1.0 INTRODUCTION

This document is the 2006 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, 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 27.6 billion m^3 (174 billion barrels) of remaining established bitumen reserves[1] (EUB 2006) 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 by far 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 and is expected to continue, given the ongoing high demand for oil sands products. Slightly less than 2.5% of the estimated established bitumen reserves of the Athabasca oil sands region have been extracted to date (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		1,366,560
Estimated Established Reserves		144,440[1]
Established Reserves under Active Development as of 31 December 2005		11,681
Mineable	10,951	
in situ	730	
Cumulative Production as of 31 December 2005		3,592
Mineable	3,384	
in situ	208	
Remaining Established Reserves		140,848

Data from EUB (2006); all figures are as of 31 December 2005.

[1] Estimated by applying provincial ratio of established to total bitumen reserves to total reserves in 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 (Alberta Energy 2006). Remaining established bitumen reserves are established bitumen reserves less cumulative bitumen production.

In addition to the oil sands operations, other development has also increased within the RMWB, such as quarry operations, pipeline construction, forestry operations (sawmill, logging), drilling activities, as well as municipal growth and associated infrastructure development.

Several organizations have been formed to address issues related to the environmental integrity of the Athabasca oil sands region in response to the rapid growth of oil sands mining and regional development, including:

- Cumulative Environmental Management Association (CEMA) – established to develop management recommendations on how best to reduce potential long-term environmental impacts due to industrial development. CEMA works with the Regional Sustainable Development Strategy (RSDS) and is focusing on acid deposition; biodiversity and landscape-diversity; ground-level ozone; reclamation; surface water (quality and quantity); trace metals and air contaminants; and wildlife and fish habitat;

- 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 thirteen 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; and

- Regional Aquatics Monitoring Program (RAMP) – established to integrate aquatic monitoring activities in the Athabasca oil sands region so that long-term trends and potential cumulative effects can be evaluated and communicated.

1.2 OVERVIEW OF RAMP

The Regional Aquatics Monitoring Program (RAMP) is an industry-funded, multi-stakeholder environmental monitoring program initiated in 1997. The intent of RAMP is to integrate aquatic monitoring activities across different components of the aquatic environment, geographical locations, and Athabasca oils sands and other developments so that long-term trends, regional issues and potential cumulative effects related to oil sands and other development can be identified and addressed. The coordination of monitoring efforts results in the development of a more comprehensive and cost-effective regional database that may be used by operators for their environmental management programs, compliance with environmental requirements in regulatory approvals and assessments of proposed developments, as well as other stakeholders interested in the health of aquatic environments in the Athabasca oil sands region.

1.2.1 RAMP Objectives

Several objectives of RAMP have been developed to guide the scope, management and implementation of the program over time. Specifically, 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 satisfies the monitoring required by regulatory approvals of oil sands and other developments;
- Collect data that satisfies 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.

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, Stantec Consulting Ltd., Mack, Slack & Associates Inc., Western Resource Solutions, Alberta Environment [AENV], Syncrude Canada Ltd., Aboriginal members, and other consultants) 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. In addition, RAMP participates in the Joint Communications Committee (JCC), established with WBEA and CEMA, to undertake collaborative communication initiatives within the RMWB.

In 2006, RAMP was funded by Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude), Albian Sands Energy Inc. (Albian Sands), Shell Canada Limited (Shell), Canadian Natural Resources Limited (CNRL), Imperial Oil Resources (Imperial Oil), Petro-Canada Oil and Gas (Petro-Canada), OPTI Canada Inc. (OPTI)/Nexen Inc. (Nexen), Husky Energy (Husky), Total E&P Canada Ltd. (Total E&P), Synenco Energy Inc. (Synenco), and Birch Mountain Resources Ltd. (Birch Mountain).

Figure 1.2-1 RAMP organizational structure.

