1.0 INTRODUCTION

This document is the 2004 Technical Report of the Regional Aquatics Monitoring Program (RAMP), a joint environmental monitoring program with participation from the oil sands industry, stakeholders of the oil sands development, and local, provincial, and federal governments, which assesses the health of rivers and lakes in the oil sands region of northeastern Alberta.

1.1 BACKGROUND

With an estimated 267 billion m^3 of total reserves of bitumen, the Alberta oil sands are the largest component of Canada's known petroleum resources. Indeed, the Alberta oil sands are a significant component of the world's petroleum resources, with its 48 billion m^3 (301 billion barrels) of recoverable bitumen reserves being equivalent to approximately one-third of the world's known reserves of conventional crude oil. The Athabasca oil sands deposit is by far the largest of Alberta's three oil sands deposits, containing almost 80% of the total provincial reserves, with the Cold Lake and Peace River deposits being significantly smaller.

In 1967, Great Canadian Oil Sands Ltd. (now Suncor Energy Inc.) initiated the region's first commercially successful bitumen extraction and upgrading facility. Since that time, investment and development in the Athabasca oil sands region near Fort McMurray has increased substantially, with 17 companies currently planning, or already undergoing, resource extraction of the Athabasca deposit via surface mining and/or *in situ* operations (Figure 1.1-1).

In addition to the oil sands operations, other development has also increased within the Regional Municipality of Wood Buffalo (RMWB), such as pipeline construction, forestry operations (sawmill, logging), drilling activities, and municipal growth/infrastructure development. Upstream of the RMWB, developments such as pulp and paper operations (five mills), agriculture and municipal wastewater facilities may also influence downstream water quality of the Athabasca River within the oil sands region.

In response to the rapid growth of mining and regional development, several organizations were initiated to address issues related to environmental integrity of the Athabasca oil sands region of northern Alberta, 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;

- Wood Buffalo Environmental Association (WBEA) – established to monitor and provide information on air quality and air-related environmental impacts in the RMWB;

- Terrestrial Environmental Effects Monitoring (TEEM) – a program under WBEA 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

- 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

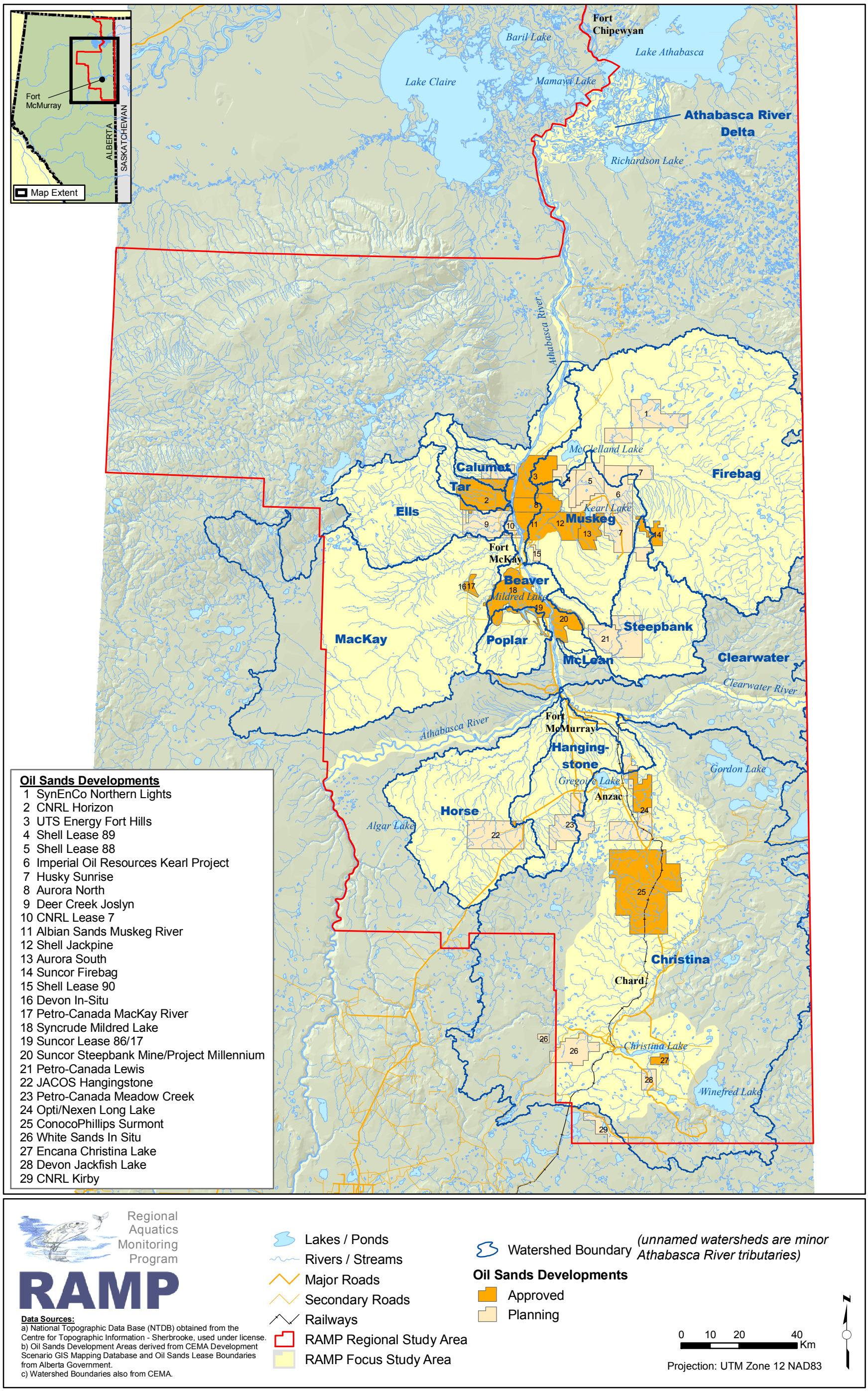
The Regional Aquatics Monitoring Program (RAMP) is an industry-funded, multi-stakeholder environmental monitoring program initiated in 1997. The intent of RAMP is to integrate aquatic monitoring activities across different components of the aquatic environment, geographical locations, and oils sands developments so that long-term trends, regional issues and potential cumulative effects related to oil sands 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 oil sands operators for their environmental management programs, compliance with environmental requirements in regulatory approvals and assessments of proposed oil sands 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 oil sands region to detect and assess cumulative effects and regional trends;
- Collect baseline data to characterize variability in the oil sands area;
- 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 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.

