.5	105.8	149.8	105.9	122.7	119.1	128.7	93.9	96.8

[a] 24-hour rainfall totals were derived from daily rainfall totals by application of a conversion factor of 1.13, developed by the United States National Weather Service (e.g., Herschfield 1961; Miller et al. 1973; Bonnin et al. 2011).

Grey shading: 24-hour rainfall totals between the 2- and 5-year return period estimates for Fort McMurray.

Blue shading: 24-hour rainfall totals between the 5- and 10-year return period estimates for Fort McMurray.

Orange shading: 24-hour rainfall totals between the 25- and 50-year return period estimates for Fort McMurray.

Comparison of the 29 regional climate stations (Appendix C) to the IDF statistics for the Fort McMurray station (Table 6.1-1) indicated that the June 2013 rain event had relatively low intensities and low return periods across much of the region (typically between the two and five year 24-hour return periods). Two regional stations had rainfall totals between the 25 and 50-year 24-hour return intervals (Table 6.1-2).

Analysis of Multi-Day (Storm Event) Precipitation Totals

IDF curves published by Environment Canada present precipitation totals and statistics up to the 24-hour period. However, precipitation totals for periods greater than 24 hours are often hydrologically important. Sustained multi-day precipitation can affect antecedent conditions by saturating soil and increasing the runoff ratio (the ratio of precipitation to runoff).

From June 5 to 11, between 23 mm and 144 mm of precipitation fell in the region (Appendix C, Figure 6.1-6). The prolonged duration of the event generated a substantial percentage of the total precipitation for the entire year (cumulative total precipitation patterns for the 2013 WY are discussed in Section 4; summary data are provided for RAMP climate stations in Table 6.1-3). For the RAMP climate stations, precipitation during the seven-day period from June 5 to 11 accounted for 11% to 25% of the total precipitation for the 2013 WY (Table 6.1-3).

Table 6.1-3 RAMP climate station total daily rainfall from June 5 to 11, 2013 compared to cumulative total precipitation in the 2013 WY.

	C1	C2	C3	C4	C5	L1	L2
	Aurora	Horizon	Steepbank	Pierre	Surmount	McClelland Lake	Kearl Lake
Date	Daily Total Rainfall (mm)						
June 5	6.3	3.2	9.0	3.8	8.4	1.6	4.5
June 6	12.2	12.3	11.6	8.2	8.4	13.6	24.5
June 7	0.2	0.1	3.3	0.0	4.6	0.0	0.2
June 8	24.3	14.2	25.8	16.4	47.8	23.6	30.1
June 9	33.9	22.1	33.8	43.6	49.1	68.9	41.0
June 10	5.3	4.8	7.1	7.1	25.3	9.2	11.4
June 11	9.1	3.9	6.1	4.4	0.0	1.1	6.6
Precipitation Event (June 5 to 11, 2013) Total	91.3	60.7	96.5	83.6	143.7	118.0	118.3
2013 WY total precipitation	444.3	575.9	512.3	534.4	569.4	497.0	553.2
June precipitation event as a percent of 2013 WY total	21%	11%	19%	16%	25%	24%	21%

6.1.2 2013 Hydrometric Conditions

Rivers in the region were dominated by two large events in 2013, as illustrated in the hydrographs of the Muskeg River (Figure 6.1-7), MacKay River (Figure 6.1-8), and Hangingstone River (Figure 6.1-9). These rivers represented three different areas in the region and showed a similar pattern and response to snowmelt and precipitation events. The first peak in the hydrographs occurred in early May and corresponded with the timing of snow melt; the second peak occurred in mid-June and showed a positive correlation with the precipitation event in that month. There were other large rain events that occurred in late July and late September, which resulted in relatively small increases in discharge compared to the response following the rain event in June.

Figure 6.1-7 The 2013 WY hydrograph for the Muskeg River near Fort McKay (WSC station 07DA008) compared to historical values and 2013 daily precipitation data (RAMP C1 - Aurora climate station).

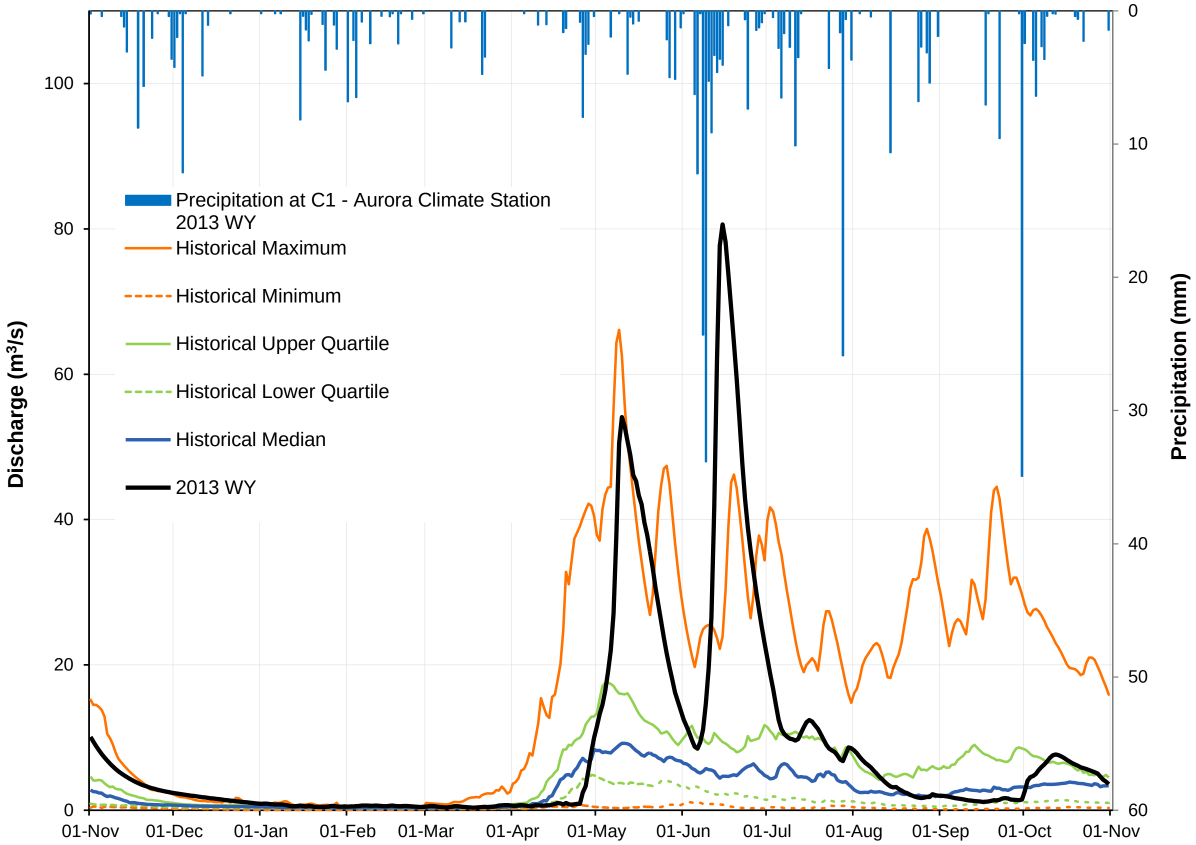


Figure 6.1-8 The 2013 WY hydrograph for the MacKay River near Fort McKay (WSC station 07DB001) compared to historical values and 2013 daily precipitation data (EC Mildred Lake climate station).

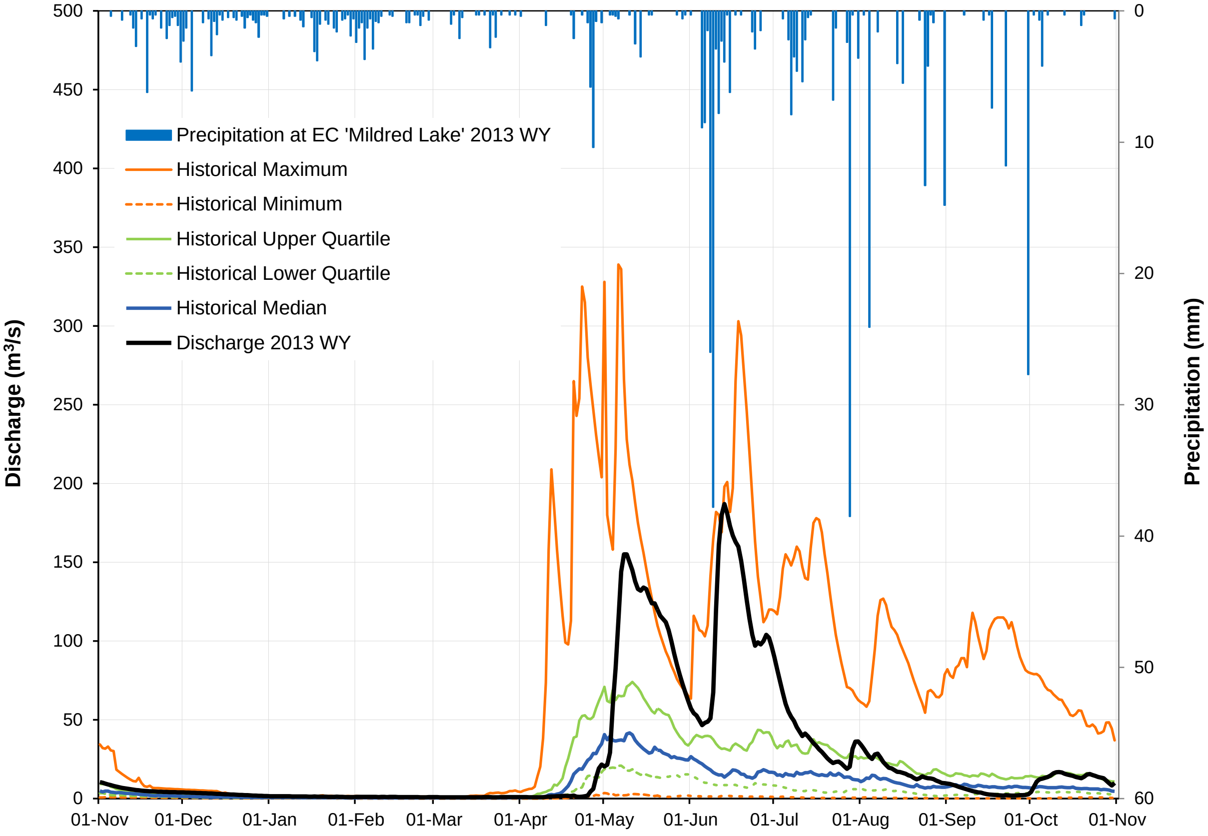
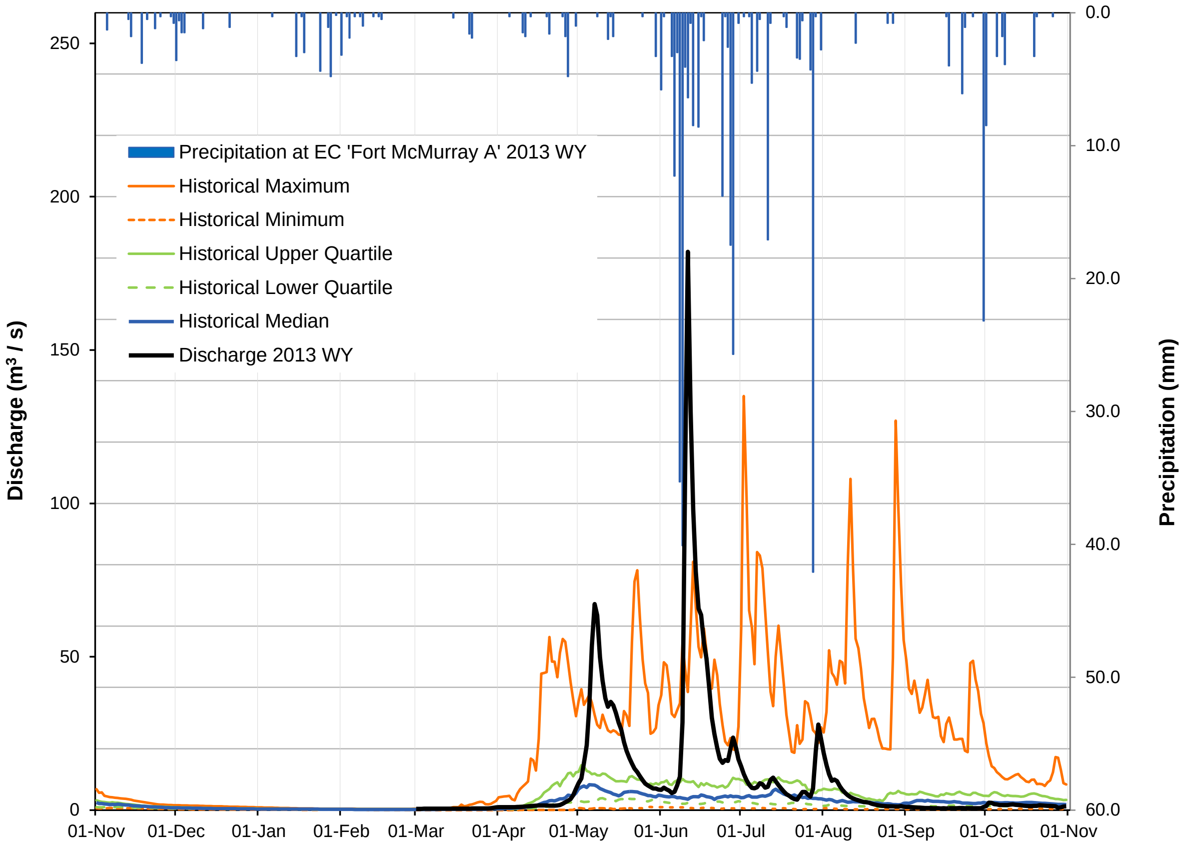


Figure 6.1-9 The 2013 WY hydrograph for the Hangingstone River near Fort McMurray (WSC station 07CD004) compared to historical values and 2013 daily precipitation data (EC Fort McMurray climate station).



6.1.3 Flood-Frequency Analysis

A flood-frequency analysis (FFA) was conducted using data from seven regional WSC hydrometric stations, with greater than 20 years of available data. This analysis was conducted to provide historical context to the magnitude of the flooding observed at each station and to compare the magnitude of the flooding between stations in 2013.

FFA is a statistical technique to fit annual peak flows to a probability distribution. Using the probability distribution, the return period associated with a flood event of a specified magnitude can then be estimated. The return period or recurrence interval, expressed in years, denotes the likelihood of a flood event of a given magnitude to be equaled or exceeded, with the understanding that a return period is simply a statistical probability and an event of any return period could occur the following year or even during the same year.

Data for the 2013 WY were received from WSC as provisional daily mean discharge data and may be modified with further analysis. The maximum daily mean discharge value for each station in June 2013 was used as instantaneous maximum flow, given that instantaneous peak discharges were not available. Therefore, return periods should be viewed as conservative estimates of the instantaneous peak.

Table 6.1-4 provides the results of the FFA for each station and lists the probability distribution that was selected for the data from each station. The probability distribution was chosen based on a visual fit of the curve to the available data for a station. The accuracy of the FFA and calculation of return periods increases with an increase in the amount of data; however, the FFA should be used with caution when estimating return periods of expected hydrologic events greater than twice the record length. Therefore, as more data become available the estimated return periods associated with the 2013 peak flows may shift, but the confidence on the estimates will also increase. The return period estimates ranged from four to greater than 100 years for the seven WSC stations (Table 6.1-4). The Firebag and Muskeg rivers produced return-period estimates of greater than 100 years. Given the relatively short available record and increased uncertainty of such large flows, the return-period estimate was truncated to greater than 100 years and the exact return period value was not presented.

Table 6.1-4 Return-period estimates from the flood-frequency analysis conducted for seven WSC hydrometric stations.

Station	**Period of Record**	**Number of Peak Discharges**	**Daily Mean Peak Discharge**			**Probability Distribution**
			Date	Discharge (m^3/s)	Return Period Estimate	
Athabasca River below Fort McMurray (07DA001)	1958-2011	48	6/26/2013	3,040	4	Log Pearson III
Clearwater River at Draper (07CD001)	1960-2011	34	6/18/2013	770	85	Log Pearson III
Firebag River near the mouth (07DC001)	1975-2011	26	6/15/2013	373	>100	Gumbel
Hangingstone River at Fort McMurray (07CD004)	1984-2011	24	6/11/2013	182	100	Log Pearson III
MacKay River near Fort McKay (07DB001)	1973-2011	30	6/13/2013	187	5	Log Pearson III
Muskeg River near Fort McKay (07DA008)	1974-2011	35	6/15/2013	81	>100	Log Pearson III
Steepbank River near Fort McMurray (07DA006)	1974-2011	35	6/16/2013	71	16	Log Pearson III

Note: The Firebag River and the Muskeg River produced return-period estimates >100 years. Given the relatively short record and increased uncertainty of such large flows the return-period estimate was truncated to >100 years.

Note: Data from the Christina River near Chard 07CE002 WSC station were provided without the peak flows for the May and June events and; therefore, was not included in the FFA. The Christina River flows in the Clearwater River; therefore, the Clearwater River was used as a proxy due to the absence of available data from the Christina River.

6.1.4 Discussion

At a regional scale, the return periods corresponded with the precipitation patterns that are presented in Figure 6.1-6, with the largest rainfall and return period events occurring to the east of the Athabasca River in the Muskeg River and Firebag River watersheds, and south of Fort McMurray in the Hangingstone River and Christina-Clearwater River watersheds. The return-period estimates for these watersheds were greater than 85 years.

The Steepbank River was the exception to the observed high flows during the spring 2013 flood events, which resulted in a return-period flood of only 16 years, which was relatively small compared to the other stations located east of the Athabasca River (i.e., Firebag and Muskeg rivers). The Steepbank River watershed received less precipitation than the Muskeg River and Firebag River watersheds (Figure 6.1-6). This could be a result of sparse rainfall data collected for the watershed or spatial variability in the rainfall pattern generating lower peak flows compared to adjacent watersheds.

The MacKay River watershed, located to the west of the Athabasca River, resulted in a FFA that correlated well with the precipitation pattern (Figure 6.1-6) indicating that the western region of the lower Athabasca River watershed was not as severely affected by the rainfall events in June 2013 as other regional watersheds. The 2013 hydrograph for the MacKay River showed the same pattern as the Muskeg and Hangingstone rivers; however, with a magnitude of approximately half the historical maximum values while the Muskeg and Hangingstone exceeded previously-recorded maximum discharges (Figure 6.1-8 and Figure 6.1-9).

The results of this analysis indicated that the flooding that occurred in June 2013 was a result of a number of contributing factors. The rainfall event in early June was large and likely would have resulted in substantial runoff responses regardless of the antecedent moisture conditions. However, the combination of wet conditions during the fall prior to freeze-up, above average snowpack, and late snowmelt contributed to generally wet antecedent moisture conditions and contributed to the size of the peaks observed in June. The generally low response to rain events in July and September suggested that antecedent conditions was an important contributing factor in the response of rivers to rain events in the Fort McMurray area.

6.2 NEXEN LAKES WATER QUALITY MONITORING

Nexen Inc. undertakes a bi-annual water quality monitoring program at select lakes in the vicinity of their Long Lake Project. This monitoring is conducted to meet requirements stipulated under their Alberta Environmental Protection and Enhancement Act (EPEA) approval and to address community concerns. A total of seven lakes south of Fort McMurray were sampled for water quality in spring and fall 2013, in conjunction with the Nexen Wetlands Monitoring Program (Hatfield 2014). Results of the water quality program have historically been presented as part of the RAMP report since this monitoring began in 2000.

6.2.1 Summary of Field Methods and Sample Analysis

The 2013 Nexen lakes program consisted of spring and fall ambient water quality monitoring at seven lakes (Table 6.2-1 and Figure 6.2-1). Water quality stations were accessed via a pontoon-equipped helicopter in both seasons. The helicopter landed near the edge of each lake and taxied out to the centre to ensure surface waters at the sample collection point were not disturbed by rotor wash.

Water quality sampling procedures in each lake followed procedures under RAMP, as outlined in Section 3.1.2. All water samples were collected, preserved, and shipped according to protocols specified by consulting laboratories. All water quality samples taken in 2013 were analyzed for the RAMP standard variables; Frog Lake (FRL-1) was also sampled for BTEX and PAHs. 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 naphthenic acids, which were analyzed by Alberta Innovates Technology Futures (AITF) in Vegreville, Alberta, and total PAHs, which were analyzed by AXYS Environmental in Sidney, British Columbia.

Table 6.2-1 Location of water quality stations for the Nexen Lakes Water Quality Monitoring Program, spring and fall 2013.

Waterbody	Station Name	UTM Coordinates (NAD83, Zone 12) Easting	UTM Coordinates (NAD83, Zone 12) Northing
Canoe Lake	CANL-1	498900	6256861
Caribou Horn Lake	CARL-1	501305	6264200
Frog Lake	FRL-1	504521	6254100
Gregoire Lake	GRL-1	493510	6255110
Kiskatinaw Lake	KIL-1	499980	6265890
Rat Lake	RAL-1	507453	6251457
Unnamed Lake One	UNL-1	502509	6249721

6.2.2 Analytical Approach

The analytical approach used in 2013 for the Program was based on the analytical approach described in Section 3.2.2 for the RAMP Water Quality component.

6.2.2.1 Development of Regional Water Quality Baseline Conditions

Determination of regional *baseline* concentrations for the Nexen lakes was conducted separately from the RAMP water quality dataset. The *baseline* range was defined from water quality data collected at all Nexen lakes between 2000 and 2008. All lakes sampled were considered to be *baseline* from 2000 to 2008 given operations at the Nexen Long Lake project did not start until 2008. This approach maximized the number of observations used to define *baseline* conditions against which observations from individual Nexen lakes could be compared.

6.2.2.2 Comparison to Historical Data and Water Quality Guidelines

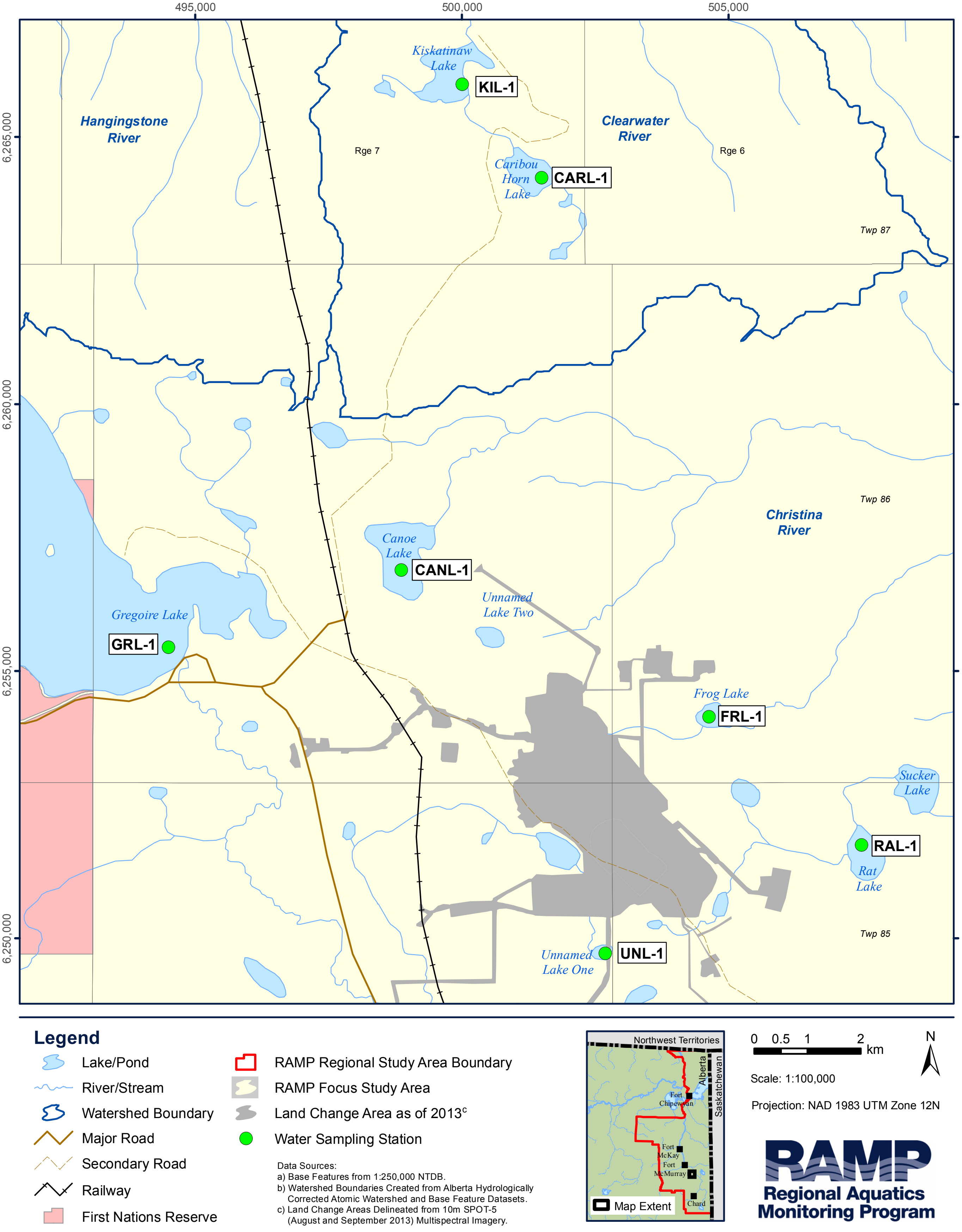
Historical variability was presented for each water quality measurement endpoint, represented by minimum, maximum, and median values, as well as the number of observations, at each station from 2000 to 2011 (fall or spring observations only as appropriate). All cases where concentrations of water quality variables exceeded relevant guidelines in spring and fall, including water quality measurement endpoints and any other water quality variables that were measured, also were reported.

6.2.2.3 Comparison to *Baseline* Conditions

Descriptive statistics describing water quality characteristics for *baseline* years (2000 to 2008) for all lakes were calculated as the 5th, 25th, 50th (median), 75th, and 95th percentiles for comparison against station-specific data. The median rather than the mean was used as an indicator of typical conditions.

