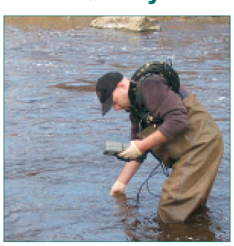
Regional Aquatics Monitoring Program

Climate and Hydrology

Water Quality



Sediment Quality

Benthic Invertebrates

Fish Populations

Acid-Sensitive Lakes

Technical Design and Rationale

December 2009

RAMP: TECHNICAL DESIGN AND RATIONALE

Prepared for:

RAMP STEERING COMMITTEE

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and WESTERN RESOURCE SOLUTIONS

DECEMBER 2009

RAMP1467.1

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ADL	Analytical detection limit
AE, AENV	Alberta Environment
AEC	Alberta Economic Development
AEP	Alberta Environmental Protection
ALPAC	Alberta-Pacific Forest Industries
ANC	Acid neutralizing capacity
ANCOVA	analysis of covariance
ANOVA	Analysis of variance
AOSERP	Alberta Oil Sands Environmental Research Program
ARC	Alberta Research Council
ARC-Vegreville	Alberta Research Council located in Vegreville
ARD	Athabasca River Delta
ASL	Acid-sensitive lakes
ASRD	Alberta Sustainable Resource Development
AUSRIVAS	Australian River Assessment System
AWI	Alberta Wetland Inventory
BCI	Bray-Curtis Index
BOD	Biological oxygen demand
BPC	Big Point Channel
Bpd	Barrels per day
CA	Correspondence analysis
CAEAL	Canadian Association for Environmental Analytical Laboratories
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative effects assessment
CEAA	Canadian Environmental Assessment Agency
CEMA	Cumulative Environmental Management Association
CFIA	Canadian Food Inspection Agency
CIR	False-colour infrared
CL	Critical load
CONRAD	Canadian Oil Sands Network for Research and Development
CPUE	Catch-per-unit-effort
CVAFS	Cold vapour atomic fluorescence spectrophotometry
CWD	Clean water discharge
CWQG	Canadian water quality guidelines

DFO	Fisheries and Oceans Canada
DIC	Dissolved inorganic carbon
DL	Environmental effects monitoring
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EEM	Environmental effects monitoring
EIA	Environmental impact assessment
ENGO	Environmental non-government organization
EPEA	Environmental Protection & Enhancement Act
EPI	External pathology index
EPT	Sum of Ephemeroptera, Plecoptera and Trichoptera
ERCB	Energy Resources Conservation Board
FLC	Fletcher Channel
FMA	Forest management agreement
FSA	Focus study area
FWIN	Fall walleye index netting
GIC	Goose Island Channel
GPS	Global Positioning System
GSI	Gonad somatic index
HAI	Health assessment index
HI	Hazard index
HMW	High-molecular weight
HQ	Hazard quotient
IBI	Index of biotic integrity
IQR	Inter-quartile range
IRC	Industry relations corporations
ISQG	Interim freshwater sediment quality guidelines
KIR	Key indicatory resource
LCS	Laboratory control sample
LMW	Low-molecular weight
LOEC	Lowest observed effects concentration
LSA	Local study area
LSI	Liver somatic index
MDL	Method detection limit
MFT	Mature fine tailings
MOELP	Ministry of Environment, Lands, and Parks

MS-222	Tricaine methane sulfonate
MSC	Meteorological Service of Canada
NOEC	No observed effects concentration
NRBS	Northern River Basins Study
NSMWG	NOx and SOx Management Working Group
NWRI	National Water Research Institute
OCA	Objective classification analysis
PAD	Peace-Athabasca Delta
PAH	Polycyclic aromatic hydrocarbon
PAI	Potential acid input
PC	Principal component
PCA	Principal component analysis
PI	Pathology index
QA	Quality assurance
QA/QC	Quality assurance/quality control
QAP	Quality assurance plan
QC	Quality control
RAMP	Regional Aquatics Monitoring Program
RCA	Reference condition approach
RIVPACS	River invertebrate prediction and classification system
RMWB	Regional Municipality of Wood Buffalo
RSA	Regional study area
RSDS	Regional sustainable development strategy
SAGD	Steam assisted gravity discharge
SBC	Ratio of alkalinity to base cations
SD	Standard deviation
SEWG	Sustainable Ecosystem Working Group (CEMA)
SOP	Standard operating procedures
SPMD	Semi-permeable membrane devices
STP	Sewage treatment plant
SWE	Snow water equivalent
SWI	Specific work instructions
TCU	Total colour units
TDG	Transportation of dangerous goods
TDN	Total dissolved nitrogen
TDP	Total dissolved phosphorus

TDS	Total dissolved solids
TEEM	Terrestrial Environmental Effects Monitoring Committee
TEH	Total extractable hydrocarbon
TEK	Traditional environmental knowledge
TID	Tar Island dyke
TIE	Toxicity identification evaluation
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
ToR	Terms of reference
TP	Total phosphorus
TPU	Potential tainting units
TRH	Total recoverable hydrogen
TSS	Total suspended solids
TVH	Total volatile hydrocarbon
USEPA	United States Environmental Protection Agency
UTF	Underground test facility
UTM	Universal transverse mercator
WBEA	Wood Buffalo Environmental Association
WHMIS	Workplace hazardous materials information systems
WSC	Water Survey of Canada
WWG	Water Working Group (CEMA)
YOY	Young of the year

ACKNOWLEDGEMENTS

RAMP is a multi-stakeholder environmental program with representatives from industry, government (municipal, provincial and federal agencies), local aboriginal communities, and environmental organizations. Through their involvement as part of the RAMP Technical Program Committee, the monitoring program has continued to adapt in response to increasing oil sands development and stakeholder concerns. The current RAMP Technical Design and Rationale document is a revision of the 2005 document, which was written in direct response to comments provided by a scientific peer review of the program conducted in 2003-2004. We thank members of RAMP for their technical guidance and expertise regarding the ongoing refinement of the study design, as well as other interested stakeholders and researchers who have provided their comments and opinions.

1.0 INTRODUCTION

The Regional Aquatics Monitoring Program (RAMP) is a multi-disciplinary initiative established to determine, evaluate and communicate the state of the aquatic environment and any changes that may result from cumulative resource development within the Regional Municipality of Wood Buffalo of northern Alberta. RAMP is a science-based and results-focused environmental monitoring program designed and directed by multi-stakeholder membership. Given the regional scope of RAMP, membership is diverse and includes members from local and Aboriginal communities, environmental non-government organizations, government agencies (municipal, provincial and federal), oil sands and other industries, and other independent stakeholders.

Although the core elements of RAMP, such as discipline-specific monitoring components, and the overall framework and approach have remained relatively consistent over time, the design of the program continues to be adapted and refined in response to new information and changes in scope associated with the ongoing increase in oil sands development in the region.

The following document provides detailed information on the technical design and rationale of RAMP as of 2008 and represents the most recent revision to the previous design and rationale document published in 2005 (RAMP 2005b).

1.1 STUDY BACKGROUND AND OBJECTIVES

1.1.1 RAMP Terms of Reference and Objectives

RAMP was initiated in 1997 and functions according to a well-defined Terms of Reference (ToR, Appendix A1). The RAMP ToR outlines the objectives of the program which are intended to guide the scope, management and implementation of the program:

1. Monitor aquatic environments in the oil sands region to detect and assess cumulative effects and regional trends;

2. Collect baseline data to characterize variability in the oil sands area;

3. Collect and compare data against which predictions contained in Environmental Impact Assessments (EIAs) can be assessed;

4. Collect data that satisfies the monitoring required by regulatory approvals of oil sands developments;

5. Collect data that satisfies the monitoring requirements of company-specific community agreements with associated funding;

6. Recognize and incorporate traditional knowledge into monitoring and assessment activities;

7. Communicate monitoring and assessment activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies and other interested parties;

8. Continuously review and adjust the program to incorporate monitoring results, technological advances and community concerns, and new or changed approval conditions; and

9. Conduct a periodic peer review of the program's objectives against its results, and recommend adjustments necessary for the program's success.

RAMP's original core monitoring program was developed in 1997 by its first Technical Subcommittee. This core monitoring program was supported by a detailed program design and rationale document first developed by the Technical Subcommittee in 2000 (Golder 2000), revised in 2002 (Golder 2002) and revised again in 2005 (RAMP 2005b).

1.1.2 RAMP Components

Over time, RAMP consisted of up to seven aquatic components:

- **Climate and Hydrology** – monitors changes in the quantity of water flowing through rivers and creeks in the oil sands region and water levels in select lakes; first became a component of RAMP in 2000 (although it operated as a separate program since 1995).

- **Water Quality** in rivers and lakes – reflects habitat quality and potential exposure of fish and invertebrates to organic and inorganic chemicals; first became components of RAMP in 1997.

- **Benthic Invertebrate Communities** and **Sediment Quality** in rivers, streams and wetlands – benthic invertebrate communities serve as a biological indicator and are an important component of fish habitat, while sediment quality is a link between physical and chemical habitat conditions to benthic invertebrate communities; first became a component of RAMP in 1997.

- **Fish Populations** in rivers, streams and lakes – biological indicators of ecosystem integrity and a highly valued resource in the region; first became a component of RAMP in 1997.

- **Acid-Sensitive Lakes** – monitoring of water quality in regional lakes in order to assess potential changes related to acid deposition; first became a component of RAMP in 1999.

- **Aquatic Vegetation** in wetlands – an ecological indicator of the health of regional wetlands; first became a component of RAMP in 1997.

In 2004, a RAMP 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 agreed 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.

Therefore, RAMP at present has six components and this study report is focused on the technical design and rationale for Climate and Hydrology, Water Quality, Sediment Quality, Benthic Invertebrate Communities, Fish Populations, and Acid-Sensitive Lakes (ASL).

1.1.3 Regional Sustainable Development Strategy

The Regional Sustainable Development Strategy (RSDS) for the Athabasca Oil Sands Area identified the importance of protecting the quality of water, air and land within the region (AENV 1999). The strategy was developed by federal, provincial and municipal governments and stakeholders, building on Alberta's current environmental and resource management system by creating a framework that would balance oil sands resource development and environmental protection.

The strategy identified a number of environmental issues and/or data gaps through a review of oil sands EIAs and from information presented during Energy Utilities Board (now the Energy Resources Conservation Board) hearings for surface mine and *in situ* bitumen projects. These issues were grouped into 14 themes, for which a "blueprint for action" was developed to resolve the various issues under each theme.

Given RAMP's strong linkage to oil sands EIAs and regulatory-stakeholder input, the technical design and monitoring activities of RAMP provide important aquatic environmental data that support and address several issues and themes outlined in the RSDS (Table 1.1). In fact, monitoring activities such as the Acid-Sensitive Lakes component, were incorporated into RAMP in response to the needs of the RSDS.

1.1.4 RAMP Technical Design and Review Process

The Regional Aquatics Monitoring Program is a multi-faceted program that strives to achieve a holistic understanding of potential changes in aquatic systems related to industrial development in the oil sands region, and to address specific issues important to communities of the region. To facilitate this process, RAMP established a Technical Program Committee that is responsible for the ongoing development and design of the monitoring program. In addition, other procedures have been instituted to ensure the program is scientifically rigorous and focused, while being responsive to monitoring results, increasing oil sands development and community concerns.

Table 1.1 Summary of RSDS needs that are addresses by RAMP activities.

Theme	Description	Information Needs provided by RAMP
7	Cumulative Impacts on Fish Habitat and Populations	• Monitor fish population status • Fish quality monitoring (health and tainting) • Flow monitoring on smaller watersheds • Impact of water flow on fish habitat
9	Effects of Acid Deposition on Sensitive Receptors	• Long-term receptor based monitoring • Acid deposition monitoring for wetlands, aquatic ecosystems
10	Cumulative Impacts on Surface Water Quality	• Impact of muskeg drainage on receiving streams • Cumulative impacts of multiple developments • Long-term hydrological and biological integrity of watersheds • Review water quality monitoring information
11	End Pit Lake Water Quality	• Cumulative impacts of multiple developments on long-term hydrological and biological integrity of watersheds • Review water quality monitoring information
12	Cumulative Impacts on Surface Water Quantity	• Tributary flow monitoring • Improved climate monitoring (evaporation and sunshine data) • Flow monitoring on smaller watersheds

1.1.4.1 Technical Program Committee

The Technical Program Committee (RAMP Tech) is comprised of technically qualified members that represent the various stakeholders of a RAMP, including oil sands industries, government/regulatory agencies (municipal, provincial and federal), Aboriginal communities, environmental non-government organizations and other independent stakeholders (e.g., Alberta Pacific Forest Industries Inc.). Several RAMP Tech members are also members of the RAMP Steering Committee (the RAMP governing body), facilitating information transfer between committees.

The functions of RAMP Tech as defined in the RAMP Terms of Reference (Appendix A1) are to:

- Recommend to the Steering Committee a program that has technical merit and relevance to the needs of the members;
- Ensure that the data collection, monitoring procedures and analytical techniques utilized are current;
- Review data collected and reports prepared for scientific validity; and
- Establish discipline-specific task groups that will be responsible for identifying and recommending monitoring activities specific to their discipline for compilation into the annual RAMP monitoring design.

RAMP Tech currently has three Task Groups: Climate and Hydrology, Fish Populations and a large multi-disciplinary group (referred to as "Super Group") that includes water quality, benthic invertebrate communities and sediment quality, and acid-sensitive lakes. The "Super Group" was established to ensure harmonization of closely related monitoring disciplines (e.g., water/sediment quality and benthic invertebrates, water quality and acid sensitive lakes) and to take advantage of the expertise of several members that could contribute to more than one of the related disciplines, but were unable to in the past because the meetings were held concurrently.

RAMP Tech meets several times annually to discuss the status of the current program, propose potential monitoring approaches/refinements, review the previous year's results and design the future programs. In addition, each discipline-specific Task Group may hold meetings or conference calls independently of other task groups to address issues specific to their discipline.

Generally, there are at least three meetings that have been implemented on an annual basis:

- October Meeting – a one- or two-day meeting of all members used to review how the recent field season had progressed, with emphasis on preliminary field data, field logistical issues, necessary modifications to the sampling design and status/timing of ongoing laboratory analyses. In addition, members may take this opportunity to introduce new up-to-date monitoring approaches and measurement endpoints for discussion, and conduct additional analyses of past data to facilitate their understanding of the information or propose changes to future monitoring programs.

- January/February Task Group Meetings – each Task Group holds a one-day meeting to discuss the results of the previous monitoring year prior to completing statistical analyses and report writing. The intent of the meeting is to provide members an opportunity to review the data and provide comments/suggestions for analyzing and interpreting the data. These meetings also allow all members to be update-to-date on monitoring results prior to designing the monitoring program for the following year.

- March/April Monitoring Design Workshop – a two-day, full-participation meeting with the objective of designing the RAMP monitoring program for the following year. To facilitate this process, each Task Group holds a breakout meeting to design their discipline-specific monitoring program. Following these smaller meetings, all RAMP Tech members reconvene to review and discuss the discipline-specific designs and ensure that they are complimentary to other disciplines and fulfill the objectives of RAMP.

1.1.5 2003 Scientific Peer Review and RAMP Design Documentation

In accordance with RAMP Objective No. 9, above, RAMP underwent a major scientific review of its program in 2003 (Ayles *et al.*, 2004), including reviews from academia and federal research agencies. The review was based primarily on the RAMP Five Year Report (Golder 2003a) that summarized the results of the RAMP monitoring program between 1997 and 2001, although annual RAMP reports were referred to when necessary. The review was focused on the first three objectives of RAMP: characterizing existing variability, detecting regional trends and cumulative effects, and monitoring to verify EIA predictions. One of the recommendations of the 2003 Scientific Peer Review was the need to provide clear documentation and rationale for the current RAMP monitoring program and its design. This recommendation was made on the basis of a finding that the original rationale and design of the RAMP needed updating to reflect:

- the scope and rapid expansion of Athabasca oil sands development that could not have been foreseen in 1997; and
- environmental issues raised by RAMP members (industry, local communities, NGOs and government) in response to oil sands development that RAMP addressed through its monitoring program.

The RAMP Steering Committee, in response to the findings of the 2004 Scientific Peer Review, undertook to revise and update documentation describing the rationale and technical design of its monitoring program; the Terms of Reference for this work has been provided in Appendix A2. With a second Scientific Peer Review of RAMP taking place in 2009-2010, the design and rationale document has been revised and updated to reflect changes since 2005.

1.2 STUDY METHODOLOGY

The purpose of this study is to document and explain the current design and rationale of RAMP, recognizing that the RAMP design is a function of a number of factors, including: scientifically-based and statistically-sound monitoring of potential changes related to Athabasca oil sands activities; oil sands approval requirements, local community concerns; and requirements for cost-effectiveness. This report describes and explains the combination of factors that has contributed to the design of each RAMP component.

Therefore, in accordance with the original 2005 ToR for this study (Appendix A2), the RAMP design and rationale document was developed using the following methodology to achieve the study objectives.

1.2.1 Review of Athabasca Oil Sands EIAs

The starting point for the technical design documentation of RAMP was the predictions made in Athabasca oil sands EIAs. These EIAs provide information relevant to at least three of RAMP’s technical objectives (i.e., monitoring to detect and assess cumulative effects and regional trends, baseline data to characterize environmental variability, and collecting data to assess EIA predictions). The EIAs also give guidance on key elements of the original ToR for this study (Appendix A2), particularly, identification of oil sands activities, key response indicators, working hypotheses and questions, impact predictions, and monitoring recommendations. In addition, it was assumed that having a basis in the scope and findings of Athabasca oil sands EIAs was sufficient (but not necessary) rationale for the RAMP technical design.

EIAs prepared for the following 17 Athabasca oil sands projects (oil sands EIAs available as of June 2005) were reviewed and the information listed in Table 1.2 was extracted and summarized for each of the RAMP components in the 2004 program:

Albian Muskeg River	Shell Jackpine
Canadian Natural Horizon	Suncor Firebag
ConocoPhillips Surmont	Syncrude Mildred Lake
Deer Creek Joslyn Phase 2	Suncor Millennium
Husky Sunrise	Suncor South Tailings
Opti/Nexen Long Lake	Suncor Steepbank
Petro-Canada MacKay River	Suncor Voyageur
Petro-Canada Meadow Creek	Syncrude Aurora
Petro-Canada/UTS Fort Hills	

Information related to impact hypotheses and key questions was extracted from the EIAs and entered into an Excel database. The information was organized around residual impact assessments because residual impact assessments are generally only considered in EIAs after the validity of the impact pathway for the project has been confirmed and after mitigation measures have been specified. Accordingly, they represent environmental impacts that are most likely to occur as a result of the particular oil sands project.

The review of EIAs was originally conducted as part of the 2005 version of the design and rationale document. At that time, it was recognized that there was a high degree of similarity among oil sands EIAs including specific elements such as potential impact pathways, key indicator resources, and residual impact assessments. Accordingly, no further review of EIAs was undertaken for the current version of this report.

Also, since the 2005 analysis, an aggregate mining industry joined RAMP as a full member (Birch Mountain Resources Ltd, presently known as Hammerstone Corporation.). Accordingly, the EIA for this project was reviewed to confirm that the effects pathways previously documented for oil sands projects encompassed the major aquatics issues specific to a limestone quarry.

Table 1.2 Description of information extracted from selected Athabasca oil sands EIAs.

Information Extracted	Description
General Information	
Summary Information	Basic project information: location; operation type (i.e., mine vs. *in situ*); disturbance area; target production; projected lifespan; date of EIA submission.
Impact Assessment Cases	A description of the three assessment cases considered in each of the EIAs: Baseline Case, Application Case, and Planned Development Case.
Key Indicator Resources	A list of Key Indicator Resources (KIRs) of concern for the project for each of the RAMP components, specific to each watercourse or waterbody if possible.
Spatial Scope	A description of the Local Study Area (LSA) and Regional Study Area (RSA) for each of the RAMP components (maps of each were extracted if they were available in the EIA documentation obtained from RAMP members).
Information for each Impact Hypothesis or Key Question	
Detailed EIA Predictions	For each RAMP component, a summary of the issues of concern, the assessment endpoint associated with each issue, the project activities hypothesized as potentially affecting the assessment endpoint, the scale of the potential effect (i.e., local, regional, or cumulative), the waterbodies and watercourses for which the issue was identified as a concern, and the project phases for which the issue was identified as a concern.
Measurement Endpoints	The specific measurement endpoints used in the EIAs for each issue, if they were specified.
Criteria for Assessment of Impact	The measures of difference between predictions made under the Baseline Case and each of the other two cases (Application and Planned Development) used in the EIAs for determining whether or not a change in the measurement endpoints was likely to occur, can be detectable, and whether the change was to be significant.
Overall Predictions of Residual Impact	For each issue, the prediction of the residual effect of the project on the measurement endpoints, including the uncertainty associated with the residual impact prediction.
Monitoring and Research	A summary of the monitoring and research recommendations.

As a supplement to the EIA reviews, Alberta Environment (AENV) approvals for these Athabasca oils sands projects were also reviewed to assess the extent to which the scope of a RAMP component was determined by approval requirements and what the specific requirements were.

1.2.2 Documentation of Technical Design of RAMP Components

The findings of the reviews of the Athabasca oil sands EIAs were used as "raw material" for documenting the technical design of the RAMP components. Each aspect of the technical design of the RAMP component was compared with the findings of the EIA reviews to assess whether the EIAs provide sufficient rationale for the RAMP technical design. Additional rationale and documentation of the RAMP technical design was provided if required; this was obtained from reviews of previous annual RAMP technical reports and requirements in project approvals, as well as information provided by key members (past and present) of the RAMP Technical and Steering Committees as needed.

For each RAMP component, this documentation consisted of:

Component History – summary of the historical and current sampling design for each component (up to and including the scope of the 2008 field season) and current detailed sampling design, including location, frequency of sampling and variables collected.

Key Indicator Resources – a list of the KIRs that guide the scope and design of the component, a rationale for their inclusion in RAMP, a comparison of the list of RAMP KIRs with the KIRs defined in the Athabasca oil sands EIAs for the component, and documentation of the reasons for any significant discrepancies between the RAMP KIRs and the KIRs assessed in the EIAs.

Hypotheses and Questions – a statement of the specific objectives of each component, the questions being answered by the component, the specific hypotheses being tested, a comparison of the key questions being addressed in RAMP with the major impact pathways contained in the Athabasca oil sands EIAs, and documentation of the rationale for any significant discrepancies between the scope of the questions being addressed in the component and the impact pathways addressed in the EIAs.

Measurement Endpoints and Criteria for Determining Change – a list of both the measurement endpoints and criteria for determining change used in the component, a comparison of these lists with those generated from the review of the Athabasca oil sands EIAs, and documentation of the reasons for any significant differences.

Sampling Station Selection and Sampling Design – a general explanation of criteria and the approach used for the location of monitoring stations, the sampling regime for these stations for both the *baseline*[1] and *test*[2] situations, the rationale for the overall sampling station selection procedures and for including each existing sampling station, and documentation of the reasons for any additions or deletions of stations over the course of RAMP.

Sampling Protocol – a summary description of sampling methods and reasons for any changes to sampling protocols methods implemented during the RAMP program.

Analytical Approach – a description of the data analysis procedures used by the component for characterization of natural baselines, assessment of oil sands project-level changes and watershed-level changes; regional trends; and cumulative effects.

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[1] The term used to characterize data and information gathered about aquatic resources from locations that are designated to be in reference (*baseline*) areas, i.e., aquatic resources and locations that are not yet influenced by oil sands developments.

[2] The term used to characterize data and information gathered about aquatic resources from locations that are designated as *test*, i.e., aquatic resources and physical locations that are downstream of any oil sands developments.

1.3 BACKGROUND INFORMATION

1.3.1 RAMP Study Area

The Regional Municipality of Wood Buffalo (RMWB) in northeastern Alberta defines the RAMP Regional Study Area (RSA, Figure 1.1). The RMWB covers an area of 68,454 km^2, and according to the 2007 Municipal Census had a population of approximately 90,000 persons of which 65,400 were residents of Fort McMurray and 18,500 persons were in work camps (RMWB 2007). The RMWB represents the RAMP Regional Study Area (RSA) 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, various demarcations on the west including the Athabasca River, and the Cold Lake Air Weapons Range on the south.

Within the RSA, a Focus Study Area (FSA) is defined by the watersheds in which oil sands development is occurring or is planned (Figure 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.

1.3.2 Oil Sands Projects and Other Developments

In 2008, eleven companies representing 21 oil sands projects and one aggregate project under construction or in operation participated in RAMP (Table 1.3). In addition, several oil sands projects located within the RAMP FSA, particularly *in situ* operations south of Fort McMurray, are being developed by companies which are not members of RAMP. While most RAMP industry members are constructing or operating oil sands projects in the RAMP FSA, others, such as Hammerstone Corporation, are companies constructing and operating other types of projects (e.g., limestone quarry). Therefore, the term "focal projects" is used and is defined as those projects owned by RAMP industry members that were under construction or operational in 2008 in the RAMP FSA.

1.3.3 Aquatic Setting

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.

As the Athabasca River flows northward through the RAMP FSA, several smaller tributary streams and rivers join and contribute to the overall flow (Figure 1.2). Some of the larger of these tributaries include, in upstream to downstream order:

- Clearwater-Christina Rivers – the Clearwater originates in Saskatchewan, joins the Athabasca River at Fort McMurray, and includes the contribution of the Christina River, a large tributary of the Clearwater River whose 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 Suncor *in situ* Meadow Creek Project and the JACOS (Japan Canada Oil Sands Limited) *in situ* Hangingstone Project;

- Steepbank River – joins the Athabasca River from the east and whose watershed includes the Suncor Steepbank/Project Millennium mines, and extensions of the Suncor North Steepbank Mine, and part of the Suncor *in situ* Firebag Project;

- Muskeg River – flows from the east and drains several oil sands development areas, including Shell-Albian Muskeg River Mine and Expansion, Syncrude Aurora North Mine and planned Aurora South Mine, part of the Suncor *in situ* Firebag Project, Shell-Albian Jackpine Mine, Husky *in situ* Sunrise Thermal Project, Imperial Oil Kearl Project and the Hammerstone Corporation Muskeg Valley Quarry and Hammerstone Project;

- MacKay River – flows from the west and whose watershed includes Suncor MacKay River and Dover *in situ* developments, as well as the approved MacKay River Expansion, and portions of Syncrude Mildred Lake project area;

- Ells River – flows from the west and whose watershed includes Total E&P Joslyn, and the proposed Total E&P Canada North Mine Project; this river is also the drinking water source for Fort McKay;

- Tar River – also flowing from the west, whose watershed contains most of the Canadian Natural Horizon Project;

- Calumet River – similar to the Tar River, flowing from the west and whose watershed is partly within the Canadian Natural Horizon Project; and

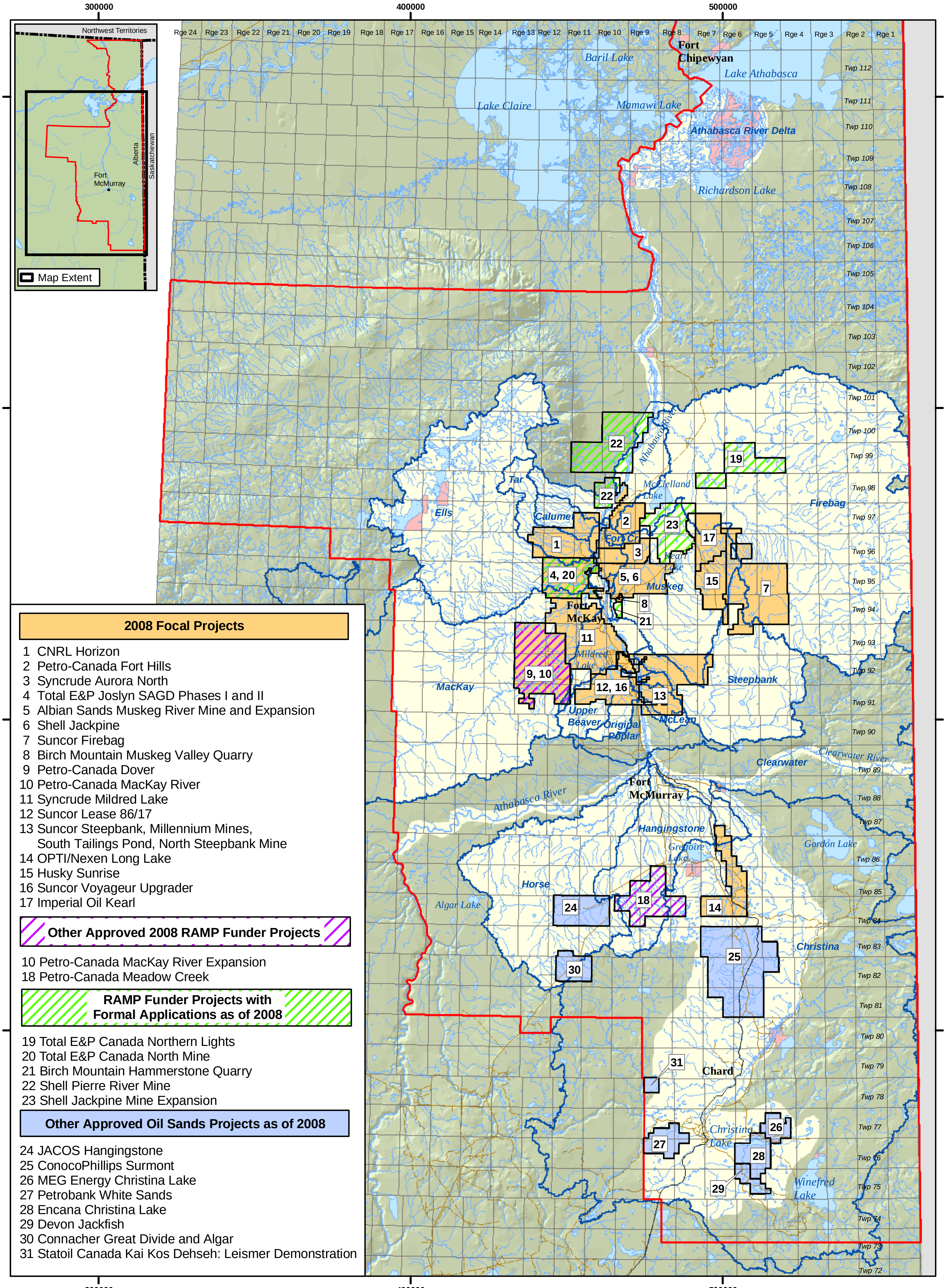
- Firebag River – a river flowing from Saskatchewan, whose watershed includes most of the Suncor *in situ* Firebag Project, parts of the Suncor Fort Hills Project, Husky Sunrise Project, Imperial Oil Kearl Project and potential future developments such as Total E&P Canada Northern Lights Project.

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, Shelley Creek, Stanley Creek, Gregoire River, Iynimin Creek, Jackpine Creek, etc.);
- smaller river tributaries of the Athabasca River (Fort Creek, Poplar Creek, McLean Creek, and Beaver River);
- specific lakes and wetlands such as Isadore's Lake, Shipyard Lake, McClelland Lake, and Kearl Lake;
- a set of regional lakes important from a fisheries perspective; and
- a set of lakes throughout the RAMP RSA for the purpose of assessing lake sensitivity to acidifying emissions.

Finally, there are a number of waterbodies and watercourses monitored under RAMP that are used as reference areas for certain RAMP components.

Figure 1.1 RAMP study areas and Athabasca oil sands areas under planning and development as of 2008.



RAMP
Regional Aquatics Monitoring Program

LEGEND

- Lake/Pond
- River/Stream
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area
- RAMP Focus Study Area
- Watershed Boundary

2008 Focal Projects are those projects within the RAMP FSA that were active in 2008 and were operated by 2008 RAMP funders. Boundaries on this map for approved projects under construction or operation consist of oil sands leases owned by 2008 RAMP funders in which land change was detected in 2008 (described in Section 2.0). Boundaries for other projects reflect oil sands lease boundaries contained in EIAs. Boundaries for Birch Mountain projects are a delineation of 2008 land change.

0 15 30 60 Km

Scale 1:1,300,000

Projection: UTM Zone 12 NAD83

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, First Nation Reserve, and Hillshade from 1:250,000 National Topographic Data Base (NTDB).
b) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
c) Watershed Boundaries from the Cumulative Management Association (CEMA).
d) Oil Sands Project Boundaries Derived from Alberta Energy Oil Sands Lease Agreements.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP1467\GIS_MXD\A_DR\RAMP1467_DR_01_StudyArea_20090423.mxd

Figure 1.2 Hydrologic schematic of RAMP Focus Study Area.

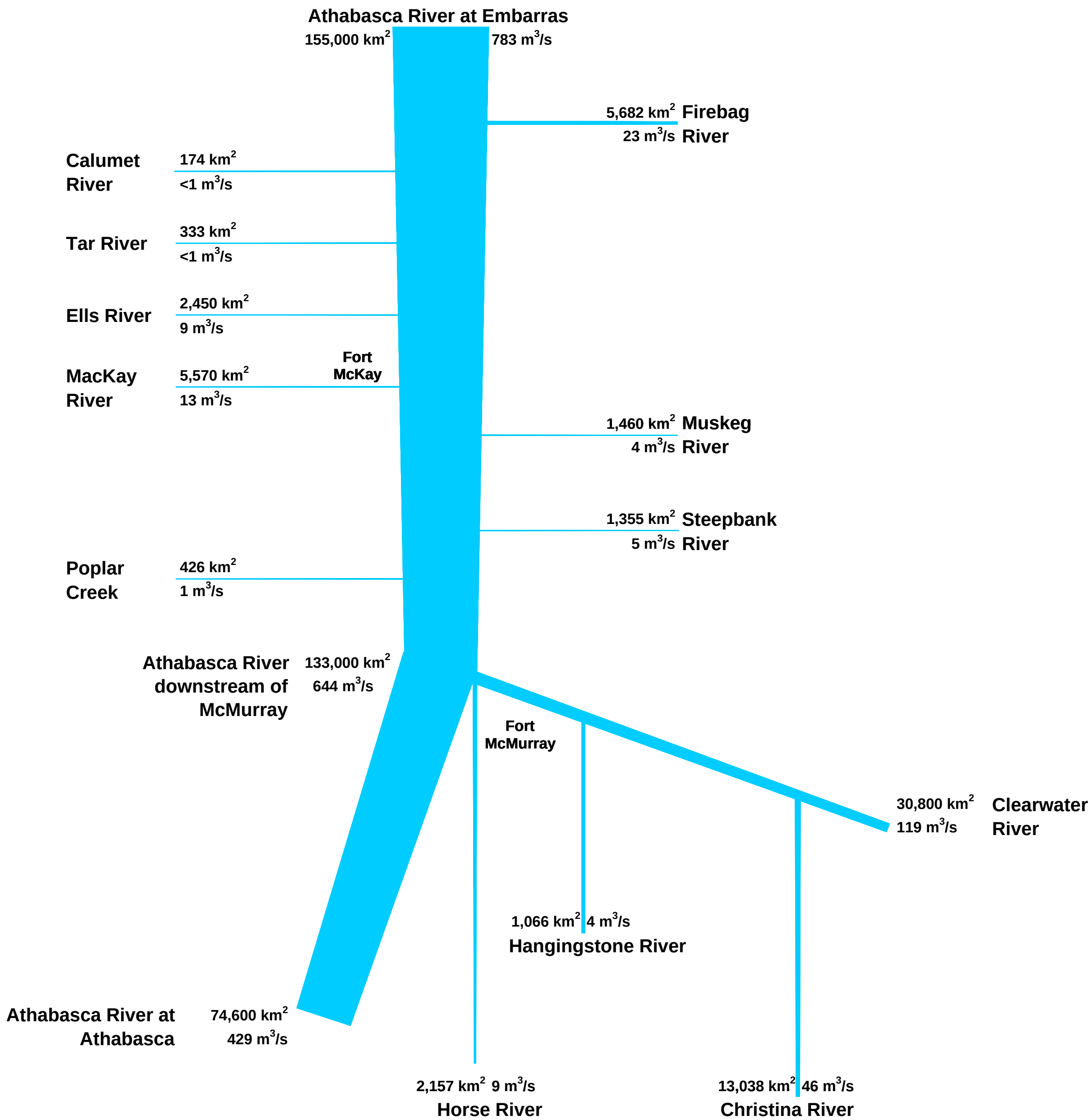


Table 1.3 Status and activities of developments (oil sands, aggregate operations) within RAMP Focus Study Area as of 2008.

Development	Location	Type of Operation	Capacity: Bitumen	Capacity: Synthetic	Date of Application	Year of First Disturbance	2008 Status	Clearwater-Christina	Hangingstone	Steepbank	Muskeg	MacKay	Ells	Tar	Calumet	Firebag	Misc. Athabasca R. Tributaries[a]	Misc. Lakes and Wetlands[b]	Athabasca River and Delta
Suncor Energy Inc.																			
Lease 86/17	30 km N of Fort McMurray	open-pit			1964	1967	**Upgrading, Storage Ponds**												
Steepbank Mine	30 km N of Fort McMurray	open-pit	280,000		1996	1997	**Operational**												
Steepbank Mine Extension	30 km N of Fort McMurray	open-pit			2005	2007	**Planning**												
Millennium Mine and Upgrader	30 km N of Fort McMurray	open-pit, processing		110,000	1998	2000	**Operational**												
Fixed Plant Expansion	30 km N of Fort McMurray	processing		220,000	1996	existing area	**Operational**												
Firebag Project	40 km NE of Mildred Lake	in-situ	280,000		2000	2002	**Operational**												
South Tailings Pond	25 km N of Fort McMurray	tailings pond	n/a	n/a	2003	2005	**Construction**												
Voyageur: North Steepbank Mine Expansion	30 km N of Fort McMurray	open-pit		180,000	2005	2007	**Construction**												
Voyageur: Voyageur Upgrader	30 km N of Fort McMurray	processing		550,000	2005	2007	**Construction**												
Syncrude Canada Ltd.																			
Mildred Lake (Base Mine)	45 km N of Fort McMurray	open-pit	90,000		1973	1973	**Operational**												
Mildred Lake Upgrader	45 km N of Fort McMurray	processing		250,000	1998	existing area	**Operational**												
North Mine	60 km N of Fort McMurray	open-pit	160,000		1995	1996	**Operational**												
Aurora North	east side of Athabasca River	open-pit	200,000		1996	1996	**Operational** - production from two mine trains												
Aurora South	east side of Athabasca River	open-pit	200,000				**Planning** - approval received from EUB but application to AENV not yet submitted												
Mildred Lake Upgrader Expansion	45 km N of Fort McMurray	processing		300,000	1995	2003	**Construction** - first of three phases more than 75% built												
Shell Albian Sands																			
Muskeg River Mine	75 km N of Fort McMurray	open-pit	155,000		1997	2000	**Operational**												
Muskeg River Mine Expansion	North of Jackpine Mine	open-pit	115,000		2005	2007	**Construction**												
Shell Canada Energy																			
Jackpine Mine (Phase 1)	East portion of lease 13	open-pit	200,000		2002	2008	**Approved** - approval in early 2004												
Jackpine Mine Expansion (Phase 2)	65 km NNE of Fort McMurray	open-pit	100,000		2007	-	**Application**												
Pierre River Mine	90 km NNE of Fort McMurray	open-pit	200,000		2007	-	**Application**												
Canadian Natural																			
Horizon Project Phase 1	80 km N of Fort McMurray	open-pit	135,000		2002	2008	**Operational**												
Horizon Project Phase 2, 3	80 km N of Fort McMurray	open-pit	135,000			2011	**Construction**												
Kirby Project	85 km NE of Lac la Biche	in situ	30,000		2002	2011	**Planning**												
Imperial Oil Resources																			
Kearl Project Phase 1	70 km NE of Fort McMurray	open-pit	100,000		2005	2010	**Approved**												
Kearl Project Phase 2	70 km NE of Fort McMurray	open-pit	100,000		2005	2012	**Approved**												
Kearl Project Phase 3	70 km NE of Fort McMurray	open-pit	100,000		2005	2018	**Approved**												
Petro-Canada																			
MacKay River Phase 1	60 km NW of Fort McMurray	in-situ	33,000		1998	2002	**Operational**												
MacKay River Phase 2	60 km NW of Fort McMurray	in-situ	40,000			2009	**Approved**												
Meadow Creek Phase 1 and 2	45 km S of Fort McMurray	in-situ	80,000		2001	unknown	**Approved**												
Fort Hills	90 km N of Fort McMurray	open-pit	190,000		2001	2011	**Approved**												
Opti Canada Ltd. /Nexen Inc.																			
Long Lake Phase 1	40 km SE of Fort McMurray	in-situ	72,000		unknown	2007	**Operational**												
Long Lake South Phase 1	41 km SE of Fort McMurray	in-situ	70,000		unknown	2010	**Planning**												
Long Lake South Phase 2	40 km SE of Fort McMurray	in-situ	70,000		2003	2012	**Planning**												
Total E&P Canada																			
Joslyn, SAGD Phase 1	60 km NW of Fort McMurray	open pit,in-situ	2,000		unknown	2004	**Operational**												
Joslyn, SAGD Phase 2	60 km NW of Fort McMurray	open pit, in-situ	10,000		2004	2005	**Operational**												
Joslyn, SAGD Phase 3A	60 km NW of Fort McMurray	in situ	15,000		2005	2007	**Planning**												
Northern Lights	100 km NE of Fort McMurray	open-pit	100,000		unknown	unknown	**Planning**												
Husky Energy																			
Sunrise Phase 1	70 km NE of Fort McMurray	in situ	60,000			2012	**Approved**												
Sunrise Phase 2	70 km NE of Fort McMurray	in situ	50,000			2014	**Approved**												
Sunrise Phase 3	70 km NE of Fort McMurray	in situ	50,000			2016	**Approved**												
Sunrise Phase 4	70 km NE of Fort McMurray	in situ	50,000			2018	**Approved**												
Hammerstone Corporation																			
Muskeg Calley Quarry	75 km N of Fort McMurray	aggregate	-		2004	2005	**Operational**												
Hammerstone Quarry	75 km N of Fort McMurray	aggregate	-		2006	-	**Approved**												
Non-RAMP Members:																			
Devon Canada Corporation																			
Jackfish Project Phase 1	15 km SE of Conklin	in sity	35,000		2003	2008	**Operational**												
Jackfish Project Phase 2	15 km SE of Conklin	in situ	35,000		n/a	2011	**Approved**												
EnCana Energy																			
Borealis Phase 1		in situ	35,000			2015	**Planning**												
Christina Lake, Phase 1A	170 km S of Fort McMurray	in-situ	10,000		1998	2002	**Operational**												
Christina Lake, Phase 1C, 1D	170 km S of Fort McMurray	in-situ	80,000		1998	20,102,011	**Planning**												
Connacher Oil and Gas																			
Great Divide Pod 1		in-situ	10,000		1996	2007	**Operational**												
Great Divide Pod 2		in-situ	10,000			2009	**Planning**												
Hangingstone East/Halfway Creek Exploratory Program		in-situ	n/a		2001	n/a	**Approved**												
ConocoPhillips																			
Surmont Phase 1	60 km SE of Fort McMurray	in-situ	25,000		1996	2006	**Operational**												
Surmont Phase 2-4	60 km SE of Fort McMurray	in-situ	75,000		2001	2008-2014	**Approved**												
JACOS																			
Hangingstone Pilot	50 km SE of Fort McMurray	in-situ	10,000		1997	2002	**Operational**												
Hangingstone	50 km SE of Fort McMurray	in-situ	50,000		unknown	unknown	**Planning**												
Petrobank Energy and Resources Ltd.																			
Whitesands Pilot	10 km NW of Conklin	in situ	1,900		2003	2006	**Operational**												
Whitesands Expansion	10 km NW of Conklin	in-situ	1,900		n/a	2008	**Planning**												

[a] any one or more of Mills Creek, Poplar Creek, McLean Creek, Fort Creek and Beaver Creek

[b] any one or more of Isadore's Lake, Shipyard Lake, McClelland Lake, or Kearl Lake

1.3.4 Designation of Baseline and Test Areas

As a result of the focal projects described in Figure 1.1 and Table 1.3, particular parts of watersheds in the RAMP FSA, including all RAMP aquatic resources and sampling locations contained in those areas, are designated as either "*baseline*"[3] or "*test*"[4]. A "*baseline*" station is defined as any station that is not influenced by approved focal projects by RAMP members. Given classification of stations may change over time, *baseline* stations can be associated with a time period (i.e., prior to focal project development) or to a condition (i.e., without focal project development) depending on their location and the specific monitoring year. A "*test*" station is defined as any station downstream of an approved focal project that is in some stage of physical development. An impact assessment is made by comparing conditions observed at specific *test* stations of interest to conditions found at *baseline* stations and/or time periods. Table 1.4 contains the watershed designations used as of 2008. In addition, Poplar Creek, McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake are designated as *test* aquatic systems, while McClelland Lake, Kearl Lake, and the Horse and Dunkirk Rivers are designated as *baseline* aquatic systems.

Table 1.4 Watershed designations (*baseline* vs. *test*) as of 2008.

Watershed	Designation and Rationale
Athabasca River mainstem	Confluence of Clearwater River designated as division between *baseline* (upstream) and *test* (downstream) with respect to focal projects.
Athabasca River Delta	Entire Athabasca River Delta designated as *test*. Athabasca River Delta is downstream of all focal project development activities.
Muskeg River	Area downstream of active focal project operations designated as *test*. Remainder of watershed designated as *baseline*.
Steepbank River	Area downstream of active oil sands operations designated as *test*. Remainder of watershed designated as *baseline*.
Tar River	Area downstream of activities being conducted by the Canadian Natural Horizon Project designated as *test*. Remainder of watershed designated as *baseline*.
MacKay River	Area downstream of activities being conducted by Suncor's MacKay River Project designated as *test* as of 2002. Remainder of watershed designated as *baseline*.
Firebag River	Area downstream of the Suncor Firebag Project designated as *test* as of 2008; Remainder of watershed designated as *baseline*.
Ells River	Area downstream of activities being conducted by Total Energy designated as *test*. Remainder of watershed designated as *baseline*.
Calumet River	Area downstream of active oil sands operations designated as *test*. Remainder of watershed designated as *baseline*.
Clearwater-Christina Rivers	Christina River downstream of the Long Lake *In situ* Project is designated as *test*. The remainder of the Christina River watershed is designated as *baseline.* Clearwater River downstream of Christina River confluence designated as *test*.. Clearwater River upstream of Christina River confluence is a long-term *baseline* area.
Hangingstone River	Entire watershed designated as *baseline*; oil sands development to date is limited to the JACOS Hangingstone SAGD Pilot Project in the upper watershed.

[3] The term *baseline* does not necessarily imply natural reference conditions given a *baseline* station or time period could be influenced by non-focal projects (i.e., forestry and sewage treatment plants).

[4] The use of the term *test* does not imply or presume that effects of focal project developments are occurring or have occurred, but simply the data collected from these locations are being tested against baseline conditions to assess for potential changes.

1.4 OUTLINE OF REPORT

In addition to the Introduction, this report contains two major chapters:

- *Chapter 2: Results of Athabasca Oil Sands EIA Review* contains a summary of the main findings of the review and documentation of the 17 Athabasca oil sands EIAs as listed above in Section 1.2.1, Page 1-6.

- *Chapter 3: RAMP Design and Rationale* contains the formal rationale for the current design of the RAMP monitoring program, up to and including the design for 2008.

The main report is supplemented by a series of technical appendices; these appendices include a set of standard operating procedures (SOPs) for each RAMP technical component.

2.0 RESULTS OF ATHABASCA OIL SANDS EIA REVIEW

A total of 809 residual impact assessments that were unique combinations of project, project phase, RAMP component, scale, and waterbodies/watercourses of concern were extracted from the 17 EIAs that were reviewed. Of the 809 residual impact assessments, 695 had formal, explicitly stated predictions about the overall effect of the project on the RAMP component. Appendix A3 contains a compilation of the 809 RAMP residual impact assessments extracted from the 17 EIAs. The EIAs summarized in this document were completed prior to 2005. Although there have been more EIAs completed since this time, they have not been added to the review as it was recognized that there is a high degree of similarity among oil sands EIAs over time.

2.1 SUMMARY BY RAMP COMPONENT

As expected, the number of residual impact assessments for each level of impact declines with the predicted severity of impact (Table 2.1). Approximately 74% of all predictions for which an assessment of residual impacts was made were assessed as Negligible. By contrast, none of the predictions for which there was a formal assessment of residual impact was assessed as High, and about 6% of all predictions for which there was a formal assessment of residual effects were assessed as Moderate. Practically all of the residual impact assessments (i.e., 94%) were classified as Negligible or Low.

The highest number of residual impact assessments in the EIAs was made for the Fish Population component (32% of all assessments), followed by Climate and Hydrology and Water Quality. By contrast, there were relatively few residual impacts identified for Sediment Quality, Benthic Invertebrate Communities, and Acid-Sensitive Lakes (ASL).

2.2 SUMMARY BY IMPACT PATHWAY

There are patterns in the 809 residual impact assessments compiled in Appendix A3 in that the same aquatic effects issues tend to appear repeatedly in the oil sands EIAs with some variation according to whether the project is a surface mine project or an *in situ* project. The residual impact assessments extracted from the 17 EIAs were summarized into synoptic descriptions of potential effects of oil sands development activities on those aquatic resources considered by RAMP (Figure 2.1 for surface mine oil sands developments and Figure 2.2 for *in situ* oil sands developments). Table 2.2 and Table 2.3 present the synoptic descriptions in table form for surface mine and *in situ* oil sands projects, respectively. The 809 residual impact predictions are described by a small number of dominant impact pathways linking oil sands project activities to aquatic resources covered within RAMP (Table 2.4).

As part of the EIA, residual impacts (impacts related to project activities that may occur despite mitigation efforts) are identified and described based on various criteria such as direction, magnitude, geographic extent, duration, reversibility of the potential impact. The frequency of occurrence of residual impact assessments in the reviewed EIAs for each impact pathway described in Table 2.4 represents the importance placed on different issues and impact mechanisms linking oils sands development to aquatic resources covered within RAMP. The results indicate the following:

- **Climate and Hydrology** – residual impact assessments related to physical changes to the surface hydrologic network were the most frequent, followed by changes in natural hydrologic processes (usually due to land cover changes and surface runoff) and planned withdrawals and releases into the existing hydrologic network.
- **Water Quality** – residual impact assessments related to the introduction of chemicals to the aquatic environment were the most frequent, followed by effects of changes in hydrologic conditions. Introduction of pollutants into waterbodies and watercourses as an indirect consequence of project activities occurred much less frequently at the residual impact assessment stage.
- **Sediment Quality** – most of the relatively few residual impact assessments for sediment quality were related to the introduction of chemicals to the aquatic environment.
- **Benthic Invertebrate Communities** – most of the relatively few residual impact assessments for benthic invertebrate communities were related to effects potentially caused by changes in water quality and in sediment quality.
- **Fish Populations** – residual impact assessments related to potential changes in water quality occurred most frequently. This was followed by changes in hydrologic conditions, and changes in amounts of physical habitat. Impact pathways related to changes in sediment quality and changes in benthic invertebrate communities were relatively rarer in the residual impact assessments.
- **Acid-Sensitive Lakes** – all residual impact assessments related to ASL addressed the effects of acidifying emissions.

Table 2.1 Summary of overall residual impact assessments by RAMP component and impact level.

RAMP Component	No. Residual Impact Assessments at Each Impact Level[1]					No. with No Explicit Assessments	Total
	High	Moderate	Low	Negligible	Total No. Predictions		
Climate and Hydrology	0	16	43	121	180	30	210
Water Quality	0	11	55	120	186	32	218
Sediment Quality	0	0	6	23	29	2	31
Benthic Invertebrate Communities	0	0	3	14	17	2	19
Fish Populations	0	9	29	224	262	45	307
Acid-Sensitive Lakes	0	3	4	14	21	3	24
Total	0	39	140	516	695	114	809

[1] Note: different EIAs defined each level differently for each environmental component.

Figure 2.1 Summary description of expected effects of surface mine oil sands projects on aquatic resources covered in RAMP.

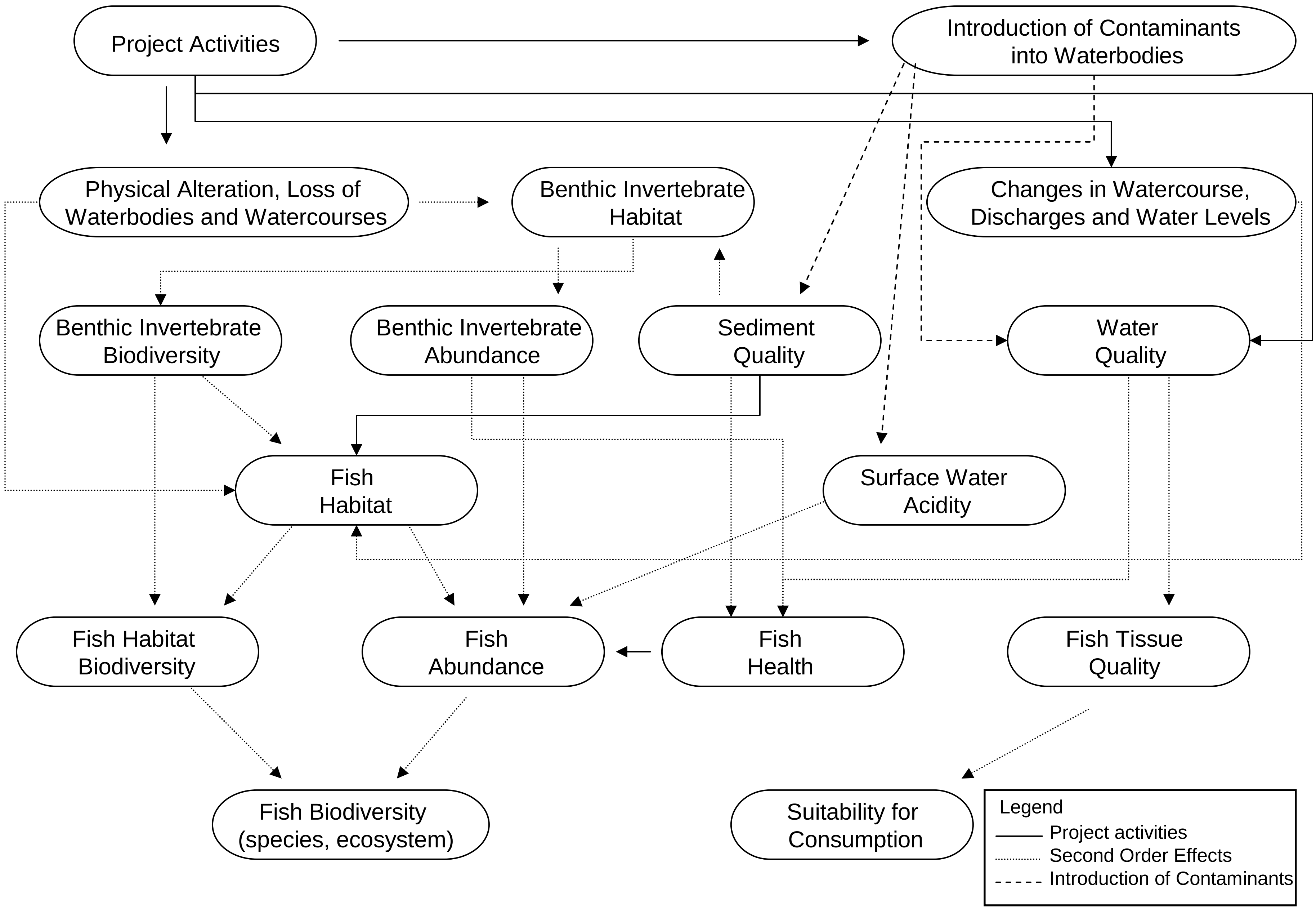


Figure 2.2 Summary description of expected effects of *in situ* oil sands projects on aquatic resources covered in RAMP.

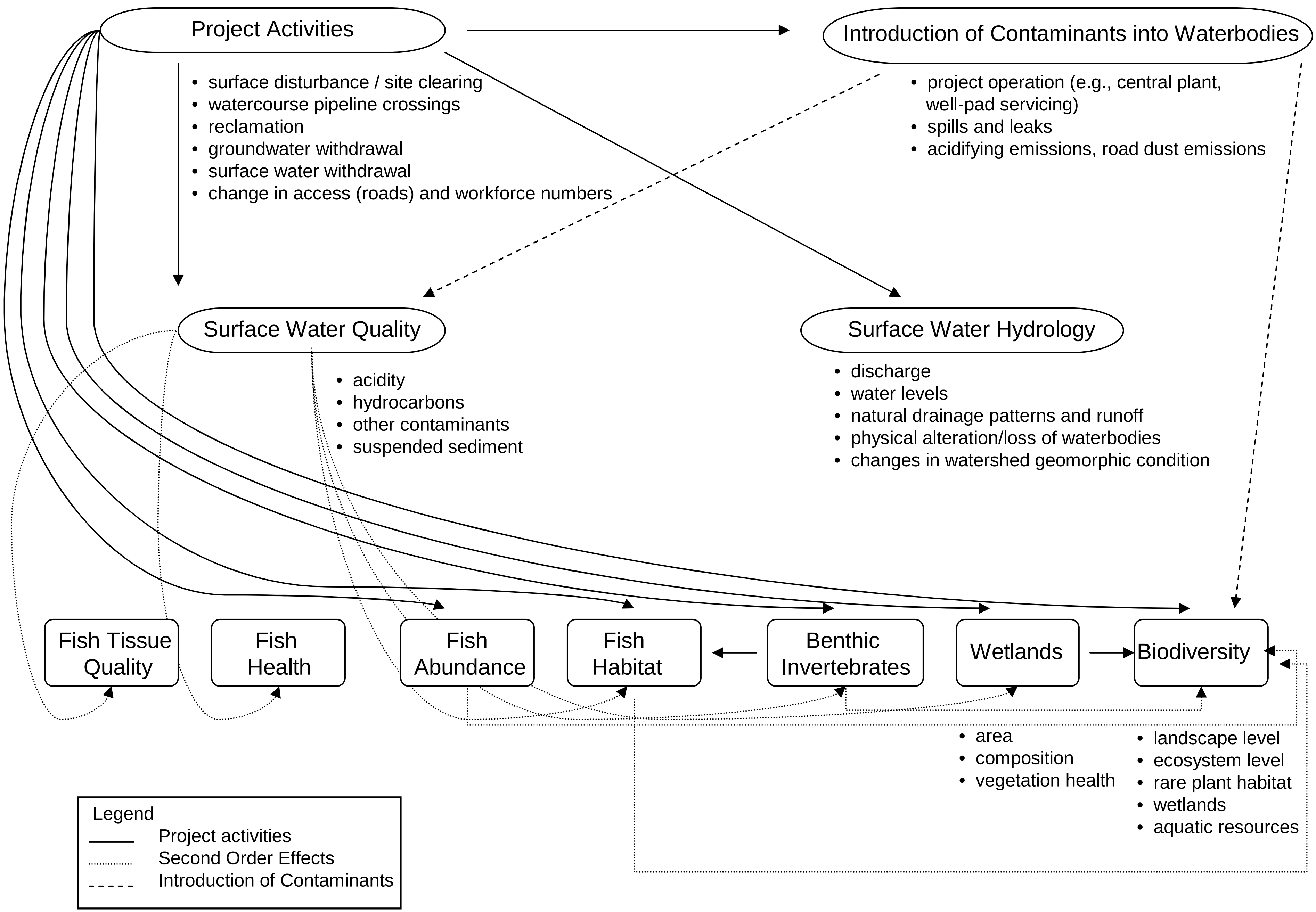


Table 2.2 Synoptic summary of Athabasca oil sands EIA predictions: surface mine projects.