Figure 1.1-1 RAMP study areas and Athabasca oil sands developments.



RAMP1110\GIS\2004_LEASES.MXD

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 industries, government agencies (municipal, provincial and federal), First Nations representatives, environmental non-government organizations (ENGOs) and other independent stakeholders (Figure 1.2-1). RAMP also has a Technical Subcommittee responsible for the development and review of the RAMP technical monitoring program from year to year. The Technical Subcommittee is divided into discipline-specific sub-groups (e.g., fisheries, water quality, etc.) that develop and review their component for integration into the overall monitoring program. Investigators (i.e., the Hatfield RAMP Team—consisting of Hatfield Consultants Ltd, Jacques Whitford Environment Ltd., Mack, Slack & Associates Inc., Western Resource Solutions, Alberta Environment, Syncrude Canada Ltd., First Nations, and other consultants) primarily carry out the fieldwork, data analysis and reporting, as defined by the program. A Finance Subcommittee and a Communications Subcommittee have also been established to focus on issues related to funding and dissemination of RAMP information.

In 2004, RAMP was funded by Syncrude Canada Ltd. (Syncrude), Suncor Energy Inc. Oil Sands (Suncor), Albian Sands Energy Inc. (Albian), Shell Canada Limited (Shell), Canadian Natural Resources Limited (CNRL), Imperial Oil Resources (Imperial), Petro-Canada Oil and Gas (Petro-Canada), Opti Canada Inc. (Opti)/Nexen Inc. (Nexen), Husky Energy (Husky), Deer Creek Energy Ltd. (Deer Creek) and Devon Canada Corporation (Devon).