To assess temporal trends for a station, data for the selected water quality measurement endpoints (see Section 3.2.2.1) were presented graphically for all years against regional *baseline* variability.

Figure 6.2-1 Locations of water quality stations for the Nexen Lakes Water Quality Monitoring Program, spring and fall 2013.



Data Sources:
a) Base Features from 1:250,000 NTDB.
b) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
c) Land Change Areas Delineated from 10m SPOT-5 (August and September 2013) Multispectral Imagery.

K:\Data\Project\RAMP6221-NV\GIS_MXD\G_TechRpt\RAMP6221_M_WaterNexen_20140130_ss.mxd

6.2.3 Water Quality Results

6.2.3.1 2013 Results Relative to Historical and *Baseline* Concentrations

Given the small number of observations from each lake, concentrations of several water quality measurement endpoints in spring 2013 were outside the range of previously-measured concentrations at almost all lakes (Table 6.2-2 to Table 6.2-8; Figure 6.2-2 to Figure 6.2-3). These included:

- Total iron, which was above previously-measured maximum concentrations at all stations;
- Dissolved iron and total mercury (ultra-trace), which were above previously-measured maximum concentrations at all stations, with the exception of GRL-1;
- Dissolved aluminum, which was above previously-measured maximum concentrations, and total boron, which was below previously-measured minimum concentrations at all stations, with the exception of UNL-1;
- Dissolved organic carbon, which was above previously-measured maximum concentrations at all stations, with the exception GRL-1 and FRL-1; and
- Sulphide, which was above previously-measured maximum concentrations at all stations, with the exception of CANL-1 and CARL-1.

Additionally, several other measurement endpoints were outside the range of previously-measured concentrations at one or more lakes in spring 2013, including:

- Physical variables – total suspended solids, total dissolved solids, pH, conductivity and total alkalinity;
- Nutrients – total nitrogen, total and dissolved phosphorus;
- Major ions – sulphate, chloride, sodium, calcium, magnesium; and
- Organic compounds – total phenols.

In fall 2013, several water quality measurement endpoints were also outside the range of previously-measured concentrations (Table 6.2-9 to Table 6.2-15; Figure 6.2-4 to Figure 6.2-5), including:

- Dissolved aluminum, which was above previously-measured maximum concentrations at all stations, with the exception of CANL-1;
- Dissolved organic carbon, which was above previously-measured maximum concentrations at all stations, with the exception of FRL-1 and KIL-1;
- Dissolved phosphorus, which was above previously-measured maximum concentrations at FRL-1, RAL-1, KIL-1, GRL-1, and UNL-1;
- Total nitrogen, which was above previously-measured maximum concentrations at CANL-1 and UNL-1;
- Calcium, which was above previously-measured maximum concentrations at FRL-1 and CANL-1, and below previously-measured minimum concentrations at KIL-1, GRL-1, and CARL-1;

- Magnesium, which was above previously-measured maximum concentrations at GRL-1, FRL-1, UNL-1, and KIL-1;
- Total alkalinity, which was above previously-measured maximum concentrations at FRL-1 and CANL-1, and below previously-measured minimum concentrations at GRL-1 and CARL-1; and
- Total ammonia, which was substantially higher than the previously-measured maximum concentration at UNL-1.

Other measurement endpoints that were outside the range of previously-measured concentrations at one or more lakes in fall 2013 included:

- Physical variables – pH, conductivity, and total dissolved solids;
- Nutrients – total nitrogen and total phosphorus;
- Major ions – sulphate, sulphide, chloride, and sodium; and
- Selected metals – total mercury (ultra-trace), total aluminum, total copper, total and dissolved iron, and total boron.

6.2.3.2 Comparison of Water Quality Measurement Endpoints to Published Guidelines

Concentrations of water quality measurement endpoints that exceeded water quality guidelines in spring and fall 2013 were (Table 6.2-16):

- total phosphorus at FRL-1 and UNL-1 in spring, and CANL-1 and UNL-1 in fall;
- dissolved phosphorus at UNL-1 in fall;
- total nitrogen in both seasons at CANL-1, CARL-1, and RAL-1; and KIL-1 in spring, and FRL-1 and UNL-1 in fall;
- total ammonia at UNL-1 in fall. Previously, the concentration of total ammonia has been below the analytical detection limit (0.05 mg/L), but was measured at 1.41 mg/L in fall 2013;
- total aluminum and copper in fall, and dissolved aluminum in both seasons at UNL-1;
- total iron in both seasons at CANL-1, CARL-1, FRL-1, KIL-1, and UNL-1, and in spring at RAL-1;
- dissolved iron in both seasons at FRL-1 and UNL-1, and in spring at all other stations;
- total phenols in both seasons at FRL-1, RAL-1, and UNL-1, and in spring at CARL-1, and fall at CANL-1;
- sulphide at all stations in both seasons; and
- pH, which was below the guideline in both seasons at UNL-1.

As discussed in the RAMP 2011 technical report (RAMP 2012), concentrations of total mercury (ultra-trace) in 2011 exceeded the guideline at all stations due to contamination of the samples. Considerable efforts to resolve the issue with the laboratory were unable to definitively isolate the potential source of the contamination, but the most likely source was the preservatives supplied by the laboratory. These results are presented again in this technical report, and should be interpreted with caution. Concentrations of total mercury (ultra-trace) in fall 2013 were substantially lower than fall 2011 and only concentrations at KIL-1, CARL-1, and FRL-1 were higher than previously-measured maximum concentrations.

In spring and fall 2013, total PAHs were measured at FRL-1. No historical PAH data existed for this lake for comparison to the 2013 data; however concentrations of all PAHs were below published guidelines for the protection of aquatic life in both seasons. Concentrations of individual PAH analytes were generally low, and PAHs were dominated by alkylated species. Concentrations of total PAHs (both alkylated and parent) were substantially below those measured in other lakes sampled by RAMP (i.e., Christina, Isadore's, Johnson, Kearl, McClelland, and Shipyard lakes, see Section 5); total PAHs at these lakes ranged from 102 ng/L in spring to 308 ng/L in fall 2013, while PAHs at FRL-1 ranged from 36 ng/L in spring to 69 ng/L in fall, with comparable results reported for the spring. Concentrations of CCME hydrocarbons were all below analytical detection limits (0.1 mg/L or 0.25 mg/L) in both seasons in 2013.

6.2.3.3 Ion Balance

The ionic composition of water in all lakes in spring and fall 2013 was dominated primarily by calcium bicarbonate, similar to previous sampling years (Figure 6.2-6 to Figure 6.2-9). In 2009 and 2011, Canoe Lake (CANL-1) had relatively higher concentrations of chloride than previously measured in both spring and fall; however, in 2013 in both seasons, the concentration of chloride shifted back towards the concentration observed in 2006 for this lake. Between 2000 and 2006, Unnamed Lake One (UNL-1) had an ionic composition that was very different from the other lakes in both spring and fall; however, from 2009 onward, the ionic composition of this lake has become more similar to the other lakes (Figure 6.2-7 and Figure 6.2-9).

6.2.3.4 Summary of Results

Water quality in the Nexen lakes in 2013 was variable relative to historical conditions. Concentrations of several water quality measurement endpoints in spring and fall 2013 were outside the range of previously-measured concentrations for the Nexen Lakes. Several analytes were measured at concentrations exceeding published guidelines for the protection of aquatic life; however, most of these guideline exceedances have been observed in previous years, with the exception of total ammonia at UNL-1, which has been below the detection limit in previous years, but was reported at 1.41 mg/L in fall 2013. The ionic composition of the lakes has remained similar to previous monitoring years at all stations. Total PAHs were measured at Frog Lake (FRL-1) in both spring and fall 2013; no historical data existed for comparison to these results; however, there were no PAHs that exceeded published guidelines and concentrations of total PAHs were substantially lower than in other lakes sampled by RAMP in the region.

Table 6.2-2 Concentrations of water quality measurement endpoints, Canoe Lake (CANL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2000-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.88	7.95	5	7.20	7.50	7.80
Total Suspended Solids	mg/L	-	8	<3	5	4	6	22
Conductivity	µS/cm	-	130	151	5	88	97	113
Dissolved organic carbon	mg/L	-	23.6	17.7	5	17.8	19.0	22.0
Total Dissolved Solids	mg/L	-	108	112	5	80	95	120
Total Alkalinity	mg/L	-	45.0	44.8	5	40.0	40.0	41.0
Nutrients								
Total phosphorus	mg/L	0.05	0.0483	0.0599	5	0.0370	0.0410	0.0554
Total dissolved phosphorus	mg/L	0.05	0.0182	0.0205	5	0.0060	0.0150	0.0190
Total nitrogen	mg/L	1.0	**2.381**	**1.321**	5	**1.200**	**1.400**	**2.250**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	5	<0.071	<0.100	0.200
Ions								
Sodium	mg/L	-	8.5	10.7	5	3.0	6.0	8.1
Calcium	mg/L	-	11.9	10.9	5	9.3	10.2	10.9
Magnesium	mg/L	-	3.76	3.94	5	3.20	3.20	3.46
Chloride	mg/L	230, 860	11.7	16.8	5	1.0	5.0	9.3
Sulphate	mg/L	50, 100	0.62	1.26	5	1.06	1.60	2.10
Organic compounds								
Naphthenic acids	mg/L	-	0.31	0.49	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.31	3.07	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00051	0.00066	5	0.00045	0.00100	<0.0010
Total aluminum	mg/L	0.1	0.0385	0.0287	5	0.0132	0.0430	2.0200
Dissolved aluminum	mg/L	0.1	0.0097	0.0059	2	0.0010	-	0.0044
Total boron	mg/L	1.2	0.0184	0.0232	5	0.0199	0.0204	0.0740
Total molybdenum	mg/L	0.073	<0.00010	0.00024	5	0.00006	0.00010	0.00140
Total mercury (ultra-trace)	ng/L	5, 13	1.3	1.0	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Sulphide	mg/L	0.002	**0.008**	0.002	5	<0.003	**0.005**	**0.013**
Total Kjeldahl nitrogen	mg/L	1.0	**2.31**	**1.25**	5	1.00	**1.30**	**1.54**
Total iron	mg/L	0.3	**0.927**	0.168	5	0.273	**0.397**	**0.480**
Dissolved iron	mg/L	0.3	**0.590**	0.063	2	0.113	0.132	0.151

[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 6.2-3 Concentrations of water quality measurement endpoints, Caribou Lake (CARL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.97	8.18	4	7.90	7.99	8.00
Total Suspended Solids	mg/L	-	5	<3	4	<3	<3	3
Conductivity	µS/cm	-	136	167	4	137	165	191
Dissolved organic carbon	mg/L	-	28.6	27.9	4	17.0	20.1	23.0
Total Dissolved Solids	mg/L	-	120	129	4	120	122	160
Total Alkalinity	mg/L	-	69.6	85.2	4	66.0	80.7	91.0
Nutrients								
Total phosphorus	mg/L	0.05	0.0133	0.0230	4	0.0120	0.0215	0.0287
Total dissolved phosphorus	mg/L	0.05	0.0092	0.0102	4	0.0040	0.0130	0.0148
Total nitrogen	mg/L	1.0	1.081	0.841	4	0.900	1.121	1.600
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.071	<0.100	0.200
Ions								
Sodium	mg/L	-	3.6	4.5	4	4.9	5	6.0
Calcium	mg/L	-	17.8	20.3	4	17.7	20.7	25.2
Magnesium	mg/L	-	5.85	7.08	4	5.70	6.93	8.10
Chloride	mg/L	230, 860	<0.5	<0.5	4	<0.5	1.0	5.0
Sulphate	mg/L	50, 100	1.5	2.1	4	2.6	3.2	4.3
Organic compounds								
Naphthenic acids	mg/L	-	0.30	0.36	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.37	2.38	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00046	0.00044	4	0.00039	0.00071	<0.0010
Total aluminum	mg/L	0.1	0.072	0.028	4	0.029	0.058	**1.950**
Dissolved aluminum	mg/L	0.1	0.0108	0.0011	2	0.0041	-	0.0077
Total boron	mg/L	1.2	0.0224	0.0348	4	0.0272	0.0306	0.0590
Total molybdenum	mg/L	0.073	<0.00010	0.00008	4	0.00008	0.00018	<0.0006
Total mercury (ultra-trace)	ng/L	5, 13	1.7	1.7	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Total phenols	mg/L	0.004	**0.0041**	**0.0053**	2	**0.0064**	-	**0.0140**
Sulphide	mg/L	0.002	**0.0064**	<0.0020	4	<0.0030	**0.0055**	**0.0080**
Total Kjeldahl nitrogen	mg/L	1.0	**1.01**	0.77	4	0.80	0.99	**1.50**
Total iron	mg/L	0.3	**0.852**	0.082	4	0.130	0.224	**0.345**
Dissolved iron	mg/L	0.3	**0.604**	0.017	2	0.161	-	0.168

[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 6.2-4 Concentrations of water quality measurement endpoints, Frog Lake (FRL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.92	8.21	4	7.70	7.87	7.90
Total Suspended Solids	mg/L	-	7	<3	4	4	5	5
Conductivity	µS/cm	-	166	211	4	141	180	201
Dissolved organic carbon	mg/L	-	28.4	26.1	4	24.0	28.5	33.0
Total Dissolved Solids	mg/L	-	159	162	4	130	144	190
Total Alkalinity	mg/L	-	70	82	4	60	72	97
Nutrients								
Total phosphorus	mg/L	0.05	**0.0741**	0.0363	4	0.0360	0.0418	**0.0760**
Total dissolved phosphorus	mg/L	0.05	0.010	0.017	4	0.012	0.014	0.019
Total nitrogen	mg/L	1.0	0.871	**1.231**	4	**1.100**	**2.066**	**2.300**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.071	<0.100	0.200
Ions								
Sodium	mg/L	-	7.2	11.4	4	6.0	9.0	13.6
Calcium	mg/L	-	20.1	20.7	4	17.6	18.9	27.3
Magnesium	mg/L	-	6.08	7.18	4	5.50	5.86	7.90
Chloride	mg/L	230, 860	7	14	4	<1	4	18
Sulphate	mg/L	50, 100	2.19	2.20	4	2.40	3.55	4.06
Organic compounds								
Naphthenic acids	mg/L	-	0.37	0.43	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.39	3.78	0	-	-	-
BTEX								
Fraction 1 (C6-C10)	mg/L	30	<0.1	-	0	-	-	-
Fraction 2 (C10-C16)	mg/L	150	<0.25	-	0	-	-	-
Fraction 3 (C16-C34)	mg/L	300	<0.25	-	0	-	-	-
Fraction 4 (C34-C50)	mg/L	2800	<0.25	-	0	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	4.45	-	0	-	-	-
Retene	ng/L	-	0.441	-	0	-	-	-
Total dibenzothiophenes	ng/L	-	2.801	-	0	-	-	-
Total PAHs	ng/L	-	69.197	-	0	-	-	-
Total Parent PAHs	ng/L	-	8.102	-	0	-	-	-
Total Alkylated PAHs	ng/L	-	61.095	-	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00044	0.00047	4	0.00034	0.00072	<0.0010
Total aluminum	mg/L	0.1	0.0324	0.0240	4	0.0298	**0.0807**	**0.1700**
Dissolved aluminum	mg/L	0.1	0.0155	0.0033	2	0.0057	-	0.0063
Total boron	mg/L	1.2	0.0308	0.0436	4	0.0389	0.0508	0.0650
Total molybdenum	mg/L	0.073	0.00016	0.00013	4	0.00008	0.00010	0.00020
Total mercury (ultra-trace)	ng/L	5, 13	2.0	1.2	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Total phenols	mg/L	0.004	**0.0079**	**0.0132**	2	0.0040	-	**0.0093**
Sulphide	mg/L	0.002	**0.014**	**0.006**	4	<0.003	**0.005**	**0.009**
Total iron	mg/L	0.3	**0.901**	0.148	4	0.139	0.289	**0.422**
Dissolved iron	mg/L	0.3	**0.637**	0.056	2	0.137	-	0.162

[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 6.2-5 Concentrations of water quality measurement endpoints, Gregoire Lake (GRL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2002-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.84	8.11	4	7.80	7.85	8.00
Total Suspended Solids	mg/L	-	5	<3	4	<3	3	14
Conductivity	µS/cm	-	120	143	4	122	140	155
Dissolved organic carbon	mg/L	-	12.5	10.1	4	9.4	10.5	14.0
Total Dissolved Solids	mg/L	-	97	90	4	80	86	120
Total Alkalinity	mg/L	-	50	64	4	50	63	69
Nutrients								
Total phosphorus	mg/L	0.05	0.0283	0.0290	3	0.0160	0.0170	0.0240
Total dissolved phosphorus	mg/L	0.05	0.0025	0.0100	3	0.0070	0.0070	0.0074
Total nitrogen	mg/L	1.0	0.901	0.611	3	0.500	0.851	0.900
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	3	<0.071	<0.100	<0.100
Ions								
Sodium	mg/L	-	3.9	3.4	4	3.0	3.6	4.0
Calcium	mg/L	-	14.4	17.3	4	15.8	18.9	20.0
Magnesium	mg/L	-	3.99	4.74	4	4.30	4.99	5.50
Chloride	mg/L	230, 860	3.09	1.99	4	1.00	1.91	3.00
Sulphate	mg/L	50, 100	4.8	5.1	4	5.6	7.0	8.2
Organic compounds								
Naphthenic acids	mg/L	-	0.23	0.26	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.28	2.16	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00065	0.00100	3	0.00057	0.00082	<0.0010
Total aluminum	mg/L	0.1	0.0451	0.0315	3	0.0223	0.0400	0.0600
Dissolved aluminum	mg/L	0.1	0.0105	0.0008	2	0.0014	-	0.0021
Total boron	mg/L	1.2	0.0151	0.0203	3	0.0169	0.0198	0.0200
Total molybdenum	mg/L	0.073	0.00045	0.00064	3	0.00042	0.00060	0.00060
Total mercury (ultra-trace)	ng/L	5, 13	<1.2	1.0	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Sulphide	mg/L	0.002	**0.0033**	<0.0020	3	<0.0020	<0.0030	**0.0030**
Total iron	mg/L	0.3	**0.421**	0.160	3	0.094	0.132	**0.369**

[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 6.2-6 Concentrations of water quality measurement endpoints, Kiskatinaw Lake (KIL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.04	8.17	4	7.80	7.99	8.00
Total Suspended Solids	mg/L	-	3	<3	4	<3	<3	5
Conductivity	µS/cm	-	146	170	4	147	175	201
Dissolved organic carbon	mg/L	-	28.7	20.7	4	17.0	20.6	24.0
Total Dissolved Solids	mg/L	-	134	128	4	100	142	160
Total Alkalinity	mg/L	-	101	87	4	73	88	100
Nutrients								
Total phosphorus	mg/L	0.05	0.0187	0.0310	4	0.0170	0.0254	0.0470
Total dissolved phosphorus	mg/L	0.05	0.0091	0.0139	4	0.0090	0.0158	0.0190
Total nitrogen	mg/L	1.0	**1.071**	0.971	4	0.900	**1.400**	**1.761**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.071	<0.100	<0.200
Ions								
Sodium	mg/L	-	4.6	5.3	4	5.7	6.0	7.0
Calcium	mg/L	-	18.7	20.6	4	19.0	22.0	26.3
Magnesium	mg/L	-	6.25	6.95	4	5.90	7.04	7.90
Chloride	mg/L	230, 860	<0.5	<0.5	4	<0.5	<1.0	1.0
Sulphate	mg/L	50, 100	1.55	1.98	4	1.50	2.35	4.10
Organic compounds								
Naphthenic acids	mg/L	-	0.27	0.42	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.43	2.02	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00039	0.00051	4	0.00037	0.00070	<0.0010
Total aluminum	mg/L	0.1	0.027	0.051	4	0.018	0.049	**2.050**
Dissolved aluminum	mg/L	0.1	0.0084	0.0019	2	0.0032	0.0049	0.0065
Total boron	mg/L	1.2	0.0323	0.0432	4	0.0402	0.0456	0.0570
Total molybdenum	mg/L	0.073	0.00008	0.00011	4	0.00008	0.00009	0.00060
Total mercury (ultra-trace)	ng/L	5, 13	1.5	<1.0	2	<1.2	<1.2	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Sulphide	mg/L	0.002	**0.0066**	0.0020	4	**0.0030**	**0.0049**	**0.0050**
Total iron	mg/L	0.3	**0.640**	0.195	4	0.130	0.258	**0.303**
Dissolved iron	mg/L	0.3	**0.416**	0.062	2	0.143	0.170	0.196

[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 6.2-7 Concentrations of water quality measurement endpoints, Rat Lake (RAL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.13	8.17	4	7.80	7.98	8.00
Total Suspended Solids	mg/L	-	4	<3	4	3	4	6
Conductivity	µS/cm	-	196	213	4	167	191	209
Dissolved organic carbon	mg/L	-	26	19	4	16	19	24
Total Dissolved Solids	mg/L	-	152	149	4	130	131	140
Total Alkalinity	mg/L	-	95	104	4	79	91	104
Nutrients								
Total phosphorus	mg/L	0.05	0.0199	0.0374	4	0.0250	0.0360	**0.0519**
Total dissolved phosphorus	mg/L	0.05	0.0070	0.0105	4	0.0090	0.0130	0.0141
Total nitrogen	mg/L	1.0	1.421	1.411	4	1.100	1.486	2.000
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.071	<0.100	<0.100
Ions								
Sodium	mg/L	-	7.1	6.9	4	6.0	6.5	7.4
Calcium	mg/L	-	23.2	24.6	4	21.0	23.8	27.6
Magnesium	mg/L	-	7.08	7.37	4	6.10	6.81	8.10
Chloride	mg/L	230, 860	2.2	2.7	4	<1.0	1.5	3.5
Sulphate	mg/L	50, 100	3.53	2.26	4	3.00	4.06	6.10
Organic compounds								
Naphthenic acids	mg/L	-	0.31	0.44	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.35	2.22	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00036	0.00039	4	0.00032	0.00069	<0.0010
Total aluminum	mg/L	0.1	0.0308	0.0066	4	0.0171	0.0396	**0.1400**
Dissolved aluminum	mg/L	0.1	0.0124	0.0005	2	0.0023	-	0.0033
Total boron	mg/L	1.2	0.0240	0.0296	4	0.0252	0.0275	0.0400
Total molybdenum	mg/L	0.073	0.00014	0.00007	4	0.00010	0.00011	0.00030
Total mercury (ultra-trace)	ng/L	5, 13	1.8	1.7	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Total phenols	mg/L	0.004	**0.0060**	**0.0080**	2	**0.0085**	-	**0.0150**
Sulphide	mg/L	0.002	**0.0070**	**0.0047**	4	**0.0027**	**0.0035**	**0.0050**
Total Kjeldahl nitrogen	mg/L	1.0	**1.35**	**1.34**	4	**1.00**	**1.40**	**1.90**
Total iron	mg/L	0.3	**1.010**	0.123	4	0.058	0.203	**0.665**
Dissolved iron	mg/L	0.3	**0.641**	0.040	2	0.058	-	0.294

[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.

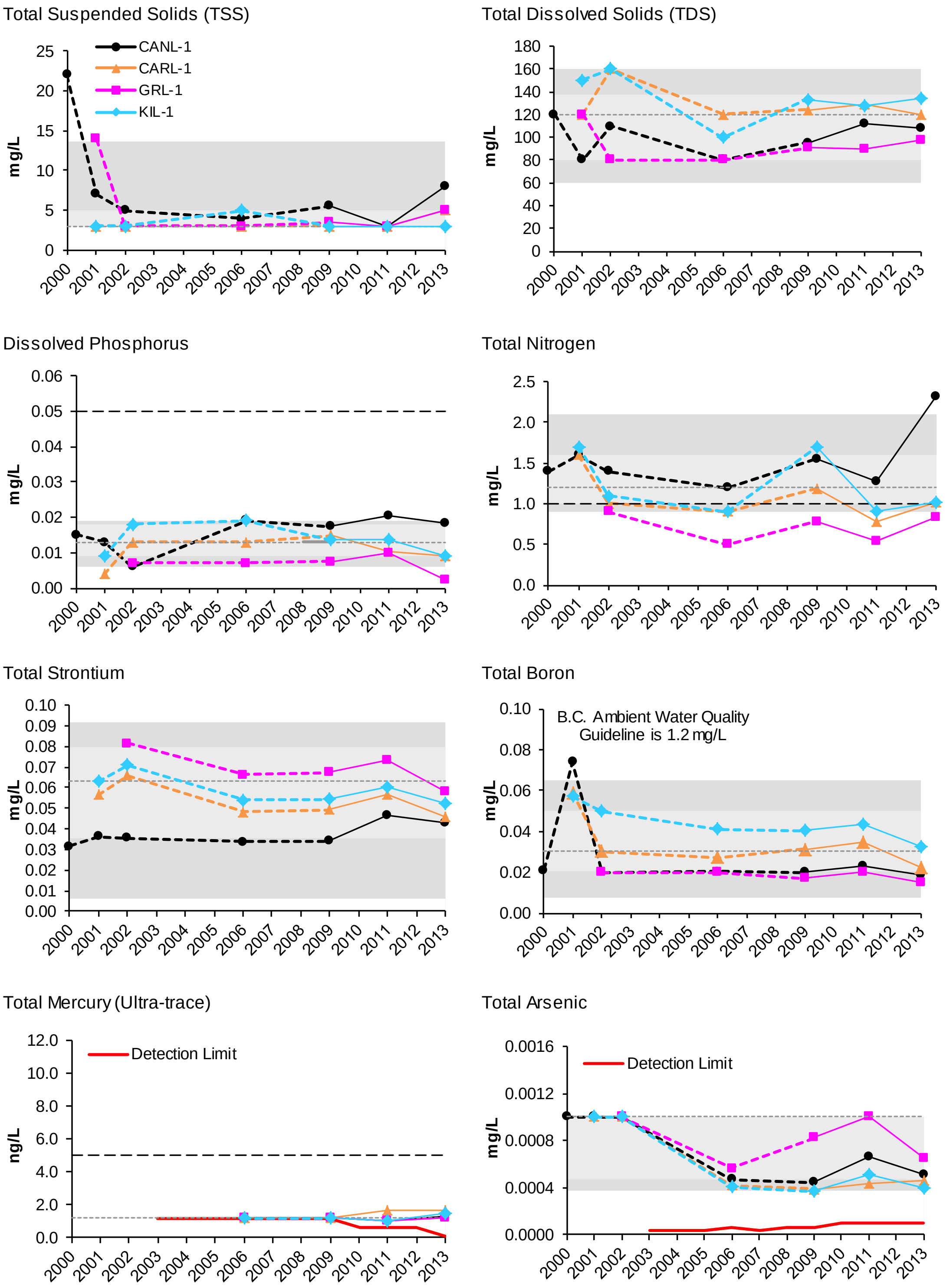
Table 6.2-8 Concentrations of water quality measurement endpoints, Unnamed Lake 1 (UNL-1) in spring 2013, compared to historical values.