Issue/Description of Potential Impact	Activities	Project									
		Albian Muskeg River	Canadian Natural Horizon	Shell Jackpine	Suncor Millennium	Suncor South Tailings	Suncor Steepbank	Syncrude Aurora	Syncrude Mildred Lake	Suncor Voyageur	Petro-Canada/UTS Fort Hills
Climate and Hydrology											
Changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	Infrastructure development, muskeg drainage and overburden dewatering, site clearing, mine pits, disposal areas, plants site and closed-circuit operation, diversion and disruption of natural drainages, water withdrawal from watercourses and waterbodies, runoff from reclaimed areas, residual seepage from mine areas, end-pit lake development	X	X	X	X	X	X	X		X	X
Change in basin sediment yield and sediment concentrations in receiving streams	Infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages, reclamation	X	X	X		X				X	X
Changes in water balance of nearby waterbodies caused by drawdown of surficial aquifer at perimeter areas of mine pits and EPLs, deep percolation loss, reduction in base flows of adjacent streams	Basal Aquifer depressurization	X						X			
Changes in channel dimension, shape, gradient, meander pattern, and erosion/sedimentation due to changes in flows	Diversion and disruption of natural drainage patterns, inflows from project activities	X								X	X
Sustainability of closure landscape and drainage system as affected by surface and gully erosion from reclaimed landscape with immature drainage density, channel evolution	Creation of closure landscape and drainage system	X	X							X	X

Table 2.2 Cont'd.

Issue/Description of Potential Impact	Activities	Project									
		Albian Muskeg River	Canadian Natural Horizon	Shell Jackpine	Suncor Millennium	Suncor South Tailings	Suncor Steepbank	Syncrude Aurora	Syncrude Mildred Lake	Suncor Voyageur	Petro-Canada/UTS Fort Hills
Water Quality											
Changes in water quality caused by direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, contamination from mine-related waters and assimilative capacity of receiving environment	Mine operations, muskeg and overburden dewatering, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), stream diversions, disruption of natural drainage, upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows, accidental releases and spills, mine drainage system	X	X	X	X	X	X	X		X	X
Alteration of thermal regime of receiving waters	Muskeg and overburden dewatering	X	X	X	X						X
Changes in dissolved oxygen levels	Muskeg and overburden dewatering	X	X	X	X						X
Ecological viability of End Pit Lakes as determined by water quality of EPL discharge waters	Mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), End Pit Lake Outflows	X	X	X	X	X		X		X	X
Year-round acidification cause by deposition of acids or acid-forming substances	Acidifying emissions, runoff containing acidifying substances released by the Project	X								X	X
Changes in water quality of waterbodies(metals, PAHs) cause by deposition of particulates containing metals and PAHs	Emissions of particulates								X		
Sediment Quality											
Increase in PAHs in sediments caused by mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies; or changes in sediment quality.	Muskeg and overburden dewatering, mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	X	X	X	X	X				X	X

Table 2.2 Cont'd.

Issue/Description of Potential Impact	Activities	Project: Albian Muskeg River	Canadian Natural Horizon	Shell Jackpine	Suncor Millennium	Suncor South Tailings	Suncor Steepbank	Syncrude Aurora	Syncrude Mildred Lake	Suncor Voyageur	Petro-Canada/UTS Fort Hills
Benthic Invertebrates											
Ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities caused by changes in water quality, sediment quality, direct uptake of from water and sediments; changes in benthic invertebrate habitat.	Releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills, water diversions, ecological viability of End-Pit Lakes		X	X		X	X			X	X
Fish Populations											
Disturbance, alteration, or loss of productive fish habitat within Project development area	Damming of watercourses and watercourse re-establishment on closure; elimination of watercourses, diversion of watercourses, elimination of reaches of watercourses, creation of new exit route for watercourses from waterbodies, by damming current outlet and creation of new channel; repositioning of watercourses	X	X	X	X	X	X	X		X	X
Changes in fish health caused by direct effects on fish health through changes in water quality, sediment quality, direct uptake of from water and sediments; indirect effects on fish health via direct effects on fish food organisms; changes in fish populations due to changes in fish health.	Releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills, muskeg and overburden dewatering	X	X	X		X		X		X	X
Changes in fish tissue quality caused by the changes in water quality, including fish tainting	Releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills, muskeg and overburden dewatering	X	X	X	X	X	X	X		X	X

Table 2.2 Cont'd.

Issue/Description of Potential Impact	Activities	Project: Albian Muskeg River	Canadian Natural Horizon	Shell Jackpine	Suncor Millennium	Suncor South Tailings	Suncor Steepbank	Syncrude Aurora	Syncrude Mildred Lake	Suncor Voyageur	Petro-Canada/UTS Fort Hills
Fish Populations Cont'd.											
Changes in fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators caused by: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	Releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills, muskeg and overburden dewatering, fish habitat compensation		X	X		X	X	X		X	X
Types of aquatic habitats that will develop in Project reclamation watercourses and waterbodies	Constructed wetlands; stream development; End Pit Lakes; No Net Loss/habitat compensation plans.	X	X	X	X	X		X		X	X
Changes in forage fish habitat caused by changes in area of lakes/ponds, changes in flow regime	Diversion and disruption of natural drainage patterns, inflows from project-related waters, mine facilities and infrastructure	X	X		X			X		X	X
Effect of acidity on fish and aquatic biota from deposition of acids and acid-forming substances	Acidifying emissions		X						X	X	X
Effect on aquatic resources from deposition of particulates containing metals and PAHs	Emissions of particulates								X		
Acid-Sensitive Lakes											
Changes in acidity of lakes caused by changes in acid deposition	Air Emissions	X	X	X	X			X	X	X	X

Table 2.3 Synoptic summary of Athabasca oil sands EIA predictions: *in situ* projects.

Issue/Description of Potential Impact	Activities	Project: Deer Creek Joslyn Phase 2	ConocoPhillips Surmont	OPTI/Nexen Long Lake	Suncor MacKay River	Petro-Canada Meadow Creek	Suncor Firebag	Husky Sunrise Thermal
Climate and Hydrology								
Changes in flow and water levels, open water areas caused by changes in groundwater flow discharges, near-surface water table	Groundwater withdrawal		x	x	x	x	x	x
Changes in flow and water levels, open water areas caused by changes in runoff to streams, drainage patterns, blockage of surface and near-surface flows	Surface disturbances (central facility, well pads, roads, etc.)	x	x	x	x	x	x	x
Changes in geomorphic conditions of watersheds and drainage systems caused by changes in surface water runoff and land cover	Surface disturbances (central facility, well pads, roads, etc.)					x		
Changes in geomorphic conditions of watersheds and drainage systems caused by Sediment runoff, stream erosion and pipeline exposure during floods	Disturbance of bed and banks of stream channels at watercourse crossings					x		
Changes in basin sediment yield and sediment concentrations caused by changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	Surface disturbance from project infrastructure and facilities			x				x
Change in flows	Water withdrawal	x					x	
Water Quality								
Changes in water quality caused by increased surface water runoff, increased sediment loading and transport of chemical contaminants	Surface disturbances (land clearing, road cut and fill, stream crossings, instream construction, bank excavation, pad construction, camps, central plant facility), drilling of wells, ancillary facilities (disposal pits), physical alteration of stream channels	x	x		x	x	x	x

Table 2.3 Cont'd.

Issue/Description of Potential Impact	Activities	Project						
		Deer Creek Joslyn Phase 2	ConocoPhillips Surmont	OPTI/Nexen Long Lake	Suncor MacKay River	Petro-Canada Meadow Creek	Suncor Firebag	Husky Sunrise Thermal
Water Quality Cont'd.								
Changes in water quality (total dissolved solids, conductivity, oil and grease) caused by small and infrequent releases of produced water to ground surface (may directly enter waterbody)	Well servicing				X			
Changes in water quality caused by small releases of produced fluids and production chemicals, overflow (flood circumstances) and seepage of water from retention pond	Operation and maintenance of central plant facility and retention pond				X			
Changes in water quality: potential increase in total suspended sediments	Dismantling of facilities, removal of roads and contaminated soil, reclamation of sites		X		X			
Changes in water quality: potential contamination of groundwater and interactions between groundwater and surface water	Introduction of chemical species into groundwater from project facilities		X					
Changes in water quality caused by interaction of groundwater and surface water - migration of chloride into surface waters and exceedance of water quality guidelines	Potential leak from lime sludge lagoon		X					
Sediment Quality								
Changes in sedimentation of receiving streams caused by physical alteration of stream channels	Activities involving instream construction and bank excavation						X	
Benthic Invertebrates								
Changes in benthic invertebrate resources caused by alteration/loss of habitat through changes in surface water hydrology, sediment levels, and stream channels	Surface facilities and disturbances, watercourse crossings, reclamation activities		X	X	X	X	X	X

Table 2.3 Cont'd.

Issue/Description of Potential Impact	Activities	Project						
		Deer Creek Joslyn Phase 2	ConocoPhillips Surmont	OPTI/Nexen Long Lake	Suncor MacKay River	Petro-Canada Meadow Creek	Suncor Firebag	Husky Sunrise Thermal
Fish Populations								
Changes in fish populations caused by changes in aquifer discharge to and flows in surface waters, changes in overwintering fish habitat	Groundwater withdrawal		X	X	X			X
Changes in fish health caused by increased sediment loading, introduction of hydrocarbons	Watercourse crossings and other project activities		X	X			X	X
Changes in fish tissue quality caused by changes in water quality, including fish tainting	Project operation activities - well servicing, operation of the central plant		X		X			
Changes in fish or aquatic resources caused by changes in natural drainage patterns	Surface facilities and disturbances	X	X		X			X
Changes in fish or aquatic resources caused by increased sediment or contaminant input to aquatic systems through surface run-off or sediment loadings	Surface facilities and disturbances, watercourse crossings, project operation activities - well servicing, operation of the central plant, reclamation activities	X	X	X	X	X		X
Changes in fisheries resources caused by increase in fishing pressure and fish harvest	Recreational angling by workforce		X	X	X			X
Changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas) caused by alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	Surface facilities and disturbances, watercourse crossings	X	X	X		X		X
Changes in forage fish habitat and forage fish health caused by increases in sediment loading, introduction of hydrocarbons	Watercourse crossings			X		X		X
Acid-Sensitive Lakes								
Changes in acidity of regional lakes through deposition of acids and acid-forming substances	Acidifying emissions			X		X	X	X

Table 2.4 Frequency of occurrence of impact pathways in EIAs that were reviewed.

Component and Impact Pathway	No. Occurrences in Reviewed EIAs[1]
Climate and Hydrology Component	
Changes in network of watercourses and waterbodies	167
Changes in natural hydrologic processes (e.g., surface runoff)	114
Purposeful water releases into and withdrawals from network of watercourses and waterbodies	97
Water Quality Component	
Changes in hydrologic conditions	121
Introduction of pollutants into waterbodies and watercourses as part of purposeful water releases into watercourses and waterbodies	152
Introduction of pollutants into waterbodies and watercourses as an indirect consequence of project activities	70
Sediment Quality Component	
Changes in hydrologic conditions	7
Introduction of pollutants into waterbodies and watercourses as part of purposeful water releases into watercourses and waterbodies	28
Introduction of pollutants into waterbodies and watercourses as an indirect consequence of project activities	0
Benthic Invertebrate Community Component	
Changes in hydrologic conditions	3
Changes in amounts of physical habitat	2
Changes in water quality	11
Changes in sediment quality	11
Fish Population Component	
Changes in hydrologic conditions	116
Changes in amounts of physical habitat	117
Changes in water quality	192
Changes in sediment quality	30
Changes in benthic invertebrate communities	14
Acid-Sensitive Lakes Component	
Input of acidifying emissions	22

[1] The total number of occurrences for a given RAMP component is greater than the number of residual impact assessments summarized in Table 2.1 because residual impact assessments are often considered more than one impact pathway.

2.3 SUMMARY OF KEY INDICATOR RESOURCES CONSIDERED

Key Indicator Resources (KIRs) are species, communities or other natural features that represent or affect the integrity of ecosystems and influence the social, cultural and/or economic valuation of an area in question. KIRs are used in the oil sands EIAs to evaluate effects on resources from developments and to focus the assessment.

None of the 17 EIAs reviewed defined KIRs for aquatic resources within the Climate and Hydrology, Water Quality, Sediment Quality, and ASL components of RAMP (Table 2.5); practically all of the aquatic KIRs fall within the Fisheries component of RAMP, save for a general KIR termed benthic invertebrates. In addition to the general KIR of forage fish guild, a total of 14 fish species were classified as KIRs in the 17 EIAs that were reviewed:

- Arctic grayling
- brook stickleback
- goldeye
- lake chub
- lake whitefish
- longnose sucker
- mountain whitefish
- northern pike
- rainbow trout
- slimy sculpin
- trout-perch
- walleye
- white sucker
- yellow perch

Table 2.5 KIRs considered in EIAs relevant to RAMP components.

Project	KIRs
Albian Muskeg River	walleye, goldeye, lake whitefish, longnose sucker, Arctic grayling, northern pike, forage fish guild
Canadian Natural Horizon	walleye, lake whitefish, northern pike, goldeye, longnose sucker, trout-perch, Arctic grayling, forage fish guild
ConocoPhillips Surmont	walleye, northern pike, Arctic grayling, rainbow trout, goldeye, forage and nonsport fish species, lower trophic levels (e.g., periphyton, benthos)
Deer Creek Joslyn Phase 2	none specified
Husky Sunrise	benthic invertebrates, small-bodied forage fish (brook stickleback, pearl dace, lake chub, fathead minnow, spottail shiner, slimy sculpin, spoonhead sculpin, trout-perch, brassy minnow, northern redbelly dace, ninespine stickleback, emerald shiner)
Opti/Nexen Long Lake	walleye, northern pike, longnose sucker, white sucker, yellow perch, brook stickleback, lake chub, other forage fish
Petro-Canada MacKay River	Arctic grayling, northern pike, walleye, goldeye, lake whitefish, forage fish group
Petro-Canada Meadow Creek	slimy sculpin, forage fish guild (brook stickleback, pearl dace, lake chub), benthic invertebrates, northern pike, longnose sucker, Arctic grayling, walleye, white sucker

Table 2.5 (Cont'd.)

Project	KIRs
Petro-Canada/ UTS Fort Hills	forage fish guild, benthic invertebrates, longnose sucker, walleye, lake whitefish, northern pike, trout-perch
Shell Jackpine	Arctic grayling, northern pike, longnose sucker, lake chub, slimy sculpin, brook stickleback
Suncor Firebag	Arctic grayling, longnose sucker, forage fish guild
Suncor Millennium	walleye, lake whitefish, longnose sucker, goldeye, northern pike, forage fish guild (lake chub, brook stickleback, pearl dace), mountain whitefish, Arctic grayling
Suncor South Tailings	walleye, northern pike, lake whitefish, Arctic grayling, longnose sucker, forage fish (spoonhead sculpin, slimy sculpin, brook stickleback, lake chub, trout-perch), benthic invertebrates
Suncor Steepbank	walleye, longnose sucker, goldeye
Suncor Voyageur	walleye, northern pike, lake whitefish, goldeye, longnose sucker, forage fish (spoonhead sculpin, slimy sculpin, brook stickleback, lake chub, trout-perch), benthic invertebrates, Arctic grayling, yellow perch, white sucker
Syncrude Aurora	walleye, goldeye, longnose sucker, Arctic grayling, forage fish
Syncrude Mildred Lake	longnose sucker, Arctic grayling, northern pike, forage fish (brook stickleback, pearl dace, and lake chub), walleye, white sucker

2.4 SUMMARY OF WATERBODIES AND WATERCOURSES CONSIDERED

There is large variation among Athabasca oil sands projects in the number of waterbodies and watercourses considered in the residual impact assessments (Table 2.6). This is due in part to both differences in the scale of Athabasca oil sands projects and to ongoing evolution in the scope of EIAs. A total of 222 waterbodies and watercourses were considered in the residual impact assessments contained in the 17 EIAs, an average of about 13 waterbodies and watercourses per EIA. Most of these were referenced in the residual impact assessments for the Climate and Hydrology, Water Quality, and Fish Population components.

Table 2.6 Summary of waterbodies and watercourses considered in the residual impact assessments, by project and RAMP component.

Project	No. of Waterbodies and Watercourses Considered in Residual Impact Assessments[1]						Total
	Climate and Hydrology	Water Quality	Sediment Quality	Benthic Invertebrate Communities	Fish Populations	Acid-Sensitive Lakes	
Albian Muskeg River	9	3	1	0	4	2	11
Canadian Natural Horizon	10	13	8	1	15	2	18
ConocoPhillips Surmont	8	8	0	7	14	0	15

Table 2.6 (Cont'd.)

Project	No. of Waterbodies and Watercourses Considered in Residual Impact Assessments[1]						Total
	Climate and Hydrology	Water Quality	Sediment Quality	Benthic Invertebrate Communities	Fish Populations	Acid-Sensitive Lakes	
Deer Creek Joslyn Phase 2	3	2	0	0	3	0	4
Husky Sunrise	14	7	0	9	14	0	26
Opti/Nexen Long Lake	9	3	0	9	9	5	16
Petro-Canada MacKay River	6	0	0	7	13	0	15
Petro-Canada Meadow Creek	4	1	0	2	2	3	7
Petro-Canada/ UTS Fort Hills	8	7	4	6	12	6	17
Shell Jackpine	5	4	4	8	11	1	14
Suncor Firebag	11	10	3	0	8	1	18
Suncor Millennium	8	9	2	2	7	3	13
Suncor South Tailings	2	3	3	3	3	0	3
Suncor Steepbank	3	7	0	6	6	0	8
Suncor Voyageur	8	8	1	3	9	2	13
Syncrude Aurora	17	15	0	1	15	0	21
Syncrude Mildred Lake	0	3	3	2	2	2	3
Total	125	103	29	66	147	27	222

[1] Groups of waterbodies or watercourses, such as "RSA lakes" or "unnamed tributaries" were considered to be a single waterbody or watercourse.

2.5 RESIDUAL IMPACT ASSESSMENTS AND PROJECT PHASES

While more residual impact assessments were considered in the EIAs for the operational phase than for either the construction or closure phases (Table 2.7, Table 2.8), differences among the three project phases are relatively modest. Many residual impact assessments in the EIAs were lumped across all project phases and were not disaggregated (for the purposes of this review, these assessments were designated as occurring in all project phases). In many cases, only overall (i.e., aggregated across construction, operation, and closure phases) assessments and predictions were made of the effects of project activities.

There are differences among RAMP components with respect to residual impact assessments and project phases. There are relatively similar proportions of residual impact assessments in each of the three project phases in the Climate and Hydrology and Fish Population components. By contrast, a higher percentage of the residual impact assessments in the Water Quality and ASL components are in the operational phase.

Table 2.7 Summary of residual impact assessments by project phase and impact level.

RAMP Component	No. Residual Impact Assessments at Each Impact Level					No. with No Explicit Assessments	Total
	High	Moderate	Low	Negligible	Total No. Predictions		
Construction	0	9	36	160	205	26	231
Operation	0	23	65	207	295	43	338
Closure	0	7	39	149	195	45	240
Total	0	39	140	516	695	114	809

Table 2.8 Summary of residual impact assessments by project phase and RAMP component.

Project Phase	RAMP Component						Total
	Climate and Hydrology	Water Quality	Sediment Quality	Benthic Invertebrate Communities	Fish Populations	Acid-Sensitive Lakes	
Construction	64	60	7	5	94	1	231
Operation	77	97	12	5	124	23	338
Closure	69	61	12	9	89	0	240
Total	210	218	31	19	307	24	809

2.6 RESIDUAL IMPACT ASSESSMENTS AND IMPACT SCALE

The majority of residual impact assessments (75%) were made at the local level (i.e., for the defined LSA), with fewer residual impact assessments (20%) made at the regional level (i.e., for the defined RSA), and only 5% of all residual impact assessments made as part of the cumulative effects assessment of the Planned Development Scenario (Table 2.9). This is in part because of the particular sequence of the assessments made in many of the EIAs:

- First for the Application Case, all effects represented by valid linkages in an impact diagram were assessed at the local (LSA) level;
- Then, only incremental effects that were predicted to be greater than Negligible magnitude at the local (LSA) level were assessed at the regional (RSA) level; and

- Finally, only incremental effects that were predicted to be greater than Negligible magnitude at the regional (RSA) level in the Application Case were assessed in the Planned Development Scenario.

Table 2.9 Summary of residual impact assessments by impact scale and impact level.

Scale	No. Residual Impact Assessments at Each Impact Level					No. with No Explicit Assessments	Total
	High	Moderate	Low	Negligible	Total No. Predictions		
Local	0	32	111	376	519	85	604
Regional	0	7	29	107	143	29	172
Cumulative	0	0	0	33	33	0	33
Total	0	39	140	516	695	114	809

There are some differences among RAMP components with respect to residual impact assessments and impact scale (Table 2.10). The Fish Populations component has a higher proportion of its residual impact assessments at the regional and cumulative level than any of the other RAMP components, except for ASL, which is considered almost exclusively to be a regional issue.

Table 2.10 Summary of residual impact assessments by impact scale and RAMP component.

Project Phase	RAMP Component						Total
	Climate and Hydrology	Water Quality	Sediment Quality	Benthic Invertebrate Communities	Fish Populations	Acid-Sensitive Lakes	
Local	178	177	25	14	210	0	604
Regional	32	38	6	5	70	21	172
Cumulative	0	3	0	0	27	3	33
Total	210	218	31	19	307	24	809

2.7 MEASUREMENT ENDPOINTS

Many of the EIAs that were reviewed defined a number of measurement endpoints for aquatic resources of concern; these are summarized by project in Table 2.11. Table 2.11 contains both:

- cases in which impacts on RAMP components are assessed by measurement endpoints in those same components (e.g., cases in which prediction of effects on, for example, fisheries, are assessed by predictions of fisheries measurement endpoints); and

- cases in which impacts on RAMP components are assessed by measurement endpoints in lower level components (e.g., cases in which predictions of effects on, for example, fisheries, are assessed by predictions of effects on hydrologic or water quality endpoints).

Table 2.11 Measurement endpoints used in Athabasca oil sands projects.

Climate and Hydrology
• **Shell Jackpine Mine** – % change in mean annual discharge in streams – % change in lake water levels and depths during open-water and ice-cover seasons – % change in daily mean water level and depth exceedance statistics at 10, 50, 90 percentiles – % change in 10-year peak flood discharge, with natural 10-year peak flood discharge in natural receiving stream being the baseline case • **Canadian Natural Horizon** – mean annual discharge – mean annual flow depth – 7Q10 low flow – 10-yr flood peak flow • **Suncor Millennium** – mean annual discharge – maximum/minimum daily flows (1 in 50 yr flood) – 1 in 100 year peak flow • **Albian Muskeg River Mine** – mean annual discharge and flow depth – mean open-water season (mid April-mid Nov.) discharge, flow depth, and 7Q10 – mean ice-cover season discharge, flow depth, and 7Q10 – 10-year flood peak discharge and flow depth – area of lakes, ponds, streams, channels, and wetlands • **Syncrude Aurora** – mean annual flow – mean open water (April to October) discharge – mean winter discharge – 7Q10 open water discharge – 10 year peak discharge – drainage area • **Husky Sunrise Thermal** – average daily discharge – average annual discharge – peak flows – low flows • **Suncor Voyageur** – Annual mean flow and depth – mean open-water flow and depth – 10-yr flood peak discharge and depth – 7Q10 low flow and depth – maximum flow depth, cross-sectional average water velocity – lake water balance • **Petro-Canada/UTS Fort Hills** – mean annual discharge – mean open-water discharge, water level/depth – mean ice-cover discharge, water level/depth – open-water season 7Q10 – 10-yr flood peak discharge – daily water level/depth exceedance statistics (10^{th}, 50^{th}, 90^{th} percentiles) – median lake water depth – area of open water – channel wetted perimeter

Table 2.11 (Cont'd.)

Water Quality

- **Shell Jackpine**
  - changes in average annual TSS concentrations
  - decreased compliance for barium, chromium, copper, total phenolics, total phosphorus, benzo(a)anthracene group; benzo(a)pyrene group; chromium, aluminum, ammonia, barium, benzo(a)pyrene group; cadmium; fish health; sulphide; total nitrogen, dissolved organic carbon and BOD
- **Canadian Natural Horizon**
  - % change in TSS
  - decreased compliance for aluminum, iron, total phosphorous, iron, mercury, chloride, arsenic, iron, mercury, chromium, copper, manganese, barium, benzo(a)anthracene group, aluminum, cadmium, copper, manganese, silver, sulphide, total phenolics, barium, lead, molybdenum, selenium, dissolved organic carbon, BOD, dissolved oxygen, summer waterbody temperature
- **Suncor Firebag**
  - sediment concentration in receiving streams
- **Suncor Millennium**
  - predicted level of pH, suspended solids, nutrients, major ions, BOD
- **ConocoPhillips Surmont**
  - levels of suspended sediments and chloride
- **Albian Muskeg River Mine**
  - concentrations and change in exceedance in guidelines (protection of aquatic life and human health) for Al, As, B, Cd, Cr, Cu, Fe, Mn, Hg, Zn
  - chronic and acute toxicity units
  - BOD of muskeg/overburden drainage waters, % of river flow from muskeg/overburden drainage waters
  - concentrations of benzo(a)pyrene, benzo(a)anthracene, naphthenic acids, total dissolved solids
- **Husky Sunrise Thermal**
  - water quality of waterbodies
  - predicted percent increase in conductivity, total dissolved solids, alkalinity, hardness, calcium, magnesium, and chloride
- **Suncor Voyageur**
  - mean annual TSS concentration
  - levels of chronic and acute whole effluent toxicity
  - predicted peak and median concentration of aluminum, iron, strontium, barium, manganese, total phosphorus, cadmium, sulphide, beryllium, sulphate, and other water quality variables
  - sediment loading
- **Petro-Canada/UTS Fort Hills**
  - mean annual TSS concentration
  - predicted concentration of benzo(a)anthracene, benzo(a)pyrene, chromium, nitrogen, phenolics, phosphorus, aluminum, barium, manganese, total dissolved solids and iron under mean open water flow conditions
  - predicted instream temperature
  - predicted levels of dissolved organic carbon and biochemical oxygen demand

Sediment Quality

- **Shell Jackpine, Canadian Natural Horizon, Suncor Millennium, Syncrude Mildred Lake, Petro-Canada/UTS Fort Hills**
  - PAHs in sediment
- **Suncor Voyageur**
  - predicted sediment quality

Table 2.11 (Cont'd.)

Benthic Invertebrate Communities

- **Shell Jackpine**
  - changes in macroinvertebrate species richness
- **Canadian Natural Horizon**
  - abundance of benthic invertebrates
- **Syncrude Aurora**
  - chronic toxicity units, % CT water in streams
- **Suncor Millennium**
  - PAHs in sediment
- **Opti/Nexen Long Lake**
  - mean monthly flow relative to recommended minimum monthly flow (determined using the Tessman approach); predicted % reduction in mean monthly flow
  - predicted acid input (PAI) relative to critical load of lake
- **Syncrude Mildred Lake**
  - predicted acid input (PAI) relative to critical load of lake
- **Husky Sunrise Thermal**
  - benthic invertebrate populations and habitat
  - percent of watershed disturbed by surface facilities, annual peak and low flows
  - total annual runoff, peak flow, likelihood of zero flow event
  - predicted PAI relative to calculated critical load
- **Suncor Voyageur**
  - ability of Pit Lake to support aquatic life based on predicted water quality, sediment quality, fish tissue quality, and MFT composition
  - abundance, richness, habitat diversity
- **Petro-Canada/UTS Fort Hills**
  - habitat

Fish Populations

- **Shell Jackpine**
  - fish habitat diversity
  - tainting potential units (TPUs)
  - ammonia, barium, benzo(a)pyrenes, chromium, naphthenic acids, nickel, beryllium, manganese, aluminum, strontium, TDS
- **Canadian Natural Horizon**
  - species level fish diversity indicators (species richness, rare/endangered species), ecosystem level diversity indicators (predator and prey/forage guild ratio)
  - watercourse and waterbody habitat heterogeneity indicator, stream order, waterbody maximum depth, waterbody area
  - mean annual flow, mean ice-cover period flow, mean ice-cover flow for 7Q10 case
  - levels of molybdenum, TDS, mercury, arsenic, barium, total nitrogen, zinc, aluminum, manganese, selenium, strontium, boron, iron, silver, sulphide, total phenolics, antimony, napthenic acids, vanadium
  - PAH levels in sediments
  - changes in Potential Acid Input (PAI) as compared to the critical loading for each lake
  - levels of benthic invertebrates
  - tainting potential units (TPUs)
- **Albian Muskeg River Mine**
  - tissue PAH and trace metal concentrations
  - mean open-water flow, open-water 7Q10, mean ice-cover flow, area of ponds/lakes
  - acute and chronic toxicity of CT waters
- **Suncor Millennium**
  - waterbody area, streamflow, water levels
  - sediment concentration, dissolved oxygen concentration, temperature regime
  - fish tissue quality

Table 2.11 (Cont'd.)

Fish Populations Cont'd.

- **Opti/Nexen Long Lake**
  - mean monthly flow relative to recommended minimum monthly flow (determined using the Tessman approach); predicted % reduction in mean monthly flow
  - predicted acid input (PAI) relative to critical load of lake
- **ConocoPhillips Surmont**
  - levels of suspended sediments
  - streamflow and water levels
- **Syncrude Aurora**
  - area of aquatic habitat (at summer 7Q10, mean winter, and 10-yr peak discharge)
  - sediment concentrations
  - chronic toxicity units
- **Syncrude Mildred Lake**
  - predicted acid input (PAI) relative to critical load of lake
  - metals and PAH levels in surface waters and sediments
- **Husky Sunrise Thermal**
  - fish populations and habitat
  - percent of watershed disturbed by surface facilities, annual peak and low flows
  - total annual runoff, peak flow, likelihood of zero flow event
  - predicted PAI relative to calculated critical load
  - number of potential new anglers
  - health, abundance, health of special status species
  - access to waterbodies
- **Suncor Voyageur**
  - habitat area, streamflow/water level, channel regime/geomorphic condition, water quality, sediment deposition, habitat accessibility
  - predicted concentrations of substances in fish tissue
  - ability of Pit Lake to support aquatic life based on predicted water quality, sediment quality, fish tissue quality, and MFT composition
  - species richness, species overlap, listed species, ecosystem diversity
  - predicted tainting potential units (TPUs) in surface waters
  - fish habitat, fish abundance
- **Petro-Canada/UTS Fort Hills**
  - habitat/instream flow for forage fish guild and juvenile sport fish
  - acute and chronic toxic units, lowest observed effects concentrations (LOECs) and no observed effects concentrations (NOECs), concentrations above guidelines relative to values for effects on aquatic biota, exceedance of critical loads of acidifying emissions
  - fish habitat diversity, species level fish biodiversity

Acid-Sensitive Lakes

- **Shell Jackpine, Canadian Natural Horizon, Suncor Firebag, Suncor Millennium, Opti/Nexen Long Lake, Syncrude Mildred Lake, Albian Muskeg River Mine, Husky Sunrise Thermal, Petro-Canada/UTS Fort Hills**
  - changes in Potential Acid Input (PAI) as compared to the critical loading for each lake
- **Syncrude Aurora**
  - acid deposition
- **Suncor Voyageur**
  - lake-specific critical loads relative to acid deposition rates

2.8 CRITERIA FOR ASSESSMENT OF IMPACT

Many of the EIAs that were reviewed also defined a number of criteria that are used to determine the significance of impacts that are predicted. This is most often done in a number ways: direction, magnitude, geographic extent, duration, reversibility, and frequency of impact. These have been extracted from the EIAs that were reviewed and are presented below in Table 2.12 (only criteria pertaining to magnitude are presented).

Table 2.12 Criteria for assessment of impact used in Athabasca oil sands projects.

Climate and Hydrology
• **Shell Jackpine and Canadian Natural Horizon** – change on measurement endpoints of +/- 5% is negligible; +/- 10% is low; 10% to 30% is moderate; > 30% is high • **Suncor Firebag, Opti/Nexen Long Lake, Albian Muskeg River** – change on measurement endpoints of +/- 1% is negligible; +/- 1-5% is low; 5% to 15% is moderate; > 15% is high • **ConocoPhillips Surmont and Syncrude Aurora** – residual impact will represent the following change in the selected variable from baseline conditions within the RSA: low (<1% change), moderate (1-10% change), high (>10% change) • **Husky Sunrise Thermal** – change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high • **Suncor Voyageur** – change in measurement endpoint – negligible: no measurable effect (<1%); low: <10% change; moderate: 10-30% change; high: >30% change • **Petro-Canada/UTS Fort Hills** – change in measurement endpoint – low: <10% change; medium: 10-30% change; high: >30% change
Water Quality
• **Shell Jackpine – TSS** – change on measurement endpoints of +/- 5% is negligible; +/- 10% is low; 10% to 30% is moderate; > 30% is high • **Shell Jackpine – Other Water Quality Variables** – significant impact defined as occurring under any of following conditions: (i) instream concentrations exceed water quality guidelines where no guideline was exceeded in baseline; (ii) instream concentrations are outside of range observed in Baseline; (iii) general upward shift in concentrations range compared to Baseline, as reflected by higher median concentrations within same concentrations range • **Canadian Natural Horizon – for TSS** – change on measurement endpoints of +/- 5% is negligible; +/- 10% is low; 10% to 30% is moderate; > 30% is high • **Canadian Natural Horizon – Other Water Quality Variables** – negligible - instream concentrations do not cause elevation in exceedance; low - releases contribute slightly to existing background exceedance; moderate - releases cause exceedance of guidelines where guidelines were not previously exceeded; high - releases cause substantial exceedance of guidelines • **Suncor Firebag** – negligible - instream concentrations do not cause elevation in exceedance; low - releases contribute slightly to existing background exceedance; moderate - releases cause exceedance of guidelines where guidelines were not previously exceeded; high - releases cause substantial exceedance of guidelines

Table 2.12 (Cont'd.)

Water Quality Cont'd.

- **Opti/Nexen Long Lake**
  - predicted change of <1% is negligible; 1-5% is low; 5-15% is moderate; >15% is high
- **ConocoPhillips Surmont and Syncrude Aurora**
  - residual impact will represent the following change in the selected variable from baseline conditions within the RSA: low (<1% change), moderate (1-10% change), high (>10% change)
- **Albian Muskeg River Mine**
  - negligible: releases do not cause exceedance of guidelines; low: releases contribute to existing background exceedances; moderate: releases cause marginal exceedance of guidelines; high: releases cause substantial exceedance of guidelines
- **Husky Sunrise Thermal**
  - change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high
- **Suncor Voyageur**
  - negligible: predicted peak levels of chronic or acute toxicity were below guidelines, predicted peak concentrations were less than the chronic effects benchmark, or frequency of compliance with chronic effects benchmark was the same as or higher than predicted to occur under the Baseline Case; low: predicted peak levels of chronic or acute toxicity were below guidelines, predicted peak concentrations were greater than associated chronic effects benchmark and the frequency of benchmark compliance is lower under Application Case than under Baseline Case; high: predicted peak levels of chronic or acute toxicity exceed guidelines
- **Petro-Canada/UTS Fort Hills**
  - low: predicted concentration exceeds WQ guideline, but is within range of natural variability; moderate: predicted concentration less than WQ guideline, but outside range of natural variability; high: predicted concentration exceeds WQ guideline and is outside the range of natural variability
  - changes in temperature - low: <3° change; moderate: 3° change; high: >3° change

Sediment Quality

- **Canadian Natural Horizon**
  - negligible - instream concentrations do not cause elevation in exceedance; low - releases contribute slightly to existing background exceedance; moderate - releases cause exceedance of guidelines where guidelines were not previously exceeded; high - releases cause substantial exceedance of guidelines
- **Petro-Canada/UTS Fort Hills**
  - low: < 1 mg/L change; moderate: 1-2 mg/L change; high: >2 mg/L change

Benthic Invertebrate Communities

- **Shell Jackpine, Canadian Natural Horizon**
  - Negligible - no measurable change, low, moderate, high: < 10%, 10%-20%, and >20% change in measurement endpoint, respectively
- **Syncrude Aurora**
  - magnitude of impact: low (<1%), moderate (1-10%), high (>10%)
- **Opti/Nexen Long Lake**
  - negligible - no measurable change, or releases do not cause exceedance of guidelines; low - <10% change in measurement endpoint, or releases contribute slightly to existing background exceedances; moderate - 10-20% change in measurement endpoint, or releases cause marginal exceedance of guidelines where guidelines were not previously exceeded; high - >20% change in measurement endpoint, or releases cause substantial exceedance of guidelines
- **Husky Sunrise Thermal**
  - change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high
- **Suncor Voyageur**
  - negligible: no measurable change, or releases do not cause values over guidelines; low: <10% change, or releases contribute slightly to existing background values over guidelines; moderate: 10-20% change, or releases cause marginal values over guidelines; high: >20% change, or releases cause substantial values over guidelines
- **Petro-Canada/UTS Fort Hills**
  - change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high

Table 2.12 (Cont'd.)

Fish Populations
• **Shell Jackpine and Canadian Natural Horizon** – negligible: no measurable change; low, moderate, high: < 10%, 10%-20%, and >20% change in measurement endpoint, respectively; Where Guidelines or Criteria Exist: negligible: guidelines not exceeded; low, moderate, high: existing background exceeded slightly, marginally, and substantially, respectively • **Shell Jackpine (tainting potential units)** – change in tainting potential units (TPU) with TPU=1 equal to the threshold for tainting • **Shell Jackpine (water quality variables)** – negligible, no measurable change, low, moderate, high: < 10%, 10%-20%, and >20% change in measurement endpoint, respectively; Where Guidelines or Criteria Exist: negligible: guidelines not exceeded; low, moderate, high: existing background exceeded slightly, marginally, and substantially, respectively • **Suncor Firebag** – negligible: no measurable change; low, moderate, high: < 10%, 10%-20%, and >20% change in measurement endpoint, respectively; Where Guidelines or Criteria Exist: negligible: guidelines not exceeded; low, moderate, high: existing background exceeded slightly, marginally, and substantially, respectively • **Albian Muskeg River Mine** – negligible: no measurable change; low: <10% change in measurement endpoint; moderate: 10-20% change in measurement endpoint; high: >20% change in measurement endpoint • **Suncor Millennium (water quality and hydrology endpoints)** – negligible: no measurable change; low, moderate, high: < 10%, 10%-20%, and >20% change in measurement endpoint, respectively • **Suncor Millennium (fish tissue quality)** – changes in measurement endpoints: negligible (no measurable change, or no exceedance of guidelines); low (<10% change, or releases contribute to existing baseline exceedances); moderate (10-20% change, or releases cause marginal exceedance of guidelines); high (>20% change, or releases cause substantial exceedance of guidelines) • **Opti/Nexen Long Lake (hydrology and PAI endpoints)** – negligible - no measurable change, or releases do not cause exceedance of guidelines; low - <10% change in measurement endpoint, or releases contribute slightly to existing background exceedances; moderate - 10-20% change in measurement endpoint, or releases cause marginal exceedance of guidelines where guidelines were not previously exceeded; high - >20% change in measurement endpoint, or releases cause substantial exceedance of guidelines • **ConocoPhillips Surmont (hydrology and water quality endpoints)** – Residual impact will represent a change in the selected variable from baseline conditions: low (<1% change), moderate (1-10% change), high (>10% change). Residual effect is significant if potential effect predicted to cause >5% change in productive capacity or survival of KIR, or productive capacity of its habitat. • **Syncrude Aurora** – magnitude of impact: low (<1%), moderate (1-10%), high (>10%) • **Husky Sunrise Thermal** – change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high

Table 2.12 (Cont'd.)

Fish Populations Cont'd.

- **Suncor Voyageur**
  - Fish Health - negligible: peak and median concentrations<chronic toxicity benchmarks for chemical specific water concentrations, whole effluent toxicity, and fish tissue concentrations; low: peak and median concentrations are 1-5 times the chronic toxicity benchmark, < whole effluent toxicity benchmark, and 1-5 times fish tissue concentration benchmark; moderate: peak and median concentrations are 5-10 times the chronic toxicity benchmark, < whole effluent toxicity benchmark, and 5-10 times the fish tissue concentration benchmark; high: peak and median concentrations are >10 times the chronic toxicity benchmark, > whole effluent toxicity benchmark, or >10 times fish tissue concentration benchmark.
  - Fish/Fish Habitat - negligible: no measurable change, or releases do not cause values over guidelines; low: <10% change, or releases contribute slightly to existing background values over guidelines; moderate: 10-20% change, or releases cause marginal values over guidelines; high: >20% change, or releases cause substantial values over guidelines.
  - Fish Tainting - negligible: peak concentration<water column tainting benchmark concentration (tainting threshold); low: peak concentration is 1-5 times the tainting threshold; moderate: peak concentration is 5-10 times the tainting threshold; high: peak concentration is >10 times the tainting threshold.
- **Petro-Canada/UTS Fort Hills**
  - changes in habitat/abundance/diversity - low: <1% loss, moderate: 1-10% loss, high: >10% loss
  - predicted concentrations - low: above guideline for protection of aquatic life, but within natural variability, or above NOECs but below LOEC; moderate: less than guideline for protection of aquatic life but outside range of natural variation, or above LOEC and NOECs; high: exceed guidelines for protection of aquatic life, and are outside range of variability, or are an order of magnitude above LOECs and NOECs.

Acid-Sensitive Lakes

- **Shell Jackpine, Canadian Natural Horizon**
  - negligible magnitude is defined as no increase in PAI or no new occurrence of PAI that is above CL; low magnitude is defined as contribution of emissions to an existing occurrence above CL or results in a new occurrence above the CL
- **Suncor Firebag, Opti/Nexen Long Lake, Albian Muskeg River Mine**
  - negligible - releases do not cause exceedance of guidelines; low - releases contribute slightly to existing background exceedances; moderate - releases cause exceedance of guidelines where guidelines were not previously exceeded; high - releases cause substantial exceedance of guidelines
- **Syncrude Aurora**
  - magnitude of impact: low (<1%), moderate (1-10%), high (>10%)
- **Husky Sunrise Thermal**
  - change in measurement endpoint: <1% is low, 1-10% is moderate, >10% is high
- **Suncor Voyageur**
  - Air Emissions Effects on Ecological Receptors - negligible: no measurable effect (<1%) on the measurement endpoint; low: <10% change in measurement endpoint; moderate: 10-20% change in measurement endpoint; high: >20% change in measurement endpoint
- **Petro-Canada/UTS Fort Hills**
  - low: PAI < critical load; moderate: PAI greater than or equal to critical load but less than or equal to 1.1* critical load; high: PAI is greater than 1.1* critical load

3.0 RAMP DESIGN AND RATIONALE

3.1 DESIGN CONSIDERATIONS

RAMP is a multi-faceted program that is designed to fulfill the monitoring needs of all RAMP stakeholders. RAMP strives to achieve a holistic understanding of potential effects of Athabasca oil sands development on aquatic resources, as well as address specific issues important to communities of the Athabasca oil sands region.

Although the core elements of RAMP, such as discipline-specific monitoring components, overall framework and approach have remained relatively consistent over time, the design of the program continues to be adapted and refined in response to new information and changes in scope associated with the ongoing increase in oil sands development in the region. Consequently, the design of RAMP as described and documented in Chapter 3 of this report is not completely static, but is influenced by a number of considerations in addition to those related to EIAs and their predictions:

- **Regulatory Approvals** – Each approved oil sands project is required to undertake environmental monitoring activities as part of their conditions for approval. Regulatory agencies, such as Alberta ERCB, AENV, DFO, and Environment Canada outline project-specific aquatic monitoring requirements, as well as a requirement to participate in a regional monitoring program focusing on potential cumulative effects on aquatic ecosystems. An important function of RAMP is to address many of these approval-related monitoring needs for the oil sands industry.

- **Local Community Issues** – Aboriginal and northern resident communities participate in RAMP to present their views and concerns regarding regional development and the effects they may have on the aquatic environments. Accordingly, several initiatives have been included in the RAMP design to address some of these issues. An important example is the work being done to evaluate fish tissue mercury concentrations in fish from regional lakes and rivers. Although it is recognized that oil sands operations may not be a significant contributor of mercury to aquatic systems, it is included under RAMP because local communities are concerned about the safe consumption of fish. Other components of RAMP influenced by local community issues include a fish health program, the River Response Network, fish fence monitoring on the Muskeg River and the fish inventory on the Athabasca and Clearwater rivers.

- **Monitoring Scale** – Potential impacts on aquatic systems related to Athabasca oil sands development may occur on a number of scales. Accordingly, the design of RAMP incorporates several levels of monitoring to evaluate potential impacts at the project level, waterbody level, watershed level, and regional level. Many of the approaches used by RAMP have been developed to evaluate potential impacts at more than one level to streamline the program and increase cost-efficiency.

- **RAMP Results** – The results and conclusions of each monitoring year are used to refine and focus the design of future monitoring programs. For example, estimates of variability in specific measurement endpoints can be used to evaluate the statistical power of comparisons of interest and whether RAMP should increase or decrease the sample size to detect a specific effect size. Each year of monitoring builds on the experience and results of previous years in an effort to continually strengthen and streamline the program in detecting potential effects.

- **Alternate Monitoring Approaches** – In some monitoring years, RAMP has included studies to evaluate the suitability of specific or new monitoring approaches. These proof-of-concept studies typically focus on incorporating recognized techniques to assess whether they would be applicable to RAMP. Following the evaluation, these techniques may be incorporated into RAMP for future years if they are found to provide more relevant, accurate or reliable data that support existing RAMP techniques. Examples of these proof-of-concept studies include: Index of Biotic Integrity using fish communities, semi-permeable membrane devices (SPMDs) for water quality, non-lethal vs. lethal tissue collection methods for fish mercury analyses, seasonal comparisons in water quality and analytical laboratory round-robin studies to evaluate laboratory quality.

3.2 OVERALL RAMP MONITORING APPROACH

RAMP incorporates a combination of both stressor- and effects-based monitoring approaches. The stressor-based approach is derived primarily from EIAs prepared for each of the focal projects. EIAs are undertaken in part to evaluate the potential impacts that the proposed project, alone or in combination with other developments, could have on the local and regional environment. To date, EIAs conducted for projects in the Athabasca oil sands region have used primarily a stressor-based approach. A potential stressor is any factor (e.g., chemicals, temperature, water flow, nutrients, food availability, and biological competition) that either currently exists in the environment and will be influenced by the proposed project or will be potentially introduced into the environment as a result of the proposed project. Using this approach, the impact of a development is evaluated by predicting the potential impact of each identified stressor on valued components of the environment (Munkittrick *et al.* 2000). Using impact predictions from various EIAs, specific potential stressors have been identified that are monitored to document baseline conditions, establish natural variation in those conditions, as well as potential changes related to development. Examples from RAMP include specific water quality variables and changes in water quantity.

Although the stressor-based impact assessment has been successful, the inherent risk of the approach is that it assumes that all potential stressors can be identified and evaluated. More recently, an effects-based approach has been advocated for impact assessments and subsequent monitoring efforts (Munkittrick *et al.* 2000).

This approach focuses on evaluating the performance of biological components of the environment (e.g., fish, benthic invertebrates, vegetation) because they integrate the potential effects of complex and varied stressors over time. This approach is independent of stressor identification, and focuses on understanding the accumulated environmental state resulting from the summation of all stressors. For example, the current federal Environmental Effects Monitoring (EEM) program for the pulp and paper and metal mining industries incorporates an effects-based monitoring approach (Environment Canada 1992, 2002, 2003, 2005). There is a strong emphasis in RAMP on monitoring sensitive biological indicators such as benthic invertebrates and fish populations that reflect and integrate the overall condition of the aquatic environment. By combining both monitoring approaches, RAMP strives to achieve a more holistic understanding of potential effects on the aquatic environment related to the development of focal projects.

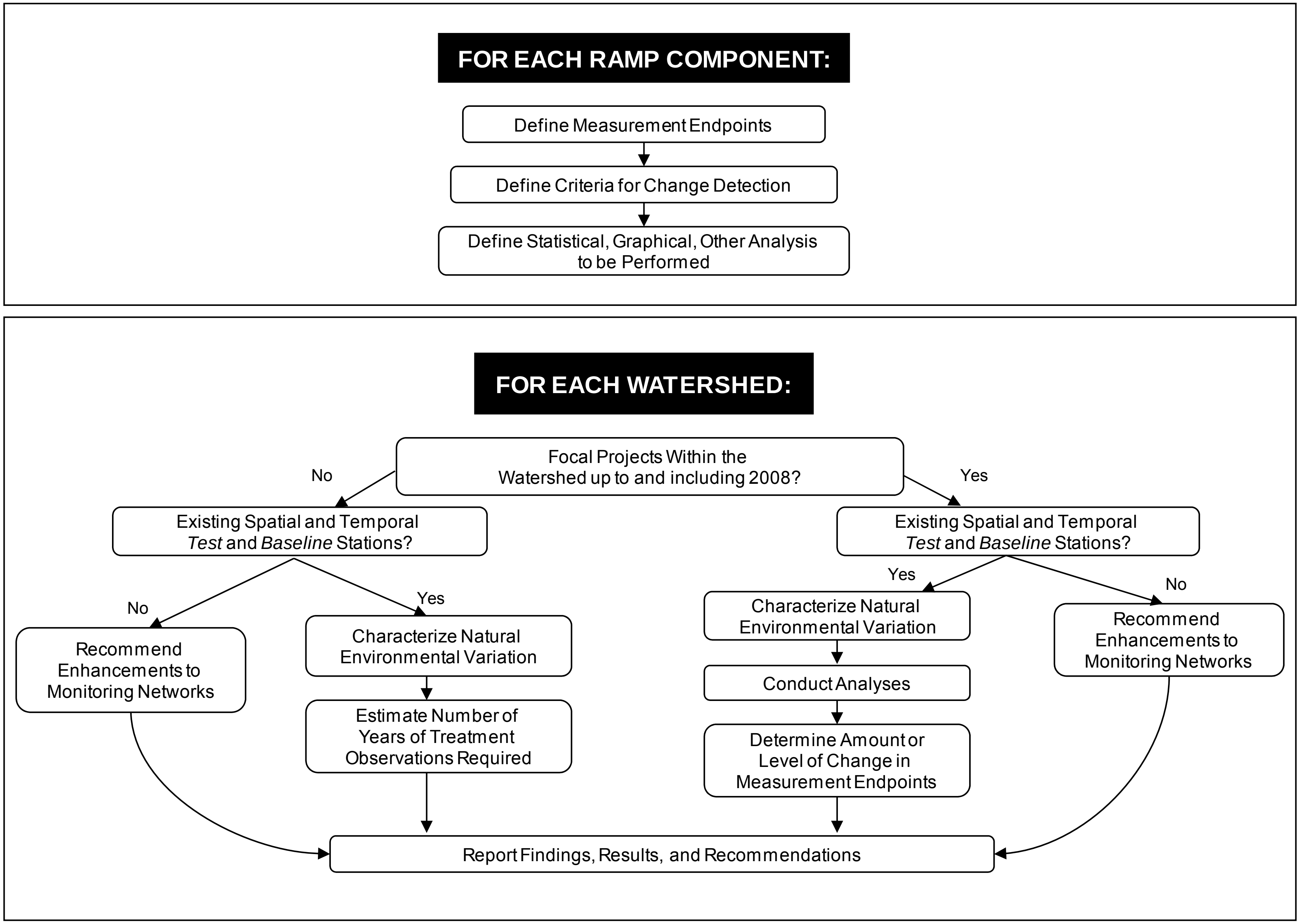
3.2.1 Overall Analytical Approach

The overall analytical approach builds on analytical approaches used in RAMP in previous years and the previous RAMP Technical Design and Rationale (RAMP 2009). Key features of the overall analytical approach are as follows:

- First, the analysis of RAMP results is conducted for the Athabasca River and Athabasca River Delta, as well as at the watershed/river basin level;
- Second, the analysis for each RAMP component uses a set of measurement endpoints representing the health and integrity of valued environmental resources within the component. These are the same measurement endpoints that were used in the RAMP 2004 to 2008 Technical Reports (RAMP 2005a, 2006, 2007, 2008, 2009);
- Third, a set of criteria are used for determining whether or not there has been a change in the values of the measurement endpoints between: (i) *test* stations; and (ii) *baseline* conditions that should be expected at those stations; and
- Fourth, the magnitude of these changes in the values of the measurement endpoints is summarized, and locations or watersheds with moderate or high levels of change become candidate sites for additional studies to identify the causes of the changes being measured.

A schematic summary of the analytical approach is provided in (Figure 3.1); component-specific details of measurement endpoints and criteria for evaluating the potential change in the value of endpoints are provided in the Sections 3.4 to 3.9.

Figure 3.1 Overall analytical approach for the Regional Aquatics Monitoring Program.



3.2.2 Harmonization of Monitoring Locations

As outlined in Section 3.1, the design of RAMP has been influenced by a number of factors. As well, the program has inherited monitoring stations from the baseline studies conducted in support of an EIA, or has had to modify the location of *baseline* and *test* stations in response to ongoing oil sands development. However, despite these challenges, the study design of RAMP has moved increasingly towards greater harmonization of sampling locations for the various monitoring components of RAMP. The rationale behind this effort is to gain as much information from common areas as possible for the purpose of obtaining a greater understanding of environmental conditions at a particular location and developing a stronger burden of evidence for the status of *test* stations.

Table 3.1 provides a summary of the extent of station harmonization among RAMP components as of 2008. There is still more progress to be made; however, a great deal of harmonization has occurred among the hydrology, water quality, sediment quality and benthic invertebrate community monitoring components. The restricted spatial extent of current fisheries monitoring activities does not lend itself to increased harmonization with the other components; however, greater harmonization may occur should a fish community-based monitoring approach be incorporated into RAMP in the future. Similarly, the Acid-Sensitive Lakes component focuses on only on pond and lake habitat throughout the RSA. Accordingly, there is currently little overlap with waterbodies monitored by other components of RAMP.

3.3 LAND CHANGE ANALYSIS

Since 2005, land change has been estimated using satellite imagery to quantify the location, extent, and type of land change in the RAMP Focus Study Area (FSA). This land change information is used to designate RAMP sampling locations as *baseline* and *test* stations and to provide information to the hydrologic analysis of effects of focal project activities. When land change analyses were first conducted in 2005, 30-meter resolution Landsat TM and Landsat MSS imagery was used to estimate land change. Since 2006, SPOT-5 10-meter resolution imagery was obtained for the FSA to assess changes related to (Landsat 30-meter resolution images are still obtained if 10-meter images are not possible due to weather conditions):

- Focal projects (i.e., those projects owned by RAMP funders, which are under construction or operational in the current in the RAMP FSA); and
- Oil sands projects within the RAMP FSA that are under active development by companies that were not funders of RAMP.

3.3.1 Methodology

3.3.1.1 Ortho-Rectification of Image Data

To ensure that assessments made from the EO imagery are spatially correct, the imagery is first geometrically corrected. The procedure is undertaken using PCI Geomatica image processing software and entails the alignment of the image data to a known map projection, essentially geo-referencing all pixel values in the data to a known location on the Earth's surface.

The procedure for ortho-rectifying the image data to a map projection involves the application of previously collected control points, topographic maps, existing ortho-rectified satellite imagery[1] and a digital elevation model (DEM)[2], to identify common ground control points (GCPs, known reference locations that can be identified on the satellite image). Once the collection of GCPs is complete, the ortho-rectification model is executed, creating a copy of the image, with the new positions, aligned to the reference maps and the elevation data. The ortho-rectification was performed for both SPOT-5 and Landsat-5 TM imagery.

3.3.2 Atmospheric Correction

Atmospheric correction[3] is applied to the SPOT-5 images using an automated routine within the PCI Geomatica image processing software using a spatially-adaptive fast atmospheric correction model for flat terrain.

3.3.3 Classification of Land Change

Initially, in 2005, eight separate land change classes were distinguished and delineated, the basic land change types are as follows:

- Cleared – logged areas;
- Bare – areas with little or no trace of vegetation remaining;
- Developed – areas on which various infrastructure facilities have been developed, but which may remain connected with the surrounding hydrology;
- Enclosed – areas from which runoff to the natural hydrologic system has likely been prevented (e.g., mines, tailings ponds, etc.); and
- Reclaimed.

Currently, only two classes of land change are distinguished and delineated: closed-circuited; and not closed-circuited.

A GIS overlay analysis is then performed to estimate the area of each land change class in each of the RAMP FSA watersheds.

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1 Geobase Landsat 7 ETM+ ortho-rectified images from 1999, 2000 and 2001.

2 Geobase 1:50 000 scale Digital Elevation Model.

3 Optical satellite imagery captures solar radiation reflected from the earth's surface. As visible light is susceptible to interference created by the presence of water vapor in the atmosphere, it is necessary to correct the imagery to remove these effects.

Table 3.1 Harmonization of station locations for each RAMP monitoring component, as of 2008.

Waterbody	Hydrology	Water Quality	Sediment Quality	Benthic Invertebrates	Fish Populations	Acid-Sensitive Lakes
Athabasca River	AENV station	ATR-OF			SS (ATR-1)	
		ATR-DC-E			00B	
		ATR-DC-W			01A, SS (ATR-2)	
		ATR-SR-W			4A, 5A, 6A	
		ATR-SR-E			4B, 5B	
		ATR-MR-W			SS (ATR-3)	
		ATR-MR-E			10B, SS (ATR-4)	
					11A	
					16A, 17A	
		ATR-DD-E			19B	
		ATR-DD-W			19A	
	S24	ATR-FR			SS (ATR-5)	
Athabasca Delta			FLC-1	FLC-1		
			GIC-1	GIC-1		
			BPC-1	BPC-1		
		ATR-OF	ATR-ER			
McLean Creek		MCC-1				
Mills Creek	S6					
Steepbank River	S38	STR-1	N/A	STR-E1	SS	
		STR-2				
		STR-3	N/A	STR-E2		
North Steepbank River		NSR-1				
Muskeg River	S7	MUR-1	N/A	MUR-E1	FF, SS	
	S33	MUR-2	MUR-D2			
		MUR-4				
	S5A	MUR-5				
	S5	MUR-6	MUR-D3			
	S20					
Jackpine Creek	S2	JAC-1	JAC-D1	JAC-D1		
	S37	JAC-2	JAC-D2	JAC-D2		
Muskeg Creek	S22	MUC-1				
Shelley Creek	S21	SHC-1				
Stanley Creek	S8	STC-1				
Iyinimin Creek	S3	IYC-1				
Beaver River		BER-1				
	S39	BER-2	BER-D2			
Tar River	S15A, S19	TAR-1				
	S34	TAR-2				
MacKay River	S26	MAR-1	N/A	MAR-E1		
	S40	MAR-2	N/A	MAR-E2		
Firebag River	S27	FIR-1	FIR-D1	FIR-D1		
		FIR-2	N/A	FIR-E1		
Ells River	S14	ELR-1	ELR-D1	ELR-D1	SS	
	S14A	ELR-2	N/A	ELR-E2	SS	
Calumet River	CNRL site	CAR-1	CAR-D1	CAR-D1		
	S18A	CAR-2	CAR-D2	CAR-D2		
Fort Creek	S12	FOC-1	FOC-D1	FOC-D1		
Wapasu Creek	S10	WAC-1				
Poplar Creek	S11	POC-1	POC-D1			
Clearwater River	07CD001	CLR-1	CLR-D1	CLR-D1	CR-3	
	07CD005	CLR-2	CLR-D2	CLR-D2	CR-2	
					CR-1	
Christina River		CHR-1	CHR-D1	CHR-D1		
	S29	CHR-2	CHR-D2			
Hangingstone River	S31	HAR-1	N/A	HAR-E1		
Isadore's Lake	L3	ISL-1	ISL-1	ISL-1		
Shipyard Lake		SHL-1	SHL-1	SHL-1		
Kearl Lake	S9,L2	KEL-1	KEL-1	KEL-1		418
McClelland Lake	S35, S36,L1	MCL-1	MCL-1	MCL-1		
Susan Lake	S25					
Surmont Creek	S32					
Horse River		HOR-1	N/A	HOR-E1	SS	
Dunkirk River		DUR-1	N/A	DUR-E1	SS	
Namur Lake					FT	436

SS-sentinel species program; FF-fish fence program; FT-fish tissue program

Regional Lakes Fish Tissue Program does not harmonize with the other components with the exception of Namur Lake

Acid-Sensitive Lakes component does not harmonize with the other components with the exception of Kearl Lake

N/A - sediment sampling was not conducted at erosional benthic invertebrate sampling reaches

baseline

test

3.4 CLIMATE AND HYDROLOGY COMPONENT

3.4.1 Component History

Climate and hydrology analyses for RAMP have relied on a combination of monitoring stations operated by federal and provincial governments and stations operated by RAMP. Government stations generally provide a longer period of record than is available at the industry-initiated stations. RAMP stations provide additional detail for the past decade, and fill data gaps in the federal and provincial networks, which are focused on monitoring larger watersheds and have limited coverage of the winter season.

