1.0 INTRODUCTION

This document is the 2008 Technical Report of the Regional Aquatics Monitoring Program (RAMP), a joint environmental monitoring program which 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, Athabasca oil sands development stakeholders, Aboriginal communities, and local, provincial, and federal governments.

1.1 ATHABASCA OIL SANDS REGION BACKGROUND

With an estimated 269 billion m^3 (1.7 trillion barrels) of total reserves of bitumen, the Alberta oil sands are the largest component of Canada's known petroleum resources. The Alberta oil sands are a significant component of the world's petroleum resources, with its 27.4 billion m^3 (173 billion barrels) of remaining established bitumen reserves[1] (ERCB 2008) being equivalent to approximately one-third of the world's known reserves of conventional crude oil. Total bitumen deposits in the Athabasca oil sands region are the largest of Alberta's three oil sands regions, containing almost 81% of the total provincial reserves, with the total deposits in the Cold Lake and Peace River areas being significantly smaller.

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 11% of the estimated established bitumen reserves were under active development as of the end of 2007, and 3% of the estimated established bitumen reserves of the Athabasca oil sands region have been extracted by the end of 2007 (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)		1,377,958
Estimated Established Reserves		143,824*
Established Reserves under Active Development as of 31 December 2007		24,971
Mineable	23,479	
in situ	1,491	
Cumulative Production as of 31 December 2007		4,285
Mineable	3,944	
in situ	341	
Remaining Established Reserves		139,540

Data from ERCB (2008); all figures are as of 31 December 2007.

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

[1] Established bitumen reserves are defined as the amount of bitumen that is recoverable under current technology and present and anticipated economic conditions specifically proved by drilling, testing, or production, plus the portion of reserves that are interpreted to exist from geological, geophysical, or similar information with reasonable certainty (ERCB 2008). Remaining established bitumen reserves are established bitumen reserves less cumulative bitumen production.

In addition to RAMP, two other multi-stakeholder organizations address issues related to the environmental integrity of the Athabasca oil sands region in response to other development in the RMWB, including:

- Cumulative Environmental Management Association (CEMA) – established to develop guidelines and management frameworks on how best to reduce cumulative environmental effects due to industrial development. CEMA is focusing on acid deposition; terrestrial biodiversity and landscape-diversity; ground-level ozone; land capability; trace metals and air contaminants; and ecosystem management; and
- Wood Buffalo Environmental Association (WBEA) – established to monitor and provide 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 fourteen 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 hence traditional resource use in the Athabasca oil sands region; and
  - A human exposure monitoring program, initiated in 2005, designed to monitor select air contaminants to which individuals in the RMWB are exposed.

1.2 OVERVIEW OF RAMP

The Regional Aquatics Monitoring Program (RAMP) 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 more comprehensive and cost-effective regional database 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.

1.2.1 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 Regional Municipality of Wood Buffalo, 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.

1.2.2 Organization of RAMP

RAMP is governed by a multi-stakeholder Steering Committee. Membership in this decision-making body is comprised of oil sands and other industries, government agencies (municipal, provincial and federal), Aboriginal representatives, environmental non-government organizations and other independent stakeholders (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 (i.e., the Hatfield RAMP Team, consisting of Hatfield Consultants Partnership, Klohn Krippen Berger Ltd., Kilgour and Associates Ltd., and Western Resource Solutions) primarily carry out the fieldwork, data analysis and reporting, as defined by the program. A Finance Subcommittee focuses on issues related to the budget and funding for the annual monitoring. Finally, RAMP has a Communications Sub-Committee for the purpose of transferring information and monitoring results to local stakeholders and the scientific community. When appropriate, the Sub-Committee participates in communications activities in collaboration with WBEA and CEMA.

In 2008, RAMP was funded by Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude), Shell Canada Ltd. (Shell), Albian Sands Energy Inc. (Albian), Canadian Natural Resources Ltd. (Canadian Natural), Imperial Oil Resources (Imperial Oil), Petro-Canada, OPTI Canada Inc. (OPTI)/Nexen Inc. (Nexen), Husky Energy (Husky), Total E&P Joslyn Ltd. (Total E&P, includes the Northern Lights Project formerly owned by Synenco Energy Inc.), and Birch Mountain Resources Ltd. (Birch Mountain).

Figure 1.2-1 RAMP organizational structure[1].