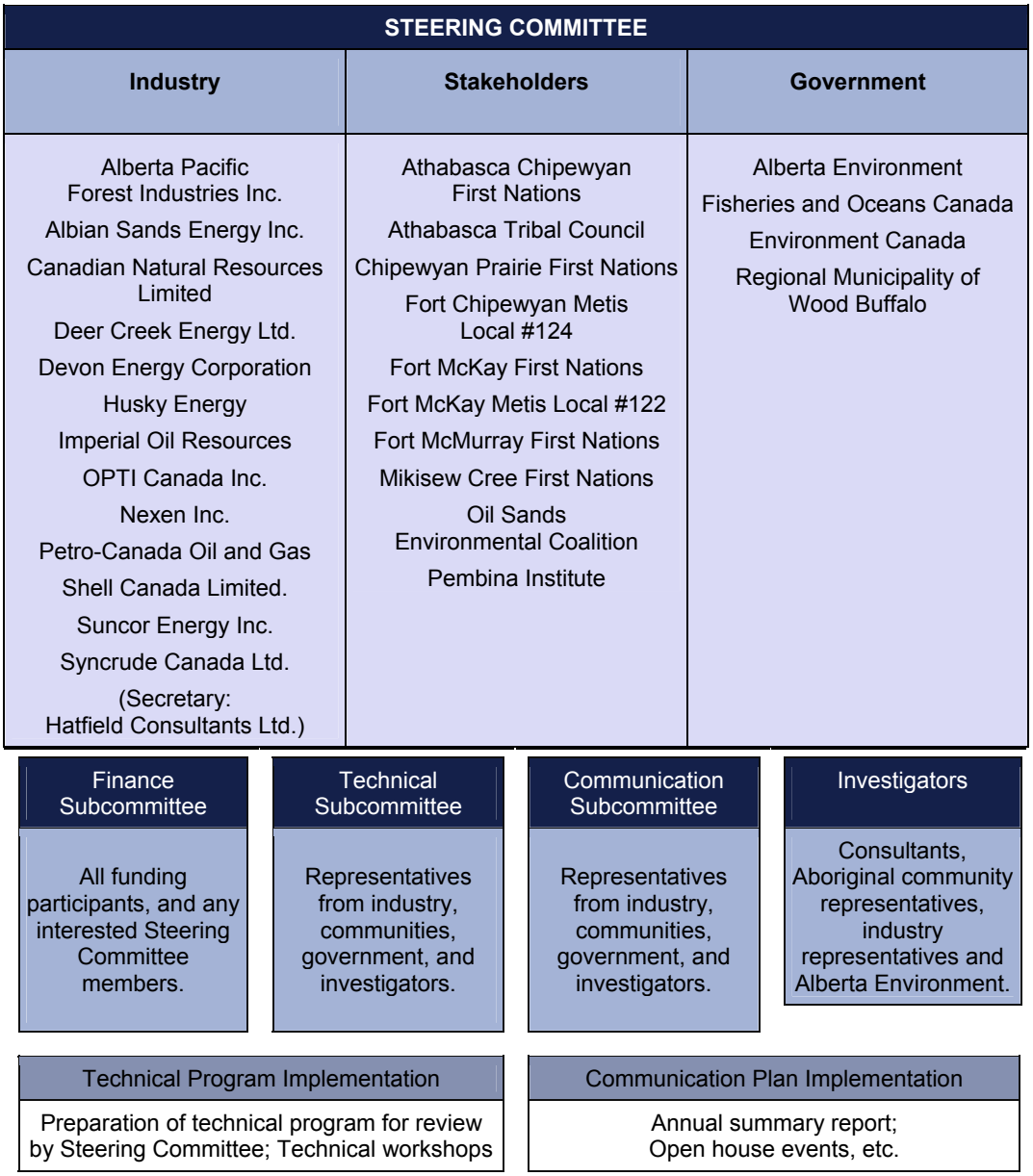
1.3 RAMP STUDY AREA

The RMWB in northeastern Alberta defines the RAMP Regional Study Area (RSA). The RMWB covers an area of 68,454 km^2, has a population of approximately 60,000 persons, and 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, and 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 (Figure 1.1-1). Accordingly, much of the intensive monitoring activity is conducted within the RAMP FSA. The RAMP FSA is comprised of two major areas: one area upstream (south) and another area downstream (north) 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 Peace-Athabasca Delta 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.

Figure 1.2-1 RAMP organizational structure.



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 Peace-Athabasca 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 Peace-Athabasca Delta, 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 1.3-1). 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 the Suncor Steepbank/Project Millennium mines, Suncor *in situ* Firebag Project, and Petro-Canada's planned Lewis project;

- Muskeg River – also flows from the east and drains several oil sands development areas, including Albian Sands' Muskeg River Mine, Syncrude's Aurora North Mine, planned Aurora South Mine, and *in situ* Firebag Project, Shell's planned Jackpine Mine and the Imperial Oil/ExxonMobil proposed Kearl Lake Oil Sands Project;

- MacKay River – flows from the west and whose watershed includes the Petro-Canada's MacKay River development, Devon's *in situ* project, and portions of Syncrude's Mildred Lake lease;

- Ells River – flows from the west and whose watershed lies partly within but mostly immediately adjacent to the CNRL Horizon Project;

- Tar River – also flowing from the west, whose drainage is largely within the disturbance area 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 Suncor's *in situ* Firebag Project and potential future developments such as 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 (Mills Creek, Poplar Creek, McLean Creek, and Beaver River);

- 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.

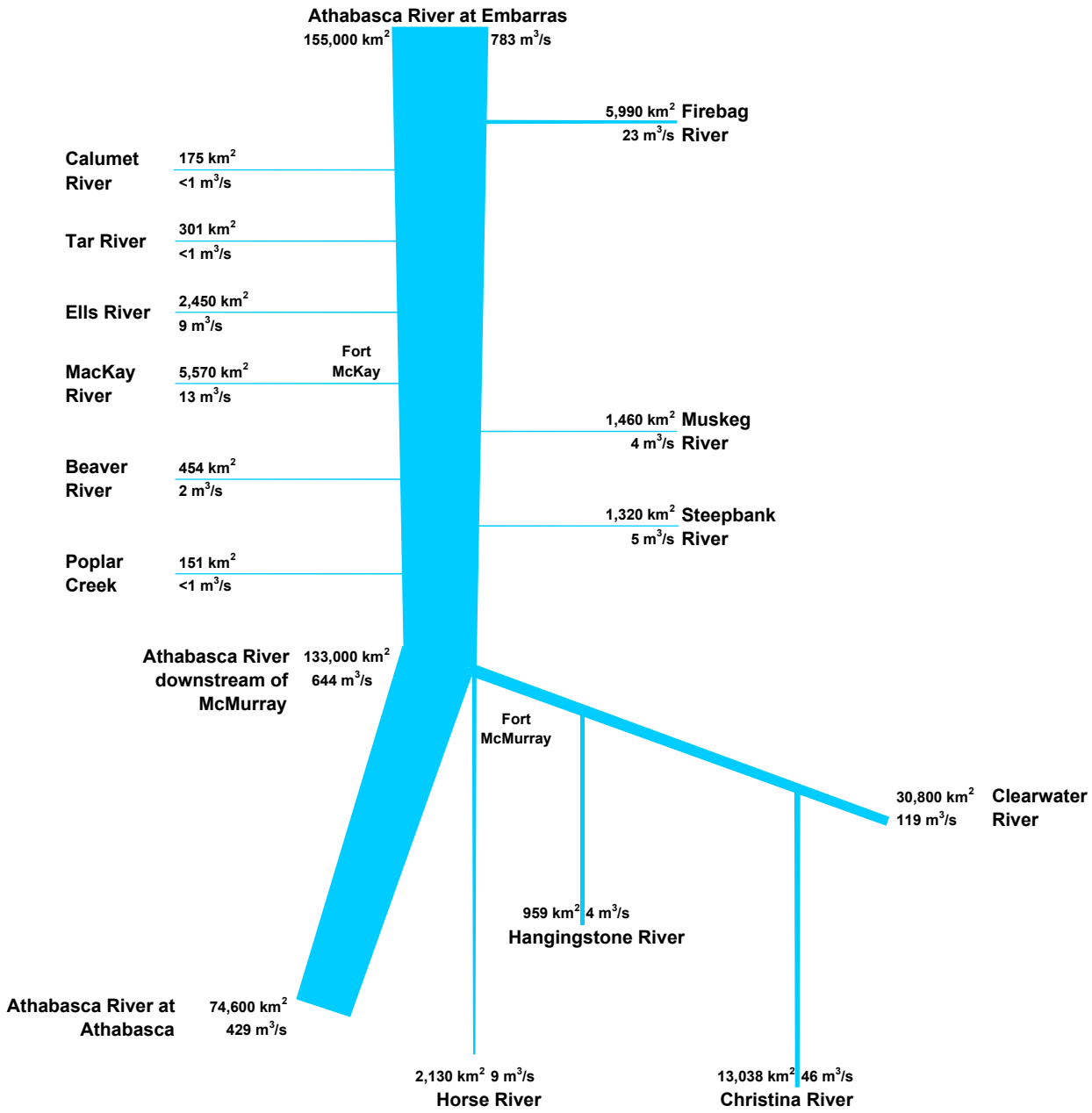
Finally, there are a number of waterbodies and watercourses monitored under RAMP that are used as reference areas for certain RAMP components, particularly the Fish Population component. This includes the Horse and Dunkirk Rivers.