STEERING COMMITTEE		
Industry	**Stakeholders**	**Government**
Alberta Pacific Forest Industries Inc.	Athabasca Chipewyan First Nations	Alberta Energy and Utilities Board
Albian Sands Energy Inc.	Chipewyan Prairie First Nations	Alberta Environment
Birch Mountain Resources Ltd.	Fort Chipewyan Metis Local #125	Fisheries and Oceans Canada
Canadian Natural Resources Ltd.	Fort McKay First Nations	Environment Canada
Husky Energy	Fort McKay Metis Local #122	Regional Municipality of Wood Buffalo
Imperial Oil Resources	Fort McMurray First Nations	
Nexen Inc.	Mikisew Cree First Nations	
OPTI Canada Inc.	Oil Sands Environmental Coalition	
Petro-Canada Oil and Gas	Pembina Institute	
Shell Canada Ltd.		
Suncor Energy Inc.		
Syncrude Canada Ltd.		
Synenco Energy Inc.		
Total E&P Canada Ltd.		
(Secretary: Hatfield Consultants)		

Finance Sub-Committee	Technical Program Committee	Joint Communications Committee	Investigators
All funding participants, and any interested Steering Committee members.	Representatives from industry, communities, government, and investigators.	Representatives from RAMP, WBEA, and CEMA	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.

1.3 RAMP STUDY AREA

The RMWB in northeastern Alberta defines the RAMP Regional Study Area (RSA, Figure 1.3-1). The RMWB covers an area of 68,454 km^2, and as of 2006 had a population of approximately 80,000 persons of which approximately 64,400 persons were residents of Fort McMurray and approximately 10,400 persons were in work-camps (RMWB 2006). 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 far south.

Within the RSA, a Focus Study Area (FSA) is defined by the watersheds in which oil sands development is occurring or is planned, as well as those parts of the Athabasca and Clearwater River channels within the RSA (Figure 1.3-1). Accordingly, much of the intensive monitoring activity is conducted within the RAMP FSA. The RAMP FSA is comprised of two major areas: one area north of Fort McMurray and another area south of Fort McMurray.

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 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 upper portion of the RAMP FSA lies within the Mid-Boreal Uplands and Wabasca Lowland Ecoregions, both of which lie in 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 subhumid mid-boreal ecoclimate, medium to tall, closed stands of trembling aspen and balsam poplar with white and 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 has little relief and is rather poorly drained, and organic materials covering about 50% of the area.

The downstream portion of the RAMP FSA, dominated by the Athabasca River from Fort McMurray to the Athabasca River Delta, is part of the Slave River Lowlands Ecoregion of the Boreal Plains Ecozone. It is characterized by an undulating sandy plain containing mixed boreal forest with up to 50% of the area 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. Upon reaching the ARD, the Athabasca River becomes a vast, interconnected series of braided channels and wetlands flowing into Lake Mamawi and Lake Athabasca. The northernmost part of the RMWB lies within the Selwyn Lake Upland Ecoregion, part of the Taiga Shield Ecozone. This area experiences a low subarctic ecoclimate, with black spruce as the climax tree species, and characteristically open stands of low, stunted black spruce with dwarf birch and Labrador tea, and a ground cover of lichen and moss prevailing.

As indicated above, 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 is a large river which 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 drainage includes several existing and planned *in situ* oil sands developments to the south of Fort McMurray;

- Hangingstone River – a small river originating in the southwestern portion of the RAMP FSA, joining the Clearwater River just upstream of Fort McMurray, and whose watershed includes the Petro-Canada *in situ* Meadow Creek Project and the JACOS *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 recently approved North Steepbank Mine, and part of the Suncor *in situ* Firebag Project;
- Muskeg River – also flows from the east and drains several oil sands development areas, including the Albian Sands Muskeg River Mine and Muskeg River Mine Expansion, Syncrude Aurora North Mine and planned Aurora South Mine, part of the Suncor *in situ* Firebag Project, Shell's Jackpine Mine, Imperial Oil's Kearl Project, the Husky *in situ* Sunrise Thermal Project, and Birch Mountain's Muskeg Valley Quarry and planned Hammerstone quarry;
- MacKay River – flows from the west and whose watershed includes the Petro-Canada MacKay River and Dover developments, as well as the planned MacKay River expansion, portions of Syncrude's Mildred Lake project area, as well as Lease 24 within which the Total E&P Joslyn projects are located;
- Ells River – flows from the west and whose watershed lies partly within but mostly immediately adjacent to the CNRL's Lease 18 and most of Lease 24, where the Total E&P Joslyn projects are located;
- Tar River – also flowing from the west, whose drainage contains most of the CNRL Horizon Project;
- Calumet River – similar to the Tar River, flowing from the west and whose drainage lies partly within the CNRL Horizon Project; and
- Firebag River – a large river flowing from Saskatchewan, whose watershed includes most of Suncor's *in situ* Firebag Project, parts of the Petro-Canada Fort Hills Project, Husky's *in situ* Sunrise project, and Imperial's Kearl Project, as well as all of Synenco's Northern Lights Project.