The first climate and hydrometric stations that later became part of the RAMP program were established in 1995 as part of Syncrude's baseline studies for the Aurora Mine development. Two of the initial five hydrometric stations and the climate station were sited at locations of abandoned stations that had been operated as part of the Other Six Lease Operators (OSLO) project in 1988 – 1989, and one at the location of an abandoned Water Survey of Canada (WSC) station. Establishment of the first stations was driven by the need for site-specific climate and streamflow data for environmental impact assessments as well as for planning and design of the proposed Aurora Mine.

In 1995, Syncrude also established a hydrometric station on Poplar Creek to replace an abandoned WSC station. Streamflows in Poplar Creek include both runoff from the Poplar Creek catchment and diversions from the Beaver River upstream of Syncrude's Mildred Lake Mine. In 1997, Shell joined Syncrude in funding the hydrological monitoring program; the program expanded in scope to include a snow course survey and hydrological monitoring on Mills Creek and McClelland Lake. Syncrude, Shell-Albian, Mobil and Suncor provided joint funding for the 1998 and 1999 monitoring programs. The program expanded in scope to include hydrological monitoring on the Kearl Lake outlet.

In 2000, the hydrological monitoring program was integrated into RAMP. Since then, the monitoring program has been reviewed and adjusted on an annual basis in order to:

- establish additional stations, usually in response to specific regulatory approval requirements;
- abandon or move stations to accommodate development-related changes in the monitored watersheds;
- abandon stations when it was determined that the hydraulic conditions at the existing station location were so poor that there was no expectation of obtaining useful information there; or
- transfer responsibility for specific stations between RAMP and individual oil sands operators, in response to operator requests.

The current (as of 2008) RAMP Climate and Hydrology component consists of:

- 4 multi-variable climate stations;
- 16 snow course survey sites;
- 3 lake level stations;
- 18 year-round streamflow stations, of which six are operated in conjunction with Water Survey of Canada;
- 13 open-water season streamflow stations; and
- monitoring of individual climate variables such as precipitation or barometric pressure at several of the hydrometric stations.

Streamflow station monitoring includes collection of samples for total suspended sediment analysis during the open-water season at all stations, and continuous water temperature sensing at several stations. A summary of RAMP data available for the Climate and Hydrology component from 1997 to 2008 is provided in Table 3.2; locations of the climate and hydrology stations at which these data have been gathered are presented in Figure 3.2 and Figure 3.3.

Table 3.2 Summary of RAMP data available for the Climate and Hydrology component, 1997 to 2008.

see symbol key at bottom

Location	Station Number	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Climate Stations																																																	
Aurora Climate Station	C1	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h
Horizon Climate Station	C2																																																h
McClelland Lake	L1																						a	a	a		a	a			a	a	a						c	c	cg	i	i	i	i	i	i	i	i
Kearl Lake	L2																																												i	i	i	i	i
Iyinimin Creek above Kearl Lake	S3						a	a	a		a	a	a						a	a	a		a	a	a		a								a	a			a	a	a			c			c	c	c
Muskeg River above Muskeg Creek	S5A																					e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e
Mills Creek at Highway 63	S6														e	e	e																																
Kearl Lake Outlet	S9										e	e	e																																				
Calumet River near the Mouth	S16																						h	h	h	cf	cf	cf	cf	f	cf	cf	cf	cf	cf	f													
Tar River Lowland Tributary near the Mouth	S19																						a	a	a		a	a	a		a	a	a		a	a	a	c	c	c	c	c	c	c	c	c	c	c	c
Christina River near Chard	S29																						a	a	a		a	a	a		a	a	a																
Muskeg River Basin Snowcourse Survey			d				d				d				d				d																														
Fort Creek Basin Snowcourse Survey															d																																		
CNRL Area Snowcourse Survey																			d				d				d																						
Wide-Area Snowcourse Survey																														d				d				d				d				d			
Athabasca River Tributaries																																																	
Mills Creek at Highway 63	S6		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Poplar Creek at Highway 63 (07DA007)	S11			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t
Fort Creek at Highway 63	S12														2	2	2		2	2	2		2	2	2														2	2	2		2	2	2		2	2	2
Ells River above Joslyn Creek	S14																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2				
Ells River at CNRL Bridge	S14A																																2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2	2t	2t	2t
Tar River near the Mouth	S15																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2								
Tar River near the Mouth	S15A																																										2	2	2		2t	2t	2t
Calumet River near the Mouth	S16																		2	2	2		2	2	2		2t	2t	2t		2	2	2t																
Tar River Upland Tributary	S17																		2	2	2		2	2	2		2	2	2		1	1	1																
Upland Calumet River	S18																		2	2	2																												
Calumet River Upland Tributary	S18A																						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Tar River Lowland Tributary near the Mouth	S19																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Susan Lake Outlet	S25																						2	2	2														2	2	2		2	2	2		2	2	2
MacKay River near Fort McKay (07DB001)	S26		4	4	4		4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4
Firebag River near the Mouth (07DC001)	S27		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4
Tar River above CNRL Lake	S34																																		2	2	2		2	2	2	2	2	2	2	2	2t	2t	2t
McClelland Lake Outlet at McClelland Lake	S35																																														2	2	2
McClelland Lake Outlet above Firebag River	S36																																														2	2	2
Steepbank River near Fort McMurray (07DA006)	S38		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4	2	4	4	4
Beaver River above Syncrude (07DA018)	S39		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4	2	4	4	4
MacKay River at Petro-Canada Bridge	S40																																													2	2t	2t	2t
Athabasca River Mainstem																																																	
Athabasca River below Eymundson Creek	S24																		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Legend

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

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

Test (downstream of focal projects)
Baseline (upstream of focal projects)

Table 3.2 (Cont'd.)

see symbol key at bottom

WATERBODY AND LOCATION	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Muskeg River Basin																																																	
Alsands Drain	S1		2	2			2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2																								
Jackpine Creek at Canterra Road	S2		2	2	2		2	2			2	2			2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t
Iyinimin Creek above Kearl Lake	S3		2	2	2		2	2	2		2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Blackfly Creek near the Mouth	S4		2	2	2		2	2	2																																								
Muskeg River above Stanley Creek	S5																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Muskeg River above Muskeg Creek	S5A		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2	2	2	2	2	2t	2t	2t
Muskeg River near Fort McKay (07DA008)	S7		4	4	4		4	4	4		4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4
Stanley Creek near the Mouth	S8											1	1		1	1	1		1	1	1		1	1	1		1	1	1																				
Kearl Lake Outlet	S9						2	2	2		2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Wapasu Creek at Canterra Road	S10		2								2	2	2						2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Albian Pond 3 Outlet	S13														2	2	2		2	2	2		2	2	2																								
Muskeg River Upland	S20																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Shelley Creek near the Mouth	S21																		1	1	1		1	1	1		1	1	1																				
Muskeg Creek near the Mouth	S22																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Aurora Boundary Weir	S23																	2	2	2	2	2	2	2	2																								
Khahago Creek below Black Fly Creek	S28																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2				
Muskeg River at the Aurora/Albian Boundary	S33																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
East Jackpine Creek near the 1300 m Contour	S37																																												2		2	2	2
Muskeg River High Water Gauging				3				3				3				3				3																													
Jackpine Creek High Water Gauging				3				3												3																													
Clearwater River Mainstem																																																	
Clearwater River above Christina River (07CD005)			4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4
Clearwater River at Draper (07CD001)		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Clearwater River Tributaries																																																	
Christina River near Chard (07CE002)	S29																					2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4
Hangingstone River at Highway 63	S30																						2	2	2																								
Hangingstone Creek near the Mouth	S31																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Surmont Creek at Highway 881	S32																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t
Wetlands																																																	
McClelland Lake	L1			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2		2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Kearl Lake	L2										1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1t	1t	1t	1t	1t
Isadore's Lake	L3													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Regional Data																																																	
Compilation of Environment Canada data																																		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Compilation of WBEA data																																										√	√	√	√	√	√	√	√

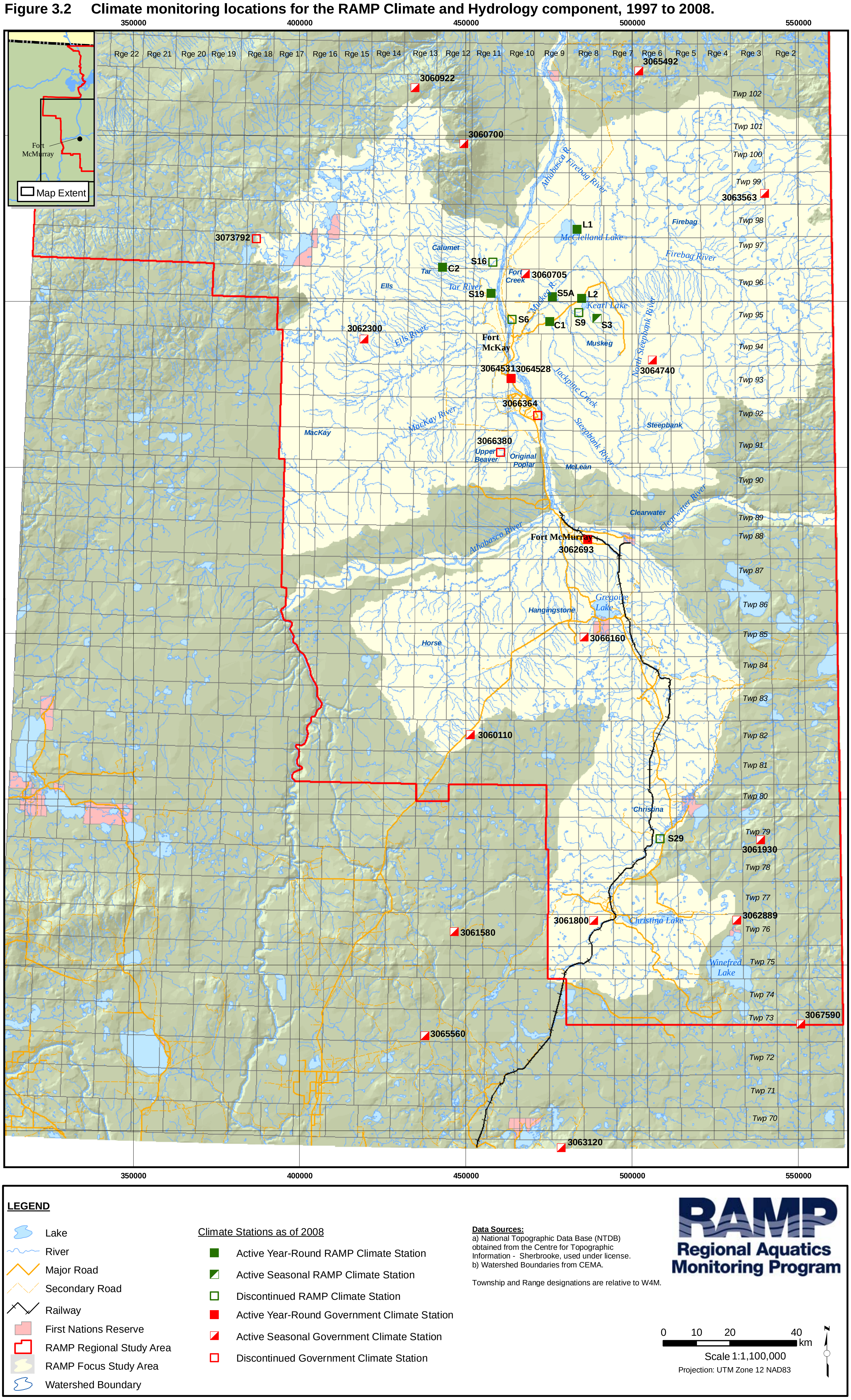
Legend

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

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

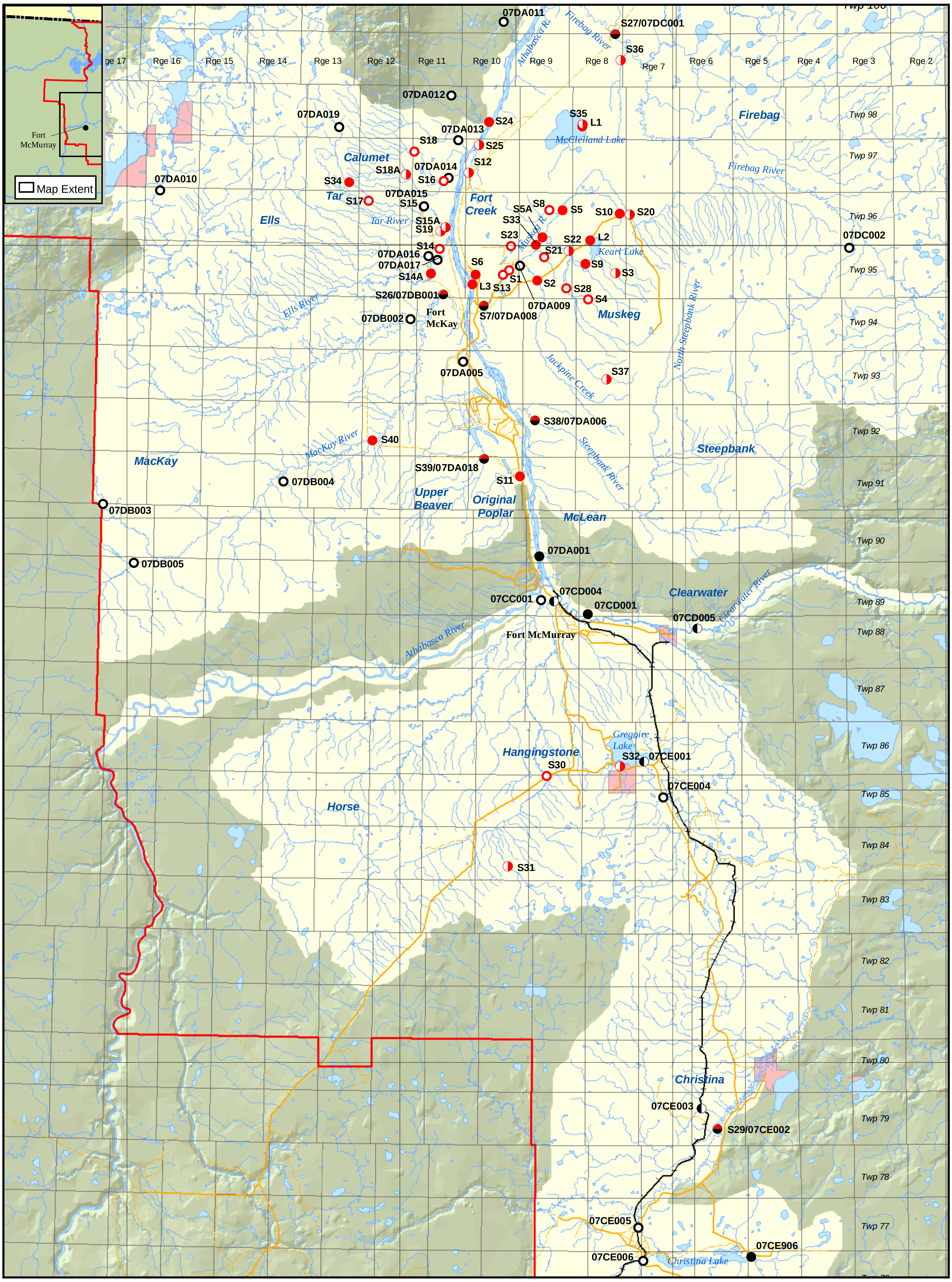
Test (downstream of focal projects) — blue
Baseline (upstream of focal projects) — green

Figure 3.2 Climate monitoring locations for the RAMP Climate and Hydrology component, 1997 to 2008.



K:\Data\Project\RAMP1467\GIS_MXD\A_DR\RAMP1467_DR_02a_Climate_20091127.mxd

Figure 3.3 Hydrology monitoring locations for the RAMP Climate and Hydrology component, 1997 to 2008.



LEGEND

- Lake
- River
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area
- RAMP Focus Study Area
- Watershed Boundary

Hydrometric Stations as of 2008

- Active Year-Round RAMP Hydrometric Station
- Active Seasonal RAMP Hydrometric Station
- Discontinued RAMP Hydrometric Station
- Active Year-Round Government Hydrometric Station
- Active Seasonal Government Hydrometric Station
- Discontinued Government Hydrometric Station
- Active Year-Round RAMP/Government Hydrometric Station

Data Sources:
a) National Topographic Data Base (NTDB) obtained from the Centre for Topographic Information - Sherbrooke, used under license.
b) Watershed Boundaries from CEMA.

Township and Range designations are relative to W4M.

RAMP
Regional Aquatics Monitoring Program

0 5 10 20 Km
Scale 1:750,000
Projection: UTM Zone 12 NAD83

K:\Data\Project\RAMP1467\GIS_MXD\A_DR\RAMP1467_DR_02b_Hydrology_20091127.mxd

3.4.2 Key Indicator Resources

Hydrological variables in RAMP do not themselves constitute KIRs from an environmental assessment perspective; this is consistent with the findings of the EIA review (Section 2.3). However, as stressors and/or supporting variables for other RAMP components, hydrological variables do provide important measurement endpoints indicating the suitability of a water body to support aquatic life and for indicating potential change within or outside the range of natural variability.

3.4.3 Hypotheses and Questions

3.4.3.1 Hypotheses and Questions from Athabasca Oil Sands EIAs

Specific EIA predictions associated with climate and hydrology, summarized from 17 different EIAs of oil sands developments in the RAMP study area, have been summarized in Chapter 2, above. Almost all (164 of a total of 180) residual impact assessments in these EIAs pertaining to climate and hydrology were predicted to have negligible or low impact; in addition, most effects are predicted to be local, not regional, in nature. Oil sands development impacts on hydrological variables, as predicted in the various EIAs, arise from a number of development and reclamation activities (Table 3.3).

Table 3.3 Athabasca oil sands activities with potential effects on hydrological conditions.

Main Impact Pathways (from Section 2.2, Page 2-1)	Oil Sands Activities (summarized from Table 2.2, Page 2-6 and Table 2.3, Page 2-10)
▪ Changes in network of watercourses and waterbodies ▪ Changes in natural hydrological processes (e.g., surface runoff) ▪ Purposeful water releases into and withdrawals from network of watercourses and waterbodies	▪ Groundwater withdrawal ▪ Surface disturbances (central facility, well pads, roads, etc.) ▪ Surface disturbances (central facility, well pads, roads, etc.) ▪ Disturbance of bed and banks of stream channels at watercourse crossings ▪ Surface disturbance from project infrastructure and facilities ▪ Water withdrawal

3.4.3.2 RAMP Objectives, Key Questions and Hypotheses

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 related to oil sands development or other activities in the oil sands region. Accordingly, RAMP monitors changes in the quantity of water flowing through rivers and creeks in the RAMP focal study area, lake levels in selected waterbodies and local climatic conditions to: 1) identify possible changes in hydrology potentially related to oil sands development in the region; and 2) contribute to our understanding of the linkages between the physical and chemical and biological characteristics of the aquatic environment.

The objectives of the RAMP Climate and Hydrology component are to:

1. provide a basis for assessing EIA predictions of hydrological changes;

2. facilitate the interpretation of water quality, sediment quality, benthic invertebrate community, and fish population information by placing in context current hydrological conditions relative to historical mean or extreme conditions;

3. document stream-specific baseline weather and hydrologic conditions to characterize natural variability and to allow detection of regional trends;

4. support regulatory applications and meet requirements of regulatory approvals; and

5. support calibration and verification of regional hydrological models that form the basis of environmental impact assessments, operational water management plans and closure reclamation drainage designs.

The first four of these objectives derive from the overall objectives of RAMP, while the final objective has been included more recently as a result of ongoing discussions among members of the RAMP Technical Program Committee (RAMP 2005b).

These five objectives lead to the following questions for the RAMP Climate and Hydrology component:

- What changes in hydrological variables are predicted in oil sands EIAs?

- What are the baseline conditions and range of natural variability of hydrological variables in the RAMP study area?

- Are hydrological conditions at monitored locations outside the range of natural variability?

- What hydrological information is required by other RAMP components to assist in interpretation?

The following hypotheses are formulated for the Climate and Hydrology component:

- H_{o1}: Hydrological conditions at each monitored location are within the range of natural variability; and

- H_{o2}: Hydrological conditions are unaffected by development.

The first hypothesis is tested by comparing annual hydrographs with historical hydrographs for the same station, as discussed in Section 3.4.6.1, below. The second hypothesis is tested by comparing measured hydrological variables against estimated values of those variables for natural conditions, as discussed in Section 3.4.6.2, below.

3.4.4 Measurement Endpoints and Criteria for Determining Change

3.4.4.1 Review of Measurement Endpoints used in Athabasca Oil Sands EIAs

A variety of measurement endpoints have been used in Athabasca oil sands EIAs to characterize hydrological conditions (Table 2.11, Page 2-19); these measurement endpoints can be categorized into four groups:

- **Catchment Area** - Changes in catchment area are expected to produce changes in the hydrological response of the catchment. Catchment changes may include changes in catchment size, which may occur due to disruption of the original drainage system and development of closed-circuit areas, and changes in catchment character, which occur due to activities such as clearing and muskeg dewatering. Catchment area changes are currently monitored using satellite imagery supplemented by information from the oil sands operators, as discussed in Section 3.2.

- **Hydrometric Variables** – Hydrometric variables (listed in Table 2.11, Page 2-18) consist of discharge and water level statistics that are not measured directly, but are calculated from a standard continuous hydrometric record. Most of the monitoring effort in the RAMP Climate and Hydrology component has historically been focused on hydrometric variables. Many of the hydrometric measurement endpoints are based on year-round data and; therefore, can only be computed for year-round stations. Many variables are the product of frequency analyses (e.g., 1:10 year flood, $7Q_{10}$ low flow), and require multiple years of stationary record to estimate with any confidence.

- **Erosion and Sediment Yield** – Sediment concentrations have historically been sampled approximately monthly during the open-water season as part of the routine RAMP hydrometric monitoring program. Sediment load and sediment yield are derived variables that can be estimated using the monthly data but for a reasonable level of accuracy would require continuous, rather than monthly, sediment sampling. The current program does not envision continuous sediment sampling, considering the high level of effort required and the opinion of the RAMP Climate and Hydrology Subgroup that the benefits of the monitoring would be relatively small.

- **Miscellaneous Variables** – Several EIAs specified measurement endpoints that do not fit into the previous three categories, including lake and total water surface area, channel erosion, and near-surface water tables. These variables are not monitored by the RAMP Climate and Hydrology component.

3.4.4.2 Measurement Endpoints used in RAMP

The following measurement endpoints have recently been used for the analysis of RAMP Climate and Hydrology component data:

- mean open-water (1 May to 31 October) season discharge;
- mean winter (1 November to 31 March) discharge;
- annual maximum daily discharge; and
- open-water season minimum daily discharge.

These measurement endpoints were selected based on a review of measurement endpoints used in various oil sands project EIAs (Table 2.11, Page 2-19), with emphasis on choosing endpoints that can be computed from limited time series of data. It will be possible to add additional endpoints to the analysis in future years, such as the 1:10 year flood flow or the 7Q10 low flow, when multiple years of both *baseline* and *test* data for *baseline* and *test* watersheds are available.

3.4.4.3 Criteria for Determining Change

The main criterion for determining change currently used in the Climate and Hydrology component is the percent difference in the measurement endpoints (above) from natural, *baseline* conditions. The procedure for calculating this change is outlined in Section 3.4.6, below.

3.4.5 Monitoring Station Selection and Monitoring Design

Historically, many hydrometric monitoring stations have been established at locations for which EIA predictions have been made. Most of these stations are located downstream of existing or proposed oil sands developments. Some stations have been located upstream of development to monitor undeveloped watersheds. Stations have frequently been established at locations where government agencies or other organizations have monitored previously, to take advantage of the existing period of record available.

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Athabasca River Tributaries						
C2	Horizon Climate Station	All year	10/2008 to present	Air temperature, total precipitation, humidity, solar radiation, snow depth, wind speed and direction		Detailed climate data west of the Athabasca River used to explain climate driven hydrometric patterns and used as input to hydrological and air quality/particulate modeling.
L1	McClelland Lake	All year	06/1997 to present	Water level, air temperature, humidity, total precipitation	Baseline	Monitoring for Suncor/UTS Fort Hills EIA predictions. Extended spatial sampling of climate parameters. Suncor interested in water balance.
L3	Isadore's Lake	All year	02/2000 to present	Water level	Test	Monitoring Shell-Albian Sands Muskeg River EIA predictions.
S6	Mills Creek at Highway 63	All year	04/1997 to present	Level, discharge	Test (Baseline from 1997 – 2000)	Monitoring Shell-Albian Sands Muskeg River EIA predictions.
S11	Poplar Creek at Highway 63 (07DA007)	All year	03/1972 to present	Level, discharge, water temperature	Test	Extend measurement record at an established WSC site. WSC station was active from 1973-86.
S12	Fort Creek at Highway 63	Open-water	04/2000 to present	Level, discharge	Test (Baseline from 2000 – 2002)	Monitoring for Suncor/UTS Fort Hills EIA predictions.
S14	Ells River above Joslyn Creek	Discontinued	05/2001 to 10/2007	Level, discharge	Test	Monitored discharge in the vicinity of the inactive WSC station 07DA017. Replaced by station S14A, due to poor hydraulic conditions.
S14A	Ells River at the CNRL Bridge	All year	10/2004 to present	Level, discharge, water temperature	Test	Monitoring for Total E&P Joslyn EIA predictions.
S15	Tar River near the Mouth	Discontinued	05/2003 to 04/2007	Level, discharge	Test	Monitored discharge below CNRL Horizon. Station was moved closer to Tar River mouth to capture CNRL diverted flow. Station renamed S15A.
S15A	Tar River near the Mouth	Open-water	05/2007 to present	Level, discharge, water temperature	Test	Monitoring for CNRL Horizon EIA predictions. Monitors flow diverted out of the channel by CNRL development.
S16	Calumet River near the Mouth	Discontinued (operated by Golder for CNRL EIA)	05/2001 to 10/2004	Level, discharge, precipitation, water temperature	Baseline	Established to monitor discharge near the inactive WSC station 07DA014. Currently operated by Golder for CNRL EIA predictions.
S17	Tar River Upland Tributary	Discontinued	05/2001 to 10/2003	Level, discharge, conductivity	Baseline	Monitored discharge on an upland tributary of the Tar River. Station was replaced with S34 because S34 was considered to be a higher priority.
S18	Calumet River Upland	Discontinued	05/2001 to 10/2001	Level, discharge	Baseline	Monitored discharge on a typical Calumet River upland tributary. Replaced by S18A due to poor hydraulic conditions.

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Athabasca River Tributaries Cont'd.						
S18A	Calumet River Upland Tributary	Open-water	06/2002 to present	Level, discharge	Baseline	Monitoring for CNRL Horizon EIA predictions. Established to characterize runoff from Calumet River upland tributaries from the east slopes of Birch Mountain. Upper reach of Tar River (S34) will eventually be diverted into Calumet River
S19	Tar River Lowland Tributary near the Mouth	Open-water	05/2001 to present	Level, discharge	Test (Baseline from 2001 – 2003)	Monitoring for CNRL Horizon EIA predictions. This channel is the likely discharge point for initial mine overburden dewatering activities.
S25	Susan Lake Outlet	Open-water	06/2002 to present	Level, discharge	Baseline	Monitoring for Suncor/UTS Fort Hills EIA predictions.
S26	MacKay River near Fort McKay (07DB001)	Winter[1]	03/1972 to present	Level, discharge	Test (Baseline from 1997 – 2001)	Monitoring to complete a full year WSC record, and for Suncor MacKay River EIA predictions.
S27	Firebag River near the mouth (07DC001)	Winter[1]	05/1971 to present	Level, discharge	Test (Baseline from 1971 to initiation of Total E&P Canada Northern Lights)	Monitoring to complete a full year WSC record. Monitoring downstream influence of Total E&P Canada Northern Lights.
S34	Tar River above CNRL Lake	All year	04/2005 to present	Level, discharge, water temperature	Baseline	Monitoring to quantify flow inputs into CNRL Lake for management purposes.
S35	McClelland Lake Outlet below McClelland Lake	Open-water	06/2008 to present	Level, discharge	Baseline	Monitoring to calculate water balance on McClelland Lake for Suncor/UTS Fort Hills development.
S36	McClelland Lake Outlet above Firebag River	Open-water	05/2008 to present	Level, discharge	Intended baseline, but minor influence in upper catchment	Monitoring due to difficulties in making accurate measurements at S35; however, S36 has larger contributing area than McClelland Lake alone.
S38	Steepbank River near Fort McMurray (07DA006)	Winter[1]	09/1972 to present	Level, discharge	Test	Monitoring to complete a full year WSC record. Monitoring influence of Suncor Steepbank mines.
S39	Beaver River above Syncrude (07DA018)	Winter[1]	03/1975 to present	Level, discharge	Baseline	Monitoring to complete a full year WSC record. Beaver River is diverted to Poplar Creek downstream of station.
S40	Mackay River at Suncor Bridge	All year	01/2008 to present	Level, discharge, water temperature	Baseline	Upstream reference for Suncor Dover and MacKay River developments.
S43	Firebag River Upstream	Open-Water	06/2009 to present	Level, discharge	Baseline	Monitoring discharge above development in Firebag catchment.

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Athabasca River Tributaries Cont'd.						
S44	Pierre River	Open-Water	06/2009 to present	Level, discharge	Baseline, but will become test with Shell-Albian Pierre River Mine development	Monitoring discharge to establish baseline prior to Shell-Albian Pierre River Mine. At same location as WSC 07DA013, which was active from 1975 – 1977.
S45	Ells River above Joslyn Creek Diversion	All year	06/2009 to present	Level, discharge	Baseline	Monitoring discharge above Total proposed diversion of Joslyn Creek into the Ells River.
West Athabasca River Snow Course Survey						
L-JP-06-1		Winter	2006 to present	Snow Course		Jackpine stand snow depth and density sampling; West of Athabasca River
M-FL-06-1		Winter	2006 to present	Snow Course		Flat low lying area snow depth and density sampling; West of Athabasca River
P-MD-06-1		Winter	2006 to present	Snow Course		Mixed deciduous stand snow depth and density sampling; West of Athabasca River
Q-OP-06-1		Winter	2006 to present	Snow Course		Open land or lakes area snow depth and density sampling; West of Athabasca River
N-MD-04-1		Winter	2004 to present	Snow Course		Mixed deciduous stand snow depth and density sampling; East of Athabasca River
B-JP-00-1		Winter	2000 to present	Snow Course		Jackpine stand snow depth and density sampling; East of Athabasca River
K-FL-04-4		Winter	2004 to present	Snow Course		Flat low lying area snow depth and density sampling; East of Athabasca River
Athabasca River Mainstem						
S24	Athabasca River below Eymundson Creek	All year	06/2001 to present	Level, discharge	Test	Monitoring for all RAMP focal projects. Meant to be downstream of all oil sands development.
Muskeg River Basin						
C1	Aurora Climate Station	All year	05/1995 to present	Air temperature, total precipitation, humidity, solar radiation, snow depth, wind speed and direction		Detailed climate data east of the Athabasca River used to explain climate driven hydrometric patterns and as input to hydrological modeling. Station was moved to current position in March 2006.
L2	Kearl Lake	All year	01/1989 to present	Water level, total precipitation, humidity, air temperature, water temperature	Baseline, but will become test with Shell-Albian Jackpine Expansion and Imperial Oil Kearl development	Extended spatial sampling of climate parameters. Imperial Oil Kearl interested in water balance for compensation lake.

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Muskeg River Basin Cont'd.						
S1	Alsands Drain	Discontinued	08/1995 to 12/2002	Level, discharge, water temperature	N/A	Established to monitor discharge from the Alsands settling pond, on Shell-Albian Muskeg River Mine. Drainage from Syncrude Aurora was conveyed to the Muskeg River via this outlet from 1995 to 2002. Channel no longer exists.
S2	Jackpine Creek at Canterra Road	All year	05/1995 to present	Level, discharge, water temperature	Test (Baseline from 1997 – 2005)	Monitoring for Shell-Albian Muskeg River and Syncrude Aurora North EIA predictions.
S3	Iyinimin Creek above Kearl Lake	Open-water	01/1989 to present	Level, discharge, rainfall	Baseline	Monitoring for Shell-Albian Jackpine and Muskeg River, and Syncrude Aurora North EIA predictions. Used as inflow to Kearl Lake water balance.
S4	Blackfly Creek	Discontinued	05/1995 to 10/2008	Level, discharge	Baseline	Monitored an upland tributary of the Muskeg River. Intended to characterize runoff from the west slopes of Muskeg Mountain. Replaced by S4A.
S4A	Blackfly Creek near the Mouth	Discontinued	05/2007 to 10/2007	Level, discharge	Baseline	Monitored streamflow upstream of development in the Muskeg watershed. Discontinued after 2007 because it was located too close to near-future mine development. Replaced by S37.
S5	Muskeg River above Stanley Creek	All year	05/2003 to present	Level, discharge	Baseline	Monitoring for Syncrude Aurora North EIA predictions.
S5A	Muskeg River above Muskeg Creek	All year	08/1995 to present	Level, discharge, barometric pressure, water temperature	Test	Monitoring for Shell-Albian Jackpine project EIA predictions.
S7	Muskeg River near Fort McKay (07DA008)	Winter[1]	01/1974 to present	Level, discharge	Test	Monitoring to complete a full year WSC record, and for Shell-Albian Jackpine and Muskeg River EIA predictions.
S8	Stanley Creek	Discontinued	09/1999 to 10/2003	Level	Baseline	Monitored water levels upstream of the Muskeg River. Discontinued due to poor hydraulic conditions.
S9	Kearl Lake Outlet	All year	01/1989 to present	Level, discharge	Baseline, but will become test with Shell-Albian Jackpine Expansion and Imperial Oil Kearl developments	Used for outflow of Kearl Lake water balance.
S10	Wapasu Creek at Canterra Road	All year	05/1997 to present	Level, discharge, water temperature	Baseline	Monitoring for Shell-Albian Jackpine and Husky Sunrise EIA predictions.
S13	Albian Pond #3 Outlet	Discontinued	03/2000 to 12/2002	Level, discharge	Test	Monitored discharge from Shell-Albian Polishing Pond #3 into the Muskeg River. Channel no longer exists.
S21	Shelley Creek near the Mouth	Discontinued	05/2001 to 10/2003	Level, discharge	Baseline	Monitored discharge on Shelley Creek upstream of the Muskeg River. Decommissioned due to poor hydraulic conditions.

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Muskeg River Basin Cont'd.						
S20	Muskeg River Upland	Open-water	05/2001 to present	Level, discharge	Baseline	Monitoring for Shell-Albian Jackpine EIA predictions.
S22	Muskeg Creek near the Mouth	Open-water	01/1989 to present	Level, discharge	Test (Baseline from 2001 – 2006)	Monitoring for Shell-Albian Jackpine and Albian Sands Muskeg River EIA predictions.
S23	Aurora Boundary Weir	Discontinued	05/2001 to 12/2002	Level, discharge	Test	Monitored clean water discharge from Syncrude Aurora to Albian Sands Muskeg River. The channel conveyed water to the Muskeg River via S1. Channel no longer exists.
S28	Khagago Creek below Black Fly Creek	Discontinued	06/2001 to 10/2007	Level, discharge, water temperature	Baseline	Monitored discharge on Khahago Creek at the upstream boundary of oil sands Lease 13. An OSLO station existed at this site in 1988-89. Discontinued due to encroaching development.
S33	Muskeg River at the Aurora/Albian Boundary	All year	04/2003 to present	Level, discharge	Test	Monitoring between Aurora and Albian Properties.
S37	East Jackpine Creek near the 1300 m contour	Open-water	09/2007 to present	Level, discharge	Baseline	Characterize Muskeg watershed upland tributaries.
Muskeg Basin Snow course Survey						
A-MD-00-2		Winter	2000 to present	Snow Course		Mixed deciduous stand snow depth and density sampling; Muskeg River headwaters
J-JP-01-1		Winter	2001 to present	Snow Course		Jackpine stand snow depth and density sampling; Muskeg River headwaters
C-FL-00-1		Winter	2000 to present	Snow Course		Flat low lying area snow depth and density sampling; Muskeg River headwaters
D-OP-04-1		Winter	2004 to present	Snow Course		Open land or lakes area snow depth and density sampling; Kearl Lake drainage
E-OP-99-2		Winter	1999 to present	Snow Course		Open land or lakes area snow depth and density sampling; Jackpine River drainage
F-JP-97-2		Winter	1997 to present	Snow Course		Jackpine stand snow depth and density sampling; Muskeg River drainage
G-FL-04-1		Winter	2004 to present	Snow Course		Flat low lying area snow depth and density sampling; Muskeg River drainage
H-OP-97-1		Winter	1997 to present	Snow Course		Open land or lakes area snow depth and density sampling; Muskeg River drainage

Table 3.4 Summary of all RAMP climate and hydrology stations, 1971 to 2008.

No.	Name	Operating Season	Period of Record	Parameters Measured	Baseline/ Test	Rationale
Clearwater River Tributaries						
S29	Christina River near Chard (07CE002)	Winter[1]	05/1982 to present	Level, discharge	Baseline	Monitoring to complete a full year WSC record. Upstream reference for southern developments.
S30	Hangingstone River at Hwy 63	Discontinued	05/2001 to 10/2002	Level, discharge	Baseline	Monitored discharge on Hangingstone River upstream of the Athabasca River. Station was established for EIA purposes, but was discontinued because development was seen as many years in the future.
S31	Hangingstone Creek near the Mouth	Open-water	04/2002 to present	Level, discharge	Baseline	Monitoring for Suncor Meadow Creek EIA predictions.
S32	Surmont Creek at Highway 881	Open-water	05/2002 to present	Level, discharge, water temperature	Baseline	Monitoring for Suncor Meadow Creek EIA predictions.
South Fort McMurray Snow Course Survey						
R-MD-04-2		Winter	2004 to present	Snow Course		Mixed deciduous stand snow depth and density sampling; Christina River drainage near Chard.

[1] Environment Canada monitors water level and discharge at these stations during the open-water season.

3.4.5.1 Monitoring Protocols

Streamflow

Current streamflow measurement procedures and standards are based on recommendations by the Water Survey of Canada (WSC 2001), the United States Geological Survey (1982), and the BC Ministry of Environment, Lands and Parks (1998). Measurements are made by wading or from the ice, from a bridge or from a boat. Measurement standards are summarized briefly below:

- Number of verticals: 20, or at a spacing of 0.1 m in small streams.
- Number of readings in the vertical for an open-water measurement: one at 60% of the depth below the water surface for depths of 1.1 m or less; otherwise one at 20% and one at 80% of the depth.
- Number of readings in the vertical for a measurement under ice: one at 60% of the depth below the surface for depths of 1.0 m or less; otherwise one at 20% and one at 80% of the depth.
- Velocity averaging: At least 20 seconds for electromagnetic meters; 45 seconds for mechanical meters.
- Winter discharge interpolation: To estimate the discharge during the intervals between manual discharge measurements, the current protocol is to use the backwater method as described by WSC (2001). Earlier analyses defined a single-valued rating curve for the entire ice-covered season.

A quality rating is applied to each manual discharge measurement based primarily on hydraulic conditions at the site, to assist in subsequent interpretation of the data.

Details of the measurement procedures used for the Climate and Hydrology Component are provided in Appendix A4.

Snow Course Surveys

Snow course surveys provide an indication of the variation in snow accumulation on various terrain types in the study area. This information can be used to estimate the total snow water available for melt in a given catchment, to provide an indication of spring runoff potential, or for use in hydrological modeling. Surveys are scheduled for the beginning of February, March and April to maximize the possibility of capturing the greatest snowpack.

The procedure for snow course sampling has evolved over the course of the program. The current (2008) protocol is to measure snow depth with an established sampling plot at approximately 40 locations at each site. At least four samples are taken for density measurements using an Adirondack snow density gauge. Snow depth and the sample mass are recorded for each density sample to allow calculation of the snow water equivalent and snow density.

3.4.6 Analytical Approach

3.4.6.1 Hypothesis H_{o1}: Characterization of Natural Variability

Characterization of natural variability in hydrological conditions and comparison of current hydrological conditions with historical conditions is done by comparison of annual hydrological data with long-term normals for the selected measurement endpoints, presented in simple tabular and graphical formats (e.g., Figure 3.4, from RAMP [2009]).

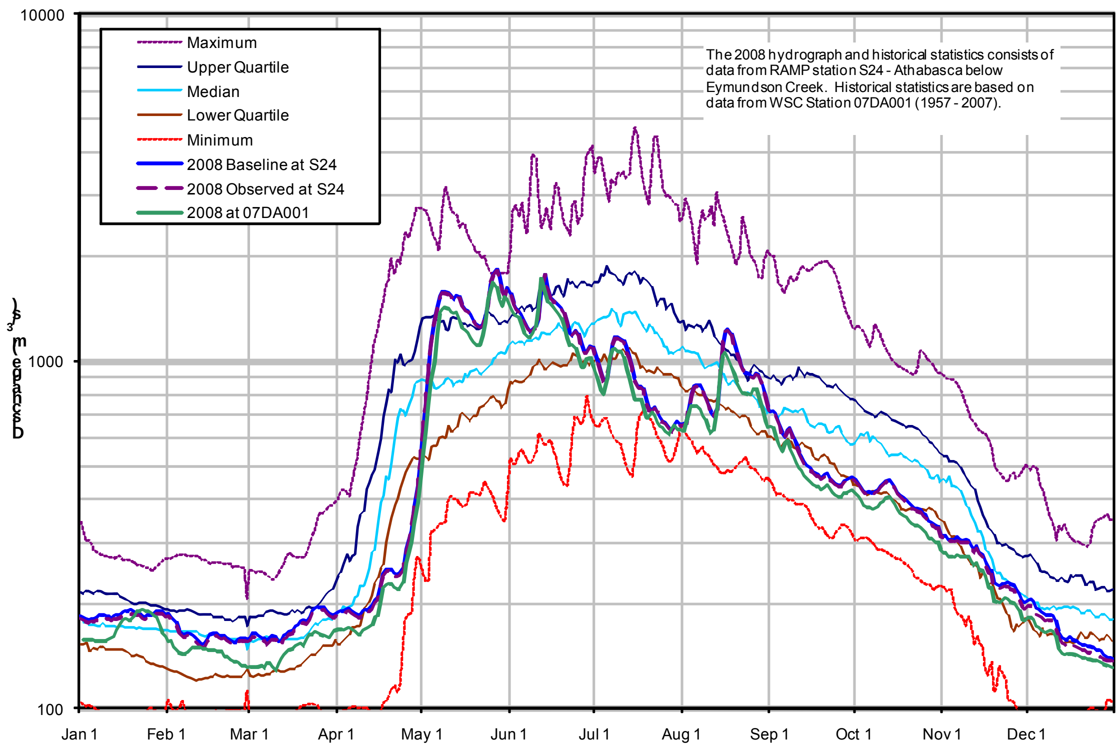
3.4.6.2 Hypothesis H_{o2}: Effects of Athabasca Oil Sands Development Activities

There are several issues in using a *baseline* and *test* watershed approach in the Climate and Hydrology component to evaluate hydrological changes of Athabasca oil sands development:

- Natural variability from year to year and from one watershed to another is large relative to the magnitude of potential effects;

- Measurement uncertainty for hydrometric monitoring is large relative to the magnitude of potential effects. Accuracy of discharge hydrographs under good conditions is often considered to be in the range of ±5% to ±10%. In many of the streams in the oil sands region, where flow measurement conditions are much less than ideal due to beaver dams, aquatic vegetation, and poorly defined stream channels, measurement uncertainty is even greater; and

Figure 3.4 2008 hydrograph for the Athabasca River below Fort McMurray (07DA001) compared to historical values (from RAMP 2009).



- Measurement endpoints used in several of the project EIAs included variables such as 1 in 10 year high and low flows. Estimating the values of these variables with any confidence requires close to ten years of stationary data (i.e., data that does not exhibit a trend). The pre-development record at most of the stations is much shorter than ten years. Streamflows measured in catchments that are experiencing ongoing development cannot be expected to be stationary. Other EIAs included 1:50 year and 1:100 year discharges as endpoints; those variables would require substantially longer periods of record to evaluate.

The current approach used to deal with these issues is to measure hydrological effects directly, using each watershed potentially affected by development as both a *baseline* and a *test* watershed simultaneously. The observed hydrograph at a selected station is used as the *test* case, and a calculated *baseline* hydrograph (similar to a "naturalized" hydrograph) is used as the *baseline*/reference case. Thus any potential effect of development is isolated from the effects of spatial and temporal variability.

The calculated *baseline* hydrograph is defined for this analysis as the hydrograph that would have occurred at a station if no oil sands development had occurred in the watershed. The calculated *baseline* hydrograph may include the effect of other non-oil sands related activities in the watershed, and so for this reason is not referred to as a naturalized hydrograph as that term is normally defined. However, the calculated *baseline* hydrograph is appropriate for identifying incremental effects of oil sands developments experienced at the mouth of major tributaries of the Athabasca River and for the Athabasca River within the oil sands area.

The computation of the calculated *baseline* hydrograph for the outlet of a given watercourse is:

Calculated *Baseline* Hydrograph = Observed, *test* Hydrograph

+ water withdrawals, from the watercourse in question, by oil sands development activities

- water releases, to the watercourse in question, by oil sands development activities

+ natural runoff that would have occurred within the watershed, but no longer occurs due to closed-circuited land-use impacts resulting from active oil sands development or areas where runoff is intercepted by development

- incremental runoff from areas that are cleared and areas that are dewatered within the watershed

- the difference between naturalized and observed hydrographs on tributaries upstream of the station in question (when considering the mainstem of the Athabasca River)

Calculated *baseline* hydrographs are derived for the outlet of each major watershed by adding water withdrawals and subtracting water releases from the observed hydrographs followed by adjustments to account for changes in land-use. For the purpose of the hydrology component, land-use impacts are classified as either; closed-circuited (no longer contributing flow measured at the mouth of the watershed) or cleared and/or dewatered (with an assumed increase in contributed flow). Incremental runoff depth from cleared and dewatering areas is assumed for this analysis to be a constant percentage of the runoff depth on natural portions of the catchment.

A comparison of the observed hydrograph to the characteristics of the calculated *baseline* hydrograph is used to assess changes in the hydrologic conditions experienced at the outlet/mouth of the watershed under consideration.

3.5 WATER QUALITY COMPONENT

3.5.1 Component History

Water quality has been sampled in the Athabasca oil sands area for several decades. Prior to the implementation of RAMP in 1997, surface water quality samples were collected by government agencies, research programs (e.g., AOSERP, NRBS), and industry. These data were summarized in the RAMP 1997 Technical Report (Golder 1998).

Water quality has been sampled by RAMP since 1997, when samples were collected from the mouths of the Muskeg and Steepbank rivers, and from the Athabasca River mainstem. Since then, the RAMP water quality component has expanded in response to planned and current oil sands development and with the overall scope of RAMP. In 2008, the fall water quality sampling program included 48 stations throughout the region including stations on the Athabasca River mainstem, the Athabasca delta, tributaries of the Athabasca River, and local lakes, with additional samples collected in winter, spring, and summer (Table 3.5, Figure 3.5).

RAMP analyzes ambient waters for a wide variety of water quality variables (Table 3.6). This list of variables was developed by the initial implementing consultant for RAMP (Golder Associates Ltd.), from previous sampling designs for baseline studies and EIAs in the region, with input from Alberta Environment and other RAMP stakeholders (L. Noton, Alberta Environment, *pers. comm.* 2005; M. Lagemodiere, Ft. McKay IRC, *pers. comm.* 2005). These variables are intended to provide data regarding specific potential stressors for aquatic biota, which may be related to oil sands operations, as well as data that support other, biological components of RAMP (i.e., the fish populations and benthic invertebrate components). Some variables measured (e.g., various metals) are not specific potential oil-sands-related stressors or supporting data, but rather are provided as part of an analytical chemistry package with other, relevant variables by consulting laboratories.

This extensive list of water quality variables has been relatively consistent over time, with the exception of the following changes:

- Discontinuation of Microtox® toxicity measurements in 2001, given the relative insensitivity of this test to ambient waters (M. Lagemodiere, *pers. comm.* 2005);
- Addition of ultra-trace analysis of total mercury (i.e., 1.2 ng/L detection limit) in 2002;
- Discontinuation of PAH analysis in water in 2005, due to non-detectable or very low concentrations in nearly all water samples; and
- Discontinuation of chlorophyll *a* analysis in samples from lotic (running water) systems in summer 2006, given that chlorophyll *a* data were not

found to be correlated with any nutrient analyte and were frequently below detection limits (see Appendix D.3 of RAMP[2006]). Water column chlorophyll *a* continues to be analyzed in lentic (lake) samples; chlorophyll *a* is also measured in periphyton in flowing waters by the RAMP benthos and sediment component.

Analytical laboratories used by RAMP also have remained generally consistent, with ALS Laboratories (formerly Enviro-Test Laboratories Ltd.) of Edmonton undertaking most water quality chemistry, and HydroQual Laboratories Ltd. of Calgary undertaking sublethal toxicity testing. In 2002, total and dissolved metals analyses (including ultra-trace total mercury) were shifted from Enviro-Test to Alberta Research Council (ARC) in Vegreville, due to concerns regarding the accuracy and intercomparability of total and dissolved metals data (P. McEachern, Alberta Environment, *pers. comm.* 2005).

The sampling program and design have been modified and refined over time as the volume of data has increased and new ideas have been adopted by the RAMP Technical Committee. Generally, the water quality sampling program has incorporated elements of each of the following types of experimental design:

- **Before/after design:** RAMP attempts to monitor water quality at specific locations of interest for three years in advance of any development in order to establish an understanding of *baseline* water quality at that location. Water quality data are then collected during project operations (*test* case) to assess potential change.

- **Control/impact design:** RAMP collects and compares water quality data from *baseline* and *test* locations. Typically, these data are collected from stations upstream and downstream of potential or existing oil sands developments.

- **Gradient design:** Where watershed size and river length are suitable, and where developments occur along the length of a river, water quality stations are established at appropriate locations along the river length to assess longitudinal changes in water quality.

- **Reference-condition design:** RAMP uses the entire *baseline* water quality dataset to develop a robust description of natural, baseline water quality conditions against which individual water quality observations can be compared (see Section 3.5.6.1). The reference-condition approach was adopted as an analytical design in 2004.

Prior to 2003, RAMP analyses of water quality data were primarily descriptive, with data presented in tables and graphs; statistical trend analyses were also conducted for specific analytes and stations. Additional statistical techniques, including principal components analysis (PCA) and correlation analysis, were conducted in 2003 in order to explore relationships between different water chemistry variables and spatial variability in water quality among different stations. Since 2004, a reference-condition approach has been used to compare water quality data from *test* stations (i.e., those downstream of approved oil sand projects) with water quality conditions characteristic of *baseline* areas (i.e., those upstream of approved oil sands projects).

From its inception, most RAMP water quality sampling has occurred in fall, a time of relatively low, open-water river flows (i.e., decreased dilution capacity) that also coincides with RAMP benthic invertebrate and sediment sampling. Water sampling in other seasons, including winter (December to April), spring (May and June), and summer (July and August) was introduced formally to RAMP in 2002, although some seasonal sampling had occurred in previous years. The intent of this seasonal sampling was more complete characterization of *baseline* water quality, and to assess potential water quality variables of concern (i.e., stressors) in these seasons, particularly in winter when river flows are lowest (see Section 3.5.7.6). RAMP attempts to collect three years of seasonal (i.e., winter, spring, summer, fall) *baseline* data from newly established sampling stations before any oil sands development occurs upstream of that station. Assessment of seasonal differences in water quality data collected by RAMP was included in the RAMP 2005 Technical Report (RAMP 2006), as discussed in Section 3.5.7.6 of this document.

From 2002 to 2005, water quality was measured at one station in the Athabasca River mainstem (ATR-DD) twice in winter, in January and March; however, given January and March data from 2002 to 2005 were similar, winter sampling on the Athabasca mainstem from 2006 onwards has been conducted only in March (along with winter sampling for other waterbodies). Winter sampling of water quality has proven problematic in many tributaries, given many smaller tributaries freeze to depth in winter.

3.5.2 Key Indicator Resources

In RAMP, water quality variables do not themselves constitute KIRs from an environmental assessment perspective. However, as stressors and/or supporting variables for other RAMP components, water quality variables do provide important measurement endpoints indicating the suitability of waterbodies and watercourses to support aquatic life and potential change within or outside the range of natural variability. Water quality measurement endpoints and criteria are discussed in Section 3.5.4.

Table 3.5 Summary of RAMP data available for the Water Quality component, 1997 to 2008.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																	
Upstream of Fort McMurray (grab) [a]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	11	13	11	13
Upstream Donald Creek (cross channel)	ATR-DC-CC		1	1	1																				1				3				1	1	1	1	1	1			1				1				
(west bank) [b]	ATR-DC-W								1								1				3				1				1				1	1	1	1	1				1				1	1			1
(east bank) [b]	ATR-DC-E								1								1				3				1				1				1	1	1	1	1				1				1	1			1
(middle)	ATR-DC-M																1																																
Upstream of the Steepbank River (middle)	ATR-SR-M																1																																
(west bank)	ATR-SR-W																1				1				1				1				1				1				1				1				1
(east bank)	ATR-SR-E																1				1				1				1				1				1				1				1				1
Upstream of the Muskeg River (middle)	ATR-MR-M																1																																
(west bank) [b c]	ATR-MR-W								1								1				1				1				1				1				1				1				1				1
(east bank) [b c]	ATR-MR-E								1								1				1				1				1				1				1				1				1				1
Upstream Fort Creek (cross channel)	ATR-1		1	1	1																																												
(west bank) [b c]	ATR-FC-W								1								1				3				1				1								1												
(east bank) [b c]	ATR-FC-E								1								1				3				1				1								1												
(middle)	ATR-FC-M																1																																
Downstream of all development (cross channel)	ATR-DD																					1,1	1	1	3	1,1	1	1	3	1,1	1	1	3	1,1	1	1	1												
(east bank)	ATR-DD-E																																					1	1	1	1	1	1	1	1	1	1	1	1
(west bank)	ATR-DD-W																																					1	1	1	1	1	1	1	1	1	1	1	1
Upstream of mouth of Firebag River	ATR-FR																								1				1				1				1				1				1				1
Upstream of the Embarras River (cross channel)	ATR-ER																1				3																												
Embarras River	EMR-1																												1																				
At Old Fort (grab) [d]	ATR-OF													11	11	11	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Athabasca River Delta																																																	
Big Point Channel [e]	ARD-1											1					1				1								1				1																
Athabasca River tributaries (Eastern)																																																	
McLean Creek (mouth)	MCC-1											6	7		6	6	9		6	6	9	1	6	6	7		6	6	7		6	6	9		6	6	9		6	6	9				9				1
(100 m upstream)	MCC-2											6	6																																				
Steepbank River (mouth)	STR-1		1	1	1		1	1	1	1							1				1	1			1				1				1				1				1				1	1			1
(upstream of Project Millennium)	STR-2																					1			1				1				1				1				1				1				1
(upstream of Nt. Steepbank)	STR-3																													1	1	1	1	1	1	1	1		1	1	1		1	1	1				1
North Steepbank River (upstream of P.C. Lewis)	NSR-1																					1	1	1	1	1	1	1	1	1	1	1	1		1	1	1				1				1				1
Fort Creek (mouth)	FOC-1														7	7	9		6	6	7	1	6	6	7		6	6	7										6	6	7				7		6	6	7
Muskeg River																																																	
Mouth [f]	MUR-1		1	1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1				1				1				1				1				1				1
Upstream of Canterra Road Crossing [f]	MUR-2									2	9	9	9	10	10	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
AENV sampling [g]						13	13	13	11	13	13	13	11	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	15
Downstream of Alsands Drain	MUR-3																																																
Upstream of Jackpine Creek [f g h]	MUR-4					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10
Upstream of Muskeg Creek [f g]	MUR-5					13	13	13	11	13,2	13,9	13,9	11,9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Upstream of Wapasu Creek	MUR-6					2			2	2	9	9	9		6	6	9		6	6	9		6	6	9		6	6	7		6	6	9		6	6	9		6	6	7				7		6	6	7

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard w.q. + chronic toxicity testing (*Selenastrum capricornutum, Ceriodaphnia dubia,* Pimephales promelusfathead minnow)
3 = standard watr quality + PAHs
4 = standard water quality + chronic tox testing + PAHs
5 = standard water quality for OPTI lakes (routine paramters and arsenic)
6 = thermograph
7 = thermograph + standard water quality
8 = thermograph + standard water quality + PAHs
9 = thermograph + standard water quality + chronic tox. testing
10 = thermograph + standard water quality + chronic tox testing + PAHs
11 = AENV routine parameters (conventional parameters, major ions, nutrients and total metals)
12 = AENV routine parameters + RAMP standard parameters
13 = AENV routine parameters + PAHs
14 = AENV routine parameters + DataSonde
15 = AENV routine parameters + PAHs + DataSonde
16 = standard water quality + chlorophyll-a

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional parameters; quarterly sampling for total and dissolved metals
[e] In 1999, one composite samples was prepared with water from Big Point, Goose Island, Embarras and an unnamed side channel
[f] All testing, with the exception of thermographs, is conducted by individual industry
[g] AENV collects/collected nine samples throughout the year, although only three are/were analyzed for PAHs
[h] In 1999, MUR-4 was located upstream of Shelley Creek

Test (downstream of focal projects)
Baseline (upstream of focal projects)
Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

√ = allowance made for potential TIE

Table 3.5 (Cont'd.)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Muskeg River Tributaries																																																	
Alsands Drain (mouth) [f g h]	ALD-1					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10																
Jackpine Creek (mouth) [g]	JAC-1					13	13	13	11	13	13	13	11,1				1				1				1				1				1				1				1				1				1
(upper)	JAC-2																																																1
Shelley Creek (mouth)	SHC-1								11				11,1																												1				1				
Muskeg Creek (mouth)	MUC-1								11,2				11,1				1				1				1				1				1		1	1	1				1				1	1	1	1	1
Stanley Creek (mouth)	STC-1								11				11,1								1	1	1	1	1	1	1	1	1				1		1	1	1				1				1				1
Iyinimin Creek (mouth)	IYC-1																																											1	1				1
Wapasu Creek (Canterra Road Crossing)	WAC-1					2			11	2			11,1																				1				1				1				1				1
Athabasca River tributaries (Western)																																																	
Poplar Creek (mouth)	POC-1																1				1	1			1				1				1				1				1				1				1
Beaver River (mouth)	BER-1																																1			1	1				1				1				1
(upper)	BER-2																																													1	1	1	1
MacKay River (mouth)	MAR-1								1								1				1	1			1				1				1				1				1				1	1	1	1	1
(upstream of P.C. MacKay)	MAR-2																					1			1	1	1	1	1				1				1				1				1	1	1	1	1
Ells River (mouth)	ELR-1						1	1	1						11	11	11	11				1	1	1	2	1	1	1	2	1	1	1	2	1	1	1	2				1				1				1
(upstream of CNRL Lease 7)	ELR-2														11	11	11	14												1	1	1	2		1	1	2		1	1	1		1	1	1				1
Tar River (mouth)	TAR-1						1	1	1													1	1	1	2	1	1	1	2	1	1	1	1		1	1	1				1				1				1
(upstream of CNRL Horizon)	TAR-2																													1	1	1	1		1	1	1		1	1	2		1	1	2				1
Calumet River (mouth)	CAR-1																					1	1	1	2	1	1	1	2	1	1	1	2		1	1	2				1				1				1
Calumet River (upstrream of CNRL Horizon)	CAR-2																																		1	1	2		1	1	2	1	1	1	2				1
Firebag River (mouth)	FIR-1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
(upstream of Suncor Firebag)	FIR-2																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
Athabasca River tributaries (Southern)																																																	
Clearwater River (upstream of Fort McMurray)	CLR-1																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7	1	7	7	7		7	7	7				1
(upstream of Christina River)	CLR-2																	3	8	8	8	1	7	7	8	1	7	7	8		6	6	7	1	7	7	7		6	6	7		7		7				1
Christina River (upstream of Fort McMurray)	CHR-1																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1
(upstream of Janvier)	CHR-2																					1	1	1	3	1	1	1	3	1	1	1	1	1	1	1	1				1	1			1				1
(mid)	CHR-2A																																									1			1				
Hangingstone River (upstream of Ft. McMurray)	HAR-1																														1	1	1		1	1	1		1	1	1		1	1	1				1
Wetlands (Lakes)																																																	
Kearl Lake (composite)	KEL-1							1									1			1	1				1	1			1			1	1			1	1				16			16	16				16
Isadore's Lake (composite)	ISL-1							1									1			1	1												1			1	1			16	16			16	16			16	16
Shipyard Lake (composite)	SHL-1							1			1	1	1			1	1			1	1			1	1			1	1			1	1			1	1			16	16			16	16			16	16
McClelland Lake (composite)	MCL-1																1			1	1				1																16				16				16
Additional Sampling (Non-Core Programs)																																																	
Unnammed Creek north of Ft. Creek (mouth)	UNC-1															1	1																																
OPTI Lakes	-																		5		5		5		5							5	5		5		5		5		5								
Potential TIE	-																								√				√				√																
QA/QC																																																	
Field and trip blanks, plus one split sample	-														1	1	1			1	1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Legend

1 = standard water quality parameters (conventionals, major ions, nutrients, total & dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard w.q. + chronic toxicity testing (*Selenastrum capricornutum, Ceriodaphnia dubia,* Pimephales promelusfathead minnow)
3 = standard watr quality + PAHs
4 = standard water quality + chronic tox testing + PAHs
5 = standard water quality for OPTI lakes (routine paramters and arsenic)
6 = thermograph
7 = thermograph + standard water quality
8 = thermograph + standard water quality + PAHs
9 = thermograph + standard water quality + chronic tox. testing
10 = thermograph + standard water quality + chronic tox testing + PAHs
11 = AENV routine parameters (conventional parameters, major ions, nutrients and total metals)
12 = AENV routine parameters + RAMP standard parameters
13 = AENV routine parameters + PAHs
14 = AENV routine parameters + DataSonde
15 = AENV routine parameters + PAHs + DataSonde
16 = standard water quality + chlorophyll-a

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional parameters; quarterly sampling for total and dissolved metals
[e] In 1999, one composite samples was prepared with water from Big Point, Goose Island, Embarras and an unnamed side channel
[f] All testing, with the exception of thermographs, is conducted by individual industry
[g] AENV collects/collected nine samples throughout the year, although only three are/were analyzed for PAHs
[h] In 1999, MUR-4 was located upstream of Shelley Creek

Test (downstream of focal projects)
Baseline (upstream of focal projects)
Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

√ = allowance made for potential TIE

Figure 3.5 Sampling locations for the RAMP Water Quality component, 1997 to 2008.