1.4 OVERALL MONITORING AND ANALYTICAL APPROACH

1.4.1 Overall 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 oil sands development. 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, 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 prepared for specific oil sands development projects, 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.

Figure 1.3-1 Hydrologic schematic of RAMP Focus Study Area.



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, 2003). 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 oil sands development.

The scope of RAMP has historically focused on key components of boreal aquatic ecosystems, including:

- Climate and hydrology – monitors changes in the quantity of water flowing through rivers and creeks in the oil sands region;
- Water and sediment quality in rivers, lakes and some wetlands – reflects habitat quality and potential exposure of fish and invertebrates to organic and inorganic chemicals;
- Benthic invertebrate community in rivers/streams and wetlands – serves as a biological indicator and is an important component of fish habitat;
- Fish populations in rivers and lakes – biological indicators of ecosystem integrity and a highly valued resource in the region;
- Water quality in regional lakes sensitive to acidification – early warning indicator of potential effects related to acid deposition; and
- Wetland aquatic vegetation – an ecological indicator of the health of regional wetlands.

Details on the monitoring design and rationale are described in the following document: "Oil Sands Regional Aquatics Monitoring Program (RAMP) - Program Design and Rationale" developed by the RAMP Technical Subcommittee (Version 2, Golder 2002a).

1.4.2 Overall Analytical Approach for 2004

For the 2004 RAMP Technical Report, the overall approach to the analysis of collected RAMP data builds from analytical approaches used in RAMP in previous years, a number of recommendations contained in the Scientific Peer Review of the Five-Year Report (1997-2001) (Ayles *et al.* 2004), and preliminary findings from the RAMP Program Design Documentation Project (summarized in Appendix A). Key features of the overall analytical approach are as follows.

First, the analysis of RAMP results for 2004 is conducted at the watershed/river basin level, with an emphasis on watersheds and river basins on which development has already occurred, as well as the Athabasaca River at the regional level. Results for other watersheds/river basins on which development has not yet started are also included, however, to establish levels of natural variation in those drainages. River systems within whose drainages oil sands development has already occurred are: Athabasca River (mainstem and delta); Muskeg River; Steepbank River; Tar River; MacKay River; as well as a series of smaller rivers and lakes throughout the RAMP FSA. River systems within whose watersheds oil sands development has not yet significantly commenced are: Hangingstone River; Calumet River; Firebag River; Ells River; and the Christina-Clearwater River System; as well as a series of smaller waterbodies throughout the RAMP FSA.

Recommendations from Scientific Peer Review

Adopt an Ecosystem Approach
- Select appropriate indicators to be measured to assess a particular development activity
- Decide how to determine when a change has occurred and its significance

Adopt Effects-Based Monitoring
- Select key response indicators for each RAMP component
- Synthesize information related to development
- Select and use reference and "low-impact" stations for each component subject area
- Use biostatistical analyses with statistical confidence levels and power analyses for indicators of change
- Incorporate other existing regional information

Test EIA Predictions
- Test predictions from already completed EIAs

Emphasize Athabasca River as Priority Watershed
- Use Athabasca River as central focus for monitoring across component subject areas

Contributions to New Knowledge
- Incorporate new knowledge into RAMP

Traditional Ecological Knowledge
- Promote the use of Traditional Ecological Knowledge

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. Ideally, the measurement endpoints that are used in the analysis should be used on a consistent basis from 2004 onwards, although these will be finalized as part of the RAMP Program Design Documentation Project in 2005.

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 whether the change is significant with respect to the health and integrity of valued environmental resources within the component (Table 1.4-1). Again, while the criteria for determination of effects that are used in the analysis should be used on a consistent basis from 2004 onwards, these will be finalized as part of the RAMP Program Design Documentation Project.

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 2004 are integrated into an overall framework that has been used for all RAMP components; this framework is presented in Figure 1.4- as a sequence of steps undertaken by all RAMP components which guided their contribution to the RAMP 2004 Report.

Table 1.4-1 Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2004 Technical Report.

RAMP Component	Measurement Endpoints Used in 2004 Technical Report	Criteria for Determining Change Used in 2004 Technical Report
Climate and Hydrology	• Mean open-water season discharge • Mean winter discharge • Snnual maximum daily discharge • Open-water season minimum daily discharge	• Differences between observed and calculated "naturalized" 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 phosphorous • 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