STEERING COMMITTEE		
Industry	**Stakeholders**	**Government**
Alberta Pacific Forest Industries Inc.	Fort Chipewyan Metis Local No. 125	Alberta Energy Resources Conservation Board
Shell Canada Ltd.	Fort McKay First Nations	Alberta Environment
Albian Sands Energy Inc.	Fort McKay Metis Local No. 122	Fisheries and Oceans Canada
Birch Mountain Resources Ltd.	Fort McMurray First Nations	Environment Canada
Canadian Natural	Mikisew Cree First Nations	Health Canada
Husky Energy		Regional Municipality of Wood Buffalo
Imperial Oil Resources		Northern Lights Health Region
Nexen Inc.		Alberta Health and Wellness
OPTI Canada Inc.		
Petro-Canada		
Suncor Energy Inc.		
Syncrude Canada Ltd.		
Total E&P Joslyn Ltd./Canada[2]		
(Secretary: Hatfield Consultants)		

Finance Sub-Committee	Technical Program Committee	Communications Sub-Committee	Investigators
All funding participants, and any interested Steering Committee members	Representatives from industry, communities, government, and investigators	Representatives from industry, communities, government, and investigators	Consultants, Aboriginal community representatives, industry representatives, and Alberta Environment

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

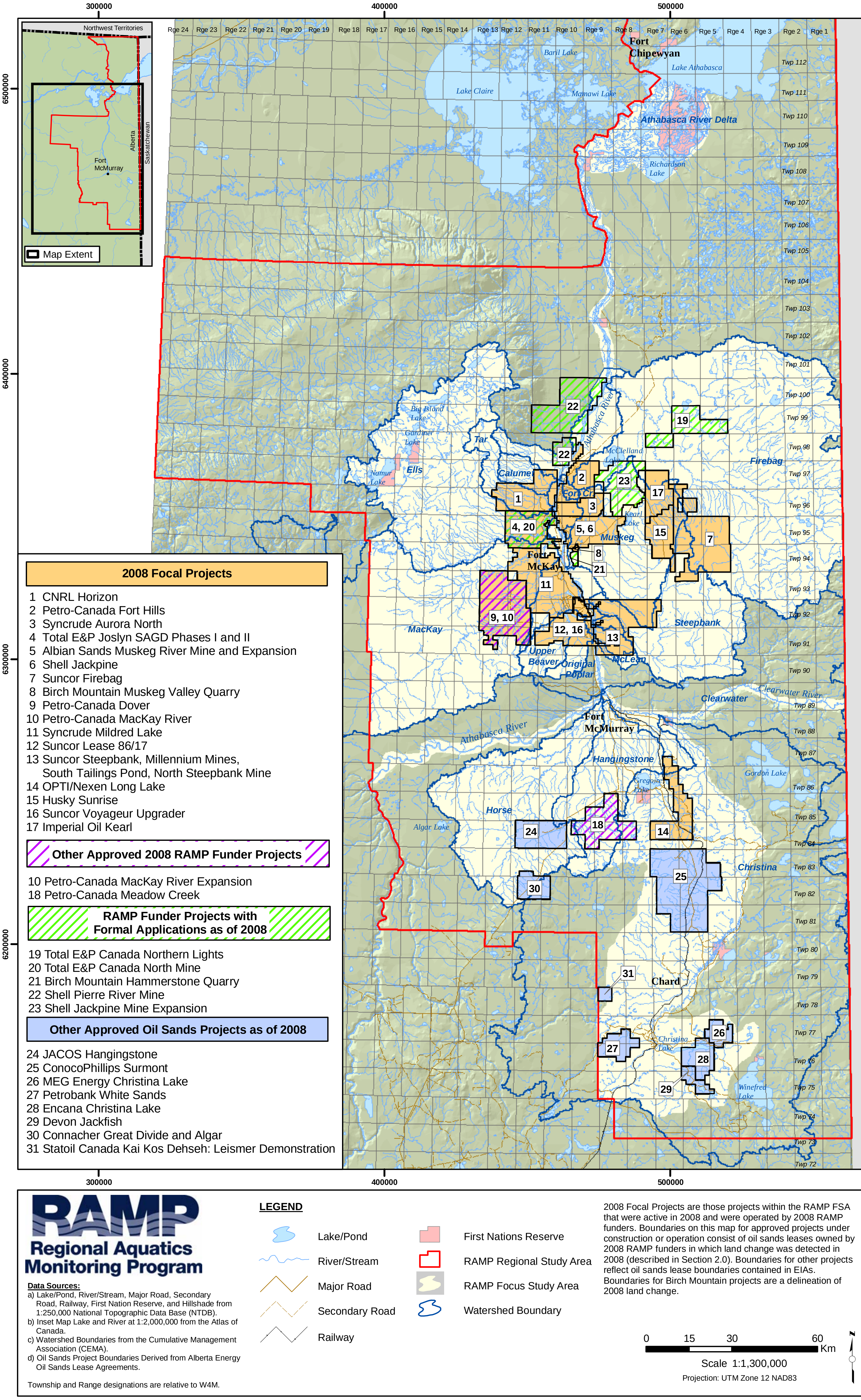
[1] composition of Steering Committee as of December 2008