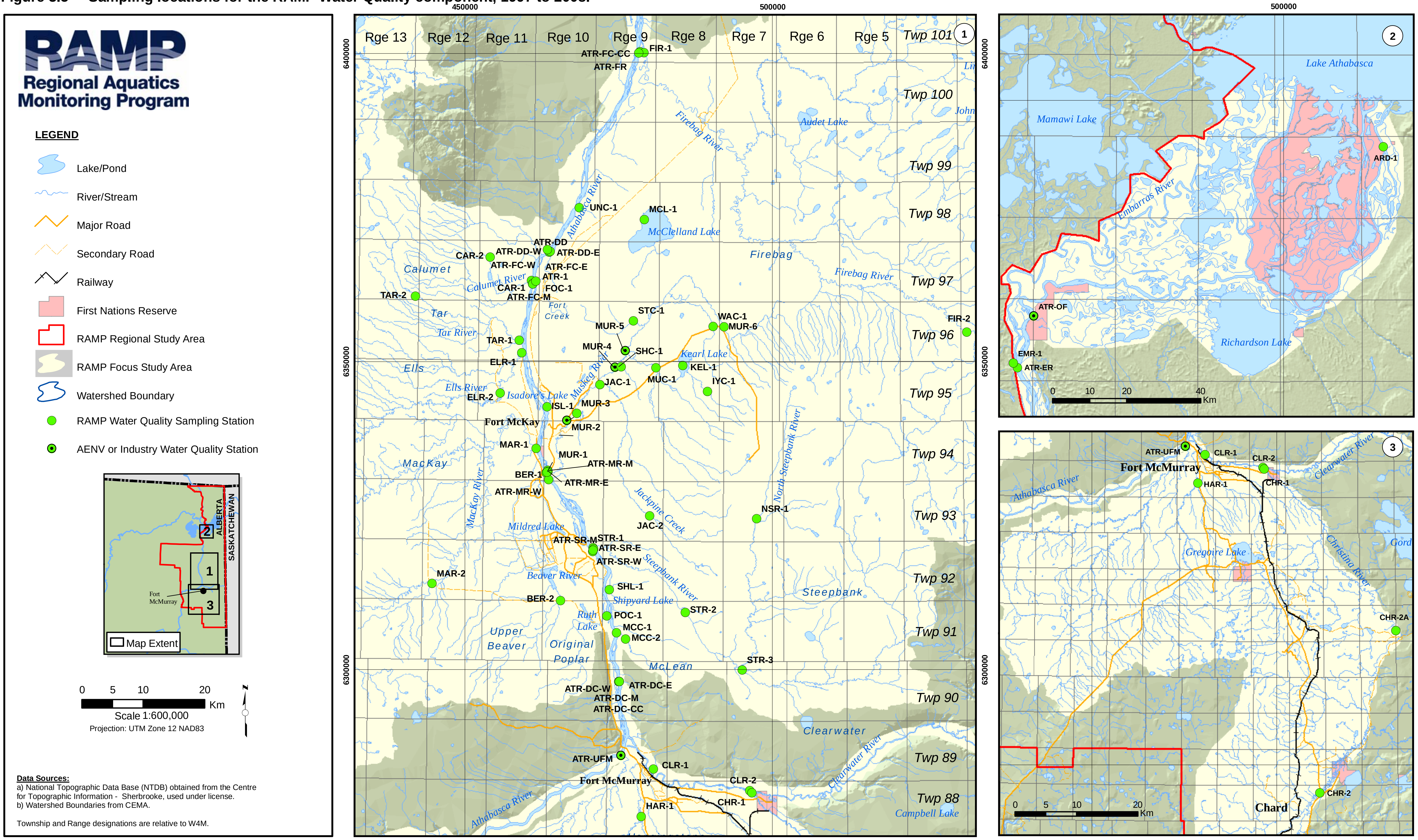


Table 3.6 Water quality variables measured by RAMP, including variables added or removed from the program since 1997.

Group	Water quality variable		
Conventional variables	Colour	Total dissolved solids (TDS)	
	Dissolved organic carbon (DOC)	Total hardness	
	pH	Total organic carbon	
	Specific conductance	Total suspended solids	
	Total alkalinity		
Major ions	Bicarbonate	Potassium	
	Calcium	Sodium	
	Carbonate	Sulphate	
	Chloride	Sulphide	
	Magnesium		
Nutrients	Nitrate + nitrite	Phosphorus – total	
	Ammonia nitrogen	Phosphorus – dissolved	
	Total Kjeldahl nitrogen	Chlorophyll *a*	
Biological oxygen demand	Biological oxygen demand		
Organics	Naphthenic acids	Total recoverable hydrocarbons	
	Total phenolics		
Total and dissolved metals	Aluminum (Al)	Chromium (Cr)	Selenium (Se)
	Antimony (Sb)	Cobalt (Co)	Silver (Ag)
	Arsenic (As)	Copper (Cu)	Strontium (Sr)
	Barium (Ba)	Iron (Fe)	Thallium (Tl)
	Beryllium (Be)	Lead (Pb)	Thorium (Th)
	Bismuth (Bi)	Lithium (Li)	Tin (Sn)
	Boron (B)	Manganese (Mn)	Titanium (Ti)
	Cadmium (Cd)	Mercury (Hg)[1]	Uranium (U)
	Calcium (Ca)	Molybdenum (Mo)	Vanadium (V)
	Chlorine (Cl)	Nickel (Ni)	Zinc (Zn)
Acute toxicity	Microtox® (1997-2000 only)		
Sublethal toxicity	Algal growth inhibition, using *Pseudokirchneriella subcapitata*		
	Invertebrate survival and reproduction, using *Ceriodaphnia dubia*		
	Fish early life-stage survival and growth, using *Pimephales promelas*		
Target PAHs	Acenaphthene	Dibenzo(a,h)anthracene	
	Acenaphthylene	Dibenzothiophene	
	Anthracene	Fluoranthene	
	Benzo(a)anthracene/chrysene	Fluorene	
	Benzo(b&k)fluoranthene	Indeno(c,d-123)pyrene	
	Benzo(a)pyrene	Naphthalene	
	Benzo(g,h,i)perylene	Phenanthrene	
	Biphenyl	Pyrene	

[1] Since 2002, total mercury (Hg) has been measured to ultra-trace levels (i.e., method detection limit of 0.000012 mg/L, or 1.2 ng/L).

Table 3.6 (Cont'd.)

Group	Water quality variable
Alkylated PAHs	C1-substituted acenaphthene
	C1-substituted benzo(a)anthracene/chrysene
	C2-substituted benzo(a)anthracene/chrysene
	C1-substituted biphenyl
	C2-substituted biphenyl
	C1-substituted benzo(b or k)fluoranthene/methyl benzo(a)pyrene
	C2-substituted benzo(b or k)fluoranthene/benzo(a)pyrene
	C1-substituted dibenzothiophene
	C2-substituted dibenzothiophene
	C3-substituted dibenzothiophene
	C4-substituted dibenzothiophene
	C1-substituted fluoranthene/pyrene
	C1-substituted fluorene
	C2-substituted fluorene
	C1-substituted naphthalenes
	C2-substituted naphthalenes
	C3-substituted naphthalenes
	C4-substituted naphthalenes
	C1-substituted phenanthrene/anthracene
	C2-substituted phenanthrene/anthracene
	C3-substituted phenanthrene/anthracene
	C4-substituted phenanthrene/anthracene
	1-methyl-7-isopropyl-phenanthrene (retene)

3.5.3 Hypotheses and Questions

3.5.3.1 Impact predictions from Athabasca Oil Sands EIAs

Specific EIA predictions associated with water quality, summarized from 17 different EIAs of oil sands developments in the RAMP study area, were summarized in Chapter 2. Almost all (175 of a total of 186) residual impact assessments in these EIAs pertaining to water quality predicted negligible or low impact; in addition, most effects were predicted to be local, not regional, in nature.

Specific EIA predictions vary by project, and typically differ significantly between mines and *in situ* projects, with *in situ* project EIAs generally predicting fewer potential effects. However, EIA predictions for water quality generally arise from a relatively small number of development and reclamation activities (Table 3.7).

Table 3.7 Athabasca oil sands activities with potential effects on water quality.

Main Impact Pathways (from Section 2.2, Page 2-1)	Oil Sands Activities (summarized from Table 2.2, Page 2-6 and Table 2.3, Page 2-10)
▪ Changes in hydrological conditions ▪ Introduction of pollutants into waterbodies and watercourses as part of purposeful water releases into watercourses and waterbodies ▪ Introduction of pollutants into waterbodies and watercourses as an indirect consequence of project activities	▪ Surface disturbances (land clearing, road cut and fill, stream crossings, instream construction, bank excavation, pad construction, camps, central plant facility), drilling of wells, ancillary facilities (disposal pits), physical alteration of stream channels ▪ Well servicing ▪ Operation and maintenance of central plant facility and retention pond ▪ Dismantling of facilities, removal of roads and contaminated soil, reclamation of sites ▪ Introduction of chemical species into groundwater from project facilities ▪ Potential leak from lime sludge lagoon

3.5.3.2 RAMP Objectives, Key Questions and Hypotheses

RAMP monitors water chemistry 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 that help identify potential chemical exposure pathways between the physical environment and biotic communities relying on water quality.

Specific objectives of the water quality component include:

- Monitoring potential changes in water quality that may identify chemical inputs from point and non-point sources, with "change" defined as a change in a water quality measurement endpoint outside the range of natural variability;
- Development of a water quality database to characterize natural or baseline variability, assess EIA predictions, and meet requirements of regulatory approvals;
- Assessment of the suitability of waterbodies to support aquatic life; and
- Provision of supporting data to facilitate the interpretation of RAMP biological surveys (i.e., fish and benthos components).

The first two of these objectives derive from the overall objectives of RAMP, while the latter two refer to assessment of water quality against accepted environmental quality guidelines and overall integration of RAMP components. These four objectives lead to the following questions for the RAMP water quality component:

- What changes in water quality are predicted in oil sands EIAs?
- What are the baseline conditions and range of natural variability of water quality in the RAMP study area?

- Is water quality at monitored locations outside the range of natural or baseline variability?
- Is water quality in the RAMP study area suitable to support aquatic life?
- What water quality data are required by other RAMP components to assist in interpretation?

From these questions, the following null hypotheses were formulated for the water quality component:

- H_{o1}: Water quality at each sampled location sampled is within the range of natural or baseline variability;
- H_{o2}: Water quality at sampled locations does not change over time;
- H_{o3}: Water quality at upstream and downstream sampling locations are similar;
- H_{o4}: Water quality characteristics at each sampling location do not exceed relevant environmental quality guidelines; and
- H_{o5}: Process water quality is the same as natural water quality.

The first hypothesis is tested through comparison of measured water quality values against a defined range of natural or baseline variability derived from a regional analysis of *baseline* data, as described in detail in Section 3.5.7.1. The second and third hypotheses are difficult to test statistically due to the nature of water quality data (see Section 3.4.6); rather, these hypotheses are assessed graphically and qualitatively. The fourth hypothesis is tested through comparison of all observed water quality data against relevant guidelines (e.g., AENV Surface Water Quality Guidelines for the Protection of Freshwater Aquatic Life, AENV 1999b). The fifth hypothesis is not yet tested on an ongoing basis within RAMP, but would be assessed by comparing concentrations of relevant analytes in process water with concentrations in natural water, the variability of these concentrations, and screening of process water characteristics against relevant guidelines.

3.5.4 Measurement Endpoints and Criteria for Determining Change

RAMP collects data for nearly 100 water quality variables in a standard sampling event. Although the water quality variables measured by RAMP generally are relevant and appropriate to the objectives of RAMP, they are too numerous for all to be presented in each report (although all variables are assessed, and all data for all variables measured are included in the RAMP database). Therefore, select water quality measurement endpoints are analyzed and presented in each RAMP report. The selection of the measurement endpoints is guided by information obtained from the following sources (Table 3.8):

- Water quality measurement endpoints used in the EIAs of oil sands projects;
- A draft list of water quality variables of concern in the lower Athabasca region developed by CEMA (2004);
- Water quality variables of interest listed in the RAMP 5-year report (Golder 2003a);
- Results of correlation analysis of the RAMP 1997-2004 water quality dataset (RAMP 2005a), which indicate significant inter-correlation of various water quality variables (particularly metals);
- Discussions among RAMP Component Managers about the importance of various water quality variables to interpretation of other RAMP components, particularly fish and benthic invertebrate communities; and
- Discussions with RAMP Technical Committee members regarding analytical strategies for this component.

In the most recent RAMP Technical Report (RAMP 2008), the following endpoints were assessed, for the reasons indicated:

- *pH:* an indicator of acidity;
- *Conductivity:* basic indicator of overall ion concentrations;
- *Total suspended solids:* a variable strongly associated with several other measured water quality variables, including total phosphorous, total aluminum and numerous other metals;
- *Dissolved phosphorous, total nitrogen and nitrate-nitrite:* indicators of nutrient status. Dissolved phosphorus rather than total phosphorus is included because it is the primary biologically available species of phosphorus, and because total phosphorus levels are strongly associated with total suspended solids;
- *Various ions (sodium, chloride, calcium, magnesium, sulphate):* indicators of ion balance, which could be affected by discharges or seepages from focal projects, or by changes in the water table and relative influence of groundwater;
- *Total alkalinity:* an indicator of the buffering capacity and acid-sensitivity of waters;
- *Total dissolved solids (TDS) and dissolved organic carbon (DOC):* indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively;
- *Total and dissolved aluminum:* aluminum is mentioned as a variable of interest in some oil sands EIAs, by CEMA, and in the RAMP 5-year report. Total aluminum, for which water quality guidelines exist, has been demonstrated to be strongly associated with suspended solids

(Golder 2003a). Dissolved aluminum more accurately represents biologically available forms of aluminum that may cause toxicity to aquatic organisms (Butcher 2001);

- *Total boron, total molybdenum, total strontium:* three metals found in predominantly dissolved form in the oil sands area, which may be indicators of groundwater influence in surface waters;
- *Total arsenic and total mercury (ultra-trace*): metals of potential importance to the health of aquatic life and to human health, which may originate from natural or anthropogenic sources; and
- *Naphthenic acids:* relatively labile hydrocarbons (carboxylic acids) associated with oil-sands deposits and processing that have been identified as a potential toxicity concern, and are found in oil-sands process waters.

Water quality data are assessed using the following criteria:

- **Comparison to water quality guidelines.** All water quality data collected by RAMP are screened against Alberta acute and chronic water quality guidelines for the protection of aquatic life (AENV 1999b) and Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) (CCME 2002). All values that exceed these guidelines are reported explicitly in the body of the annual RAMP technical reports. These comparisons are used to address the question stated in Section 3.5.3.2, "Is water quality in the RAMP study area suitable to support aquatic life?"
- **Comparison against historical and baseline data.** Concentrations of water quality measurement endpoints at specific locations are compared against concentrations from previous years, including years before development, to identify and assess any observed changes in water quality over time that may be attributable to oil sands activities or other factors.
- **Comparison to natural variation in baseline conditions.** The concentration of each selected water quality measurement endpoint is assessed against a rigorously defined range of baseline concentrations of that endpoint, to identify and assess any observed changes in water quality that are outside the range of natural variability. Where possible, comparisons are made between upstream (*baseline)* and downstream (*test*) stations. RAMP's approach to definition of baseline water quality conditions is explained in Section 3.5.7.1.
- **Calculation of a Water Quality Index.** Overall water quality at each station sampled by RAMP in fall is summarized in a Water Quality Index, described further in Section 3.5.7.5, which expresses the degree to which specific measurement end-points of water quality are consistent with regional *baseline* water quality characteristics.

3.5.5 Monitoring Station Selection and Monitoring Design

3.5.5.1 Establishing Stations and Monitoring Frequency

RAMP water quality stations are located throughout the RAMP study area, from the upper Christina River to the Athabasca River delta. A large number of water quality stations are monitored in the fall when water flows are generally low, and the resulting assimilative capacity of a receiving waterbody is limited. A smaller number of stations are monitored in winter, spring, and summer, depending on data needs, the extent of oil sands development, and logistical and budgetary constraints.

In Athabasca River tributaries, RAMP generally monitors water quality slightly upstream (approximately 100 m) of the tributary mouth. This location, downstream of any developments within the watershed (i.e., *test* case), provides an integrated assessment of water quality in the tributary watershed. Stations are also typically established upstream of any development within the watershed, to provide *baseline* data against which data from downstream (affected) stations can be compared. In watersheds where multiple oil sands developments occur or are proposed—such as the Steepbank and Muskeg watersheds, for example—additional stations are established and monitored along the stream mainstem and in tributaries where appropriate, to assess potential incremental changes in water quality. Water quality is also monitored at several locations along the Athabasca River mainstem and in regionally important lakes. New water quality stations are established in response to data needs and changes in oil sands developments.

The frequency of water quality sampling at each station depends on the amount of data already collected from that station, the degree of development upstream of the station, monitoring requirements found in operator approvals, and other considerations specific to each site. RAMP attempts to collect three years of seasonal (i.e., winter, spring, summer, fall) *baseline* data before any oil sands development occurs upstream of that station. *Test* stations in tributary watersheds located downstream of oil sands development, and *baseline* stations (i.e., stations located upstream of approved oil sands development) within these watersheds, are monitored each fall. Stations in watersheds unaffected by oil sands development with at least three years of seasonal data are sampled on a rotating basis, so that each of these stations is sampled at least once every three years. Athabasca River mainstem stations are sampled each fall, with the exception of ATR-DD (downstream of all development), which is sampled in each season.

Table 3.8 Water quality variables of interest to RAMP, from oil sands EIA predictions, CEMA assessments and other sources.

Analyte Group	Variables Assessed as Having Greater than Negligible Potential for EIAs (n=17 projects)[1]	CEMA Variables of Concern (WRS 2003)[2]	RAMP 5-Year Report (Golder 2003a)	Variables Required by Other Components for Impact Assessment[3]
Physical Variables	Temperature (3) Total suspended solids (9) Dissolved oxygen (3) Conductivity (1) pH (1) Dissolved Organic Carbon (1)	(None)	pH Total suspended solids	Temperature Dissolved oxygen pH Total suspended solids Conductivity
Nutrients	Ammonia-N (1) Total nitrogen (3) Total phosphorous (3) Sulphide (1) Biological Oxygen Demand (1)	Ammonia-N Total nitrogen Total phosphorous	Dissolved organic carbon Total Kjeldahl nitrogen Total phosphorous	Dissolved phosphorous Nitrate+nitrite
Ions and Ion Balance	Chloride (2) Sulphide (2) Total dissolved solids (3)	Sodium Chloride Potassium Fluoride Sulphate	Total dissolved solids Sulphate Total alkalinity	Total alkalinity Hardness
Dissolved and Total Metals	Aluminum (5) Antimony (1) Arsenic (3) Barium (4) Beryllium (1) Boron (2) Cadmium (4) Chromium (4) Copper (3) Iron (4) Manganese (4) Mercury (2) Molybdenum (2) Selenium (2) Silver (2) Strontium (1) Vanadium (1) Zinc (1)	Aluminum Antimony Boron Cadmium Chromium Lithium Molybdenum Nickel Strontium Vanadium	Total chromium Total boron Total aluminum	Total & dissolved copper Total & dissolved lead Total & dissolved nickel Total & dissolved zinc Ultra-trace mercury

All variables currently are monitored by RAMP except those in **bold**.

[1] The number in brackets refers to the number of EIAs in which the particular water quality variable was predicted to have a non-negligible effect from the proposed project (Chapter 2).

[2] Includes variables not necessarily related to oil sands operations.

[3] Primarily benthic invertebrate communities and fish populations (inferred).

Table 3.8 (Cont'd.)

Analyte Group	Variables Assessed as Having Greater than Negligible Potential for EIAs (n=17 projects)	CEMA Variables of Concern (WRS 2003)[2]	RAMP 5-Year Report (Golder 2003a)	Variables Required by Other Components For Impact Assessment[3]
Organics/ Hydrocarbons	Oil & grease (1) Napthenic acids (1) Total phenolics (4)	Oil & grease Total hydrocarbons Naphthenic acids Toluene Xylene	(None)	(None)
PAHs	Benzo(a)anthracene (5) Benzo(a)pyrene (3) Misc. PAHs (5)	Napthelene Biphenyl Acenapthene Acenaphtylene Flourene Fluoranthene Alkyl-napthelenes Alkyl-biphenyls Alkyl-acenapthene Alkyl-benzo(a)anthracene Alkyl-flourenes Alkyl-phenanthrenes Dibenzothiophene Alkyl-dibenzothiophenes	(None)	(None)
Effects-based endpoints	Acute toxicity (1) Chronic toxicity (2)	Acute toxicity Chronic toxicity Fish tainting		Fish tainting Fish health

All variables currently are monitored by RAMP except those in **bold**.

[1] The number in brackets refers to the number of EIAs in which the particular water quality variable was predicted to have a non-negligible effect from the proposed project (Chapter 2).

[2] Includes variables not necessarily related to oil sands operations.

[3] Primarily benthic invertebrate communities and fish populations (inferred).

The RAMP 5-Year Report (Golder 2003a) recommended collection of five rather than three years of baseline data, to increase statistical power of before-after comparisons. The reference-condition analytical approach established in the 2004 Technical Report was an attempt to overcome potential issues of replication and statistical power, which are problematic for water quality data, as discussed below in Section 3.5.6.

3.5.5.2 Station Classification and Inclusion of Non-RAMP Data

When possible, RAMP includes appropriate water quality data from other sources in its analyses. Historically, RAMP recognized and included data from four types of water quality sampling stations, namely:

- Core RAMP stations, which were defined as stations sampled by RAMP on an ongoing basis as part of the RAMP sampling design;
- Non-core RAMP stations, which include stations sampled by RAMP on a short-term basis and stations sampled to meet industry commitments;
- Industry sampling locations, which are sampled by industry members for compliance monitoring; and
- AENV long-term sampling locations, monitored routinely by AENV.

In recent years, discrimination between core and non-core RAMP stations has been discontinued, as non-core stations sometimes are better considered to be approval-related industry data which happened to be collected by the implementing consultant for RAMP (e.g., data for the "OPTI Lakes" in 2002), and sometimes have been called non-core but became core stations as oil sands developments have progressed (e.g., monitoring in the Calumet River). Therefore, RAMP currently recognizes and includes water quality data collected by RAMP itself, by industry members, and by AENV. Water quality data stored in the RAMP database only include those collected directly by RAMP.

3.5.5.3 Rationale for Specific Monitoring Locations

Specific reasons for the establishment of each RAMP water quality monitoring station are listed in Table 3.9 to Table 3.13. This information builds upon previously stated reasons for each station from earlier RAMP Design and Rationale documents (Golder 2000, 2002; RAMP 2005b), as well as incorporating more recent information.

Athabasca River Mainstem and Delta

Stations have been established along the Athabasca River mainstem using a combined control/impact (upstream/downstream) and gradient design (Table 3.9). These stations have been established to assess potential changes in water quality arising from tributary inflows. The two long-term AENV stations along the mainstem, ATR-UFM (upstream of Fort McMurray) and ATR-OF (at Old Fort, in the Athabasca delta), provide long-term, seasonal data to examine longitudinal changes in river water quality through the RAMP study area.

At most stations on the Athabasca mainstem, samples are collected at the east and west banks of the river, given previous studies have shown that cross-channel mixing in the Athabasca River in this reach occurs slowly. A cross-channel composite sample is collected at ATR-FR (upstream of the Firebag River); cross-channel composites have also been collected at ATR-DC (upstream of Donald Creek) and ATR-DD (downstream of development) in recent years, although sampling in 2008 at these locations was changed to west and east bank samples, consistent with other, upstream locations on the Athabasca River mainstem.

All stations are sampled annually in fall. ATR-DD is sampled seasonally (i.e., winter, spring, summer, fall) at the west and east bank, to provide seasonal data from this reach of the river, which can be compared with data collected further upstream and downstream by AENV.

Table 3.9 Rationale for RAMP water quality sampling locations in the Athabasca River and delta, 1997 to 2008.

Station Identifier and Location		Sampler	Rationale
Athabasca River mainstem			
ATR-UFM	*Upstream of Fort McMurray*	*AENV (monthly)*	*Alberta Environment long-term monitoring station; provides a long-term baseline description of Athabasca River water quality upstream of Fort McMurray and oil sands developments.*
ATR-DC *(-E,-W)*	Upstream of Donald Creek (east and west bank)	RAMP	An “upstream” sampling location unaffected by oil sands development further downstream, but downstream of the Town of Fort McMurray and the Clearwater River.
ATR-SR *(-E,-W)*	Upstream of the Steepbank River (east and west bank)	RAMP	Located to assess potential effects of operational and reclamation water releases from Suncor Steepbank, Project Millennium and the lower portion of Suncor Lease 86/17, including the Tar Island Dyke (TID).
ATR-MR *(-E,-W)*	Upstream of the Muskeg River (east and west bank)	RAMP	Located downstream of the Steepbank River and upstream of the Muskeg River.
ATR-FC *(-E,-W)*	Upstream of Fort Creek	RAMP	Established to assess potential cumulative effects of upstream developments on Athabasca River water quality, including projects along the river and in the Steepbank, Muskeg, MacKay, Ells, Tar, and other upstream tributary watersheds. Sampling was discontinued here after 2003, given its location upstream of potential influences of the Fort Hills and Canadian Natural-Horizon projects and the proximity of station ATR-DD.
ATR-DD *(-CC,-E,-W)*	Downstream of all development (east and west bank)	RAMP	Located downstream of all direct operational and reclamation water releases of oil sands developments, and intended to be an indicator of cumulative effects, this station is now adjacent to Fort Hills and upstream of proposed projects in the Firebag watershed. Sampled as a cross-channel composite until 2008.
ATR-FR (-CC)	Upstream of the Firebag River (cross-channel composite)	RAMP	Located upstream of the Firebag River. Like ATR-DD, provides data describing cumulative effects of upstream development as well as supplementing the gradient of stations from ATR-UFM to ATR-OF.

Table 3.9 Cont'd.

Station Identifier and Location		Sampler	Rationale
Athabasca River mainstem Cont'd.			
ATR-ER	Upstream of the Embarras River (cross-channel composite)	RAMP	Sampled in 2000 and 2001 as an indicator of downstream water quality. Eliminated due to its proximity to ATR-OF.
ATR-OF	*Old Fort*	*AENV (monthly)*	*Alberta Environment long-term monitoring station; sampled monthly.*
Athabasca River delta			
EMR-1	Embarras River[1]	RAMP	Sampled once in 2003, to assess differences between Embarras River and Athabasca River water quality.
ARD-1	Big Point Channel	RAMP	Sampled irregularly, given monthly water quality data are collected nearby by AENV at upstream station ATR-OF.

[1] Note that the Embarras River is not a tributary to the Athabasca River, but rather is a distributary deltaic channel of mainstem Athabasca River flowing through the Athabasca River delta.

Muskeg River Watershed

The Muskeg River watershed has been a major focus of oil sands development to date, with several operational or planned oil sands developments within its watershed boundaries, including the Shell-Albian Muskeg River Mine, Syncrude Aurora North, Shell-Albian Jackpine Mine, Suncor/UTS Fort Hills, Husky Sunrise, Shell-Albian Leases 88, 89, and 90, Imperial Kearl Project, Syncrude Aurora South, and Suncor Firebag.

Like the Athabasca River mainstem, stations along the Muskeg River have been established using a combined upstream/downstream (control/impact) and gradient design, to assess potential changes in water quality (Table 3.10). RAMP monitors two mainstem stations annually (MUR-1 and MUR-6), and receives data from regular industry and AENV sampling that occurs in the middle reaches of this watershed. All major tributaries to the Muskeg River have been sampled by RAMP near their mouths; no upstream stations on tributaries are proposed, given the small size of these streams. Kearl Lake, located within the Muskeg River watershed, also is monitored by RAMP, and is discussed in the *Regional Lakes and Wetlands* sub-section later in this chapter.

Alberta Environment has recently embarked on an Interim Management Framework for the Muskeg River watershed, which also includes an integrated water-quality monitoring program. The aim of this framework is to reduce the short-, medium-, and long-term impacts of resource development in the Muskeg River watershed to acceptable levels of change (AENV 2008) by focusing on the development of limits to protect and manage the water quality and quantity of the Muskeg River watershed. Water quality targets and limits developed under this initiative will be considered by RAMP in the analysis of data from the Muskeg River watershed.

All samples are collected as grab samples. All samples typically are collected in fall, except at newly-established stations which may be sampled seasonally. Winter sampling has been problematic at stations in the Muskeg River watershed (i.e., Stanley Creek, Muskeg Creek), as these stations have been frozen to depth during all winter sampling attempts.

Table 3.10 Rationale for RAMP water quality sampling locations in the Muskeg River watershed, 1997 to 2008.

Station Identifier and Location		Sampler	Rationale
Muskeg River mainstem			
MUR-1	Muskeg River (mouth)	RAMP	Provides data describing cumulative effects of upstream development in the watershed.
MUR-2	*Downstream of Canterra Rd. crossing*	*Albian, Syncrude, AENV*	*Downstream of the Muskeg River mine and other upstream developments. Routinely monitored seasonally by Albian Sands and Syncrude for Approval purposes, and by AENV (quarterly water quality + DataSonde).*
MUR-4	*Upstream of Jackpine Creek*	*Albian*	*Located downstream of Aurora North and other upstream developments, but upstream of Muskeg River Mine.*
MUR-5	*Upstream of Muskeg Creek*	*Syncrude*	*Located upstream of Aurora North, but downstream of Stanley Creek (which has received water releases from Aurora North) and downstream of potential water releases from the Kearl project.*
MUR-6	Upstream of Wapasu Creek	RAMP	Historically a *baseline* station, although this station is now downstream or within Sunrise and Kearl project leases.
Muskeg River tributaries			
ALD-1	*Alsands Drain*	*Albian, Syncrude*	*Now discontinued. Previously received muskeg drainage water and was monitored by Albian and Syncrude.*
JAC-1	Jackpine Creek (mouth)	RAMP	Selected to monitor potential effects of Shell-Albian Muskeg River and Jackpine mines
JAC-2	Jackpine Creek (upstream)	RAMP	Selected to provide an upstream *baseline* station for JAC-1.
MUC-1	Muskeg Creek (mouth)	RAMP	Selected to monitor potential effects of Shell-Albian Jackpine Mine and Aurora South projects.
STC-1	Stanley Creek (mouth)	RAMP	Selected to monitor potential effects of Aurora North project.
SHC-1	Shelley Creek (mouth)	RAMP	Selected to monitor potential effects of Shell-Albian Jackpine Mine
WAC-1	Wapasu Creek (Canterra Rd. crossing)	RAMP	Selected to monitor potential effects of Aurora South and Kearl projects.
IYC-1	Iyinimin Creek	RAMP	Established in 2007 as a *baseline* station.

Note: *Italics* represent non-RAMP sampling stations.

Other Tributaries to the Athabasca River Downstream of Fort McMurray

In addition to the Muskeg River, RAMP monitors water quality in several tributaries to the Athabasca River downstream of Fort McMurray, as reported in Table 3.11.

Table 3.11 Rationale for RAMP water quality sampling locations in various watersheds downstream of Fort McMurray, 1997 to 2008.

Station Identifier and Location		Sampler	Rationale
McLean Creek			
MCC-1	McLean Creek (mouth)	RAMP	Selected to monitor potential effects of Suncor Project Millennium and contributions of this creek to Athabasca R. water quality.
MCC-2	McLean Creek (100 m upstream)	RAMP	Temperatures monitored over summer once, in 1999, for comparison with MCC-1.
Steepbank River			
STR-1	Steepbank River (mouth)	RAMP	Selected to monitor potential effects of Suncor Steepbank and Project Millennium, potential future projects (PC Lewis and Husky Sunrise), downstream indicator of cumulative effects on water quality in this watershed, and contributions of this river to Athabasca R. water quality.
STR-2	Steepbank River (upstream of Project Millennium)	RAMP	Baseline station upstream of Suncor Project Millennium; downstream of PC Lewis
STR-3	Steepbank River (upstream of North Steepbank River)	RAMP	Baseline station upstream of PC Lewis and influences of North Steepbank River.
NSR-1	North Steepbank River (upstream of PC Lewis)	RAMP	Baseline station upstream of PC Lewis, although now downstream of Husky Sunrise and Suncor Firebag projects.
Poplar Creek and Beaver River (previously contiguous watersheds)			
POC-1	Poplar Creek (mouth)	RAMP	Sampled to assess potential effects of Syncrude Mildred Lake operations and Suncor Voyageur Updgrader development.
BER-1	Beaver River (mouth)	RAMP	Sampled to assess potential effects of Syncrude Mildred Lake site drainage and seepage on this creek.
BER-2	Beaver River (upper)	RAMP	Selected to provide a *baseline* upstream station for BER-1 and POC-1 (Upper Beaver River flowed into the lower Beaver River until 1970s, when it was re-routed to the Poplar Reservoir, discharging to Poplar Creek.
MacKay River			
MAR-1	MacKay River (mouth)	RAMP	Selected to assess potential effects of Suncor MacKay and Syncrude Mildred Lake, and contributions of this river to Athabasca R. water quality.
MAR-2	MacKay River (upstream of PC MacKay)	RAMP	Selected to provide a *baseline* upstream station for MAR-1 (location moved in 2008).
Ells River			
ELR-1	Ells River (mouth)	RAMP	Selected to assess potential effects of Total E&P Joslyn project, and contributions of this river to Athabasca R. water quality.
ELR-2	Ells River (upstream of Canadian Natural Lease 7)	RAMP	Selected to provide a *baseline* upstream station for ELR-1.

Table 3.11 (Cont'd.)

Station Identifier and Location		Sampler	Rationale
Tar River			
TAR-1	Tar River (mouth)	RAMP	Selected to assess potential effects of Canadian Natural Horizon, and contributions of this river to Athabasca R. water quality.
TAR-2	Tar River (upstream of Canadian Natural Horizon)	RAMP	Selected to provide an upstream *baseline* station for TAR-1 (at the upstream corner of the Horizon lease). Moved further upstream in 2006.
Calumet River			
CAR-1	Calumet River (mouth)	RAMP	Selected to assess potential effects of Canadian Natural Horizon, and contributions of this river to Athabasca R. water quality.
CAR-2	Calumet River (upper)	RAMP	Selected to provide an upstream *baseline* station for CAR-1.
Fort Creek			
FOC-1	Fort Creek (mouth)	RAMP	Selected to assess potential effects of Fort Hills projects.
Firebag River			
FIR-1	Firebag River (mouth)	RAMP	Selected to assess potential effects of projects in this watershed, including Suncor Firebag and Husky Sunrise.
FIR-2	Firebag River (upstream of Suncor Firebag)	RAMP	Selected to provide an upstream *baseline* station for FIR-1; located upstream of all proposed projects.

Tributaries to the Athabasca River Upstream of Fort McMurray

South of Fort McMurray, several *in situ* oil sands developments are operational or proposed. These developments are predominantly in the Christina River watershed, which flows into the Clearwater upstream of its confluence with the Athabasca River mainstem at Fort McMurray. RAMP monitors water quality in the Clearwater and Christina rivers, as well as in the Hangingstone River (Table 3.11).

Table 3.12 Rationale for RAMP water quality sampling locations in watersheds upstream of Fort McMurray, 1997 to 2008.

Station Identifier and Location		Sampler	Rationale
Clearwater River			
CLR-1	Clearwater River (u/s of Fort McMurray)	RAMP	Selected to assess potential effects of upstream *in situ* oil sands developments on the Clearwater River, and contributions of this river to Athabasca R. water quality.
CLR-2	Clearwater River (upstream of Christina R.)	RAMP	Selected to provide an upstream *baseline* station for CLR-1, and provides *baseline* data on Clearwater River water quality.
Christina River			
CHR-1	Christina River (mouth)	RAMP	Selected to assess potential effects of upstream *in situ* oil sands developments.
CHR-2	Christina River (upstream of Janvier)	RAMP	Selected to provide an upstream *baseline* station for CHR-1, although downstream of Encana Christina Lake and proposed Whitesands and Jackfish Lake projects, which do not participate in RAMP.
CHR-2A	Christina River (mid-river)	RAMP	Temporary station in 2007 sampled to assess suitability as a Christina River *baseline* station (to replace CHR-2); discontinued in 2008 due to its similarity to CHR-2.
Hangingstone River			
HAR-1	Hangingstone R. (upstream of Fort McMurray)	RAMP	Selected to assess potential effects of upstream projects, including Suncor Meadow Creek. Also downstream of the JACOS Hangingstone project, which does not participate in RAMP.

Regional Lakes and Wetlands

Four regional lakes are monitored by RAMP, as outlined in Table 3.13.

Table 3.13 Rationale for RAMP water quality sampling in various regional lakes and wetlands, 1997 to 2008.

Station Identifier and Location		Sampler	Rationale
KEL-1	Kearl Lake	RAMP	Monitored to assess potential effects of nearby projects on Kearl Lake, including Shell-Albian Jackpine and Husky Sunrise.
ISL-1	Isadore’s Lake	RAMP	Shell-Albian Approval-related monitoring requirement undertaken by RAMP.
SHL-1	Shipyard Lake	RAMP	Suncor Approval-related monitoring requirement undertaken by RAMP.
MCL-1	McClelland Lake	RAMP	Potential Fort Hills Approval-related monitoring requirement undertaken by RAMP.

3.5.5.4 Sampling Protocols

RAMP water quality sampling follows broadly accepted standards and protocols, including comprehensive quality control/quality assurance procedures. RAMP Standard Operating Procedures (SOPs), initially based on Golder Associates Ltd. Technical Procedures, have been followed since the beginning of RAMP. These SOPs were revised and formalized for the RAMP 2005 program (Appendix A4), and have been used in all subsequent programs.

Generally, sampling involves collection of single grab samples of water from tributaries to the Athabasca Riversmaller creeks or rivers, collection of cross-channel composite samples or bank-adjacent grab samples in Athabasca River mainstem, and collection of multi-location composites in lakes/wetlands. For all samples except total hydrocarbons (oil and grease), grab samples are collected by submerging each sample bottle to a depth of approximately 30 cm, uncapping and filling the bottle, and recapping at depth. For total hydrocarbons, grab samples are collected from the water surface to capture any floating hydrocarbons.

Composite samples are collected at stations where average concentrations of monitored variables are desired, including lentic waterbodies (i.e., lakes or wetlands) and selected stations along the Athabasca River. Composites are collected through combining a series of 2-L grabs collected at regularly spaced intervals (Table 3.14) into a triple-rinsed polymer bucket. Samples are removed from the composite bucket with a clean glass vessel and transferred to laboratory-supplied sample bottles. Caution is taken to ensure that composite samples remained covered when not in use and that no contaminants are introduced during the course of sub-sampling.

Table 3.14 RAMP water quality composite sample sub-groups.

Wetted width	Grab Location and Frequency
> 50m	Three 2L grabs at each of five equally spaced locations along a river cross-section
20-50m	Four 2L grabs collected at each of three equally spaced locations along a river cross-section
< 20m	Ten 2L grabs from a single centre-channel position

At all water quality stations, *in situ* measurements of dissolved oxygen (DO), temperature and conductivity are collected using a YSI Model 85 multi-probe water meter and/or a handheld thermometer (temperature), a handheld conductivity meter (conductivity) and a LaMott portable Winkler titration kit (dissolved oxygen). In 2007 and 2008, all DO measurements were made using Winkler titrations, to reduce potential calibration issues associated with electronic meters.

On the Athabasca River mainstem, water samples at mouths of tributaries are collected approximately 100 m upstream of their confluence, where possible, to avoid influences of mainstem water on sampled water quality at each station. Similarly, stations located on river mainstems near influent tributaries are sampled approximately 100 m upstream of the influent tributary confluence.

Sampling methods are modified during winter in response to environmental conditions, and to account for and preclude any sampling error or contamination associated with the requisite use of secondary sample transfer vessels and ice augers. Water is collected through holes in the river/lake ice drilled using a gas-powered auger. For stations designated as single grab, one hole was drilled at the estimated stream thalweg. For stations where cross-channel composites were collected, multiple holes were drilled following guidelines in Table 3.14.

Winter water quality samples are collected from approximately 0.2 m below the bottom of river/lake ice using a 2-L Van Dorn sampler, to minimize the possibility of contaminant introduction associated with augering. Each grab is composited into a triple-rinsed polymer bucket. Composite water is transferred to individual sample bottles using a clean glass vessel, and then preserved.

Station locations are identified using GPS coordinates, Alberta Forestry, Lands and Wildlife Resource Access Maps, and where applicable, written descriptions from past RAMP reports. Stations are accessed by boat, helicopter, snowmobile and/or four-wheel drive vehicle. Detailed descriptions of location and access to all stations, including specific geographic coordinates, are described in a database accessible through the RAMP project website.

For all laboratory analyses, a suitable number of field duplicates, field blanks and trip blanks are collected during each field program to provide quality control and assurance regarding potential effects of field sampling and shipment protocols on sample quality, following a general guideline that 10% of samples should be QA/QC samples.

In addition to measuring water quality, water temperature is occasionally monitored using continuously-recording thermographs during open-water seasons at several locations where concerns have been expressed regarding potential changes in water temperature. These have included McLean Creek (MCC-1), Fort Creek (FOC-1), the upper Muskeg River (MUR-6), and the Clearwater River (CLR-1 and CLR-2). Thermographs are set to record temperatures at least every hour, and are fixed in place at sampling stations using rebar, cable, or other appropriate equipment. Given water levels change significantly from spring to fall in most of these locations, and that bedloads continually shift and migrate downstream in the Clearwater River, difficulties have regularly been encountered in establishing thermographs in ways that will keep them exposed to flowing water and ensure a reliable and continuous data record.

3.5.6 Analytical Approach

In order to address the objectives of RAMP generally and of the RAMP water quality component specifically, RAMP uses a mix of analytical approaches. Specific approaches have changed over time as the volume of data has increased (Table 3.15). In 2008, RAMP collected over 6,200 water quality observations; from 1997 to 2008, almost 73,000 water quality observations had been collected. All of these data have been entered into a relational database and are accessed each year to provide historical context and comparisons.

Discussions of the ability of the RAMP program to detect change often have been framed by considerations of statistical power, a testable statistical concept used to assess the likelihood that the result of a statistical test is not a false negative. However, while power is a valuable concept for environmental studies involving biological endpoints such as benthic invertebrate abundance or fish health, its application to the RAMP water quality program is problematic for the following reasons:

- *Repeated water quality measurements are not true replicates:* Samples collected from the same station over time are not replicates, as these samples are not collected from the same "population" of data (samples collected from the same river also may be auto-correlated due to downstream flow);

- *Water quality data typically are highly variable and not normally distributed:* Even if one accepts year-to-year measurements as true replicates, water quality data typically are highly variable and positively skewed (i.e., many low values with a few very high values), meaning that the number of annual replicates required to provide sufficient power for hypothesis-testing may be very high; and may vary substantially among different variables measured;

- *Sufficient numbers of replicates must exist for both baseline and test observations:* To test with sufficient statistical power, comparisons of data between *baseline* and *test* stations require sufficient replication in both treatments, meaning that possible changes in water quality at *test* stations cannot be statistically assessed until sufficient post-development data exist, slowing the feedback from monitoring results to management decisions based on these results; and

- *Achieving sufficient "depth" may sacrifice "breadth":* Collection of potentially large numbers of replicate (or pseudo-replicate) samples at specific stations to achieve acceptable statistical power may require re-allocation of monitoring efforts from abbreviated sampling at many stations to intensive sampling at a few stations, reducing the geographic coverage of the RAMP water quality program.

Table 3.15 Analytical approaches taken by the RAMP water quality component, 1997 to 2008.

Method	1997	1998	1999	2000	2001	2002	5-yr rpt.	2003	2004	2005	2006	2007	2008
Descriptive													
Tabular	✓	✓	✓	✓	✓	-	-	✓	✓	✓	✓	✓	✓
Graphical	-	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Statistical													
Trend Analysis	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	✓
Correlation	-	-	-	-	-	-	-	✓	-	-	-	-	-
Principal Component Analysis*	-	-	-	-	-	-	-	✓	-	-	-	-	-
Regional Baseline Development	-	-	-	-	-	-	-	-	✓	✓	✓	✓	✓
Water Quality Index	-	-	-	-	-	-	-	-	-	-	-	-	✓

* Principal Components Analysis was conducted from 2004 to 2007 as part of the regional baseline development, in order to determine groups of stations exhibiting similar water quality (see Section 3.5.6.1).

3.5.6.1 Regional Baselines: Alternatives to Power-Based Designs

An alternative to power-based experimental and analytical designs for environmental studies involves the definition of regional baseline characteristics, developed from numerous observations in unaffected areas, against which individual observations may be assessed. Examples of such approaches include the British River Invertebrate Prediction and Classification System (RIVPACS) (Wright *et al*. 1997), the Australian River Assessment System (AUSRIVAS) (http://ausrivas.canberra.edu.au/), and the Reference-Condition Approach (RCA) developed by Environment Canada (Reynoldson *et al*. 1998).

These approaches use large amounts of data collected from numerous unaffected waterbodies to define and predict the structure of invertebrate communities in natural streams, against which individual observations collected from locations potentially affected by development may be compared.

In these models, the likelihood of a new sample being assigned as a false negative or false positive is minimized through rigorous definition of natural baseline conditions. The conceptual foundation of these regional bioassessment techniques—i.e., assessment of individual samples against a rigorously defined natural condition—was adapted in 2004 for analysis of RAMP water quality data; this method of assessing changes in water quality has been included in all subsequent RAMP water quality analyses. Specifically, individual fall water quality observations from the current year are assessed against a range of regional baseline concentrations of that analyte. These regional baseline concentrations are determined by pooling all RAMP fall water quality data from baseline stations. To ensure that water quality observations from each station are compared to regional baseline data from stations exhibiting similar water quality characteristics, groups of RAMP *baseline* stations with similar water quality characteristics are developed objectively using multivariate data reduction and clustering techniques.

This regional baseline comparison approach has the following advantages:

- Individual observations may be assessed against a robustly defined regional baseline, providing greater assurance that any observed values outside this range of baseline values may actually represent change outside the range of natural variability, allowing prompt follow-up or management response;
- Instead of comparing observations against three (pseudo-replicated) years of baseline data, individual observations are compared against many baseline observations collected over several years that encompass a range of natural conditions;
- Water quality at stations lacking a directly comparable *baseline* station (such as those collected from small watersheds that have already experienced development, such as lower Beaver River) may still be assessed against regionally defined baseline conditions; and

- The broad geographic scope of the RAMP program is an advantage in data analysis rather than a limitation.

Potential disadvantages of using this regional baseline approach include:

- Potential pooling of water quality data from stations with divergent water quality characteristics; and
- Potential pooling of data from watersheds exhibiting narrow natural variability with watersheds exhibiting wide natural variability.

Both of these potential disadvantages relate to the risk of overstating the range of natural variability against which annual data are assessed. The risk that stations with divergent water quality will be pooled is addressed through grouping of data using Objective Classification Analysis (OCA). This method involves multivariate data reduction of the RAMP total metals, dissolved metals and major ions dataset using Principal Component Analysis (PCA), followed by application of hierarchical and k-means clustering algorithms to define meaningful, internally consistent groups of stations from the RAMP fall dataset that exhibit consistently similar water quality characteristics. Similar approaches to consolidation and analysis of large water quality datasets are presented and discussed by Jones and Boyer (2002) and Güler *et al.* (2004). Clustering of water quality stations using this approach from 2004 to 2007 has shown good fidelity of station water quality data to specific clusters (see Section 3.5.6.2).

The latter concern with this approach—that watersheds exhibiting low natural variability in water quality would be pooled with those that exhibit high natural variability—is addressed by presenting results for all measurement endpoints for all stations monitored, as well as graphical comparisons of results to water quality group ranges, so that station-specific conditions and changes in these variables over time are included in each year's assessment.

3.5.6.2 Development and Assessment of Regional Baseline Data for Water Quality

Objective classification analysis of RAMP water quality data is conducted each year on the updated dataset (i.e., including the most recently collected baseline data). Results of OCA have been generally consistent since 2004, indicating three major groups of stations with similar water quality types. These groups generally include:

- Stations located on the Athabasca River mainstem and delta;
- Stations located in tributary watersheds to the northwest of Fort McMurray (e.g., the Ells River); and
- Stations in tributary watersheds to the northeast and south of Fort McMurray, including the Muskeg, Steepbank, Firebag, and Clearwater-Christina systems.

A few station-year data points have clustered differently from other station-year data points within the watershed on occasion; regional lakes have also clustered with different groups in different years of analysis. However, for many stations included in the cluster analysis, samples from different years have clustered closely together, indicating that water quality at these stations was generally consistent at specific locations across years of sampling (i.e., spatial variation was more important than temporal variation in defining cluster membership).

These groupings are generally consistent with results of similar cluster-based analyses of water quality in the oil sands area by AOSERP (Corkum 1985), and generally consistent with patterns of underlying and surficial geology (Corkum 1985).

For each of these clusters, data from *baseline* stations (i.e., those located in watersheds where oil sands development has not yet occurred, or stations located upstream of oil sands development) are pooled to develop descriptions of regional baseline water quality, against which data from RAMP stations are assessed.

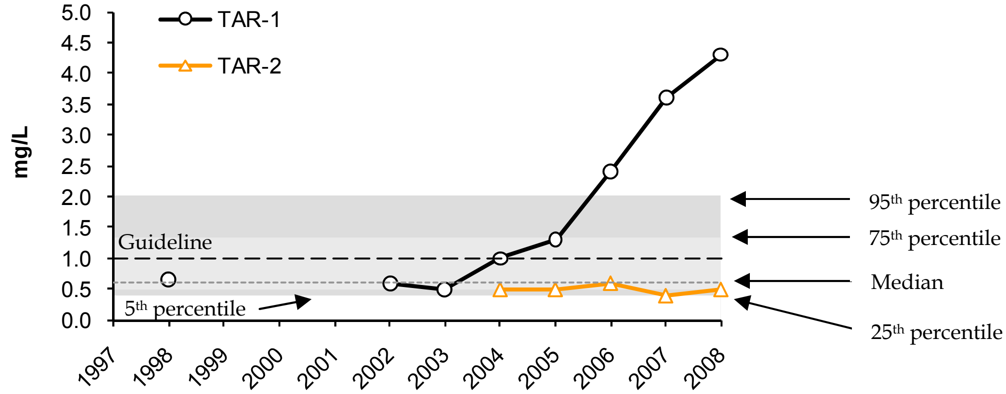
3.5.7 Analytical Methods

3.5.7.1 Comparison to Natural Variation in Baseline Conditions

To allow regional comparisons, untransformed fall data from all *baseline* stations sampled by RAMP since its inception, for all water quality measurement endpoints, are pooled from each cluster of similar stations. Descriptive statistics describing baseline water quality characteristics for each group are then calculated; for each water quality cluster, the 5^{th}, 25^{th}, 50^{th} (median), 75^{th}, and 95^{th} percentiles are determined for comparison against the current year's data. The number of observations for each of the selected water quality measurement endpoints varies by cluster. Given water quality data are characteristically positively skewed, the median rather than the mean is used as an indicator of typical conditions. Data for a subset of the water quality measurement endpoints are presented graphically in the context of relevant regional variability (e.g., Figure 3.6). For regional baseline water quality calculations, any station that is downstream of non-RAMP oil sands activities is excluded in addition to all *test* stations (see Table 3.5).

In the example in Figure 3.6, concentrations of total nitrogen at TAR-1 (near the mouth of the Tar River) in 2006 and 2007 are shown to exceed the 95^{th} percentile baseline concentration of total nitrogen for the group of stations to which the Tar River stations belong. Upon further investigation, it was found that these elevated nitrogen concentrations were likely related to approved discharges from the sewage treatment at the Canadian Natural Horizon project, upstream of station TAR-1. This example illustrates the efficacy of the regional baseline approach in highlighting observed concentrations outside the range of natural variability, allowing for timely investigation and response.

Figure 3.6 Example of graphical presentation of total nitrogen relative to baseline conditions, 1997 to 2008.



3.5.7.2 Temporal Trends

For each station, concentrations of a subset of measurement endpoints from all years of RAMP sampling are shown graphically (e.g., Figure 3.6) to allow assessment of any temporal trends. Where possible, stations located in the upper and lower reaches in specific watersheds are presented together, to allow assessment of any differences in values or trends between upstream/downstream locations.

In addition to qualitative trend analysis using graphical means (Section 3.5.7.1), statistical trend analysis is undertaken on water quality data for the Athabasca River mainstem, which has been monitored continuously by Alberta Environment since 1976.

Statistical trend analysis is not undertaken on RAMP data from most tributaries to the Athabasca River, partly due to typically insufficient sample sizes (numbers of years of data), and partly because changes in water quality in these smaller tributaries due to oil sands or other anthropogenic activities may not occur incrementally, but rather in a step-wise fashion, which would not necessarily be captured by statistical assessment of incremental trends in water quality. By contrast, incremental changes in water quality may be postulated in the Athabasca River, given its large volume relative to its tributaries from which changes in water quality in the Athabasca River mainstem may be most likely expected. Beginning in 2007, trend analysis is also conducted in larger tributaries (e.g., the Muskeg River) with sufficient data (i.e., at least seven years of data). For all other stations, besides the two AENV long-term monitoring stations on the Athabasca mainstem and tributary stations with at least seven years of data, any trends in water quality in key variables of interest are assessed qualitatively by graphical means.

Statistical trend analyses are undertaken using analyte concentrations over time, rather than loadings, given flow data are not available for all stations sampled and also given modes of potential toxicity of most analytes examined (i.e., metals and ions) relate to their concentration in water.

3.5.7.3 Ion Balance

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

An example of a Piper diagram used to illustrate changes in ion balance in each waterbodies sampled by RAMP appears in Figure 3.7.

3.5.7.4 Comparison to Water Quality Guidelines

To assess suitability of water to support aquatic life, all water quality data collected by RAMP are compared to relevant Alberta Environment or Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life. Any values that exceed these guidelines are reported.

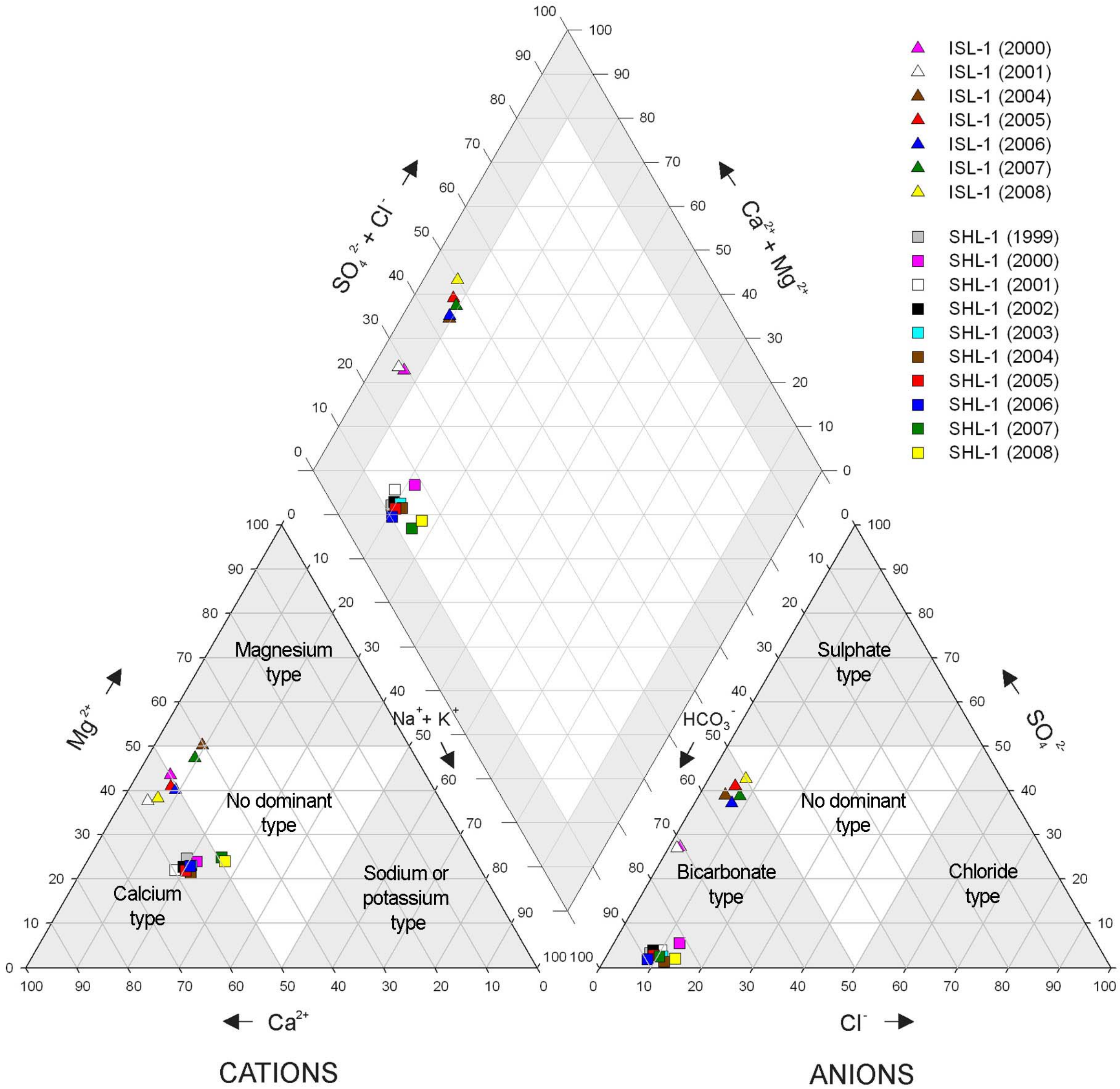
3.5.7.5 Water Quality Index

In 2008, RAMP added computation of a Water Quality Index to the range of assessments of water quality undertaken in the annual RAMP Technical Report. The purpose of presenting this single index value describing water quality at each water quality station in fall was to provide a single, summary indicator of water quality, in response to comments that the other assessment end-points were too technical detailed or complex for generalist readers of the RAMP report to quickly understand and digest.