Analyte	Units	Guideline[a]	May 2013	May 2011	Spring Historical (2000-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	**5.48**	**6.06**	4	**5.20**	**5.86**	**6.20**
Total Suspended Solids	mg/L	-	5	<3	4	<3	<3	3
Conductivity	µS/cm	-	25.2	22.3	4	22.9	25.2	29.0
Dissolved organic carbon	mg/L	-	38.0	25.7	4	19.0	23.2	28.0
Total Dissolved Solids	mg/L	-	84	63	4	50	60	66
Total Alkalinity	mg/L	-	<5	<5	5	<5	<5	8
Nutrients								
Total phosphorus	mg/L	0.05	**0.1920**	**0.2040**	4	0.0250	0.0465	**0.1270**
Total dissolved phosphorus	mg/L	0.05	0.0260	**0.1900**	4	0.0160	0.0365	**0.1160**
Total nitrogen	mg/L	1.0	0.991	**1.141**	4	0.900	**1.350**	**1.751**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.071	<0.100	0.200
Ions								
Sodium	mg/L	-	<1	<1	4	<1	<1	<1
Calcium	mg/L	-	2.3	2.3	4	2.3	2.4	3.0
Magnesium	mg/L	-	0.57	0.76	4	0.70	0.76	1.00
Chloride	mg/L	230, 860	<0.5	<0.5	4	<0.5	<1.0	3.0
Sulphate	mg/L	50, 100	<0.5	0.7	4	0.7	1.6	3.1
Organic compounds								
Naphthenic acids	mg/L	-	0.46	0.45	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.69	3.35	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.0003	0.0004	4	0.0003	0.0006	<0.0010
Total aluminum	mg/L	0.1	0.0924	0.0737	4	0.0810	0.0913	**0.1100**
Dissolved aluminum	mg/L	0.1	0.069	0.059	2	0.069	-	0.071
Total boron	mg/L	1.2	0.0070	0.0105	4	<0.002	0.0078	0.0400
Total molybdenum	mg/L	0.073	0.00004	0.00006	4	0.00003	0.00008	<0.00010
Total mercury (ultra-trace)	ng/L	5, 13	3.0	4.5	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in spring 2013								
Total phenols	mg/L	0.004	**0.0113**	**0.0118**	2	**0.0090**	-	**0.0104**
Sulphide	mg/L	0.002	**0.0129**	**0.0065**	4	**<0.0030**	**0.0043**	**0.0090**
Total Kjeldahl nitrogen	mg/L	1.0	0.92	**1.07**	4	0.80	**1.20**	**1.68**
Total iron	mg/L	0.3	**0.761**	**0.341**	4	0.105	0.273	**0.503**
Dissolved Iron	mg/L	0.3	**0.639**	0.275	2	**0.341**	-	**0.471**

[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 6.2-2 Selected water quality measurement endpoints in CANL-1, CARL-1, FRL-1, and RAL-1 (spring data) relative to spring *baseline* concentrations.



Total Suspended Solids (TSS)

Total Dissolved Solids (TDS)

Dissolved Phosphorus

Total Nitrogen

Total Strontium

Total Boron

Total Mercury (Ultra-trace)

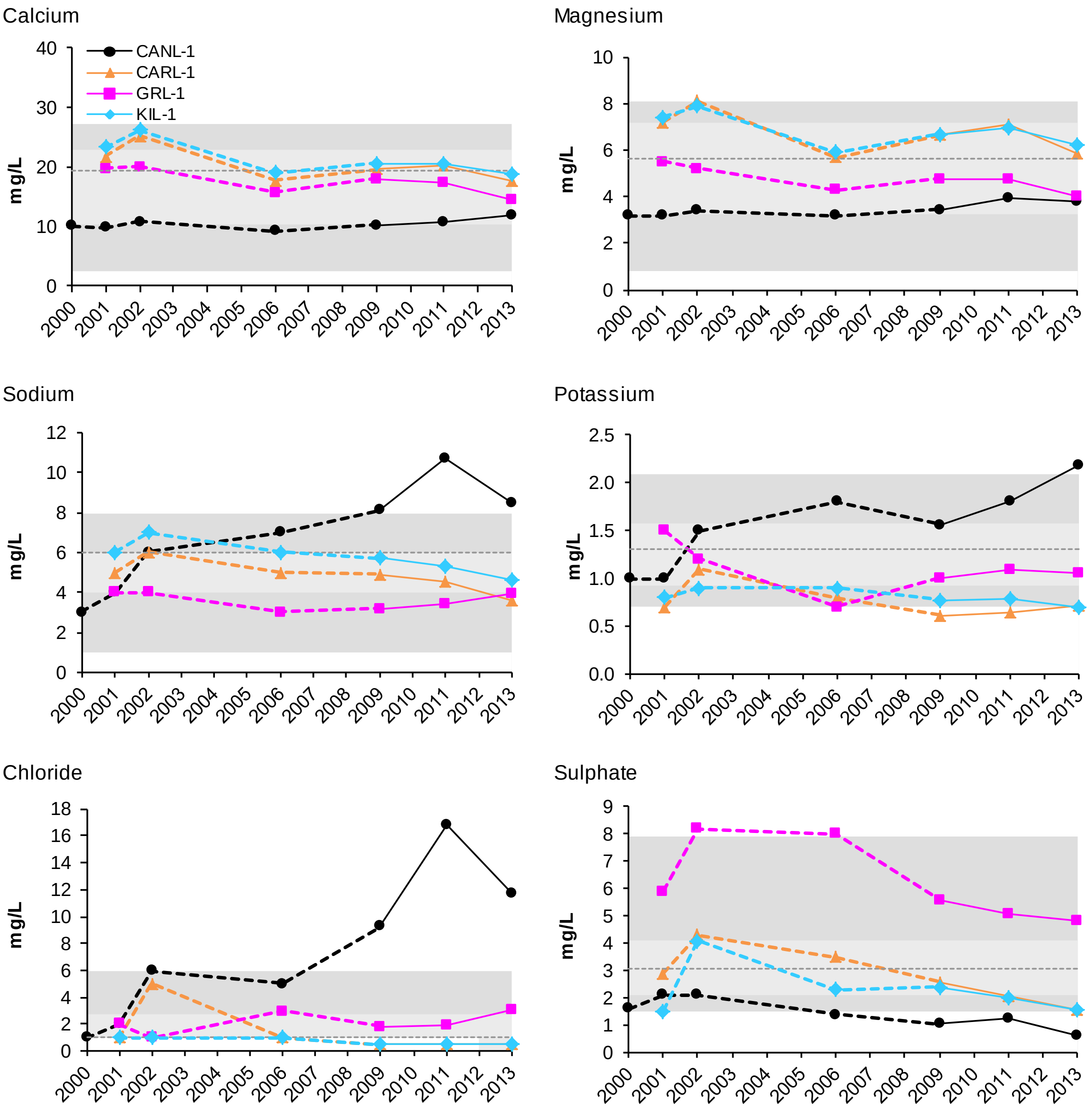
Total Arsenic

Non-detectable values are shown at the detection limit.

– – – Water quality guideline. See Table 3.2-5 (table with all WQ guidelines).

○-----○ Sampled as a baseline site ●——● Sampled as a test site

Figure 6.2-2 (Cont'd.)



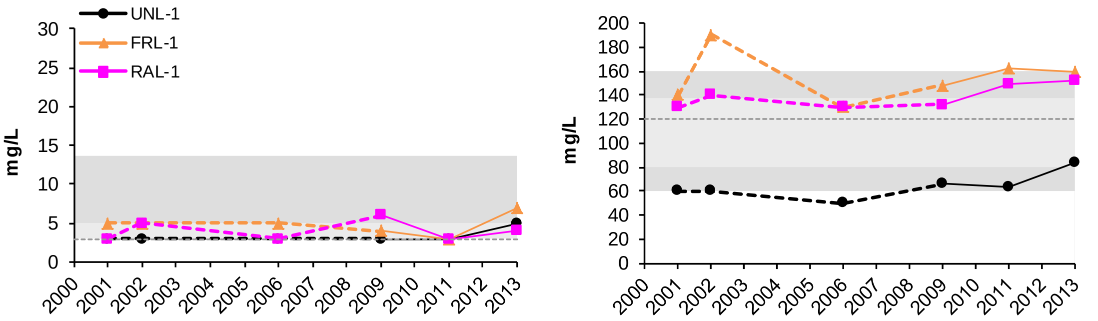
Non-detectable values are shown at the detection limit.

- - - Water quality guideline. See Table 3.2-5 (table with all WQ guidelines).

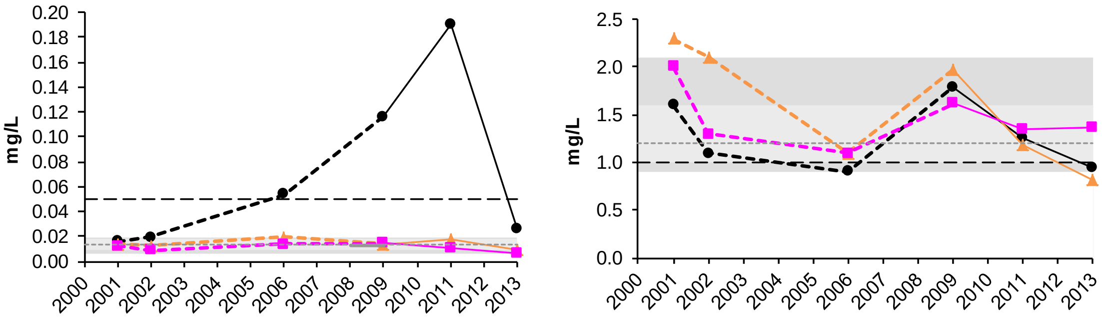
○- - - -○ Sampled as a baseline site ●——● Sampled as a test site

Figure 6.2-3 Selected water quality measurement endpoints in UNL-1, GRL-1, and KIL-1 (spring data) relative to spring *baseline* concentrations.

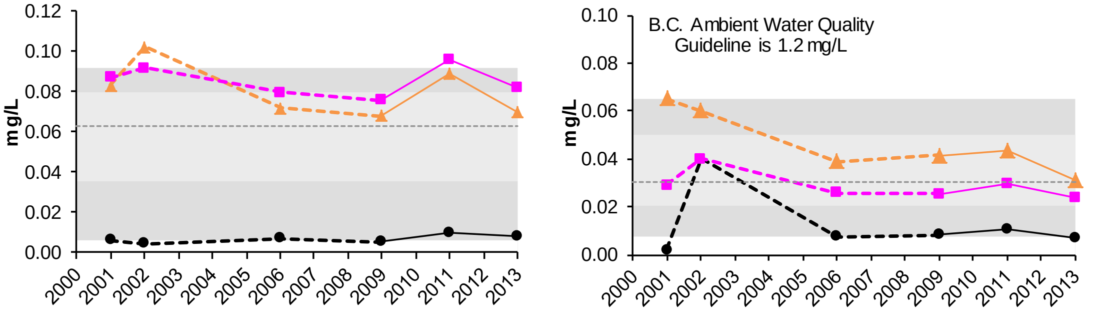
Total Suspended Solids (TSS) Total Dissolved Solids (TDS)



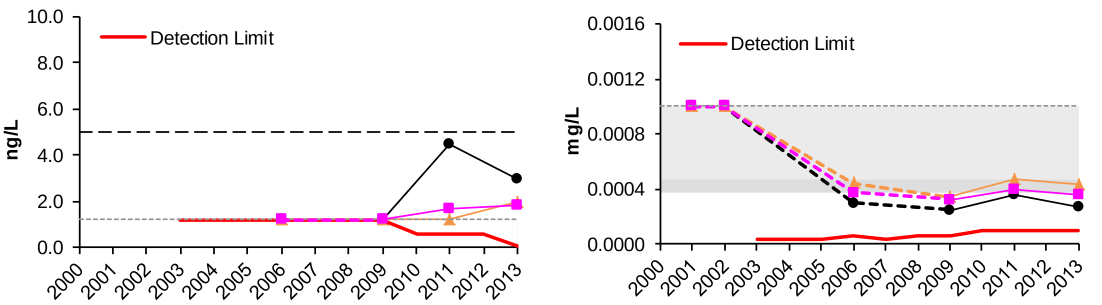
Dissolved Phosphorus Total Nitrogen



Total Strontium Total Boron



Total Mercury (Ultra-trace) Total Arsenic

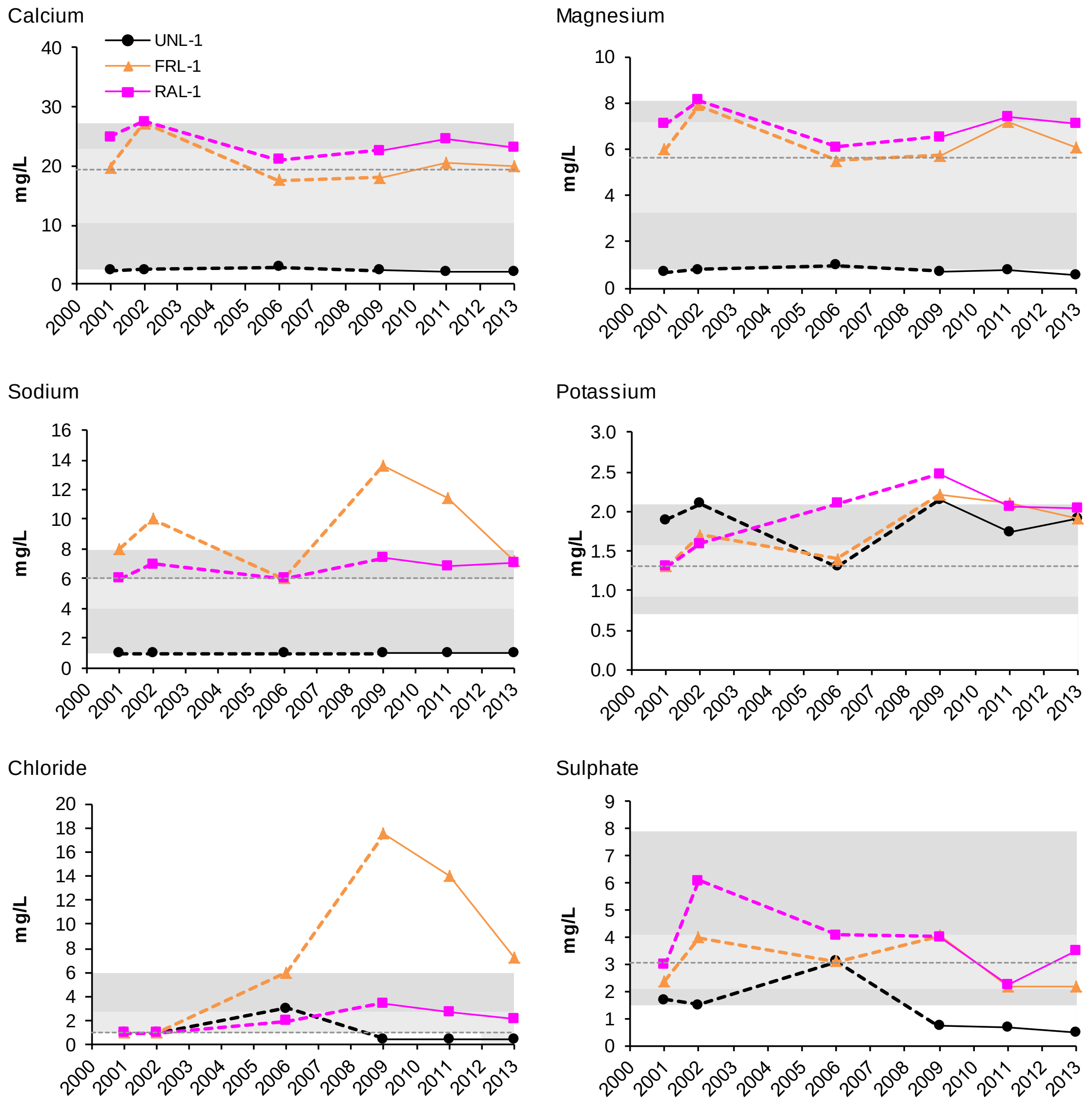


Non-detectable values are shown at the detection limit.

— — Water quality guideline. See Table 3.2-5 (table with all WQ guidelines).

○- - - -○ Sampled as a baseline site ●——● Sampled as a test site

Figure 6.2-3 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – Water quality guideline. See Table 3.2-5 (table with all WQ guidelines).

○----○ Sampled as a baseline site ●——● Sampled as a test site

Table 6.2-9 Concentrations of water quality measurement endpoints, Canoe Lake (CANL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2000-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.80	7.63	5	6.80	7.32	7.53
Total Suspended Solids	mg/L	-	6	7	5	1	4	19
Conductivity	µS/cm	-	139	143	5	83	94	140
Dissolved organic carbon	mg/L	-	24.4	18.4	5	20.0	22.0	24.0
Total Dissolved Solids	mg/L	-	109	101	5	46	109	130
Total Alkalinity	mg/L	-	49.3	39.9	5	36.0	41.0	43.0
Nutrients								
Total phosphorus	mg/L	0.05	**0.0575**	0.0391	5	0.0350	**0.0577**	**0.1400**
Total dissolved phosphorus	mg/L	0.05	0.0258	0.0192	4	0.0130	0.0217	**0.0650**
Total nitrogen	mg/L	1.0	**2.151**	**1.201**	5	**1.101**	**1.221**	**1.400**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	5	0.061	<0.100	<0.100
Ions								
Sodium	mg/L	-	9.4	10.7	5	3.0	5.0	10.8
Calcium	mg/L	-	12.4	10.6	5	9.2	10.2	11.7
Magnesium	mg/L	-	4.08	3.79	5	3.14	3.20	4.09
Chloride	mg/L	230, 860	12.3	16.1	5	1.0	1.8	15.6
Sulphate	mg/L	50, 100	0.53	1.26	5	0.80	2.18	2.50
Organic compounds								
Naphthenic acids	mg/L	-	0.60	0.43	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.60	0.59	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00056	0.00050	5	0.00023	0.00058	<0.0100
Total aluminum	mg/L	0.1	0.0272	0.0303	5	0.0140	0.0277	**0.1100**
Dissolved aluminum	mg/L	0.1	0.0056	0.0122	2	0.0034	0.0049	0.0063
Total boron	mg/L	1.2	0.028	0.026	5	0.015	0.018	0.022
Total molybdenum	mg/L	0.073	<0.00010	<0.00010	5	0.00002	0.00005	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	1.2	**10.9**	2	<1.2	-	1.7
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Total phenols	mg/L	0.004	**0.0051**	**0.0073**	4	<0.0010	0.0025	**0.0080**
Sulphide	mg/L	0.002	**0.0058**	**0.0053**	4	**0.0050**	**0.0061**	**0.0170**
Total Kjeldahl nitrogen	mg/L	1.0	**2.08**	**1.13**	5	**1.04**	**1.15**	**1.30**
Total iron	mg/L	0.3	**0.386**	0.085	4	0.165	**0.322**	**0.383**

[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 6.2-10 Concentrations of water quality measurement endpoints, Caribou Lake (CARL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.00	8.02	4	7.20	7.75	8.00
Total Suspended Solids	mg/L	-	<3	8	4	2	3	5
Conductivity	µS/cm	-	139	162	4	157	168	182
Dissolved organic carbon	mg/L	-	28.7	20.7	4	18.0	23.4	26.0
Total Dissolved Solids	mg/L	-	128	126	4	97	130	180
Total Alkalinity	mg/L	-	72.7	81.7	4	74.0	77.8	94.0
Nutrients								
Total phosphorus	mg/L	0.05	0.0379	0.0273	4	0.0260	0.0357	0.1400
Total dissolved phosphorus	mg/L	0.05	0.0163	0.0079	3	0.0090	0.0131	0.0170
Total nitrogen	mg/L	1.0	**1.141**	**1.001**	4	0.616	**1.066**	**1.200**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.006	0.086	0.200
Ions								
Sodium	mg/L	-	3.6	4.4	4	4.3	5.6	6.0
Calcium	mg/L	-	18.9	19.3	4	19.8	21.8	23.1
Magnesium	mg/L	-	6.50	6.55	4	6.37	7.20	7.56
Chloride	mg/L	230, 860	<0.5	<0.5	4	<0.5	1.1	2.0
Sulphate	mg/L	50, 100	1.9	1.8	4	1.3	2.6	16.1
Organic compounds								
Naphthenic acids	mg/L	-	0.31	0.30	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.57	0.57	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00069	0.00042	4	0.00028	0.00059	<0.0100
Total aluminum	mg/L	0.1	0.0412	0.0356	4	0.0193	0.0407	**0.1160**
Dissolved aluminum	mg/L	0.1	0.0086	0.0062	2	0.0026	0.0053	0.0080
Total boron	mg/L	1.2	0.0342	0.0383	4	0.0113	0.0316	0.0332
Total molybdenum	mg/L	0.073	0.00010	0.00009	4	0.00002	0.00008	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	1.7	**9.3**	2	<1.2	-	1.4
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Sulphide	mg/L	0.002	**0.0044**	**0.0048**	3	<0.0020	**0.0050**	**0.0070**
Total Kjeldahl nitrogen	mg/L	1.0	**1.07**	0.93	4	0.61	0.93	**1.10**
Total iron	mg/L	0.3	**0.349**	0.144	3	0.240	0.264	**0.407**

[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 6.2-11 Concentrations of water quality measurement endpoints, Frog Lake (FRL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.19	8.03	4	7.52	7.70	7.97
Total Suspended Solids	mg/L	-	<3	8	4	3	4	6
Conductivity	µS/cm	-	222	228	4	178	181	196
Dissolved organic carbon	mg/L	-	33.6	26.9	4	28.0	32.1	39.0
Total Dissolved Solids	mg/L	-	179	212	4	100	175	200
Total Alkalinity	mg/L	-	102	92	4	78	86	95
Nutrients								
Total phosphorus	mg/L	0.05	0.0458	0.0546	4	0.0350	0.0471	**0.1600**
Total dissolved phosphorus	mg/L	0.05	0.031	0.010	3	0.0107	0.015	0.015
Total nitrogen	mg/L	1.0	**1.411**	**1.701**	4	**1.300**	**1.459**	**1.600**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.006	<0.086	<0.100
Ions								
Sodium	mg/L	-	9.9	12.9	4	7.5	8.5	11.4
Calcium	mg/L	-	26.1	24.2	4	22.4	24.3	24.5
Magnesium	mg/L	-	8.75	7.91	4	6.58	7.34	7.60
Chloride	mg/L	230, 860	9	13	4	<1	3	12
Sulphate	mg/L	50, 100	1.94	2.02	4	0.67	2.38	3.40
Organic compounds								
Naphthenic acids	mg/L	-	0.28	0.02	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.31	0.37	0	-	-	-
BTEX								
Fraction 1 (C6-C10)	mg/L	30	<0.1	-	0	-	-	-
Fraction 2 (C10-C16)	mg/L	150	<0.25	-	0	-	-	-
Fraction 3 (C16-C34)	mg/L	300	<0.25	-	0	-	-	-
Fraction 4 (C34-C50)	mg/L	2800	<0.25	-	0	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	-	1.53	-	0	-	-	-
Retene	ng/L	-	0.42	-	0	-	-	-
Total dibenzothiophenes	ng/L	-	2.01	-	0	-	-	-
Total PAHs	ng/L	-	35.36	-	0	-	-	-
Total Parent PAHs	ng/L	-	3.92	-	0	-	-	-
Total Alkylated PAHs	ng/L	-	31.44	-	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00067	0.00045	4	0.00043	0.00045	<0.010
Total aluminum	mg/L	0.1	0.0181	0.0275	4	0.0162	0.0293	0.0430
Dissolved aluminum	mg/L	0.1	0.0175	0.0125	2	0.0026	0.0031	0.0037
Total boron	mg/L	1.2	0.0464	0.0458	4	0.0375	0.0476	0.0696
Total molybdenum	mg/L	0.073	0.00007	<0.00010	4	0.00005	0.00007	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	1.5	**6.6**	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Total phenols	mg/L	0.004	**0.0072**	**0.0087**	3	<0.0010	**0.0098**	**0.0100**
Sulphide	mg/L	0.002	**0.013**	**0.008**	3	**0.007**	**0.010**	**0.011**
Total Kjeldahl nitrogen	mg/L	1.0	**1.34**	**1.63**	4	**1.20**	**1.41**	**1.52**
Total iron	mg/L	0.3	**0.709**	0.142	3	0.238	0.268	**0.426**
Dissolved iron	mg/L	0.3	**0.545**	0.131	3	0.122	0.133	0.137

