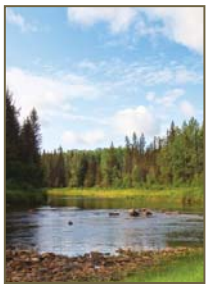
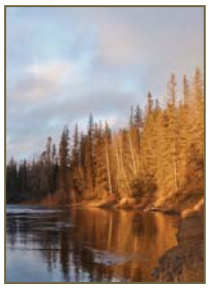
RAMP
Regional Aquatics Monitoring Program



2011 TECHNICAL REPORT

EXECUTIVE SUMMARY

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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 2011, RAMP was funded by Suncor Energy Inc., Syncrude Canada Ltd., Shell Canada Energy, Canadian Natural Resources Limited, Imperial Oil Resources, Nexen Inc., Husky Energy, Total E&P Canada Ltd., MEG Energy Corp., Dover Operating Corp., ConocoPhillips Canada, Devon Energy Corp., Teck Resources Ltd., Cenovus Energy, Japan Canada Oil Sands Ltd., and Hammerstone Corporation. Non-funding participants included municipal, provincial and federal government agencies and one First Nations group.

The Regional Municipality of Wood Buffalo 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-Christina rivers, 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, and Fort Creek);
- Specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- A selected group of 50 regional acid-sensitive lakes.

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

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

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

1. Climate and hydrology are monitored to provide a description of changing climatic conditions in the RAMP FSA, as well as changes in the water level of selected lakes and in the quantity of water flowing through rivers and creeks.
2. Water quality in rivers, lakes and the Athabasca River Delta is monitored to assess the potential exposure of fish and invertebrates to organic and inorganic chemicals.

3. Benthic invertebrate communities and sediment quality in rivers, lakes and the Athabasca River Delta are monitored because they reflect habitat quality, serve as biological indicators, and are important components of fish habitat.

4. Fish populations in rivers 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 2011 Technical Report to define those projects owned and operated by the 2011 industry members of RAMP listed above that were under construction or operational in 2011 in the RAMP FSA. For 2011, these projects included a number of oil sands projects and a limestone quarry project.

2011 RAMP industry members do have other projects in the RAMP FSA that were in the application stage as of 2011, or had received approval in 2011 or earlier, but construction had not yet started as of 2011. These projects are noted throughout this technical report, but are not designated as focal projects, as these projects in 2011 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 2011 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, AEW and CCME water quality and sediment quality guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in the measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources.

The RAMP 2011 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 2011) or were (prior to 2011) 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 2011 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 2011, it is estimated that approximately 94,300 ha of the RAMP FSA had undergone land change from focal projects and other oil sands developments. The percentage of the area of watersheds with land change as of 2011 varies from less than 1% for many watersheds (MacKay, Ells, Christina, Hangingstone, Horse, and Firebag rivers), to 1% to 5% for the Calumet, Poplar and Steepbank watersheds, to 5% to 10% for the Upper Beaver watershed, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, and McLean Creek watersheds, as well as the smaller Athabasca River tributaries from Fort McMurray to the confluence of the Firebag River.

ASSESSMENT OF 2011 MONITORING RESULTS

A tabular summary of the 2011 results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology The mean open-water period (May to October) discharge, open-water minimum daily discharge, annual maximum daily discharge, and mean winter discharge calculated from the observed *test* hydrograph were 0.5%, 1.4%, 0.3% and 1.9% lower, respectively, than from the estimated *baseline* hydrograph when only focal projects are considered. These differences were all classified as **Negligible-Low**. The results of the hydrologic assessment are essentially identical to results for the case in which focal projects plus other oil sands developments are considered.

Water Quality Differences in water quality measured in fall 2011 between all *test* and one of the upper *baseline* stations in the Athabasca River were classified as **Negligible-Low** compared to the regional *baseline* conditions, with the exception of the *test* station at the Muskeg River on the west bank of the Athabasca River, which showed **Moderate** differences from regional *baseline* conditions due to high TSS and associated particulate metals. Concentrations of water quality measurement endpoints at *test* stations were generally similar to those at the upstream *baseline* stations at Donald Creek on the east and west banks of the Athabasca River and consistent with regional *baseline* conditions. Concentrations of total aluminum and total iron exceeded guidelines at all stations, but no upstream-downstream station trends were observed.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at four locations in the Athabasca River Delta (ARD) in fall 2011:

1. Differences in measurement endpoints for benthic invertebrate communities in Big Point Channel in fall 2011 were classified as **Negligible-Low** because with the exception of the weak significant difference in Correspondence analysis (CA) Axis 1 scores, there were no significant time trends in any measurement endpoints for benthic invertebrate communities. All measurement endpoints were within previously-measured values for this reach.

2. Differences in measurement endpoints for benthic invertebrate communities in Fletcher Channel in fall 2011 were classified as **Moderate** because significant decreases in diversity and evenness accounted for greater than 20% of the variance in annual means. In addition, diversity and evenness in 2011 were lower than the range of previously-measured values for reaches in the delta, while EPT was higher in 2011 than previous years. The high relative abundance of tubificid worms in Fletcher Channel has been consistently observed since sampling began in 2002.