Water quality at each RAMP monitoring station in fall 2008 was summarized into a single index value, ranging from 0 to 100, using an approach based on the CCME Water Quality Index[4]. This index is calculated using comparisons of observed water quality against user-specified benchmark values, such as water quality guidelines or background concentrations. It considers three factors: (i) the percentage of variables with values that exceed a given user-specified benchmark; (ii) the percentage of comparisons that exceed a given user-specified benchmark; and (iii) the degree to which observed values exceed user-specified benchmark values.

[4] A detailed description of the index is found at http://www.ccme.ca/ourwork/water.html?category_id=102.

Figure 3.7 Example Piper diagram, illustrating relative ion concentrations in waters from Isadore's Lake and Shipyard Lake (1997 to 2008)



Index calculations for RAMP water quality data used regional *baseline* conditions as benchmarks for comparison. Specifically, individual water quality observations were compared to the 95th percentiles of *baseline* concentrations (for the appropriate water quality station cluster) for each water quality variable.

Variables included in calculation of the water quality index included all RAMP water quality measurement endpoints (except nitrate+nitrite, which was excluded because of autocorrelation with total nitrogen, which was included in index calculations). Index values were calculated for all *baseline* and *test* stations.

Calculation of water quality index values for all stations sampled by RAMP in fall since 1997 (n=374) yielded index values ranging from 49.4 to 100.

Water-quality-index scores were classified using the following scheme:

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

This classification scheme, based on similarity to regional *baseline* conditions, differs somewhat from that used by CCME to classify water quality based on water-quality guidelines. Specifically, only three categories were used (versus five used by CCME), to ensure consistency with classification schemes used for other RAMP components. A classification of "Negligible-Low" difference from baseline in this classification, corresponds with CCME guideline-based index classes "Good" and "Excellent"; RAMP classification of "Moderate" difference from baseline generally corresponds with CCME class "Fair"; and RAMP classification of "High" difference from baseline corresponds with CCME classes "Marginal" and "Poor".

3.5.7.6 Other Analyses

In most years since 2004, additional, one-time analyses of the water quality dataset and/or pilot applications of other monitoring approaches, have been undertaken. These are routinely reported in appendices to each year's RAMP Technical Report. Results of two such items are summarized below.

Seasonal Differences in Water Quality

Although the fall RAMP water quality sampling program is the most extensive, and forms the basis for all findings and recommendations, water quality measurements have also been made in winter, spring and summer to varying degrees since 1997. In 2005, seasonal water chemistry data were analyzed to determine what, if any, seasonal patterns were apparent in the data. Analyses were conducted to determine whether fall data are sufficient for broadly characterizing the state of aquatic environments throughout the year, the ability of fall monitoring to capture extreme seasonal fluctuations, and whether fall data adequately represent the range of variability exhibited by metals and ions in other seasons.

The data from the Athabasca River and delta, various tributaries to the Athabasca River, and regional lakes were used in the 2005 seasonal water quality analysis. Two separate analyses were undertaken to determine whether seasonal patterns could be detected in the data. First, the frequency with which water quality variables exceeded guidelines for the protection of aquatic life were compared across seasons. Second, Principal Components Analysis (PCA) was used to reduce the seasonal water quality dataset to identify the source of seasonal variability. Principal Components (PCs) were also correlated against conventional variables such as total suspended solids to determine what underlying processes may influence the observed patterns.

The analytes most commonly exceeding guidelines were similar from season to season, with total aluminum and iron exceeding guidelines more often than any other analyte in all seasons. Fall water quality, however, tended to stay within guidelines more frequently than in other seasons; in the Athabasca River and delta, guideline exceedances occurred twice as often in spring. This suggests that while fall is perhaps representative of the types of analytes that commonly exceed guidelines, it may not capture extreme fluctuations that occur in other seasons. The frequency of spring exceedances likely results from higher flows during spring melt, which suspend previously settled material and elevate concentrations of total suspended solids (TSS) and analytes associated with suspended particulates (e.g., iron, aluminum, phosphorus, and copper).

Findings from the PCA were mixed, and depended on a variety of factors. Data from Athabasca River tributaries and regional lakes showed few seasonal patterns, although the high variability in physical characteristics of these waterbodies may have masked seasonal findings when the data were pooled. Data from the Athabasca River and delta clustered into clearly distinguishable seasonal patterns. Spring and winter data were most different, with high concentrations of total metals, especially iron and aluminum, in spring; winter concentrations of iron and aluminum were much lower, while concentrations of lithium and boron—metals indicative of groundwater influence—were high. Ion concentrations also differed substantially between spring and winter, with much lower concentrations of certain ions, including sodium, calcium, magnesium, and sulphate, in spring than in winter. Summer and fall data tended to vary across the spring/winter range.

Results of the seasonal data analysis indicated that although fall data are best suited for general annual reporting, there are specific seasonal issues, particularly apparent in the Athabasca River, that seem to relate to the annual flow regime. Water flowing during spring and winter has different characteristics that arise from the relative influence of different water sources, which in turn influence the frequency with which guidelines are exceeded. Additional seasonal data collection may help to identify seasonal changes that may be occurring at tributary and regional lake stations. Seasonal patterns at these stations are less clear, although patterns similar to those observed for the Athabasca River were observed. Additional information describing methods and results of this study appear in Appendix D of the RAMP 2005 report (RAMP 2006).

Semi-Permeable Membrane Device (SPMD) Pilot Project

In summer 2006, a pilot project using semi-permeable membrane devices (SPMDs) was implemented to explore the use of this technology for assessing levels of polycyclic aromatic hydrocarbons (PAHs) in rivers within the RAMP study area. SPMDs are sampling devices that mimic the bioconcentration of dissolved (potentially bioavailable) hydrophobic organic chemicals from aquatic ecosystems into the fatty tissue of organisms (Huckins *et al*. 2002). SPMDs consist of a segment of tubing containing a small amount of neutral lipid that accumulates non-polar chemicals passing through the tubing membrane. These chemicals can then be extracted from the lipid and analyzed to provide data on organic contaminants in aquatic ecosystems. Because SPMDs are deployed in the field for days to months, they can provide a temporally integrated or time-weighted average concentration of the target chemicals (USGS 2004).

SPMDs were deployed for approximately four weeks (from the end of July to the end of August) in 2006 at three locations in the Muskeg River, representing a gradient of potential impacts of focal project activities on water quality. Upon retrieval from the river, SPMDs were shipped frozen to Environmental Sampling Technologies, Inc. (St. Joseph, Missouri) for extraction and clean-up. Laboratory analysis of parent and alkylated PAHs in the SPMD extract was conducted by AXYS Analytical Services in Sidney, B.C. Concentrations of PAHs found within the SPMDs are proportional to concentrations of PAHs within the sampled medium (i.e., air or water; USGS 2004), and provide an indication of relative levels of PAHs at different sites. Detailed methods are provided in Appendix D of the RAMP 2006 Technical Report (RAMP 2007).

The SPMD in the lower Muskeg River was exposed to air due to a large decrease in river flows over the sampling period, and was not analyzed for PAHs. SPMDs deployed at the other two sample stations as well as trip and day zero blanks were analyzed for over forty species of parent and alkylated PAHs. The total concentration of detectable PAHs was similar in the trip blank and SPMD extract from the upstream station (upstream of oil sands development), and approximately four times higher in the SPMD extract from the station located in the middle reaches of the Muskeg River. High molecular weight PAHs comprised a similar fraction of total detectable PAHs at MUR-5 and MUR-6, but comprised a lower proportion of PAHs in the trip blank sample. While several PAH species were not detected in either the day zero or trip blank, concentrations of some PAHs were higher in these samples than in the samples from Muskeg River sites.

The SPMD pilot study indicated that using SPMDs to collect data on PAH species and relative concentrations within the aqueous environment is feasible. However, the following factors must be considered for implementation of an SPMD sampling program:

- SPMD holders and canisters must be borrowed or purchased;
- Additional costs associated with using SPMDs relative to grab sampling include the cost of the SPMD membranes, dialysis and GPC clean-up, shipping costs, and the cost of an additional field trip (field trips are required for deployment and retrieval);

- Dependence of site conditions (e.g., water depth, flow velocity) on the practicality of deploying SPMDs to ensure adequate water coverage and field crew safety for installing/retrieving the SPMDs; and

- Results for some analytes may be invalid due to high concentrations in the day zero or trip blank, limiting interpretation of results to a subset of PAH species.

Seasonal Differences in Water Quality

Although the fall RAMP water quality sampling program is the most extensive, and forms the basis for all findings and recommendations, water quality measurements have also been made in winter, spring and summer to varying degrees since 1997. In 2005, seasonal water chemistry data were analyzed to determine what, if any, seasonal patterns were apparent in the data. Analyses were conducted to determine whether fall data are sufficient for broadly characterizing the state of aquatic environments throughout the year, the ability of fall monitoring to capture extreme seasonal fluctuations, and whether fall data adequately represent the range of variability exhibited by metals and ions in other seasons.

The data from the Athabasca River and delta, various tributaries to the Athabasca River, and regional lakes were used in the 2005 seasonal water quality analysis. Two separate analyses were undertaken to determine whether seasonal patterns could be detected in the data. First, the frequency with which water quality variables exceeded guidelines for the protection of aquatic life were compared across seasons. Second, Principal Components Analysis (PCA) was used to reduce the seasonal water quality dataset to identify the source of seasonal variability. Principal Components (PCs) were also correlated against conventional variables such as total suspended solids to determine what underlying processes may influence the observed patterns.

The analytes most commonly exceeding guidelines were similar from season to season, with total aluminum and iron exceeding guidelines more often than any other analyte in all seasons. Fall water quality, however, tended to stay within guidelines more frequently than in other seasons; in the Athabasca River and delta, guideline exceedances occurred twice as often in spring. This suggests that while fall is perhaps representative of the types of analytes that commonly exceed guidelines, it may not capture extreme fluctuations that occur in other seasons. The frequency of spring exceedances likely results from higher flows during spring melt, which suspend previously settled material and elevate concentrations of total suspended solids (TSS) and analytes associated with suspended particulates (e.g., iron, aluminum, phosphorus, and copper).

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Data from the Athabasca River and delta clustered into clearly distinguishable seasonal patterns. Spring and winter data were most different, with high concentrations of total metals, especially iron and aluminum, in spring; winter concentrations of iron and aluminum were much lower, while concentrations of lithium and boron—metals indicative of groundwater influence—were high. Ion concentrations also differed substantially between spring and winter, with much lower concentrations of certain ions, including sodium, calcium, magnesium, and sulphate, in spring than in winter. Summer and fall data tended to vary across the spring/winter range.

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3.6 BENTHOS AND SEDIMENT COMPONENT: BENTHIC INVERTEBRATE COMMUNITY

From 1997 to 2005, the benthic-invertebrate-community and sediment-quality components of RAMP were undertaken as separate investigations. However, in 2006, the sediment-quality component was folded into the benthic-invertebrate component, to better focus the sediment-quality component on depositional areas, and to increase the program's ability to interpret any observed differences or changes in benthic invertebrate community structure in the context of local sediment quality. Further discussion of this integration appears in Section 3.7 of this document.

3.6.1 Sub-Component History

Surveys of benthic macroinvertebrates have been a component of the RAMP studies since 1997. Surveys of benthic invertebrates (sensitive bioindicators) were included in RAMP to address a regulatory requirement, and to compliment fisheries, water and sediment quality surveys by indicating the availability of food for fish, and environmental quality of the various waterbodies.

The program has evolved from initial surveys of the mainstem Athabasca River (in 1997) to inventories of tributary reaches, the Athabasca River Delta (ARD), and lakes (Table 3.16, Figure 3.8). In 1998, the focus shifted from the mainstem to tributaries. The mainstem was taken out of the program for two reasons. One, benthic invertebrates in the shifting sands of the Athabasca River are typically tolerant to disturbance. In the diluted environment of the Athabasca River, it could be anticipated that the benthic fauna of the Athabasca River might not be an adequate indicator of possible changing conditions due to oil sands operations. Second, tributary rivers, typically with more stable substrates, tend to contain more sensitive benthic invertebrate taxa that are anticipated to respond well in advance of benthos from the mainstem, to oil sands development-related stressors.

Sampling shifted from the Athabasca mainstem to tributaries in 1998, and included sample collection from rivers exposed (Muskeg and Steepbank Rivers) and unexposed to development (MacKay River). No sampling was carried out in 1999 because of low flows in the one system targeted for that year (McLean Creek). In 2000, the first lake benthos samples were collected (Shipyard Lake). In 2001, the Clearwater River, Fort Creek and Kearl Lake were added to the program to increase the characterization of background baseline conditions.

The benthic invertebrate component of RAMP now consists of annual baseline sampling of selected tributaries and lakes over a three-year period, followed by continued monitoring at a frequency that is to be adjusted to the development schedules of nearby oil sands operations.

The tributary monitoring approach adopted by RAMP has focused on the lower reach of each river to allow detection of the cumulative effects of all developments within each basin, or followed the control-impact (upstream-downstream) approach. To increase the amount of *baseline* site data in the RAMP database and allow upstream-downstream comparisons, tributary monitoring is gradually being expanded by also sampling the upper river reaches where feasible. To monitor lakes, sampling effort is distributed over the entire open-water area of a lake, but is restricted by depth to reduce variation in the data. Both river reach and lake sampling includes the collection of a full suite of supporting data (e.g., flow velocity, substrate grain size and organic matter content, chlorophyll *a* content) to allow separation of the effects of natural variation on benthic community structure from the potential changes related to oil sands developments.

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 of the RAMP program are used to place current results in context with historical trends in community structure.

3.6.2 Key Indicator Resources

Five of the 17 EIAs that were reviewed included benthic invertebrate communities as a KIR (Table 2.5, Page 2-14). However, no specific benthic invertebrate taxonomic groups were mentioned in any of these five EIAs. By contrast, the other EIAs did not consider benthic invertebrate communities to be KIRs but rather as supporting variables for considering natural variability and changes in other aquatic resources, particularly fish populations.

Table 3.16 Summary of RAMP data available for the Benthic Invertebrate Community component, 1997 to 2008.

see symbol key at bottom

WATERBODY AND LOCATION	TYPE	HABITAT	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Delta																																																			
Athabasca River Delta	1	depositional	FLC,GIC,BPC																								1				1				1				1								1,1				1,1
Calumet River																																																			
Lower Reach	1,2[1]	depositional	CAR-D-1																				2				1				1				1				1												
Upper Reach	1	depositional	CAR-D-2																												1				1				1				1,2								
Christina River																																																			
Lower Reach	1	depositional	CHR-D-1																								1				1				1				1				1,2				1				
Middle Reach	1	erosional	CHR-E-2A																																												1				
Upper Reach	1	depositional	CHR-D-2																								1				1				1				1				1,2								
Clearwater River																																																			
Downstream of Christina River	1	depositional	CLR-D-1																				1				1				1				1				1												1
Upstream of Christina River	1	depositional	CLR-D-2																				1				1				1				1				1												1
Ells River																																																			
Lower Reach	1	depositional	ELR-D-1																												1				1				1				1,2				1				
Upper Reach	1	erosional	ELR-E-2																												1				1				1				1								
Firebag River																																																			
Lower Reach	1	erosional	FIR-D-1																												1				1				1				1,2				1				
Upper Reach	1	depositional	FIR-E-2																												1				1				1				1				1				
Fort Creek																																																			
Lower Reach	1	depositional	FOC-D-1												2								1				1				1								1,2				1,2				1,2				1,2
Hangingstone River																																																			
Lower Reach	1	erosional	HAR-E-1																																1				1				1				1				1
Jackpine Creek																																																			
Lower Reach	1	depositional	JAC-D-1																								1				1				1				1				1,2				1				1
Upper Reach	1	depositional	JAC-D-2																												1				1				1				1,2				1				1
MacKay River																																																			
Lower Reach	1	erosional	MAR-E-1																1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	MAR-E-2																								1				1				1				1				1				1				1
Muskeg River																																																			
Lower Reach	1	erosional	MUR-E-1																1				1				1				1				1				1				1				1				1
Middle Reach	1	depositional	MUR-D-2																1				1				1				1				1				1				1,2				1,2				1,2
Upper Reach	1	depositional	MUR-D-3																								1				1				1				1				1,2				1,2				1,2
Steepbank River																																																			
Lower Reach	1	erosional	STR-E-1																1				1				1				1				1				1				1				1				1
Upper Reach	1	erosional	STR-E-2																												1				1				1				1				1				1
Tar River																																																			
Lower Reach	1[1]	depositional	TAR-D-1																				2				1				1				1				1				1,2								
Upper Reach	1	erosional	TAR-E-2																												1				1				1				1								

Type Legend:

1 = RAMP station

2 = Sampled outside of RAMP (data available to RAMP)

,1 = RAMP standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)

,2 = RAMP standard sediment quality + sediment toxicity (*Chironomus tentans, Hyalella azteca*)

Test (downstream of focal projects)

Baseline (upstream of focal projects)

Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

[1] sampled outside of RAMP in 2001, became RAMP station in 2002

[2] sampled outside of RAMP in 1999, became RAMP station in 2000

Table 3.16 (Cont'd.)

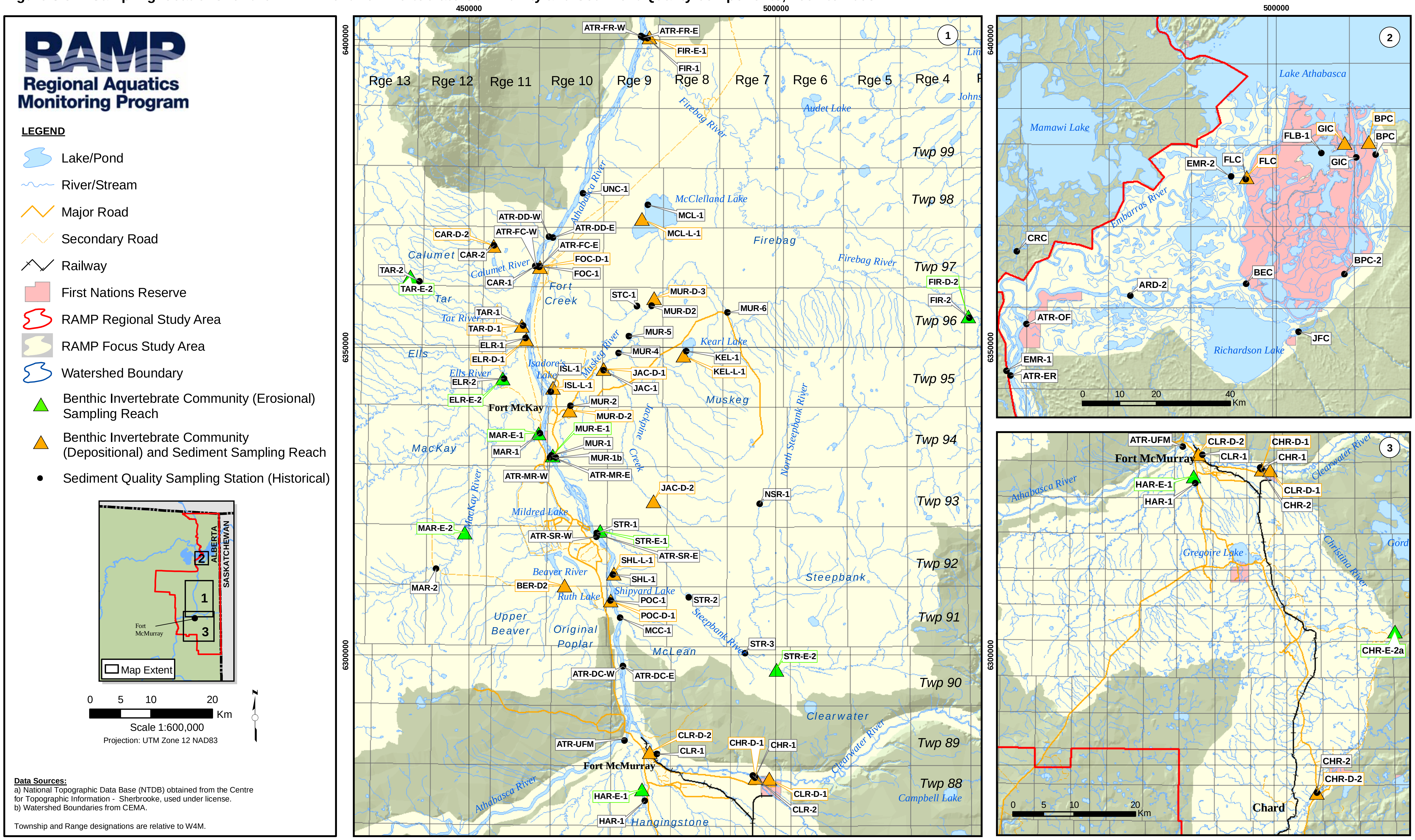
see symbol key at bottom

WATERBODY AND LOCATION	TYPE	HABITAT	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008			
				W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Beaver River																																																			
Lower Reach	1	depositional	BER-D2																																																1
Poplar Creek																																																			
Lower Reach	1	depositional	POC-D1																																																1
Wetlands and Lakes																																																			
Isadore's Lake	1	lake	ISL-1																																						1,2				1,2				1,2
Kearl Lake	1	lake	KEL-1																				1				1				1				1				1				1,2				1,2				1,2
McClelland Lake	1	lake	MCL-1																								1				1												1,2				1,2				1,2
Shipyard Lake	1	lake	SHL-1																1				1				1				1				1				1				1,2				1,2				1,2
Historical Data																																																			
Historical Data Review																1	1	1	1					1	1	1	1																								
5-Year Summary Report																																																			
Summary Report																								1	1																										
Locations No Longer in Sample Design																																																			
Athabasca River																																																			
Near Fort Creek (east bank)	1	depositional	ATR-B-A1 to A3				1																																												
(west bank)	1	depositional	ATR-B-A4 to A6				1																																												
Near Donald Creek (east bank)	1	depositional	ATR-B-B1 to B3				1																																												
(west bank)	1	depositional	ATR-B-B4 to B6				1																																												
Suncor near-field monitoring	2	depositional	-																				2																												
MacKay River																																																			
200 m upstream of mouth	1	erosional	MAR-1								1																																								
500 m upstream of mouth	1	erosional	MAR-2								1																																								
1.2 km upstream of mouth	1	erosional	MAR-3								1																																								
Muskeg River																																																			
50 m upstream of mouth	1	erosional	MUR-1								1																																								
200 m upstream of mouth	1	erosional	MUR-2								1																																								
450 m upstream of mouth	1	erosional	MUR-3								1																																								
Steepbank River																																																			
50 m upstream of mouth	1	erosional	STR-1								1																																								
150 m upstream of mouth	1	erosional	STR-2								1																																								
300 m upstream of mouth	1	erosional	STR-3								1																																								

Type Legend:
1 = RAMP station
2 = Sampled outside of RAMP (data available to RAMP)
,1 = RAMP standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)
,2 = RAMP standard sediment quality + sediment toxicity (*Chironomus tentans, Hyalella azteca*)

Test (downstream of focal projects)
Baseline (upstream of focal projects)
Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.
[1] sampled outside of RAMP in 2001, became RAMP station in 2002
[2] sampled outside of RAMP in 1999, became RAMP station in 2000

Figure 3.8 Sampling locations for the RAMP Benthic Invertebrate Community and Sediment Quality components, 1997 to 2008.



3.6.3 Hypotheses and Questions

3.6.3.1 Hypotheses and Questions from Athabasca Oil Sands EIAs

There are few residual impact assessments in oil sands EIAs related to effects on benthic invertebrate communities. Of the 17 EIAs reviewed for this project (Chapter 2), only 17 residual impact assessments pertained to benthic invertebrate communities; all residual impacts were predicted to be negligible or low in magnitude, and practically all were local in extent. Oil sands development impacts on benthic invertebrate communities, as predicted in the various EIAs, arise from a number of development and reclamation activities (Table 3.17).

Table 3.17 Athabasca oil sands activities with potential effects on benthic invertebrate communities.

Main Impact Pathways (from Section 2.2, Page 2-1)	Oil Sands Activities (summarized from Table 2.2, Page 2-6 and Table 2.3, Page 2-10)
▪ Changes in hydrological conditions	▪ surface facilities and disturbances, watercourse crossings, reclamation activities
▪ Changes in amounts of physical habitat ▪ Changes in water quality ▪ Changes in sediment quality	▪ releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills, water diversions, ecological viability of End-Pit Lakes

3.6.3.2 RAMP Objectives, Key Questions and Hypotheses

RAMP monitors benthic invertebrate communities as a regulatory requirement (i.e., because the member companies require the studies as part of their certificates of approval to operate), and to compliment the other biophysical components in an overall comprehensive assessment of conditions in the oil sands region. Oil sands EIA's have predicted that changes in hydrologic regimes, water and sediment quality, and changes in aquatic habitat would variously cause reductions in abundance, diversity and number of taxa benthic macroinvertebrate taxa, and changes in composition. The RAMP Benthic Invertebrate Community component thus has three general objectives as proposed in the RAMP 5-year report (Golder 2003):

- Collect scientifically defensible baseline and historical data to characterize variability of indices of composition of benthic invertebrate communities in the oil sands area;
- Monitor benthic macroinvertebrates in the oil sands area to detect and assess cumulative effects and regional trends in indices of composition; and
- Collect data against which predictions, pertaining to benthic invertebrates, contained in environmental impact assessments can be verified.

These objectives lead to the following questions for the RAMP benthic invertebrate component:

- What changes in benthic invertebrate composition are predicted from the EIAs?
- What are the baseline conditions and range of natural variability of indices of benthic invertebrate community composition in the RAMP study area?
- Do indices of benthic invertebrate community composition vary significantly between exposed (*test*) areas and unexposed (*baseline*) areas to oil sands development?
- Do indices of composition from *test* areas have the same time trend as indices in *baseline* areas?
- Where indices of community composition demonstrate a local change either spatially or temporally, do those indices fall outside the range of natural variability as observed over time in *baseline* areas in the RAMP study area?

From these questions, the following hypotheses are formulated for the benthic invertebrate community component.

- H_{o1}: Indices of community composition are the same in areas exposed (*test*) and unexposed (*baseline*) to oil sands development.
- H_{o2}: Time trends in indices of community composition are the same in areas exposed (*test*) and unexposed (*baseline*) to oil sands development.
- H_{o3}: Indices of community composition in *test* areas are within the normal range of variability as expressed in *baseline* areas in the RAMP study area.

A contrast of upstream (*baseline*/unexposed) and downstream (*test*/exposed) communities tests the first null hypothesis, for individual tributary systems. A comparison of time trends in indices of composition between *baseline* and *test* reaches tests the second null hypothesis. All data from *baseline* reaches and lakes are used to quantify the observed variability in indices of composition. A comparison of observations from *test* areas to the normal range of variability tests the third null hypothesis.

3.6.4 Measurement Endpoints and Criteria for Determining Change

The RAMP benthic invertebrate sampling program collects samples of surficial sediments from which benthic macroinvertebrates are removed, identified to lowest practical levels and counted. The enumerated data are used to calculate the following indices for every individual sample:

- Abundance (total number of individuals/m^2);
- Taxon richness (number of distinct taxa) per sample;
- Diversity (Simpson's Index, D);
- Evenness; and
- EPT Index (percent of fauna as Ephemeroptera, Plecoptera, Trichoptera).

These indices of benthic invertebrate community composition have been selected because they are measures typically used in surveys of benthic invertebrates (e.g., Environment Canada 2005), and because they represent fundamental attributes of benthic invertebrate communities. Further, oil sands EIA's predicted reductions in abundance, richness and diversity, and changes in composition of the benthic community. These attributes; therefore, pertain either directly or indirectly to the EIA predictions.

Abundance reflects the density of animals. Nutrient enriched systems tend to support more invertebrates, reflected in an increase in abundance. Chemicals that cause short- or long-term toxicity, or physical alterations of benthic habitats can cause reductions in total abundance.

Number of taxa is a fundamental measure of community composition. Sites with more taxa are typically considered to be in better condition. Moderate nutrient enrichment can increase the number of taxa that a site can support, while excessive nutrient enrichment can lead to anoxia that will reduce or eliminate certain taxa and reduce taxa richness. Toxic conditions and physical alterations to habitats will also reduce taxa richness.

Simpson's Diversity is one of several measures of "diversity" that incorporates a measure of abundance. Diversity is lower when sites are dominated by a few taxa. Evenness is an alternative measure of diversity, standardized against the "maximum possible" diversity (or against a community with equal numbers of all taxa). Higher diversity and evenness are considered an indication of better conditions. Reductions in diversity and evenness tend to indicate stresses on the system.

Percent EPT has been used as a measure of community composition because it reflects the fraction of the community comprised by what are typically considered to be the more sensitive groups (Ephemeroptera, mayflies; Plecoptera, stoneflies; Trichoptera, caddisflies). Percent EPT is widely used in Canada and the United States to characterize benthic invertebrate communities (Rosenberg and Resh 1993; Davis and Simon 1995).

The RAMP analytical approach also uses multivariate procedures (in the most recent years correspondence analysis – CA) to provide a holistic summary of variations in taxonomic composition. Multivariate measures (such as scores from an ordination like CA) tend to highlight changes in the benthic invertebrate community before changes are evident in the other, more general, indices (Kilgour *et al.* 2005). The multivariate methods are; therefore, considered more sensitive.

Potential changes in benthic invertebrate communities are determined by comparing indices of community composition (i.e., measurement endpoints) between *test* and *baseline* areas and/or pre-development conditions. Comparisons are made using analysis of variance statistical procedures, using variation among replicates within reaches to judge spatial variations, and trends over time. The RAMP design has very high statistical power because of high replication within reaches and lakes, and is thus able to detect changes that are very small, and potentially of little environmental consequence. Observations indicative of a possible change in invertebrate communities are compared to variability observed among regional *baseline* areas. Values falling outside the normal range of variability (defined as the 95% region, or the mean ± 2 standard deviations) are considered large effects, with potential ecological relevance. Variations falling within the normal range, though they may be statistically detectable, are considered to be likely of less ecological relevance though still requiring consideration. These definitions have support from federal agencies, particularly Environment Canada (Lowell 1997; Lowell *et al.* 2003; Environment Canada 2005). Changes in indices of benthic community composition in excess of the baseline mean ± 2 SDs often coincide with effects on fish communities of the same or greater magnitude in stream environments (Yoder and Rankin 1995; Kilgour and Stanfield 2006). Kilgour *et al.* (2005) consider changes in excess of 2 SDs from the baseline state to be a warning of potentially ecologically important effects, highlighting a requirement for additional monitoring. Though a benthic community may produce index values that are unusual (i.e., lie outside the normal range), the condition may be considered sustainable if there is no further degradation over time. Continued degradation of indices of community composition over time implies an unsustainable condition.

3.6.5 Monitoring Station Selection and Monitoring Design

The Benthic Invertebrate Community component focuses on tributaries of the Athabasca River and regional wetlands (shallow lakes). Samples are also collected in three Channels of the Athabasca River Delta because that is an area of active deposition of sediment and considered an area potentially at risk from chemical loadings.

In RAMP, the following nomenclature for sampling units is used.

The **Sample** is the fundamental sampling unit, and is the unit area from which the benthic community is collected, using either an Ekman grab or Neill-Hess Sampler.

Samples are collected within **Sites** that are somewhat arbitrarily (pseudo-randomly) selected within larger Sampling Areas. Sites will generally be selected in a fashion that ensures that they represent the desired physical conditions (i.e., erosional or depositional habitats) and that they cover the desired geographic spread.

RAMP contains three kinds of **Sampling Areas:** Tributary **Reaches**, **Lakes**, ARD **Channels**.

A **Reach** consists of relatively homogeneous stretches of river typically 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 the tributary. Fifteen samples were collected per Reach between 1999 and 2004. In 2005, the number of samples per Reach was reduced to 10 from 15, recognizing the very high statistical power of the surveys (ten samples still produces very high power).

The 5-year report (Golder 2003) argued for multiple samples from fewer sites. An analysis of richness data from three reaches in 1998 (i.e., lower MacKay, lower Muskeg, lower Steepbank) showed that a single sample per site is sufficient to estimate richness (number of taxa) to within a recommended precision ±20% (Box 1). Variation among sites is greater than variation within sites, justifying maximizing the number of sites and minimizing replication within sites. Further, since it is variation among sites that is used to judge differences among Reaches, increasing the number of sites increases the statistical power of the RAMP Benthic Invertebrate Community component.

Box 1: Number of Replicate Samples per River Reach Site

Environment Canada (2005) recommends collecting the minimum number of samples within a site that ensures that mean index values lie within ± 20% of the true mean 95% of the time. The number of samples per site can be estimated from: $n = \frac{S^2}{D^2 \overline{X}^2}$, where $\overline{X}$ is the sample mean, n is the number of samples, S^2 is the sample variance, and D is the index of precision, here set to 0.2 (or 20%). This equation was "solved" using data from 1998 for the lower reaches of the Muskeg, Mackay and Steepbank Rivers when five replicate samples were collected from each of three sites. The aggregated variance (S^2) was 16. With a typical mean ($\overline{X}$) of 30, the number of samples required to estimate the mean to within ± 20% of its actual value was one (1). A single sample per site can, therefore, be justified for river reach monitoring in this program.

The reduction in the number of sites per reach from 15 to 10 was also based on recommendations from field crews to reduce the physical effort of sampling, and recognition of the high statistical power even with 10 samples per reach (Box 2).

Box 2: Number of Sites per Reach

The statistical power analysis equation was used to estimate the likelihood of detecting effects with 10 and 15 samples per reach. The power equation is: $n = 2(t_{\alpha} + t_{\beta})^2 \bullet \left(\frac{SD}{ES}\right)^2$, where n is the number of samples per reach, t_{α} and t_{β} are the critical t-values at significance levels for Type 1 and Type 2 error rates respectively, SD is the within reach standard deviation, and ES is the critical effect size. As per Environment Canada (2005), we set the ES to the mean reference condition ± 2 SDs assuming that effects exceeding ± 2 SDs are of interest. The equation can be re arranged to solve for β, or power (the probability of correctly declaring an effect has occurred. With n=15, and t_{α}= 0.05, there is about a 99% chance of detecting differences of about ± 2 SDs between two reaches. With n=10, there is about a 98.5% chance of detecting a difference of about ± 2 SDs between two reaches. Considering that RAMP compares time trends in reference and exposed reaches, the statistical power is considerably higher. The number of samples per reach could be considerably lower. Maintaining 10 samples per reach ensures the geographic spread of samples, and allows RAMP to make inferences across those broader areas.

One upstream Reach is used as *baseline* for each *test* Reach exposed to oil sands development. So, for example, in the Muskeg River system there is one Reach upstream of all proposed developments in the Muskeg River that serves as a *baseline* for the downstream *test* Reaches. Other *baseline* Reaches within the RAMP study area can serve as "regional" *baseline* reaches for any *test* Reach. Regional Reaches help to quantify the normal range of variability in the study area.

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. Lakes have been sampled with 10 samples (one per each of 10 random sites) since inception of Lake monitoring. As with river Reaches, collecting one sample from each of 10 sites in a Lake is superior in terms of characterizing spatial variability, and maximizes statistical power. Kearl and McClelland Lakes are *baseline* Lakes.

Within the ARD, samples are collected from three Channels (Big Point, Fletcher, Goose Island). Five replicate samples were collected from one site within each Channel from 2002 to 2004. There is no *baseline* area for the ARD. Trends over time will be the evidence used to demonstrate changes in benthic invertebrate communities in the ARD.

The rationale for the selection of specific sampling areas is provided in Table 3.18. The Athabasca River mainstem was sampled in 1997 only, in areas upstream and downstream of the principal oil sands projects. Mainstem sampling was discontinued because the shifting sands were dominated by a few tolerant taxa, and there was a realization that the benthic invertebrate community in the mainstem would not react as quickly to development-related stressors as would communities in the tributaries. In 1998, sampling was conducted in the Muskeg River near the mouth, and the Steepbank River (mouth) to assess potential effects of existing projects. The MacKay River was sampled in 1998 to provide a *baseline* river for the Muskeg and Steepbank Rivers. Shipyard Lake was added in 2000, as *baseline* for future monitoring of exposed or *test* lake environments, and has been sampled every year since. The Tar and Clearwater Rivers were added to the RAMP list of *baseline* rivers in 2001, while the Calumet, Christina and Ells rivers, and Jackpine Creek were added in 2002. The Firebag River was added in 2003. The intention has been to collect at least three years of baseline (pre-development) data in Reaches or Lakes, but some have been sampled on four or more occasions (Calumet Lower Reach, Clearwater River, Kearl Lake).

A middle reach of the Christina River was sampled in 2007 as a potential replacement for the Upper Christina River (CHR-D-2). A natural saline seep between CHR-D-1 and CHR-D-2 made comparisons of benthic communities between the Upper and Lower Christina reaches somewhat confounded. It was hoped that CHR-D-2a would be downstream of the seep, while still being upstream of oil sands develops and provide an appropriate *baseline* reach for CHR-D-1. Sodium concentrations at CHR-D-2 were; however, higher (70 mg Na/L in 2007) than the Lower reach, CHR-D-1 (20 to 34 mg Na/L in 2007) or the Upper reach, CHR-D-2 (6 to 10 mg Na/L in 2007), making comparisons to the Lower or Upper reaches complicated. The decision was made to eliminate that reach from future study in subsequent years.

An upper reach of the Beaver River (BER-D-1) was first sampled in 2008 as a *baseline* station for the lower reaches on Beaver River and Poplar Creek given the two watercourses are connected. A lower reach of Poplar Creek (POC-D-1) was also added in 2008 to monitor current activities upstream of the station from Syncrude Mildred Lake Operations.

3.6.5.1 Sampling Protocol

The benthic field program is carried out during early to mid September. Sampling is done in the fall because that is a time of year when water levels are reasonably low (safe and easy working conditions), and when larval forms of insects are large enough to be identifiable to reasonable taxonomic levels (genus/species for larger insects like mayflies and stoneflies). Fall is a conventional time of year for sampling for these reasons (Environment Canada 2005; AENV 1990b).

Depositional habitats (lakes, slow river reaches) are sampled using an Ekman grab, while a Neill-Hess cylinder is used to sample erosional environments. Benthic communities associated with river reaches are characterized by collecting single samples from normally 10 stations. Benthos from lakes and Athabasca River Delta (ARD) Channels are also characterized by collecting single samples from each of ten sampling stations. In river reaches, sampling 10 sites is a reduction of effort as of 2005 (from 15 sites). For ARD Channels, sampling 10 sites is an increase of effort as of 2005 (from 5 sites).

Table 3.18 Rationale for RAMP benthic invertebrate community sampling locations in the lower Athabasca River, tributaries of the lower Athabasca River and the delta, 1997 to 2008.

Watercourse	Station Code	Station	Rationale
Athabasca River Mainstem	ATR-B-B4 to B6	Near Donald Creek (west bank)	Upstream *baseline* area for Athabasca River mainstem. Used only in 1997. Downstream of the Fort McMurray and Clearwater River.
	ATR-B-B1 to B3	Near Donald Creek (east bank)	
	ATR-B-A4 to A6	Near Fort Creek (west bank)	Downstream *test* area for Athabasca River mainstem. Used only in 1997. Potentially reflects cumulative effects of oil sands development.
	ATR-B-A1 to A3	Near Fort Creek (east bank)	
Athabasca River Delta	FLC-D-1	Fletcher Channel, ARD	Depositional area, potentially reflecting cumulative effects of oil sands development.
	GIC-D-1	Goose Island Channel, ARD	Depositional area, potentially reflecting cumulative effects of oil sands development.
	BPC-D-1	Big Point Channel, ARD	Depositional area, potentially reflecting cumulative effects of oil sands development.
Beaver River	BER-D-2	Upper Reach	Selected as *baseline* site for lower Poplar Creek.
Calumet River	CAR-D-1	Lower reach near mouth	Selected to assess potential effects of Canadian Natural Horizon. Sampled in 2001 outside of RAMP, and since 2002 as part of RAMP.
	CAR-D-2	Upper reach	Selected as a *baseline* reach for the lower reach. Sampled since 2003.
Christina River	CHR-D-1	Downstream of Christina River	Selected to assess effects of upstream *in situ* oil sands development on the Christina River. Sampled since 2002, now with 3 years of baseline.
	CHR-D-2	Upstream of Christina River	Selected as a *baseline* reach for the lower reach. Sampled since 2002, now with 3 years of baseline.
Clearwater River	CLR-D-1	Downstream of Christina River	Selected to assess effects of upstream *in situ* oil sands development on the Clearwater River. Sampled since 2001, now with 4 years of baseline.
	CLR-D-2	Upstream of Christina River	Selected as a *baseline* reach for the lower reach. Sampled since 2001, now with 4 years of baseline.
Ells River	ELR-D-1	Lower Reach near mouth	Selected to assess potential effects of Total E&P Joslyn project.
	ELR-E-2	Upper Reach	Selected as a *baseline* reach for lower reach.

Table 3.18 (Cont'd.)

Watercourse	Station Code	Station	Rationale
Firebag River	FIR-E-1	Lower Reach near mouth	Selected to assess potential effects of upstream projects including Suncor Firebag and Husky Sunrise.
	FIR-D-2	Upper Reach	Selected as *baseline* site for lower reach.
Fort Creek	FOC-D-1	Lower Reach near mouth	Selected to assess potential effects of Fort Hills and Aurora North projects.
Hangingstone River	HAR-E-1	Lower Reach near mouth	Selected to assess potential effects of upstream projects including Suncor Meadow Creek.
Jackpine Creek	JAC-D-1	Lower Reach near mouth	Selected to assess potential effects of upstream projects including Shell-Albian Muskeg River and Jackpine mines.
	JAC-D-2	Upper reach	Selected as a regional *baseline* reach.
MacKay River	MAR-1	200 m upstream of mouth	Selected as *baseline* in 1998 to assess future development (Suncor MacKay, and Syncrude Mildred lake)
	MAR-2	500 m upstream of mouth	
	MAR-3	1.2 km upstream of mouth	
	MAR-E-1	Lower reach near mouth	Selected to assess upstream projects. Baseline in 2000 and 2001; *test* from 2002 on.
	MAR-E-2	Upper reach	Selected as *baseline* for lower reach.
	MAR-E-3	Upper MacKay River	Selected as *baseline* for lower reach.
Muskeg River	MUR-1	50 m upstream of mouth	Selected to assess upstream projects. Exposed to development effects in 1998, and later.
	MUR-2	200 m upstream of mouth	
	MUR-3	450 m upstream of mouth	
	MUR-E-1	Lower reach near mouth	Selected to assess upstream projects.
	MUR-D-2	Lower to middle reach	Selected to asses upstream projects.
	MUR-D-3	Upstream of Stanley Creek	Selected as *baseline* for downstream reaches.
Poplar Creek	POC-D-1	Lower reach near mouth	
Steepbank River	STR-1	50 m upstream of mouth	Selected to monitor existing upstream projects (Suncor Steepbank and Project Millennium) and future projects (Suncor Lewis and Husky Sunrise). Design based on sites, not reaches.
	STR-2	150 m upstream of mouth	
	STR-3	300 m upstream of mouth	
	STR-E-1	Lower reach near mouth	Selected to assess upstream projects. Design modified in 2000 to reach scheme.
	STR-E-2	Upper reach	Selected as *baseline* for downstream reaches.
Tar River	TAR-D-1	Lower reach near mouth	Selected to monitor upstream projects (Canadian Natural Horizon); exposed to development effects in late 2004.
	TAR-E-1	Upper reach	Selected as *baseline* for downstream reaches.

Supporting environmental variables measured at each station include conductivity, water temperature, pH, dissolved oxygen, water depth, substrate grain size, plant/algal growth and sediment organic carbon. Current velocity, and bankfull and wetted width are also characterized at river sites.

Benthic community samples are sieved in the field and preserved on site with buffered formalin. Mesh size of field sieves varies with habitat type, with erosional habitats sieved through 210-µm mesh, and depositional habitats sieved through 250-µm mesh. Samples are sorted and identified to lowest practical taxonomic levels to ensure maximum sensitivity.

3.6.6 Analytical Approach

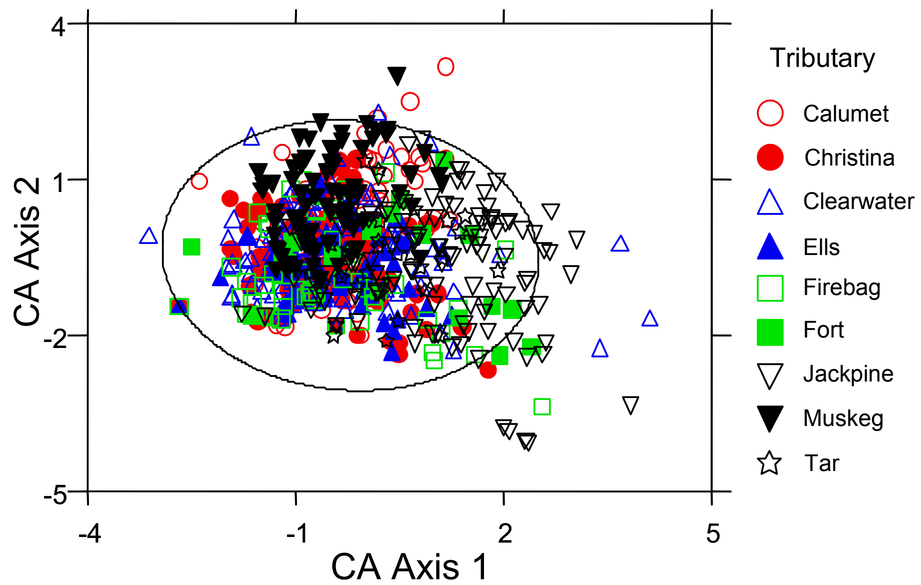
3.6.6.1 Reaches

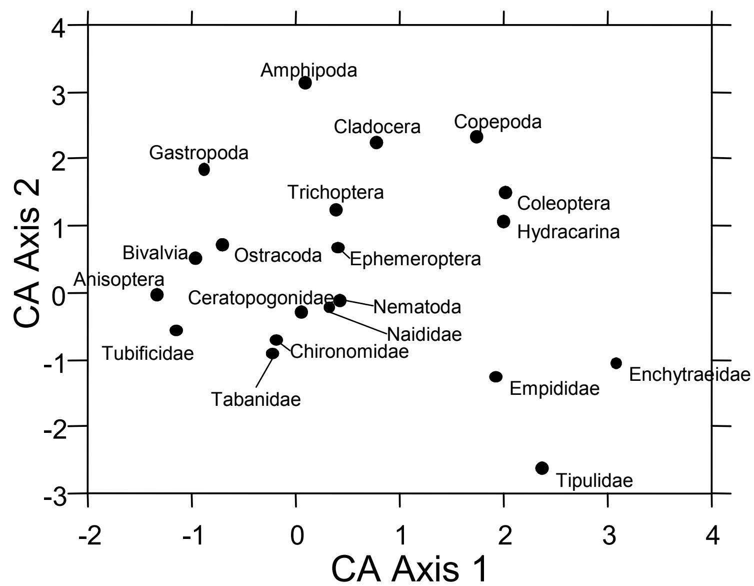
Potential changes or differences in benthic invertebrate communities are evaluated by comparing indices of community composition (abundance, richness, diversity, evenness, and percent EPT) in *test* reaches to upstream *baseline* reaches and/or to pre-impact conditions with analysis of variance (ANOVA). When necessary, dependent variables (indices) are $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances. One-way ANOVAs are conducted for each benthic community index with each reach-year combination as the factorial variable. Planned comparisons are then used to identify differences between *baseline* and *test* reaches, between pre- and post-impact periods, and changes over time. A comparison that tests for the interaction between *baseline* and *test* reaches and trends over time makes it possible to evaluate if temporal patterns differ between the *baseline* and *test* reaches of a system. Differences between *baseline* and *test* reaches are also evaluated for data collected in the most recent surveyed year only. In all cases, the comparisons are tested against the residual error of the omnibus one-way ANOVA, because that error term is the best estimator of residual (among sites) variation.

Habitat types between upstream and downstream reaches are not always the same. In these cases the proposed model (comparison of upstream and downstream reaches) assumes that trends over time are the same in both *baseline* and *test* reaches. When effects are large, time trends in different habitat types should be similar. Time trends may not be similar in different habitat types if effects are subtler.

Baseline ranges are established separately for erosional and depositional reaches because they are distinct in composition. Multivariate analysis (correspondence analysis) is also used to produce a fully statistically-based characterization of normal ranges. Figure 3.9, for example, illustrates a correspondence analysis of *baseline* erosional reach data from 1998 to 2007. Points falling outside the *baseline* ellipse (95% region) indicate potential effects exceeding the normal background variability.

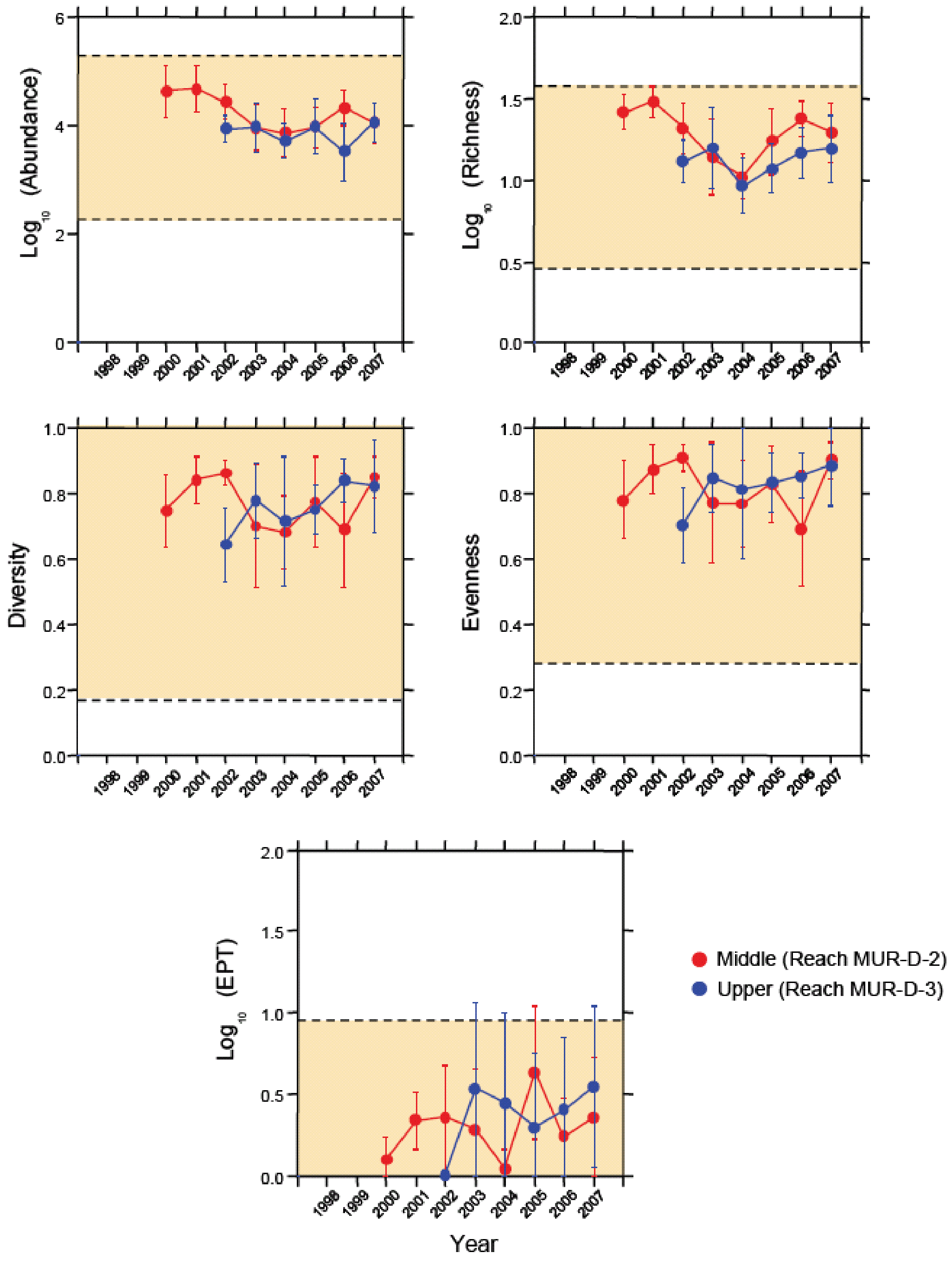
Figure 3.9 Biplot of benthic invertebrate community sample scores based on a correspondence analysis of taxon abundances for erosional *baseline* reaches (1998 to 2007).





For all significant and non-significant results, time trends of indices are compared with the background variability observed in all *baseline* reaches (e.g., Figure 3.10). Variability in *baseline* reaches is represented by the mean ± two standard deviations ($\overline{X}$ ± 2 SDs), where the mean is the average of all baseline observations across years. For regional baseline benthic invertebrate calculations, reaches that are downstream of non-RAMP oil sands activities are excluded in the background baseline variability calculations in addition to all *test* reaches (see Table 3.16). The analysis could be modified to produce a "floating" annual average by estimating means and SDs for each year if year-to-year variability is shown to be significant.

Figure 3.10 Variations in indices of benthic invertebrate community composition in the middle and upper reaches of the Muskeg River system (Figure 5.2-9 in the 2007 Annual Report).



Upper and lower dotted lines represent the mean baseline condition ± 2 standard deviations.

3.6.6.2 Lakes

Shipyard and Isadore's lakes are the two "*test*" lakes in the RAMP design. Variations in indices of benthic community composition are compared to Kearl and McClelland Lakes using ANOVA as above, and testing for differences in time trends between lakes using planned contrasts. No comparison to regional baseline ranges of index values is performed because there are too few lakes to carry out that style of analysis.

3.6.6.3 ARD Channels

There are no baseline data specific to the ARD channels. Trends in index values from the ARD channels are therefore compared over time and to the regional baseline ranges established for depositional river reaches.

3.7 BENTHOS AND SEDIMENT COMPONENT: SEDIMENT QUALITY

3.7.1 Component History

Sediment quality within the Athabasca River was described by various researchers in the 1970s and 1980s, although these studies did not include intensive sampling (Golder 1998). In the early 1990s, small-scale sediment sampling occurred in studies conducted for industry (e.g., baseline studies for the Steepbank Mine EIA) and in studies sponsored by the federal Panel for Energy Research and Development (PERD) (Golder 1998).

The first RAMP study in 1997 included sediment sampling at two locations in the Athabasca River (above and below the oil sands area), in the Muskeg, Steepbank, and MacKay rivers, and in Jackpine and Poplar creeks. The RAMP sediment quality program expanded in subsequent years with planned oil sands development and the overall scope of RAMP, with samples collected in baseline tributary watersheds, tributary watersheds with oil sands development, the Athabasca River mainstem and delta, and regionally important lakes and wetlands (Table 3.19, Figure 3.8).

Sediment sampling in the Athabasca River mainstem was discontinued in 2005. Most sediments in the Athabasca River mainstem flowing through the RAMP study area are comprised of sand, and are not, therefore, truly depositional. Sediment accumulation, which allows monitoring of temporal changes in sediment quality, does not generally occur in the river mainstem, largely because of the flushing of sediments in the Athabasca River during the freshet, when average discharge increases from about 125 to 2,000 m^3/s. Sampling efforts were shifted to the Athabasca River delta, a depositional area where the quality of sediments that accumulate over time can be monitored (Conly *et al.* 2002).

In 2006, by a decision of the RAMP Technical Program Committee, the sediment quality component was integrated with the benthic invertebrate component to collect physical and chemical data for facilitating interpretation of benthic invertebrate community results. This resulted in the relocation of sediment sampling stations to the lower end of depositional reaches sampled by the benthic invertebrate component and the discontinuation of sediment sampling in erosional reaches, as well as a shift in the analytical approach (see Section 3.7.6). Sediment quality in benthic invertebrate depositional reaches is evaluated to assess benthic invertebrate habitat quality and whether newly deposited (accumulating) fine sediments are changing over time in ways that may be related to oil sands operations or other processes. Resources that had been allocated originally to sediment sampling on the Athabasca River for the 2006 sampling season were instead reallocated to a one-time, extensive study of sediments within the Athabasca River Delta.

The original RAMP sediment quality sampling network and design (until 2006) were intentionally similar to the water quality component design, to provide consistency, comparability and efficiency between the two components. Similar to the current water quality component, the RAMP sediment quality program prior to 2006 incorporated elements of before/after, control/impact, gradient, and reference-condition experimental designs in order to assess sediment quality at potentially impacted stations relative to regional baseline data. Since 2006, sediments are sampled concurrently with benthic invertebrate sampling at the most downstream benthic invertebrate replicate sampling station in depositional reaches, and at one randomly selected benthic invertebrate sampling station in regional lakes.

RAMP analyzes numerous physical, chemical and toxicological variables in sediment samples (Table 3.20). This list of variables was first developed by the initial implementing consultant for RAMP from previous sampling designs for baseline studies and EIAs in the region, with input from Alberta Environment and other RAMP stakeholders (Noton, L., *pers. comm.* 2005; Lagemodiere, M., *pers. comm.* 2005). These variables are intended to provide data that support habitat assessments for the biological components of RAMP (i.e., benthic invertebrate and fish), and also may be specific potential stressors of aquatic biota related to oil sands operations. Some variables measured (e.g., various metals) are not specific potential oil-sands-related stressors or supporting data, but rather are provided as part of an analytical chemistry package with other, relevant variables by consulting laboratories.

The analytical list of variables has been relatively consistent over time, although some changes have occurred, including:

- In 1998, addition of particle size distribution, total inorganic carbon, total carbon, and 10-day sublethal toxicity tests using *Chironomus tentans*, *Hyalella azteca* and *Lumbriculus variegatus*;
- In 2000, addition of Total Volatile Hydrocarbons (TVH) and Total Extractable Hydrocarbons (TEH);
- In 2004, elimination of the 10-day *L. variegatus* sublethal test, primarily due to QA/QC interpretation issues related to organism breakage; and

- In 2005, substitution of the Canadian Council of Ministers of the Environment (CCME) four-fraction hydrocarbon assay for Total Recoverable, Total Extractable and Total Volatile Hydrocarbon tests (following implementation of both tests in 2004 for comparison), given improved discrimination of hydrocarbon fractions using the standard CCME test and the availability of associated environmental quality guidelines.

Analytical laboratories used by RAMP for sediment quality analyses generally have remained consistent: ALS Laboratories (formerly Enviro-Test Laboratories Ltd.) has undertaken physical measurements and metals analysis of sediments since 1997; HydroQual Laboratories Ltd. has undertaken sublethal toxicity testing; and AXYS Analytical Ltd. of Sidney, BC has undertaken PAH analyses since 1998 (ETL analyzed sediment PAHs in 1997).

3.7.2 Key Indicator Resources

Sediment quality variables do not themselves constitute KIRs from an environmental assessment perspective. However, as stressors and/or supporting variables for other RAMP components, these variables provide important measurement endpoints indicating the suitability of a waterbody or watercourse to support aquatic life, particularly benthic invertebrates. Sediment quality data can also indicate potential change (accumulation) of chemicals of concern, within or outside the range of natural variability. Sediment quality measurement endpoints and criteria are discussed in Section 3.7.4.