[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 6.2-12 Concentrations of water quality measurement endpoints, Gregoire Lake (GRL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2002-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.79	7.98	3	7.60	7.60	7.92
Total Suspended Solids	mg/L	-	<3	10	3	<3	6	7
Conductivity	µS/cm	-	116	139	3	127	136	146
Dissolved organic carbon	mg/L	-	14	11	3	11	11	11
Total Dissolved Solids	mg/L	-	81	92	3	96	97	120
Total Alkalinity	mg/L	-	48	63	3	53	59	64
Nutrients								
Total phosphorus	mg/L	0.05	0.0231	0.0460	3	0.0210	0.0250	0.0275
Total dissolved phosphorus	mg/L	0.05	0.0139	0.0109	3	0.0060	0.0064	0.0070
Total nitrogen	mg/L	1.0	0.611	0.891	3	0.600	0.771	0.900
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	3	<0.071	<0.100	<0.100
Ions								
Sodium	mg/L	-	3.1	3.2	3	3.2	4.0	4.0
Calcium	mg/L	-	14.4	17.9	3	16.9	17.3	18.3
Magnesium	mg/L	-	3.93	4.83	3	4.44	4.50	4.90
Chloride	mg/L	230, 860	2.03	1.93	3	1.00	1.70	3.00
Sulphate	mg/L	50, 100	8.2	4.5	3	5.3	6.4	6.7
Organic compounds								
Naphthenic acids	mg/L	-	0.30	0.00	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.31	0.2	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00085	0.00147	3	0.00073	0.00105	0.00110
Total aluminum	mg/L	0.1	0.0488	0.0634	3	0.0210	0.0335	0.0548
Dissolved aluminum	mg/L	0.1	0.0047	0.0051	2	0.0017	0.0023	0.0028
Total boron	mg/L	1.2	0.0193	0.0195	3	0.0174	0.0186	0.0197
Total molybdenum	mg/L	0.073	0.00061	0.00077	3	0.00056	0.00070	0.00074
Total mercury (ultra-trace)	ng/L	5, 13	0.67	**7.6**	2	<1.2	-	1.2
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Sulphide	mg/L	0.002	**0.005**	<0.002	3	<0.002	<0.003	<0.003

[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 6.2-13 Concentrations of water quality measurement endpoints, Kiskatinaw Lake (KIL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	7.96	8.08	4	7.70	7.79	8.00
Total Suspended Solids	mg/L	-	<3	11	4	1	3	4
Conductivity	µS/cm	-	133	164	4	158	174	185
Dissolved organic carbon	mg/L	-	27.1	22.2	4	20.0	24.5	40.0
Total Dissolved Solids	mg/L	-	124	139	4	102	143	160
Total Alkalinity	mg/L	-	68.8	83.1	4	79.7	86.0	99.0
Nutrients								
Total phosphorus	mg/L	0.05	0.0366	0.0412	4	0.0242	0.0270	**0.1500**
Total dissolved phosphorus	mg/L	0.05	0.0232	0.0087	3	0.0079	0.0080	0.0110
Total nitrogen	mg/L	1.0	0.901	**1.161**	4	0.776	**1.051**	**1.100**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.006	<0.086	<0.100
Ions								
Sodium	mg/L	-	4.4	5.7	4	5.5	6.6	7.0
Calcium	mg/L	-	18.1	21.4	4	20.9	22.0	24.1
Magnesium	mg/L	-	6.02	7.09	4	6.46	6.75	7.31
Chloride	mg/L	230, 860	<0.5	<0.5	4	<0.5	1.1	2.0
Sulphate	mg/L	50, 100	2.05	1.52	4	1.10	2.44	3.80
Organic compounds								
Naphthenic acids	mg/L	-	0.25	0.27	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.53	0.49	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00050	0.00051	4	0.00002	0.00049	<0.0100
Total aluminum	mg/L	0.1	0.0343	0.0304	4	0.0020	0.0256	0.0470
Dissolved aluminum	mg/L	0.1	0.0061	0.0061	2	0.0022	0.0026	0.0029
Total boron	mg/L	1.2	0.0466	0.0499	4	<0.00008	0.0423	0.0480
Total molybdenum	mg/L	0.073	0.000078	0.000082	4	<0.000020	0.000088	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	1.5	**11.5**	2	<1.2	-	<1.2
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Sulphide	mg/L	0.002	**0.0024**	**0.0086**	3	**0.0040**	**0.0049**	**0.0060**
Total iron	mg/L	0.3	**0.411**	0.227	3	<0.003	0.197	0.253

[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 6.2-14 Concentrations of water quality measurement endpoints, Rat Lake (RAL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.16	8.09	4	7.69	7.80	8.15
Total Suspended Solids	mg/L	-	<3	7	4	<1	4	6
Conductivity	µS/cm	-	211	225	4	204	207	209
Dissolved organic carbon	mg/L	-	28	19	4	18	20	26
Total Dissolved Solids	mg/L	-	168	147	4	113	163.5	180
Total Alkalinity	mg/L	-	108	110	4	100	102	109
Nutrients								
Total phosphorus	mg/L	0.05	0.0331	0.0349	4	0.0349	0.0435	**0.1100**
Total dissolved phosphorus	mg/L	0.05	0.0176	0.0087	3	0.0090	0.0120	0.0127
Total nitrogen	mg/L	1.0	**1.111**	**1.091**	4	0.826	**1.246**	**1.400**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.006	<0.086	<0.100
Ions								
Sodium	mg/L	-	7.6	8.3	4	6.5	7.8	8.0
Calcium	mg/L	-	26.2	28.3	4	26.6	26.7	27.0
Magnesium	mg/L	-	8.00	8.69	4	7.64	7.92	8.30
Chloride	mg/L	230, 860	1.4	2.5	4	0.9	1.5	2.6
Sulphate	mg/L	50, 100	3.39	1.90	4	2.17	3.55	4.60
Organic compounds								
Naphthenic acids	mg/L	-	0.44	0.41	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.57	0.64	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00045	0.00012	4	0.00039	0.00040	<0.0100
Total aluminum	mg/L	0.1	0.0208	0.0060	4	0.0157	0.0161	0.0330
Dissolved aluminum	mg/L	0.1	0.0066	0.0059	2	<0.0010	0.0010	0.0011
Total boron	mg/L	1.2	0.0351	0.0303	4	0.0230	0.0321	0.0341
Total molybdenum	mg/L	0.073	0.00009	0.00005	4	0.00007	0.00008	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	1.3	**7.9**	2	<1.2	-	1.4
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Total phenols	mg/L	0.004	**0.0049**	**0.0090**	3	<0.001	0.0038	**0.0070**
Sulphide	mg/L	0.002	**0.0078**	**0.0039**	3	**0.0050**	**0.0069**	**0.0080**
Total Kjeldahl nitrogen	mg/L	1.0	**1.04**	**1.02**	4	0.82	**1.16**	**1.30**

[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.

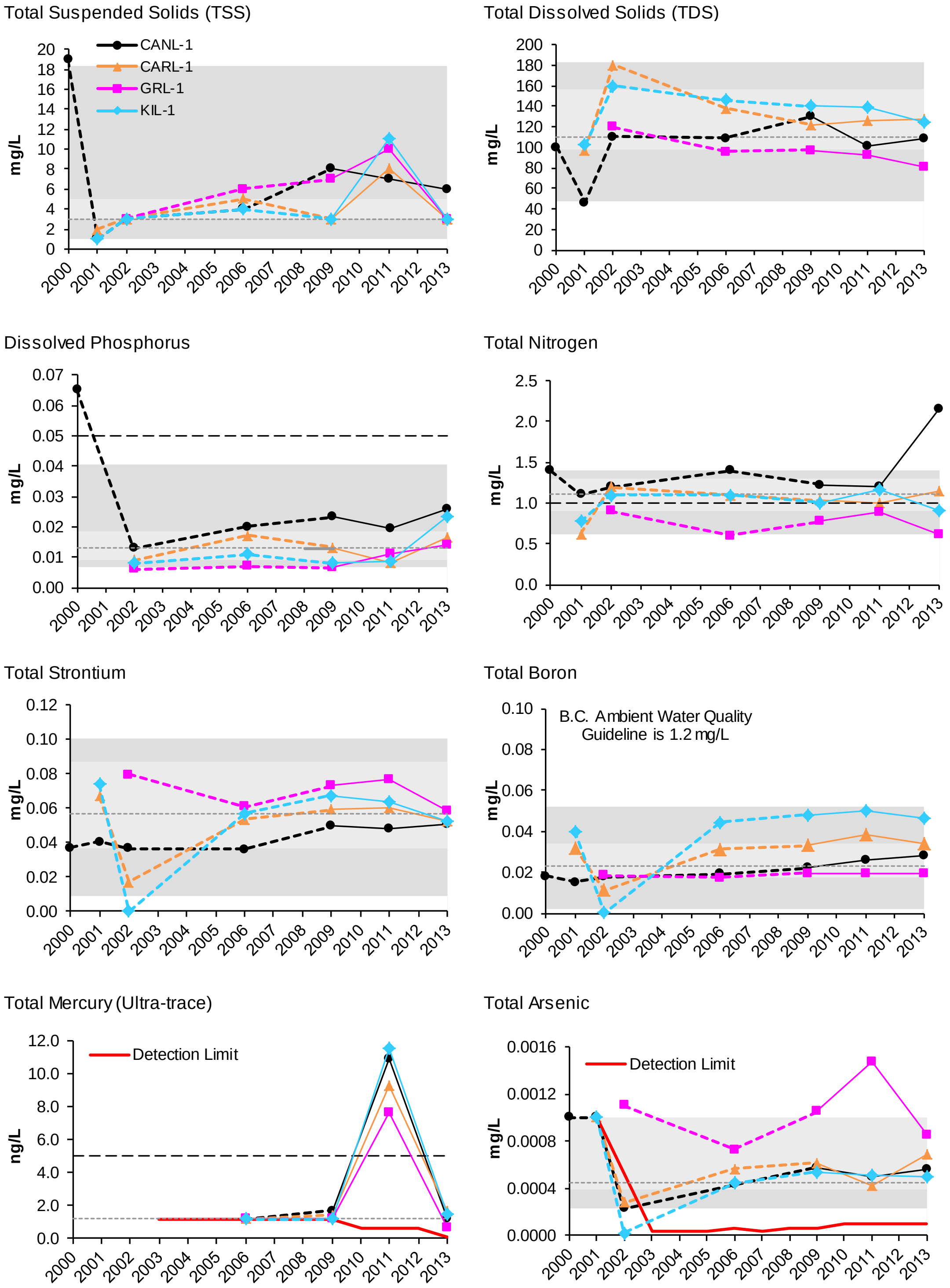
Table 6.2-15 Concentrations of water quality measurement endpoints, Unnamed Lake 1 (UNL-1) in fall 2013, compared to historical values.

Analyte	Units	Guideline[a]	September 2013	September 2011	Fall Historical (2001-2009)			
			Value	Value	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	**6.43**	7.60	5	**5.30**	**5.61**	**6.40**
Total Suspended Solids	mg/L	-	<3	10	5	<1	5	22
Conductivity	µS/cm	-	32.2	83.3	5	22.3	24.3	39.2
Dissolved organic carbon	mg/L	-	30.4	21.9	5	21.0	22.0	29.4
Total Dissolved Solids	mg/L	-	76	168	5	13	74	100
Total Alkalinity	mg/L	-	6	39	5	<5	8	15
Nutrients								
Total phosphorus	mg/L	0.05	**0.2570**	0.0368	4	0.0320	0.0800	**0.1630**
Total dissolved phosphorus	mg/L	0.05	**0.218**	0.008	3	0.023	0.030	**0.140**
Total nitrogen	mg/L	1.0	**2.581**	**1.451**	4	0.656	**1.091**	**1.300**
Nitrate+Nitrite	mg/L	-	<0.071	<0.071	4	<0.006	<0.086	<0.100
Ions								
Sodium	mg/L	-	<1.0	1.7	5	0.6	<1.0	<1.0
Calcium	mg/L	-	2.7	10.9	5	2.4	3.0	3.3
Magnesium	mg/L	-	0.53	2.76	5	0.72	0.80	0.90
Chloride	mg/L	230, 860	<0.5	<0.5	5	<0.5	<1.0	2.0
Sulphate	mg/L	50, 100	<0.5	<0.5	5	0.6	2.0	2.7
Organic compounds								
Naphthenic acids	mg/L	-	0.69	0.49	0	-	-	-
Oilsands Acid Extractable	mg/L	-	0.70	0.82	0	-	-	-
Selected metals								
Total arsenic	mg/L	0.005	0.00040	0.00002	4	0.00029	0.00038	<0.010
Total aluminum	mg/L	0.1	**0.124**	0.009	4	0.058	0.088	0.097
Dissolved aluminum	mg/L	0.1	**0.106**	0.007	2	0.070	-	0.075
Total boron	mg/L	1.2	0.0119	0.0161	4	<0.002	0.0093	0.0249
Total molybdenum	mg/L	0.073	0.00009	0.00001	4	0.00004	0.00008	<0.0010
Total mercury (ultra-trace)	ng/L	5, 13	2.1	**5.9**	2	<1.2	-	2.2
Variables that exceeded CCME/AESRD guidelines in fall 2013								
Total phenols	mg/L	0.004	**0.0078**	**0.0111**	3	<0.0010	**0.0100**	**0.0125**
Sulphide	mg/L	0.002	**0.0033**	**0.0029**	4	**0.0040**	**0.0056**	**0.0080**
Ammonia	mg/L	1.19	**1.41**	<0.05	3	<0.05	<0.05	<0.05
Total Kjeldahl nitrogen	mg/L	1.0	**2.51**	**1.38**	4	0.65	**1.01**	**1.20**
Total copper	mg/L	0.00037	**0.00771**	0.00013	4	0.00008	0.00030	<0.0010
Total iron	mg/L	0.3	**0.479**	**0.309**	3	0.162	**0.321**	**0.557**
Dissolved Iron	mg/L	0.3	**0.455**	**0.302**	3	0.088	0.284	**0.481**

[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 6.2-4 Selected water quality measurement endpoints in CANL-1, CARL-1, FRL-1, and RAL-1 (fall data) relative to fall *baseline* concentrations.



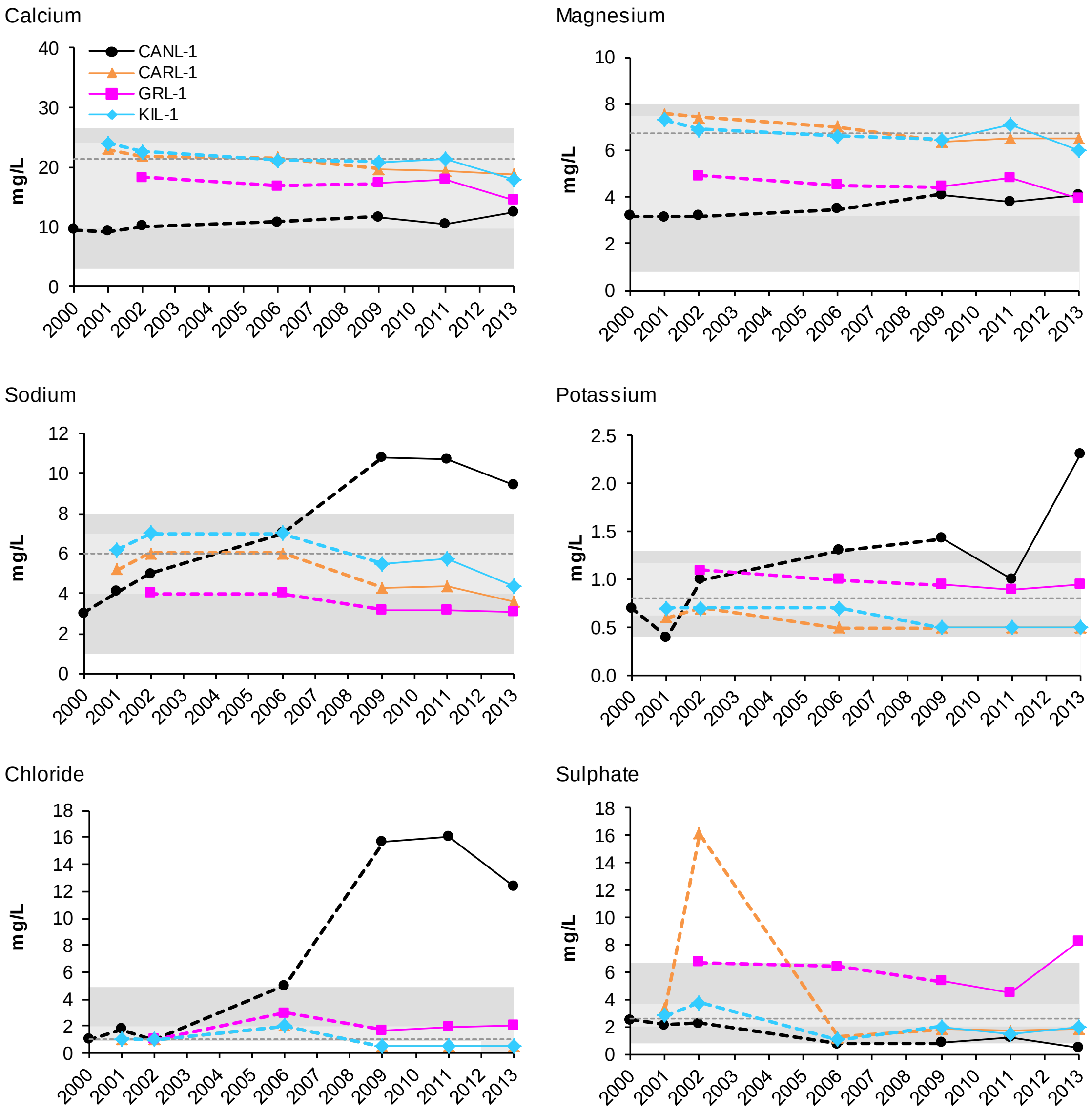
Non-detectable values are shown at the detection limit.

– – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

Regional *baseline* ranges reflect pooled results for all years during the *baseline* period.

Figure 6.2-4 (Cont'd.)



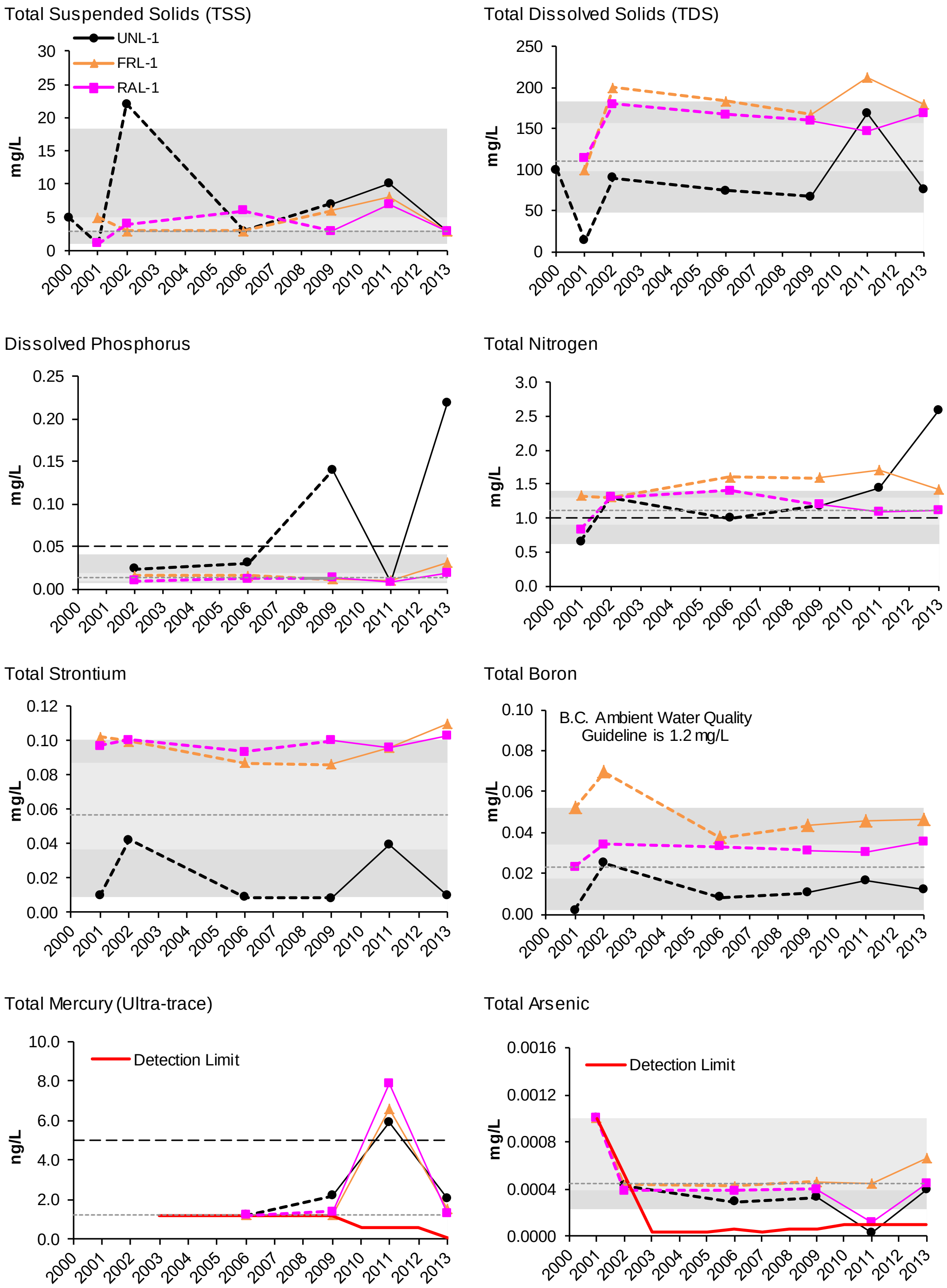
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* ranges reflect pooled results for all years during the *baseline* period.

Figure 6.2-5 Selected water quality measurement endpoints in UNL-1, GRL-1, and KIL-1 (fall data) relative to fall *baseline* concentrations.



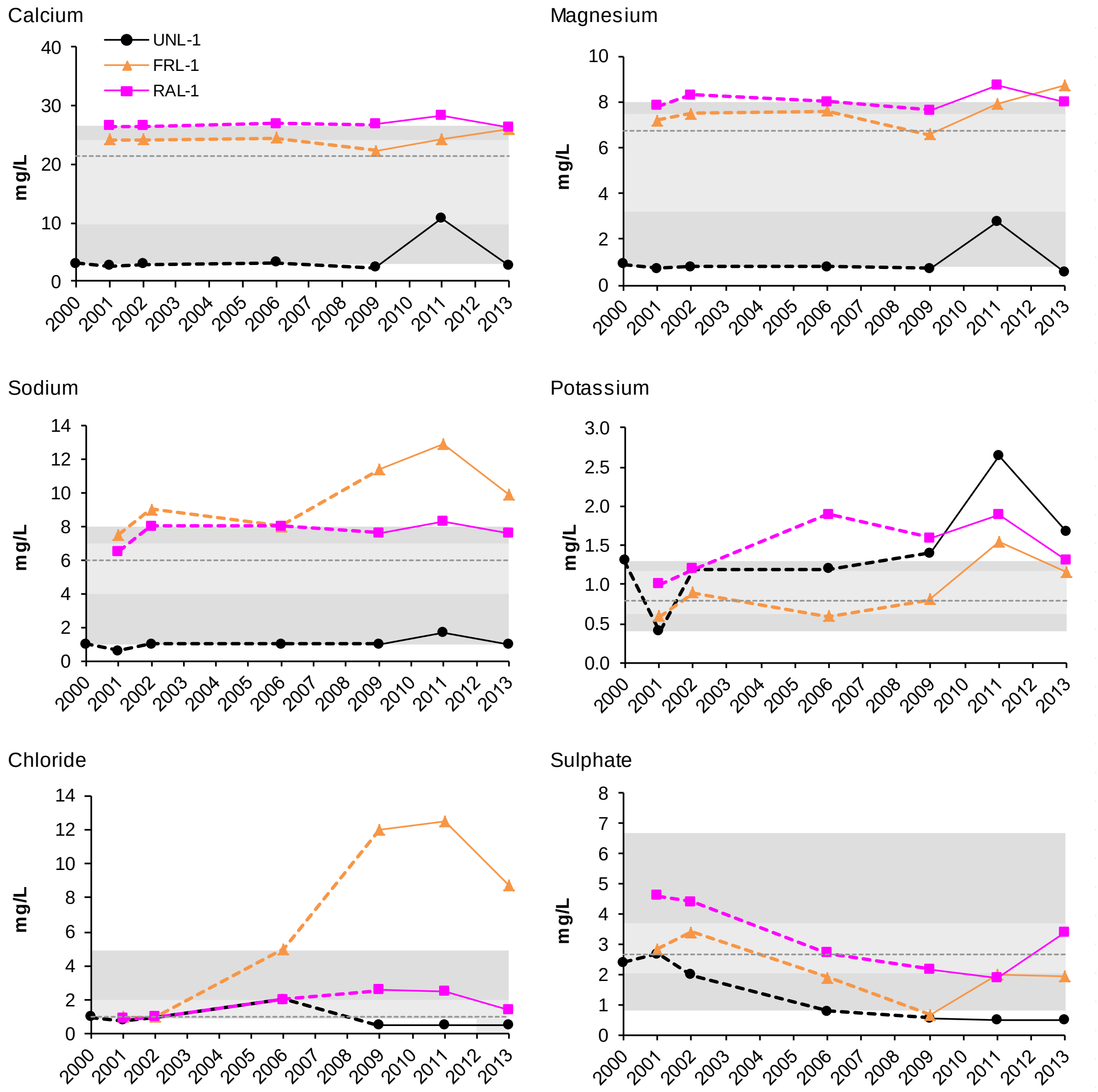
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-5 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* ranges reflect pooled results for all years during the *baseline* period.

Figure 6.2-5 (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* ranges reflect pooled results for all years during the *baseline* period.

Table 6.2-16 Water quality guideline exceedances in the Nexen lakes, spring and fall 2013.