[2] bought Synenco Energy Inc. in 2008 including projects previously under development by Synenco

1.3 RAMP STUDY AREAS

The RMWB in northeastern Alberta defines the RAMP Regional Study Area (RSA, Figure 1.3-1). The RMWB covers an area of 68,454 km², and according to the 2007 Municipal Census had a population of approximately 90,000 persons of which approximately 65,400 persons were residents of Fort McMurray and approximately 18,500 persons were in work-camps (RMWB 2007). The RAMP RSA is bounded by the Alberta-Saskatchewan border on the east, the Alberta-Northwest Territories border on the northeast, 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.

Figure 1.3-1 RAMP study areas.



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). Accordingly, much of the intensive monitoring activity is conducted within the RAMP FSA.

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 a recent initial assessment of the ecological health of the water quality, sediment quality, and non-fish biota was recently conducted as part of the Healthy Aquatic Ecosystems component of the initiative (Alberta Environment 2007).

The upper 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 River and Christina rivers, as well as a series of smaller rivers, primarily the Hangingstone and the Horse rivers. The area is characterized by a predominantly sub-humid mid-boreal ecoclimate, closed stands of trembling aspen, balsam poplar with white spruce, black spruce, and balsam fir occurring in late successional stages, as well as cold and poorly-drained fens and bogs covered primarily with tamarack and black spruce. The western part of the southern portion of the RAMP FSA has little relief and is poorly-drained.

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

As the Athabasca River flows northward through the RAMP FSA, several smaller tributary streams and rivers join and contribute to the overall flow (Figure 1.3-2). 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 and planned *in situ* oil sands developments in the southern portion of the RAMP FSA;
- Hangingstone River – a small river originating in the southwestern portion of the RAMP FSA, joining the Clearwater River immediately upstream of Fort

McMurray, and whose watershed includes the Petro-Canada *in situ* Meadow Creek Project and the JACOS (Japan Canada Oil Sands Limited) *in situ* Hangingstone Project;