Table 3.19 Summary of RAMP data available for the Sediment Quality component, 1997 to 2008.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																	
Upstream of Fort McMurray (cross channel)	ATR-UFM																								1				3				1																
Upstream of Donald Creek (west bank)[a]	ATR-DC-W				3				3								1				3				1				3				1																
(east bank)[a]	ATR-DC-E				3				3								1				3				1				3				1																
Upstream of Steepbank River (west bank)	ATR-SR-W																1				3				1				3				1																
(east bank)	ATR-SR-E																1				3				1				3				1																
Upstream of the Muskeg River (west bank)[a b]	ATR-MR-W								3								1				3				1				3				1																
(east bank)[a b]	ATR-MR-E								3								1				3				1				3				1																
Upstream of Fort Creek (west bank)[a b]	ATR-FC-W				3				3								1				3				1				3																				
(east bank)[a b]	ATR-FC-E				3				3								1				3				1				3																				
Testing inter-site variability (3 composite samples)	-																1								1																								
Downstream of all development (west bank)	ATR-DD-W																								1				3				1																
(east bank)	ATR-DD-E																								1				3				1																
Upstream of mouth of Firebag River (west bank)	ATR-FR-W																								1				3				1																
(east bank)	ATR-FR-E																								1				3				1																
Upstream of the Embarras River	ATR-ER																3				1				1				3				1				1								1				3
Athabasca Delta / Lake Athabasca																																																	
Delta composite[c]	ARD-1											3					3																																
Big Point Channel	BPC																				3				3				3								1								1				3
Goose Island Channel	GIC																				3				3				3								1								1				3
Fletcher Channel	FLC																				3				3				3								1								1				3
Flour Bay	FLB-1																3																																
Athabasca River Tributaries (South of Fort McMurray)																																																	
Clearwater River (upstream of Fort McMurray)	CLR-1/CLR-D-1																				1				3				3																				3
(upstream of Christina River)	CLR-2																				1				3				3																				3
Christina River (upstream of Fort McMurray)	CHR-1																								1				3				3																
(upstream of Janvier)	CHR-2																								1				3				3																
(benthic reach at mouth)	CHR-D-1																																								3				1				
benthic reach at upper Christina River)	CHR-D-2																																								3								
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																3				3												
Athabasca River Tributaries (North of Fort McMurray)																																																	
McLean Creek (mouth)	MCC-1												3				3				1				3												3												
Beaver River	BER-D-2																																																3
Poplar Creek (mouth)	POC-1/POC-D-1				1																				3								3																3
Steepbank River (mouth)	STR-1				1				1																3												3												
(upstream of Suncor Project Millennium)	STR-2				1																				3												3												
(upstream of North Steepbank)	STR-3																																				3												
North Steepbank River (upstream of P.C. Lewis)	NSR-1																								3				3				1				1												
MacKay River (mouth)	MAR-1				1				1												3				3								3																
(upstream of Petro-Canada MacKay)	MAR-2																				1				3								3																

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)
2 = sediment toxicity testing (*Chironomus tentans, Lumbriculus variegatus,* Hyalella azteca)
3 = standard sediment quality + toxicity testing
√ = allowance made for potential TIE
* Sediment program integrated with Benthic Invertebrate Community component in 2006.

Footnotes

[a] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)
[b] Samples were collected downstream of tributary in 1998
[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

Test (downstream of focal projects)
Baseline (upstream of focal projects)
Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

Table 3.19 (Cont'd.)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Tributaries (North of Fort McMurray) (cont'd)																																																	
Ellis River (mouth)	ELR-1								1																3				3				3				1												
(benthic reach at mouth)	ELR-D-1																																								3				3				
(upstream of CNRL Lease 7)	ELR-2																																3				1												
Tar River (mouth)	TAR-1								1																3				3				1				1												
(benthic reach at mouth)	TAR-D-1																																								3								
(upstream of CNRL Horizon)	TAR-2																																1				1												
Calumet River (mouth)	CAR-1																								3								3				3												
(upstream of CNRL)	CAR-2																																				3												
(benthic reach at upper Calumet)	CAR-D-2																																								3								
Fort Creek (mouth)	FOC-1																1								3																								
(benthic reach at mouth)	FOC-D-1																																				3				3				3				3
Firebag River (mouth)	FIR-1																								3				3				1				1												
(benthic reach at mouth)	F1R-D-1																																								3				1				
(upstream of Suncor Firebag)	FIR-2																								3				3				1				1												
Muskeg River																																																	
Mouth	MUR-1				1				1				3				1				1				3				3				3																
1 km upstream of mouth	MUR-1b																1												1																				
Upstream of Canterra Road Crossing	MUR-2																1								3				3				3																
Upstream of Jackpine Creek	MUR-4				1												1												1																				
Upstream of Muskeg Creek	MUR-5																1												1																				
Upstream of Stanley Creek	MUR-D-2																								3				3				3																
Upstream of Wapasu Creek	MUR-6																1												1																				
(benthic reach - downstream of Jackpine Creek)	MUR-D-2																																								3				3				3
(benthic reach - upstream of Stanley Creek)	MUR-D-3																																								3				3				3
Muskeg River Tributaries																																																	
Jackpine Creek (mouth)	JAC-1				1																												3																
(benthic reach at mouth)	JAC-D1																																								3				1				3
(benthic reach at upper Jackpine Creek)	JAC-D2																																								3				1				3
Stanley Creek (mouth)	STC-1																												1																				
Wetlands																																																	
Kearl Lake (composite)	KEL-1																				1												1								3				3				3
Isadore's Lake (composite)	ISL-1																				1																				3				3				3
Shipyard Lake (composite)	SHL-1																				1				3				1				3								3				3				3
McClelland Lake (composite)	MCL-1																								1																3				3				3
Additional Sampling (Non-Core Programs)																																																	
Potential TIE	-																				√																												
QA/QC																																																	
One split and one duplicate sample	-																1				1				1				1				1				1				1				1				1

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)
2 = sediment toxicity testing (*Chironomus tentans, Lumbriculus variegatus,* Hyalella azteca)
3 = standard sediment quality + toxicity testing
√ = allowance made for potential TIE
* Sediment program integrated with Benthic Invertebrate Community component in 2006.

Footnotes

[a] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)
[b] Samples were collected downstream of tributary in 1998
[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

Test (downstream of focal projects)
Baseline (upstream of focal projects)
Baseline, but excluded from Regional Baseline calculations because of upstream non-RAMP oil-sands activities.

Table 3.20 Sediment quality variables measured by RAMP, including variables added or removed from the program since 1997.

Group	Sediment quality variable	
Physical variables	Percent sand Percent silt	Percent clay Moisture content
Carbon content	Total inorganic carbon Total organic carbon Total carbon	
Total metals	Aluminum Arsenic Barium Beryllium Boron Cadmium Calcium Chromium Cobalt Copper Iron Lead Magnesium	Manganese Mercury Molybdenum Nickel Potassium Selenium Silver Sodium Strontium Thallium Uranium Vanadium Zinc
Organics	AEP Tier 1 total hydrocarbons:[1] Total recoverable hydrocarbons[1] Total volatile hydrocarbons (C5-C10)[1] Total extractable hydrocarbons (C11-C30)[1] CCME 4-fraction total hydrocarbons:[1] BTEX (Benzene, Toluene, Ethylene, Xylene)[1] F1 (C6-C10)[1] F2 (C10-C16)[1] F3 (C16-C34)[1] F4 (C34-C50)[1]	
Parent PAHs	Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene/chrysene Benzo(a)pyrene Benzofluoranthenes Benzo(g,h,i)perylene Biphenyl	Dibenzo(a,h)anthracene Dibenzothiophene Fluoranthene Fluorene Indeno(c,d-123)pyrene Naphthalene Phenanthrene Pyrene

[1] CCME 4-fraction test added in 2004; AEP Tier-1 variables (i.e., TVH, TEH, TRH) eliminated in 2005.

[2] 10-day *L. variegatus* test eliminated in 2004.

Table 3.20 (Cont'd.)

Group	Sediment quality variable
Alkylated PAHs	C1-substituted acenaphthene
	C1-substituted benzo(a)anthracene/chrysene
	C2-substituted benzo(a)anthracene/chrysene
	C1-substituted biphenyl
	C2-substituted biphenyl
	C1-substituted benzofluoranthene/ benzo(a)pyrene
	C2-substituted benzofluoranthene/benzo(a)pyrene
	C1-substituted dibenzothiophene
	C2-substituted dibenzothiophene
	C3-substituted dibenzothiophene
	C4-substituted dibenzothiophene
	C1-substituted fluoranthene/pyrene
	C2-substituted fluoranthene/pyrene
	C3-substituted fluoranthene/pyrene
	C1-substituted fluorene
	C2-substituted fluorene
	C3-substituted fluorene
	C1-substituted naphthalenes
	C2-substituted naphthalenes
	C3-substituted naphthalenes
	C4-substituted naphthalenes
	C1-substituted phenanthrene/anthracene
	C2-substituted phenanthrene/anthracene
	C3-substituted phenanthrene/anthracene
	C4-substituted phenanthrene/anthracene
	1-methyl-7-isopropyl-phenanthrene (retene)
Chronic toxicity testing	Survival and growth of Chironomus tentans midge larvae
	Survival and growth of the amphipod Hyalella azteca
	Survival and growth of the earthworm Lumbriculus variegatus2

[1] CCME 4-fraction test added in 2004; AEP Tier-1 variables (i.e., TVH, TEH, TRH) eliminated in 2005.

[2] 10-day *L. variegatus* test eliminated in 2004.

3.7.3 Hypotheses and Questions

3.7.3.1 Hypotheses and Questions from Athabasca Oil Sands EIAs

There are few residual impact assessments in oil sands EIAs related to effects on sediment quality. Of the 17 EIAs reviewed for the 2005 RAMP Technical Design and Rationale document (Chapter 2), only 29 residual impact assessments pertained to sediment quality; all of these residual impact assessments were predicted to be low or negligible in magnitude, and typically local in extent. Predictions relating to sediment quality typically were associated with surface mines only, not *in situ* operations, and related to potentially increased PAH concentrations in sediments related to muskeg dewatering, release of project waters, or end-pit lake discharges (Table 3.21).

Other predictions were related to potential effects of increased sedimentation (i.e., changes in sediment quantity, rather than quality) from dewatering, accidental spills or leaks, or in-stream construction. Issues of increased suspended sediment loads are addressed by the water quality component, through monitoring of total suspended solids.

Table 3.21 Athabasca oil sands activities with potential effects on sediment quality.

Main Impact Pathways (from Section 2.2, Page 2-1)	Oil Sands Activities (summarized from Table 2.2, Page 2-6 and Table 2.3, Page 2-10)
▪ Changes in hydrological conditions	▪ Activities involving instream construction and bank excavation
▪ Introduction of pollutants into waterbodies and watercourses as part of purposeful water releases into watercourses and waterbodies ▪ Introduction of pollutants into waterbodies and watercourses as an indirect consequence of project activities	▪ Muskeg and overburden dewatering, mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows

3.7.3.2 RAMP Objectives, Key Questions and Hypotheses

RAMP monitors sediments in order to provide supporting habitat data for interpretation of benthic invertebrate community monitoring results, to support the RAMP fish component, and to identify human and natural factors affecting sediment quality in streams and lakes in the oil sands region. Assuming that the sampled depositional areas accumulate sediments over time, monitoring the physical and chemical composition of sediment provides a time-integrated measurement of environmental quality. This helps to identify environmental change and potential chemical exposure pathways between the physical environment and biotic communities associated with bottom sediments and overlying waters.

The specific objectives of the sediment quality sub-component are to:

- provide data that can be used to aid interpretation of RAMP benthic invertebrate surveys;
- assess the suitability of waterbodies to support aquatic life (e.g., benthic invertebrates, fish); and

- provide data for inclusion in a sediment quality database, to characterize natural variability, assess EIA predictions, and meet requirements of regulatory approvals.

These objectives lead to the following questions for the RAMP sediment quality sub-component:

- What sediment quality data are required by other RAMP components to assist in interpretation of monitoring results?
- Is sediment quality in the RAMP study area suitable to support aquatic life?
- Are sediment quality measurement endpoints correlated with benthic invertebrate measurement endpoints?

From these questions, the following hypotheses are formulated for the sediment quality component:

- H_{o1}: Sediment quality characteristics at each sampling location do not exceed relevant environmental quality guidelines.
- H_{o2}: Sediment quality measurement endpoints are not correlated with benthic invertebrate measurement endpoints.

The first hypothesis is tested through comparison of all observed sediment quality data against relevant guidelines. The second hypothesis is assessed by conducting correlation analysis to identify relationships between sediment quality variables and benthic invertebrate measurement endpoints.

3.7.4 Measurement Endpoints and Criteria for Determining Change

RAMP collects approximately 80 sediment quality variables at each station, with over 1,300 measurements of sediment quality collected in 2008. Although the sediment quality variables measured by RAMP are relevant to assessment of aquatic habitat quality and are appropriate to RAMP objectives, they are too numerous for correlation analysis to be conducted on each and to all be presented in each RAMP report. Therefore, a short list of sediment quality measurement endpoints has been identified for more detailed analysis and presentation. This list is reviewed and updated annually as required. The selection of the sediment quality measurement endpoints is guided by information obtained from the following sources:

- Sediment quality measurement endpoints listed in the environmental impact assessments of oil sands projects as being potentially affected;
- Sediment quality variables of interest listed in the RAMP 5-year report (Golder 2003a);
- Results of correlation analysis of the RAMP 1997-2004 sediment quality dataset indicating significant inter-correlation of various variables;

- Discussions among RAMP Component Managers about the importance of various sediment quality variables to interpretation of other RAMP components, particularly benthos; and
- Discussions with RAMP Technical Subcommittee members during regular meetings held to discuss analytical strategies for the benthic invertebrate/sediment quality components.

Table 3.22 presents variables listed in these various sources. In the most recent RAMP Technical Report (RAMP 2009), the following sediment quality measurement endpoints were selected for detailed consideration, as follows:

- *Particle size distribution (clay, silt and sand)*: sediment particle size is an indicator of depositional regime at a given station, and an important factor affecting organic chemical sorption and benthic invertebrate communities;
- *Total organic carbon*: an indicator of organic matter in sediment, including hydrocarbons;
- *Total hydrocarbons (CCME fractions)*: Indicators of the total hydrocarbon content of sediments, with each indicator (fraction) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms);
- *Various PAH measurement endpoints, including:*
    - *Total PAHs:* a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
    - *Total parent PAHs:* a sum of concentrations of all non-alkylated PAHs measured in a given sample;
    - *Total alkylated PAHs:* a sum of concentrations of all alkylated PAHs measured in a given sample (typically, alkylated species comprise the majority of PAHs associated with bitumen);
    - *Naphthalene:* a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;
    - *Retene:* an alkylated phenanthrene generated through decomposition of plant materials (i.e., not associated with petroleum sources);
    - *Total dibenzothiophenes:* a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic); and
    - *Predicted PAH toxicity:* an estimate of the cumulative toxicity of all parent and alkylated PAHs measured in a sediment sample, derived using an equilibrium partitioning approach described in Neff *et al*. (2004);

- *Metals:* with the exception of total arsenic, only metals that exceeded CCME ISQG values are presented, as metals in sediments are not listed in oil sands EIAs as being potentially affected by development;
- *Total arsenic:* In analyses of sediment quality in the ARD and in regional analyses of sediment quality in tributaries, data for total arsenic in sediments are included as a measurement endpoint, given recent stakeholder concerns regarding arsenic in regional sediments; and
- *Sublethal toxicity:* sublethal toxic effects of sediment on the survival and growth of the amphipod (seed shrimp) *Hyalella azteca* or the midge *Chironomus tentans*.

Table 3.22 Sediment quality variables of interest to RAMP, from oil sands EIA predictions and other sources.

Analyte Group	Variables Listed in EIAs (n=17 projects)	RAMP 5-year Report (Golder 2003a)	Variables to Support Other RAMP Components[1]	Additional Suggested Variables
Physical Variables	(None)	(None)	Particle size distribution	
Carbon Content	(None)	(None)	Total organic carbon	Total inorganic carbon Total organic carbon
Total Hydrocarbons	(None)	TRH	CCME F1, F2 Tier 1 TEH	CCME F1-F4+BTEX Tier 1 TVH, TEH, TRH
Metals	(None)	Total metals	Total metals	(Metals that are high relative to SQGs)
PAHs	General PAHs (4)	Naphthalene C1 Naphthalene	Total PAHs Parent PAHs Alkylated PAHs	Naphthalene Dibenzothiophenes Retene
Effects-based Endpoints	Chronic toxicity (1)		Chronic toxicity	

[1] Primarily benthos (inferred).

Sediment quality data are analyzed or assessed as follows:

- **Assessed for correlation with benthic invertebrate measurement endpoints**. Selected sediment quality variables are evaluated for correlation with benthic invertebrate variables in order to identify the physical and chemical variables that may be influencing benthic invertebrate populations. This method is used to address the question stated in Section 3.7.3, "Are sediment quality measurement endpoints correlated with benthic invertebrate measurement endpoints?"
- **Comparison to sediment quality guidelines.** All sediment quality data collected by RAMP are screened against Canadian Council of Ministers of the Environment (CCME) Canadian sediment quality guidelines. All

values that exceed these guidelines are reported explicitly in the body of the annual RAMP technical reports. These comparisons are used to address the question stated in Section 3.7.3, "Is sediment quality in the RAMP study area suitable to support aquatic life?"

- **Comparison against historical and baseline data.** Sediment quality measurement endpoints at specific stations are compared against results at that location from previous years, if available, to identify and assess any changes in sediment quality over time that may be attributable to oil sands activities or other factors. Where possible, comparisons are made between upstream (*baseline)* and downstream (*test*) stations.

- **Calculation of a Sediment Quality Index.** Overall sediment quality at each station is summarized in a Sediment Quality Index, described further in Section 3.7.6.3, which expresses the degree to which specific measurement end-points of sediment quality are consistent with regional *baseline* water quality characteristics.

3.7.5 Monitoring Station Selection and Monitoring Design

3.7.5.1 Station Establishment and Monitoring Over Time

Since Integration with Benthic Invertebrate Sampling in 2006

Sediments are monitored at stations located throughout the RAMP study area, from the upper Christina River to the Athabasca River delta (Figure 3.8). On tributaries to the Athabasca River, sediment sampling occurs at the most downstream benthic invertebrate sampling station, generally near the mouth of each tributary river or creek where depositional sediments, carried downstream through these tributary watersheds, typically may be found. In the delta and in lakes, sediments are sampled at one randomly selected benthic invertebrate replicate station at each site.

Additional samples of sediment physical characteristics of sediment (i.e., particle size distribution and TOC only) also are collected at all other replicate sampling locations within depositional benthos reaches.

Prior to Integration with Benthic Invertebrate Sampling (1997 to 2005)

Previous to harmonization with the benthic-invertebrate component in 2006, sediments were monitored at specific stations located throughout the RAMP study area, from the upper Christina River to the Athabasca River delta. On tributaries to the Athabasca River, the majority of sediment sampling occurred near the mouth of each tributary river or creek, in conjunction with water quality sampling locations; depositional sediments, carried downstream through these tributary watersheds, typically may be found near these stream mouths.

The initial RAMP Program Design and Rationale (Golder 2000, 2002) document outlined planned sampling schedules, as follows:

- New stations located in waterbodies not yet monitored by RAMP, were to be sampled for sediment each fall for three years to establish baseline (i.e., pre-development) conditions, with at least two years of sampling including measurement of sublethal toxicity;

- New sampling locations in waterbodies/watersheds already sampled by RAMP were to be sampled less frequently, following the sampling schedule of other stations in that waterbody/watershed (typically once every three years), unless initial sampling indicated that sediment quality at a station substantially differed from other stations already sampled in that watershed;

- Ongoing sampling at all stations occurred at three year intervals, with the exception of the lower Muskeg River (MUR-1), which was sampled annually;

- Sublethal toxicity testing at ongoing sampling stations also occurred every three years, but was limited or not conducted in regional lakes/wetlands or upper reaches of tributaries; and

- Ongoing sampling schedules were staggered over three-year cycles, with tributaries to the west and east of Fort McMurray sampled in different years, to distribute sampling efforts.

Sediment sampling locations and frequency now are dictated by the benthic-invertebrate-sampling design.

3.7.5.2 Rationale for Specific Monitoring Locations

The RAMP sediment quality component has grown with the overall RAMP program since 1997, in response to new proposed and operational oil sands developments. As discussed above, since 2006 the sediment quality sampling design has been harmonized with the sampling design used for benthic invertebrate community component. Accordingly, the rationale for the location of sediment quality stations is consistent with the rationale previously outlined for benthos sampling stations in Table 3.18.

Specific reasons for establishment of each RAMP sediment quality monitoring station from 1997 to 2006 are listed in the following tables (Tables 3-23 to 3-28). This information builds upon previously stated reasons for each station from earlier RAMP Program Design and Rationale documents (Golder 2000, 2002, RAMP 2005b). In almost all cases, sediment sampling locations were co-located with water quality stations until 2005, to facilitate efficient sampling and inter-comparisons of water and sediment quality results. All sediment sampling was undertaken by RAMP.

Generally, sediments along the Athabasca River mainstem between Fort McMurray and the Athabasca River delta are composed of sand, and do not accumulate over years. Although suspended sediments deposit in the river mainstem in fall and winter, these sediments are flushed out during spring freshet when the average discharge increases from about 125 to about 2,000 m^3/s. From 1997 to 2004, sediments were sampled from the east and west banks of the Athabasca River mainstem, at identical stations to those sampled for water quality (Table 3.23), following a combined control/impact (upstream/downstream) and gradient design. Sediments in the Athabasca River delta, an area of continual sediment deposition and accumulation, have been sampled irregularly since 1999 (Table 3.24). In 2005, previously allocated sampling resources for the Athabasca River mainstem were reallocated to allow a one-time extensive survey of sediment chemistry in the Athabasca River delta, with future RAMP sediment sampling efforts to be focused on the Athabasca River delta, an area of known sediment accumulation downstream of all oil sands development. As with the benthic-invertebrate component, sediment chemistry has been sampled annually in the Athabasca delta since 2005 (since the programs were redesigned that year), except in 2006, when sampling was could not be completed because of very low water levels in the Athabasca River and delta that fall.

Table 3.23 Rationale for RAMP sediment quality sampling locations in the Athabasca River mainstem, 1997 to 2004.[1]

Station Identifier and Location		Rationale
ATR-UFM	Upstream of Fort McMurray	Alberta Environment long-term water quality monitoring station; provides a baseline sediment quality upstream of Fort McMurray and oil sands developments.
ATR-DC	Upstream of Donald Creek (east and west banks)	An “upstream” sampling location unaffected by oil sands development further downstream, but downstream of the town of Fort McMurray and Clearwater River.
ATR-SR	Upstream of the Steepbank River (east and west banks)	Located upstream of Steepbank River at RAMP water quality station ATR-SR.
ATR-MR	Upstream of the Muskeg River (east and west banks)	Located downstream of the Steepbank River and upstream of the Muskeg River, at WQ station ATR-MR.
ATR-FC	Upstream of Fort Creek (east and west banks)	Established to assess potential cumulative effects of upstream developments on Athabasca River water quality, including projects along the river and in the Steepbank, Muskeg, MacKay, Ells, Tar, and other upstream tributary watersheds. Sampling discontinued here after 2003, given potential downstream influences of Fort Hills and Canadian Natural-Horizon projects, and proximity of ATR-DD.
ATR-DD	Downstream of all development (east and westbanks)	Located to be directly below all operations and reclamation water releases of oil sands developments, and intended to be an indicator of cumulative effects, this station is now adjacent to Fort Hills and upstream of proposed projects in the Firebag watershed.
ATR-FR	Upstream of the Firebag River (cross-channel composite)	Located upstream of the Firebag River; Like ATR-DD, provides data describing cumulative effects.
ATR-ER	Upstream of the Embarras River (cross-channel composite)	Sampled since 2000. Located downstream of all development, but upstream of potential influences of Lake Athabasca on sedimentation regime. Historical concerns regarding presence of eroding bank material into sampling area at this location.

[1] Sediment sampling discontinued at all stations in the Athabasca River mainstem except ATR-ER after 2004, given lack of consistent sediment deposition and accumulation, and RAMP Technical Committee decision to focus sampling efforts on the Athabasca River delta. Sediment sampling at ATR-ER continues annually, given increasing concentrations of PAHs observed over some years.

Table 3.24 Rationale for RAMP sediment quality sampling locations in the Athabasca River delta, 1999 to 2008.

Station Identifier and Location		Rationale
ARD-1	Athabasca River Delta (composite)	Composite sample of sediments from stations BPC, FLC and GIC (below), intended to provide a general indication of delta sediment quality. Sampled 1999 and 2000 only.
BPC-1	Big Point Channel	A main channel in the Athabasca River delta, located in an area of interest to local stakeholders. Ongoing annual sampling, harmonized with benthic component since 2006.
FLC-1	Fletcher Channel	A main channel in the Athabasca River delta, located in an area of interest to local stakeholders. Ongoing annual sampling, harmonized with benthic component since 2006.
BPC-1	Goose Island Channel	A main channel in the Athabasca River delta, located in an area of interest to local stakeholders. Ongoing annual sampling, harmonized with benthic component since 2006.
FLB-1	Flour Bay	An area of interest to local stakeholders. Sampled in 2000 only.

Table 3.25 Rationale for RAMP sediment quality sampling locations in the Muskeg River watershed, 1997 to 2005.[1]

Station Identifier and Location		Rationale
Muskeg River mainstem		
MUR-1	Muskeg River (mouth)	Provides data describing cumulative effects of upstream development in the watershed. Sampled annually.
MUR-1B	Muskeg River (1 km u/s of mouth)	Sampled to assess variability in lower reaches of the Muskeg River.
MUR-2	Upstream of Canterra Rd. crossing	Downstream of the Muskeg River Mine and other upstream developments; corresponds to AENV and industry water quality monitoring locations.
MUR-4	Upstream of Jackpine Creek	Located downstream of Aurora North and other upstream developments, but upstream of Muskeg River Mine; corresponds to industry water quality monitoring station.
MUR-5	Upstream of Muskeg Creek	Located upstream of Aurora North, but downstream of Stanley Creek and the proposed Kearl project; corresponds to industry water quality monitoring station.
MUR-6	Upstream of Wapasu Creek	An upstream *baseline* station for all downstream stations, although this station is now downstream or within Sunrise and Kearl project leases.
Muskeg River tributaries		
JAC-1	Jackpine Creek (mouth)	Selected to monitor potential effects of the Shell-Albian Jackpine Mine. Sampled in 1997 and 2004.
STC-1	Stanley Creek (mouth)	Selected to monitor potential effects of Aurora North project.

[1] Sediment sampling locations harmonized with depositional benthic-invertebrate sampling locations since 2006.

Table 3.26 Rationale for RAMP sediment quality sampling locations in various watersheds downstream of Fort McMurray, 1997 to 2005.[1]

Station Identifier and Location		Rationale
McLean Creek		
MCC-1	McLean Creek (mouth)	Selected to monitor potential effects of Suncor Project Millennium.
Poplar Creek		
POC-1	Poplar Creek (mouth)	Sampled to assess potential effects of Syncrude Mildred Lake operations.
Steepbank River		
STR-1	Steepbank River (mouth)	Selected to monitor potential effects of Suncor Steepbank Project Millennium, and Suncor Firebag, potential future projects (Suncor Lewis), downstream indicator of potential cumulative effects on sediment quality in this watershed.
STR-2	Steepbank River (upstream of Project Millennium)	Upstream *baseline* station for Suncor Project Millennium; downstream of PC Lewis.
STR-3	Steepbank River (upstream of North Steepbank River)	Upstream *baseline* station for Suncor Lewis and influences of North Steepbank River.
NSR-1	North Steepbank River (upstream of P-C Lewis)	Upstream *baseline* station for Suncor Lewis although now downstream of Suncor Firebag.
MacKay River		
MAR-1	MacKay River (mouth)	Selected to assess potential effects of Suncor MacKay and Syncrude Mildred Lake.
MAR-2	MacKay River (upstream of Suncor MacKay)	Upstream *baseline* station for MAR-1.
Ells River		
ELR-1	Ells River (mouth)	Selected to assess potential effects of Total E&P Joslyn project.
ELR-2	Ells River (upstream of Canadian Natural Lease 7)	Upstream *baseline* station for ELR-1.
Tar River		
TAR-1	Tar River (mouth)	Selected to assess potential effects of CRNL Horizon.
TAR-2	Tar River (upstream of Canadian Natural Horizon)	Upstream *baseline* station for TAR-1 (above CNRL-Horizon lease).
Calumet River		
CAR-1	Calumet River (mouth)	Selected to assess potential effects of CNRL-Horizon.
CAR-2	Calumet River (upper)	Upstream *baseline* station for CAR-1.
Fort Creek		
FOC-1	Fort Creek (mouth)	Selected to assess potential effects of Fort Hills and Aurora North projects.
Firebag River		
FIR-1	Firebag River (mouth)	Selected to assess potential effects of projects in this watershed, including Suncor Firebag, Husky Sunrise, and Synenco Northern Lights
FIR-1	Firebag River (upstream of Suncor Firebag)	Upstream *baseline* station for FIR-1, located upstream of all proposed projects.

[1] Sediment sampling locations harmonized with depositional benthic-invertebrate sampling locations since 2006.

Table 3.27 Rationale for RAMP sediment quality sampling locations in watersheds upstream of Fort McMurray, 1997 to 2005.[1]

Station Identifier and Location		Rationale
Clearwater River		
CLR-1	Clearwater River (upstream of Fort McMurray)	Selected to assess potential effects of upstream *in situ* oil sands developments on the Clearwater River.
CLR-2	Clearwater River (upstream of Christina River)	Upstream *baseline* station for CLR-1.
Christina River		
CHR-1	Christina River (mouth)	Selected to assess potential effects of upstream *in situ* oil sands developments.
CHR-2	Christina River (upstream of Janvier)	Upstream *baseline* station for CHR-1.
Hangingstone River		
HAR-1	Hangingstone R. (upstream of Fort McMurray)	Selected to assess potential effects of the future Suncor Meadow Creek project.

[1] Sediment sampling locations harmonized with depositional benthic-invertebrate sampling locations since 2006.

Table 3.28 Rationale for RAMP sediment quality sampling in various regional lakes and wetlands, 1997 to 2008.

Station Identifier and Location		Rationale
KEL-1	Kearl Lake	Monitored to assess potential effects of nearby oil sands projects on Kearl Lake. Ongoing sampling, harmonized with benthic-invertebrate sampling in this waterbody.
ISL-1	Isadore's Lake	Monitored to assess potential effects of nearby oil sands projects on Isadore's Lake. Ongoing sampling, harmonized with benthic-invertebrate sampling in this waterbody.
SHL-1	Shipyard Lake	Monitored to assess potential effects of nearby oil sands projects on Shipyard Lake. Ongoing sampling, harmonized with benthic-invertebrate sampling in this waterbody.
MCL-1	McClelland Lake	Monitored to assess potential effects of nearby oil sands projects on McClelland Lake. Ongoing sampling, harmonized with benthic-invertebrate sampling in this waterbody.

3.7.5.3 Sampling Protocols

RAMP sediment quality sampling follows accepted standards. RAMP Standard Operating Procedures (SOPs), initially based on Golder Associates Ltd. Technical Procedures, have been followed since the beginning of RAMP, and were revised and formalized for the RAMP 2005 program. These RAMP SOPs have been followed in each subsequent year (Appendix A4). Expanded QA/QC sampling also was added in 2005, as further described below.

The RAMP sediment quality field program is implemented each fall, with sediment quality samples collected at the same time as benthic invertebrate samples. Stations are accessed by helicopter, jet boat, dinghy, or four-wheel drive vehicle.

At each station, 2 to 4 grabs of sediment are collected with a 6″ x 6″ stainless steel Ekman dredge (0.023 m^2 area). Grab samples are transferred to a stainless steel pan; once sufficient sediment is collected for analysis, all samples are homogenized in the pan into a single composite sample with a stainless steel spoon. To minimize potential for sample contamination, pans, spoons, and the dredge are cleaned with a metal-free soap (e.g., Liquinox), rinsed with hexane and acetone, and triple-rinsed with ambient water at each station prior to sampling.

Homogenized samples are transferred into labelled, sterilized glass jars for chemical analyses, and/or to re-sealable plastic bags for toxicological analysis. All samples are stored on ice prior to and during shipment to analytical laboratories.

For all laboratory analyses, a suitable number of field duplicates and rinsate blanks (i.e., samples of water used to rinse cleaned sediment collection equipment) are collected during the field program to provide quality control and assurance regarding potential effects of field sampling and shipment protocols on sample quality.

3.7.6 Analytical Approach

The analytical approach undertaken for the sediment quality component includes the following steps:

- Review and selection of particular sediment quality variables as sediment quality measurement endpoints, including predicted toxicity of sediments due to PAHs (calculated using an equilibrium-partitioning model);
- Tabular presentation of results, comparing measurement endpoint results from the current year with concentrations previously observed within the reach or waterbody (for lakes), where data are available, and with sediment quality guidelines;
- Calculation of a sediment quality index, summarizing sediment quality at a given station relative to regionally typical sediment quality; and
- Analysis of the relationship between various sediment quality measurement endpoints and benthic invertebrate community measurement endpoints, using correlation analysis

3.7.6.1 Sediment Quality Measurement Endpoints

Review and selection of sediment quality measurement endpoints are described in Section 3.7.4.

3.7.6.2 Comparison to Historical Data and Sediment Quality Guidelines

Sediment quality data for each sediment quality measurement endpoint are tabulated for each station sampled. Historical variability, represented by minimum, maximum and median values observed (as well as number of observations) since 1997, is presented for each measurement endpoint and station. Concentrations of any sediment quality measurement endpoint that exceed relevant guidelines are highlighted and reported.

3.7.6.3 Sediment Quality Index

Beginning in 2008, sediment quality in each depositional benthic-invertebrate sampling reach was summarized using the CCME Sediment Quality Index calculator (http://www.ccme.ca/ourwork/water.html?category_id=103). This index uses an identical calculation to that developed by CCME for water quality (see Section 3.5.7.5), also yielding a single index value ranging from 0 to 100.

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

Index calculations for RAMP sediment quality data use regional *baseline* conditions as benchmarks for comparison. Specifically, 5th or 95th percentiles of *baseline* values for all variables included in the index were used as benchmarks against which individual water quality observations were compared. All sediment quality data collected by RAMP since 1997 at stations classified as *baseline* was used to develop *baseline* ranges of sediment quality.

Seventy-eight sediment-quality variables are included in calculation of the index, including total and fractional hydrocarbons, all parent and alkylated PAH species, all metals measured consistently in sediments by RAMP since 1997, and sediment-toxicity endpoints. For hydrocarbons and metals, data are compared against the 95th percentile of *baseline* data, while for sediment-toxicity endpoints, data re compared against the 5th percentile. Index values are calculated for all *baseline* and *test* stations. For all sediment-quality station observations from 1997 to 2008 (n=243), sediment quality index values of 45.7 to 100 were calculated.

Sediment-quality-index scores were classified using the following scheme:

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

3.7.6.4 Correlation Analyses

Spearman's rank correlations are used to evaluate the relationship between benthic community metrics (i.e., abundance, diversity, evenness, taxa richness, and EPT values) and selected sediment quality measurement endpoints. Statistically significant relationships are identified, and correlations identified as moderate (r_s between $|0.50|$ and $|0.75|$) and strong (r_s between $|0.75|$ and $|1.00|$) are identified.

3.8 FISH POPULATIONS COMPONENT

3.8.1 Component History

Fish population monitoring has been a component of RAMP since its inception in 1997. Surveys of fish populations were included in RAMP because they were considered an important biological indicator of aquatic health and a highly valued resource in the oil sands region. Fisheries monitoring is also consistently stipulated in regulatory approvals for each oil sands development.

From the beginning, the fish program focused on key waterbodies and fish species in an effort to streamline the scope of the monitoring program and maximize cost-efficiency. It was recognized early on that it was not logistically possible to broadly monitor fish populations in the manner used for other RAMP components such as water quality or benthic invertebrates. In addition, the mobile nature of many fish populations, particularly larger species of the Athabasca River, was a complicating factor when designing a program specific to the oil sands region. Consequently, the fish program of RAMP has included a wide variety of surveys since 1997 in an effort to:

- collect baseline information about fish populations (both resident and seasonal) in waterbodies that may be influenced by proposed oil sands development (supplemented with data from project-specific EIA baseline surveys);
- refine the design of long-term monitoring surveys used to evaluate potential changes in fish populations related to oil sands operations;
- evaluate the usefulness or suitability of alternate approaches for monitoring the integrity of fish populations in the region (i.e., proof-of-concept studies); and
- respond to concerns and needs of the various stakeholders and local communities.

The diversity of fisheries studies conducted from 1997 to 2008, and the specific waterbodies sampled, are summarized in Table 3.29 and Figure 3.11.

During the first few years of RAMP, the fish program focused on fish inventory work on the mainstem Athabasca River, as well as other watercourses such as the lower Muskeg and MacKay rivers. Inventory work on the Athabasca River was a continuation of Syncrude's original program and focused on reaches near Poplar Creek, the Steepbank River, the Muskeg River and the Tar and Ells rivers. With the exception of 1999 and 2000, the Athabasca inventory has been conducted annually, with emphasis on the spring and fall seasons. In 2004, three reaches on the Clearwater River were added to the inventory program in collaboration with ASRD. In 2006, two reaches were added to the Athabasca inventory near Fort Creek and Calumet River to encompass new development downstream of the existing reaches. The inventory information has been used to evaluate traditional fisheries statistics including length-at-age, condition, length frequency distributions and fish-habitat associations for key fish species. In 1997 and 1998, several walleye and lake whitefish were radio-tagged to evaluate the extent of seasonal movement patterns of these species within the Lake Athabasca-Athabasca River corridor. This information was obtained to better understand the degree of residency and extent of potential exposure of these important species in the oil sand region of the Athabasca River.

In 1998, analyses of fish tissue concentrations of PAHs and metals was initiated in response to local and Aboriginal community concerns regarding the safety of eating fish from the region. In addition, tissue burdens of chemicals were assessed in relation to fish health. This effort focused on composite samples of regionally important species from the Athabasca River and was harmonized with the fish inventory sampling effort. Over time, tissue work focused more on evaluating mercury levels in individual walleye, northern pike and lake whitefish of specific size ranges (and ages). The full PAH scan (40 PAHs) of composite samples was eventually dropped (unlikely to be detected in muscle) and the chemical suite was refined to include specific tainting compounds (nine PAHs) and total metals. Currently, RAMP conducts tissue analyses in fish from the Athabasca River and the Clearwater River, and from select regional lakes.

1998 was also the first year of fish fence monitoring to evaluate spring spawning use of tributary habitat by mainstem Athabasca River fishes. Much of this effort focused on the Muskeg River system due to expanding oil sands development in the watershed and presence of Arctic grayling, listed as sensitive species in Alberta (Alberta Sustainable Resource Development, 2001). Fences were deployed in 1998, 2001, 2002, 2003 and 2006 with varying levels of success due to high flows and unstable substrates. The fence in 2003 and 2006 were very successful and resulted in the Fish Subgroup considering fish fence monitoring as a core monitoring tool. However, due to discharge rates above the safety threshold, the fish fence was delayed in 2004, 2005, 2007 and 2008.

Table 3.29 Summary of RAMP data available for the Fisheries Component, 1997 to 2008.

WATERBODY AND LOCATION	REACH	1997				1998				1999				2000				2001				2002			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Poplar Area	0/1[a]		1	1,5	1,5		1,6	1,5	1,3,6														1		
Steepbank Area	4[a]/5[a]/6		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Muskeg Area	10/11		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Tar-Ells Area	16/17		1	1,5	1,5		1,6	1	1,3,6									7					1		
Fort-Calumet Area	19[a]																								
CNRL/TrueNorth Area (Fort/Asphalt reaches)																							1		
Reference Area - about 200 km upstream[b]	5/6							1,5	1,3,6																
Reference Area - upstream of Fort McMurray[c]			1																						
Radiotelemetry study region[d]					2		2		2						2	2	2	2	2						
Downstream of Suncor's Discharge	AR-SD												1,3												10,3
Below Muskeg River	AR-MR												1,3												10,3
Reference site upstream of Ft. McMurray STP																									3
Reference site between STP and Suncor	AR-R												1,3												3
Downstream of Development (near Firebag River)																									
Athabasca River Tributaries																									
Fort Creek (mouth)															1,8,5,9	1									
Historical Review of Tributary Fish Data																									
Clearwater River	CR1																								
Clearwater River	CR2																								
Clearwater River	CR3																								
Christina River [l]																									
Ells River																									
Upper Ells River[h]													1,3												
Lower Ells River[h]													1,3												
Mackay River																									
Lower reach (85 km section from bridge to mouth) [j]	MAR-1		1																				1		
Muskeg River																									
Lower 35 km below Jackpine Creek confluence				1			4						1,3		2,8	2	2	2	2	1	6			1	6
Mouth (within 1 km of confluence with Athabasca River)	MR-MT												1,3						4		3		4		4
Reference sites (Steepbank, Horse and Dunkirk rivers)																	3				3				
Upper Muskeg River (near Wapasu Creek Confluence)																							1,4		1,4
Muskeg River Tributaries																									
Alands Drain																									
Jackpine Creek (accessable areas of lower creek)															8					1				1	
Shelley Creek																									
Muskeg Creek (Canterra road crossing)[e]																							1,4		1,4
Stanley Creek																									
Wapasu Creek (mouth or Canterra road)[e]																							1,4		1,4
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014			1																					
Vicinity of Steepbank Mine	SR-MN												1,3								3				
Reference site in vicinity of Bitumin Heights	SR-R												1,3												
Setinel reference site[g]	SR-EC												1,3				3				3				
Sentinel reference sites (Horse and Dunkirk R.)																	3				3				
Regionally-Important Lakes																									
Various lakes in water/air emissions pathway																									

WATERBODY AND LOCATION	REACH	2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Poplar Area	0/1[a]						1		1		1		1		1		1		1		1		1		1,6
Steepbank Area	4[a]/5[a]/6				6		1		1		1		1,6		1		1		1		1		1		1,6
Muskeg Area	10/11				6		1		1		1		1,6		1		1		1		1		1		1,6
Tar-Ells Area	16/17						1		1		1		1		1		1		1		1		1		1
Fort-Calumet Area	19[a]														1		1		1		1		1		1
CNRL/TrueNorth Area (Fort/Asphalt reaches)																									
Reference Area - about 200 km upstream[b]	5/6																								
Reference Area - upstream of Fort McMurray[c]																									
Radiotelemetry study region[d]																									
Downstream of Suncor's Discharge	AR-SD				10															3	3				
Below Muskeg River	AR-MR				10															3	3				
Reference site upstream of Ft. McMurray STP					10															3	3				
Reference site between STP and Suncor	AR-R				10															3	3				
Downstream of Development (near Firebag River)					10,6															3	3				
Athabasca River Tributaries																									
Fort Creek (mouth)																									
Historical Review of Tributary Fish Data																									
Clearwater River	CR1		1		1		1		1,6		1		1		1		1,6		1		1,6		1		1
Clearwater River	CR2		1		1		1				1				1		1,6		1				1		1
Clearwater River	CR3		1	10	1		1				1				1		1,6		1				1		1
Christina River [l]									1																
Ells River																									
Upper Ells River[h]							4		3		4		3							3	3				
Lower Ells River[h]							4		3		4		3							3	3				
Mackay River																									
Lower reach (85 km section from bridge to mouth) [j]	MAR-1			10			4																		
Muskeg River																									
Lower 35 km below Jackpine Creek confluence								1	6							1	6								
Mouth (within 1 km of confluence with Athabasca River)	MR-MT		4						3						4		3								
Reference sites (Steepbank, Horse and Dunkirk rivers)									3								3								
Upper Muskeg River (near Wapasu Creek Confluence)																									
Muskeg River Tributaries																									
Alands Drain																									
Jackpine Creek (accessable areas of lower creek)								1																	
Shelley Creek																									
Muskeg Creek (Canterra road crossing)[e]																									
Stanley Creek																									
Wapasu Creek (mouth or Canterra road)[e]																									
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014																								
Vicinity of Steepbank Mine	SR-MN								3							3	3								
Reference site in vicinity of Bitumin Heights	SR-R																								
Setinel reference site[g]	SR-EC								3							3	3								
Sentinel reference sites (Horse and Dunkirk R.)									3							3	3								
Regionally-Important Lakes																									
Various lakes in water/air emissions pathway					6				6											6	6				6

Legend

1 = fish inventory
2 = radiotelemetry; 1997-1998 walleye, lake whitefish (Athabasca River)
2000-2001: longnose sucker, northern pike, Arctic grayling (Athabasca River and Muskeg River)
3 = sentinel fish monitoring; 1998-1999: longnose sucker (Athabasca River)
2002-2008: trout-perch (Atha. River); slimy sculpin (Muskeg, Steepbank)
4 = fish fence: aluminum counting fence (large bodied fish); small-mesh fyke nets (small bodied fish)
5 = fish habitat association
6 = fish tissue: walleye and lake whitefish (Athabasca River); northern pike (Muskeg River), northern pike (Clearwater River), northern pike, walleye and lake whitefish (lakes)

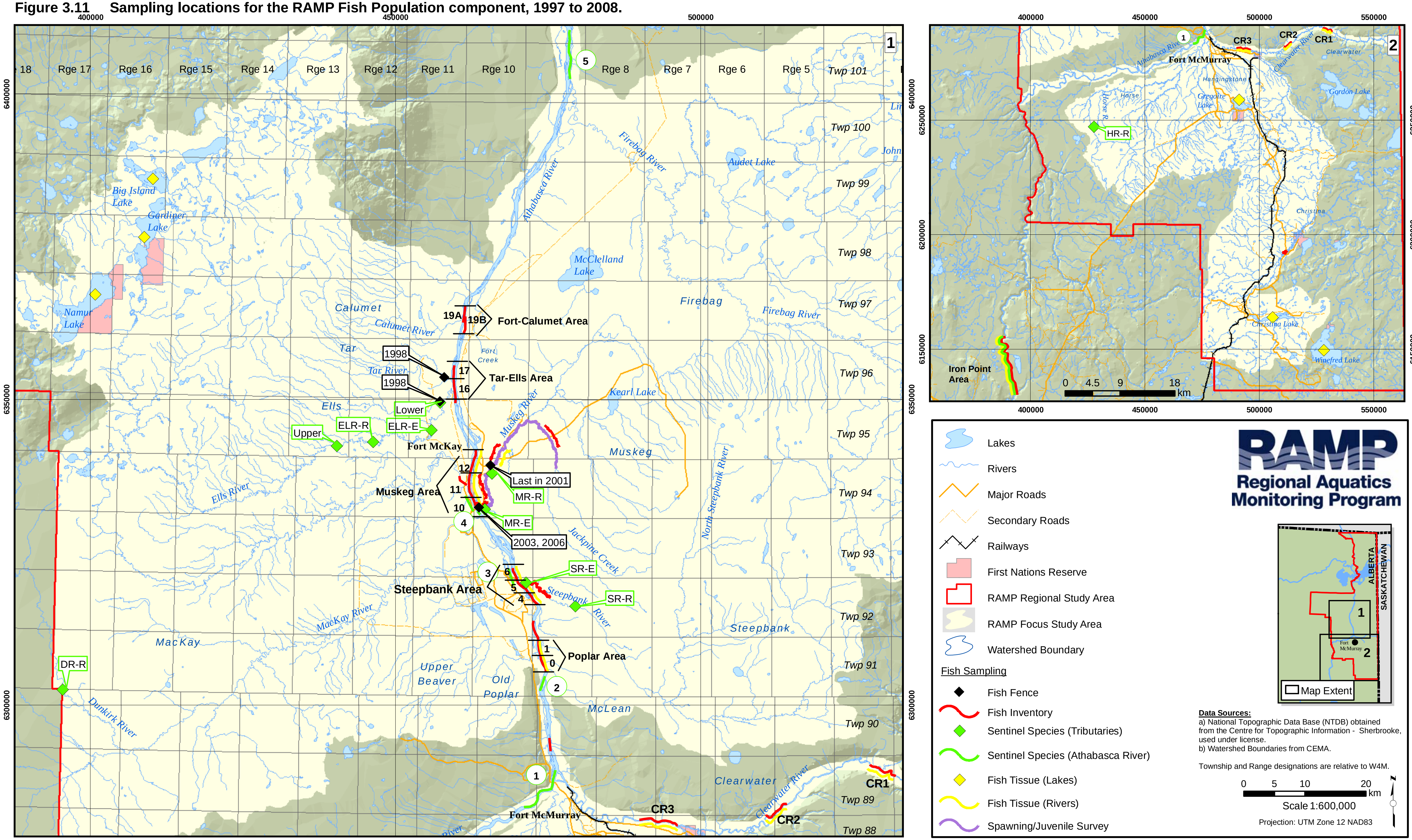
7 = winter fish habitat sampling
8 = spawning survey
9 = benthic drift survey
10 = IBI Assessment - Test program

Blue = Test (downstream of focal projects)
Green = Baseline (upstream of focal projects)

Footnotes

[a] Reaches include east and west banks
[b] Reference area upstream of Fort McMurray; includes a 22 km section extending 1 km upstream of the Duncan Creek Confluence downstream to Iron Point
[c] Reference area upstream of Fort McMurray. It was investigated as a potential reference area for longnose sucker sentinel species monitoring but found to be inadequate due to habitat differences and concerns about longnose sucker mobility.
[d] Radiotelemetry region includes the area 60 km upstream of Fort McMurray to 250 km downstream of Fort McMurray.
[e] small bodied fish inventory done by fish fence (fyke net) to record fish movements in and out of watercourse. Needs to be done prior to Kearl Project.
[f] Located from 3 to 11 km upstream of the confluence with the Athabasca River.
[g] Reference site located approximately 21 km upstream of confluence with Athabasca River; sampling done by Environment Canada, NWRI, Burlington, Ontario
[h] In 2004 the Ells River was evaluated as a potential reference site for sentinel species (slimy sculpin) monitoring on the Muskeg and Steepbank Rivers. Several sites were sampled but no slimy sculpin were captured. Hence, the site was determined not to be suitable as a reference site for this species. In 2004 a fish fence reconnaissance was carried out on the Ells and Mackay Rivers.
[i] Reconaissance inventory carried out in the Christina River upstream and downstream of the Hwy 881 bridge crossing.
[j] In 2004 a fish fence reconnaissance was carried out on the Ells and Mackay Rivers.

Figure 3.11 Sampling locations for the RAMP Fish Population component, 1997 to 2008.



K:\Data\Project\RAMP1467\GIS_MXD\A_DR\RAMP1467_DR_05_Fish_200901127.mxd

Sentinel species monitoring was first conducted on the Athabasca River in 1998 using longnose sucker. Although sucker were easily collected in the oil sands region, it was difficult to find suitable baseline areas. As well, a radio-telemetry study conducted from 2000 to 2002 indicated that longnose sucker were quite mobile in the lower Athabasca River and not suitable as a sentinel for localized exposure areas. In 1999, 2002 and 2007 the small-bodied trout-perch was successfully used as the sentinel species, with sampling sites located upstream and downstream of the oil sands development area. In 1999, a sentinel program was also initiated on the Muskeg and Steepbank rivers using slimy sculpin. This work continued in 2000, 2001, and 2004, and 2006. During this time the sampling design expanded to incorporate three *baseline* sites (Horse, Dunkirk and Steepbank rivers) in addition to the two exposure sites (lower Muskeg and Steepbank rivers). In 2005 and 2007, sentinel monitoring was conducted on the Ells River focusing on longnose dace. Beginning in 2004, a non-lethal approach to sentinel monitoring was introduced in RAMP.

During the course of RAMP, the fish population component conducted a variety of other studies in an effort to improve the understanding of baseline conditions and variability in the oil sands region, to evaluate the suitability of alternate monitoring approaches, and to conduct "proof-of-concept" studies to refine the existing monitoring program. Supporting studies conducted to date include:

- Spawning surveys and juvenile fish surveys;
- Fish inventories (including winter sampling and fish-habitat surveys);
- Small stream fish fence studies;
- Benthic drift studies (food resource);
- Radio-telemetry studies to identify movement/exposure;
- Index of Biotic Integrity (IBI) fish community assessment;
- Non-lethal fish tissue collection methods; and
- Non-lethal sentinel species monitoring approach.

The diversity of studies conducted under the fish population component improved our understanding of regional fish populations and provided important information that facilitated the selection and refinement of specific monitoring approaches. However, to some extent, the broad focus of the program during the early years resulted in data that were of relatively limited use for monitoring potential changes in fish populations over time. Some of the limitations of the dataset were related to variability in sampling methods, study site locations, time of sampling and measurement endpoints. More recently, and in partial response to results of the Scientific Peer Review, the RAMP Technical Program Committee and the Fisheries Sub-group have been refining the program with particular focus on detection of potential oil sands–related changes in fish populations. These impact monitoring approaches represent the core elements of the fish program and include:

- Fish inventory on the Athabasca and Clearwater rivers (presence/absence, frequency distribution analyses);
- Sentinel species monitoring in the Athabasca River and select tributaries;
- Fish tissue analyses of organic and inorganic chemicals; and
- Fish fence monitoring – tributary habitat use by mainstem fish populations.

Table 3.29 provides a summary of key fish monitoring activities since 1997. Not all impact monitoring approaches are conducted on an annual basis and not all waterbodies are monitored in a given year (see Table 3.30) Most of the RAMP fish monitoring occurs during the open-water season (i.e., April to October), with emphasis on the spring spawning period and fall low-flow conditions (i.e., decreased dilution capacity). A limited number of winter studies have been done in the past related to identifying overwintering fish habitat (direct sampling and radio-tracking).

Use of external laboratories for the fish population component is limited relative to other RAMP components (e.g., water/sediment quality, benthic invertebrates). Fish tissue samples have historically been analyzed by Enviro-Test Laboratories Ltd. (Enviro-Test), now ALS Laboratory Group, in Edmonton. Analyses of small tissue samples collected to evaluate non-lethal tissue sampling methods (for mercury analysis only) have been conducted by both ALS Laboratory Group and Flett Research Ltd. of Winnipeg. Fish aging has been conducted by either the RAMP consultant, Syncrude Canada Ltd. or outsourced to Mr. John Tost of North Shore Environmental Services in Thunder Bay, Ontario and most recently to North/South Consultants in Winnipeg, Manitoba.

3.8.2 Key Indicator Resources

KIRs selected for fish and fish habitat assessments have included specific fish species, fish guilds and their respective habitats. Generally, KIRs have been selected by ranking fish species for each waterbody according to specific criteria regarding species abundance, life history characteristics and significance (regional, cultural, social and economic importance), and through consultation with local residents and Aboriginal communities.

Table 3.30 Historical summary of key elements of the RAMP fisheries populations component, 1997-2008.

Monitoring Element	RAMP Program Year											
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
1) Impact Monitoring:												
Athabasca Fish Inventory	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
Clearwater Fish Inventory								✓	✓	✓	✓	✓
Sentinel Fish Studies:												
Athabasca River		✓	✓			✓					✓	
Tributaries			✓	✓	✓			✓	✓	✓	✓	
Fish Tissue Studies:												
Athabasca River		✓			✓	✓	✓		✓			✓
Clearwater River								✓		✓	✓	
Muskeg River					✓	✓		✓				
Regional Lakes						✓	✓	✓			✓	✓
Fish Fence Studies (Muskeg River)		✓			✓	✓	✓			✓		
2) Baseline Studies	✓	✓	✓	✓	✓	✓		✓				
3) Supporting/Alternate Studies	✓	✓		✓	✓	✓	✓	✓	✓			

Section 2.3 summarized the various fish KIRs that have been used in past EIAs. A total of 14 individual fish species have been chosen, as well as the general forage fish guild. More recently, the Sustainable Ecosystem Working Group (SEWG) of CEMA identified similar indicator fish species for monitoring and management purposes (CEMA 2001). Although the RAMP fish program attempts to evaluate the integrity of the total fish community, where possible, particular emphasis has been placed on waterbody-specific KIRs due to their ecological importance and value to local communities. Table 3.31 summarizes the KIRs that the RAMP fish program has selected.

3.8.3 Hypotheses and Questions

3.8.3.1 Hypotheses and Questions from Athabasca Oil Sands EIAs

Specific EIA predictions associated with assessments of fish and fish habitat, compiled from 17 different oil sands EIAs in the RAMP study area, have been summarized in Chapter 2 above. Almost all (224 of a total of 262) residual impact assessments in these EIAs pertaining to fish populations were predicted to have negligible or low impact. In addition, most effects were predicted to be local in nature.

Table 3.31 Summary of Key Indicator Resource (KIR) fish species used by the RAMP fish monitoring program.

Waterbody	Key Indicator Resource
Athabasca River	walleye[1] lake whitefish[1] longnose sucker[2] white sucker goldeye northern pike trout-perch[2]
Clearwater River	walleye[1] northern pike[1]
Muskeg River	northern pike[1] longnose sucker Arctic grayling slimy sculpin[2]
Steepbank River	Arctic grayling slimy sculpin[2]
Ells River	longnose dace[2]
Regional Lakes	walleye[1] lake whitefish[1] northern pike[1]

[1] Species used for tissue analyses.

[2] Species used for sentinel fish monitoring.

Specific EIA predictions vary by project, and typically differ significantly between open-pit mines and *in situ* projects, with *in situ* project EIAs generally predicting fewer potential effects. However, EIA predictions for fish populations and their respective habitats arise from a number of development, operational and reclamation activities (Table 3.32).

Table 3.32 Athabasca oil sands activities with potential effects on fish populations and fish habitat.

Main Impact Pathways (from Section 2.2, Page 2-1)	Oil Sands Activities (summarized from Table 2.2, Page 2-6 and Table 2.3, Page 2-10)
▪ Changes in hydrological conditions ▪ Changes in amounts of physical habitat ▪ Changes in water quality ▪ Changes in sediment quality ▪ Changes in benthic invertebrate communities	▪ Damming of watercourses and watercourse re-establishment on closure; elimination of watercourses, diversion of watercourses, interception of runoff, elimination of reaches of watercourses, creation of new exit route for watercourses from waterbodies, repositioning of watercourses ▪ Releases of consolidated tailings water; releases of seepage water; introduction of substances to project area watercourses from surface runoff and/or accidental spills, muskeg and overburden dewatering ▪ Changes in aquifer discharge to and flows in surface waters, changes in overwintering fish habitat ▪ Changes in water quality and consequent changes in fish tissue quality, including fish tainting

3.8.3.2 RAMP Objectives, Key Questions and Hypotheses

The RAMP Fish Population component was established to monitor the health and sustainability of fish populations within the oil sands region. 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 oil sands region. In addition, the oil sands EIAs have predicted that changes in hydrologic conditions, water quality, air quality (acidifying emissions) and changes in physical habitat (and to a lesser extent sediment quality and benthic communities) may variously influence fish health, fish abundance, tissue quality and fish habitat availability.

Specific objectives of the fish population component include:

- Collecting fish population data to characterize the natural or baseline variability, assess EIA predictions, and meet requirements of regulatory approvals;
- Monitoring of potential changes in fish populations due to stressors or impact pathways (chemical, physical, biological) resulting from oil sands development by assessing attributes such as growth, reproduction and survival; and
- Assessing the suitability of fisheries resources in the oil sands region for human consumption.

The first two objectives derive from the overall objectives of RAMP, whereas the third objective addresses local community and Aboriginal concerns regarding the quality and safety of fish captured in the region for consumption. These objectives lead to the following questions for the RAMP fish population component:

- What changes in fish populations and fish health are predicted in oil sands EIAs?
- What are the baseline conditions and range of natural variability of fish measurement endpoints in the RAMP study area?
- Do fish measurement endpoints vary significantly between areas or waterbodies exposed (*test*) and unexposed (*baseline*) to oil sands development?
- Do fish measurement endpoints from *test* areas exhibit time trends reflective of effects associated with increasing oil sands development?
- Do tissue concentrations of select organic and inorganic compounds in fish captured in the region exceed established guidelines for safe consumption?

- What data on fish populations are required by other RAMP components to assist in interpretation?