Variable	Units	Guideline[a]	CANL-1	CARL-1	FRL-1	GRL-1	KIL-1	RAL-1	UNL-1
Spring									
pH	pH units	6.5-9.0	-	-	-	-	-	-	5.48
Total phosphorus	mg/L	0.05	-	-	0.074	-	-	-	0.192
Total nitrogen	mg/L	1.0	2.381	1.081	-	-	1.071	1.421	-
Dissolved aluminum	mg/L	0.11	-	-	-	-	-	-	0.0686
Total iron	mg/L	0.30	0.590	0.604	0.637	-	0.416	0.641	0.639
Dissolved iron	mg/L	0.30	0.927	0.852	0.901	0.421	0.640	1.010	0.761
Total phenols	mg/L	0.004	-	0.0041	0.0079	-	-	0.0060	0.0113
Sulphide	mg/L	0.0023	0.0075	0.0064	0.0135	0.0033	0.0066	0.0070	0.0129
Fall									
pH	pH units	6.5-9.0	-	-	-	-	-	-	6.43
Total phosphorus	mg/L	0.05	0.058	-	-	-	-	-	0.257
Total dissolved phosphorus	mg/L	0.05	-	-	-	-	-	-	0.218
Total nitrogen	mg/L	1.0	2.151	1.141	1.411	-	-	1.111	2.581
Ammonia-N	mg/L	1.19	-	-	-	-	-	-	1.41
Total aluminum	mg/L	0.1	-	-	-	-	-	-	0.124
Dissolved aluminum	mg/L	0.11	-	-	-	-	-	-	0.106
Total copper	mg/L	0.00037	-	-	-	-	-	-	0.00771
Total iron	mg/L	0.30	0.386	0.349	0.709	-	0.411	-	0.479
Dissolved iron	mg/L	0.30	-	-	0.545	-	-	-	0.455
Total phenols	mg/L	0.004	0.0051	-	0.0072	-	-	0.0049	0.0078
Sulphide	mg/L	0.0023	0.0058	0.0044	0.0132	0.0053	0.0024	0.0078	0.0033

[a] Sources for all guidelines are outlined in Table 3.2-5.

Figure 6.2-6 Piper diagram of spring ion concentrations at stations CANL-1, CARL-1, GRL-1, and KIL-1.

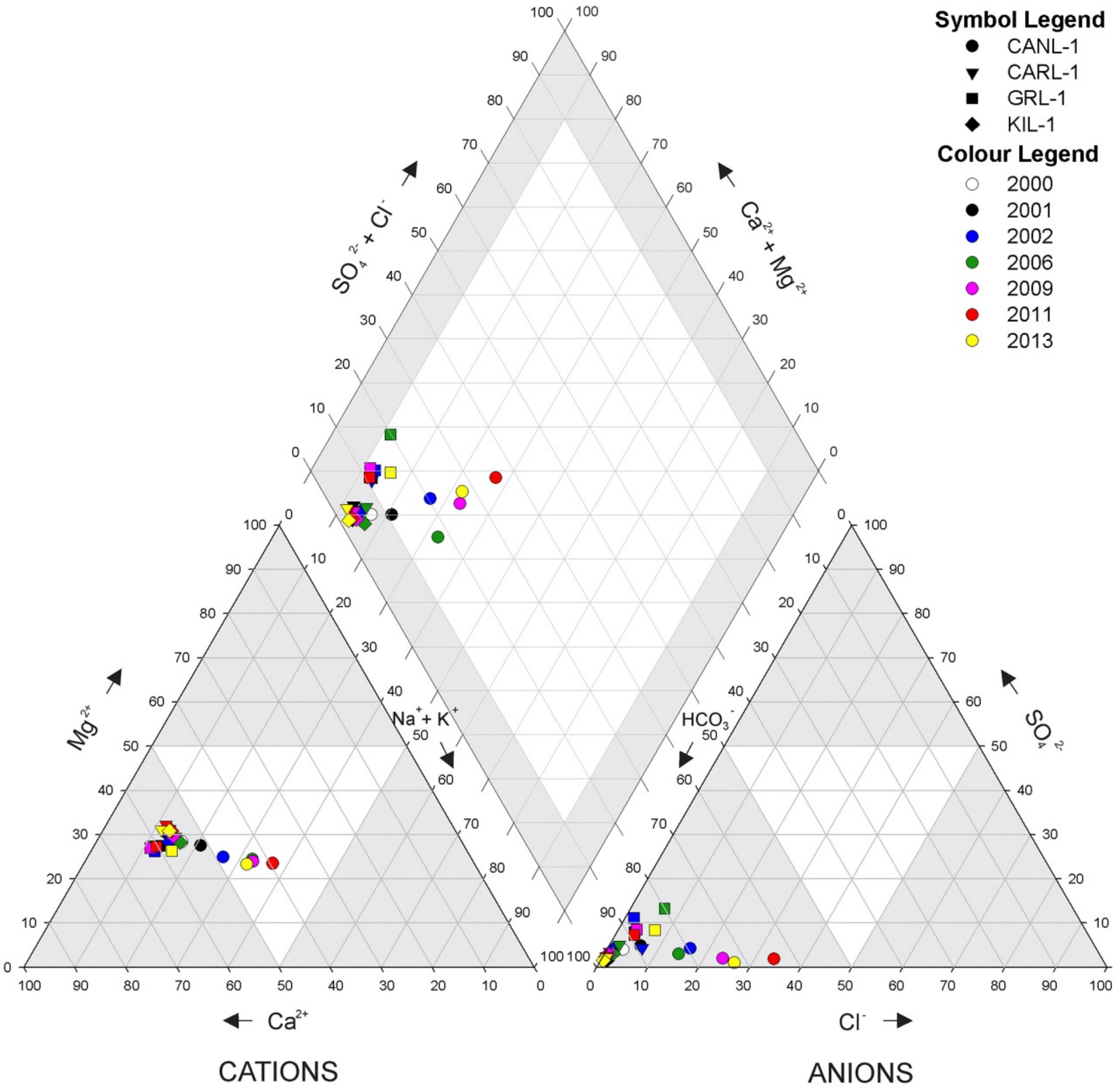


Figure 6.2-7 Piper diagram of spring ion concentrations at stations UNL-1, FRL-1, and RAL-1.

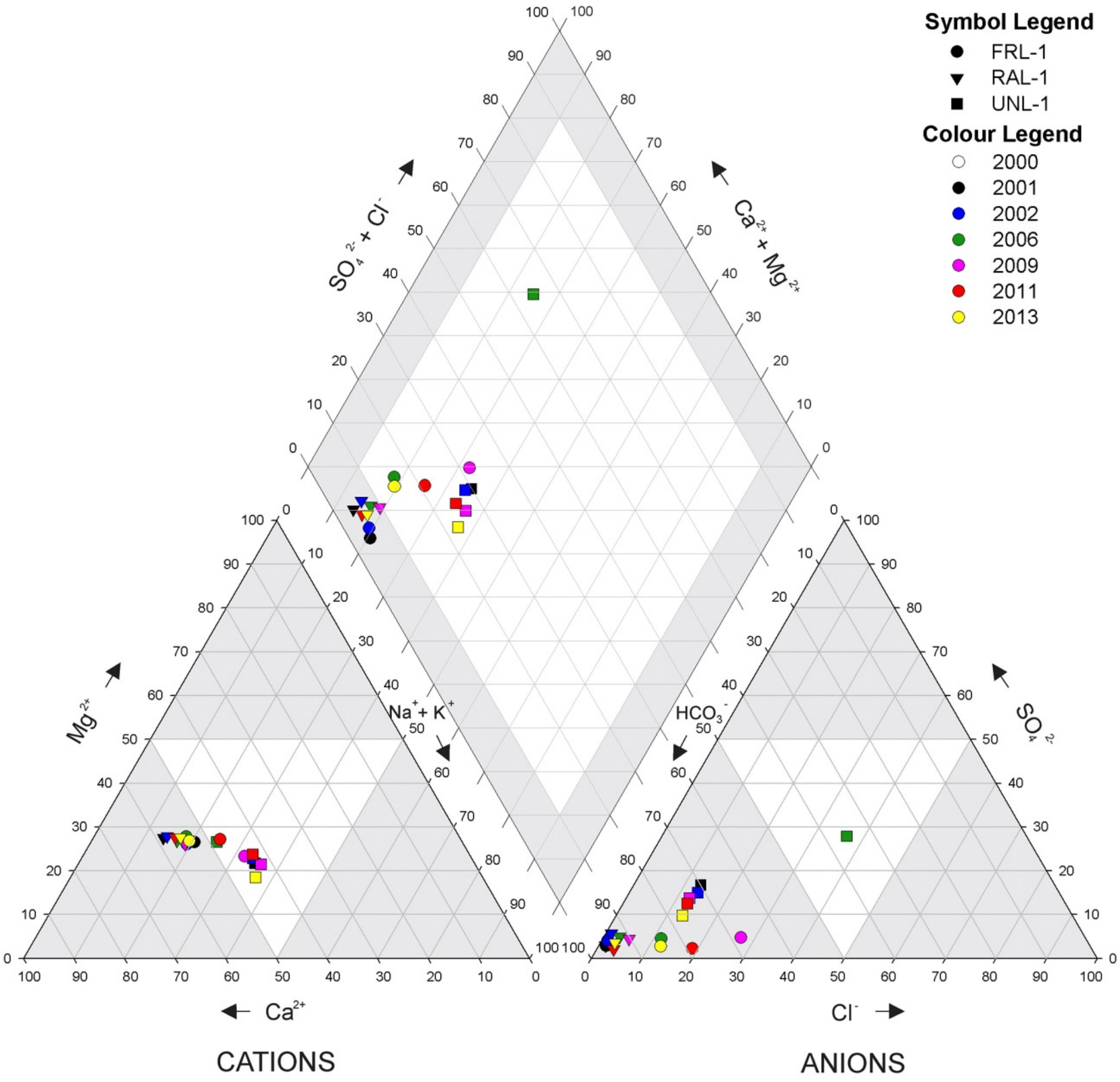


Figure 6.2-8 Piper diagram of fall ion concentrations at stations CANL-1, CARL-1, GRL-1, and KIL-1.

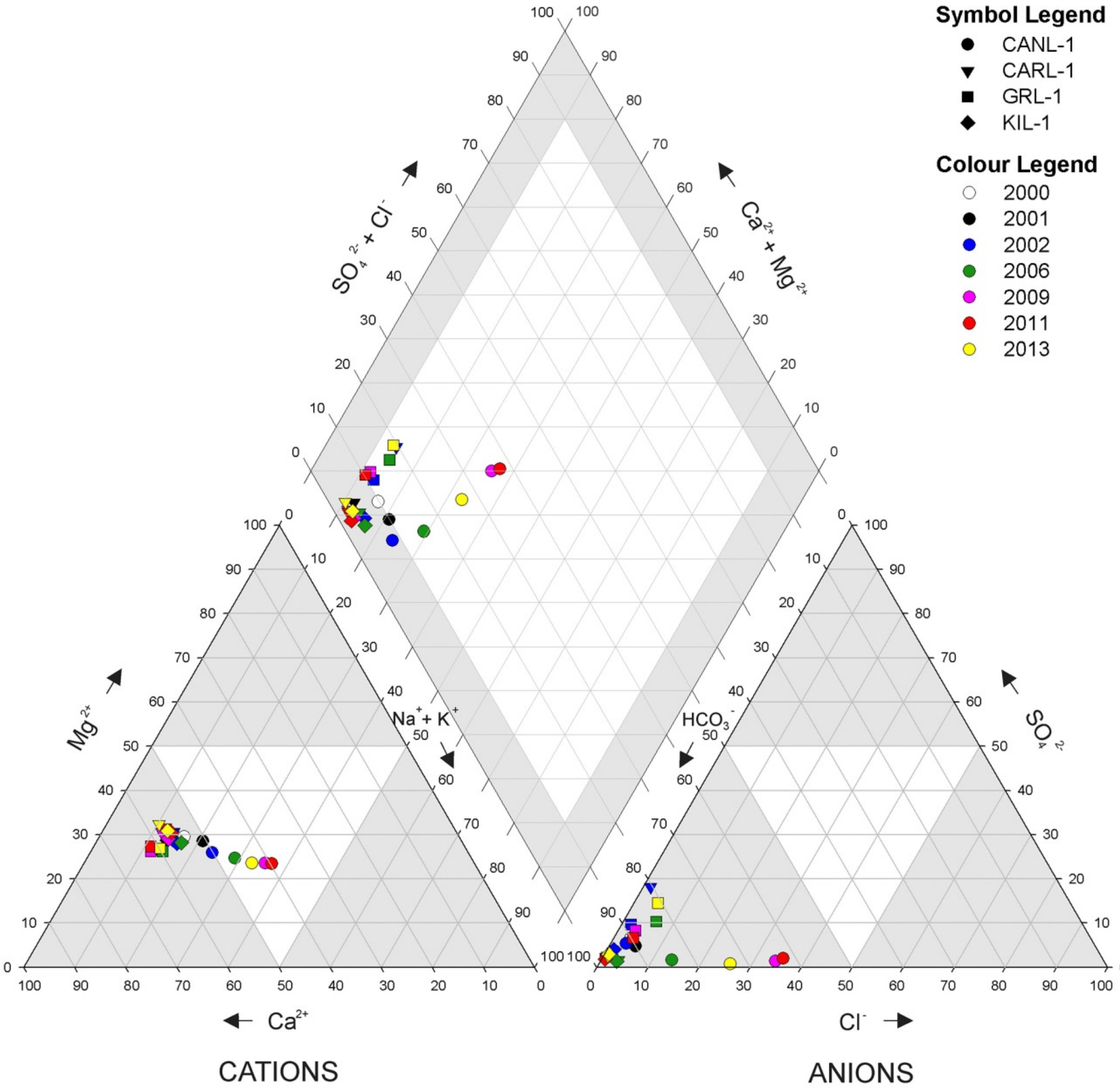
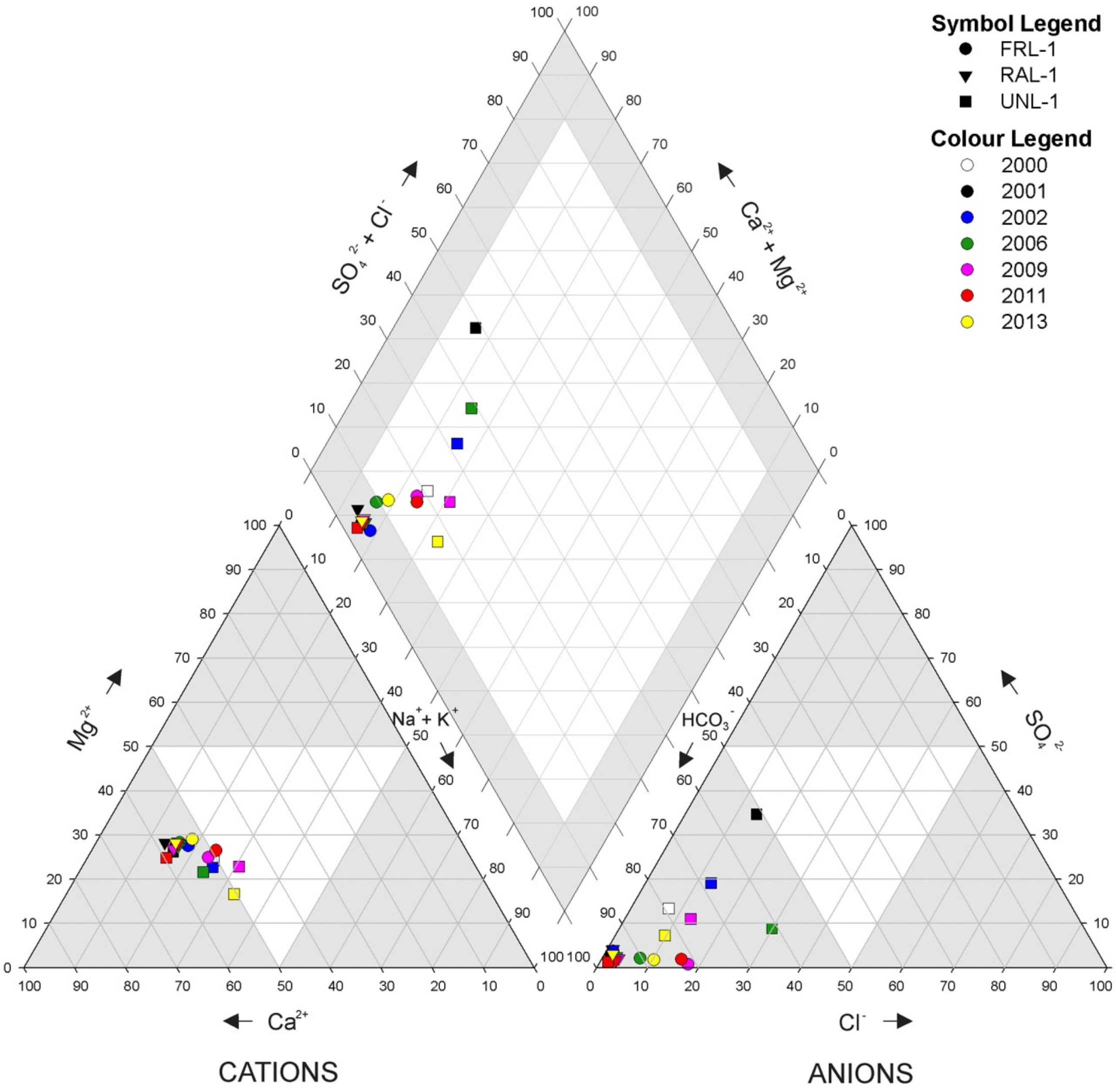


Figure 6.2-9 Piper diagram of fall ion concentrations at stations UNL-1, FRL-1, and RAL-1.



7.0 CONCLUSIONS AND RECOMMENDATIONS

The 2013 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 2013 RAMP results by watershed and by component. In addition, overall conclusions, general comments, and recommendations for each component are presented for consideration by the Water Component Advisory Committee of the JOSMP. Recommendations provided in this section may also be beyond the current scope of RAMP; however, given that RAMP is now working within the JOSMP, some recommendations may be relevant to new monitoring initiatives for the oil sands region.

7.1 CLIMATE AND HYDROLOGY

7.1.1 Summary of 2013 Results

Hydrologic changes in the RAMP FSA in the 2013 WY were assessed as **Negligible-Low** in eight of 13 watersheds assessed. The exceptions to this were the Muskeg River, Tar River, Mills Creek, Poplar 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 2013 WY, the activities of focal projects and other oil sands developments contributing to hydrologic changes in the RAMP FSA, in order of decreasing water volumes, were:

- industrial water withdrawals, releases, and diversions;
- closed-circuited land area resulting in a loss of flow to natural watercourses that would have occurred in the absence of 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 S24, Athabasca River below Eymundson Creek from 2004 to 2011 and Station S46, Athabasca River near Embarras Airport from 2012 to 2013. In a comparison of water balances calculated for the 2012 WY (RAMP 2013), the magnitude of hydrologic changes for both stations were essentially identical. 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 2013 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 -1.70% (mean winter discharge) to -0.56% (annual maximum daily 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 2013 in changes from *baseline* to *test* conditions in the four measurement endpoints (Figure 7.1-1).

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 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 JOSMP 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.

Table 7.1-1 Summary assessment of RAMP 2013 monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Fish Populations: Human Health Risk from Mercury in Fish Tissue[7]			Acid-Sensitive Lakes: Variation from Long-Term Average Potential for Acidification[8]
	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	🟠	🟡	🟡	🟡	🟠/🟤	-	-			-
Jackpine Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Kearl Lake	nm	🟡	🟡	n/a	-	-	-			-
Steepbank River	🟡	🟡	🟠	-	🟠	-	-			-
Tar River	🟤	🟠	🟠	🟠	🟡	-	-			-
MacKay River	🟡	🟡	🟠/🟡	-	🟤/🟠	-	-			-
Calumet River	🟡	🟡/🟠	nm	nm	nm	-	-			-
Firebag River	🟡	🟡	🟡	🟡	🟡	-	-			-
McClelland Lake	nm	n/a	🟡	n/a	-	-	-			-
Johnson Lake	-	n/a	n/a	n/a	-	-	-			-
Ells River	🟡	🟡	🟠	🟠	🟠	-	-			-
Namur Lake	-	-	-	-	-	-	LKWH LKTR	🟡 🟤	🟡 🟤	
Clearwater River	nm	🟡	nm	nm	-	-	-			-
High Hills River	-	🟡	n/a	-	n/a	-	-			-
Christina River	🟡	🟡/🟠	🟠/🟡	🟡	-	-	-			-
Christina Lake	nm	n/a	🟡	n/a	n/a	-	LKWH NRPK WALL	🟡 🟤 🟤	🟡 🟠 🟠	-
Jackfish River	nm	🟡	🟡	🟡	🟡	-	-			-
Sawbones Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Sunday Creek	nm	🟡	🟡	🟡	🟤	-	-			-
Birch Creek	nm	🟠	n/a	🟡	n/a	-	-			-
Unnamed Creeks (east and south of Christina Lake)	nm	🟡	🟡	🟡	🟡/🟤	-	-			-
Hangingstone River	🟡	🟤	-	-	-	-	-			-
Fort Creek	🟤	🟠	🟡	🟡	🟠	-	-			-
Beaver River	-	🟠	-	-	-	-	-			-
McLean Creek	-	🟡	-	-	-	-	-			-
Mills Creek	🟤	🟤	-	-	-	-	-			-
Isadore's Lake	nm	n/a	🟡	n/a	-	-	-			-
Poplar Creek	🟤	🟡	🟠	🟡	🟡	-	-			-
Shipyard Lake	-	n/a	🟡	n/a	-	-	-			-
Big Creek	-	🟡	n/a	🟡	n/a	-	-			-
Pierre River	-	🟡	n/a	🟡	n/a	-	-			-
Red Clay Creek	-	🟡	n/a	🟡	n/a	-	-			-
Eymundson Creek	-	🟠	n/a	🟡	n/a	-	-			-
Stony Mountains	-	-	-	-	-	-	-			🟡
West of Fort McMurray	-	-	-	-	-	-	-			🟡
Northeast of Fort McMurray	-	-	-	-	-	-	-			🟠
Birch Mountains	-	-	-	-	-	-	-			🟡
Canadian Shield	-	-	-	-	-	--	-			🟡
Caribou Mountains	-	-	-	-	-	-	-			🟡

Legend and Notes

🟡 Negligible-Low change
🟠 Moderate change
🟤 High change

"-" program was not completed in 2013.

nm - not measured in 2013.

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 was assessed as Negligible-Low, and Minimum Open-Water Season Discharge was assessed as High.

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

[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-Low at Goose Island Channel and Big Point Channel and Moderate at Embarras River and Fletcher Channel.

Note: Benthic invertebrate communities at the lower reach of the MacKay River were assessed as Moderate and benthic invertebrate communities at the middle reach was 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 3.2.4.4 for a detailed description of the classification methodology.

Note: Fish assemblages in the Muskeg River were assessed as Moderate at the lower and middles reaches and High at the upper reach.

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

[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 3.2.4.3 for a description of the classification methodology.

[7] **Fish Populations (human health):** Uses Health Canada criteria for risks to human health. LKWH – lake whitefish; LKTR – lake trout; NRPK – northern pike; WALL – walleye; Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.2.4.2).

[8] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2013 were more than twice the standard deviation from their long-term mean in each lake.

Table 7.1-2 Summary assessment of the RAMP 2013 WY hydrologic monitoring results.

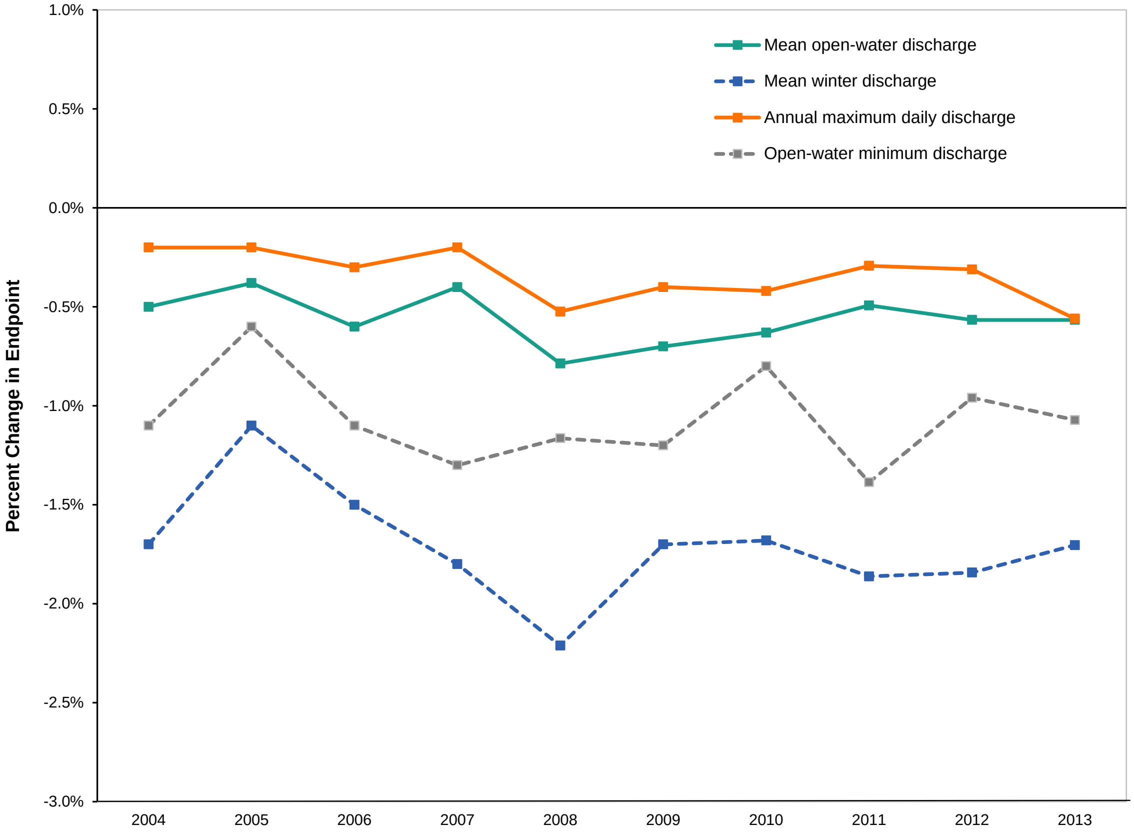
Watershed	Hydrologic Measurement Endpoint			
	Mean Open-Water Season Discharge	Mean Winter Discharge	Annual Maximum Daily Discharge	Minimum Open-Water Season Discharge
Athabasca River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Muskeg River	Moderate (-)	Negligible-Low	Moderate (-)	High (+)
Steepbank River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Tar River	High (-)	not measured	High (-)	High (-)
MacKay River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Calumet River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Firebag River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Ells River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Christina River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Hangingstone River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Poplar Creek	High (+)	High (+)	High (+)	High (+)
Mills Creek	High (-)	High (-)	High (-)	High (-)
Fort Creek	High (-)	not measured	High (-)	High (-)

Assessments based on comparisons of calculated incremental change in hydrologic measurement endpoints with criteria used in Section 5: Negligible-Low: ± 5%; Moderate: ±15%; High: > ± 15%.