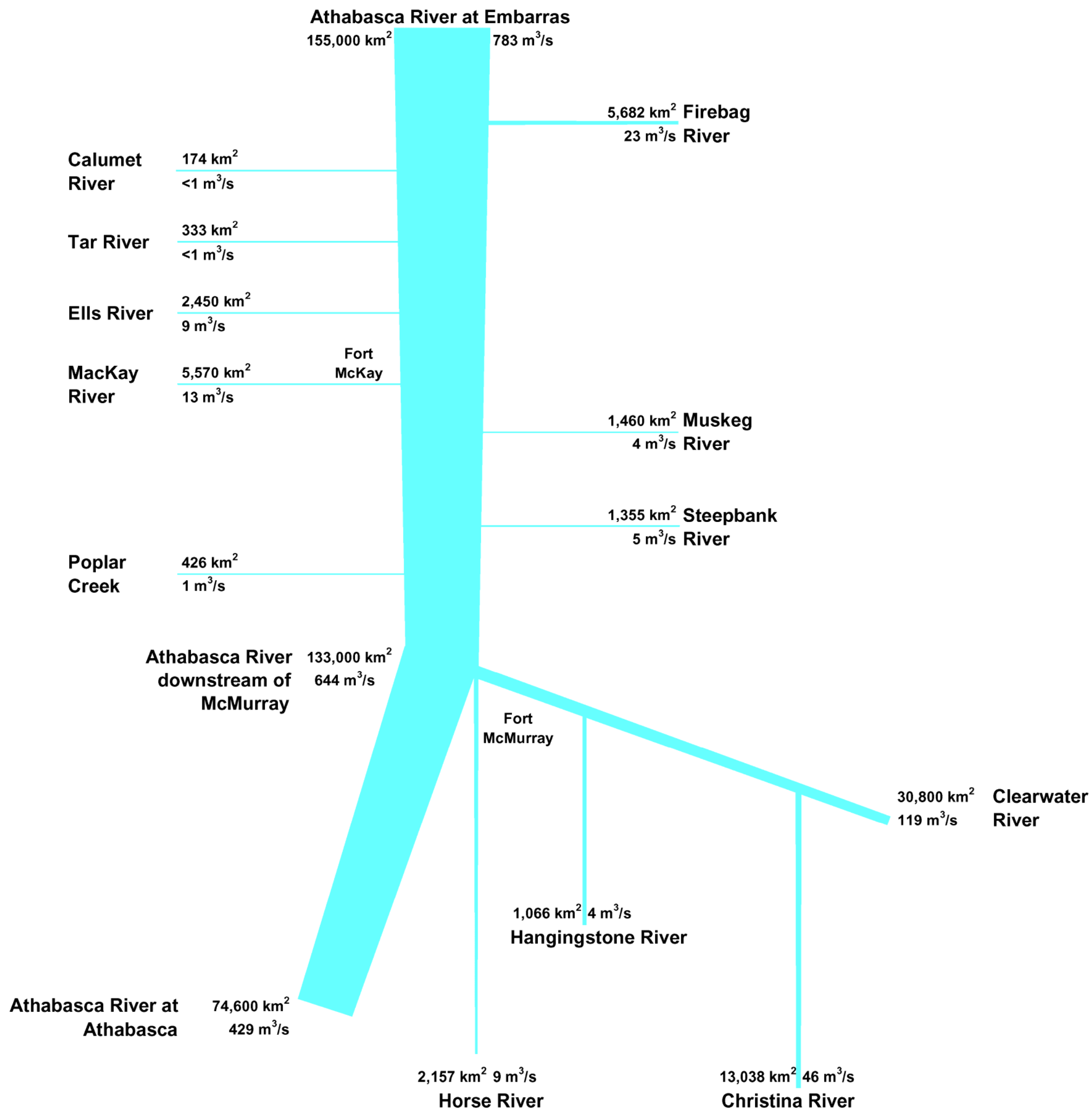
- Steepbank River – joins the Athabasca River from the east and whose watershed includes Suncor's existing Steepbank/Project Millennium mines and extensions, the Suncor North Steepbank Mine, and part of the Suncor *in situ* Firebag Project;
- Muskeg River – flows from the east and drains several oil sands development areas, including the Albian Sands Muskeg River Mine and Expansion, Shell Jackpine Mine, Syncrude Aurora North Mine and planned Aurora South Mine, part of the Suncor *in situ* Firebag Project, Imperial Oil Kearl Project, Husky *in situ* Sunrise Thermal Project, and Birch Mountain Muskeg Valley Quarry and recently-approved Hammerstone quarry;
- MacKay River – flows from the west and whose watershed includes the Petro-Canada MacKay River and Dover developments, as well as the approved MacKay River expansion, and portions of Syncrude Mildred Lake project area;
- Ells River – flows from the west and whose watershed includes a small portion of the Canadian Natural Horizon Project, the *in situ* projects of Total E&P Joslyn, and the proposed Total E&P Canada Joslyn North Mine Project; this river is also the drinking water source for Fort McKay;
- Tar River – also flowing from the west, whose watershed contains most of the Canadian Natural Horizon Project;
- Calumet River – similar to the Tar River, flowing 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, parts of the Petro-Canada Fort Hills Project, Husky *in situ* Sunrise project, and Imperial Kearl Project.

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

- tributaries within watersheds described above (e.g., Muskeg Creek, Wapasu Creek);
- smaller river tributaries of the Athabasca River (Fort Creek, Mills Creek, Poplar Creek, McLean Creek, and Beaver River) which contain parts of a number of oil sands projects, including the Petro-Canada Fort Hills Project (Fort Creek), Albian Sands Mine (Mills Creek), Syncrude's Mildred Lake developments (Beaver River), and Suncor's 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, and Kearl Lake;
- a set of regional lakes important from a fisheries perspective; and
- a set of lakes throughout the RAMP FSA 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, particularly the Fish Population component. This includes the Horse and Dunkirk rivers.

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



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

1.4 GENERAL RAMP MONITORING AND ANALYTICAL APPROACH

1.4.1 Focal Projects

While most of the 2008 RAMP funders are companies that are constructing and operating oil sands projects in the RAMP FSA, other RAMP funders, such as Birch Mountain, are companies constructing and operating other projects in the RAMP FSA. Therefore, the term "focal projects" is used in the 2008 Technical Report and is defined as those projects owned by 2008 RAMP funders (Section 1.2.2) that were under construction or operational in 2008 in the RAMP FSA. For 2008, these projects include a number of oil sands projects and a limestone quarry project (in the case of Birch Mountain); the focal projects are listed and described in Section 2.0.

2008 RAMP funders do have other projects in the RAMP FSA that were in the application stage as of 2008, or which received approval in 2008 or earlier, but on which construction had not yet started as of 2008. These projects are noted throughout this technical report but are not designated as focal projects, as these projects in 2008 would not have contributed to any possible influences on aquatic resources covered by RAMP components.

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 potential changes related to development. Examples from RAMP include specific water quality variables and changes in water quantity.