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

- Tributaries within watersheds described above (i.e., Muskeg Creek, Wapasu Creek, Gregoire River, etc.);
- 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), 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; and
- A set of regional lakes important from a fisheries perspective, or known to be sensitive to acidifying emissions.

Finally, there are a number of waterbodies and watercourses monitored under RAMP that are used as reference areas for certain RAMP components, particularly the Fish Population component. This includes the Horse and Dunkirk Rivers.

Figure 1.3-1 RAMP study areas.

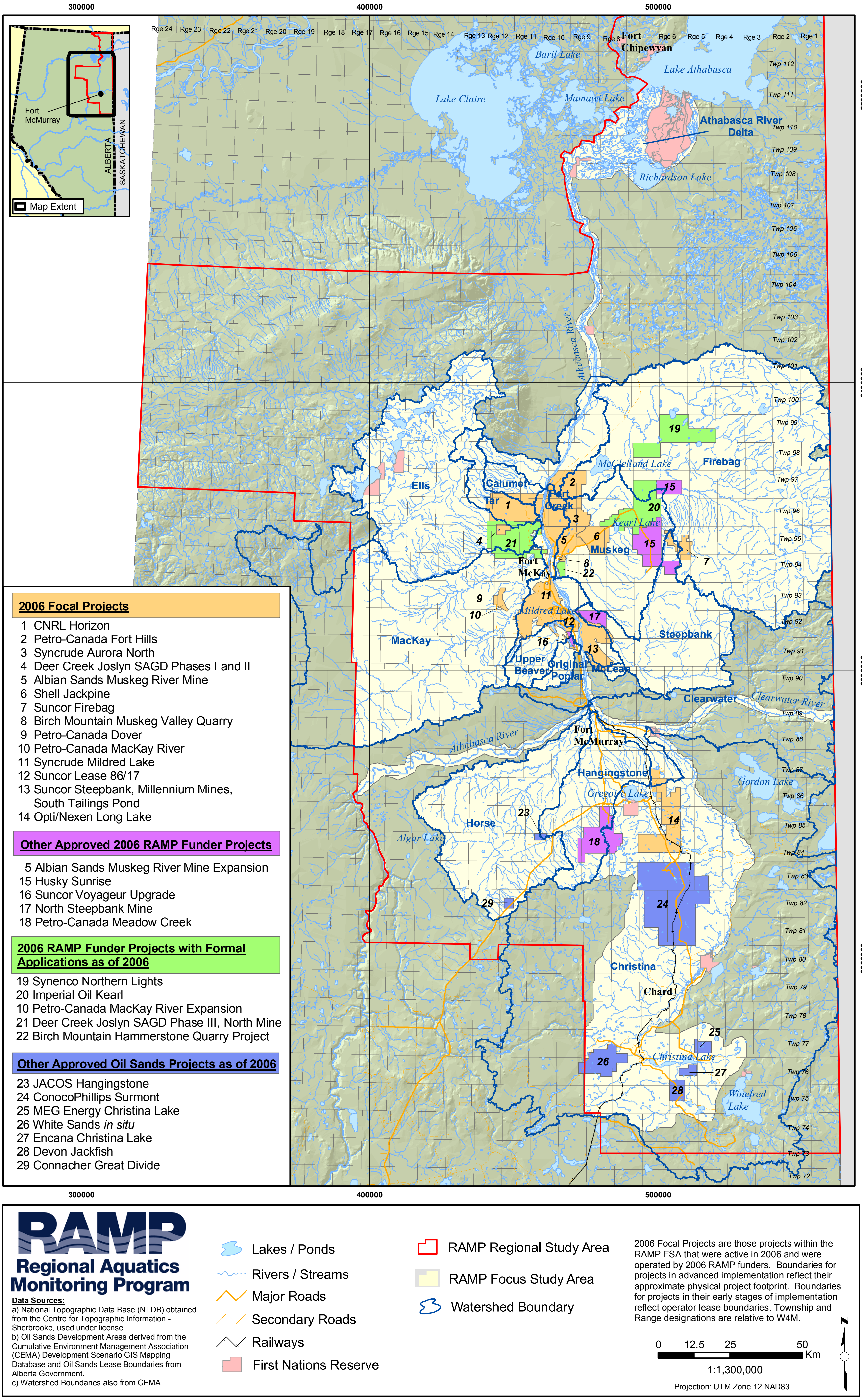

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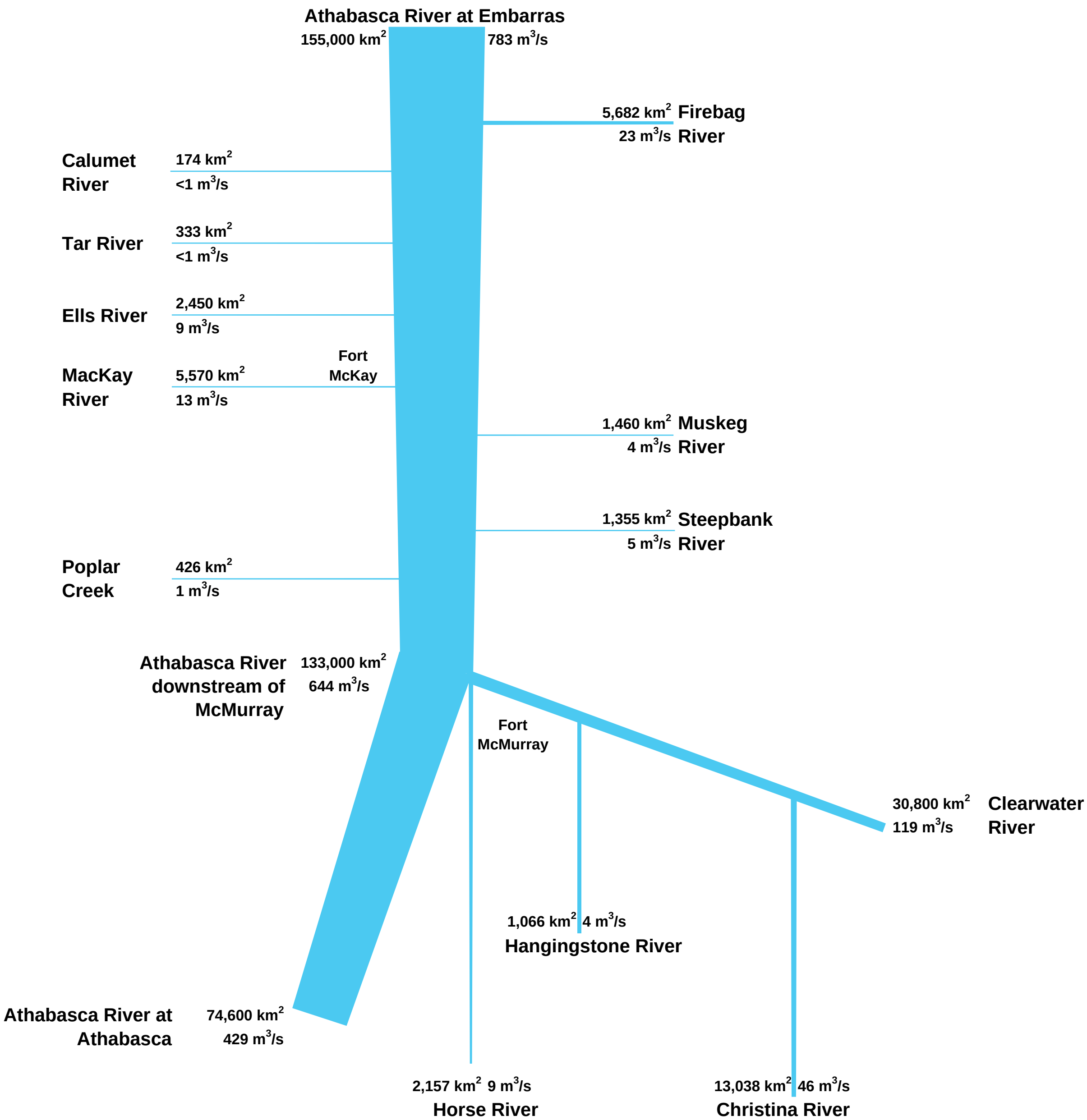
Figure 1.3-2 Hydrologic schematic of RAMP Focus Study Area.