3. Differences in measurement endpoints for benthic invertebrate communities in Goose Island Channel in fall 2011 were classified as **Negligible-Low** because there were no strongly significant time trends in any measurement endpoints for benthic invertebrate communities. Values for all measurement endpoints were within previously-measured values for the reach and for all reaches in the ARD.

4. Differences in measurement endpoints for benthic invertebrate communities in the Embarras River in fall 2011 were classified as **Negligible-Low** because measurement endpoints were within previously-measured values for reaches in the ARD. High relative abundances of mayflies and caddisflies at this reach indicate that the community is robust and healthy.

Concentrations of sediment quality measurement endpoints at all five stations in the ARD showed generally low concentrations of hydrocarbons, metals and PAHs, which were similar to previously-measured concentrations. Similar to previous years, PAHs at all stations in fall 2011 were dominated by alkylated species indicating a petrogenic origin of these compounds. Sediment fractions at all stations in 2011 showed higher proportions of sand and lower concentrations of silt and clay than measured previously with the exception of Goose Island Channel, where silt was the dominant substrate. From 1999 to 2010, an increase in concentrations of total PAHs was observed in Big Point Channel, although this trend was not evident in concentrations of carbon-normalized total PAHs. In fall 2011, total PAH concentrations at this station were near previously-measured minimum concentrations. With the exception of Goose Island Channel, all stations in the ARD exhibited a decrease in total PAHs and total organic carbon in fall 2011 relative to fall 2010. The increase in total organic carbon in Goose Island Channel relative to 2010 may be related to the historically low proportions of silt and clay in fall 2010. Generally coarser sediments present at most delta stations in 2011 (with associated lower TOC, metals and total PAHs) relative to previous years may relate to the sedimentary regime in the delta in 2011, with less fine sediment deposited in 2011 due to high Athabasca River mainstem flows in summer 2011. The PAH Hazard Index was higher than previously-measured values for Goose Island Channel, and above the potential chronic toxicity threshold, while this measurement was lower than previously-measured at *test* station ATR-ER. The increase in the Hazard Index value at this station related to low concentrations of total hydrocarbons, rather than high concentrations of total PAHs; however, it suggests greater bioavailability of PAHs in sediments. Acute and chronic toxicity of sediments were lower than previously-measured for *Hyalella* survival at the station in the Embarras River, whereas growth for *Hyalella* was higher than previously-measured at stations in Big Point and Fletcher channels. Additionally, there was a significant improvement in *Chironomus* survival compared to 2010 at the station in Fletcher Channel.

Fish Populations (fish inventory) The Athabasca River fish inventory is considered to be a community-driven activity, primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than detailed community structure.

As of 2011, 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. Statistically significant differences were observed among years for condition in some KIR species; however, the variability of this measurement endpoint among years does not indicate consistent negative or positive changes in the fish populations and likely reflect natural variability over time.

The fish health assessment indicated that abnormalities observed in 2011 in all species were within the historical range and consistent with studies done prior to the major oil sands development in the upper Athabasca River, the ARD, and the Peace and Slave rivers.

Fish Populations (fish tissue) Measurement endpoints used in the assessment for the Athabasca River fish tissue program included metals and tainting compounds in fish tissue of both individual and composite samples. Potential human health risks from contaminated fish tissue were predicted from both individual and composite samples. In 2011, the mean concentration of mercury in lake whitefish was lower than previous years, with the exception of 2008 and the mean concentration of mercury in walleye was higher in 2011 compared to previous years, with the exception of 2003. The mean mercury concentration across all size classes of lake whitefish were below the Health Canada guideline for subsistence fishers indicating a **Negligible-Low** risk to human health. The mean mercury concentration in size classes of walleye greater than 300 mm exceeded the subsistence fishers guideline for consumption indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers.

Muskeg River Watershed

Hydrology The calculated mean open-water discharge was 7.1% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Moderate.** The calculated mean winter discharge and the open-water period minimum daily discharge were 85% and 261% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph, respectively. These differences were classified as **High**. The calculated annual maximum daily discharge was 4.4% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

Water Quality Concentrations of many water quality measurement endpoints in Jackpine Creek were higher than previously-measured maximum concentrations, primarily in dissolved species. Concentrations of water quality measurement endpoints in other portions of the Muskeg River watershed in fall 2011 were mostly within the range of previously-measured concentrations and generally consistent with regional *baseline* conditions. Differences in water quality in fall 2011 at all stations in the Muskeg River watershed compared to regional *baseline* water quality conditions were classified as **Negligible-Low**. Shelley Creek could not be sampled in 2011 because water has been diverted from this creek by approved oil-sands development.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored at five *test* reaches in the Muskeg River watershed in fall 2011:

1. Differences in the measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Muskeg River in fall 2011 were classified as **Negligible-Low** because the significant increase in total abundance in 2011 relative to 2010 and previous years did not coincide with changes in other measurement endpoints that would imply a negative change to the benthic invertebrate community (i.e., richness and diversity were also higher). The increase in total abundance (> 150,000 individuals per m^2 in 2011) could imply a significant increase in available habitat (or nutrients) for the benthic invertebrate community. The benthic invertebrate community at this reach; however, appears to be in good condition given the high relative abundances of mayflies, caddisflies and the presence of stoneflies. The percent of the fauna as worms (tubificids and naidids) was generally consistent with previous years indicating no significant change in the quality of the habitat (i.e., water and sediment quality).