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. More recently, 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, benthic invertebrates, vegetation) 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 1992, 2002, 2003, 2005). 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 2008 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** – benthic invertebrate communities serves as a biological indicator and are important component of fish habitat, while sediment quality is a link between physical and chemical habitat conditions to benthic invertebrate communities;
- **Fish Populations** in rivers and lakes – biological indicators of ecosystem integrity and a highly-valued resource in the Athabasca oil sands region; and
- **Acid-Sensitive Lakes** – monitoring of water quality in regional lakes in order to assess potential changes in water quality as a result of acidification.

1.4.4 Monitoring Approaches for RAMP Components

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

1.4.4.1 Climate and Hydrology

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

Streams in the same region may have different hydrologic characteristics related to differences in topography, vegetation, surficial geology, lake storage, groundwater-surface interaction and geographic influences on precipitation. Accordingly, the scope of the RAMP Climate and Hydrology component has gradually expanded geographically to include catchments affected, or expected to be affected, by focal projects in the area around Fort McMurray. Some watersheds outside the catchments containing 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 and Alberta Environment climatic and hydrologic monitoring stations in the Athabasca oil sands region are also integrated into the RAMP database to provide greater spatial and temporal context.

Some streams are monitored year-round, while others, particularly smaller streams that tend to freeze completely in winter, are monitored only during the open-water season. RAMP also monitors winter (November to April) flows on some streams that Environment Canada and Alberta Environment monitor during the open-water season.

1.4.4.2 Water Quality

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

The specific objectives of the Water Quality component are to:

- develop 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 the development, 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 increasing development, including the focal projects.

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

RAMP water quality stations are located throughout the RAMP FSA, from the upper Christina River to the Athabasca River downstream of development. Water quality is monitored annually each fall when water flows are generally low and the resulting assimilative capacity of a receiving waterbody is limited. New water quality stations located in waterbodies already monitored by RAMP are sampled seasonally (i.e., in winter, spring, summer and fall) in the first year to determine seasonal variation in water quality. Three years of seasonal baseline data are collected at stations established in new waterbodies and watercourses.

1.4.4.3 Benthic Invertebrate Communities and Sediment Quality

Benthic macroinvertebrates are a commonly-used indicator of aquatic environmental conditions. Benthic invertebrate communities are included as a component of the RAMP for a variety of reasons:

- They integrate biologically relevant variations in water, sediment and habitat quality;
- Given 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 benthic invertebrate life span (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 what animals are present (Rooke and Mackie 1982).

The RAMP Benthic Invertebrate Community component has three objectives:

- collect scientifically defensible baseline and historical data to characterize variability 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 relative dominance in areas downstream of development relative to benthic invertebrate communities upstream of development.

The Benthic Invertebrate Community 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 three areas within the Athabasca River Delta because that is an area of significant sediment deposition, and an area that is considered to have the potential to be affected by long-term development in the RAMP FSA.

With an increasing number of focal projects, the component has expanded to include new Athabasca River tributaries and additional stations on 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 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 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 community component to provide a better link of physical and chemical habitat conditions to a specific biological endpoint. Beginning of 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 the same as in past years:

- 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 biotic communities in the aquatic environment.

A range of compounds are measured to characterize sediment quality: particle size; carbon content; target and alkylated PAHs (polycyclic aromatic hydrocarbons); total hydrocarbons; and metals. Sub-lethal bioassay tests also are conducted to assess potential toxicity related to chronic exposure of different aquatic organisms to sediments from selected stations.

1.4.4.4 Fish Populations

The goal of the RAMP Fish Population component is to monitor the health and sustainability 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 Population 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 migration patterns in the Athabasca oil sands region. The core elements of the Fish Population component are:

- fish inventories and spawning surveys;
- tissue sampling for organic and inorganic chemicals;
- monitoring of fish health through evaluation of performance indicators (physical condition, population age, and length/weight comparisons) in sentinel fish species; and
- monitoring of fish population movements using fish fences.

Specific key indicator fish species (or key indicator resources, KIRs) have been identified for the Athabasca River and select 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 2009). Although the Fish Population 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.

RAMP conducts fish tissue assessments to 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. As part of the ongoing program, muscle tissues are collected from lake whitefish and walleye from the Athabasca River and northern pike from the Clearwater and Muskeg rivers. 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 other agencies (e.g., Alberta Sustainable Resources Development [ASRD]), either through opportunistic sampling, or in conjunction with fisheries investigations mandated separately from RAMP. The program, known as the "Regional Lakes Program", has to date included analysis of fish tissue from Gregoire (Willow) Lake (2002, 2007), Lake Claire (2003), Christina Lake (2003), Winefred Lake (2004), Namur (Moose) Lake (2007), Gardiner (Buffalo) Lake (2008) and Big Island Lake (2008).