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

With the addition in 2006 of Birch Mountain as a member of RAMP, RAMP is now funded by companies that are not exclusively constructing and operating oil sands projects in the RAMP FSA. Therefore, the term "focal projects" has been introduced to the RAMP 2006 Technical Report; focal projects are defined as those projects owned by 2006 RAMP funders (Section 1.2.2) which were under construction or operational in 2006 in the RAMP FSA. For 2006, 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.

2006 RAMP funders do have other projects in the RAMP FSA that were in the application stage as of 2006 (e.g., Imperial's Kearl project), or which received approval in 2006 (or earlier) but were not in the construction phase as of 2006 (e.g., Suncor's Voyageur project). These projects are noted throughout this technical report but are not designated as focal projects, as these projects in 2006 would not have potentially influenced 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 Environmental Impact Assessments (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 currently exists in the environment and will be influenced by 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 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 development of focal projects.

1.4.3 RAMP Components

RAMP in 2006 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 is an 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** – Water quality in regional lakes sensitive to acidification – early warning indicator of potential effects related to acid deposition.

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 2005b). 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 to meet 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 effects 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 catchments 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 to receiving streams. Data from long-term Environment Canada 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 March) flows on some streams that Environment Canada monitors during the open-water season.

1.4.4.2 Water Quality

RAMP monitors water chemistry 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 relying on aquatic resources.

Specific objectives of the Water Quality component include:

- Development of a water quality database to verify EIA predictions, support regulatory applications and to meet requirements of regulatory approvals;
- Monitoring of potential changes in water quality that may identify chemical inputs from point and non-point sources;
- Assessment of the suitability of waterbodies to support aquatic life; and
- Provision of supporting data to facilitate the interpretation of biological surveys.

In order to determine if and how a development may be affecting water quality, stations potentially influenced by the development are compared to upstream reference stations (where possible), located beyond the influence of the development, and against an appropriate range of regional natural variability. Stations are monitored over time to characterize natural temporal variability in baseline conditions, and to identify potential trends in water quality related to increasing anthropogenic activity, 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 bioassay tests also are conducted to assess potential toxicity related to chronic exposure of different aquatic organisms to ambient river water from selected stations.

RAMP water quality stations are located throughout the RAMP study area, from the upper Christina River to the Athabasca River downstream of development. Water quality stations are 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 variations in water quality. Three years of seasonal baseline data are collected at stations established in new waterbodies added to RAMP.

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. First, they integrate biologically relevant variations in water and habitat quality. Second, they are limited in their mobility and, therefore, 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 impending effects on fish communities (Kilgour and Barton 1999). Finally, 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 1982a,b).

The RAMP Benthic Invertebrate Community component has three general 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.

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 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 tributaries and additional stations on tributaries near active development sites. The tributary monitoring approach adopted by RAMP focuses on characterizing benthic communities on the basis of total abundance, taxonomic richness, and relative dominance within the lower reach of each river (i.e., downstream of development) relative to communities found in an upper, reference reach. 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 season-associated variability in composition of the benthic community. Where available, historical data collected in previous years through RAMP are used to place current results in context with historical trends in community structure that may be occurring.

Until 2006, sediment quality was a separate component of RAMP. Beginning in 2006, however, sediment quality sampling was integrated into the benthic invertebrate community component in order to provide a better link of physical and chemical habitat conditions to a specific biological endpoint. Sediment quality in 2006 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, specifically:

- 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 relying on aquatic resources.

A range of compounds are measured to characterize sediment quality: particle size; carbon content; target and alkylated PAHs; total hydrocarbons; and metals. Sublethal bioassay tests also are conducted to assess potential toxicity related to chronic exposure of different aquatic organisms to ambient river water or sediment 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 effects from natural and anthropogenic influences. Fish also represent a highly valued recreational and subsistence resource. In this regard, there are expectations from regulators, Aboriginal peoples, and the general public with respect to comprehensive ongoing 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, northern pike, trout-perch, and walleye (CEMA 2001, RAMP 2005b). 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 direct or indirect toxicity effects on fish. As part of the ongoing program, muscle tissues are collected from lake whitefish and walleye from the Athabasca River and northern pike from the Muskeg River. Tissues are analyzed for metals, including mercury, and specific organic compounds known to cause tainting of fish flesh. Fish tissue analyses (mercury only) 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”, to date has included analysis of fish tissue Gregoire Lake (2002), Lake Claire (2003), Christina Lake (2003), and Winefred Lake (2004).