2. Differences in the measurement endpoints of benthic invertebrate communities at the middle *test* reach of the Muskeg River in fall 2011 were classified as **Negligible-Low** because there was an increase in percent EPT, which does not imply a negative change and all measurement endpoints with the exception richness were within the range of variation for *baseline* depositional reaches. In fall 2011, richness exceeded the 95th percentile of regional *baseline* conditions, which was not indicative of degraded habitat.

3. Differences in the measurement endpoints of benthic invertebrate communities at the upper *test* reach of the Muskeg River in fall 2011 were classified as **Moderate** because the decrease in taxa richness from the *baseline* period to the *test* period explained 25% of the variation in annual means. In addition, the shift in composition suggested by variations in CA Axis 2 scores reflected an absence of *Hydracarina* in the reach over the last three years, an increase in tubificid worms in 2011, and a decrease in the relative abundance of mayflies. The absence of *Hydracarina* (i.e., water mites) were informative given that mites are not good "indicators" of water or substrate quality and the increase in the relative abundance of tubificid worms may indicate degraded conditions of the water or sediment quality. The percent of the fauna as tubificids has always been higher at this reach than the middle *test* reach despite the fact that the middle *test* reach has been designated as *test* since RAMP began sampling this reach in 2000. The decrease in the relative abundance of mayflies at the upper *test* reach may also indicate degraded conditions.

4. Differences in the benthic invertebrate community at the lower *test* reach of Jackpine Creek as of fall 2011 were classified as **Negligible-Low** because of the significant increases over time in taxa richness, diversity, and evenness at reach JAC-D1 once the reach became *test* do not imply a negative change in the benthic invertebrate community. In addition, values of some measurement endpoints in fall 2011 for benthic invertebrate communities at both the lower *test* reach and the upper *baseline* reach of Jackpine Creek exceeded the range of regional *baseline* conditions, but were not indicative of degraded conditions.

5. Differences in measurement endpoints for benthic invertebrate communities in Kearl Lake were classified as **Moderate** because of the significant decrease in percent EPT (i.e., mayflies and caddisflies) compared to the period when Kearl Lake was designated as *baseline* and the increase in multivariate CA Axis scores. The benthic invertebrate community of Kearl Lake contained a diverse fauna and included several taxa that are typically associated with relatively good water and sediment quality in lakes (e.g., the mayfly *Caenis* and the caddisfly *Mystacides*). The benthic invertebrate community of Kearl Lake in fall 2011 also contained higher relative abundances of ostracods and mites (totaling over 40% of total numbers) compared to previous years and compared to other lakes in *baseline* condition in the RAMP FSA

Sediment quality at all Muskeg River watershed stations sampled in fall 2011 was generally consistent with that of previous years and regional *baseline* conditions. Concentrations of total PAHs at all stations were within previously-measured concentrations with a few exceptions where concentrations of PAHs were lower than previously-measured concentrations. Differences in sediment quality in fall 2011 at all four stations in the Muskeg River watershed were classified as **Negligible-Low** compared to regional *baseline* conditions.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower and upper *test* reaches of the Muskeg River and regional *baseline* conditions were classified as **Negligible-Low** because most measurement endpoints were within the regional range of variation of *baseline* reaches. 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 all measurement endpoints were lower than the range of variation of *baseline* reaches (i.e., abundance, species richness, diversity, evenness, and the ATI value).

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

Steepbank River Watershed

Hydrology The calculated mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.37%, 0.46%, 0.25% and 0.24% greater, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Concentrations of many water quality measurement endpoints in the Steepbank River watershed in fall 2011 were higher than previously-measured concentrations, particularly at the middle *test* station of the Steepbank River, the *test* station on the North Steepbank River, and the upper *baseline* station of the Steepbank River. Although several ions were near previously-measured maximum concentrations at the lower *test* station of the Steepbank River, there were few variables that exceeded previously-measured maximum concentrations, perhaps due to the longer period of record at this station. When compared with regional *baseline* conditions for fall (1997 to 2011), 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 2011 was consistent with previous years, despite historically high concentrations of ions at several stations. Differences in water quality in fall 2011 at water quality monitoring stations compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for the middle *test* station of the Steepbank River, the *test* station on the North Steepbank River, and the upper *baseline* station on the Steepbank River. *Test* station STR-1 showed a **Moderate** difference from regional *baseline* conditions due to regionally high concentrations of some ions, suspended solids and some metals, although nearly all measurement endpoints were within previously-measured concentrations at this station.

Benthic Invertebrate Communities Differences in measurement endpoints of the benthic invertebrate community at the *test* reach of the Steepbank River were classified as **Moderate** because total abundance, richness, percent EPT, and CA Axis scores were significantly lower in this reach than the upper *baseline* reach. The benthic invertebrate community; however, was diverse at the lower *test* reach, and although it was numerically dominated by tolerant naidids, many other taxa that require cool, clean water, were documented indicating that there hasn't been an increase in degraded conditions at this reach over time. With the exception of total abundance, all values of measurement endpoints of benthic invertebrate communities were within the range of *baseline* conditions at both reaches of the Steepbank River.