General fish inventories are conducted to monitor and assess temporal and spatial changes in species presence, relative abundance and population variables in selected watercourses. In the Athabasca and Clearwater rivers, the inventory is conducted annually in the spring and fall (and the summer in 2008 on the Athabasca River) and is designed to assess populations of large-bodied key indicator species in the vicinity of focal projects. Other watercourses such as Muskeg River, MacKay River, Christina River and the Firebag River have been surveyed in the past as part of the RAMP Fish Population component. 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 frequency of fish anomalies.

Sentinel fish species monitoring is part of the RAMP Fish Population component to assess the potential effects of stressors on populations of fish species that have limited movement relative to the location of the potential stressors. The approach evaluates the performance (characterized by growth, survival, condition, and reproduction) of a specific sentinel species in test areas downstream of development relative to baseline and/or historical performance data. 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 2005) and metal mining (Environment Canada 2002, 2003) effluent regulations. Sentinel species monitoring is conducted at regular intervals at several sites in the Athabasca River (trout-perch), as well as several Athabasca tributaries including the Muskeg and Steepbank Rivers (slimy sculpin), and the Ells River (longnose dace).

Fish fence monitoring by RAMP, limited to the Muskeg River, is used to generate data on the biology and movement of spawning populations of large-bodied fish species that use the Muskeg River and its tributaries. These data assist in the identification and quantification of local and watershed-level environmental changes in the Muskeg River drainage.

1.4.4.5 Acid-Sensitive Lakes

The Regional Sustainable Development Strategy (RSDS) identified the importance of protecting the quality of water, air and land within the Athabasca oil sands region (AENV 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 which would provide specific measurement endpoints capable of detecting incipient lake acidification;
- collect scientifically defensible baseline and historical data (both chemical and biological) to characterize the natural variability of these measurement endpoints in the regional lakes;
- collect data on the regional lakes against which predictions contained in environmental impact assessments (EIAs) could be verified; and
- quantify and document individual lake sensitivity to acidification.

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

The ASL component contains the following features:

- The locations of the lakes are selected to represent a gradient in acid deposition from both current and anticipated developments in the RAMP FSA;
- For scientific validity, the lake selection includes lakes in the Caribou Mountains and Canadian Shield that are distant from the sources of acidifying emissions;
- Certain regional lakes, which have been the subject of long-term monitoring by AENV, are included to maintain the continuity of their data and additional information on potential trends;
- The lakes selected for monitoring exhibit moderate to high sensitivity to acidification as defined by a total alkalinity less than 400 μeq/L;
- 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; and
- 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.

1.4.5 Definition of Terms

Finally, 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 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 2008) or were (prior to 2008) 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.

1.4.6 Overall Analytical Approach for 2008

For the 2008 RAMP Technical Report, the overall analytical approach builds on analytical approaches used in RAMP in previous years and as described in the RAMP Technical Design and Rationale (RAMP 2009) (Figure 1.4-1). Key features of the overall analytical approach are as follows.

First, the analysis of RAMP results for 2008 is conducted for the Athabasca River and Athabasca River Delta, as well as at the watershed/river basin level.

Second, 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 2007 Technical Reports (RAMP 2005, RAMP 2006, RAMP 2007, and RAMP 2008).

Third, a set of criteria are used for determining whether or not there has been a change in the values of the measurement endpoints between: (i) *test* stations; and (ii) *baseline* conditions that should be expected at those stations (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 2008.