“not measured” means hydrologic information was not obtained for times of year for which the measurement endpoint was applicable.

Direction indicators (+ or -) indicate a calculated increase or decrease in discharge in observed *test* conditions as compared to estimated discharge in estimated *baseline* conditions. Direction indicators were shown only for differences of 5% or greater (i.e., Moderate or High).

Figure 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 were calculated from estimated *baseline* and observed *test* hydrographs at Station S24, Athabasca River below Eymundson Creek, from 2004 to 2011 and Station S46, Athabasca River near Embarras Airport, from 2012 to 2013. A comparison of water balances from both stations, using 2012 WY data, indicated essentially no difference in the value of measurement endpoints (RAMP 2013).

7.2 WATER QUALITY

7.2.1 Summary of 2013 Results

In recent years of monitoring, water quality measured by RAMP in various waterbodies in fall has been strongly influenced by highly variable river flow, including very high flows in fall 2012. In 2013, historically high river flows were observed in June in several watersheds (see Section 4), but in fall, all waterbodies exhibited river flows generally typical of long-term conditions observed by RAMP since 1997, reducing the potential confounding effect of river flow on interpretation of long-term water quality data.

Water quality at all stations in most larger watersheds (i.e., Athabasca, Muskeg, Steepbank, Ells, Firebag, Clearwater) in fall 2013 was typical of historical and regional *baseline* observations in the RAMP FSA. However, data from several stations in smaller watersheds or headwaters, and in some lakes, exhibited differences from regional *baseline* conditions or historical conditions, shown by significant temporal trends in water quality measurement endpoints. These stations included the following:

- **Upper Christina River and Birch Creek** – *Baseline* stations CHR-4 and BRC-1, upstream of Christina Lake, indicated **Moderate** differences from regional *baseline* water quality conditions, associated with concentrations of several water quality measurement endpoints outside the range of regional *baseline* conditions, including some ions and metals.

- **Eymundson Creek** – Differences in water quality in fall 2013 between *baseline* station EYC-1 and regional *baseline* fall conditions were classified as **Moderate,** due to relatively high concentrations of ions and total suspended solids.

- **Mills Creek and Isadore's Lake** – Differences in water quality in fall 2013 between Mills Creek and regional *baseline* fall conditions were classified as **High**, due to relatively high concentrations of many ions and other dissolved species that exceeded regional *baseline* concentrations. Water quality in Isadore's Lake, where Mills Creek flows into, exhibited similar water quality to Mills Creek and showed increasing trends in several measurement endpoints, including total dissolved solids, sulphate, chloride, sodium, total strontium, and total boron.

- **Lower Beaver River** – Concentrations of several water quality measurement endpoints, primarily ions, exceeded regional *baseline* concentrations at the lower Beaver River, resulting in a **Moderate** difference from regional *baseline* conditions. Water quality at this station has typically exhibited regionally different water quality since RAMP monitoring began in 2003.

- **Fort Creek** – Differences in water quality in fall 2013 between *test* station FOC-1 and regional *baseline* conditions were classified as **Moderate**. Relatively high concentrations of several water quality measurement endpoints, primarily ions, were observed in 2013, as well as a long-term increase in sulphate concentrations.

- **Lower Tar River** – Differences in water quality observed in fall 2013 between *test* station TAR-1 and regional *baseline* fall conditions were classified as **Moderate,** which was mainly associated with high concentrations of total suspended solids and various total metals, relative to historical observations and regional *baseline* conditions.

- **Upper Calumet River** – Water quality at the upper *baseline* station of the Calumet River showed **Moderate** differences from regional *baseline* conditions, mainly due to regionally high concentrations of various ions.

- **Hangingstone River upstream and downstream of Fort McMurray** – Differences in water quality in fall 2013 between stations upstream of Fort McMurray and at the mouth of the Hangingstone River and regional *baseline* fall conditions were classified as **High**, and were attributed to higher concentrations of ions and dissolved metals in the Hangingstone River relative to regional *baseline* concentrations.
- **Shipyard Lake** – Although concentrations of most water quality measurement endpoints in fall 2013 in Shipyard Lake were within historical conditions, concentrations of sodium and chloride in the lake have been consistently increasing over time.

Most *test* stations that showed changes in 2013 have previously shown these differences from regional *baseline* conditions or have exhibited significant trends across monitoring years in some measurement endpoints, likely indicating anthropogenic influences on water quality. Aside from these localized changes, water quality in the RAMP FSA in 2013 was largely consistent with regional *baseline* conditions (Table 7.1-1).

Conclusions could not be drawn from monthly water quality sampling programs undertaken by RAMP in the Muskeg, MacKay, Poplar, Clearwater, and Christina rivers, given 2013 was the first year of complete monthly sampling.

7.2.2 Recommendations

The following recommendations are outlined to further improve monitoring conducted for the Water Quality component:

- Consider maintaining water quality stations in smaller watersheds in the design of the JOSMP to continue to monitor observed localized changes.
- Continue to expand monthly water quality sampling in larger tributaries, to better capture the range of conditions in these locations and allow better discrimination of natural versus anthropogenic changes in water quality.

7.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

7.3.1 Benthic Invertebrate Communities

7.3.1.1 Summary of 2013 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 were collected in lower reaches where changes from all upstream developments are anticipated to be the most significant. Differences in the lower reaches are in part judged against observations from previous years, from upper reaches that are classified as *baseline*, or from regional *baseline* conditions. Differences in measurement endpoints within reaches (and lakes) are judged using analyses of variance. Where changes are statistically significant, the magnitude of the observed change was considered, as is the nature of the change (i.e., in a positive or negative direction). The environmental tolerances of the biota are used to aid the interpretation of whether changes indicate degradation of habitat quality. A summary of the key findings from 2013 are provided below.

Athabasca River Delta Differences in measurement endpoints for benthic invertebrate communities in Big Point Channel and Goose Island Channel were classified as **Negligible-Low** because the significant changes in CA Axis 2 scores across years at both reaches and the increase in the percentage of EPT taxa in Goose Island Channel did not indicate degradation of the benthic invertebrate community. Additionally, all measurement endpoints of benthic invertebrate communities were within the tolerance limits of the normal range of variability for reaches of the ARD. Differences in measurement endpoints for benthic invertebrate communities of Fletcher Channel and the Embarras River were classified as **Moderate** because of the significant increase in equitability, exceeding the historical range of variability, and a decrease in richness over time in Fletcher Channel and the significant decreases in abundance, richness, and CA Axis 1 scores over time in the Embarras River.

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. Johnson Lake, which is in a baseline condition, was sampled for the third time in 2013. Time trends in Johnson Lake can be used to track regional influences that pertain most specifically to McClelland Lake, if trends in McClelland develop. Changes in 2013 in each of the lakes were evaluated in comparison to what was observed in previous years, and in *baseline* years when available (e.g., McClelland Lake). Statistical tests for lakes were carried out using measurement endpoints that had been adjusted to a common depth of 2 m, based on a model developed using RAMP data.

Differences in values of measurement endpoints for benthic invertebrate communities in all *test* lakes sampled by RAMP (i.e., Kearl, McClelland, Isadore's, Shipyard, and Christina lakes) were classified as **Negligible-Low** because changes in measurement endpoints compared to historical variability were not indicated of negative conditions in the benthic community.

Rivers The focus of the analysis of benthic invertebrate communities in river reaches in 2013 was a comparison of lower *test* reaches to their historical range of variability (up to and including 2012), to an upper *baseline* reach, or to a regional *baseline* range of variability.

There were no reaches where changes in benthic invertebrate communities in 2013 were classified as **High**.

Changes in benthic invertebrate communities of the following *test* reaches were classified as **Moderate** because:

- **Steepbank River (lower)** – Abundance, richness, CA Axis 1 and 2 scores, and percent EPT were significantly lower compared to *baseline* reach STR-E2. The benthic invertebrate community; however, was diverse and contained many taxa that require cool, clean water indicating a lack of degradation at this reach. Differences in the benthic invertebrate communities between the upper and lower reaches may be related to natural differences in substrate texture. The substrate at *test* reach STR-E1 was slightly more dominated by finer cobble, gravel, and sand than *baseline* reach STR-E2, and was more embedded; therefore, there was less surface area for benthic organisms to colonize.

- **Tar River (lower)** – Abundance, richness, and equitability differed between the *baseline* and *test* periods for this reach. The percentage of EPT taxa was lower in 2013 than it has been since 2006 and diversity decreased from 2012. All measurement endpoints of benthic invertebrate communities were within the historical range of variation for the lower Tar River, with the caveat that there were no mayflies or caddisflies, which were present during the *baseline* period and in most previous sampling years.

- **MacKay River (lower)** – Equitability significantly increased over time; percent EPT was significantly lower in 2013 compared to *baseline* reach MAR-E3; and richness was lower than the historical and regional *baseline* variability. It should be noted; however, that there was an increase in the relative proportion of EPT taxa and a decrease in relative worm abundance from 2012, indicating an improvement in taxa composition from 2012 to 2013 at *test* reach MAR-E1.

- **Ells River (lower)** – There were significant decreases in abundance, EPT, and richness over time, which were indicative of potentially degrading conditions. Abundance in fall 2013 (48 organisms per sample or about 2,000 individuals per m^2) was the lowest observed in the lower Ells River, and has previously ranged between 8,000 and 32,000 individuals per m^2. Most of the major groups of larger organisms (e.g., clams, snails, mayflies, caddisflies) that have previously been sparse were absent in 2013. All of the smaller and previously abundant organisms remained abundant in 2013. Chironomids were dominated by forms that are not known to be particularly tolerant of degraded water quality. Water velocity at the lower Ells River in 2013 (0.6 m/s) was higher than previously reported (normally in the 0.05 to 0.2 m/s range), and likely considered to be the explanation for the absence of larger forms of benthic invertebrates at *test* reach ELR-D1 in 2013.

- **Poplar Creek** – There were significant and large differences in abundance, equitability, percentage of fauna as EPT taxa, and CA axis scores compared to the upper *baseline* reach (BER-D2). Richness and abundance have been decreasing since 2001 at *test* reach POC-D1 and EPT taxa, which were increasing until 2012, have decreased in 2013. The lower equitability, which was outside of the inner tolerance limit for the 5th percentile of regional *baseline* conditions, does not denote a negative change, but suggested that *test* reach POC-D1 was becoming more diverse. The benthic invertebrate community at *test* reach POC-D1 was typical of a sand-bottom creek and dominated by worms and chironomids.

Changes in the benthic invertebrate communities of the following *test* reaches were classified as **Negligible-Low** because there were no significant changes in measurement endpoints indicative of degraded conditions and few exceedances of historical or regional *baseline* variability:

- Muskeg River (lower, middle, and upper);
- Jackpine Creek;
- MacKay River (middle);
- Firebag River;
- Christina River (upstream of Jackfish River);
- Jackfish River;

- Sunday Creek;
- Sawbones Creek;
- Unnamed Creeks East and South of Christina Lake; and
- Fort Creek.

7.3.1.2 Study Design Considerations

As in 2012, CABIN kick and sweep samples were collected under the JOSMP at the Steepbank River (STR-E1, STR-E2), MacKay River (MAR-E1, MAR-E3), and Ells River (ELR-E3) reaches in fall 2013, concurrently with Hess sampling conducted by RAMP. The purpose of the concurrent sampling was to provide 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 (or conversion factor) 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; 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 is to determine whether Hess sampling should be maintained in erosional reaches for future years of monitoring.

7.3.1.3 Recommendations

Assessments of lakes habitat is somewhat more challenging than river habitat 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 6 to 8 m are "trapped" in summer 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 an opportunity to develop in the open-water season. Such sampling would ensure that any changes in deep-water habitats are detected, if they occur.

The analyses of benthic invertebrate communities for the 2013 report demonstrated that there is relatively trivial, but still statistically significant influences of sampling depth and water velocity on the composition of benthic communities. In order to ensure that the data are as consistent as possible across years, it is recommended that field crews be provided additional instruction on the precise depths that should be sampled in each reach, lake, or channel, to the extent feasible, recognizing that there are natural variations in depths and flows from year to year in many of the habitats.

7.3.2 Sediment Quality

7.3.2.1 Summary of 2013 Results

Sediments in the RAMP FSA naturally contain concentrations of hydrocarbons and PAHs that may exceed environmental-quality guidelines.

In fall 2013, differences in sediment quality from regional *baseline* conditions were classified as **Moderate** at *test* stations of the Ells and Tar rivers, primarily due 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 typically 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).

From 2001 to 2013, sediments in Shipyard Lake have shown a significant increase in heavy (F3 and F4) hydrocarbon fractions and total alkylated PAHs, although results in 2013 showed a decrease in these variables relative to previous years.

Sediment from many stations in 2013, from both *baseline* and *test* locations, exhibited historically low survival but historically high growth of *Chironimus*, suggesting a potential influence of laboratory cultures or handling on sediment-toxicity results in 2013.

Sediments collected from many depositional stations in 2013, particularly those in the Muskeg River watershed, generally exhibited coarser grain size (i.e., more sand) and lower organic content and hydrocarbons than in other recent years of monitoring, perhaps related to the historically high flows observed in these watersheds in June 2013, which may have scoured sediments from the substrates of these watercourses.

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 ARD, 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 2013 RAMP Fish Populations component consisted of:

- seasonal fish inventories on the Athabasca and Clearwater rivers;
- fall fish assemblage monitoring on tributaries to the Athabasca and Clearwater rivers and on channels of the Athabasca Delta;
- a sentinel species program using trout-perch at five sites on the Athabasca River; and
- a fish tissue program on Christina and Namur lakes.

7.4.1 Summary of 2013 Results

7.4.1.1 Fish Inventory

In 2013, 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 2013, 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. Goldeye and lake whitefish were among the large-bodied

KIR species that have exhibited the greatest increase in abundance over time. Significant increases were observed in total catch and CPUE of goldeye in the last three years (i.e., 2011 to 2013), potentially due to warm, calm, spring seasons in the last three years, which can provide favourable conditions for goldeye recruitment. Similarly, CPUE of lake whitefish in fall 2013 was higher than previous years. Both goldeye and lake whitefish have shown significant increases in catch at the majority of *test* reaches in fall since 1997. Furthermore, shifts toward older dominant age classes and significant increases in mean condition were observed in both species.

The fish health assessment indicated that abnormalities observed among all species in 2013 were within the historical range and consistent with studies published prior to major oil sands development in the upper Athabasca River, the ARD, and the Peace Slave rivers.

Coupled with a decrease in total catch, species richness and abundance were relatively low in the Clearwater River in 2013. Compared to 2012, total catch was notably lower in summer and fall, likely due to a decrease in available habitat resulting from lower discharge in the sampling reaches. White sucker and longnose sucker continued to dominate overall species composition while the abundance of goldeye has returned to historical ranges after an increase in summer and fall 2012. The transient increase in goldeye abundance could be related to the warm, calm spring season that occurred in 2011 and 2012, but was not observed in 2013.

Following a shift towards a younger dominant age class in 2012, there was an increase in catch of older northern pike in 2013. In addition, significant increases in size-at-age across the last three years indicate that northern pike were larger at age in 2013. Conversely, a dominance of younger size classes continued to persist for walleye. This observation may be reflective of continued fishing pressure on older adult fish in the Clearwater River, causing a shift to a population dominated by younger individuals.

Mean condition factor was relatively similar for the large-bodied KIR species between *test* and *baseline* reaches in summer and fall 2013; northern pike and walleye showed slight differences, with higher condition at the *test* reach compared to the *baseline* reaches in summer. Historical data indicated considerable increases in condition for both longnose sucker and walleye in 2013. The percentage of external abnormalities increased slightly in 2013 compared to 2012, with the majority of abnormalities observed in white sucker and a higher percentage of abnormalities observed in summer.

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 and channels of the Athabasca River Delta. A summary of the key findings from the 2013 results are provided below (Table 7.1-1).

Athabasca River Delta In 2012, the tributary fish assemblage monitoring program was expanded to channels of the Athabasca River Delta where benthic invertebrate communities and sediment were sampled. This expansion increased harmonization of RAMP monitoring activities in the delta and further aligned the RAMP activities with proposed monitoring outlined in the JOSMP. Results of the fish assemblage monitoring in the ARD in August 2013 indicated high species richness and abundance across all channels, with the highest catches observed in Big Point Channel and the Embarras River. The dominant species included small-bodied fish species (emerald shiner and lake chub) as well as northern pike as the dominant large-bodied species. Measurement endpoints were fairly consistent across channels, with high ATI values, given that most species captured were tolerant (Whittier et al. 2007) The fish species composition of the channels of the ARD was consistent with the species composition in the Athabasca River, as documented during the RAMP fish inventory surveys.

Rivers 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, CPUE, species richness, diversity, and the assemblage tolerance index) for fish assemblages were classified as **Negligible-Low** compared to regional *baseline* conditions at the following *test* reaches:

- Tar River;
- Firebag River;
- Christina River (above Jackfish River);
- Sunday Creek;
- Jackfish River; and
- Poplar Creek.

Differences in measurement endpoints for fish assemblages were classified as **Moderate** at the following *test* reaches given that at least three of the five measurement endpoints exceeded the range of variability for *baseline* reaches or there was a statistical change in any one measurement endpoints, in a direction suggesting negative change:

- Muskeg River (lower and middle);
- Ells River;
- Fort Creek;
- MacKay River (middle);
- Steepbank River; and
- Unnamed Creek, south of Christina Lake.

Differences in measurement endpoints for fish assemblages were classified as **High** at the following *test* reaches given that at least three of the five measurement endpoints exceeded the range of variability for *baseline* reaches or there was a statistical change in three of the five measurement endpoints, in a direction suggesting a negative change:

- Jackpine Creek;
- MacKay River (lower);
- Sawbones Creek;
- Unnamed Creek east of Christina Lake; and
- Muskeg River (upper).

7.4.1.3 Fish Tissue Monitoring

In 2013, the potential risk to human health related to mercury concentrations in fish was assessed using muscle samples of lake trout and lake whitefish collected from Namur Lake, northwest of Fort McMurray, and lake whitefish, northern pike, and walleye collected from Christina Lake, south of Fort McMurray.

Christina Lake

Mercury concentrations in lake whitefish from Christina Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in northern pike and walleye from Christina Lake in 2013 were above Health Canada subsistence guidelines indicating a **High** risk to the health of subsistence fishers consuming northern pike and walleye. Given that all northern pike and most walleye exceeded the guideline for subsistence fishers, there was a **Moderate** risk to general consumers of northern pike and walleye, dependent on the quantity of fish consumed.

Mercury concentrations in fish from Christina Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes.

Namur Lake

Mercury concentrations in lake whitefish from Namur Lake in 2013 were below any Health Canada consumption guidelines indicating a **Negligible-Low** risk to human health. Mercury concentrations in lake trout from Namur Lake in 2013 were above Health Canada consumption subsistence fishers and general consumer guidelines indicating a **High** risk to the health of both subsistence fishers and general consumers of lake trout.

Mercury concentrations in lake whitefish from Namur Lake were generally within the historical range of mercury concentrations in fish sampled from other regional lakes; no data were available for lake trout from other lakes in the region.

7.4.1.4 Sentinel Species Monitoring

A sentinel species monitoring program using trout-perch was undertaken at *test* and *baseline* sites on the Athabasca River. Trout-perch at three sites downstream of oil sands development were compared to trout-perch at *baseline* sites upstream of oil sands development.

The effects criteria for age, weight-at-age, relative gonad weight, and relative liver weight defined by Environment Canada (2010) is a ± 25% difference between a *test* site and *baseline* site ATR-2 and a ± 10% difference for condition (body weight at length). Differences greater than the effects criteria between *baseline* and *test* sites suggested an ecologically relevant change in the trout-perch population at the *test* site.

A difference in measurement endpoints that exceeded the Environment Canada effects criteria was observed for age of female trout-perch and gonad weight of male trout-perch at *test* site ATR-5. The age of female trout-perch at ATR-5 was 25.2% younger than for trout-perch *baseline* site ATR-2, which was also observed in female trout-perch at *test* site ATR-5 in 2010. The gonad weight of male trout-perch at *test* site ATR-5 was 25.3% greater than trout-perch at *baseline* site ATR-2, which had also been observed in 2002, but the opposite pattern was observed in 2010. With no other exceedances in response patterns; and given that the 25% criteria were only marginally exceeded, these results suggested very little variability in trout-perch populations among *test* sites and *baseline* site ATR-2 in 2013.

Based on the results of the 2013, which provided a fairly consistent response patterns in energy use and energy storage (growth, gonad weight, and liver size) in female and male trout-perch at *test* sites, differences from the *baseline* site ATR-2 were classified as **Negligible-Low** (Table 7.1-1**)**.

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 JOSMP, 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, particularly for fish assemblage monitoring given it occurs throughout the province. This will eventually result in more efficient sampling in the region and increased data and information sharing to meet the objectives of all stakeholder needs.

7.5 ACID-SENSITIVE LAKES

7.5.1 Summary of 2013 Results

Concentrations of chemical variables that were elevated in 2012 (pH, TDS, Gran alkalinity, conductivity, sum of base cations, and DOC) returned to their historical levels in 2013. In among-year comparisons, pH, Gran alkalinity, TDS, conductivity, sodium, and potassium have significantly increased over time, and in most cases, at both *baseline* and *test* lakes. There were no significant increases in sulphates or nitrates. These changes did not suggest acidification of the RAMP lakes from NO_xSO_x emissions but rather were due to hydrological changes over time or a possible increase in the role of surficial groundwater on lake chemistry.

Critical loads in 2013 ranged from -0.761 keq H^+/ha/yr to 3.613 keq H^+/ha/yr, with a median CL of 0.457 keq H^+/ha/y. The median critical load was lower than 2012 and closer to values in previous years; however, critical loads in the RAMP lakes are generally increasing over time consistent with increases in lake buffering capacity (i.e., Gran alkalinity). The lowest critical loads were found in lakes in the upland regions including the Stony Mountains, Birch Mountains, and Canadian Shield subregions. Lakes in the Stony Mountains, having the lowest critical loads, are the most acid-sensitive of the RAMP lakes. A total of 12 (24%) of the 50 lakes had critical loads exceeded by the Net PAI. Seven of the 12 lakes were found in the Stony Mountains subregion.

As in previous years, 18 of the 19 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. Trend analysis of measurement endpoints showed consistent results with among-year comparisons, with significant increases (rather than decreases) in Gran alkalinity and pH in many of the RAMP lakes. A significant increasing trend in dissolved aluminum occurred in Lake 452/NE1. This lake will be monitored in future years to determine whether the observed trend in dissolved aluminum continues.

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 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 was no evidence to suggest that acidification is occurring in the RAMP lakes although chemical changes in these lakes were evident. Five of the subregions were classified as having a **Negligible-Low** indication of incipient acidification while the Northeast of Fort McMurray subregion was classified as having a **Moderate** indication of incipient acidification due to relatively high concentrations of nitrates in one lake.

8.0 REFERENCES

[AENV] Alberta Environment. 1990. Selected methods for the monitoring of benthic invertebrates in Alberta rivers. Edmonton (AB): Environmental Quality Monitoring Branch, Environmental Assessment Division, AENV. 41 p.

AENV. 1999a. Regional sustainable development strategy for the Athabasca oil sands area. Edmonton (AB): Alberta Environment. Publication No. 1/754. ISBN 0-7785-0680-0.

AENV. 1999b. Surface water quality guidelines for use in Alberta. Edmonton (AB): Environmental Assurance Division, Science and Standards Branch, AENV.

AENV. 2000. Spring Creek watershed post harvesting – phase II impacts of timber harvesting. Edmonton (AB): Water Sciences Branch, Hydrology/Forecasting Section, AENV. 64 p. Report No. 7GF, 2000-314. Prepared for: Water Sciences Branch. Prepared by: John Taggart.

AENV. 2006. Aquatic ecosystems field sampling protocols. Edmonton (AB): AENV. Publication No: T/883. ISBN 0-7785-5079-6.

AENV. 2007a. Water management framework: instream flow needs and water management system for the lower Athabasca River. Edmonton (AB): AENV and Ottawa (ON): Fisheries and Oceans Canada. 37 p.

AENV. 2007b. Review of the acid deposition management framework and its implementation. Edmonton (AB): Environmental Policy Branch, AENV. 19 p.

[AEP] Alberta Environment Protection. 1990. A review of approaches for setting acidic deposition limits in Alberta. Special report. Edmonton (AB): AENV. 63 p.

[AESRD] Alberta Environment and Sustainable Resource Development. 2012. Fisheries and wildlife management information system. Edmonton (AB): AESRD; [cited December 2012]. Available from: http://xnet.env.gov.ab.ca/imf/imfAlbertaUserAgreeSubmit.jsp?site=fw_mis_pub

[AITF] Alberta Innovates Technology Futures. 2011. 2010 regional aquatics monitoring program (RAMP) scientific review. Edmonton (AB): AITF. 160 p. Prepared by: RAMP Review Panel. Prepared for: RAMP Steering Committee.

Alberta Water Council. 2009. Provincial ecological criteria for healthy aquatic ecosystems. Edmonton (AB): Alberta Water Council. Available from: http://www.albertawatercouncil.ca/LinkClick.aspx?fileticket=1LxcW7%2f%2flqQ%3d&tabid=59

Almodóvar A, Nicola GG. 2004. Angling impact on conservation of Spanish stream-dwelling brown trout *Salmo trutta*. Fish. Manag. Ecol. 11: 173-182.

Anderson AM. 1990. Selected methods for the monitoring of benthic invertebrates in Alberta rivers. Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment. 82 p.

[AOSERP] Alberta Oil Sands Environmental Research Program. 1977. Survey of baseline levels of contaminants in aquatic biota of the AOSERP study area. Edmonton (AB): AOSERP. 66 p. Prepared by A. Lutz and M. Hendzel.

Astel A, Tsakovski S, Barbieri P, Simeonov V. 2007. Comparison of self-organizing maps classification approach with cluster and principal components analysis for large environmental data sets. Water Res. 41(19): 4566-4578.