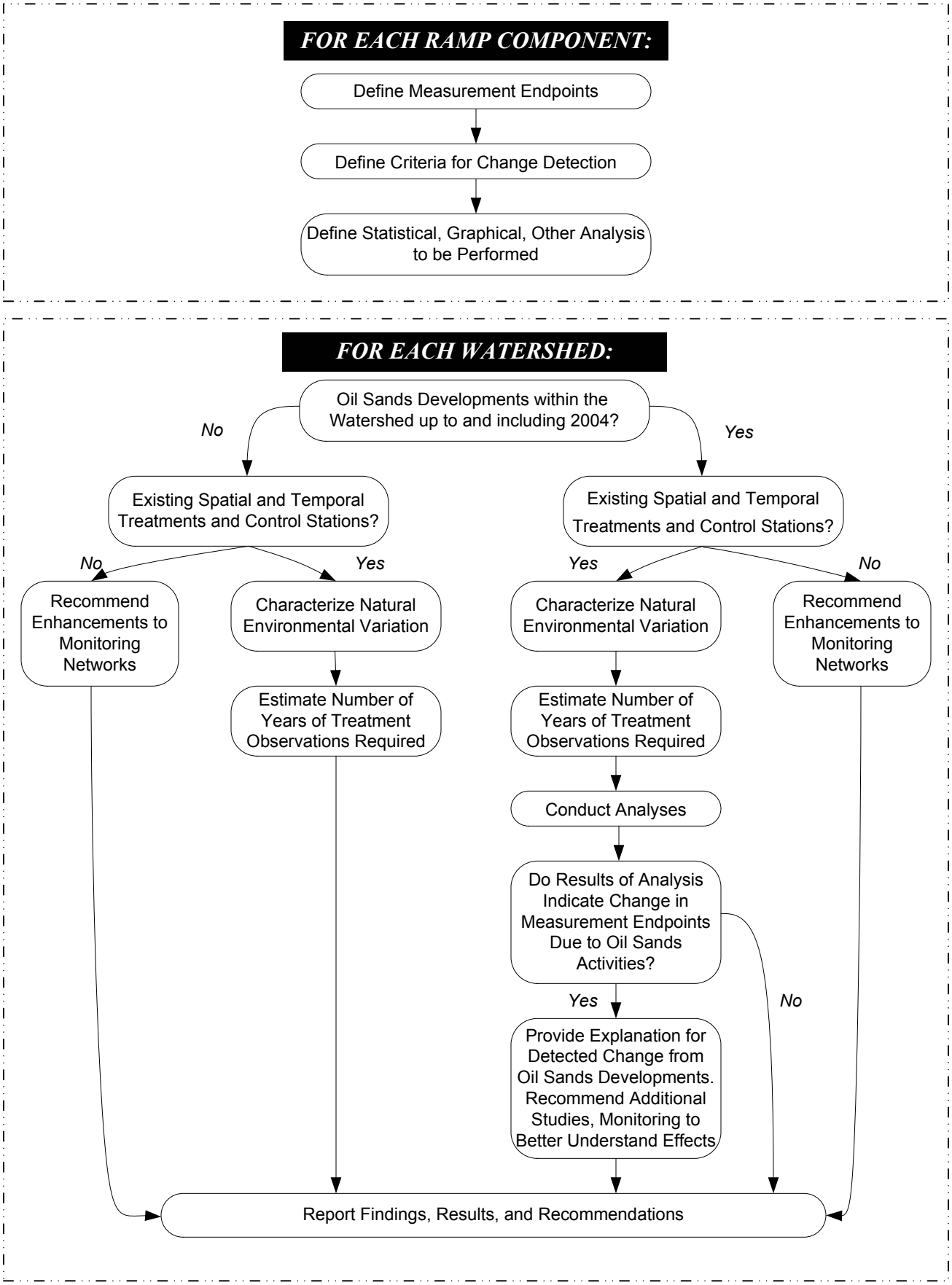
Sediment Quality	• Particle size distribution (clay, silt and sand)
	• Total organic carbon
	• Total hydrocarbons (CCME and Alberta Tier 1)
	• Various PAH end-points, including:
	  • Total PAHs
	  • Total Low-Molecular Weight PAHs
	  • Total High-Molecular Weight PAHs
	  • Naphthelene
	  • Retene
	  • Total dibenzothiophenes
	• Predicted PAH toxicity
	• Metals
	• Chronic toxicity
		• Comparison to natural range of regional baseline conditions
		• 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 $\overline{X} \pm 2SD$

Table 1.4-1 (cont'd.)

RAMP Component	Measurement Endpoints Used in 2004 Technical Report	Criteria for Determining Change Used in 2004 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 trends in abundance and population parameters for large-bodied species. It is not specifically designed for assessing environmental effects of oil sands activities
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. **Protection of Wildlife** *Negligible-Low*: Fish tissue concentrations for mercury below CCME criteria for effects on wildlife. *Moderate-High*: Fish tissue concentrations for mercury above criteria for effects on wildlife. **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	**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.
Fish Populations: Sentinel Species	**Lethal Sampling Approach** • Condition factor • Relative gonad size (Gonad Somatic Index) • Relative liver size (Liver Somatic Index) **Non-Lethal Approach** • Condition factor	**Lethal Sampling Approach** • Condition factor at exposure site ± 10% difference from exposure site • Relative gonad size at exposure site ± 25% difference from exposure site • Relative liver size at exposure site ± 25% difference from exposure site **Non-Lethal Approach** • Condition factor at exposure site ± 10% difference from exposure site
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 2004.



RAMP1110: AnalyticalFramework.VSD

1.4.3 Definition of Terms

The RAMP 2004 Technical Report uses the following definitions for monitoring status:

- ***exposed*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) that may be influenced by oil sands developments. The use of this term does not imply or presume that effects of oil sands developments 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 are not yet influenced by oil sands developments 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 ***exposed*** and ***reference*** do not depend solely on location of the aquatic resource in relation to the location of the oil sands developments, but to the possible effects of oil sands developments that are being considered and the potential impact pathway (Appendix A). 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 ***exposed*** 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 exposed.

1.5 MONITORING AND ANALYTICAL APPROACHES FOR RAMP COMPONENTS

1.5.1 Climate and Hydrology Component

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 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 water and sediment quality, fisheries, benthic and aquatic vegetation surveys by placing in context current hydrologic conditions relative to historical mean or 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 program has gradually expanded geographically to include catchments affected, or expected to be affected, by oil sands development in the area around Fort McMurray. Some catchments outside the oil sands developments 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 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.