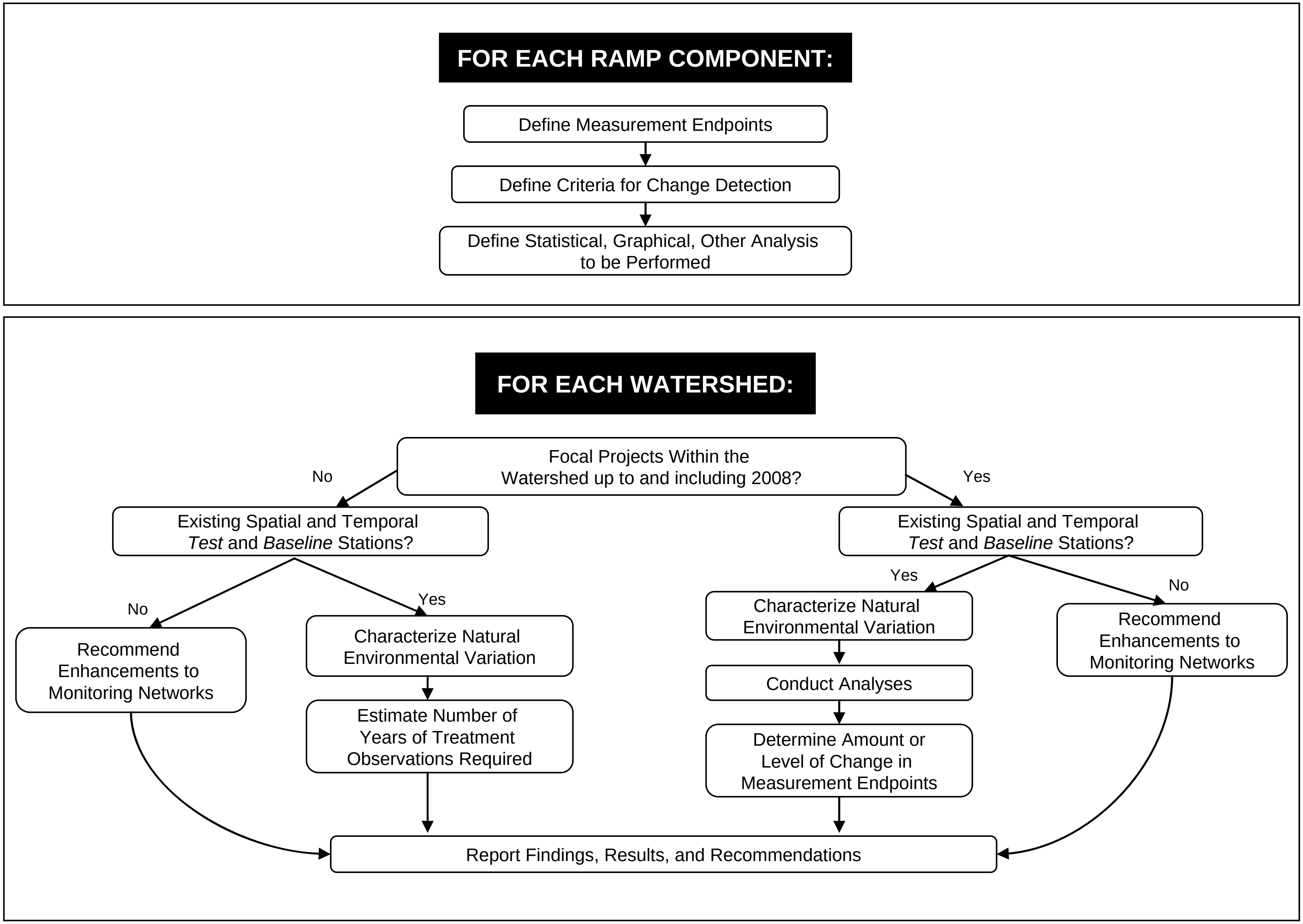


Table 1.4-1 Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2008 Technical Report.

RAMP Component	Measurement Endpoints Used in 2008 Technical Report	Criteria for Determining Change Used in 2008 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 Overall ionic composition	Comparison to range of regional *baseline* conditions. Comparison to CCME and other water quality guidelines. Calculation of water quality index based on CCME water quality index found at http://www.ccme.ca/ourwork/water.html?category_id=102 , with water quality index scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions 60 to 80: Moderate difference from regional *baseline* conditions Less than 60: High difference from regional *baseline* conditions
Benthic Invertebrate Communities	Abundance Richness (number of taxa) Simpson's Diversity Evenness Abundance of EPT (mayflies, stoneflies, caddisflies) Axes of Correspondence Analysis ordination	Exceedance of regional range of *baseline* variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* waterbodies as compared to *baseline* waterbodies; 1. Negligible-Low: no statistically significant difference in any measurement endpoint between *test* and *baseline* waterbodies 2. Moderate: statistically significant difference in one any measurement endpoint between *test* and *baseline* waterbodies, with low "noise" in the statistical test, but no measurement endpoint outside *baseline* range of natural variation 3. High: statistically significant difference in one any measurement endpoint between *test* and *baseline* waterbodies and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (iii) 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

Table 1.4-1 (Cont'd.)