Fish Populations Differences in fish assemblages observed in fall 2011 between the lower *test* reach of the Steepbank River and regional *baseline* conditions were classified as **Negligible-Low** with all median values of measurement endpoints within the range of regional *baseline* variability.

Tar River Watershed

Hydrology The calculated mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 17.6% 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 2011 between the Tar River and regional *baseline* fall conditions were classified as **Negligible-Low**. All water quality measurement endpoints at the upper *baseline* station and the lower *test* station of the Tar River in fall 2011 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints of the benthic invertebrate communities at the lower *test* reach of the Tar River were classified as **Moderate** because significant differences were observed for total abundance, taxa richness,

diversity, and evenness from before to after the reach was designated as *test* and because two of the five measurement endpoints were outside the range of variation for *baseline* depositional reaches. Percent EPT and CA axes scores 1 and 2 also varied over time (linearly) during the *test* period. In addition, the statistical signal in all of these differences explained more than 20% of the variance in the values of these measurement endpoints. The benthic fauna at the lower *test* reach was dominated numerically by tubificid worms, indicating that the reach is potentially exhibiting degrading conditions.

Differences in sediment quality observed in fall 2011 between the lower *test* station of the Tar River and regional *baseline* conditions were classified as **Moderate**, primarily because of high metal concentrations relative to *baseline* data. These high metal concentrations were likely related to the relatively high percent-fines measured in fall 2011 at *test* station TAR-D1, given similar metal concentrations were observed in TAR-1 in 2004, when percent-fines was similar to that observed in 2011. With the exception of total metals, concentrations of most other sediment quality measurement endpoints were within previously-measured concentrations in fall 2011, including total PAHs and predicted PAH toxicity, although CCME Fraction-4 and total hydrocarbons represented historical minimum concentrations.

Fish Populations Differences in measurement endpoints for fish assemblages at the lower *test* reach of the Tar River and regional *baseline* conditions were classified as **Negligible-Low** given there were no measurement endpoints that exceeded the regional range of variation of *baseline* reaches.

MacKay River Watershed

Hydrology The 2011 WY mean winter and open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated from the observed *test* hydrograph were 0.05% lower than from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality Concentrations of all water quality measurement endpoints in the MacKay River watershed in fall 2011 were within the range of previously-measured concentrations with the exception of total arsenic, which exceeded previously-measured concentrations at the upper *baseline* station. Water quality measurement endpoints in the MacKay River watershed in fall 2011 were within the range of regional *baseline* concentrations with the exception of total mercury, which was below the 5th percentile at the middle *test* station and the upper *baseline* station of the MacKay River. Water quality in fall 2011 at both *test* stations and the *baseline* station was very similar with differences relative to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Benthic Invertebrate Communities Differences in measurement endpoints for benthic invertebrate communities at the lower *test* reach of the MacKay River were classified as **Moderate** because percent EPT was significantly higher at the upper *baseline* reach compared to this reach and abundance and richness were significantly higher during the *baseline* period for this reach, although the statistical signal in the difference explained slightly less than 20% of the variance in annual means. Despite having a lower proportion of EPT taxa compared to the upper *baseline* reach, the benthic invertebrate community at the lower *test* reach still had a number of sensitive mayfly, stonefly and caddisfly taxa that are typical of an erosional watercourse. Differences in measurement endpoints of benthic invertebrate communities for the middle *test* reach of the MacKay River were classified as **Negligible-Low** because the significant increases in richness, diversity, and percent EPT did not imply a negative change in the benthic invertebrate community. The benthic invertebrate community at the middle *test* reach was diverse, and contained a number of sensitive chironomid, mayfly, stonefly and caddisfly taxa typical of an erosional watercourse.

Fish Populations Differences in measurement endpoints for fish assemblages between the lower and middle *test* reaches of the MacKay River and the regional *baseline* conditions were classified as **Negligible-Low** given there were no median values of measurement endpoints that exceeded the regional range of variation of *baseline* reaches.

Calumet River Watershed

Hydrology The 2011 WY mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge calculated from the observed *test* hydrograph were estimated to be 1.0% lower than from the estimated *baseline* hydrograph; these differences were classified as **Negligible-Low**.

Water Quality In fall 2011, water quality at the lower *test* station and the upper *baseline* station of the Calumet River showed **Negligible-Low** differences from regional *baseline* conditions. Concentrations of all water quality measurement endpoints at the lower *test* station in fall 2011 were within the range of regional *baseline* concentrations with the exception of total dissolved solids, dissolved phosphorous, total strontium, total arsenic and sodium, which exceeded the 95th percentile of regional *baseline* concentrations. The ionic composition of water at the lower *test* station was consistent with previous years, and the ionic composition of the upper *baseline* station returned to that of historical measurements after a deviation in fall 2010.

Firebag River Watershed

Hydrology The calculated mean open-water period discharge was 0.12% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph; the mean winter discharge and open-water minimum daily discharge were 0.11% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph, while the calculated annual maximum daily discharge was 0.10% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2011, water quality at the lower *test* station and upper *baseline* station of the Firebag River showed **Negligible-Low** differences from regional *baseline* water quality conditions. The ionic composition of water in fall 2011 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* station and upper *baseline* station of the Firebag River were within the range of regional *baseline* concentrations in fall 2011. Many water quality measurement endpoints, primarily ions and select metals, exceeded previously-measured maximum concentrations at all stations in the Firebag River watershed (Firebag River stations, McClelland Lake, and Johnson Lake).