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 River, the inventory is conducted annually in the spring and fall 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, Clearwater River, Christina River and the Firebag River have been surveyed in the past as part of the RAMP Fish Population component. In addition to the scientific value of the work, the fish inventories provide useful information to local stakeholders on species diversity, the relative strength of age classes, and the frequency of fish abnormalities.

Sentinel fish species monitoring is part of the RAMP Fish Population component to assess the potential effects of stressors on wild fish populations. The approach evaluates the performance (characterized by growth, survival, condition, and reproduction) of a specific sentinel species potentially influenced by development relative to reference 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 resides. The approach has also been included as part of the federal government's EEM programs under the pulp and paper (Environment Canada 1992, 2005) and metal mining (Environment Canada 2002, 2005) 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, to date 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

Potential effects of focal projects include the acidification of regional lakes. This effect occurs through increased emissions of acidifying substances that include oxides of nitrogen and sulphur.

The Regional Sustainable Development Strategy identified the importance of protecting the quality of water, air and land within the Athabasca oil sands region (AENV 1999a). The effects of acid deposition on sensitive receptors were identified in the RSDS as a regional issue or "theme". Actions taken to address this issue were designed to support the goal of conserving acid-sensitive soils, rivers, lakes, wetlands and associated vegetation complexes under the cumulative impacts of 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 under RAMP was initiated in 1999 to conduct annual monitoring of water chemistry in regional lakes to determine the long-term effects of 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. In the case of the ASL program, these data 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 ASL 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, as designed, 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 reference 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;
- A fall sampling program is implemented to capture a picture of lake water chemistry after conditions have stabilized; and
- In recent surveys (2002 to 2006), small water bodies (ponds), previously ignored, were included in the program because of their proximity to oil sands developments and the possibility that they might be low in alkalinity and therefore sensitive to acid deposition.

1.4.5 Overall Analytical Approach for 2006

For the 2006 RAMP Technical Report, the overall approach to the analysis of collected RAMP data builds from analytical approaches used in RAMP in previous years and the RAMP: Technical Design and Rationale report (RAMP 2005b). Key features of the overall analytical approach are as follows.

First, the analysis of RAMP results for 2006 is conducted at the watershed/river basin level, as well as the Athabasca River at the regional 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 and 2005 Technical Reports (RAMP 2005a, RAMP 2006).

Third, the analysis for each RAMP component uses a set of criteria for determining whether or not a change in the measurement endpoints has occurred and qualifying the amount of change with respect to the health and integrity of valued environmental resources within the component (Table 1.4-1). Again, these are the same effects criteria that were used in the RAMP 2004 and 2005 Technical Reports (RAMP 2005a, 2006).

Fourth, 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 selected sampling stations and monitoring years are categorized into combinations of spatial and temporal treatments and controls. This enables statistical analyses to be conducted on the collected RAMP data.

These features of the overall analytical approach for RAMP 2006 are integrated into an overall framework that is used for all RAMP components; this framework is presented in Figure 1.4-1 as a sequence of steps undertaken by all RAMP components which guided their contribution to the RAMP 2006 Technical Report.