RAMP Component	Measurement Endpoints Used in 2008 Technical Report	Criteria for Determining Change Used in 2008 Technical Report
Fish Populations: Fish Inventory	Relative abundance (catch per unit effort) Length-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 Tissue Sampling	Range of metals (including mercury) and tainting compounds (PAHs) in fish muscle tissue	**Risk to Human Health** *Negligible-Low*: Fish tissue concentrations for all variables below USEPA and Health Canada criteria for recreational and subsistence fishers and the general consumer. *High (subsistence)*: Fish tissue concentrations for one or more variables above USEPA and Health Canada criteria for subsistence fishers, but below criteria for recreational fishers and general consumers. *High (general)*: Fish tissue concentrations for one or more variables above USEPA and Health Canada criteria for general consumers, and recreational and subsistence fishers. **Risk to Fish Health** *Negligible-Low*: Fish tissue concentrations for all variables below literature-based criteria for sublethal and lethal effects on fish. *Moderate*: Fish tissue concentration for one variable above literature-based criteria for sublethal effects. *High*: Fish tissue concentrations for more than one variable above literature-based criteria for effects on fish. **Tainting** *Negligible-Low:* Fish tissue concentrations for tainting compounds below criteria for palatability of fish (Jardine and Hrudey 1993). *Moderate-High:* Fish tissue concentrations for tainting compounds above criteria for palatability of fish.
Fish Populations: Regional Lakes Fish Tissue	Mercury concentration in food fish muscle tissue	**Risk to Human Health** *Negligible-Low:* Fish tissue concentrations for mercury below USEPA and Health Canada criteria for recreational and subsistence fishers and the general consumer. *High (subsistence):* Fish tissue concentrations for mercury above USEPA and Health Canada criteria for subsistence fishers, but below criteria for recreational fishers and general consumers. *High (general):* Fish tissue concentrations for mercury above USEPA and Health Canada criteria for general consumers, and recreational and subsistence fishers.
Acid-Sensitive Lakes	Critical Load of acidity pH Gran alkalinity Base cation concentrations Nitrate plus nitrite concentrations DOC 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 2008 within each subregion with endpoint values greater than two standard deviations from the mean is calculated. *Negligible-Low*: subregion has <2% endpoint-lake combinations exceeding ± 2SD criterion. *Moderate*: subregion has 2% to 10 % endpoint-lake combinations exceeding ± 2SD criterion. *High*: subregion has > 10% of endpoint-lake combinations exceeding ± 2SD criterion.

1.5 ORGANIZATION OF THE RAMP 2008 TECHNICAL REPORT

Together with this Introduction, the RAMP 2008 Technical Report contains nine sections within which the results of the 2008 RAMP monitoring program developed by the RAMP Technical Program Committee and implemented by the Hatfield RAMP Team are presented.

Section 2: Activities in the RAMP Focus Study Area in 2008 – This part of the report contains:

- a description of the activities in 2008 for each of the focal projects;
- a list of projects owned by 2008 RAMP funders that were in the application stage as of 2008 or which received approval in 2008 (or earlier) but were not in the construction phase as of 2008; and
- a list of active oil sands projects in the RAMP study areas owned or operated by companies that were not members of RAMP in 2008.

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

Section 3: 2008 RAMP Monitoring Activities – This section of the report contains concise descriptions of the RAMP monitoring program that was conducted in 2008 for each RAMP component, and includes:

- an overview of the 2008 program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, 2008 RAMP funders, RAMP stakeholders and other oil sands operators, knowledge obtained from local communities, and other sources);
- a short overview of field methods;
- a description of changes in monitoring network from the 2007 field program;
- a description of the challenges and issues encountered during 2008 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 contains a description of the detailed approach used for analyzing the RAMP data; this includes:

- a description and explanation of the measurement endpoints that were selected;
- a description and explanation of the criteria that were used in assessing whether or not changes in the selected measurement endpoints have occurred; and
- 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.

Section 4: Climatic and Hydrologic Characterization of the RAMP Focus Study Area in 2008 – This section of the report describes the 2008 hydrologic year and how 2008 compares with previous years with respect to climatic and hydrologic conditions. This helps set the context for the results, analyses, and conclusions presented in Section 5.

Section 5: Assessment of 2008 Results – This is the main results section of the RAMP 2007 Technical Report, consisting of three major parts:

- Section 5.1 is the report of 2008 findings for the mainstem Athabasca River and the Athabasca River Delta; and
- Sections 5.2 to 5.11 are watershed-level reports of the 2008 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations.

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 concludes with a summary assessment of the overall status of aquatic environmental resources and possible relation to oil sands developments on those resources.

Section 6: Regional Synthesis – This part of the report presents regional assessments of the status of aquatic environmental resources within the scope of monitoring under RAMP and the possible influence of focal projects at the regional level. This section also presents the results of the ASL component for 2008 given the regional nature of this component.

Section 7: Conclusions and Recommendations – This section of the report contains a summary of the findings, conclusions, and recommendations from RAMP 2008. The recommendations include proposed changes to the RAMP monitoring network for future years based on the results for 2008.

Throughout the report, where possible and appropriate, recommendations are made for modifications to RAMP based on findings and conclusions. In addition, Traditional Ecological Knowledge (TEK) is included in the RAMP 2008 Technical Report to the extent possible.

The main report concludes with **Section 8: References** and **Section 9: Glossary and List of Acronyms**. The main report is supported by a series of technical appendices that present the detailed analytical results and supporting material for each RAMP component.