Benthic Invertebrate Communities and Sediment Quality The differences in measurement endpoints for benthic invertebrate communities of McClelland Lake were classified as **Negligible-Low** because, while there were significant increases in total abundance, taxa richness, and diversity between the period the lake has been designated as *test* and the period it was designated as *baseline*, these increases generally imply improvements in water and/or sediment quality, particularly given that the dominant organisms in the lake did not change over time. The general composition of the community in terms of relative abundances, presence of fully aquatic forms and presence of generally sensitive taxa such as the mayfly *Caenis* and the caddisfly *Mystacides* all suggested that the benthic invertebrate community in McClelland Lake was in good condition and generally consistent with the community during the *baseline* period. The benthic invertebrate community of Johnson Lake was indicative of good water and sediment quality conditions due to a large relative abundance of permanent aquatic forms such as Amphipoda and bivalve clams, the presence of relatively sensitive and large aquatic insect larvae (caddisflies *Molanna*, *Molannodes* and *Oecetis*), and a low relative abundance of tubificid worms.

Concentrations of sediment quality measurement endpoints in McClelland Lake were generally within previously-measured concentrations in fall 2011, including total PAHs and predicted PAH toxicity, although concentrations of silt and total organic carbon were higher than previously-measured maximum concentrations and concentrations of sand and naphthalene were lower than previously-measured minimum concentrations. Sediment toxicity to invertebrates showed historically high survival of both *Hyalella* and *Chironomus*, and historically high growth of *Hyalella* in McClelland Lake. Fall 2011 represented the first year of sampling in Johnson Lake; sediment quality was generally similar to McClelland Lake, with the exception of concentrations of total hydrocarbons and total metals that were slightly higher, and measurement endpoints for sediment toxicity that were slightly lower.

Ells River Watershed

Hydrology The 2011 WY mean winter discharge (November to March) was 0.05% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The calculated mean open-water discharge (May to October), the annual maximum daily discharge, and the open-water minimum daily discharge were 0.07% 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 2011 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**. Water quality conditions were consistent with previous years for the lower *test* station and the middle *test* station of the Ells River and generally within the range of previously-measured concentrations and regional *baseline* conditions. Water quality at the upper *baseline* station of the Ells River in fall 2011 was similar to that at the other two stations and consistent with results from fall 2010 at this station.

Benthic Invertebrate Communities and Sediment Quality Differences in values of benthic invertebrate community measurement endpoints at the lower *test* reach of the Ells River were classified as **Negligible-Low** because the significant increase in taxa richness over time did not imply a negative change in the benthic invertebrate community. In addition, although evenness in fall 2011 was lower than regional *baseline* conditions, there were no other measurement endpoints that exceeded the range of *baseline* conditions and evenness was lower in 2005 than 2011. It should be noted; however, that habitat conditions at the lower *test* reach were of marginal quality for benthic invertebrate communities. The high relative abundance of tubificid worms, the absence of caddisflies and stoneflies, and the low relative abundance of mayflies, indicated an environment that was slightly limiting to depositional fauna. Differences in sediment quality observed in fall 2011 between the lower *test* station of the Ells River and regional *baseline* conditions were classified as **Moderate**, with concentrations of PAHs exceeding regional *baseline* conditions but within previously-measured concentrations at this station.

Fish Populations Differences in the fish assemblage observed in fall 2011 between the lower *test* reach of the Ells River and regional *baseline* conditions were classified as **Negligible-Low** with all median values of measurement endpoints within the range of regional *baseline* variability.

Clearwater-Christina River System

Hydrology The 2011 WY mean open-water period (May to October) discharge, annual maximum daily discharge, and open-water minimum discharge at the mouth of the Christina River were 0.02%, 0.03%, and 0.02%, respectively, greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality In fall 2011, water quality at stations on the Clearwater River, the Christina River, and the High Hills River indicated **Negligible-Low** differences from regional *baseline* conditions.

Concentrations of several water quality measurement endpoints were outside the range of previously-measured concentrations; however, this could be related to low water levels in September 2011, which would contribute to increases in conductivity, nutrients and dissolved species of metals. Concentrations of water quality measurement endpoints that were outside of regional *baseline* conditions were all lower than the 5th percentile of the range of *baseline* variation.

Benthic Invertebrate Communities and Sediment Quality Differences in values of measurement endpoints of benthic invertebrate communities at the lower *test* reach of the Clearwater River were classified as **Moderate** because of the significant differences in abundance, richness, and percent EPT between the lower *test* reach and the upper *baseline* reach. It should be noted that although the values of these measurement endpoints were generally lower at the *test* reach, values have increased in the two recent sampling years (2008 and 2001) to a level consistent with the *baseline* reach. Values of measurement endpoints at the *test* reach of the Clearwater River were well within the range of *baseline* conditions. In addition, the lower *test* reach was diverse, and contained a number of taxa considered sensitive to degrading habitat conditions including chironomids (e.g., *Lopesocladius*), mayflies (*Ametropus neavei*), and stoneflies (e.g., *Isoperla* and *Taeniopteryx*). There was a high percentage of worms, indicating potential organic enrichment as well as a high percent of chironomids and EPT taxa, which reflect good water quality.