The analytical framework shown in Figure 1.4-1 was used to guide the analysis of hydrologic data, with some adjustments to account for the differences between hydrologic and biological data. Most importantly, each watershed affected by development was used as both a control and a treatment watershed simultaneously. The observed hydrograph was used to evaluate defined measurement endpoints for the treatment case, and a naturalized hydrograph was used to evaluate the same defined measurement endpoints for the control case. The approach is discussed in more detail in Section 3.1.

1.5.2 Water and Sediment Quality Components

RAMP monitors water and sediment chemistry in order to identify human and natural factors affecting the quality of streams and lakes in the oil sands region. Monitoring the chemical signatures of water provides point-in-time measurements, while sediment analyses provide information on the rate of chemical accumulations over time. Together, 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 and Sediment Quality components include:

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

- Monitor potential changes in water and 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.

In order to determine if and how a development may be affecting water and sediment 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 and sediment quality related to increasing anthropogenic activity, including oil sands development.

A range of compounds are measured in the Water Quality and Sediment Quality components, including:

Water Quality
- Conventional variables
- Major ions
- Nutrients
- Biological Oxygen Demand
- Target and alkylated PAHs
- Other organics
- Total and dissolved metals

Sediment Quality
- Particle size
- Carbon content
- Target and alkylated PAHs
- Total hydrocarbons
- Metals

Bioassay testing is also conducted to assess toxicity related to chronic exposure of different aquatic organisms to ambient river water or sediment from selected stations.

RAMP water quality stations are located throughout the RAMP study area, from the upper Christina River to the Athabasca River delta. 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.

In the lower Athabasca River, bottom sediments are very transient and are almost completely flushed by high flows related to spring freshet. Existing RAMP sediment quality stations in the Athabasca River are monitored annually in the fall to take advantage of the accumulation of fine sediments that occurs from late spring to late fall. In addition, sediment sampling is conducted occasionally in the Athabasca River delta where upstream sediments transported during high flows accumulate over time. Other waterbodies (e.g., tributaries of the Athabasca River, regional lakes/wetlands) are sampled less frequently, because they are generally exposed to less cumulative development and sedimentation rates are lower than in the Athabasca River. New sediment stations are monitored every fall for the first three years, with toxicity testing being conducted for the first two years to establish baseline conditions. After this time, sampling becomes periodic.

1.5.3 Benthic Invertebrate Community Component

Benthic macroinvertebrates are a commonly used indicator of aquatic environmental conditions. Benthic invertebrates 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 invertebrate life span (typically about one year) allows them to integrate the physical and chemical aspects of water 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 oil sands area;
- Monitor aquatic environments in the oil sands area 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 of RAMP focuses on tributaries of the Athabasca River and regional wetlands (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 oil sands area.

With recent expansion of oil sands operations, the program has expanded to include new tributaries and additional stations on tributaries near active oil sand extraction 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.

1.5.4 Fish Population Component

The RAMP Fish Population component was established to monitor the health and sustainability of fish populations within the oil sands region. Monitoring activities focus on the Athabasca River, as well as tributaries potentially influenced by current or future development. 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, First Nations and the general public with respect to comprehensive ongoing monitoring of fish populations in the oil sands region.

The specific objectives of the Fish Population component are to:

- Appraise the ecological integrity of fish populations in the oil sands region by assessing attributes such as growth, reproduction and survival;
- Assess the suitability of fisheries resources in the oil sands region for human consumption; and
- Generate high quality data on fish populations for use in environmental impact predictions.

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 oil sands region. Specific elements of the core fish program include: fish inventories and spawning surveys; tissue sampling for organic and inorganic chemicals; monitoring of fish health through evaluation of performance indicators (e.g., physical condition, population age, length/weight comparisons etc.) in sentinel fish species; and monitoring of fish population movements using fish fences.

In the oil sands region of Alberta, 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 First Nations, government and industry representatives, and include goldeye, lake whitefish, longnose sucker, northern pike, trout-perch, and walleye (CEMA 2001). Although the 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.

Fish tissue assessments are conducted by RAMP to quantify and monitor contaminant 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. Historically, polycyclic aromatic hydrocarbons (PAHs) have been measured, but the analysis was discontinued in 2002 because these compounds are easily metabolized in fish and unlikely to accumulate in fish muscle. In 2002, analysis of fishes from regionally important lakes was initiated to provide a mechanism to analyze fish captured during opportunistic sampling, or in conjunction with fisheries investigations

mandated separately from RAMP. Regionally important lakes sampled to date consist of 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 parameters 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 oil sands development. The Clearwater River was added to the inventory program in 2003, and 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 fisheries program. 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 fisheries program to assess the potential effects of stressors (e.g., industrial development) on wild fish populations. The approach evaluates the performance (e.g., growth, survival, condition, 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 Environmental Effects Monitoring (EEM) programs under the pulp and paper (Environment Canada 1992) and metal mining (Environment Canada 2002) effluent regulations. Sentinel species monitoring is conducted at regular intervals at several sites in the Athabasca River (trout-perch, longnose sucker), as well as several Athabasca tributaries (slimy sculpin), including the Muskeg River and the Steepbank River. Sentinel species monitoring is conducted on a three year cycle.

Fish fence monitoring, 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 drainage. These data assist in the identification and quantification of local and regional environmental changes in the Muskeg River watershed.

In addition to the core activities, the Fish Population component also includes a variety of other studies designed to address specific data gaps that may arise concerning fish populations in the oil sands region. In particular, these studies have included radiotelemetry studies on the Athabasca and Muskeg rivers, spawning/egg surveys, winter fish habitat surveys and an experimental program looking at the possible application of the fish community-based Index of Biotic Integrity (IBI).