[ATSDR] Agency for Toxic Substances & Disease Registry. 2009. A determination of inorganic arsenic concentrations in fish from the North Fork of the American Fork Canyon. Atlanta (GA): ATSDR. Prepared by: T. Jewkes and J. Contreras. Available from: http://www.atsdr.cdc.gov/hac/pha/

Back W, Hanshaw BB. 1965. Chemical geohydrology. Adv. Hydrosci 2: 49-109.

Bailey RC, Norris RH, Reynoldson TB. 2004. Bioassessment of freshwater ecosystems: using the reference condition approach. Dordrecht (NL): Kluwer Academic Publishers.

Baker JD, Schofield, CL. 1982. Aluminum toxicity to fish in acidic waters. Water, Air, and Soil Pollution. 18: 289-309.

Baker JP, Van-Sickle J, Gagen CJ, Dewalle DR, Sharpe WE, Carline RF, Baldigo BP, Murdoch PS, Bath DW, Kretser WA, Simonin HA, Wigington PJ Jr. 1996. Episodic acidification of small streams in the northeastern United States: Effects on fish populations. Ecological Applications. 6(2): 422-437.

Baker RF, Blanchfield PJ, Patterson MJ, Flett RJ, Wesson L. 2004. Evaluation of nonlethal methods for the analysis of mercury in fish tissue. Trans. Am. Fish. Soc. 133: 568-576.

Balagus P, de Vries A, Green J. 1993. Collection of fish from the traditional winter fishery on the Peace-Athabasca delta, February 1993. Edmonton (AB): Northern River Basins Study Project, AENV. Report No. 20.

Barbosa AC, Sousa J, Dórea JG, Jardim WF, Fadini PS. 2003. Mercury biomagnification in a tropical black water, Rio Negro, Brazil. Archives of Environmental Contamination and Toxicology. 45: 235-246.

Barrett TJ, Tingley MA, Munkittrick KR, Lowell RB. 2010. Dealing with heterogeneous regression slopes in analysis of covariance: new methodology applied to environmental effects monitoring fish survey data. Environmental Monitoring and Assessment. 166(1-4): 279-291.

Barton DR. 1979. Benthic macroinvertebrate communities of the Athabasca River near Ft. MacKay, Alberta. Hydrobiologia. 74: 151-160.

Barton BA, Bjornson CP, Egan KL. 1993. Special fish collections, upper Athabasca River, May, 1992. Edmonton (AB): Northern Rivers Basins Study Project, AENV. 37 p. plus appendices. Report No. 8.

Barton DR, Lock MA. 1979. Numerical abundance and biomass of bacteria, algae and macrobenthos of a large northern river, the Athabasca. Int. Revue ges. Hydrobiol. 64:345-359.

Barton DR, Smith SM. 1984. Insects of extremely small and extremely large aquatic habitats. In: Resh VH, Rosenberg DM, editors. The ecology of aquatic insects. New York (NY): Praeger. p. 456-483.

[BC MOE] Ministry of Environment, Government of British Columbia. 1982. British Columbia Ministry of Environment procedure manual vol. 6, sec. 9, subsec. 01. p. 5-72.

BC MOE. 2009. Manual of British Columbia hydrometric standards. v. 1.0. Victoria (BC): Resources Information Standards Committee. Prepared by: Science and Information Branch, Ministry of Environment, Government of British Columbia.

Beckvar N, Field J, Salazar S, Hoffman DJ. 1996. Contaminants in aquatic habitats at hazardous waste sites: mercury. Seattle (WA): NOAA Technical Memorandum NOS ORCA 100, Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration.

Berthouex PM, Hau I. 1991. Difficulties related to using extreme percentiles for water quality regulations. Research Journal of the Water Pollution Control Federation 63:873-879.

Bishop K, Laudon H, Kohler S. 2000. Separating the natural and anthropogenic components of spring flood pH decline: A method for arears that are not chronically acidified. Water Resources Research. 31: 1873-1889.

Bloom SA. 1980. Multivariate quantification of community recovery. In, J. Cairns Jr. (ed). The Recovery Process. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Bloom NS. 1992. On the methylmercury content of fish tissue. Can. J. Fish. Aquat. Sci. 49 p.

Bode RW, Novak, MA, Abele LE. 1996. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Albany, NY. 89 p.

Bond WA, Machniak K. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Edmonton (AB): AOSERP. Project AF 4.5.1. Prepared by the Department of Fisheries.

Bond WA, Machniak K. 1979. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. AOSERP Project AF 4.5.1. p. 164-171.

Bond WA. 1980. Fisheries resources of the Athabasca River downstream of Fort McMurray, Alberta. vol 1. Edmonton (AB): AOSERP. AF 4.3.2. 93 p.

Bonnin G, Martin D, Parzybok T, Lin B, Riley D, Yekta M. 2011. Precipitation-frequency atlas of the United States. Silver Spring (MD): National Weather Service. National Oceanic and Atmospheric Administration (NOAA) atlas 14 volume 1 version 5.0.

Boyacioglu H, Boyacioglu H. 2010. Detection of seasonal variations in surface water quality using discriminant analysis. Environ. Monit. Assess. 162 (1): 15-20.

Brakke DF, Henriksen A, Norton SA. 1990. A variable F-factor to explain changes in base cation concentrations as a function of strong acid deposition. Verh. Internat. Verein. Limnol. 24: 146-149.

Brinkhurst RO. 1989. A phylogenetic analysis of the Lumbriculidae (Annelida, Oligochaeta). Can. J. Zool. 67: 2731-2739.

Brodersen KP, Lindegaard C. 1999. Classification, assessment and trophic reconstruction of Danish lakes using chironomids. Freshwater Biol. 42:143-157.

Brooks AR, Kelton LA. 1967. Aquatic and semiaquatic Heteroptera of Alberta, Saskatchewan and Manitoba. (Hemiptera). Memoirs of the Entomological Society of Canada. 99(51): 1-92.

Butcher GA. 2001. Water quality criteria for aluminum. Overview report. Victoria (BC): Ministry of Water, Land and Air Protection, Government of British Columbia.

Cadle SH, Dasch JM, Gossnickle NE. 1984. Retention and release of chemical species in a northern Michigan snowpack. Water, Air, and Soil Pollution. 22:303-319.

Campbell PGC, Hansen HJ, Dubreuil B, Nelson WO. 1992. Geochemistry of Quebec north shore salmon rivers during snowmelt: Organic acid pulse and aluminium mobilization. Canadian Journal of Fisheries and Aquatic Sciences. 49 (9): 1938-1952.

Canada and Government of Alberta. 2012. Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring [Internet]. [cited 7 March 2014]. Available from: http://www.jointoilsandsmonitoring.ca

Cantrell KJ, Serkiz SM, Perdue EM. 1990. Evaluation of acid neutralizing capacity data for solutions containing natural organic acids. Geochimica et Cosmochimica Acta. 54: 1247-1254.

[CCME] Canadian Council of Ministers of the Environment. 2001. Canada-wide standards for petroleum hydrocarbons (PHCs) in soil: scientific rationale [supporting technical document]. Winnipeg (MB): CCME.

CCME. 2002. Canadian sediment quality guidelines for the protection of aquatic life. Winnipeg (MB): CCME.

CCME. 2007. Canadian water quality guidelines for the protection of aquatic life. Winnipeg (MB): CCME.

CCME. 2008. Canada-wide standard for petroleum hydrocarbons (PHC) in soil: scientific rationale [supporting technical document]. Winnipeg (MB): CCME. Available from: http://www.ccme.ca/assets/pdf/phc_standard_1.0_e.pdf

CCME. 2011. Canadian environmental quality guidelines and summary table [Internet]. Winnipeg (MB): CCME.

[CEMA] Cumulative Environmental Management Association. 2001. Terms of reference and work plan for the sustainable ecosystem working group. Fort McMurray (AB): CEMA.

CEMA. 2004a. Development of reach specific water quality objectives for variables of concern in the lower Athabasca River: identification of variables of concern and assessment of the adequacy of available guidelines. Fort McMurray (AB): CEMA.

CEMA. 2004b. Recommendations for the acid deposition management framework for the oil sands region of north-eastern Alberta. Report to NO_xSO_x Management Working Group, Cumulative Environmental Management Association (CEMA). Fort McMurray (AB): CEMA. 39 p.

CEMA. 2008. Proposed interim nitrogen (eutrophication) management recommendations and work plan for the regional municipality of Wood Buffalo. Fort McMurray (AB): CEMA. 57 p. Prepared for the NO_xSO_x Management Working Group, CEMA.

CEMA. 2010a. Terms of reference — reclamation working group (RWG). Fort McMurray (AB): CEMA; [cited 15 March 2013]. Available from: http://cemaonline.ca/index.php/administration/doc_download/9-terms-of-reference-reclamation-working-group-rwg-revised-2010

CEMA. 2010b. The assessment of acid deposition in the Alberta oil sands region – phase 2 of stage 2 implementation of the CEMA acid deposition management framework. Fort McMurray (AB): CEMA. Report No. 08-1331-0023. Prepared by Golder Associates Ltd.

CEMA. 2012. Water working group (WWG) terms of reference — final. Fort McMurray (AB): CEMA; [cited 15 March 2013]. Available at: http://cemaonline.ca/index.php/administration/doc_download/213-terms-of-reference-water-working-group-december-2012

Chambers JM, Cleveland WS, Kleiner B, Tukey PA. 1983. Graphical methods for data analysis. Pacific Grove (CA): Wadsworth & Brooks/Cole. 62 p.

Clarke AH. 1981. The freshwater molluscs of Canada. Ottawa (ON): National Museum of Natural Sciences/National Museum of Canada.

Clifford HF. 1991. Aquatic invertebrates of Alberta. Edmonton (AB): University of Alberta Press.

[CLRTAP] Convention on Long-range Transboundary Air Pollution. 2004. Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads & Levels and Air Pollution Effects, Risks and Trends. Convention on Long-range Transboundary Air Pollution. Federal Environmental Agency (Umweltbundesamt). Postfach 33 00 22, 14191 Berlin. ISSN 0722-186X. 266 p.

Cohen J. 1977. Statistical power analysis for the behavioral sciences (rev. ed.). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc. xv 474 pp.

Cohen J. 1988. Statistical Power Analysis for the Behavioral Sciences. L. Erlbaum Associates. 567 p.

Colbeck SC. 1981. A simulation of the enrichment of atmospheric pollutants in snow cover runoff. Water Resources Res. 17: 1381-1388.

Conover WJ, Iman RL. 1982. Analysis of covariance using the rank transformation. Biometrics. 38(3): 715-724.

Cummins KW. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Midl. Nat. 67: 477-504.

Currie DC. 1986. An Annotated list of and keys to the immature black flies of Alberta (Diptera: Simuliidae). Mem. ent. Soc. Can. 136.

Davis Wayne S, Simon Thomas P. eds. 1995. Biological assessment and criteria: tools for water resource planning and decision making. CRC Press.

Davies TD, Tranter M, Wigington PJ, Eshleman K. 1992. Acidic episodes in surface waters in Europe. Journal of Hydrology. 132:25-69.

Denning AS, Baron J, Mast MA, Arthur M. 1991. Hydrologic pathways and chemical composition of runoff during snowmelt in Loch Vale watershed, Rocky Mountain National Park, Colorado, USA. Water, Air, and Soil Pollution. 59: 107-124.

DNI. 2012. Technical Report, Supplementary Ree-Y-Sc-Th Inferred Resource Estimate To Accompany The Maiden Resource Mo-Ni-U-V-Zn-Cu-Co-Li Estimate, Buckton Mineralized Zone, Sbh Property, Northeast Alberta. Report Prepared for DNI Metals Inc., Toronto Ontario by APEX Geoscience Ltd.

Dowdeswell L, Dillon P, Ghoshal S, Miall A, Rasmussen J, Smol JP. 2010. A foundation for the future: building an environmental monitoring system for the oil sands. Gatineau (QC): Environment Canada. 49 p. Prepared for the Minister of Environment.

Driscoll CT, Fuller RD, Schecher WD. 1989. The role of organic acids in the acidification of surface waters in the eastern U.S. Water, Air, and Soil Pollution. 43: 21-40.

Driscoll CT, Newton RM, Gubala CP, Baker JP, Christensen SW. 1991. Case study – Adirondack Mountains. In: Charles DF, editor. Acidic deposition and aquatic ecosystems. New York (NY): Springer Verlag. p. 133-202.

Edmunds GF, Lensen SL, Berner L. 1976. The mayflies of North and Central America. Don Mills (ON): Burns and MacEachern Limited.

[ERCB] Energy Resources Conservation Board. 2013. Alberta’s energy reserves 2012 and supply/demand outlook 2013-2022. Calgary (AB): ERCB. ST98-2013.

Environment Canada. 1993. Guidelines for monitoring benthos in freshwater environments. Gatineau (QC): Environment Canada. 81 p. Prepared by EVS Consultants.

Environment Canada. 1997. 1997 Canadian acid rain assessment. vol. 3. In: Environment Canada. The effects on Canada’s lakes, rivers and wetlands. Gatineau (QC): Environment Canada.

Environment Canada. 2010. 2010 pulp and paper environmental effects monitoring (EEM) technical guidance document. Gatineau (QC): Environment Canada.

Environment Canada. 2012. 2012 Metal mining environmental effects monitoring technical guidance document [Internet]. [cited 7 March 2014]. Gatineau (QC): Environment Canada. En14-61/2012E-PDF 978-1-100-20496-3. Available from: http://www.ec.gc.ca

Environment Canada, Government of Alberta. 2012. Joint Canada-Alberta implementation plan for oil sands monitoring. Gatineau (QC): Environment Canada.

Environment Canada intensity-duration-frequency (IDF) files [Internet]. 2012. Ottawa (ON): Environment Canada; [updated 2012 February 9; cited 2014 April 16]. Available from: ftp://ftp.tor.ec.gc.ca/Pub/Engineering_Climate_Dataset/IDF/

Epler JH. 2001. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina. A Guide to the Taxonomy of the Midges of the Southeastern United States, including Florida. Spec. Publ. SJ 2001-SP 13. North Carolina Dept. Envir. Nat. Resources, Raleigh, NC and St. Johns Water Management District, FL. 528 pp. http://www.esb.enr.state.nc.us/BAUwww/Chironomid.htm.

Evans MS, Talbot A. 2012 Investigations of mercury concentrations in walleye and other fish in the Athabasca River ecosystem with increasing oil sands development. J. Environ. Monit. DOI: 10.1039/c2em30132f

Findlay DL, Kasian SEM. 1996. The effect of incremental pH recovery on the Lake 223 phytoplankton community. Canadian Journal of Fisheries and Aquatic Sciences. 53:856-864.

Forsius M, Kamari J, Posch M. 1992. Critical loads for Finnish lakes: comparison of three steady state models. Environ. Pollut. 77(2-3): 185-193.

Freeze RA, Cherry JA. 1979. Groundwater. Englewood Cliffs (NJ): Prentice Hall.

Galloway JN, Schofield CL, Hendrey GR, Peters NE, Johannes AH. 1980. Sources of acidity in three lakes acidified during snowmelt. In: Drablos D, Tollan A, editors. Proceedings of an International Conference on the Ecological Impact of Acid Precipitation; 1980; Sandefjord, Norway. p. 264-265.

Gauch HG. 1982. Multivariate analyses in community ecology. Cambridge (UK): Cambridge University Press.

Gibbons WN, Munkittrick KR. 1994. A sentinel monitoring framework for identifying fish population responses to industrial discharges. J. Aquatic Ecosystem Health. 3: 227-237.

Gibbons WN, Munkittrick KR, McMaster ME, Taylor WD. 1998. Monitoring aquatic environments receiving industrial effluents using small fish species 2: comparison between responses of trout-perch (*Percopsis omicomaycus*) and white sucker (*Catostomus commersoni*) downstream of a pulpmill. Environmental Toxicology and Chemistry. 17(11): 2238-2245.

Gibson JJ. 2002. Short-term evaporation and water budget comparisons in shallow Arctic lakes using non-steady isotope mass balance. J. Hydrol. 264: 242-261.

Gibson JJ, Birks SJ, Kumar S, McEachern PM. 2010. Inter-annual variation in water yield to lakes in northeastern Alberta: implications for estimating critical loads of acidity. J. Limnol., 69 (Suppl. 1): 126-134.

Gibson JJ, Edwards TWD. 2002. Regional water balance trends and evaporation-transpiration partitioning from a stable isotope survey of lakes in northern Canada. Global Biogeochem. Cy. 16: 10-1 to 10-14.

Gibson JJ, Edwards TWD, St. Amour NA, Buhay W, McEachern P, Wolfe BB, Peters DL. 2005. Progress in isotope trace hydrology in Canada. Hydrol. Processes 19: 303-327.

Gibson JJ, Prepas EE, McEachern P. 2002. Quantitative comparison of lake throughflow, residency and catchment runoff using stable isotopes: modelling and results from a regional survey of Boreal lakes. J. Hydrol. 262: 128-144.

Gilbert RO. 1987. Statistical methods for environmental pollution monitoring. New York (NY): Van Nostrand Reinhold Company. 320 p.

[GOA] Government of Alberta. 2009. Human health risk assessment: mercury in fish. Alberta Health and Wellness. October 2009.

GOA. 2011. Fish survey methods for lakes: ASRD, ABMI, and ACA Collaboration. Version 2011-10-10.

GOA. 2012. Lower Athabasca regional plan [Internet]. [cited 7 March 2014]. Edmonton (AB): Government of Alberta. 978-1-4601-0538-2. Available from: http://environment.alberta.ca

GOA. 2013a. Athabasca Oil Sands Projects and Upgraders [Internet]. [cited 7 March 2014]. Edmonton (AB): Government of Alberta. Available from:
www.energy.alberta.ca/LandAccess/pdfs/OilSands_Projects.pdf

GOA. 2013b. Alberta Oil Sands Industry Quarterly Update - September 18 to December 5, 2013 [Internet]. [cited 7 March 2014]. Edmonton (AB): Government of Alberta. Available from:
http://albertacanada.com/business/statistics/oil-sands-quarterly.aspx

Golder. 2003. Oil Sands Regional Aquatics Monitoring Program (RAMP) Five Year Report. Prepared for the RAMP Steering Committee by Golder Associates.

Golder. 2004. Review of historical fisheries information for tributaries of the Athabasca River in the oil sands region. Fort McMurray (AB): Regional Aquatics Monitoring Program. 194 p.

Government of Canada. 2008. Technical guidance document for water quality index practitioners reporting under the Canadian environmental sustainability indicators (CESI) initiative 2008. Ottawa (ON): Government of Canada. 48 p. En4-138/2010E-PDF 978-1-100-17220-0

Government of Canada. 2012. Joint Canada-Alberta implementation plan for oil sands monitoring. Ottawa (ON): Government of Canada. En84-89/2013E-PDF 978-1-100-21630-0. Available from: http://www.ec.gc.ca

Green RH. 1989. Power analysis and practical strategies for environmental monitoring. Environ. Res. 50:195-205.

Grey BJ, Harbicht SM, Stephens GR. 1995. Mercury in fish from rivers and lakes in southwestern Northwest Territories. Gatineau (QC): Northern Affairs Program, Northern Water Resources Studies, Aboriginal Affairs and Northern Development Canada.

Griffiths RW. 1998. Sampling and evaluating the water quality of streams in southern Ontario. Toronto (ON): Planning Policy Branch, Ministry of Municipal Affairs and Housing, Government of Ontario.

Griffiths RW. 1993. Effects of zebra mussels (*Dreissena polymorha*) on the benthic fauna of lake St. Clair. Zebra mussels: biology, impacts, and control. Edited by TF Nalepa and DW Schloesser. Lewis Publishers, Boca Raton, Fla. 414-437 pp.

Grigal DF. 2003. Mercury sequestration in forest and peatlands. J. Environ. Qual. 32: 393-405.

Güler C, Thyne JD, McCray JE, Turner AK. 2002. Evaluation of graphical and multivariate statistical methods for classification of water chemistry data. Hydrogeol. J. (2002) 10:455–474.

Güler C, Thyne GD, McCray JE, Turner AK. 2004. Evaluation of graphical and multivariate statistical methods for classification of water chemistry data. Hydrogeol. J. 10: 455-474.

Harvey HH, Whelpdale DM. 1986. On the prediction of acid precipitation events and the effect on fishes. Water, Air, Soil Pollut. 30: 579-586.

[Hatfield] Hatfield Consultants. 2009. Current state of surface water quality and aquatic ecosystem health in Alberta-Northwest Territories transboundary waters. Edmonton (AB): AENV. 222 p.

Hatfield. 2014. 2013 wetlands monitoring program for the Nexen Long Lake project. Report prepared for Nexen Inc. Fort McMurray (AB) by Hatfield Consultants, Vancouver (BC).

Hatfield and Kilgour & Associates Ltd. 2014. Draft Framework of Tiers and Triggers to Assess Environmental Monitoring Data. Report prepared for the Canadian Oil Sands Innovation Alliance. Calgary (AB) by Hatfield Consultants and Kilgour & Associates Ltd, Vancouver (BC).

Health and Welfare Canada. 1979. Methylmercury in Canada — exposure of Indian and Inuit residents to methylmercury in the Canadian environment. Ottawa (ON): Medical Services Branch, Health and Welfare Canada. 200 p.

Health Canada. 2007. Canadian standards ("maximum limits") for various chemical contaminants in foods. Ottawa (ON): Health Canada. http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php.

Hebben T. 2009. Analysis of water quality conditions and trends for the long-term river network: Athabasca River, 1960-2007. Edmonton (AB): AENV.

Henriksen A, Dillon PJ, Aherne J. 2002. Critical loads of acidity for surface waters in south-central Ontario, Canada: regional application of the steady-state water chemistry (SSWC) model. Can. J. Fish. Aquat. Sci. 59: 1287-1295.

Henriksen A, Kamari J, Posch M, Wilander A. 1992. Critical loads of acidity: Nordic surface waters. Ambio. 21: 356-363.

Henriksen A, Lien L, Traaen TS, Sevaldrud IS, Brakke DF. 1988. Lake acidification in Norway-present and predicted chemical status. Ambio. 17: 259-266.

Henriksen A, Skofheim OK, Rosseland BO. 1984. Episodic changes in pH and aluminium-speciation kill fish in a Norwegian salmon river. Vatten. 40: 255-260.

Herrman R, Pecher K. 1992. Behaviour of aluminum species within the hydrological cycle. Journal of Water Supply: Research and Technology-Aqua. 41:169-180.

Herschfield, DM. 1961. Rainfall frequency atlas of the United States. United States Department of Commerce. Weather Bureau Technical Paper 40.

Heyes A, Moore TR, Rudd JWM, Dugoua JJ. 2000. Methyl mercury in pristine and impounded boreal peatlands, experimental lakes area, Ontario. Can. J. Fish. Aquat. Sci. 57: 2211-2222.

Hoke RA, Geisy JP, Adams JR. 1990. Use of linear orthogonal contrasts in environmental data. Environ. Toxicol. Chem. 9:815-819.

Hvenegaard PJ, Boag TD. 1993. Burbot collections, Smoky, Wapiti and Peace rivers, October and November, 1992. Edmonton (AB): Northern River Basins Study Project, AENV. 13 p. plus appendices. Report No. 12.

Hunt JW, Anderson BS, Phillips BM, Newman J, Tjeerdema RS, Fairey R, Puckett HM, Stephenson M, Smith RW, Wilson CJ, Taberski KM. 2001. Evaluation and use of sediment toxicity reference sites for statistical comparisons in regional assessments. Environmental Toxicology and Chemistry. 20:1266-1275.

Hynes HBN. 1960. The biology of polluted waters. Liverpool (UK): Liverpool University Press.

Hynes HBN. 1970. The Ecology of Running Waters. Liverpool Univ. Press, Liverpool. 555 pp.

[INAC] Indian Northern Affairs Canada. 2003. Northern contaminants program-Canadian Arctic contaminants assessment report II; [updated 2006]. Available from: http://www.ainc-inac.gc.ca/nth/ct/ncp/pubs/hig/hil-eng.pdf

[IRIS] Integrated Risk Information System. 1998. Arsenic, inorganic. Washington (DC): IRIS, United States Environmental Protection Agency. Available from: http://www.epa.gov/iris/subst/0278.htm.

Ishi B, Laudon H, Seibert J, Mörth CM, Bishop K. 2008. Spatial heterogeneity of the spring flood acid pulse in a boreal stream network. Science of the Total Environment. 407(1): 708–722.

Jackson DA. 1993. Stopping rules in principal components analysis: a comparison of heuristic and statistical approaches. Ecology 74:2204-2214.

Jardine CG, Hrudey SE. 1998. Threshold detection values of potential fish tainting substances from oil sands wastewaters. Wat. Sci. Tech. 20: 19-25.

Jarvinen AW, Ankley GT. 1999. Linkage of effects to tissue residues: development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. Pensacola (FL): Society of Environmental Toxicology and Chemistry (SETAC). 364 p.

Jeffries DS. 1990. Snowpack storage of pollutants, release during melting, and impact on receiving waters. In: Norton SA, Lindberg SE, Page LA, editors. Acidic Deposition. Volume Four. New York (NY): Springer Verlag. p. 107-132.

Jeffries DS, Cox CM, Dillon PJ. 1979. Depression of pH in lakes and streams in central Ontario during snowmelt. Journal of the Fisheries Research Board of Canada. 36: 640-646.

Jeffries DS, Lam DCL. 1993. Assessment of the effect of acidic deposition on Canadian lakes: determination of critical loads for sulphate deposition. Water Sci. Technol. 28 (3-5): 183-187.

Jeffries DS, Semkin RG. 1983. Changes in snowpack, stream, and lake chemistry during snowmelt in the Turkey Lakes Watershed. VDI- Berichte Nr. 500: 377-387.

Jeffries DS, Snyder WR. 1981. Variations in the chemical composition of the snowpack and associated meltwaters in central Ontario. In: Proceedings of the Eastern Snow Conference, 38th Annual Meeting; 1981 June 4-5; Syracuse, NY. p. 11-22.

Johannes AH, Galloway JN, Troutman DE. 1980. In: Drablos D, Tollan A, editors. Proceedings of an International Conference on the Ecological Impact of Acid Precipitation; 1980; Sandefjord, Norway. p. 260-261.