Concentrations of sediment quality measurement endpoints at the lower *test* station and the upper *baseline* station of the Clearwater River in fall 2011 were generally lower than previously measured. The substrate at both stations was comprised almost entirely of sand, with low concentrations of total organic carbon. Direct measurements of sediment toxicity indicated good survival (i.e., ≥90%) at both stations. Differences in sediment quality in fall 2011 were classified as **Negligible-Low** compared to regional *baseline* conditions.

Fish Populations (fish inventory) Species richness in 2011 was higher than all years in spring, with the exception of 2007 and 2008; significantly higher than summer 2010; and lower than fall 2010 but within the historical range (2003 to 2011).

The relative abundance of fish species in the Clearwater River was variable without any clear trends observed over time. Similarly, there has been no marked shift in species dominance from year to year. There have been no significant differences in condition of large-bodied KIR fish species in the Clearwater River across years. Condition cannot necessarily be attributed to the environmental conditions in the capture location, as these populations are highly migratory throughout the region. In 2011, a shift towards a younger age class was observed in northern pike and walleye. Although uncertain, this may reflect increasing fishing pressure on adult fish over the years within the Clearwater River causing a shift to a population dominated by younger individuals.

Fish Populations (fish assemblage) The fish assemblage at the *baseline* reach of High Hills River was generally consistent with other *baseline* erosional reaches in the region and all median values of measurement endpoints were within the range of regional *baseline* conditions. The fish assemblage had a high proportion of slimy sculpin, which are typical of riffle habitat with faster flowing water.

Hangingstone River Watershed

Hydrology The 2011 WY mean open-water period discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Miscellaneous Aquatic Systems

Isadore's Lake and Mills Creek The calculated mean open-water discharge, minimum daily discharge, annual maximum daily discharge, and mean winter discharge for Mills Creek were 37% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **High**.

The water level in Isadore's Lake increased in late June and early July in response to rainfall events and backwater effects from the Athabasca River to the maximum recorded lake level over the 12-year record period at Isadore's Lake. Following the increase in lake levels in July, water levels receded to near lower quartile levels by the end of the 2011 WY.

Differences in water quality in fall 2011 between Mills Creek and regional *baseline* fall conditions were classified as **Moderate**, likely due to relatively high concentrations of many ions and other dissolved species that exceeded the 95th percentile of regional *baseline* concentrations. The ionic compositions of *test* stations in Isadore's Lake and Mills Creek were similar, with an increase in bicarbonate relative to previous years.

Differences in the benthic invertebrate community in Isadore's Lake were classified as **Negligible-Low** because there were no significant time trends in any of the benthic invertebrate community measurement endpoints. In addition, diversity was the only measurement endpoint that was outside (below) the range of previously-measured values. Historically, Isadore's Lake has had a unique benthic invertebrate community compared to other lakes in the region (e.g., McClelland, Kearl and Shipyard lakes), with low diversity and a high abundance of nematodes. While there has been very little negative change over time, the benthic invertebrate community in Isadore's Lake has been representative of a degraded system since sampling was initiated in 2006.

Shipyard Lake Concentrations of most water quality measurement endpoints in fall 2011 in Shipyard Lake were within previously-measured concentrations with only a few exceptions (i.e., sulphate and total strontium). The ionic composition of water continues to exhibit an increase in sodium and chloride concentrations relative to historical concentrations, perhaps due to reduced surface-water inflow and increased groundwater influence in the lake associated with focal projects in the upper portion of the Shipyard Lake watershed (the upper 93% of the Shipyard Lake watershed has been disturbed).

Differences in the benthic invertebrate community in Shipyard Lake in fall 2011 were classified as **Negligible-Low**. The increasing time trends in abundance and richness were significant and explained more than 20% of the variation in annual means, but did not imply a negative change in the benthic invertebrate community. The lake contained a number of fully aquatic forms including amphipods, clams and snails, indicating generally good water and sediment quality. Sediment quality was very similar to that observed in previous years, although Fraction-4 hydrocarbons were historically high. Three non-alkylated PAHs—benz[a]anthracene, benz[a]pyrene, and chrysene—exceeded the relevant CCME Interim Sediment Quality Guideline (ISQG) by approximately two times, but were between six and 12 times lower than the CCME Probable Effect Level (PEL).

Poplar Creek and Beaver River The calculated mean open-water discharge (May to October) was 4.9% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph of Poplar Creek. This difference was classified as **Negligible-Low**. The annual maximum daily discharge was 1.2% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**. The open-water minimum daily discharge was 1.8% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Negligible-Low**.

Concentrations of several water quality measurement endpoints, primarily ions and other dissolved species, were historically high and/or 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 historically high at *test* station POC-1 and *baseline* station BER-2, water quality was generally similar to regional *baseline* conditions, with differences classified as **Negligible-Low**.