1.5.5 Acid Sensitive Lakes Component

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

The objectives of the Acid Sensitive Lakes (ASL) component within RAMP were originally derived from Alberta Environment's Regional Sustainable Development Strategy (RSDS) for the Athabasca oil sands (AENV 1999). The RSDS identified the importance of protecting the quality of water, air and land within the oil sands region.

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 the continued, long-term monitoring of regional receptors of acidifying emissions under Terrestrial Environmental Effects Monitoring Committee (TEEM) for terrestrial receptors and RAMP for aquatic receptors.

The 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. Additional objectives of the ASL component were stated explicitly in later documents (e.g., RAMP 2004) and include:

- The collection of scientifically defensible baseline and historical data (both chemical and biological) to characterize the natural variability of these parameters in the study lakes;
- The monitoring of aquatic environments to detect and assess cumulative effects and regional trends; and
- The collection of data against which predictions contained in environmental impact assessments (EIAs) can be verified.

The lakes were monitored for various chemical and biological parameters that would be capable of indicating long-term trends in acidification. These included: 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 oil sands developments;
- 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 are to exhibit moderate to high sensitivity to acidification as defined by a total alkalinity less than 400 μeq/L;
- A fall sampling program was implemented to capture a picture of lake water chemistry after conditions have stabilized; and
- In recent surveys (2002 to 2004), small water bodies (ponds), previously ignored, were included in the program because of their proximity to oil sands developments and belief that they might be low in alkalinity and hence highly sensitive to acid deposition.

The 2004 monitoring program continued the design and approach taken in 2003. The same set of 50 lakes used in the 2003 program was sampled during August and September, 2004. As in 2003, the assessment included the calculation of a critical load of acidity for each lake to be compared with levels of predicted Potential Acidic Input (PAI) from all regional activities. The critical load, in units of keq H^+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology. Exceedances of the critical load by the PAI in a lake imply a potential for acidification.

The RAMP lakes are generally highly coloured due to high concentrations of dissolved organic carbon (DOC). These organic substances play a significant role in the acid-base dynamics of these lakes but this role has been poorly defined. As in 2003, detailed analyses were conducted to determine the buffering or acid-neutralizing capacity (ANC) attributable to weak organic acids and the role of strong organic acids in lowering the acid neutralizing capacity of these lakes. Unlike previous years, and consistent with recent research conducted by the NOxSOx Management Working Group (NSMWG), critical loads for each lake were then recalculated for these two effects of organic acids. Determination of the role of organics in the acid-base characteristics of these lakes was one of the major recommendations of the Scientific Peer Review of the Five-Year Report (1997-2001) (Ayles *et al.* 2004). The effort also addresses another of the Scientific Peer Review's recommendations, that of integrating RAMP's ASL component with the efforts of other regional programs.

As in 2003, the chemical characteristics of the RAMP lakes were compared to regional lake chemistry database of 450 lakes reported by the NSMWG (WRS 2004). This comparison is consistent with another recommendation of the Scientific Peer Review Committee on the necessity of determining how representative the RAMP lakes are from a regional perspective.

Increased effort was made in 2004 into detecting potential trends in key chemical parameters that might indicate incipient acidification. Alkalinity, sum of the base cations, sulphate and nutrients were examined over the six monitoring years of the program and longer periods for lakes having more extensive data.

In 2004, metal concentrations in the RAMP lakes were examined for the first time. The examination of metals in these lakes (in particular aluminum) was another of the recommendations of the Scientific Peer Review Committee.

1.5.6 Aquatic Vegetation

Wetlands are an important component of the boreal aquatic ecosystem because they filter out sediment and pollutants from water, recharge the water table, reduce soil erosion of downstream waterbodies and provide food and important habitat for aquatic and terrestrial biota. In addition, specific aquatic plants found in some wetlands are important to First Nation communities from a spiritual perspective.

RAMP monitors select wetlands, such as Shipyard Lake, Isadore's Lake and Kearl Lake, located in close proximity to existing and planned oil sands developments, to assess the health of these systems over time. Historically, monitoring at these wetlands included assessment of water and sediment quality, benthic invertebrate communities, water levels and aquatic vegetation.

The Scientific Peer Review of the Five-Year Report (1997-2001) (Ayles *et al.* 2004) raised a number of concerns regarding several issues, including the objectives and rationale of the program, establishing meaningful vegetation metrics that reflect potential effects related to oil sands development, developing a sampling design that can account for the highly variable nature of wetland ecosystems (spatial and temporal variability), and the ability to evaluate potential impacts on aquatic vegetation given the lack of suitable reference wetlands in the region. Members of the RAMP Steering Committee and Technical Subcommittee agreed with the reviewers concerns, and questioned the need to specifically measure aquatic vegetation as a measure of wetland health given RAMP currently monitors several other biological, chemical and hydrologic assessment indicators in each wetland of interest.

In 2004, an Aquatic Vegetation Task Group recommended that the funds originally allocated to conduct aquatic vegetation fieldwork be used to solicit the assistance of an external expert in wetland aquatic vegetation to evaluate and redesign the monitoring program. However, prior to implementing this recommendation, the Steering Committee (January 13, 2005 meeting) passed a motion to omit this component from RAMP with the proviso that aquatic vegetation monitoring could again be included in RAMP, should the need arise and if a defensible program could be developed.

1.6 COMMUNITY ISSUES AND RAMP

An important focus of RAMP is to communicate monitoring and assessment activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo. In 2004, this goal was achieved using a number of engagement mechanisms that provided both a forum for interested stakeholders to present their concerns regarding regional development and the effects these may be having on the aquatic environment, and by utilizing various media to disseminate current and past technical findings.

The RAMP communications sub-group was reinvigorated in late 2004; members are currently undergoing a scoping exercise that will officially define the RAMP communications mandate. This mandate will identify an engagement strategy and will guide the implementation of specific communications outputs, and provide criteria for evaluating their performance. The group will build upon past achievements as well as identify new communication avenues.