From these questions, the following hypotheses are formulated for the fish population component:

- H_{o1}: Population characteristics of key indicator fish species do not change over time;
- H_{o2}: Growth, reproduction and survival of sentinel species are similar between *test* and *baseline* areas, and over time;
- H_{o3}: Chemical constituents in fish tissues of key indicator species do not change over time; and
- H_{o4}: Chemical constituents in fish tissues of key indicator species do not exceed relevant environmental quality and consumption guidelines.

The first hypothesis is addressed through comparisons of fish inventory data collected over time from the oil sands region of the Athabasca River (e.g., data from previous RAMP years, Alberta Oil Sands Environmental Research Program [AOSERP] data collected in the 1970s). The comparison focuses on select KIR species and, from a fish community perspective, provides a coarse-filter view of potential changes over time. Fish fence monitoring also contributes to testing H_{o1} (in addition to providing valuable baseline data) by comparing the relative abundance and species composition of spawning runs utilizing specific tributaries of the Athabasca River over time. The second hypothesis is tested directly through the sentinel species monitoring at exposure areas on the Athabasca River and select tributaries relative to unexposed populations. The final two hypotheses are tested through comparisons of all observed fish tissue concentrations of organic and inorganic compounds over time and against relevant guidelines.

3.8.4 Measurement Endpoints and Criteria for Determining Change

The fish population component is unique in that the program consists of four core monitoring elements or approaches in an effort to address multiple issues. Consequently, measurement endpoints and criteria for determining change identified by RAMP are specific to each monitoring approach. These endpoints and criteria are discussed in detail below for each approach.

Fish Inventory Monitoring

With respect to the fish inventory studies, measurement endpoints include:

- Relative abundance (catch per unit effort);
- Length/Age-frequency;
- Percent composition (relative to all fish captured); and
- Condition factor.

All of the above endpoints collected by non-lethal sampling represent traditional fisheries statistics used to characterize fish populations.

Relative abundance is a coarse estimate of population size, whereas percent composition characterizes the species dominance of the selected large-bodied species. Shifts in species dominance and/or abundance often reflect species-specific sensitivity or tolerance to alterations in environmental conditions.

Characterizing the age or size distribution/structure of fish populations identifies the age or size classes potentially affected by environmental stressors. Alterations in age or size structure result from changes in adult mortality and recruitment success and provide a focus for follow-up study to confirm and validate the response and investigate potential causes.

Fish may allocate energy to growth, reproduction or storage (Adams and Breck 1990). Fish store energy primarily in the form of lipids in the mesenteric cavity, muscle tissues and liver (i.e., fish are fatter). Variables such as fish condition provide an estimate of energy allocation to storage and reflect the nutritional status and health of fish.

Fish inventory studies conducted by RAMP are generally considered to be a community-driven activity that is best suited for assessing trends in abundance and population variables for large-bodied species, rather than fish community structure. As a result, it was determined that, in order to establish criteria for detecting and assessing change in the designated measurement endpoints, it would be necessary to determine the range of variability in each variable over the maximum number of sampling years. Once the extent of variability is estimated, appropriate criteria for determining change in the measurement endpoints can be formulated and the overall monitoring approach will be refined.

Sentinel Fish Species Monitoring

Measurement endpoints selected for RAMP sentinel species monitoring on the Athabasca River and select tributaries are dependent on whether a lethal or non-lethal sampling approach is used. In both cases, the selected endpoints are based on Environment Canada's Environmental Effects Monitoring (EEM) guidelines developed for the metal mining and pulp and paper sectors (Environment Canada 2002, 2005). Table 3.33 provides a summary of measurement endpoints for each sentinel monitoring approach as they are related to growth, reproduction, condition and survival.

Environment Canada (2002, 2005) defines an effect as a statistical or significant difference and has selected specific measurement endpoints to be used for determining effects (identified with an asterisk in Table 3.33). However, it is recognized that a significant difference does not necessarily translate to an ecologically meaningful change. Accordingly, effect sizes (≈effects criteria) have been established where possible to evaluate ecologically important changes:

- ***Lethal sampling approach:***
  - Condition factor - ± 10% difference between fish in *test* and *baseline* areas;
  - Relative gonad size - ± 25% difference between fish in *test* and *baseline* areas;
  - Relative liver size - ± 25% difference between fish in *test* and *baseline* areas;
- ***Non-lethal approach:***
  - Condition factor - ± 10% difference between fish in *test* and *baseline* areas.

Table 3.33 Summary of measurement endpoints for lethal and non-lethal sentinel species monitoring (adapted from Environment Canada [2005]).

Indicator	Standard Sentinel Monitoring	Non-lethal Sentinel Monitoring
Growth	▪ Length / *weight at age	▪ *Length / weight of young of year at end of growth period ▪ Size of 1+ fish ▪ Size at age
Reproduction	▪ *Relative gonad size ▪ Fecundity (vs. size, age)	▪ Abundance of young of year ▪ Young of year survival
Condition	▪ *Body weight vs. length (k) ▪ *Relative liver weight ▪ Egg size (vs. size, age)	▪ *Body weight vs. length (k)
Survival	▪ *Age frequency distribution ▪ Length frequency distribution	▪ Age frequency distribution (if possible) ▪ *Length frequency distribution

***** Measurement endpoints used for determining change. Other endpoints used for supporting analyses.

Fish Fence Monitoring

Measurement endpoints for fish fence monitoring are consistent with those outlined previously for Fish Inventory Monitoring:

- Relative abundance of migrants (fence count data by species);
- Length/Age-frequency;
- Percent composition (relative to all fish captured); and
- Condition factor.

In addition, other endpoints specific to fence monitoring during the spawning period include sex ratio, onset and peak timing of spawning runs, and residency time in the spawning tributary (assuming out-migration is monitored).

The use of a fish counting fence as a monitoring tool for RAMP is a relatively recent decision and is, in part, due to the success achieved in 2003 and 2006. As with fish inventory studies, 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 necessitates the need to collect the maximum number of sampling years before RAMP can be confident in the observed trend. Once the extent of variability is estimated, appropriate criteria for determining change in the measurement endpoints can be formulated and the overall monitoring approach will be refined.

Fish Tissue Monitoring

Measurement endpoints selected for fish tissue evaluations include total metals, with emphasis on total mercury, and tainting compounds measured by RAMP (Table 3.34). Historically, a full suite of polycyclic aromatic hydrocarbons (PAHs) had been measured in muscle tissue; however, in 2002 the analysis was refined to focus only on potential tainting PAH compounds. This was done because the majority of PAHs are easily metabolized and unlikely to accumulate in fish muscle at the environmental concentrations experienced in the oil sands region.

Table 3.34 Current suite of total metals and tainting compounds measured in composite fish tissue samples analyzed by RAMP.

Group	Fish Tissue Variable	
Total Metals	Aluminum (Al)	Manganese (Mn)
	Antimony (Sb)	Mercury (Hg)[1]
	Arsenic (As)	Molybdenum (Mo)
	Barium (Ba)	Nickel (Ni)
	Beryllium (Be)	Phosphorus (P)
	Boron (B)	Potassium (K)
	Cadmium (Cd)	Selenium (Se)
	Calcium (Ca)	Silver (Ag)
	Chromium (Cr)	Sodium (Na)
	Cobalt (Co)	Strontium (Sr)
	Copper (Cu)	Thallium (Tl)
	Iron (Fe)	Tin (Sn)
	Lead (Pb)	Titanium (Ti)
	Lithium (Li)	Vanadium (V)
	Magnesium (Mg)	Zinc (Zn)
Tainting Compounds (PAHs)	1,3,5-Trimethylbenzene	Toluene
	M+P-Xylenes	Toluene d8
	Naphthalene	1,2-Dichloroethane d4
	o-Xylene	4-Bromofluorobenzene
	Thiophene	2-Methylthiophene

[1] Mercury concentrations also measured in 25 individual fish (five fish in each of five size classes).

To provide a screening-level assessment of the potential effects of ingestion of fish tissue on human health, fish tissue data are compared against the following criteria:

- Health Canada Guidelines for chemical contaminants in fish (CFIA 2003, HC 2007) and for exposure of Aboriginal residents to methyl-mercury in the Canadian environment (INAC 2006);
- Region III USEPA risk-based criteria for consumption of fish tissue for recreational and subsistence fishers (USEPA 2003); and
- National USEPA risk-based screening values for consumption of fish tissue (USEPA 2000).

Values that exceed these guidelines are reported explicitly in the body of the RAMP report and directed to agencies responsible for setting consumption guidelines (i.e., Health Canada and Alberta Health and Wellness). These values are used to address the question "Do tissue concentrations of select organic and inorganic compounds in fish captured in the region exceed established guidelines for safe consumption?" (Section 3.8.3.2)

To assess potential tainting of fish tissues, concentrations of tainting compounds are compared to criteria developed by Jardine and Hrudey (1988). Tainting compounds present at concentrations above 1 mg/kg are considered to result in detectable, undesirable odours or flavour.

To assess potential effects on fish health, fish tissue data are compared to the lowest tissue residue concentrations linked to effects (or a lack of effects). Effects thresholds/criteria used by RAMP are derived from laboratory-based studies summarized in Jarvinen and Ankley (1999); these effects thresholds relate tissue residues to sublethal and lethal effects for aquatic organisms exposed to a number of inorganic and organic chemicals. Table 3.35 summarizes effects criteria used by RAMP for the fish tissue program.

Table 3.35 Criteria used by RAMP to evaluate fish tissue concentrations on human health, tissue palatability and fish health.

Issue	Criteria for Determining Change
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 consumers)*: 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 consumers)*: Fish tissue concentrations for one or more analytes above USEPA and Health Canada criteria for general consumers, and recreational and subsistence fishers.
Fish Palatability	*Negligible-Low*: Fish tissue concentrations for tainting compounds below criteria for palatability of fish. *Moderate-High*: Fish tissue concentrations for tainting compounds above criteria for palatability of fish.
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.

3.8.5 Monitoring Station Selection and Monitoring Design

Monitoring surveys conducted as part of the RAMP fish population component focus on specific waterbodies where oil sands developments are currently operating, or are planned to operate in the near future. These studies are conducted on a routine basis (frequency depends on study type) to evaluate potential changes in fish population characteristics over time. Conversely, the fish program also includes the collection of required baseline data; however, these surveys are often one-time events and the location of sampling is dictated by baseline data gaps and location of upcoming oil sand operations.

The Athabasca River is a specific focus of the fish program because: a) it represents the ultimate receiving environment in the oil sands region; b) fish populations, particularly KIR species, in this system are important from a recreational and subsistence perspective; and c) many fish species of the Athabasca River utilize tributary watersheds during some portion of their life (e.g., spawning, rearing, feeding etc.) and, hence, may be exposed to potential effects of oil sands operations.

The Muskeg River represents another major focus for fish monitoring because: the level of oil sands development within the watershed continues to expand; it provides important spawning/rearing/feeding habitat for several mainstem fish species (including Arctic grayling – classified as a sensitive species at risk); and the watershed is within the territorial boundaries of several First Nations communities. Less extensive monitoring is also conducted in the Steepbank River, Ells River, MacKay River and the Clearwater/Christina system due to recent developments and local concerns regarding the sustained environmental integrity of these waterbodies and associated fish populations.

Table 3.36 provides the rationale for RAMP fish sampling locations used for each core impact monitoring activity. The following discussion provides more detail on the design of each fish monitoring study implemented by RAMP.

Fish Inventory Studies

RAMP fish inventories are primarily designed to monitor specific fish communities over time. Although, spatial comparisons are of interest (i.e., between fish captured in different areas), this is often not possible due to large-scale movement patterns of most large-bodied species present in the region (e.g., Athabasca River), and the lack of barriers to movement that, if present, would ensure geographical separation of populations or communities. In addition, in many of the smaller tributaries and watercourses, habitat conditions are often not consistent between *test* and *baseline* reaches resulting in naturally different communities (i.e., confounding factor).

For the Athabasca River, inventories are conducted annually in spring and fall to correspond with periods of highest abundance. The east and west bank of the river are sampled within specific reaches previously established by Syncrude Canada Ltd. in 1989 (T. Van Meer, Syncrude Canada Ltd., *pers. comm.* 2005). A total of 13 reaches are sampled, which correspond to five basic sampling areas (Figure 3.11, Table 3.29).

Similarly, a fish inventory on the Clearwater River was initiated in 2004 to evaluate the fish community in this system. This work represents an extension of the study conducted on the Athabasca River. The inventory on the Clearwater River is conducted annually and focuses on three spatially separate reaches to provide a more accurate representation of the community and to account for observed differences in baseline habitat characteristics (Figure 3.11, Table 3.29).

Historical inventories on other watercourses such as the Muskeg River, Jackpine Creek and MacKay River focused on the lower reaches, located downstream of existing or planned developments. These smaller systems were monitored approximately every three years in the mid- to late-summer when flows are higher and more navigable, relative to the fall low-flow periods. This time also aids in the capture of young of the year that may be rearing in the watercourse following spring hatch.

Table 3.36 Rationale for RAMP fish sampling locations used during core impact monitoring activities.

Monitoring Type / Watershed	Area Code	General Location	Rationale
Fish Inventory			
Athabasca River	0/1	Poplar Creek area	Located to assess potential effects related to oil sands development in the Poplar Creek watershed.
	4/5/6	Steepbank River area	Located to assess potential effects of operational and reclamation water releases from Suncor Steepbank, Project Millennium and the lower portion of Suncor Lease 86/17, including the Tar Island Dyke (TID).
	10/11/12	Muskeg River area	Located to assess potential effects related to oil sands development in the Muskeg River watershed
	16/17	Tar-Ells River area	Located to assess potential effects related to oil sands development in the Ells River and Tar River watersheds.
	19	Fort-Calumet area	Located to assess potential effects related to oil sands development in the Fort Creek and Calumet River watersheds. Potentially suitable for monitoring of the cumulative effect of all upstream disturbance.
Muskeg River	na	Lower reaches from Jackpine Creek to mouth	Provides data describing cumulative effects of upstream development in the watershed. Lower reach of river is erosional, providing spawning habitat for sucker and Arctic grayling.
Jackpine Creek	na	Lower reach	Selected to monitor potential effects of proposed Shell Jackpine Mine. Important spawning habitat for Arctic grayling and sucker species.
Clearwater River	CR-1	Approximately 40 km upstream of Christina River confluence	Provides data from a *baseline* area well beyond anthropogenic influences.
	CR-2	Approximately 20 km upstream of Christina River confluence	Provides baseline data upstream of Christina River confluence.
	CR-3	Downstream of Christina River confluence	Provides data upstream of the oil sands region and the Town of Fort McMurray, but downstream of development on the Christina River.

Table 3.36 (Cont'd.)

Monitoring Type / Watershed	Area Code	General Location	Rationale
Sentinel Species Monitoring			
Athabasca River	1	Upstream of Fort McMurray STP	Baseline area upstream of influences of the Town of Fort McMurray and STP to help isolate potential STP effects from potential oil sands development effects
	2	Between STP and Suncor	Baseline area downstream of Fort McMurray/STP influence, but upstream of oil sands development area.
	3	Downstream of Beaver Creek along west bank	Exposure area to assess potential effects of the Suncor and Syncrude operations.
	4	Downstream of Muskeg River along east bank	Exposure area located to assess potential effects related to oil sands development in the Muskeg River watershed
	5	Downstream of the Firebag River along east bank	Exposure area to assess potential cumulative effects of upstream oil sands development
Muskeg River	MR-E	0.5 km upstream from mouth	Exposure area downstream of potential cumulative influences of upstream developments in the watershed
Steepbank River	SR-E	0.5 km upstream from mouth	Selected to monitor potential effects of Suncor Steepbank Mine.
	SR-R	16 km upstream of mouth	Baseline area beyond influence of Steepbank Mine development for comparison with lower Steepbank and Muskeg exposure areas.
Horse River	HR-R	140 km upstream from mouth	Additional *baseline* area for Steepbank and Muskeg exposure areas
Dunkirk River	DR-R	25 km upstream of mouth at MacKay River	Additional *baseline* area for Steepbank and Muskeg exposure areas
Ells River	Upper	Approximately 40 km upstream of the Canadian Natural road bridge	Baseline area located upstream of the Joslyn Creek project.
	Lower	Between the Canadian Natural access road bridge and the Ells River mouth	Provides exposure data to assess potential effects of Joslyn Creek Project
Fish Fence			
Muskeg River	na	Approximately 16.5 km upstream from the mouth	Original fish fence location on Muskeg River, provided easy access, stable substrates and low flow conditions. Abandoned because significant spawning habitat exists downstream of fence site.
	na	Approximately 800 m upstream from mouth	Location maximizes the amount of spawning habitat upstream of fence site to improve accuracy of spawning counts.

Table 3.36 (Cont'd.)

Monitoring Type / Watershed	Area Code	General Location	Rationale
Fish Tissue			
Athabasca River	4/5/6	Steepbank River area	Provides tissue data on lake whitefish and walleye. Located to assess potential effects of operational and reclamation water releases from Suncor Steepbank, Project Millennium and the lower portion of Suncor Lease 86/17, including the Tar Island Dyke (TID).
	10/11/12	Muskeg River area	Provides tissue data on lake whitefish and walleye. Located to assess potential affects related to oil sands development in the Muskeg River watershed
Muskeg River	na	Lower reaches downstream of Jackpine Creek	Exposure area downstream of potential cumulative influences of upstream developments in the watershed. Provides tissue data on northern pike.
Clearwater River	CR-1 to CR-3	Samples from all three inventory reaches	Provides tissue data on northern pike. Pike population in Clearwater more abundant vs. Athabasca River.
Regional Lakes	na	Various regional lakes in collaboration with ASRD (to date Lake Clair, Gregoire Lake, Christina Lake, Winefred Lake, Namur Lake, Big Island Lake, Gardiner Lake)	Implemented to take advantage of ongoing ASRD inventory work. Health of regional lakes is a concern to First Nations. Various lakes in water/air emissions pathway.

Sentinel Fish Monitoring

The sentinel monitoring program is designed to evaluate both spatial and temporal differences in measurement endpoints.

In 1998, sentinel monitoring on the Athabasca River focused on longnose sucker from the oil sands area, as well as a *baseline* area located approximately 200 km upstream of Fort McMurray near Iron Point (Figure 3.11). However, this design was not suitable due to natural habitat differences between study areas, as well as logistical constraints related to collecting fish from Iron Point. Because of the mobility of longnose sucker, no alternate *baseline* areas were available. The decision to use the small-bodied trout-perch (limited mobility, abundant) as the Athabasca sentinel species circumvented this problem and in 1999, a sentinel program of one *baseline* area and two *test* areas was conducted. Later in 2002, a second *baseline* area upstream of Fort McMurray and the sewage treatment plant was added to help isolate potential Fort McMurray/STP effects from oil sands effects. In addition, the *test* area downstream of Suncor's water discharge was moved downstream below Beaver Creek to assess potential effects of both Suncor's and Syncrude's operations. The resulting design includes two *baseline* areas and three *test* areas, with exposure areas corresponding to specific areas of oil sands development (Table 3.36). The same study design was used for the trout-perch sentinel program in 2007.

Also in 1999, sentinel monitoring was initiated in the lower Muskeg River and Steepbank River using slimy sculpin. Slimy sculpin was selected because it exhibits territorial behaviour and limited mobility (i.e., maximum exposure), are found in many tributaries of the Athabasca River and spawn only once per year, making it easier to assess reproductive effort. At the time, the only suitable *baseline* area for this program was located on the mid-portion of the Steepbank River. In 2000, a survey for additional *baseline* areas was conducted resulting in *baseline* areas on the Horse River and Dunkirk River being added to the design in 2001 and continued in 2004 and 2006. As recommended by Environment Canada (1992, 2002, 2005), multiple *baseline* areas provide a more accurate representation of non-oil sands influenced populations for comparison to *test* populations.

The frequency of sentinel monitoring was set at a maximum of every three years. This was particularly important for the lethal sentinel program using slimy sculpin in smaller watercourses (i.e., minimize potential sampling effects). More frequent monitoring had the potential to significantly alter these populations due to low immigration of new individuals associated with low mobility and strong territorial behavior. In 2004, non-lethal sentinel monitoring was introduced to eliminate sampling-related mortality of fish populations. As a result, non-lethal sentinel monitoring on the Muskeg, Steepbank, Athabasca and Ells rivers was increased to every second year in response to increasing development in both watersheds.

Fish Fence

With the exception of brief and unsuccessful attempts to operate fish fences on the lower Tar and Ells rivers in 1998, all RAMP fish fence monitoring has focused on the Muskeg River. Data collected at the fence are used to describe the biology and movement of spring spawning populations of large-bodied fish species that use the Muskeg River watershed. In 1998, the fence was located approximately 16.5 km upstream from the mouth. However, this location was abandoned because significant spawning habitat exists downstream of the fence site resulting in an underestimate of the spawning run size measured at the fence. In 2001, 2002, 2003 and 2006, the fence was relocated to a site 800 m upstream of the mouth in an effort to maximize the amount of spawning habitat upstream of fence site.

Success has varied from year-to-year, depending on spring discharge and streambed stability (subject to undercutting due to the presence of easily eroded bitumen near the surface of the riverbed). Fencing success in 2001 and 2002 was poor; however, fence monitoring in 2003 and 2006 was successful, due in part to relatively stable flows that were <9 m^3/s, suitable site conditions, and use of a newly designed fence that reduced water turbulence at the fence-river bed interface in an effort to minimize undercutting of the fence.

A fence on the Muskeg River was scheduled for 2004, 2005, 2007 and 2008; however, spring flows were 2 to 3 times higher than the established threshold of $9m^3/s$. Fence monitoring in the Muskeg River has been rescheduled for spring

2009. To date, no definite schedule has been established for fish fence monitoring. Due to the uncertainty of successfully installing a fence from year to year, fence monitoring has been included in the program following the success (or lack of) from the previous years. The RAMP Fish Population Sub-group recognizes the value of the data collected; however, they also recognize that the success of temporary fence operations is often controlled by annual environmental conditions.

The potential exists for additional fish fence studies to be conducted in other Athabasca River tributaries within the oil sands region; these tributaries will be identified as needed by the Fish Population Sub-group based on gaps in baseline knowledge and development plans for individual operators.

Fish Tissue Studies

RAMP fish tissue studies are conducted on fish collected from: the Athabasca River within the oil sands region; the Clearwater River; the Muskeg River; and select lakes within the RAMP regional study area. Rationale for each sampling location is provided in Table 3.36.

In general, fish are collected from watersheds where oil sands development is occurring or planned. Sampling is conducted in the fall to avoid spring spawning species (uncertain exposure due to spawning movements, possible reduction in muscle burdens related to reproduction) and focus on fish following the growing season and maximum exposure and potential chemical uptake.

Fish tissue studies for the Athabasca and Clearwater rivers take advantage of fish collected during the fall fish inventory. Walleye (a KIR species) is currently monitored in both river systems. Northern pike is also monitored on the Clearwater River (more abundant in this system than in the Athabasca River); whereas lake whitefish are also studied on the Athabasca River. All three species are KIRs of the oil sands region and represent important food species for recreational and subsistence consumers. From an oil sands perspective, the rationale for monitoring lake whitefish is limited. Lake whitefish migrate every fall from Lake Athabasca up the Athabasca River through the oil sands region enroute to spawning grounds at Grand, Mountain and Cascade rapids located south (upstream) of Fort McMurray. As such, potential exposure to oil sands-related chemicals is brief; however, the influx of large numbers of whitefish provides an opportunity for RAMP to capture whitefish for tissue analyses in response to local community/Aboriginal concerns regarding safe consumption.

For the Muskeg River, northern pike has been selected for tissue analyses. Pike are collected in early fall in collaboration with periodic fish inventory monitoring for this watershed. The only other species of interest resident in the Muskeg River watershed is Arctic grayling. The status of Arctic grayling in Alberta has been classified as a sensitive from the perspective of species at risk (ASRD 2000; http://www3.gov.ab.ca/srd/fw/speciesatrisk). Consequently, grayling are not used for monitoring purposes under RAMP.

In 2002, an additional fish tissue program was initiated focusing on mercury levels in fish from lakes located within the RAMP regional study area. The program started due to concerns expressed by local community/Aboriginal stakeholders of RAMP, and because many of the lakes are in the pathway of water and/or air emissions from oil sand developments. Originally, the program was established to provide a mechanism for opportunistic testing of fish collected in the region by local and Aboriginal communities (e.g., fishing by-catch, subsistence fish samples, etc.). Several logistical constraints were identified early in the program, particularly related to sampling QA/QC requirements and sample integrity. Since that time, a more structured program has developed through collaboration with the Alberta Sustainable Resource Development (ASRD) agency in Fort McMurray. RAMP obtains tissue muscle samples of northern pike, walleye, lake whitefish, and lake trout (when available) from ASRD through their annual Fall Walleye Index Netting (FWIN) programs. To date, tissues analyses have been conducted on fish collected from Gregoire Lake (2002), Lake Claire (2003, provided by Robert Grandejambe), Christina Lake (2003) and Winefred Lake (2004). The Regional Lakes program was not conducted in 2005 or 2006 but resumed in 2007 in Gregoire and Namur lakes and in Gardiner and Big Island lakes in 2008.

3.8.5.1 Sampling Protocols

RAMP sampling for the fish population component follows accepted standards, protocols and quality assurance/quality control procedures. RAMP Standard Operating Procedures, initially based on Golder Associates Ltd. Technical Procedures, have been followed since the beginning of RAMP and have been revised and updated for RAMP in 2008, accommodating new techniques and approaches (Appendix A4).

The following is a brief description of sampling methods for each of the core impact monitoring approaches conducted as part of the fish population component. All data are recorded in monitoring-specific field sheets and/or in a field log book.

Fish Inventory Studies

<u>Athabasca River and Clearwater River</u>

Syncrude Canada Ltd. conducts the fish inventory work on the Athabasca and Clearwater rivers, often in collaboration with ASRD, other RAMP stakeholders and the RAMP consultant. Fish are collected using an electrofishing boat. Stunned fish are captured with dip-nets and held in an on-board flow-through live well.

Large-bodied species are measured for fork length and body weight; an external pathology examination is conducted to assess the presence of anomalies, disease and/or parasites. Sex and state of maturity is recorded when discernible by external examination. Small-bodied species (e.g., forage fish) are typically measured for fork length only. Prior to live release, key indicator resource (KIR) species of sufficient size (>20 cm in length) are fixed with RAMP-specific Floy tags; each tag is marked with a contact phone number to encourage anglers to report their catch. Non-lethal ageing structures are collected for captured fish following procedures described by MacKay *et al*. 1990. Initial fish ageing is typically done by Syncrude personnel or an outsourced laboratory, followed by QA/QC verifications by the RAMP consultant and/or an external expert in ageing temperate fish species. All ageing structures have been archived by Syncrude or the RAMP consultant, pending additional analysis.

Muskeg River, Jackpine Creek and Similar Sized Rivers

Fish inventory studies in the Muskeg River are typically collected using a portable boat electrofishing unit deployed in an inflatable boat (e.g., Zodiac®). Current is applied to the water in five to 10 second bursts and sampling is concentrated along productive shoreline areas. Stunned fish are collected using a long pole-mounted dip net. In addition, baited Gee-type minnow traps are set to target small-bodied fish species or life stages and checked daily.

Fish inventory studies in Jackpine Creek have been conducted using a backpack electrofishing unit. Fish are collected using a hand net and/or pole seine positioned downstream of the electrofishing unit. Sampling is concentrated along the shoreline areas. Baited Gee-type minnow traps are typically set overnight and checked daily.

All captured fish are identified and measured for fork length and body weight. Fish are then processed according methods previously discussed for the Athabasca River. After the assessment, fish are revived and released at or near the point of capture.

Sentinel Species Monitoring

Procedures used to conduct RAMP sentinel species monitoring follow those described in the Technical Guidance Documents for the metal mining and pulp and paper industries (Environment Canada 2002, 2005).

Athabasca River Sentinel Studies

Trout-perch are collected using a combination of boat electrofishing along the margins of the river, and beach seining. For the standard sentinel program, the target number of mature trout-perch to be collected is 40 males and 40 females.

Large trout-perch considered to be adult are transported to a fish processing location (away from wind and precipitation) and measured for fork length and total body weight. Following dissection, gonads, liver and carcass weight are weighed. External and internal health examinations are conducted for anomalies, disease and parasites, and to identify sex and stage of maturity. For females, both ovaries are preserved for fecundity analysis. Scales and sagittal otoliths are collected from each fish, placed in a small labeled enveloped and stored pending ageing analysis.

A non-lethal approach for sentinel monitoring has been adopted in the most recent monitoring year (2007) on the Athabasca River using trout-perch. The non-lethal program was conducted by the RAMP consultant in two discrete sampling periods, summer and fall, using a combination of boat electrofishing and beach seining, similar to the lethal program. A sample size of 100 individuals is targeted per area per sampling period.

All trout-perch are transported to a fish processing location (away from wind and precipitation) and enumerated for life history stage and measured for fork length and total body weight. External and internal health examinations are conducted for anomalies, disease and parasites, and to identify sex and stage of maturity.

Tributary Sentinel Studies

Fish collections of slimy sculpin (Muskeg, Steepbank, Horse and Dunkirk rivers) and longnose dace (Ells River) are conducted using identical methods. Fish sampling is concentrated in habitat considered optimum for slimy sculpin and longnose dace (i.e., moderate to fast flow, with gravel/cobble/boulder substrate). Fishing is conducted using a portable backpack electrofishing unit and fish are collected using dip nets as well as portable pole seine held downstream of the electrofishing unit.

During past lethal sentinel studies, slimy sculpin were processed according to procedures previously outlined for trout-perch, with the exception that total length is measured rather than fork length (a sculpin caudal fin is not forked) and otoliths are collected for ageing analysis (sculpin lack scales).

For the non-lethal approach, small-bodied sentinel species are collected during two discrete sampling periods (summer and late fall). During the first trip, an area is defined by placing two small-mesh, full span block nets approximately 50 to 80 m apart to stop upstream/downstream movement of fish. The area is systematically sampled using backpack electrofishing unit and a portable pole seine. If possible, multiple passes of the enclosed area are conducted to ensure all sentinel fish have been captured. This information is used to estimate the density of the sentinel species. A sample size of 100 fish is targeted per area (may need to go outside of enclosure to meet this target). In late fall (i.e., the second sampling trip), blocking nets are not used, but 100 fish are again collected from the general sampling area.

Captured fish are enumerated by life history stage and measured for fork length and weight; an external pathology examination is conducted to assess the presence of abnormalities, disease and/or parasites. Sex and state of maturity is recorded when discernible by external examination.

Habitat assessments are also conducted to evaluate inter-site comparability. The assessment includes a range of variables relating to channel morphology and flow, substrate, water quality, and fish cover as outlined in Golder (1998) and BC MOELP (1998).

Fish Fence Monitoring

Fish fences deployed on the Muskeg River span the full width of the river and are constructed with aluminum conduit piping held in place by an aluminum frame and wooden tripods. RAMP operates a two-way fence, which has two trap boxes facing in opposite directions, each with its own set of wings of fencing material to capture fish moving upstream and downstream. Fences are placed in easily accessible areas of low to moderate current velocity (i.e., $<9\ m^3/s$), stable substrate (i.e., not easily eroded) and at a depth that can be safely waded. The traps are checked at least twice daily; once in the morning and again in the evening; traps are checked more frequently during active spawning runs. Fish are removed from the trap using a dip net and enumerated by species, date, time, and direction of movement (upstream or downstream). The fence is typically deployed for a period of 30 days extending from late April to end of the upstream migration runs (mid to late May).

Captured fish are measured for fork length and body weight; an external pathology examination is conducted to assess the presence of anomalies, disease and/or parasites. Sex and state of maturity is recorded when discernible by external examination. Non-lethal ageing structures are collected and placed in scale envelopes and dried for future aging. In addition, adipose fins from all Arctic grayling are clipped and archived in individually-labeled envelopes pending future DNA analysis by ASRD.

RAMP-specific Floy tags are affixed to sport fish species (i.e., northern pike and walleye, but not Arctic grayling due to concerns of handling stress) and to the first 50 white sucker and longnose sucker processed each day. All fish are released unharmed in the direction they were moving (i.e., upstream or downstream) when captured.

If spring flow measurements, estimated from snow pack levels and late winter discharge conditions, are predicted to exceed a discharge threshold of $9\ m^3/s$, the RAMP Fisheries Sub-group may determine that the fence operation should be re-scheduled for the following year. Similarly, if actual discharge conditions immediately prior to fence installation exceed $9\ m^3/s$, installation of the fence is postponed until conditions recede below the threshold. The fence program is cancelled if it is felt that a significant portion of the spawning runs has already been missed (depends on flow and water temperature conditions). Based on knowledge gained from past fencing studies, a discharge of $9\ m^3/s$ is the highest discharge that the fence could sustain for an extended period of time; also, these conditions are suitable for the crew to safely install, maintain and monitor the fence.

Fish Tissue Studies

Fish sacrificed for tissue analysis are acquired from a sub-sample of fish captured during the inventory work on the Athabasca River, Clearwater River, the Muskeg River system and selected lakes within the RAMP regional study area.

Initial tissue studies conducted on the Athabasca River and the Muskeg River composited five individual fish per sex per species for analyses. The rationale for this approach was that a) consumers typically eat a “composite” of fish tissue over time; b) it was a cost-effective approach to allow the program to grow over time; and c) the simple design still made it possible to assess for possible differences in tissue burdens between fish species and gender (due to differences in male/female energetics). In 2002, the sampling design for mercury analyses was expanded to provide data from individual fish from five different size classes. The approach recognized that mercury was the dominant concern of local communities and more data were required to better understand the dynamics between fish size (and age) and mercury concentrations in populations being assessed. Table 3.37 summarizes the range of size classes used for each species collected for mercury analyses. The target size classes were selected following examination of the typical size ranges available in the fall, based on existing inventory data. Size classes for lake whitefish from the Athabasca River were relatively narrow compared to other species because lake whitefish present in the fall are mainly adults (i.e., fall spawning run). The size of fish used for composite samples also was standardized at this time; these samples were analyzed for total metals and tainting compounds.

Table 3.37 Target fork length classes for the selection of fish for the RAMP fish tissue programs.

Species	Target Size Classes for Mercury Analysis (mm) (5 fish per class)					Target Size Class for Composite Samples (mm)	
	1	2	3	4	5	Female	Male
Walleye (regional lakes and Athabasca River)	200-300	301-400	401-500	501-600	601-700	500-550	450-500
Northern pike (regional lakes and Clearwater River)	200-300	301-400	401-500	501-600	601-700	600-700	550-600
Lake whitefish (Athabasca River)	350-400	401-450	451-500	501-550	551-600	400-450	400-450
Lake whitefish (regional lakes)	200-300	301-400	401-500	501-600	601-700	400-450	400-450

Fork length and total weight are measured for each fish. An external health assessment is also conducted prior to tissue collection.

Historically, the program has used lethal sampling methods to collect muscle tissue; however, in 2004 non-lethal methods (i.e., biopsy needles or tissue plugs) were evaluated and are now used for collecting individual tissue samples for mercury analyses. Lethal tissue collection is still required for the composite samples.

For the composite analyses, the left side of the fish is filleted to collect a sample for organics analysis and the right side of the fish is filleted to collect a sample for metals analysis. Specific procedures for sampling tissue for organic and metal analyses, including appropriate methods to minimize sample contamination, are provided in Appendix A4. Minimum muscle tissue requirements per fish are 20 g for organic compound analyses and 2 g for metals. Muscle samples collected for organics analyses are individually wrapped in solvent-rinsed (hexane and acetone) aluminum foil and samples collected for metals analyses are individually wrapped in plastic wrap. All samples are labeled with fish ID number, the sampling location, date, and analyses requested, stored on dry ice, and shipped to the analytical lab.

Following the dissection, carcass weight, liver weight and gonad weight are measured for each fish. An internal health assessment is conducted on each fish and ageing structures are collected for future age analyses.

Non-lethal sampling of tissue for mercury analyses follow procedures described by Baker *et al.* (2004). Briefly, fish are anaesthetized and tissue is sampled with either a biopsy needle or dermal punch. A biopsy needle is inserted forward at an oblique angle beneath a scale into the dorsal musculature (i.e., along the muscle wall), The outer barrel of the needle possesses a sharp leading edge, which when extended over the inner needle, cuts and captures a small tissue plug within a cannula. Alternatively, a dermal punch is placed against the exposed epidermis and a downward twisting motion is used to penetrate several millimetres into the tissue. The punch then is rotated parallel to the fish and twisted to cut and capture a small piece of muscle. The wound left from the plug is sealed with a tissue adhesive. Tissue samples are placed in a pre-weighed vial and weighed immediately after collection. The minimum tissue weight required is 40 mg. Samples are stored and shipped on dry ice to Flett Research in Winnipeg, who has refined their analyses to accommodate the smaller samples obtained using non-lethal procedures.

Tissue samples collected from fish related to the regional lakes program follow a modified protocol. The tail sections (between the last rib and end of the caudal peduncle) of each fish are collected on-site by ASRD, placed on ice and transported to the RAMP consultant where they are dissected to provide the laboratory with skinless, interior tissue samples from each specimen. Tissue samples are then frozen and shipped to Flett Research.

Non-Core Activities

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: radio-telemetry studies on the Athabasca and Muskeg rivers, spawning/egg surveys, winter fish habitat surveys, baseline inventory surveys, benthic drift studies and pilot studies evaluating the Index of Biotic Integrity (IBI) and non-lethal approaches to monitoring. Due to the non-core nature of these activities, a summary of sampling methods have not been provided here; however, detailed methods have been described previously in the RAMP annual technical reports specific to the year the studies were conducted.

Similarly, a fish health program was initiated in response to Aboriginal concerns regarding the analysis of fish they capture with anomalies. This program trains community individuals to sample fish and send the tissue to a specified laboratory for analyses. The program is ongoing and provides data to investigate individual fish with anomalies; however, the design of the program does not lend itself to rigorous analyses, nor is it considered a monitoring tool for the fish program.

3.8.6 Analytical Approach

To address the overall objectives of RAMP and the specific objectives of the fish population component, RAMP uses a mix of analytical approaches.

Generally, there are four approaches relevant to the fish component:

a) Control/Impact (e.g., upstream (*baseline*)/downstream (*test*)) comparisons of fish measurement endpoints;

b) Evaluating possible changes or trends in measurement endpoints over time;

c) Combination of a) and b) (i.e., Before-After-Control-Impact design); and

d) Comparisons of tissue measurement endpoints against established guidelines.

Accordingly, baseline conditions are estimated using data collected prior to development, or data collected upstream or beyond the influence of current development. Table 3.38 summarizes the analytical approaches used to test data from each of the core monitoring activities.

Table 3.38 Summary of analytical approaches used to test each hypothesis according to monitoring activity.

Hypothesis	Fish Inventory Monitoring	Sentinel Monitoring	Fish Fence Monitoring	Fish Tissue Monitoring
H_{o1}	Time Trend	Control/Impact, Time Trend	Time Trend	
H_{o2}		Control/Impact, Time Trend		
H_{o3}				Time Trend
H_{o4}				Guidelines

Fish Inventory Monitoring

The focus of the analysis of inventory data is to provide a coarse-filter view of temporal changes in fish community structure. To date, inventory work on the Athabasca River is the most extensive and most suitable for temporal analyses.

All fish captured during the inventory are summarized by species composition (i.e., percent of total catch) and relative abundance (i.e., catch-per-unit-effort [CPUE]). To date, this information has been evaluated qualitatively using graphical and tabular means, recognizing the high-level of variability in both endpoints and the need for greater sample sizes (number of years of data) for statistical trend analyses.

Comparison of length-frequency distributions (and age-frequency if sufficient data are available) among years is based on data collected from spring and fall inventories (i.e., summer data were not always collected). High numbers of lake whitefish are only present in the oil sands region of the Athabasca River during the fall spawning migration. Accordingly, length-frequency analyses for lake whitefish is limited to fall inventory data only. Differences in length-frequency distributions among years for each species are compared separately using the G-test for independence for two-way frequency tables (Sokal and Rohlf 1981). G or the log-likelihood ratio is distributed approximately as X^2. Tables of standardized deviates (year-by-length class) are also examined to identify any obvious pattern in distributions over time. Where possible, data are also compared to historical data collected in connection with the 1970s Alberta Oil Sands Environmental Research Program (AOSERP).

Analysis of condition is completed separately for fish collected during the spring and fall inventories. For most fish species, the spring represents the spawning season, with the exception of lake whitefish, which spawn in the fall. Accordingly, the separate analysis provides information on condition during spawning and non-spawning times of the year. To be consistent with past years, analyses are restricted to fish of a minimum length: walleye >400 mm; lake whitefish >350 mm; northern pike >400 mm; goldeye >300 mm; and longnose sucker >350 mm. For each species, fish condition is estimated by the relationship of total body weight versus fork length ($\log_{10}$ data). Potential differences in condition among years are tested using Analysis of Covariance (ANCOVA). When a high number of outliers (studentized residuals>4) are present in the dataset, the residual values for each fish derived from the ANCOVA model are saved and these data are used to test for differences in condition among years using the non-parametric Kruskall-Wallis test (similar to ANOVA). This approach avoids the potential problems associated with arbitrarily omitting high numbers of fish from the analyses based on residual values, and potentially biasing the results of the test. For graphical purposes, Fulton's Condition Factor is also calculated using the following equation: K=(body weight/fork length^{3}x10^5).

Sentinel Species Monitoring

The sentinel species approach incorporates a control/impact design. As more programs are conducted, greater emphasis can be placed on evaluating changes in measurement endpoints over time, and whether these changes are consistent for populations in *baseline* and *test* areas.

As described in Section 3.5.4, measurement endpoints used for sentinel monitoring is, in part, dictated by whether a lethal or non-lethal approach to monitoring is used. Similarly, the analytical approach is also influenced by the approach used.

Standard Approach

For standard (lethal) sentinel program, the analytical approach used by RAMP is consistent with guidelines described by Environment Canada (2002, 2005) for the metal mining and pulp and paper industries. Lethal sampling of this type was last conducted by RAMP in the 2002 program year (Golder 2003b). Variables tested using this approach includes:

- Growth (size and age);
- Fulton's Condition Factor;
- Gonadal Somatic Index (GSI) (gonad weight relative to carcass weight);
- Liver Somatic Index (LSI) (liver weight relative to carcass weight);
- Fecundity Index (number of eggs per female divided by carcass weight); and
- Pathology Index (uses a scoring system based on internal and external anomalies) (Goede 1993).

The control/impact data analysis involves a simple ANOVA for univariate variables such as age, length and body weight. Assumptions of ANOVAs are tested using residual plots and data are $\log_{10}$-transformed if needed.

For variables that are estimated by a bivariate relationship (i.e., size-at-age, condition, gonad size, fecundity, and liver size), ANCOVA is used to test for differences between populations in *baseline* and *test* areas. With the exception of size-at-age and condition, carcass (i.e., eviscerated weight) is used instead of body weight to avoid potential confounding effects of differences in organ weights on the interpretation of variables related to body weight. ANCOVA includes the assumption that the slopes of regression lines calculated for populations in *baseline* and *test* areas (for a given study variable) are equal. Differences in slopes are tested prior to conducting each ANCOVA. If slopes are statistically different ($p<0.01$; Paine 1998), scatterplots are used to qualitatively assess differences between areas. If needed, data are $\log_{10}$-transformed and, if transformations do not allow the data to meet assumptions for the ANCOVA, analyses are performed on ranked data.

Non-lethal Approach

Monitoring endpoints tested under the non-lethal approach do not, by definition, require lethal sampling of fish. Therefore, measures for GSI, LSI, fecundity and internal pathology index are not calculated in favour of the endpoints discussed below.

Population Size Distribution: For small-fish species, length frequency distributions are broken into 2 mm size classes and compared using the two-sample Kolmogorov-Smirnov test (K-S test)(α = 0.05). The distributions of fish from *test* and *baseline* areas are compared, assessing both the shape and position of distributions of populations from *test* and *baseline* areas.

Growth: Length and weight distributions are compared between summer and fall sampling events to determine growth of the species populations. Length and weight are log-transformed and compared among sites and between seasons (summer and fall) using ANOVA, with Bonferroni adjusted post-hoc multiple comparisons for differences between areas.

Energy Storage: Condition factor (i.e., "fatness") was analyzed among sites using analysis of covariance (ANCOVA; α = 0.05) in which weight represented the dependent variable, site the independent, and length the covariate (plus the interaction term). The first step in an ANCOVA analysis (beyond assessment of issues surrounding normality) involves comparing slopes of length-weight regressions from different populations with the second step being the assessment of the intercepts. An assumption of the ANCOVA model is that the slopes of the regression lines are equal between areas. For graphical purposes, Fulton's Condition Factor was also calculated, as K=(body weight/fork length^3 x 10^5).

Fish Fence Monitoring

For the 2006 Muskeg River fish fence program (the most recent time this sub-component was conducted), data were analyzed by calculating the mean and standard error for fork length, weight, age, Fulton's Condition Factor and Pathology Index value for large-bodied fish species captured.

For large-bodied species with an adequate sample size (i.e., n ≥ 30), the following population characteristics were examined:

- size (fork length) frequency distribution;
- age frequency distribution;
- weight versus fork length relationship (i.e., condition); and
- size-at-age (fork length versus age) relationship.

For each fish species caught at the fence, ANOVA was used to compare fork length between sexes. Estimates of size-at-age (fork length vs. age) and condition (body weight vs. fork length) between sexes were evaluated using an ANCOVA approach. Generally, ANCOVA is fairly robust even when slopes are not equal, so slopes were considered different when $p<0.01$ (Paine 1998). Data are $\log_{10}$ transformed where appropriate.

Data are examined graphically to identify peak times for fish movement and the number of fish entering and exiting the river (by species) while the fence is installed. Data are compared to previous fish fence studies in the Muskeg River including those conducted under RAMP and the Alberta Oil Sands Environmental Research Program (Bond and Machniak 1977).

Fish Tissue Studies

Scatterplots are used to initially assess the relationships between mercury concentrations in fish and whole-organism variables. Rank correlations are then used to evaluate relationships between these variables for each species and sex combination. The significance of a correlation is determined using critical values of Spearman's correlation coefficient (r_s). A correlation is described as moderate if $|0.50| > r_s < |0.75|$ and strong if $r_s > |0.75|$. If significant rank correlations are observed, linear regression is used to further evaluate the relationship. Assumptions of regression models are tested and if necessary regressions are performed using $\log_{10}$-transformed or ranked data.

To assess potential effects of ingestion of fish tissue on human health, fish tissue data are screened against guidelines for chemical contaminants in fish (CFIA 2003) and for exposure of Aboriginal residents to methyl-mercury in the Canadian environment (Health Canada 1978, cited in Lockhart *et al.* 1985; CCME 2001), Region III USEPA risk-based criteria for consumption of fish tissue for recreational and subsistence fishers (USEPA 2003), and National USEPA risk-based screening values for consumption of fish tissue (USEPA 2000). To assess potential tainting of fish tissues, concentrations of tainting compounds are compared to criteria developed by Jardine and Hrudey (1988). To assess potential effects on fish health, fish tissue data are compared to the lowest tissue residue concentrations linked to effects (or a lack of effects) as derived from laboratory-based studies summarized in Jarvinen and Ankley (1999). Annual results are also compared to tissue results from previous RAMP years as well as historical data (e.g., Lutz and Hendzel 1976).

It is important to note that RAMP undertakes only a screening-level assessment of fish tissue concentrations of chemicals relative to available fish consumption guidelines. However, all data are provided to federal (Health Canada) and provincial (Alberta Health and Wellness) agencies responsible for reviewing and developing fish consumption guidelines and recommedations for consumers in Canada and Alberta, respectively.

3.9 ACID-SENSITIVE LAKES COMPONENT

3.9.1 Component History

The origin of the Acid-Senstive Lakes (ASL) program can be traced to 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 Athabasca 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 TEEM (Terrestrial Environmental Effects Monitoring Committee) for terrestrial receptors and RAMP for aquatic receptors.

The ASL component of RAMP was initiated in 1999. The stated objective of the new component was "to monitor lake water chemistry as an early-warning indicator of excessive acid deposition" (RAMP 2000). Acid-sensitive lakes were expected to show changes in their buffering capacities "before soils or vegetation could provide a clear indication that acid limits were reached ". A total of 32 lakes were sampled between 1999 and 2001. In 2002, the ASL program was expanded by 18 lakes, thereby increasing the number of monitored lakes to 50 (Table 3.39, Figure 3.12).

Table 3.39 Summary of RAMP data available for the ASL component, 1997 to 2008.

NO_x-SO_x GIS No.	Original RAMP Designation	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
168	A21	+	+	+	+	+	+	+	+	+	+
169	A24	+	+	+	+	+	+	+	+	+	+
170	A26	+	+	+	+	+	+	+	+	+	+
167	A29	+	+	+	+	+	+	+	+	+	+
166	A86	+	+	+	+	+	+	+	+	+	+
287	25 (287)				+	+	+	+	+	+	+
289	27 (289)				+	+	+	+	+	+	+
290	28 (290)				+	+	+	+	+	+	+
342	82 (342)				+	+	+	+	+	+	+
354	94 (354)				+	+	+	+	+	+	+
165	A42	+	+	+	+	+	+	+	+	+	+
171	A47	+	+		+	+	+	+	+	+	+
172	A59	+	+	+	+	+	+	+	+	+	+
223	P94 (223)				+	+	+	+	+	+	+
225	P96 (225)				+	+	+	+	+	+	+

Table 3.39 (Cont'd.)

NO_x-SO_x GIS No.	Original RAMP Designation	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
226	P97 (226)				+	+	+	+	+	+	+
227	P98 (227)				+	+	+	+	+	+	+
267	1 (267)				+	+	+	+	+	+	
452	L4	+	+	+	+	+	+	+	+	+	+
470	L7	+	+	+	+	+	+	+	+	+	+
471	L8	+	+	+	+	+	+	+	+	+	+
400	L39	+	+	+	+	+	+	+	+	+	+
268	E15 (268)		+	+	+	+	+	+	+	+	+
182	P23 (182)				+	+	+	+	+	+	+
185	P27 (185)				+	+	+	+	+	+	+
209	P7 (209)				+	+	+	+	+	+	+
270	4 (270)				+	+	+	+	+	+	+
271	6 (271)				+	+	+	+	+	+	+
418	Kearl L.					+	+	+	+	+	+
436	L18 Namur	+	+	+	+	+	+	+	+	+	+
442	L23 Otasan	+	+	+	+	+	+	+	+	+	+
444	L25 Legend	+	+	+	+	+	+	+	+	+	+
447	L28	+	+	+	+	+	+	+	+	+	+
448	L29 Clayton	+		+	+	+	+	+	+	+	+
454	L46 Bayard	+	+	+	+	+	+	+	+	+	+
455	L47	+	+	+	+	+	+	+	+	+	+
457	L49	+	+	+	+	+	+	+	+	+	+
464	L60	+	+	+	+	+	+	+	+	+	+
175	P13 (175)				+	+	+	+	+	+	+
199	P49 (199)				+	+	+	+	+	+	+
473	A301			+	+	+	+	+	+		+
118	L107 Weekes		+	+	+	+	+	+	+	+	+
84	L109 Fletcher	+	+	+	+	+	+	+	+	+	+
88	O-10	+	+	+	+	+	+	+	+	+	+
90	R1	+	+	+	+	+	+	+	+	+	+
146	E52 Fleming	+	+	+	+	+	+	+	+	+	+
152	E59 Rocky Is.	+	+	+	+	+	+	+	+	+	+
89	E68 Whitesand		+	+	+	+	+	+	+	+	+
91	O-1	+	+	+	+	+	+	+	+	+	+
97	O-2	+	+	+	+	+	+	+	+	+	+
428	L1	+									
83	O3/E64	+									
85	R2	+									
86	R3	+									
310	A300			+							

The RAMP lakes were monitored for various chemical variables that were deemed capable of indicating long-term trends in acidification (Table 3.40). These included: pH, total alkalinity, gran alkalinity (acid neutralizing capacity), base cations, sulphate, chloride, nitrates, dissolved organic carbon, dissolved inorganic carbon and chlorophyll.

Gran alkalinity and dissolved inorganic carbon were added to the variable list by AENV in 2002. Gran alkalinity is accepted as the normal and most accurate measure of alkalinity because it determines the inflection point in the alkalinity titration curve. Gran alkalinity includes both inorganic buffers (bicarbonates/ carbonates) and weak organic acid buffers. In the same year, Alberta Environment added metals analysis of each lake to the list of ASL monitoring variables. Each lake is now routinely monitored for a suite of 29 metals including both the total and dissolved fractions. In 2004, Alberta Environment initiated a seasonal sampling of 10 ASL lakes to quantify the seasonal variability in ASL monitoring variables. Reporting of these results and of the results for the metals analysis was incorporated into the annual RAMP Technical report.

Figure 3.12 Sampling locations for the RAMP Acid-Sensitive Lakes component, 1997 to 2008.

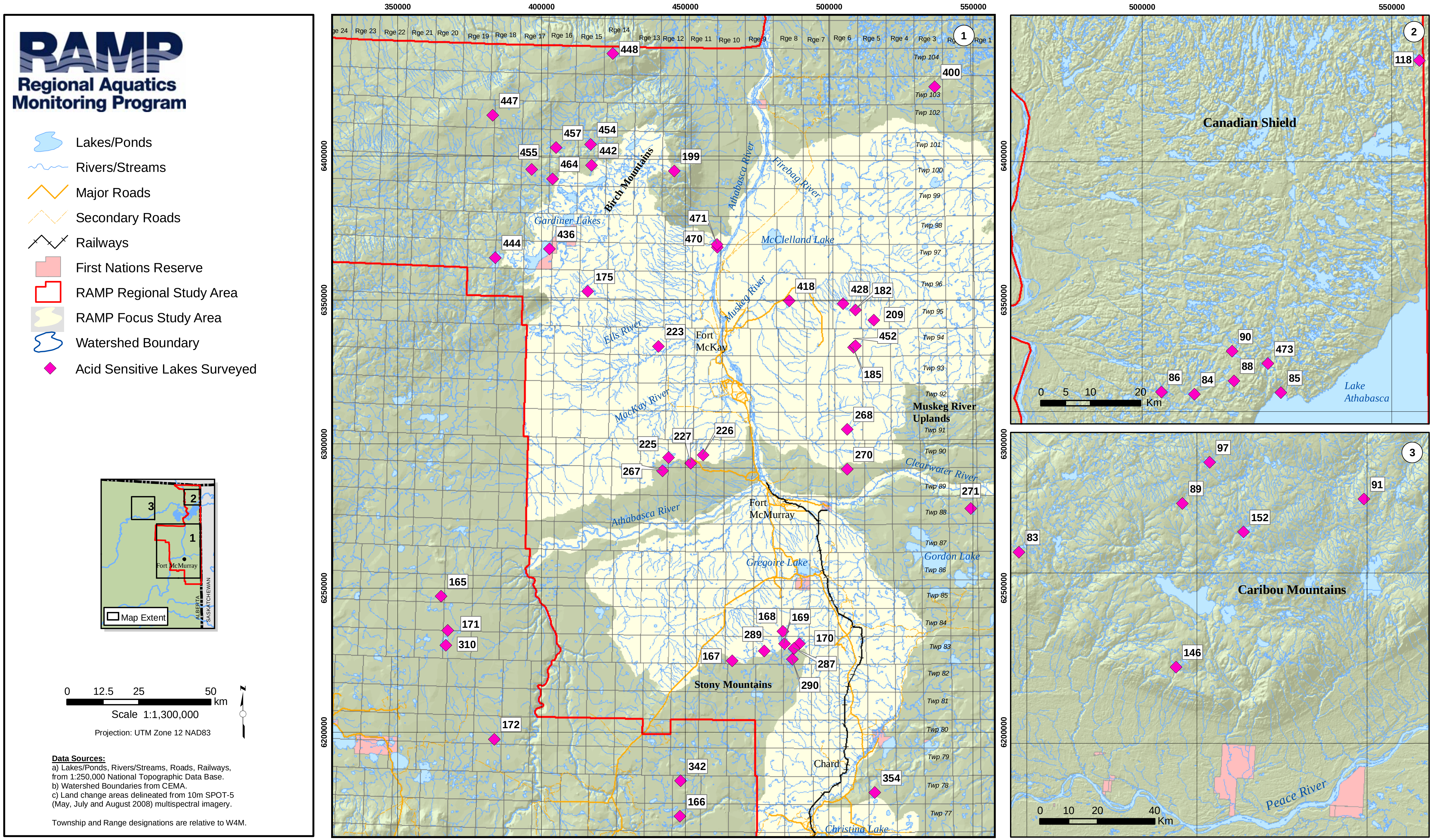


Table 3.40 Water quality variables measured for the ASL Component.

pH	Bicarbonate	ammonia
turbidity	Gran alkalinity	nitrite + nitrate
colour	chloride	total Kjeldahl nitrogen (TKN)
total suspended solids (TSS)	sulphate	total nitrogen (TN)
total dissolved solids (TDS)	calcium	total phosphorus (TP)
dissolved organic carbon (DOC)	potassium	total dissolved phosphorus (TDP)
dissolved inorganic carbon (DIC)	sodium	chlorophyll *a*
conductivity	magnesium	total and dissolved metals
total alkalinity (fixed point titration to pH 4.5)	iron	
	silicon	
	total dissolved nitrogen (TDN)	

Initial analyses of the lake monitoring data were largely descriptive, especially in the first year of the ASL component (RAMP 2000). Ranges for major variables were presented and outliers and extreme values were noted. Significant relationships were observed between DOC and colour, pH and total alkalinity and total phosphorus and chlorophyll *a*. Similar relationships are well noted in the literature (e.g., Kortelainen and Manio 1990; Dillon and Rigler 1974). No relationship was observed between H+ and sulphur, a significant finding since a relationship between H+ and sulphate is assumed in studies on lake acidification in eastern North America and Europe.

By 2002, analyses had incorporated calculations of lake-specific critical loads of acidity, defined as the highest rate of acidic deposition that will not cause long-term ecological effects on a lake. The lake-specific critical loads were calculated from the Henriksen steady state water quality model. Following the practice of recent EIAs, the lake-specific critical loads were compared to the modelled PAI (potential acid input) defined as the total acidifying potential of atmospheric deposition attributable to both wet and dry forms of sulphur and nitrogen minus the neutralizing effects of base cations. Year-to-year changes were observed in some key variables but insufficient data were available for statistical trend analyses.

In 2003 and 2004, analyses of the RAMP monitoring data had a different emphasis than in previous years (RAMP 2004; RAMP 2005a). The addition of Gran alkalinity and dissolved inorganic carbon (DIC) as monitoring variables in 2002 permitted the determination of the role of weak and strong organic acids in the acid-base status of these lakes. Using techniques derived from the international literature on humic lakes, the RAMP data were used to calculate the:

- the concentrations of free dissociated organic acids in each lake;
- the degree of 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 each lake.

In addition, the chemistry and morphometric characteristics of the RAMP lakes were compared to the range of these variables in the NO_XSO_x Management Working Group's database of 450 lakes within the oil sands region. The goal was to determine how typical the RAMP lakes were of lakes in the region.

In 2004, the standard Henriksen steady state model for determining critical loads of acidity was modified to incorporate the effects of weak and strong organic anions in each of the RAMP lakes (Henriksen 1980). The same process had been applied to the entire database of regional lakes in a report commissioned by the NO_XSO_x Management Working Group (NSMWG). As sufficient data were now available on a subset of the 50 RAMP lakes, trend analysis was applied to a number of water quality variables in an attempt to detect possible impacts from acid deposition.

3.9.2 Key Indicator Resources

As with a number of the other RAMP components, the ASL component does not easily lend itself to the KIR concept. The water quality variables measured for the ASL component are more accurately defined as measurement endpoints indicating the acid sensitivity or acid-base status of the lake. Measurement endpoints and criteria for determining potential impacts of acidifying deposition are discussed in Section 3.9.4, below.