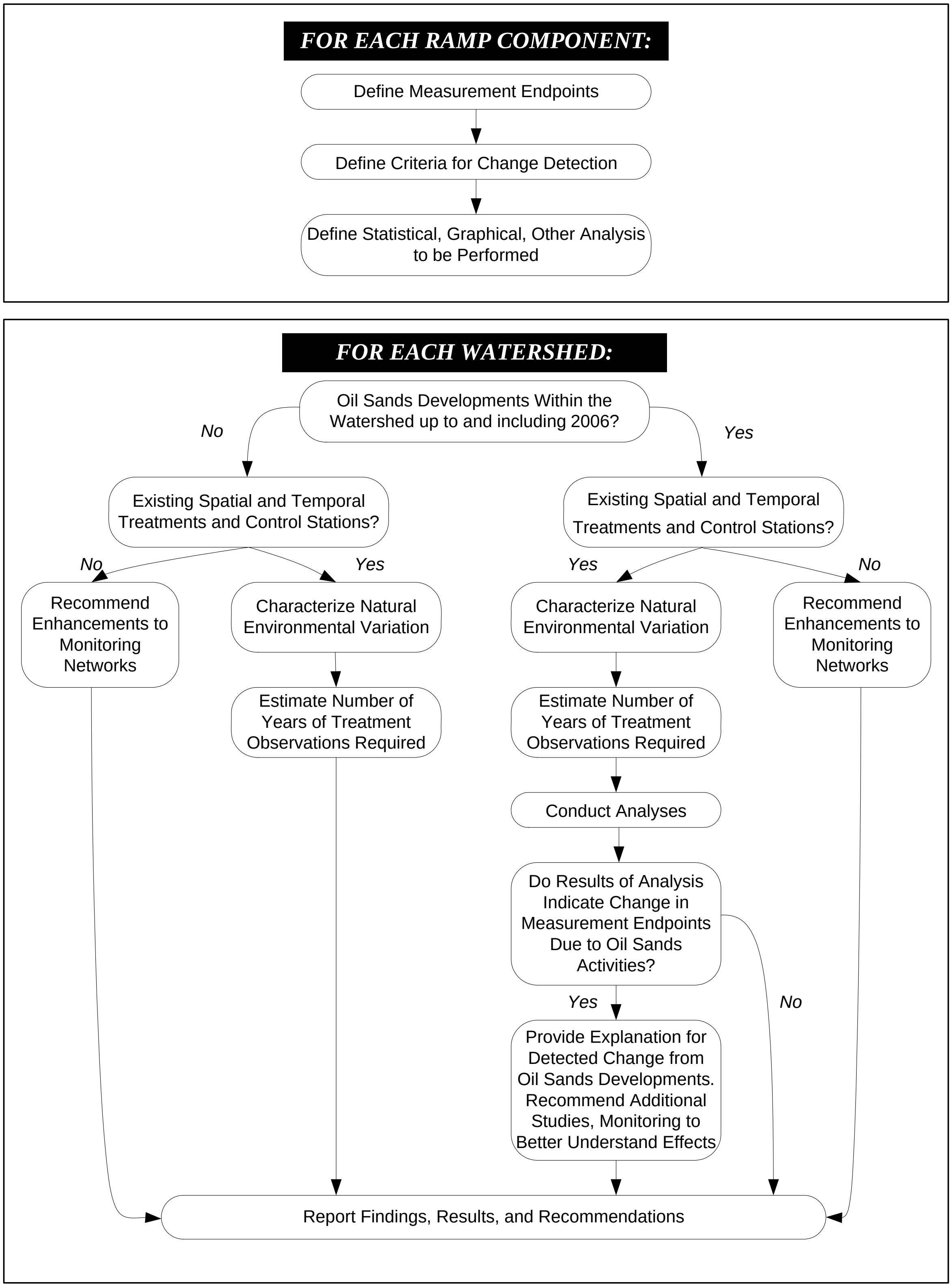
Table 1.4-1 Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2006 Technical Report.

RAMP Component	Measurement Endpoints Used in 2006 Technical Report	Criteria for Determining Change Used in 2006 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, operational and calculated baseline hydrographs (i.e., the hydrograph that would have been observed had oil sands development not occurred in the drainage, so that changes in water withdrawals, discharges, and diversions are accounted for).
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 boron Total molybdenum Naphthenic acids Overall ionic composition	Comparison to natural range of regional baseline conditions. Comparison to CCME and other water quality guidelines.
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.
Benthic Invertebrate Communities	Abundance Richness (number of taxa) Simpson's Diversity Evenness Abundance of EPT (mayflies, stoneflies, caddisflies)	Exceedance of regional range of natural variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$.
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 trends in abundance and population parameters for large-bodied species. It is not specifically designed for assessing environmental effects of focal project activities.

Table 1.4-1 (Cont'd.)