Johannessen M, Henriksen A. 1978. Chemistry of snow meltwater: Changes in concentration during melting. Water Resources Research. 14: 615-619.

Jones HG. 1984. The influence of boreal forest cover on the chemical composition of snowcover. Proceedings of the 41st Eastern Snow Conference. Washington, D.C. 7–9 June, 1984: 126–138.

Jones RD, Boyer JN. 2002. FY2001 annual report of the water quality monitoring project for the water quality protection program in the Florida Keys national marine sanctuary. Southeast Environmental Research Center technical report #T181. Miami (FL): Florida International University. 48 p.

Kelly EN, Schindler DW, Hodson PV, Short JW, Radmanovich R, Nielsen CC. 2010. PNAS. 107(37): 16178-16183.

Kersting K. 1991. Microecosystem state and its response to the introduction of a pesticide. Internationale Verinigung fur Theoretische und Angewandte Limnologie Verhandlungen. 24: 2309-2312.

Kilgour BW, Somers, KM, Matthews, DE. 1998. Using the normal range as a criterion for ecological significance in environmental monitoring and assessment. Ecoscience. 5.4: 542-550.

Kilgour BW, Barton DR. 1999. Associations between stream fish and benthos across environmental gradients in southern Ontario, Canada. Freshwater Biol. 41: 553-566.

Kilgour BW, Munkittrick KR, Portt CB, Hedley K, Culp J, Dixit S, Pastershank G. 2005. Biological criteria for municipal wastewater effluent monitoring programs. Water Qual. Res. J. Can. 40:374-387.

Kilgour BW, Somers KM, Matthews DE. 1998. Using the normal range as a criterion for ecological significance in environmental monitoring and assessment. Écoscience. 5:542-5550.

Klemm DJ, Lewis PA, Fulk F, Lazorchak JM. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. U.S. Environmental Protection Agency. EPA/600/4-90/030. xii, 256 p.

Kline KM, Eshleman KN, Morgan II RP, Castro NM. 2007. Analysis of trends in episodic acidification of streams in western Maryland. Environmental Science and Technology. 41 (16): 5601-5607.

Krishnamoorthy K, Mathew T. 2009. Statistical Tolerance Regions, Theory, Applications, and Computation. John Wiley & Sons, Inc., New Jersey.

Kortelainen P, Mannio J, Forsius M, Kamari J, Verta M. 1989. Finnish lake survey: the role of organic and anthropogenic acidity. Water Air Soil Poll. 46: 235-249.

Kortelainen P, Saukkonen S. 1995. Organic vs. minerogenic acidity in headwater streams in Finland. Water, Air, and Soil Pollution. 85: 559-564.

Kundzewicz ZW, Robson AJ. 2004. Change detection in hydrological records-a review of the methodology. Hydrolog. Sci. 49(1).

Lau YK. 1982. Precipitation chemistry. Edmonton (AB): Pollution Control Division, Air Quality Control Branch, Alberta Environment. 75 p.

Laudon H, Bishop KH. 2002. The rapid and extensive recovery from episodic acidification in northern Sweden due to declines in SO_4^{2-} deposition. Geophysical Research Letters. 29: 1594.

Laudon H, Clair TA, Hemond HF. 2002. Long-term response in episodic acidification to declining $SO4^{2-}$ deposition in two streams in Nova Scotia. Hydrology and Earth System Sciences. 6(4): 773–781.

Laudon H, Hemond HF. 2002. Recovery of streams from episodic acidification in northern Sweden. Environmental Science and Technology. 36: 921-928.

Laudon H, Kohler S, Bishop KH. 1999. Natural acidity or anthropogenic acification in the spring flood of northern Sweden. Science of the Total Environment. 234: 67-73.

Laudon H, Norton SA. 2010. Drivers and evolution of episodic acidification at the Bear Brook Watershed in Maine, USA. Environmental Monitoring and Assessment. 171:59–69.

Laudon H, Westling O, Bishop KH. 2000. Cause of pH decline in stream water during spring melt runoff in northern Sweden. Canadian Journal of Fisheries and Aquatic Sciences. 57:1888-1900.

Laudon H, Westling O, Bergquist A, Bishop K. 2004. Episodic acidification in northern Sweden: A regional assessment of the anthropogenic component. Journal of Hydrology. 297(1–4): 162–173.

Laudon H, Westling SL, Bishop K. 2001. Modeling preindustrial ANC and pH during the spring flood in northern Sweden. Biogeochemistry. 54: 171–195.

Lawrence GB. 2002. Persistent episodic acidification of streams linked to acid rain effects on soil. Atmospheric Envrionment. 36: 1589-1598.

Legge AH (Kananaskis Centre of Environmental Research, University of Calgary, Calgary, AB). 1988. The present and potential effects of acidic and acidifying air pollutants on Alberta's environment. 79 p. ADRP-B-16-88. Prepared for the Acid Deposition Research Program.

Leivestad H, Muniz IP. 1976. Fish kill at low pH in a Norwegian river. Nature. 259: 391-392.

Lien L, Raddum GG, Fjelheim A. 1991. Critical Loads for Surface Waters. – Invertebrates and Fish. Acid Rain Research Report No. 21. Norwegian Institute for Water Research. 46 pp.

Lipkovich I, Smith EP. 2002. Biplot and singular value decomposition macros for Excel. Blacksburg (VA): Department of Statistics, Virginia Polytechnic Institute and State University.

Lowell RB, Ribey SC, Ellis IK, Porter EL, Culp JM, Grapentine LC, McMaster ME, Munkittrick KR, Scroggins RP. 2003. National assessment of the pulp and paper environmental effects monitoring data. Burlington (ON): National Water Research Institute, Environment Canada. NWRI Contribution No. 03-521.

MacCafferty WP, Randolph RP. 1998. Canada mayflies: a faunistic compendium. Proceedings of the Entomological Society of Ontario. 129: 47-97.

Mackay D, Shiu WY, Ma KC. 1992. Illustrated handbook of physical-chemical properties and environmental fate for organicchemicals I. Monoaromatics, chlorobenzenes, and PCBs. Boca Raton (FL): LewisPublishers.

Madarish DM, Kimmel WG. 2000. Benthic macroinvertebrate community structure in relation to seasonal and geochemical changes in a chronically acidified stream. J. Freshwater Ecology.: 15: 13-27.

Mandeville SM. 2001. Taxa tolerance values – benthic macroinvertebrates in freshwaters. Dartmouth (NS): Soil & Water Conservation Society of Metro Halifax. Project G-2.

Mandeville SM. 2002. Benthic macroinvertebrates in freshwaters-taxa tolerance values, metrics, and protocols. Dartmouth (NS): Soil & Water Conservation Society of Metro Halifax.

Merritt RW, Cummins KW. 1996. An introduction to the aquatic insects of North America, 3rd ed. Dubuque (IA): Kendall/Hunt.

Mill TA, Sparrow-Clark P, Brown RS. 1996. Fish distribution, movement and gross external pathology information for the Peace, Athabasca, and Slave river basins. Prepared for the Northern River Basins Study February 1997. NRBS Report No. 147.

Miller JF, Frederick RH, Tracey RJ. 1973. Precipitation-frequency atlas of the western United States. Silver Spring (MD): National Weather Service. National Oceanic and Atmospheric Administration (NOAA) atlas 2 volume 1.

Molot LA, Dillon PJ, LaZerte BD. 1989. Factors affecting alkalinity concentrations of streamwater during snowmelt in centarion Ontario. Canadian Journal of Fisheries and Aquatic Sciences. 46: 1658-1666.

Monikh FA, Karami O, Hosseini M, Karami N, Abdi Bastami A, Faraz Ghasemi A. 2013. The effect of primary producers of experimental aquatic food chains on mercury and PCB153 biomagnification. Ecotoxicology and Environmental Safety. 94: 112-115.

Mooi E, Sarstedt M. 2011. A concise guide to market research. Springer Berlin Heidelberg. 307 p.

Morrison LW. 2008. Use of control charts to interpret environmental monitoring data. Nat. Area J. 28(1): 66-73.

Munkittrick KR, McMaster ME, Van Der Kraak G, Portt C, Gibbons WN, Farwell A, Gray M. 2000. Development of methods for effects-driven cumulative effects assessment using fish populations: Moose River project. Pensacola (FL): Society of Environmental Toxicology and Chemistry (SETAC). 236 p.

Munson RK, Guerini SA. 1993. Influence of organic acids on the pH and acid-neutralizing capacity of Adirondack lakes. Water Resources Research. 29: 891-899.

[NAS] National Academy of Sciences. 1977. Arsenic. Washington (DC): NAS. 332 p.

Neff JM, Burns WA. 1996. Estimation of polycyclic aromatic hydrocarbon concentrations in the water column based on tissue residues in mussels and salmon: an equilibrium partitioning approach. Environ. Toxicol. Chem. 15:2240-2253.

Neff JM, Stout SA, Gunster DG. 2005. Ecological risk assessment of polycyclic aromatic hydrocarbons in sediments: identifying sources and ecological hazard. Integr. Environ. Assess. Manag. 1(1): 22-33.

Nielson DM. 2005. Practical handbook of environmental site characterization and ground-water monitoring. 2nd ed. Boca Raton (FL): CRC Press. 1,328 p.

Niemi GJ, DeVore P, Detenbeck N, Lima A, Pastor J, Yount JD, Naiman RJ. 1990. Overview of case studies on recovery of aquatic systems from disturbance. Environ. Manag. 14:5(571-587).

[NRBS] Northern River Basins Study. 1996. Contaminants in environmental samples: mercury in the Peace, Athabasca, and Slave river basins. Edmonton (AB): Northern River Basins Study Project, AENV. 66 p. Report No. 105.

Oilsands Advisory Panel. 2010. A foundation for the future: building an environmental monitoring system for the oil sands. Gatineau (QC): Environment Canada. Submitted to the Minister of Environment.

Oliver DR, Roussel ME. 1983. The insects and arachnids of Canada. Part 11. The genera of larval midges of Canada (Diptera: Chironomidae). Minister of Supply and Services, Ottawa (ON).

[OSDG] Oil Sands Developers Group. 2013. Oil Sands Project List - July 2013 [Internet]. [cited 7 March 2014]. Fort McMurray (AB): Oil Sands Developers Group. 10 p. Available from: http://www.oscaalberta.ca/library/

O'Toole CO, Donohue I, Moe SJ, Irvine K. 2008. Nutrient optima and tolerances of benthic invertebrates, the effects of taxonomic resolution and testing of selected metrics in lakes using an extensive European data base. Aquat. Ecol. 42(277-291).

Parrott J, Tetreault G, Colavecchia M, Hewitt M, Sherry J, McMaster M. 2002. Fish health effects from oil sands wastewater discharges and naturally-occurring oil sands compounds in the Athabasca River system. Burlington (ON): NWRI PERD Report 2002. 9 p.

Parsons BG, Watmough SA, Dillon PJ, Somers KM. 2010. Relationships between lake water chemistry and benthic macroinvertebrates in the Athabasca oil sands region, Alberta. J. Limnol. 69:118-125.

Paul AJ. 2013. Environmental flows and recruitment of walleye (Sander vitreus) in the Peace-Athabasca Delta. Can. J. Fish. Aquat. 70: 307-315.

Peck DV, Herlihy AT, Hill BH, Hughes RM, Kaufmann PR, Klemm DJ, Lazorchak JM, McCormick FH, Peterson SA, Ringold PL, et al. 2006. Environmental monitoring and assessment program - surface waters western pilot study: field operations manual for wadeable streams. Washington (DC): US EPA. EPA/620/R-06/003.

Pennak RW. 1989. Fresh-water invertebrates of the United States, protozoa to Mollusca. 3rd ed. New York (NY): John Wiley & Sons.

Plafkin JL, Barbour MT, Porter KD, Gross SK, Hughes RM. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency. EPA 440/4-89/001.

Prepas PA, Mitchell EE. 1990. The atlas of Alberta lakes. In: Mitchell PA, Prepas EE, editors. Edmonton (AB): University of Alberta.

R Development Core Team. 2012. R: A language and environment for statistical computing. Vienna (AT): R Foundation for Statistical Computing. ISBN 3-900051-07-0. Available from: http://www.R-project.org/.

[RAMP] Regional Aquatics Monitoring Program. 2003. RAMP 2002 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Golder Associates.

RAMP. 2004. RAMP 2003 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Jacques-Whitford; Mack, Slack, and Associates; and Western Resource Solutions.

RAMP. 2005. RAMP 2004 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants Ltd.; Stantec Consulting Ltd.; Mack, Slack, and Associates Inc.; and Western Resource Solutions. Revised November 2005.

RAMP. 2006. RAMP 2005 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Stantec Consulting; Mack, Slack, and Associates Inc.; and Western Resource Solutions.

RAMP. 2008. RAMP 2007 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Stantec Consulting; Klohn Crippen Berger; and Western Resource Solutions.

RAMP. 2009a. RAMP 2008 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; Klohn Crippen Berger; and Western Resource Solutions. April 2009.

RAMP. 2009b. RAMP technical design and rationale document. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; Klohn Crippen Berger; and Western Resource Solutions.

RAMP. 2010. RAMP 2009 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; Klohn Crippen Berger; and Western Resource Solutions.

RAMP. 2011. RAMP 2010 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; and Western Resource Solutions.

RAMP. 2012. RAMP 2011 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; and Western Resource Solutions.

RAMP. 2013. RAMP 2012 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; and Western Resource Solutions.

Ran Y, He Y, Yang G, Johnson JLH, Yalkowsky SH. 2002. Estimation of aqueous solubility of organic compounds by using the general solubility equation. Chemosphere. 48:487–509.

Reinhardt RL, Norton SA, Handley M, Amirbahman A. 2004. Dynamics of P, Al, and Fe during High Discharge Episodic Acidification at the Bear Brook Watershed in Maine, U.S.A. Water, Air and Soil Pollution: Focus June 2004, Volume 4, Issue 2-3, pp 311-323

Resh VH, Unzicker JD. 1975. Water quality monitoring and aquatic organisms: the importance of species identification. Res. J. Water Pollut. C. 47(1):9-19.

Reynoldson TB, Logan C, Pascoe R, Thompson. SP 1999. Methods manual: I. The creation of reference-condition data bases for benthic invertebrate community structure. NWRI Contribution No. 99-211.

Reynoldson TB, Logan C, Pascoe T, Thompson SP. 2004. CABIN (Canadian Aquatic Biomonitoring Network) invertebrate biomonitoring field and laboratory manual. Environment Canada, National Water Research Institute.

Reynoldson TB, Bailey RC, Day KE, Norris RH. 1995. Biological guidelines for freshwater sediment based on Benthic Assessment of Sediment (the BEAST) using a multivariate approach for predicting biological state. Australian Journal of Ecology 20: 198-219.

Reynoldson TB, Keller W, Somers K, Watson G, Brereton C. 2003. The development of an invertebrate RCA biomonitoring network for northern Ontario to meet metal-mining EEM requirements. Study design report, March 2003. Acadia University, Laurentian University and INCO Limited.

R.L. & L. Environmental Services Ltd. 1994. A general fish and riverine habitat inventory, Athabasca River, October 1993. Edmonton (AB): Northern River Basins Study Project, AENV. 129 p. Report No. 40.

[RMWB] Regional Municipality of Wood Buffalo. 2012. Municipal census 2012. Wood Buffalo (AB): RMWB. 156 p.

[RMCC] Research and Monitoring Coordinating Committee. 1990. The 1990 Canadian long-range transport of air pollutants and acid deposition report part 4: aquatic effects. Ottawa (ON): Federal–Provincial Research and Monitoring Committee. 151 p.

Rooke JB, Mackie GL. 1982. An ecological analysis of lotic environments: II. comparison to existing indices. J. Freshwat. Ecol. 1: 433-442.

Rosenberg DM, Resh VH, editors. 1993. Freshwater biomonitoring and benthic macroinvertebrates. New York (NY): Chapman & Hall. 488 p.

Saffron KA, Trew DO. 1996. Sensitivity of Alberta lakes to acidifying deposition: an update of maps with emphasis on 109 northern lakes. Edmonton (AB): Water Management Division, Alberta Environmental Protection. 70 p.

Schaefer D, Driscoll C, Van Dreason R, Yatsko C. 1990. The episodic acidification of Adirondack lakes during snowmelt. Water Resources Research. 26: 1639-1647.

Scott WB, Crossman EJ. 1973. Freshwater fishes of Canada. Bulletin 184. Ottawa (ON): Fisheries Research Board of Canada. 965 p.

[Shell] Shell Canada Limited. 2007. Jackpine Mine Expansion Project and Pierre River Mine Project - Application, Environmental Impact Assessment and Socio-Economic Assessment. Volume 4. Prepared by Golder Associates Ltd., Calgary, AB. Submitted December, 2007.

Shewhart WA. 1931. Economic control of quality of the manufactured product. New York (NY): Van Nostrand.

Simon TP. ed. 1998. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press.

Simon TP. (editor). 1999. Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton.

Singh KP, Malik A, Mohan D, Sinha S. 2004. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)–a case study. Water Res. 38(18): 3980-3992.

Small MJ, Sutton MC. 1986. A regional pH-alkalinity relationship. Water Res. 20: 335-343.

Smith RW. 2002. The use of random-model tolerance intervals in environmental monitoring and regulation. Journal of Agricultural, Biological, and Environmental Statistics. 7: 74-94.

St. Louis VL, Rudd J, Kelly CA, Beaty KG, Bloom NS, Flett RJ. 1994. Importance of wetlands as sources of methyl mercury to boreal forest ecosystems. Can. J. Fish. Aquat. Sci. 51: 1065-1076.

Stansley W, Cooper G. 1990. An acidic snowmelt event in a New Jersey (USA) stream: Evidence of effects on an indigenous trout population. Water, Air, and Soil Pollution. 53(3-4): 227-238.

Stewart KW, Stark BP. 1988. Nymphs of North American stonefly genera (Plecoptera). Lanham (MD): Entomological Society of America. 460 p.

Stottlemyer R, Toczydlowski D. 1990. Pattern of solute movement from snow into an upper Michigan stream. Can. J. Fish. Aquat. Sci. 47:290-300.

Stumm W, Morgan JJ. 1981. Aquatic Chemistry. 2nd edition. New York (NY): Wiley-Interscience.

Sullivan TJ. 2000. Episodic Acidification. In: Aquatic Effects of Acidic Deposition. Boca Raton (FL): Lewis Publishers. p. 139-153.

Syncrude Canada Ltd. 1977. Water quality and aquatic resources of the Beaver Creek diversion system, 1977. Prepared by Noton LR and Chymko NR, Chemical and Geological Laboratories Ltd., for Syncrude Canada Ltd. Environmental Research Monograph 1978-3.

Systat. 2004. Systat software manual. Chicago (IL): SYSTAT Software Inc.

Teck. 2011. Frontier oil sands mine project – environmental impact assessment vol 1-8 plus Appendices. Submitted by Teck Resources Ltd. and SilverBirch Energy Corporation.

Teskey HJ. 1969. Larvae and pupae of some eastern North American Tabanidae (Diptera). Mem. Entomol. Soc. Can. 101(63): 1-147.

Tetreault GR, McMaster ME, Dixon DG, Parrott JL. 2003. Using reproductive endpoints in small forage fish species to evaluate the effects of Athabasca oil sands activities. Environ. Toxicol. Chem. 22(11): 2775-2782.

Thorp JH, Covich AP. (eds.) 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. ISBN: 0-12-690645-9.

Timoney KP, Lee P. 2009. Does the Alberta tar sands industry pollute? The scientific evidence. Open Conserv. Biol. J., 3, 65–81.

Tranter M, Brimblecombe P, Davies TD, Vincent CE. 1985. Composition of meltwaters and preferential elution of solute from snowpack. EOS, Transactions American Geophysical Union. 66: 896.

Tranter M, Davies TD, Brimblecombe, P, Vincent CE. 1987. The composition of acidic meltwaters during snowmelt in the Scottish Highlands. Water, Air, and Soil Pollution. 36: 75-90.

Tranter M, Davies TD, Wigington PJ, Eshleman KN. 1994. Episodic acidification of surface waters in Canada. Water, Air, and Soil Pollution. 72: 19-39.

US Energy Information Administration. 2013. International energy statistics: proved reserves of crude oil (billion barrels) [Internet]. Washington (DC): United States Department of Energy; [cited January 2014]. Available from: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=57&aid=6

[USEPA] United States Environmental Protection Agency. 2000. Guidance for assessing chemical contaminant data for use in fish advisories vol. 1: fish sampling and analysis. 3rd ed. Washington (DC): Office of Water, USEPA. EPA-823-B-00-007.

USEPA. 2004. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: PAH mixtures. Washington (DC): Office of Research and Development, USEPA. EPA-600-R-02-013.

[USGS] United States Geological Survey. 1982. Measurement and computation of streamflow vol. 1: measurement of stage and discharge. Washington (DC): United States Government Printing Office. Prepared by Rantz SE et al. Geological Survey Water Supply Paper 2175.

Väinölä R, Witt JDS, Grabowski M, Bradbury JH, Jazdzewski K, Sket B. 2008. Global diversity of amphipods (Amphipoda; Crustacea) in freshwater. Hydrobiologia. 595:241-255.

Wenzel HG Jr. 1982. Rainfall for urban storm water design. In: Kibler DF, editor. Urban stormwater hydrology. American Geophysical Union Water Resources Monograph 7.

Westfall MJ, May ML. 1996. Damselflies of North America. Gainesville (FL): Scientific Publisher. 502 p.

Westgard JO, Barry PL, Hunt MR, Burnett RW, Hainline A, Thiers RE, Nipper H. 1981. A multi-rule Shewhart chart for quality control in clinical chemistry. Clin. Chem. 27:493-501.

Wetzel RG. 2001. Limnology – lake and river ecosystems. 3rd ed. San Diego (CA): Academic Press.

Whitfield CJ, Aherne J, Cosby J, Watmough SA. 2010. Modelling catchment response to acid deposition: a regional dual application of the MAGIC model to soils and lakes in the Athabasca oil sands region, Alberta. J. Limnol. 69: 147-160.

Whittier TR, Hughes RM, Lomnicky GA, Peck DV. 2007. Fish and amphibian tolerance values and an assemblage tolerance index (ATI) for western USA streams and rivers. T. Am. Fish. Soc. 136:254-271.

Wiederholm T, editor. 1983. Chironomidae of the Holarctic region: keys and diagnosis part 1 - larvae. Ent. Scand. Suppl. No. 19.

Wiggins GB. 1977. Larvae of the North American caddisfly genera (Trichoptera). Toronto (ON): University of Toronto Press. 401 p.

Wiggins GB. 1996. Larvae of the North American caddisfly genera (Trichoptera). Toronto (ON): University of Toronto Press.

Wigington PJ, Davies TD, Traner M, Eshleman KN. 1992. Comparison of episodic acidification in Canada, Europe, and the United States. Environmental Pollution. 78: 29-35.

Wigington PJ, DeWall DR, Kretser WA, Murdoch PS, Simonin HA, Van Sickle J, Baker JP. 1996a. Episodic acidification of small streams in the northeastern United States: Episodic Response Project. Ecological Applications 6: 374-388.

Wigington PJ, DeWall DR, Murdoch PS, Kretser WA, Simonin HA, Van Sickle J, Baker JP. 1996b. Episodic acidification of small streams in the northeastern United States: Ionic control of episodes. Ecological Applications. 6: 389-407.

Wilkinson KJ, Jones HG, Campbell PGC, Lachance M. 1992. Estimating organic acid contributions to surface water acidity in Quebec. Water, Air, and Soil Pollution. 61: 57-74.

Wrona FJ, Culp M, Davies RW. 1982. Macroinvertebrate subsampling: a simplified apparatus and approach. Can. J. Fish. Aquat. Sci. 39:1051-1054.

[WRS] Western Resource Solutions. 2001. Critical loads of acidity to 162 lakes samples by Alberta-Pacific forest industries during 1998. Report for Syncrude Canada Ltd.

WRS 2003. Analysis of the water quality of the Steepbank, Firebag, and Muskeg Rivers during the spring melt (1989-2001). Report by Western Resource Solutions for Alberta Environment and the Wood Buffalo Environmental Association.

WRS. 2004. Calculations of critical loads of acidity to lakes in the oil sands region. Fort McMurray (AB): CEMA. Report by Western Resource Solutions for the NO_x-SO_x Management Working Group, CEMA.

WRS. 2006. Critical loads of acidity to lakes in the Athabasca oil sands region – modification of the Henriksen model for lake organic content. Final report. Fort McMurray (AB): NO_x-SO_x Management Working Group, CEMA.

[WSC] Water Survey of Canada. 2001. Hydrometric technician career development program. Fredericton (NB): WSC, Environment Canada. Available from: http://www.smc-msc.ec.gc.ca/wsc/CDP/

Yan ND, Keller W, Somers KM, Pawson TW, Girard RE. 1996. Recovery of crustacean zooplankton communities from acid and metal contamination: comparing manipulated and reference lakes. Canadian Journal of Fisheries and Aquatic Sciences. 53: 1301-1327.

Zloty J, Pritchard G. 1997. Larvae and adults of Ameletus mayflies (Ephemeroptera: Ameletidae) from Alberta. The Canadian Entomologist. 129(2): 251-289.

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.
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
COSIA	Canada's Oil Sands Innovation Aliiance
CPUE	Catch Per Unit Effort
CVAFS	Cold Vapor Atomic Fluorescence Spectraphotometry
CV	Coefficient of Variation
CWN	Canadian Water Network
CWQG	Canadian Water Quality Guidelines
CYMM	Fort McMurray Airport Code
DFO	Fisheries and Oceans Canada
DL	Detection Limit
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EC	Environment Canada
EDA	Exploratory Data Analysis
EEM	Environmental Effects Monitoring
EIA	Environmental Impact Assessment
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Priority Areas
EPT	Ephemeroptera, Plecoptera, and Trichoptera
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
JOSMP	Joint Oil Sand Monitoring Plan
KIR	Key Indicator Resource
LSI	Liver Somatic Index
LTRN	Long-term Regional Network
LWD	Large woody debris
MAKESENS	Mann-Kendall test for trend and Sen’s slope estimates
MDL	Method Detection Limit
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
SPIN	Summer Profundal Index Netting
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