1.6.1 Issues Identified in 2004

Currently, the primary avenue for concerned stakeholders to bring forth concerns to RAMP is through the Steering Committee. In 2004, issues raised at the Steering Committee level included:

- Monitoring of lakes north of Fort McMurray that have traditionally been used by First Nations; and
- Increasing monitoring in the Richardson backcountry region.

Although it was agreed that these requests fall outside the RAMP monitoring mandate, they are currently under review by members of the Steering Committee to determine how they may be addressed. Possible options considered include partnering with government agencies such as Alberta Environment (AENV) or Alberta Sustainable Resource Development (ASRD).

1.6.2 Ongoing RAMP Initiatives

Joint open houses were conducted in Anzac and Fort McKay by RAMP, CEMA and WBEA in 2004. The goal was to provide an opportunity for First Nations communities, students and the general public to meet people involved in managing various environmental activities undertaken in the RMWB, and to express any concerns they may have on how regional developments may be affecting the environment. The open house approach was well received by interested stakeholders, who have requested that these events be held on a regular basis both in Fort McMurray and other outlying communities.

In support of the open houses, RAMP has produced a variety of posters and flysheets outlining monitoring activities, results and recommendations and community contact information. These materials have been circulated to representatives from each of the communities visited, and are available to all interested parties upon request.

Summary reports of the RAMP 2003 technical document and Five-Year Report were produced and circulated to Steering Committee members, Anzac public schools, First Nation Industry Relations Corporations (IRC), and the Oil Sands Discovery Centre. It is generally agreed that this document is written at a technical level that is suitable for "environmentally informed" public and for mid-grade students. Suggestions have been made to increase the school circulation of these documents in the future, and potentially to compose them so that they could be used as a teaching module. This recommendation will be addressed by the communications sub-group in 2005. Summary reports are publicly available from RAMP upon request.

The RAMP fish abnormality program provides training to members of outlying communities so that any fish caught in the area can be scientifically assessed for potential abnormalities. In 2004, Workplace Hazardous Information Materials Information System (WHIMS) and Transportation of Dangerous Goods (TDG) training was offered by RAMP to the regional First Nation IRCs. This certification process is scheduled to be followed by fish dissection training in the spring of 2005. At this point each community will have members outfitted and trained to identify common abnormalities, and dissect, preserve and ship any unidentified fish to a representative at the Fisheries and Oceans Canada in Winnipeg for more detailed analysis.

A number of fish in the Athabasca River have been fitted with radio transmitters and/or external tags. The tagged fish are part of a collaborative fish movement study conducted on behalf of RAMP and CEMA. Members of the public can be an integral part of this study by reporting any tagged fish that are caught. The tag number, tag colour, and the fish's length and weight are important details to report. In 2004, tag recapture information from 17 fish was reported back to RAMP.

The River Response Network was established by RAMP to respond to reports of non-spill type phenomena on the lower Athabasca River. In the event that a report is made, RAMP will provide a coordinated investigation into the scope and nature of the incident. Currently, the program is intended to operate only during the open-water season on the Athabasca River mainstem below Fort McMurray. In 2004, no reports of non-spill events were received by RAMP.

The RAMP webpage has been developed to provide useful tools and easy access to community members or other interested parties. The webpage provides current news, maps, sample site locations, past RAMP reports and current contact information. There also are online reporting forms for people to fill out in the event a fish with abnormalities or a tag is observed. The RAMP webpage can be visited at www.ramp-alberta.org.

1.7 ORGANIZATION OF THE RAMP 2004 TECHNICAL REPORT

Together with this Introduction, the RAMP 2004 Technical Report contains nine sections within which the results of the 2004 RAMP technical monitoring program developed by the RAMP Technical Subcommittee and implemented by the Hatfield RAMP Team are presented.

Section 2: Status and Activities of Athabasca Oil Sands Developments in 2004 – This part of the report contains a description of the activities of:

- each of the oil sands projects financed by RAMP member companies that occurred in 2004;
- oil sands projects financed by companies that are not members of RAMP; and
- other developments in the RMWB.

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

Section 3: Summary of 2004 RAMP Monitoring Program – This section of the report contains concise descriptions of the RAMP monitoring program that was conducted in 2004 for each RAMP component, and includes:

- an overview of the 2004 program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, the 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 2003 field program;
- a description of the challenges and issues encountered during 2004 and the means by which these challenges and issues were addressed; and
- a summary of the component data that is now available.

Each component section of Section 3 includes 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 Oil Sands Development Area in 2004 – This section of the report describes the hydrologic year that was 2004 and how 2004 compares with previous years. This helps set the context for the results, analyses, and conclusions presented in Section 5.

Section 5: Major Results of RAMP to 2004 – This is the main results section, consisting of two major parts:

- Sections 5.1 to 5.9 focus on watersheds in which oil sands developments were underway as of 2004; and

- Sections 5.10 to 5.13 focus on watersheds in which there has been no significant oil sands development to date.

The presentation of the RAMP results for each watershed:

- presents the RAMP results for the particular watershed for each RAMP component following the analytical approaches contained in each of the component sections of Section 3, as described above; and

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

Section 6: Regional Perspectives – This part of the report presents regional assessments of the status of aquatic environmental resources and the possible influence of oil sands developments at the regional level.

Section 7: Conclusions and Recommendations – This section of the report contains a summary of the findings, conclusions, and recommendations from the 2004 RAMP program. The recommendations include proposed changes to the RAMP monitoring network for future years based on the results for 2004.

Throughout the report, where possible and appropriate, recommendations are made for modifications to RAMP based on findings and conclusions. In addition, Traditional Ecological Knowledge is included in the RAMP 2004 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 for each RAMP component.