RAMP Component	Measurement Endpoints Used in 2006 Technical Report	Criteria for Determining Change Used in 2006 Technical Report
Fish Populations: Fish Tissue Sampling	Range of metals (including mercury) and tainting compounds (PAHs) in fish muscle tissue	**Protection of Human Health** *Negligible-Low*: Fish tissue concentrations for all analytes below USEPA and Health Canada criteria for recreational and subsistence fishers and the general consumer. *High (subsistence)*: Fish tissue concentrations for one or more analytes 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 analytes above USEPA and Health Canada criteria for general consumers, and recreational and subsistence fishers. **Protection of Fish Health** *Negligible-Low*: Fish tissue concentrations for all analytes below literature-based criteria for sublethal and lethal effects on fish. *Moderate*: Fish tissue concentration for one analyte above literature-based criteria for sublethal effects. *High*: Fish tissue concentrations for more than one analyte 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: Fish Fence Studies	Relative abundance (catch per unit effort) Length-frequency Percent composition Condition factor Sex ratio Onset and peak timing of spawning runs Residency time in the spawning tributary	While data from fish fences are best suited for assessing time trends in abundance and population variables for each spawning species, the high level of natural annual variability common in spawning run strength means it is necessary to collect a large number of sampling years before observed trends and possible effects of development activities can be described with confidence.
Fish Populations: Regional Lakes Fish Tissue	Mercury concentration in food fish muscle tissue	**Protection of 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.

Figure 1.4-1 Overall analytical approach for RAMP 2006.



1.4.6 Definition of Terms

The RAMP 2006 Technical Report uses the following definitions for monitoring status:

- ***Potentially influenced*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) that may be influenced by the activities of the focal projects. 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 to be designated as ***operational*** for the purposes of data analysis (see below);
- ***Reference*** is the term used in this report to describe aquatic resources and physical locations that were not influenced by the activities of the focal projects in 2006, and that data on aquatic resources collected from these locations are to be designated as ***baseline*** for the purposes of data analysis (see below). The terms ***potentially influenced*** and ***reference*** do not depend solely on location of the aquatic resource in relation to the location of the focal projects, but to the possible effects of these projects that are being considered and the potential impact pathway. For example, Lake A29 (one of the ASL lakes) is characterized as ***reference*** with respect to possible effects on water quality via changes in hydrologic conditions, but is designated as ***potentially influenced*** with respect to possible effects related to acid deposition;
- ***Baseline*** is the term used to characterize data and information gathered from stations that are designated as ***reference***; and
- ***Operational*** is the term used to characterize data and information gathered from stations that are designated as ***potentially influenced.***

1.5 ORGANIZATION OF THE RAMP 2006 TECHNICAL REPORT

Together with this Introduction, the RAMP 2006 Technical Report contains eight sections within which the results of the 2006 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 2006 – This part of the report contains:

- A description of the activities in 2006 of each of the focal projects;
- A list of projects owned by 2006 RAMP funders that were in the application stage as of 2006 or which received approval in 2006 (or earlier) but were not in the construction phase as of 2006; and
- As well as a list of oil sands projects in the RAMP study areas owned or operated by companies that were not members of RAMP in 2006.

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

Section 3: 2006 RAMP Monitoring Activities – This section of the report contains concise descriptions of the RAMP monitoring program that was conducted in 2006 for each RAMP component, and includes:

- An overview of the 2006 program;
- A description of any other information that was obtained (i.e., information from regulatory agencies, 2006 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 2005 field program;
- A description of the challenges and issues encountered during 2006 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 Athabasca Oil Sands Region in 2006 – This section of the report describes the 2006 hydrologic year and how 2006 compares with previous years. This helps set the context for the results, analyses, and conclusions presented in Section 5.

Section 5: Assessment of 2006 Results – This is the main results section of the RAMP 2006 Technical Report, consisting of two major parts:

- Sections 5.1 to 5.12 are watershed-level reports of the 2006 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations; and
- Section 5.13 is a presentation of the findings of the Acid-Sensitive Lakes component for 2006.

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: Conclusions and Recommendations – This section of the report contains a summary of the findings, conclusions, and recommendations from RAMP 2006. The recommendations include proposed changes to the RAMP monitoring network for future years based on the results for 2006.

Throughout the report, where possible and appropriate, recommendations are made for modifications to RAMP based on findings and conclusions. In addition, TEK is included in the RAMP 2006 Technical Report to the extent possible.

The main report concludes with Section 7: References and Section 8: 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.