Differences in measurement endpoints of benthic invertebrate communities at the lower *test* reach of Poplar Creek were classified as **Moderate** because of the significant difference in percent EPT and CA Axis scores compared to the upper *baseline* reach of the Beaver River, implying a negative change in the benthic invertebrate community. The benthic invertebrate community at the lower *test* reach was generally in good condition, reflected by low relative abundance of tubificid worms and higher relative abundance of fingernail clams; however, the low relative abundance of mayflies and caddisflies, and absence of stoneflies potentially indicated some level of disturbance.

Differences in sediment quality observed in fall 2011 at the lower *test* station of Poplar Creek and the upper *baseline* station of the Beaver River compared to regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of most sediment quality measurement endpoints were within the range or lower than previously-measured concentrations at both stations.

Differences in measurement endpoints for fish assemblages between the lower *test* reach of Poplar Creek and regional *baseline* conditions were classified as **Negligible-Low** because the decrease in the assemblage tolerance index (ATI) value in fall 2011 for this reach did not imply a negative change in the fish assemblage. A lower ATI value indicates that there is a greater proportion of sensitive fish species in the fish assemblage compared to the *baseline* reaches in the region.

McLean Creek Concentrations of water quality measurement endpoints at the *test* station on McLean Creek were often higher than previously-measured maximum concentrations and higher than regional *baseline* concentrations in fall 2011. Many ions and dissolved species of water quality measurement endpoints caused a shift in ionic balance, as well as a **Moderate** difference from regional *baseline* concentrations.

Fort Creek The calculated mean open-water period (May to October) discharge volume was 11.3% greater in the observed *test* hydrograph than in the estimated *baseline* hydrograph. This difference was classified as **Moderate**. In addition to changes in flow volume, variability in daily flow had also increased due to focal project activity in the watershed.

Differences in water quality in fall 2011 between the *test* station on Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**. Relatively high concentrations of several water quality measurement endpoints were observed in fall 2011 at the *test* station on Fort Creek, but these were within the range of previously-measured concentrations and within regional *baseline* water quality conditions. Only total iron exceeded relevant water quality guidelines. A large increase in the concentration of sulphate have been observed at this station since 2008 (although a slight decrease was observed in 2011), which appeared to have occurred in the absence of other apparent changes in ionic composition.

Differences in measurement endpoints of benthic invertebrate communities at the *test* reach of Fort Creek were classified as **High** because decreases in abundance, richness, diversity and evenness were significant and abundance, richness, diversity and evenness were below the 5th percentile of regional *baseline* conditions. There was also a shift in dominant taxa from chironomids in the *baseline* period to the more tolerant tubificid worms in the *test* period suggesting degradation of habitat quality at this reach.

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

Big Creek, Pierre River, Red Clay Creek, and Eymundson Creek Differences in water quality in fall 2011 between *baseline* stations on Big Creek, Pierre River, and Red Clay Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. Differences in water quality were classified as **Moderate** at the *baseline* station on Eymundson Creek, where concentrations of several water quality measurement endpoints exceeded water quality guidelines or regional *baseline* concentrations. The *baseline* station on Eymundson Creek also differed from the other *baseline* stations (Big Creek, Pierre River, and Red Clay Creek) in its ion balance, with a higher concentration of sulphate and less bicarbonate, which may suggest greater groundwater influence at this station

Acid-Sensitive Lakes

Results of the analysis of the 2011 RAMP lakes compared to historical data suggest that there was no significant change in the overall chemistry of the 50 RAMP lakes across years that were attributable to acidification. A long-term decline was noted for DOC, although this appeared to be the result of factors other than acidifying emissions (e.g., hydrology). Based on the analysis of among-year differences in concentrations of ASL measurement endpoints, as well as trend analysis and control plotting of ASL measurement endpoints on individual lakes, there was no evidence to suggest acidification in these lakes.

A summary of the state of the RAMP lakes in 2011 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In general, data in 2011 were more variable than previous years resulting in a greater number of exceedances of the two standard deviation criterion than in previous years. In most cases, these exceedances were caused by one lake in a subregion having unusual water chemistry in 2011 (e.g., Lake 225/WF5 in the West of Fort McMurray subregion, Lake 448/BM7 in the Birch Mountains and Lake 146/CM1 in the Caribou Mountains). There was no indication that acidification has occurred in any lakes and that these exceedances were caused by other factors influencing water chemistry such as changes in hydrology or groundwater inputs. Taking into account these other factors, the subregions were classified as having a **Negligible-Low** indication of incipient acidification.

Integration Analysis of RAMP Data

Over the last several years, RAMP has made an increasing effort to harmonize and integrate its monitoring components (i.e., water quality, sediment quality, benthic invertebrate communities and fish assemblages) with respect to space and time. This harmonization provided an opportunity to undertake exploratory analyses to gain a better understanding of possible relationships between environmental variables and the observed temporal and spatial variability in benthic invertebrate communities and fish assemblages of the region. From this analysis, the following general patterns were observed:

- Benthic invertebrate communities tended to be more abundant, rich and diverse during sampling periods or in rivers with low flows, which logically coincided with higher ion concentrations in water (conductivity, DOC, alkalinity);
- Benthic invertebrate community tended to be more abundant with increasing periphyton biomass. This may reflect a response to increasing food availability, particularly for grazing taxa such as Ephemeroptera and Plecoptera (among others), which also were found to increase with increasing periphyton;

- Neither benthos nor periphyton correlated with nutrient concentrations nor sediment chemistry (PAHs, metals, hydrocarbons), suggesting the variation in benthos communities is related to other chemical or physical factors unrelated to oil sands chemicals;
- As with benthic evenness, fish abundance and the fish assemblage tolerance index (ATI) in depositional reaches varied negatively with variables related to discharge; however, unlike benthic communities, fish richness and diversity were either not related (erosional reaches) or negatively associated (depositional reaches) with general ion concentrations in water; and
- Fish abundance was lower in depositional reaches with higher sediment concentrations of hydrocarbons/PAHs/metals; however, it is possible that fish assemblages were more difficult to capture in deeper pool/run depositional habitats using backpack/boat electrofishing gear.

Generally, strong relationships between variables describing benthic invertebrate communities and fish assemblages and environmental variables were limited; however, the above correlations do suggest some areas that warrant further investigation. As well, future analyses will need to consider other potential factors that may play a role in the observed variation in aquatic biota of the region.

Summary and Recommendations

The following table provides a summary of the 2011 RAMP monitoring program results, by watershed and component.

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

- Continue monitoring existing climate and hydrometric stations to enhance record length and data availability;
- Expand the climate and hydrologic monitoring network to support the provision of *baseline* and *test* hydrometric information and regional climate data;
- Evaluate additional hydrometric measurement endpoints and indicators (such as the timing and frequency of flow conditions) that would further support RAMP's assessment and understanding of aquatic conditions;
- Conduct water balance assessments as a consistent approach applicable to tributary watersheds, independent of the length of the data record, and, as possible, continue to refine inputs such as the time-step of industrial data;
- Continue to add *baseline* stations to the RAMP sampling design, particularly stations that are expected to remain *baseline* well into the future given the steady decline in the number of stations designated as *baseline* in the current RAMP design, and the need to continually update the ranges of natural variability (i.e., *baseline* conditions) in the RAMP FSA;
- Add seasonal sampling of water quality to assess any differences in water quality that may occur across seasons;
- Continue analyzing CCME 4-fraction Total Petroleum Hydrocarbons in water samples, with this suite of analytes replacing Total Recoverable Hydrocarbons;
- Continue to analyze for PAHs in water to further clarify sources of within- and among-watershed variability observed in PAH concentrations;

- Evaluate whether sampling erosional habitat in the mainstem Athabasca River is feasible based on habitat availability. If so, consider sampling benthic invertebrate communities using a Neill-Hess cylinder; otherwise, sampling could be conducted in more abundant depositional habitat using a grab sampling device, recognizing that the benthic invertebrate communities in depositional habitat will be dominated by more tolerant species;
- Consider the use of sediment traps in some channels (especially Fletcher Channel), to estimate sediment deposition rates (which may be changing over time as natural succession occurs in the ARD), and also to specifically assess concentrations of hydrocarbons and metal in sediments deposited in the ARD in a given year;
- Continue to develop more thorough protocols for assessing fish pathology in individual fish. RAMP is continuing to collect data on fish abnormalities and working with a fish pathologist to develop a better understanding of abnormalities in fish in Northern Alberta. RAMP is facilitating the analyses of fish with abnormalities submitted by community members and continues to find means to work with communities to assess fish health; and
- Based on the first year of the fish assemblage monitoring program, it was evident that there is value to the increased harmonization of the RAMP components in an effort to assess the surface watercourse conditions on a holistic basis. It is; therefore, recommended that RAMP continue this monitoring activity to gain more years of data to assess trends in fish assemblage measurement endpoints over time and in relation to water quality, hydrology, benthos, and sediment quality.

Summary assessment of RAMP 2011 monitoring results.

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

Legend and Notes

○ Negligible-Low change
● Moderate change
● High change

"-" program was not completed in 2011.

nm - not measured in 2011.

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

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

Note: As not all hydrology measurement endpoints are calculated for each watershed because of differing lengths of the hydrographic record for 2010, hydrology results above are for those endpoints that were calculated.

Note: All calculated hydrology measurement endpoints in the Muskeg River watershed were assessed as Negligible-Low with the exception of Annual Maximum Daily Discharge which was assessed as Moderate.

Note: All calculated hydrology measurement endpoints in the Fort Creek watershed were assessed as High with the exception of Annual Maximum Daily Discharge which was assessed as Negligible-Low.

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

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

[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 at all reaches in the Athabasca River Delta was assessed as Negligible-Low with the exception of Fletcher Channel, which was assessed as Moderate.

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

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

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

[5] **Fish Populations (Fish Assemblages):** Classification based on exceedances of measurement from the regional variation in *baseline* reaches; see Section 3.2.4.3 for a detailed description of the classification methodology.

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

[6] **Fish Populations (Fish Tissue):** Uses Health Canada criteria for risks to human health.

LKWH - lake whitefish; WALL - walleye.

Note: For Fish Population Human Health Classification - Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada.

[7] **Acid-Sensitive Lakes:** Classification based the frequency in each region with which values of seven measurement endpoints in 2010 were more than twice the standard deviation from their long-term mean in each lake.