3.9.3 Hypotheses and Questions

3.9.3.1 Hypotheses and Questions from Athabasca Oil Sands EIAs

There are few residual impact assessments in oil sands EIAs related to effects on acid-sensitive lakes. Of the 17 EIAs reviewed for this project (Chapter 2), only 21 residual impact assessments pertained to acid-sensitive lakes; 18 of these residual impact assessments were predicted to be negligible or low in magnitude. Practically all residual impact assessments related to acid-sensitive lakes were considered at the regional (RSA) scale. Oil sands development impacts on acid-sensitive lakes as predicted in the various EIAs arose from the generation, atmospheric transport, and deposition of acidifying emissions.

3.9.3.2 RAMP Objectives, Key Questions and Hypotheses

The RAMP ASL component was originally designed to monitor lake water chemistry in regional lakes "as an early-warning indicator of excessive acid deposition" (RAMP 2000). Acid-sensitive lakes were expected to show changes in their buffering capacities before soils or vegetation could provide a clear indication that acidic thresholds have been reached. While the order of these events (observed effects in lakes preceding those in soils) may be debated, the basic objective of the ASL program remains relatively simple: the lakes are monitored to detect effects of acidifying deposition on water quality and lake biology. Currently, the RAMP ASL component is focused on monitoring for potential changes in water quality. However, Alberta Environment, in collaboration with Environment Canada, has undertaken concurrent collections of phytoplankton and zooplankton to assess possible changes in lake biology.

As in most RAMP components, the objectives of the ASL program evolved over time. Specific objectives of the ASL program, similar to the general rationale for the RAMP program, were articulated in the five-year report (Golder 2003a) and other documents (e.g., Ayles *et al.* 2004) to include the:

1. Establishment of a database on 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;

2. Collection of scientifically defensible baseline and historical data (both chemical and biological) to characterize the natural variability of these measurement endpoints in the ASL lakes;

3. Collection of data on the regional lakes against which predictions contained in environmental impact assessments (EIAs) could be verified; and

4. Quantification and documentation of individual lake sensitivity to acidification.

This fourth objective, although not stated explicitly in the RAMP literature, has evolved in the 2003 and 2004 reports.

These objectives of the ASL component suggest the following questions that have been discussed in RAMP technical meetings:

- What is the natural or normal range of variability of measurement endpoints used to detect acidification in these lakes?

- Are there trends in lake chemistry that would indicate incipient acidification?

- Are the predictions of the EIAs on the potential for lake acidification supportable?

These questions can be re-phrased as null hypotheses to be tested by the RAMP program:

- $H_{01:}$ The RAMP lakes do not show any evidence of incipient acidification beyond the natural variability of relevant measurement endpoints; and

- H_{02}: There are no effects of Athabasca oil sands developments on the potential for acidification of the RAMP lakes.

The first hypothesis is tested by determining the variability of measurement endpoints in each lake through continual water quality monitoring during the life of the RAMP program. The ever-enlarging database will provide an increasingly accurate estimate of the natural variability of these variables. As data are accumulated, trend analyses and other statistical tests can be applied to detect significant changes in relevant measurement endpoints in time.

The second hypothesis, that of validating EIA predictions, may prove more difficult to test. If the lakes identified in the EIAs are RAMP lakes or are currently monitored under a company's approvals, then any changes in measurement endpoints will become evident in the tests for the second hypothesis. If the lakes are not RAMP lakes or are not currently monitored, then potential changes can only be surmised by examining the effects of each development on RAMP lakes that are similar in chemistry, size, drainage area and are exposed to a similar rate of acid deposition.

3.9.4 Measurement Endpoints and Criteria for Determining Change

Measurement endpoints known to be affected during acidification include the pH, Gran alkalinity, base cation concentrations, nitrate+nitrite concentrations, DOC, sulphate, and the aluminum concentration of each lake. Sulphate is included in the list of measurement endpoints but, unlike lakes in other regions (e.g., Eastern Canada), sulphate and acidity (H^+) in Alberta lakes are poorly correlated because of the abundance of neutral sulphate compounds in wet deposition (AEP 1990; Lau 1982; Legge 1988). In fact, sulphate correlates better with calcium than with H^+. The poor correlation between sulphate and H^+ in the RAMP lakes was demonstrated in RAMP (2004, Section 8.4.2).

In general, the oil sands EIAs have not specified criteria for determining change in acid sensitive lakes, choosing instead to enumerate the number of lakes with a potential acid input (PAI) exceeding the lake-specific critical loads. This process only identified specific lakes having the *potential* for acidification under the various cases examined. While monitoring and participation in the RAMP program were specified in each EIA, specific criteria that would indicate changes or impacts were not formulated.

A significant change in a lake from acid deposition is concluded if a significant difference is noted in one or more measurement endpoints beyond natural variability. A significant change is defined as a statistically significant difference at $P<0.05$ that is directly attributable to increased deposition of acidifying substances. Natural variability is measured as the variance of the measurement endpoint. These endpoints include a reduction of lake pH, gran alkalinity, critical load or base cation concentrations or an increase in nitrates or aluminum concentrations.

3.9.5 Lake Selection and Monitoring Design

3.9.5.1 Lake Selection

The criteria for lake selection have changed somewhat as the ASL component has evolved. Initially, the criteria for selecting the RAMP lakes included the following:

- In the context of lakes in Alberta, the lakes were to exhibit moderate to high sensitivity to acidification as defined by a total alkalinity less than 400 μeq/L;
- The lakes were to cover a range in organic content (clear water to brown water lakes);
- The lakes were to be located along a gradient of potential acidic deposition radiating from the oil sands region. Acid deposition was determined as PAI from air quality modelling conducted during recent EIAs;
- The lakes had to be accessible by float plane to ensure a cost-effective program;
- For scientific validity, the lake selection were to include baseline lakes in the Caribou Mountains and Canadian Shield that were distant from the sources of acidifying emissions;
- The lakes were to include several lakes already having long-term monitoring data (e.g., L4, L7 and L25 from Saffron and Trew 1996);
- Lakes were chosen to represent all the physiographic subregions within the oil sands area (Birch Mountains, Caribou Mountains, Muskeg Mountain Uplands, Canadian shield); and
- A fall sampling program was implemented to capture a picture of lake water chemistry after conditions had, theoretically stabilized.

In 2002, the additional 18 lakes added to the ASL component were selected by:

- adding lakes between 55.7°N and 57.7°N and from 110°W to 113.2°W, corresponding to the area with the greatest density of existing and planned oil sands developments;
- including lakes where PAI exceeded critical loads under Planned Development (cumulative) scenarios from EIAs of recent oil sands developments;
- including lakes with low critical loads (i.e., highly acid sensitive lakes) from each of four separate quadrants (NE, SE, SW, and NW) relative to Fort McMurray; and

- including very small water bodies (ponds), previously ignored because of their size and inaccessibility by fixed wing aircraft. These ponds were believed to be, generally, very low in alkalinity and hence highly sensitive to acid deposition in the Alberta context.

3.9.5.2 Sampling Protocol

Overview of Field Methods

AENV provides the sampling equipment and logistical support for the lake sampling program. A float plane is used to access the majority of study lakes while a helicopter with floats is used to reach the smaller lakes.

Water samples are collected from the euphotic zone at a single deep-water site in each major basin of each lake using weighted Tygon tubing and are then combined to form a single composite sample for chemical analysis. When the euphotic zone extends to the lake bottom, sampling is restricted to depths greater than 1 m above the lake bottom. In shallow lakes (< 3 m deep), composite samples are created from five to ten, one litre grab samples collected at 0.5 m depth along a transect dictated by wind direction (upwind to downwind shore).

The euphotic zone is defined as twice the Secchi disk depth. 1% light penetration has been found to correlate reasonably well with twice the Secchi depth. Vertical profiles of dissolved oxygen, temperature, conductivity and pH are measured at the deepest location using a field-calibrated water quality meter. Secchi depth is also recorded. Samples for chemical analysis are stored on ice and are shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection.

In support of activities undertaken by Alberta Environment and Environment Canada, subsamples of 150 mL volume are taken from the euphotic zone composite samples for phytoplankton taxonomy. These samples are preserved using Lugol's solution. One or two replicate zooplankton samples are also collected in each lake as vertical hauls through the euphotic zone, using a #20 mesh (63 µm), conical plankton net. Zooplankton samples are preserved in approximately 5% formalin after anaesthetizing in club soda. Plankton samples are stored at AENV pending future analysis.

Field and Laboratory Quality Control Protocols

As part of the QA/QC program, one blind field blank is collected using deionized water from the Limnology Laboratory, University of Alberta. Split samples are additionally assessed by the University of Alberta lab. Quality control samples are analyzed for all variables.

3.9.6 Analytical Approach

The ASL component includes both primary and supporting analyses of the data. The primary analyses are intended to detect and evaluate trends in the ASL measurement endpoints in the RAMP ASL lakes that would indicate incipient changes in the buffering capacity and acid sensitivity of the lakes according to the criteria for determining change are described above. Four specific primary data analyses are conducted:

- Between-year comparison of measurement endpoints over the entire population of 50 lakes;
- Calculation of critical loads of acidity and comparison to modeled potential acid input;
- Mann-Kendall trend analysis on measurement endpoints in individual lakes; and
- Graphical trend analysis on ASL measurement endpoints in those lakes determined to be most at risk to acidification.

The supporting data analyses include analyses aimed at describing the chemistry of the ASL lakes, quantifying the variability in monitoring variables and describing the relationship between the RAMP lakes to regional lake chemistry. Supporting data analyses include the following:

- An update of the ASL database, calculation of summary statistics, identification of lakes with unusual chemical characteristics;
- Comparisons of the chemistry of the RAMP lakes to the range of chemical characteristics of lakes within the Athabasca oil sands region;
- Update and analysis of the metals database available on the ASL lakes; and
- Update and analysis of the database on measurement endpoints in the ten ASL lakes monitored by AENV to determine seasonal variabilty.

3.9.6.1 Details of the Analytical Approach

Primary Analyses

Between-Year Comparison of Measurement Endpoints An Analysis of Variance (ANOVA) is conducted to determine whether there have been any significant changes in the concentrations of the ASL measurement endpoints in the 50 RAMP lakes, as a group, during the years when all 50 lakes were sampled. Any observed changes are discussed in relation both to acidification and natural variability.

Calculation of Critical Loads of Acidity and Comparison to Modeled Potential Acid Input The critical load (CL), in units of keq H+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology and represents a measure of a lake's sensitivity to acidification. CLs for the RAMP lakes in 2008 were calculated using the

Henriksen steady state water chemistry model (Henriksen and Posch 2001; Henriksen *et al*. 1992; Forsius *et al*. 1992; Rhim 1995) modified for the effects of organic acids on buffering and acid sensitivity (RAMP 2005a; WRS 2006).

In the normal Henriksen model the critical load for a lake is calculated as:

$$CL = ([BC]^*_0 - [ANC_{lim}]) \cdot Q$$

where:

- CL in the critical loading level of acidity;
- $[BC]^*_0$ is the pre-industrial (original) non-marine base cation concentration in the lake assumed, equivalent to the current base cation concentrations;
- Q is the mean annual catchment runoff calculated from regional analysis of flow data collected from over 40 hydrometric stations monitored by the Water Survey of Canada; and
- ANC is the critical value for the acid neutralizing capacity in the water for a given indicator organism. ANC_{lim} was assumed to be 75 µeq/L based on discussions in WRS (2004).

The equation states that the critical load is equivalent to the acid neutralizing capacity (ANC) or alkalinity generated within the lake catchment (acid consuming processes) less a critical chemical threshold of ANC (ANC_{lim}) required to protect a selected biological indicator. The alkalinity generating processes are represented by the original or historical export of base cations from the catchment (weathering). By including Q, the runoff, in the equation, both ANC generation and the critical chemical threshold are expressed in terms of a flux (mass/time).

Following an approach initiated by the NSMWG and discussed in RAMP (2005a), the original Henriksen model has been modified to account for both the buffering of weak organic anions and the lowering of ANC attributable to strong organic acids. The modified model assumes that DOC, with its associated buffering from weak organic acids (ANC_{org}) and reduction of ANC from strong organic acids (A^-_{SA}), is exported from the catchment basin to the lake in the same way that we assume the export of base cations (carbonate alkalinity). The relationships developed between ANC_{org} and DOC and pH, and between A^-_{SA} and DOC are then substituted into the Henriksen equation.

Thus:

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

where,

$$ANC_{org} = 0.0068 * DOC * \exp(0.8833*pH) \text{ and}$$

$$A^{-}_{SA} = 6.05 * DOC + 21.02$$

The two empirical formulae for ANC_{org} and A^{-}_{SA} were derived for the RAMP lakes in RAMP (2005).

The runoff to each lake (Q) can be calculated both from traditional hydrometric methods and from previous analyses of heavy isotopes of oxygen (^{18}O) and (^{2}H) in each lake. In the latter technique, the natural evaporative enrichment of ^{18}O and ^{2}H in the lakes is used to partition water losses between evaporation and liquid outflow and hence derive an estimate of runoff (Gibson 2002; Gibson *et al.* 2002; Gibson and Edwards 2002). This technique utilizes a different set of assumptions from the hydrometric method which extrapolates water yields from one or more gauged catchments to the ungauged lake catchments. Potential inaccuracies in the hydrometric method, especially in low-relief catchments, have long been recognized (WRS 2004). The isotopically derived values of runoff are taken from a study by Bennett *et al.* (2008) and are tabulated in recent RAMP technical reports (e.g., RAMP 2008). Critical loads are calculated using both estimates of runoff and the values compared.

The critical loads for each lake are compared to levels of the Potential Acid Input (PAI) to each lake basin taken as the modeled rate of acid deposition (planned development case) for each lake published in the most recent impact assessment conducted in the oil sands region. As listed values of PAI are generally unavailable for lakes in the Caribou Mountains and the Shield region, they are estimated from background PAI values (no industrial input) determined from RELAD modeling conducted by Alberta Environment in 2002. Exceedances of the critical loads imply that a lake has a potential for acidification although acidification may not be imminent.

Mann-Kendall Trend Analysis on Measurement Endpoints in Individual Lakes Potential trends in the ASL measurement endpoints are examined for all lakes for which at least 7 consecutive years of data are available. The analysis uses the Mann-Kendall non-parametric test (Gilbert 1987). Estimates of analytical error (determined as the percent error of the analysis reported by the laboratory at each concentration) are incorporated in the analyses to evaluate the validity of any trends observed in ASL measurement endpoints. Significant trends are discussed relative to PAI and other factors.

Trends Analysis by Control Charting of ASL Measurement Endpoints in Individual Lakes In addition to the Mann Kendall analyses described above, key measurement endpoints (pH, Gran alkalinity, sulphate, sum of base cations and nitrates, dissolved organic carbon) were charted in Shewhart control plots for 10 lakes deemed most at risk to acidification. These ten lakes are selected for control charting on the basis of a high ratio of PAI to the value of the critical load; the greater this ratio in a lake, the greater is the risk for acidification. The control plots follow standard analytical control chart theory where control limits representing two and three standard deviations are plotted on the graphs with the points and the mean value (Gilbert 1987). The lines at two standard deviations represent warning limits while the lines at three standard deviations identify distinct outliers. A trend in a measurement endpoint is often assumed if three consecutive points fall on the same side outside of the two standard deviation warning limits or one point outside of the three standard deviation control limit.

Supporting Analyses

Update of the ASL Database, Summary Statistics and Comparisons of RAMP ASL Lake Chemistry to Regional Lake Chemistry The chemical data from all years of the ASL component are tabulated and summarized statistically. Lakes with unusual chemical characteristics are identified based on exceedances of the 95th percentile in measurement endpoints. A Piper plot is prepared to characterize the RAMP ASL lakes by their major ion chemistry. The chemical characteristics of the RAMP ASL lakes are compared to those of 450 regional lakes reported in the lake sensitivity mapping study produced for the NOxSOx Management Working Group (NSMWG) (WRS 2004). Comparisons involve:

- examination of the ranges, medians and mean values of key chemical variables for 2008 in the RAMP lakes relative to the regional dataset;
- graphical presentation of both datasets in box plots; and
- statistical comparison of chemical variables between the RAMP ASL lakes and the regional dataset. The mean concentrations of the variables in the two lake populations are compared statistically using Student's *t* tests after appropriate transformations to ensure normality and homogeneity of variances.

Analysis of Metal Concentrations in the RAMP ASL Lakes The total and dissolved metal fractions from all the years of metals monitoring by AENV are tabulated and summarized statistically for each metal. Lakes having extremely high metals concentrations are identified as those exceeding the 95th percentile concentration for individual metals; exceedances of the Alberta and CCME surface water quality guidelines were also identified. The metal concentrations are discussed relative to the physiographic subregions in which the lakes are found.

Analysis of Seasonal Data from AENV. The database from the seasonal sampling program on 10 ASL lakes is updated, tabulated and examined statistically. Analysis includes calculation of the range, mean, standard deviation and coefficient of variation of each measurement endpoint for each of the ten lakes. The data for each variable/lake are normalized by subtracting the mean from each value and dividing by the standard deviation. Normalization permits between-lake comparisons in the variability of measurement endpoints when the lakes differ greatly in chemistry. Both the absolute and the normalized values of each measurement endpoint for each lake are plotted against sampling date to show the range and pattern of seasonal changes.

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5.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

HATFIELD CONSULTANTS:

Approved by: Heather Keith — December 14, 2009

Heather Keith
Project Manager
Date

Approved by: Wade Gibbons — December 14, 2009

Wade Gibbons
Project Director
Date

APPENDICES

Appendix A1

RAMP Terms of Reference (membership list updated as of December 2009)

Regional Aquatics Monitoring Program for the Athabasca Oil Sands
Terms of Reference as of December 15, 2008

1.0 DEFINITIONS AND INTERPRETATIONS

1.1. The following definitions apply to the terms of reference for the Regional Aquatics Monitoring Program for the Athabasca Oil Sands;

b. "RAMP" **-**means the Regional Aquatics Monitoring Program for the Athabasca Oil Sands within the Regional Municipality of Wood Buffalo**.**

-is science-based, primarily industry funded, consultant administered, and Member directed

c. "member" means any organization that has applied for and met the requirements for membership of RAMP as set out in these terms of reference**.**

d. A **"funding member**" is a member of the Steering Committee that provides either direct or in-kind funding (equipment or personnel) to carry out RAMP activities.

e. A **"non-funding member"** is any member of the Steering Committee that does not provide direct or in-kind funding for RAMP activities but offers expertise and/or knowledge that furthers the understanding required to carry out RAMP activities

f. "Consensus" means that all group members accept and will abide by the decision, i.e. "can live with it".

2.0 MANDATE

2.1. The Mandate of the Regional Aquatics Monitoring Program (RAMP) is to determine, evaluate and communicate the state of the aquatic environment and any changes that may result from cumulative resource development within the Regional Municipality of Wood Buffalo.

3.0 OBJECTIVES

3.1. The Objectives of RAMP are:

a. To monitor aquatic environment in the oil sands area to detect and assess cumulative effects and regional trends;

b. To collect baseline data to characterize variability in the oil sands area;

c. To collect and compare data against which predictions contained in environmental impact assessments (EIA's) can be assessed;

d. To collect data that satisfies the monitoring required by regulatory approvals of oil sand developments;

e. To collect data that satisfies the monitoring requirements of company-specific community agreements with associated funding;

f. To recognize and incorporate traditional knowledge into monitoring and assessment activities;

g. To communicate monitoring and assessment activities and results to RAMP members, communities in the Regional Municipality of Wood Buffalo, regulatory agencies and other interested parties;

h. To continuously review and adjust the program to incorporate monitoring results, technological advances, community concerns and new or changed approval conditions; and

i. To conduct a periodic peer review of the program's objectives against its results, and to recommend adjustments necessary for the program's success.

4.0 TERMS OF REFERENCE

4.1. The Terms of Reference of RAMP shall be reviewed at least every two years with the first review in October, 1999.

4.2. The chairperson shall initiate this review.

4.3. Recommendations for changes will be prepared by the chairs and vice-chairs of the committees and subcommittees and submitted to the steering committee for ratification.

5.0 ORGANIZATION

5.1. RAMP is composed of the following committees and subcommittees:

- The Steering Committee (SC), and
- The Technical Program Committee (RAMP TECH).
- Finance Subcommittee, and
- Communications Subcommittee

5.2. The Steering Committee is the decision making body for RAMP. Its functions are to:

- Prioritize projects within the program objectives to maximize use of available resources;
- Review program progress against budget and schedule;
- Review program results for relevance to program objectives; and
- Communicate results and solicit input from interested parties.

- Facilitate communication and linkage with other regional environmental initiatives.

5.3. The functions of the Technical Program Committee are to:

- Recommend to the Steering Committee a program that has technical merit and relevance to the needs of the members, and
- To ensure that the data collection, monitoring procedures and analytical techniques utilized are current.
- Review data collected and reports prepared for scientific validity.
- RAMPTECH will be composed of Discipline Specific Tasks Groups that will be responsible to identify and recommend monitoring activities specific to their discipline for compilation into the Annual RAMP Annual Monitoring Program.

5.4. Sub-committees of the Steering Committee are:

a. The Finance Committee

- Is a sub-committee of the Steering Committee.
- Consists of all funding participants and others as maybe designated by the Finance Chair.
- Will review proposed annual budgets and the funding members will determine the appropriate funding mechanisms. The funding formula, once developed by the Finance Subcommittee funding members, and approved by the Steering Committee, shall form an appendix to this document.

b. Communications Subcommittee.

- Is a sub-committee of the Steering Committee,
- Consists of any interested representatives of RAMP member organizations, and
- Will develop strategies for the communication of RAMP programs and results that will be attached as an appendix to these Terms of Reference.

5.5. The Steering Committee may create or strike committees or sub-committees as necessary.

6.0 MEMBERSHIP ON THE STEERING COMMITTEE

6.1. Members represent industrial, regulatory and local community interests. Other interested parties have participated as appropriate. Current members of RAMP are:

- Alberta Energy Resources Conservation Board
- Alberta Environment
- Alberta Pacific Forest Industries Inc. (ALPAC)
- Shell Energy Canada – Shell Albian Sands
- Alberta Sustainable Resource Development
- Hammerstone Corporation
- Canadian Natural Resources Ltd.
- Environment Canada
- Department of Fisheries and Oceans Canada
- Fort McKay First Nation and Metis Local 122
- Fort McMurray First Nation
- Health Canada
- Husky Energy Inc.
- Imperial Oil Resources
- Regional Municipality of Wood Buffalo
- Nexen Canada Inc.
- Suncor Energy Inc.
- Syncrude Canada Ltd.
- Total E&P Canada Ltd.

6.2. Application for membership in RAMP shall be through submission of a letter to the Chair of the Steering Committee.

6.3. New members may be admitted to RAMP provided:

a. The concept of consensus agreement is accepted by the new member,
b. The new member outlines in writing their potential contribution to RAMP and the needs of the member from RAMP,
c. The admission of the new member is approved by consensus, or failing that, by 75% majority vote of all existing members of the RAMP Steering Committee in good standing

6.4. Any non-funding member of the Steering Committee may relinquish its membership upon giving thirty (30) days written notice to RAMP through the Chairperson.

6.5. Any funding member of RAMP may relinquish its membership at the end of the calendar year upon giving 30 days written notice to RAMP through the Chairperson and after remitting any monies owing for the activities for that year.

6.6. Members are expected to adhere to the ground rules (see Section 14.0). Failure to do so could result in membership being revoked.

6.7. The Steering Committee, may by a 75% majority vote of all members in good standing and at a meeting convened in accordance with the requirements set out in Section 9.0, elect to revoke membership from the Steering Committee or the Technical Program Review Committee.

7.0 MEMBERSHIP ON THE TECHNICAL PROGRAM COMMITTEE

7.1. Members may be admitted to the Technical Program Committee (i.e., “RAMP TECH”) following written application to the Chair of the Steering Committee, following the process outlined in Section 6.2.

7.2. The Steering Committee may solicit members for the Technical Program Committee. Solicited members do not need to formally apply for membership on the Technical Program Committee.

7.3. The Technical Program Committee may invite specialists to assist with review without reference to the Steering Committee provided that specialist does not become a permanent or voting member.

7.4. All voting members of the Technical Program Committee must be approved by the Steering Committee. However, representation by any member organization is not limited though votes are limited to one per member organization. Additional RAMP TECH participants may be added at the discretion of the RAMP TECH chair.

8.0 REPRESENTATIVES

8.1. Each member organization shall designate in writing to the Chairperson the name of its representative. That representative is thereby authorized to act and vote in the affairs of RAMP.

8.2. Each member organization may also designate in writing to the Chairperson the name of up to two alternate representatives with full powers to act and vote in the absence of its designated representative.

8.3. Each member organization may change, by notice in writing to the Chairperson, the member’s name, its designated representative, or alternate representatives. Written notice must be received by the Steering Committee Chairperson ten days prior to the next meeting.

9.0 Steering Committee Structure

9.1. The Steering Committee will have 2 officers, namely Chairperson and Vice-Chairperson. Any member of the Steering Committee is eligible for these positions.

9.2. The Steering Committee will appoint a Secretariat. This position serves a coordination function. The Steering Committee may hire an individual or organization in the position of Secretariat.

9.3. Chairperson: The Chairperson shall be an ex-officio member of all Committees. The Chairperson shall, when present, preside at all meetings of the Steering Committee.

9.4. Vice-Chairperson: The Vice-Chairperson, in the absence or disability of the Chairperson, shall perform the duties and exercise the powers of the Chairperson. The Vice-Chair of the Steering Committee shall be the chair of RAMP TECH.

9.5. Secretariat: It shall be the duty of the Secretariat to attend all meetings of the Steering Committee and to ensure that accurate minutes are kept. The Secretariat shall also ensure that;

a. A record of all the members of RAMP and their addresses are kept, and

b. All notices of meetings are sent as required.

9.6. RAMP TECH will elect a Chairperson who will be a member of the Steering Committee.

10.0 MEETINGS

10.1. The Steering Committee shall schedule a minimum of four (4) meetings per year.

10.2. There will be an attempt to hold one meeting annually in one of the local communities other than Ft. McMurray.

10.3. A RAMPTECH meeting will be held annually in the 1st quarter to propose a technical program for the upcoming year for approval by the Steering Committee in time for budget consideration by the funders.

10.4. Meetings of any of the committees may be called at any time by the Chairperson (or the Secretary as instructed by the Chairperson) by written notice to the last known address of each member, mailed, faxed or e-mailed 10 days prior to the date of such meeting. A special meeting shall be called by the Chairperson upon receipt of a petition signed by one-third of the members, setting forth the reasons for calling such a meeting. The notice of such special meeting shall be by letter, fax or e-mail sent to the last known address of each member, at least 10 days prior to the meeting.

11.0 DECISION MAKING

11.1. Members of RAMP shall strive to reach agreement by the process of consensus. If circumstances arise such that consensus cannot be reached, then a 75% majority decision by all members in good standing at that time shall prevail. Dissenting members may submit a “dissenting opinion” in writing to the chairperson, setting out their reasons for dissent, which will be filed with appropriate regional regulators. Absence from a meeting does not imply consent. However, if a member cannot attend he/she must provide to the chairperson a written position within 2 weeks of issuance of meeting minutes, otherwise consensus will be assumed.

11.2. The representatives of a least fifty-one percent (51%) of the members then in good standing on a committee shall constitute a quorum at any meeting of RAMP. Meetings of RAMP may be conducted by teleconference.

11.3. For election of officers or as otherwise noted in these terms of reference, each member shall have one vote in the affairs of RAMP, such votes must be made in person by the representative or the member organization designated to vote.

11.4. These terms of reference may be rescinded, altered or added to by passing a resolution with a 75% majority of all members in good standing at a Steering Committee meeting.

12.0 <u>REPORTING</u>

12.1. An Annual Report shall be generated by RAMP that will include the following:

a. A review of the work carried out by RAMP during the year of the report,

b. The information necessary to meet regulatory requirements for the industrial partners,

c. A discussion of results and impacts or trends (if any) which may have been observed,

d. Overview of the annual program and results suitable for wide circulation, and

e. Raw data and field reports as an appendix.

13.0 <u>STUDY AREA</u>

13.1. The study area includes the waters within the boundaries indicated in Attachment A.

13.2. Changes to the study area can be made following the decision-making criteria outlined in Section 11.

14.0 <u>GROUND RULES</u>

14.1. Chair Tenure and Succession

a. Chairs will serve a one-year term.

b. Vice-chairs will also serve a one year term and then will be expected to serve as Chair for at least one additional year, but not more that 2 years e.g., The RAMP TECH Chair, Steering Committee Vice-Chair, will serve as RAMP Steering Committee Chair for 1 year following one year as RAMP TECH Chair.

14.2. Role of Members

a. All member organizations have equal voice in decision-making.

b. While it is recognized that attendance at every meeting is not possible, each member is responsible for reviewing minutes and supporting documents in a timely manner. Participants will have 2 weeks to respond to the content of the minutes. After this period, acceptance of changes cannot be guaranteed.

c. Members are responsible to ensure that positions taken are consistent with those of their constituency; and

d. Members are expected not to be absent from three consecutive meetings otherwise their membership will be reviewed.

14.3. Role of the Consultant

a. The consultant will carry out approved program, including:

- Conduct Field Program
- Provide technical expertise and /or advice to all levels of RAMP as requested
- Provide meetings logistics and minutes, meeting minutes will be prepared, and distributed, for all meetings within 2 weeks of the meeting date.
- Implement Communications Strategies as directed, and
- Prepare and steward to program budgets.

b. The consultant will not:

- Act as Chair or Lead on any RAMP committee, subcommittee or Task Group,
- Approve program activities,
- Conduct activities not approved by the Steering Committee, unless done so at the consultants cost.

14.4. Communication

a. Minutes not prepared by the consultant, e.g. Conference Calls, will be submitted to the consultant for inclusion in the records

b. Decisions and/or Recommendations made at meetings not so documented will be deemed to be non-binding.

Appendix A2

RAMP Design Documentation Terms of Reference

RAMP PROGRAM COMPONENT DESIGN DOCUMENTATION TERMS OF REFERENCE

1.0 BACKGROUND

One of the main and consistent themes received from independent scientific reviewers during the 2003 Peer Review was the lack of documentation to explain the current Regional Aquatics Monitoring Program (RAMP) and its design. The ***objectives*** of the program are clearly laid out in the RAMP Terms of Reference; however, there is a need to update and expand the original design documents.

Performing this task was Recommendation #2 of the Steering Committee and it was acknowledged that, if at all possible, this should be undertaken in 2004 as it is a logical prelude to several of the other recommendations.

One related item from the Peer Review was the need to understand/document the individual oil sands projects; however, this is not considered feasible, either within the design documentation or in other forms, because of the rapid transitional nature of the current oil sands industry in northeastern Alberta.

2.0 HOW THE REVISED DESIGN DOCUMENTATION WOULD BE PREPARED

The design documentation should be prepared on a component-by-component basis with key linkages between the various components noted as required. For example, RAMP has exercised a policy of collecting water, sediment, and benthic samples from the same sites, at the same time, as feasible. Bridging design considerations such as this should be recorded in each of the components affected.

The components are:

- ◊ Climate
- ◊ Hydrology
- ◊ Water Quality
- ◊ Sediment Quality
- ◊ Benthic Invertebrates
- ◊ Fish Populations
- ◊ Aquatic Vegetation
- ◊ Acid Sensitive Lakes

The best and most logical sources for design information are the past and current Chairs of the components, with additional info coming from key RAMP Technical and Steering Committee members.

There are several reasons why it is recommended that the design documentation be compiled by the current RAMP implementation team of Hatfield/Jacques-Whitford. The RAMP implementation team is in constant contact with the component leaders; compiling the design documentation would improve the team's knowledge of the program and should improve the working relationship with the new Science Director, who will be using these documents extensively. Furthermore, current contracts exist with this group, making logistics more efficient.

3.0 CONTENT OF THE DESIGN DOCUMENTS

3.1 APPROACH

The design documentation for RAMP is an important record of the evolving program and is the key communication vehicle both within RAMP and for outside readers and reviewers. The design documents also become condensed sources of program information as statisticians and other design specialists are consulted to improve the program and its integration. The internal transfer of knowledge and policies on design will become increasingly important as members of the current team move to other jobs or locations.

In preparing this statement of content selected sections of the Peer Review were reviewed, which spanned the scope of RAMP work from physical to chemical to biological. The following generic scope covers the main observations provided and is often repeated throughout the Peer Review.

A phased approach might be best suited to the task at hand, particularly considering the statistical content of the design documentation. Therefore, it is recommended that component design documentation be prepared up to but not including the statistical design; then, each group representative could meet with Carl Schwarz to review the statistical approach and chart a new revised approach. It is possible that the latter step might be held until the new Science Director is in place.

4.0 SCOPE AND CONTENT OF DESIGN DOCUMENTATION

It will be necessary to prepare one design document for the overall program, as well as one for each of the components listed in Section 2.0 above. These documents should clearly describe for outside audiences the monitoring program design rationale.

RAMP is an effects-based monitoring program. The objective should be to document change occurring as a result of development rather than to carry out descriptive studies. Included in this approach should be the following:

- Identifying those oil sands activities which have the potential to impact the aquatic environment and identifying what these compounds or effects are, including specific markers or WQ indicators of oil sands development;

- Establishing key response indicators for each component, based on potential changes anticipated in oil sands development and on how an "effect" will be quantified and measured for each indicator;

- Establishing a core level of consistency for sample station selection, indicator selection, sampling frequency, and timing; and

- Establishing standardized statistical analysis procedures for future reports (Phase 2).

4.1 COMPONENT SCOPE AND OPERATION HYPOTHESES

Each of the component design documents should start with a clearly stated working hypothesis or question that is to be tested in detecting long term changes from the specific industrial inputs (pollutants), either now or in the future. This requires a listing of the specific chemicals or attributes (i.e., flows, temperature) which are expected to change as a result of oil sands activity, and the magnitude of the impact that is necessary to detect change. The linkage between the pollutant and the anticipated effect to key response indicators should be clearly stated, as should the evaluative criteria that will be used to test the hypothesis. Note that there is no need to specify the acceptable limits – these will come from CEMA or elsewhere.

A description of how the component will measure natural variability should be provided, as well as a power analysis to demonstrate the amount of change statistically detectable as significant under the monitoring design currently operating and proposed. Note that, for most designs, power increases with each year's observations. Since statistical assistance may be provided in Phase 2, see the comments on phasing above. Based on this discussion, the variability, controls, sample sizes, etc. that enable detection should be determined.

For those components that provide monitoring information to support other components (i.e., water quality for fish), the specific linkage and the association should be described as part of the justification for the inclusion of this parameter in the program.

4.2 METHODS DESCRIPTION

The sampling methods used for each of the elements of the component should be described, including how they relate to provincial, national, and/or international protocols, if these exist. Any changes to methods implemented during the monitoring program and the reasons for these should be carefully documented. The statistical effect of these changes should be described. If other components depend on the information, a description of a core level of consistency in sample station selection, indicator selection, sampling frequency, and timing should be provided, relating these also to any program wide design "policies" that may exist (i.e., sampling tributary rivers three years before disturbance occurs).

4.3 SITE SELECTION

A general explanation of the criteria and the approach used in the sitting of stations should be provided, including a note as to whether each station is for monitoring a specific industrial activity, or for monitoring regional effects. Any program wide sitting policies of criteria which affect this component should be identified and any additions or deletions of sites carefully recorded and justified.

4.4 CUMULATIVE EFFECTS AND EIA PREDICTIONS

A synthesis or summary should be prepared, on a component basis, of what the impact predictions were for oil sands project activities, including location and timing of impact and Valued Ecosystem Components affected. This summary would provide the basis for the monitoring program. The sampling plan and selection of core parameters should be directly related to the location and nature of existing and proposed developments.

1. Provide in the report the rationale and theoretical basis for the monitoring design chosen to address cumulative effects detection, including its strengths and weaknesses, and an explanation for the chosen sampling intensities.

2. Conduct a power analysis of the monitoring design to determine whether the monitoring network that currently exists will be able to detect an effect (and to what degree) if it is present.

4.5 STATISTICAL DESIGN

Because of the rapidly evolving nature of industrial development in northeastern Alberta, it has been difficult or RAMP to forecast what the size of the programs will be for each component; this has adversely affected statistical design in the past. Many on the Peer Review criticized the statistical designs employed in the various components, and the Steering Committee recognized that once design documentation was complete for each component it would be desirable to have the revised program submitted for professional help with statistical design.

Therefore, the task at hand for Phase 1 work will not be to do extensive work on the statistical design; but rather, to complete the component descriptions in order that sufficient documentation is generated for the component leaders to work on with statistics experts to improve statistical power and the ability to detect change.

The one bridging comment regarding statistics, which components may be able to address, dealt with within-site variability. In this case, it would be desirable to recommend approaching this deficiency within the design documentation.

It is anticipated that the question of statistical methods with which to evaluate future data sets will be left to Phase 2.

Appendix A3

Compilation of Residual Impact Assessments Extracted from Athabasca Oil Sands EIAs

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 1 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
44	ASJP	C	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	L	N	N	L	M	H	R	N
45	ASJP	C	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	R	N	N	R	M	H	R	N
46	ASJP	C	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	L	N	N	L	M	H	R	N
47	ASJP	C	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	R	N	N	R	M	H	R	N
48	ASJP	O	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, mine pits, disposal areas, plants site and closed-circuit operation, diversion and disruption of natural drainages, Pleistocene Channel and Basal Aquifer depressurization, water withdrawal from Athabasca	L	N	N	L	M	H	R	N
49	ASJP	O	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, mine pits, disposal areas, plants site and closed-circuit operation, diversion and disruption of natural drainages, Pleistocene Channel and Basal Aquifer depressurization, water withdrawal from Athabasca	R	N	N	R	M	H	R	N
50	ASJP	O	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, mine pits, disposal areas, plants site and closed-circuit operation, diversion and disruption of natural drainages, Pleistocene Channel and Basal Aquifer depressurization, water withdrawal from Athabasca	L	N	N	L	M	H	R	N
51	ASJP	O	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, mine pits, disposal areas, plants site and closed-circuit operation, diversion and disruption of natural drainages, Pleistocene Channel and Basal Aquifer depressurization, water withdrawal from Athabasca	R	N	N	R	M	H	R	N
52	ASJP	R	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	closure drainage systems, reclaimed landscape, End Pit Lakes	L	N	N	L	M	H	R	N
53	ASJP	R	CAH	changes in waterflow in receiving streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	closure drainage systems, reclaimed landscape, End Pit Lakes	R	N	N	R	M	H	R	N
54	ASJP	R	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	closure drainage systems, reclaimed landscape, End Pit Lakes	L	N	N	L	M	H	R	N
55	ASJP	R	CAH	changes in water levels in receiving streams, changes in open-water areas of lakes and streams	changes in flows and levels in receiving streams, changes in open-water areas of lakes and streams	closure drainage systems, reclaimed landscape, End Pit Lakes	R	N	N	R	M	H	R	N
56	PCMR	O	CAH	changes in flow and water level	groundwater flow discharges to MacKay River	groundwater withdrawal from the Birch Channel aquifer	L	N	N					N
57	PCMR	C	CAH	changes in flow and water level	changes in runoff to streams, blockage of surface and near-surface flows	surface disturbances (central facility, well pads, roads)	L	N	L	L				N
58	PCMR	O	CAH	changes in flow and water level	changes in runoff to streams, blockage of surface and near-surface flows	surface disturbances (central facility, well pads, roads)	L	N	L	L				N
59	SUSB	C	CAH	surface water flows	water withdrawal	water withdrawal for extraction and upgrading	R	N	N					N
60	SUSB	O	CAH	surface water flows	water withdrawal	water withdrawal for extraction and upgrading	R	N	N					N
61	SUSB	R	CAH	surface water flows	water withdrawal	water withdrawal for reclamation	R	N	N					N
62	PCMC	C	CAH	changes in open water areas, flows, and water levels	changes in surface water runoff and drainage patterns	surface disturbances (plant, roads and pipelines, wellpads)	L	N	L	L	M	M	R	N
63	PCMC	O	CAH	changes in open water areas, flows, and water levels	changes in surface water runoff and drainage patterns, change in near-surface water table	surface disturbances (plant, roads and pipelines, wellpads), groundwater withdrawal	L	N	L	L	M	M	R	N
64	PCMC	R	CAH	changes in open water areas, flows, and water levels	changes in surface water runoff and drainage patterns	surface disturbances	L	N	L	L	M	M	R	N
65	PCMC	C	CAH	changes in geomorphic conditions of watersheds and drainage systems	changes in surface water runoff and land cover	surface disturbances (plant sites, camp, wellpads, access roads, pipeline alignments)	L	N	N	L	M	M	R	N
66	PCMC	O	CAH	changes in geomorphic conditions of watersheds and drainage systems	changes in surface water runoff and land cover	surface disturbances (plant sites, camp, wellpads, access roads, pipeline alignments)	L	N	N	L	M	M	R	N
67	PCMC	R	CAH	changes in geomorphic conditions of watersheds and drainage systems	changes in surface water runoff and land cover	surface disturbances	L	N	N	L	M	M	R	N
68	PCMC	C	CAH	changes in geomorphic conditions of watersheds and drainage systems	sediment runoff, stream erosion and pipeline exposure during floods	disturbance of bed and banks of stream channels at watercourse crossings	L	N	L	L	S	L	R	N
69	PCMC	O	CAH	changes in geomorphic conditions of watersheds and drainage systems	sediment runoff, stream erosion and pipeline exposure during floods	disturbance of bed and banks of stream channels at watercourse crossings	L	N	L	L	S	L	R	N
70	ONLL	C	CAH	changes in surface water flows and levels	changes in surface water runoff, drainage patterns, and near-surface water table	diversion and disruption of natural drainages, surface compaction	L	N	N	L	M	H	R	N
71	ONLL	O	CAH	changes in surface water flows and levels	changes in surface water runoff, drainage patterns, and near-surface water table	diversion and disruption of natural drainages, surface compaction	L	N	N	L	M	H	R	N
72	ONLL	R	CAH	changes in surface water flows and levels	changes in surface water runoff, drainage patterns, and near-surface water table	reclamation, revegetation, grading for natural drainage	L	N	N	L	M	H	R	N
73	ONLL	O	CAH	changes in surface water flows and levels	changes in surface water runoff, drainage patterns, and near-surface water table	groundwater withdrawal to supply water to steam generation facilities	L	N	L	L	M	H	R	N
74	ONLL	O	CAH	changes in surface water flows and levels	changes in surface water runoff, drainage patterns, and near-surface water table	groundwater withdrawal to supply water to steam generation facilities	R	N	L	L	M	H	R	N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 2 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
75	ONLL	C	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
76	ONLL	O	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
77	ONLL	R	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
78	ONLL	C	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
79	ONLL	O	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
80	ONLL	R	CAH	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
81	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns, site clearing and infrastructure development, additional inflow from muskeg drainage and overburden dewatering	L	N	H	L	M	C	R	N
82	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns, site clearing and infrastructure development, additional inflow from muskeg drainage and overburden dewatering	L	N	L	L	M	I	R	L
83	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage due to construction of tailings settling pond	L	N	L	L	M	C	R	L
84	ASMR	C	CAH	changes in water levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage due to construction of tailings settling pond	L	N	N	L	M	C	R	N
85	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural watershed drainage patterns	R	n	N	L	M	C	R	N
86	ASMR	O	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns, site clearing and infrastructure development, additional inflow from muskeg drainage and overburden dewatering	L	N	H	L	M	C	R	N
87	ASMR	O	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns, site clearing and infrastructure development, additional inflow from muskeg drainage and overburden dewatering	L	N	L	L	M	C	R	L
88	ASMR	O	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns, site clearing and infrastructure development, additional inflow from muskeg drainage and overburden dewatering	L	N	L-H	L	M	C	R	M
89	ASMR	O	CAH	changes in water levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage	L	N	N	L	M	C	R	N
90	ASMR	O	CAH	changes in water levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural watershed drainage patterns, withdrawal of water	R	n	N	L	M	C	R	N
91	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage, outlet for EPL	L	n	L-H	L	L	C	R	N
92	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage, seepage inflows from reclaimed areas	L	N	L	L	L	C	I	L
93	ASMR	C	CAH	changes in surface water flows and levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage, seepage inflows from reclaimed areas	L	N	M	L	L	C	I	M
94	ASMR	C	CAH	changes in surface water levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural drainage patterns (tributaries)	L	N	N	L	L	C	I	N
95	ASMR	C	CAH	changes in surface water levels	changes in drainage area, runoff, and inflows	diversion and disruption of natural watershed drainage patterns	R	n	N	L	L	C	I	N
96	ASMR	O	CAH	changes in water balance of nearby waterbodies	drawdown of surficial aquifer at perimeter areas of mine pits and EPLs, deep percolation loss, reduction in base flows of adjacent streams	basal aquifer depressurization	R	N	N	L	M	C	R	N
97	ASMR	C	CAH	changes in sediment yield and concentration	discharge of sediment-containing waters into receiving streams, direct introduction of sediments into streams, channel erosion due to increased flows	muskeg drainage/overburden dewatering, construction of access corridors and pipeline and road stream crossings, diversion and disruption of watershed drainage patterns	L	N	N	L	M	C	R	N
98	ASMR	O	CAH	changes in sediment yield and concentration	discharge of sediment-containing waters into receiving streams, direct introduction of sediments into streams, channel erosion due to increased flows	muskeg drainage/overburden dewatering, construction of access corridors and pipeline and road stream crossings, diversion and disruption of watershed drainage patterns	L	N	N-L	L	M	C	R	L
99	ASMR	R	CAH	changes in sediment yield and concentration	gully and channel erosion	reclamation of landscape and drainage system	L	N	L	L	L	C	I	L
100	ASMR	C	CAH	changes in channel regime	changes in channel dimension, shape, gradient, meander pattern, and erosion/sedimentation due to changes in flows	diversion and disruption of natural drainage patterns, inflows from project activities	L	n	N	L	M	C	R	N
101	ASMR	O	CAH	changes in channel regime	changes in channel dimension, shape, gradient, meander pattern, and erosion/sedimentation due to changes in flows	diversion and disruption of natural drainage patterns, inflows from project activities	L	n	N	L	M	C	R	N
102	ASMR	R	CAH	changes in channel regime	changes in channel dimension, shape, gradient, meander pattern, and erosion/sedimentation due to changes in flows	diversion and disruption of natural drainage patterns, inflows from tailings settling pond	L	N	N	L	L	C	I	N
103	ASMR	R	CAH	changes in channel regime	changes in channel dimension, shape, gradient, meander pattern, and erosion/sedimentation due to changes in flows	diversion and disruption of natural drainage patterns	L	n	N	L	L	C	I	N
104	ASMR	C	CAH	changes in open-water areas of lakes, ponds, wetlands, and streams	direct loss of waterbody area, subsurface water table drawdown	site clearing, infrastructure development, diversion and disruption of drainage patterns, drawdown of water table	L	N	L	L	M	C	R	L

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
105	ASMR	O	CAH	changes in open-water areas of lakes, ponds, wetlands, and streams	direct loss of waterbody area, subsurface water table drawdown	site clearing, infrastructure development, diversion and disruption of drainage patterns, drawdown of water table	L	N	L	L	M	C	R	L
106	ASMR	R	CAH	changes in open-water areas of lakes, ponds, wetlands, and streams	changes in area/type of waterbodies	reclamation and replacement of streams, wetlands, shallow lakes	L	n-P	H	L	L	C	I	N
107	ASMR	R	CAH	Sustainability of closure landscape and drainage system	surface and gully erosion from reclaimed landscape with immature drainage density, channel evolution	creation of closure landscape and drainage system	L	N	L	L	L	C	I	L
108	CPSU	O	CAH	changes in surface water levels and flows	changes in runoff from disturbed catchment areas	surface disturbances (central facilities, wellpads, exploration activities)	L							N
109	CPSU	O	CAH	changes in surface water levels	drawdown of water level	groundwater withdrawal	L	N						N
110	CPSU	R	CAH	changes in surface water levels	residual impacts from drawdown of water level and changes in runoff patterns	surface disturbances and groundwater withdrawal	L			L				N
111	CPSU	R	CAH	changes in discharge	residual impacts from drawdown of water level and changes in runoff patterns	surface disturbances and groundwater withdrawal	L	n	M	L				N
112	CPSU	R	CAH	changes in discharge	drawdown of water level	groundwater withdrawal	L	N	M	L	L			N
113	CPSU	R	CAH	changes in discharge	drawdown of water level	groundwater withdrawal	L	N	M	L				N
114	CPSU	R	CAH	changes in discharge	drawdown of water level	groundwater withdrawal	R	N	M	R	L			N
115	CPSU	R	CAH	changes in discharge	residual impacts from changes in runoff patterns	surface disturbances	L							N
116	CPSU	R	CAH	changes in discharge	residual impacts from drawdown of water level	groundwater withdrawal	L							L
117	SYAN	O	CAH	change in surface water flows and levels	reduction of drainage areas	closed circuit operation	L					N	L-M	L
118	SYAN	C	CAH	changes in surface water flows and levels	increased inflows to receiving streams	muskeg dewatering, overburden dewatering	L					N	L	L
119	SYAN	O	CAH	changes in surface water flows and levels	increased inflows to receiving streams	muskeg dewatering, overburden dewatering, mine water seepage	L					N	L	L
120	SYAN	O	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns	stream diversions	L					N	L	L
121	SYAN	O	CAH	changes in water levels	drainage of muskeg	drainage of surficial aquifers alongside mine pits	L					n or P	M	L
122	SYAN	R	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns	drainage of reclaimed areas and diversion of natural streams to fill end pit lakes	L					N	L	L
123	SYAN	R	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns	stream diversions	L					N	L	L
124	SYAN	R	CAH	changes in surface water flows and levels	increased inflows to receiving streams	runoff from reclaimed areas, residual seepage of mine water	L					N	L	L
125	SYAN	R	CAH	changes in surface water flows and levels	reduction of high flows	withdrawal of water from Athabasca River for end pit lake development	R					N	M	N
126	SYAN	R	CAH	changes in surface water flows and levels	attenuation of low and high flows	end pit lake development	L					P	L	L
127	SYAN	R	CAH	changes in surface water flows and levels	surface water losses due to evaporation from lake surfaces	end pit lakes in reclamation landscape	L					N	L	L
128	SYAN	R	CAH	changes in water levels	drainage of muskeg	end pit lake development	L					n or P	M	L
129	SYAN	C	CAH	change in area of watercourses	displacement of lakes and watercourses in footprint of mine development	mine development, surface disturbances, drainage of surficial aquifer	L	1			1	N	L	L
130	SYAN	O	CAH	change in area of watercourses	displacement of lakes and watercourses in footprint of mine development	mine development, surface disturbances, drainage of surficial aquifer	L	1			1	N	L	L
131	SYAN	R	CAH	change in lake area	creation of lake area in reclamation landscape	development of end pit lakes	L					P	H	L
132	SYAN	R	CAH	change in watercourse area	creation of watercourses in reclamation landscape	development of reclamation drainage systems (wetland ponds, major and secondary drainage channels)	L					P	L	L
133	DCJS	C	CAH	changes in surface water hydrology	changes in runoff volume and peak flows	surface disturbances	L							N
134	DCJS	O	CAH	changes in surface water hydrology	changes in runoff volume and peak flows	surface disturbances	L							N
135	DCJS	O	CAH	changes in surface water hydrology	change in flows	water withdrawal	R							N
136	CNHZ	C	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	M	L	M	R	H	L
137	CNHZ	C	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	L				N
138	CNHZ	C	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	L				N
139	CNHZ	C	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	R				N
140	CNHZ	C	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	L				N
141	CNHZ	C	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	R				N
142	CNHZ	O	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	M	L	M	R	H	L
143	CNHZ	O	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	L				N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 4 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
144	CNHZ	O	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	L				N
145	CNHZ	O	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	R				N
146	CNHZ	O	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	L				N
147	CNHZ	O	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	R				N
148	CNHZ	R	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	M	L	M	R	H	L
149	CNHZ	R	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	L				N
150	CNHZ	R	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	L				N
151	CNHZ	R	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	R				N
152	CNHZ	R	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	L				N
153	CNHZ	R	CAH	changes in water levels in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	R				N
154	CNHZ	C	CAH	changes in open water areas of lakes and streams	diversion and disruption of natural drainage, construction of new waterbodies	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
155	CNHZ	O	CAH	changes in open water areas of lakes and streams	diversion and disruption of natural drainage, construction of new waterbodies	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site	L	N	N					N
156	CNHZ	R	CAH	changes in open water areas of lakes and streams	diversion and disruption of natural drainage, construction of new waterbodies	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N					N
157	CNHZ	C	CAH	changes in basin sediment yields to receiving streams	change in runoff from disturbed areas	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	L	L	M	H	R	N
158	CNHZ	O	CAH	changes in basin sediment yields to receiving streams	change in runoff from disturbed areas	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	L	L	M	H	R	N
159	CNHZ	R	CAH	changes in basin sediment yields to receiving streams	Erosion from reclaimed areas	reclaimed landscape, closure drainage system, and end pit lakes	L	N	L	L	M	H	R	N
160	CNHZ	C	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N	R				N
161	CNHZ	O	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas, basal aquifer depressurization, open-pit mining, muskeg and overburden storage, external tailings storage pond, plant site, closed-circuit operation, water withdrawal from Athabasca River	L	N	N	R				N
162	CNHZ	R	CAH	changes in flows in receiving streams	diversion and disruption of natural drainage, additional inflow from muskeg drainage and overburden dewatering	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N	R				N
163	SUFB	C	CAH	surface water runoff, drainage patterns, and near-surface water table	decreased permeability of plant area, blockage of surface and near-surface flows, impact from groundwater withdrawal if there is communication between deep and surficial aquifers	plant, roads and pipelines, well pads, groundwater withdrawal for potable water supply	L	N	N	L	M	H	R	N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 5 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
164	SUFB	O	CAH	surface water runoff, drainage patterns, and near-surface water table	decreased permeability of plant area, blockage of surface and near-surface flows, impact from groundwater withdrawal if there is communication between deep and surficial aquifers	plant, roads and pipelines, well pads, groundwater withdrawal for potable water supply	L	N	N	L	M	H	R	N
165	SUFB	C	CAH	flows and water levels in streams	effects on flows and water levels at stream crossings	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	S	L	R	N
166	SUFB	O	CAH	flows and water levels in streams	effects on flows and water levels at stream crossings	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	S	L	R	N
167	SUFB	O	CAH	flows and water levels in Athabasca River	change in riverflow caused by provision of water supply to Firebag Project	provision of water supply to Firebag Project	R	N	L	R	M	L	R	N
168	SUFB	R	CAH	flows and water levels in Athabasca River	change in riverflow caused by provision of water supply to Firebag Project	provision of water supply to Firebag Project	R	N	L	R	M	L	R	N
169	SUST	C	CAH	changes in surface water flows (peak flows)	diversion and disruption of natural drainage patterns	surface disturbances	L	N						NO
170	SUST	O	CAH	changes in surface water flows (peak flows)	diversion and disruption of natural drainage patterns	surface disturbances	L	N						NO
171	SUST	R	CAH	changes in surface water flows (peak flows)	diversion and disruption of natural drainage patterns	surface disturbances	L	N						NO
172	SUST	O	CAH	changes in surface water flows (open water low flows)	diversion and disruption of natural drainage patterns	pumping of Wood Creek Sand Channel	L	P						NO
173	SUST	R	CAH	changes in surface water flows (open water low flows)	diversion and disruption of natural drainage patterns	pumping of Wood Creek Sand Channel	L	P						NO
174	SUST	C	CAH	changes in flows and geomorphic stability	diversion and disruption of natural drainage patterns	surface disturbances	R	N	N					N
175	SUST	O	CAH	changes in flows and geomorphic stability	diversion and disruption of natural drainage patterns	surface disturbances	R	N	N					N
176	SUST	R	CAH	changes in flows and geomorphic stability	diversion and disruption of natural drainage patterns	surface disturbances	R	N	N					N
177	TNFH	C	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	H					M
178	TNFH	O	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns	muskeg drainage/overburden dewatering; closed-circuit operations; seepage from out-of-pit tailings area; overburden disposal area drainage	L	N	H					M
179	TNFH	R	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns	reclamation landscape	L							NO
180	TNFH	R	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns	reclamation landscape	L							NO
181	TNFH	C	CAH	McClelland Lake outflow	changes to flow inputs and natural drainage patterns	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	H					M
182	TNFH	O	CAH	McClelland Lake outflow	changes to flow inputs and natural drainage patterns	muskeg drainage/overburden dewatering; closed-circuit operations; seepage from out-of-pit tailings area; overburden disposal area drainage	L	N	H					M
183	TNFH	R	CAH	McClelland Lake outflow and water level	changes to flow inputs and natural drainage patterns	reclamation landscape	L							NO
184	TNFH	C	CAH	McClelland Lake water level	changes to flow inputs and natural drainage patterns	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	H					M
185	TNFH	O	CAH	McClelland Lake water level	changes to flow inputs and natural drainage patterns	muskeg drainage/overburden dewatering; closed-circuit operations; seepage from out-of-pit tailings area; overburden disposal area drainage	L	N	H					M
186	TNFH	C	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns of tributaries	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L		N					N
187	TNFH	O	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns of tributaries	muskeg drainage/overburden dewatering; closed-circuit operations; seepage from out-of-pit tailings area; overburden disposal area drainage	L		N					N
188	TNFH	R	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns of tributaries	reclamation landscape	L		N					N
189	TNFH	O	CAH	changes in flows and water levels	changes in drainage area, changes in inflows from tributaries, direct water withdrawal	closed circuit operation, muskeg drainage/overburden dewatering, seepage, river water withdrawal	R	N	L					L
190	TNFH	R	CAH	changes in flows and water levels	changes to flow inputs and natural drainage patterns	reclamation landscape	R	N	L					L
191	TNFH	O	CAH	changes in open water area	direct and indirect impacts on open water area	surface disturbances, stream diversions, construction of settling ponds, progressive reclamation	L	P	L					L
192	TNFH	R	CAH	changes in open water area	direct and indirect impacts on open water area	reclamation landscape	L	P	M					M
193	TNFH	O	CAH	changes in channel wetted perimeter and channel erosion	changes in channel regime due to changes in flows and sediment yields	muskeg drainage/overburden dewatering; drainage water from overburden disposal areas; runoff; construction at watercourse crossings	L	N	L					L
194	TNFH	R	CAH	changes in channel wetted perimeter and channel erosion	changes in channel regime due to changes in flows and sediment yields	reclamation landscape	L	N	L					L
195	TNFH	O	CAH	geomorphology of Athabasca River valley wall	changes in groundwater movement, occurrence of seeps, and loading of valley wall may affect rate of valley wall evolution and natural configuration	mining development adjacent to the river	R	N	L		L			L
196	TNFH	R	CAH	geomorphology of Athabasca River valley wall	changes in groundwater movement, occurrence of seeps, and loading of valley wall may affect rate of valley wall evolution and natural configuration	reclamation landscape	R	N	L		L			L

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
197	TNFH	R	CAH	sustainability of closure landscape and drainage systems	risk of erosion and higher sediment yields	reclamation landscape	L	N	L		L			L
198	HKST	C	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal for construction/camp water supply	L	N	M	L				M
199	HKST	O	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal for construction/camp water supply	L	N	M	L				M
200	HKST	O	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal during start-up	L	N	H	L	S			M
201	HKST	C	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal for construction/camp water supply	L	N	L	L				L
202	HKST	O	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal for construction/camp water supply	L	N	L	L				L
203	HKST	O	CAH	surface water discharge	withdrawal of groundwater linked to surface water discharge	groundwater withdrawal during start-up	L	N	M	L	S			L
204	HKST	C	CAH	surface water discharge	changes to total runoff to streams	clearing of vegetation; construction of infrastructure (roads, well pads, pipelines, plant site); surface disturbances	L	N	L	L	L			L
205	HKST	O	CAH	surface water discharge	changes in total runoff to streams	clearing of vegetation; construction of infrastructure (roads, well pads, pipelines, plant site); surface disturbances	L	N	L	L	L			L
206	HKST	C	CAH	surface water discharge	changes in total runoff to streams	clearing of vegetation; construction of infrastructure (roads, well pads, pipelines, plant site); surface disturbances	L	N	M	L				M
207	HKST	O	CAH	surface water discharge	changes in total runoff to streams	clearing of vegetation; construction of infrastructure (roads, well pads, pipelines, plant site); surface disturbances	L	N	M	L				M
208	HKST	CUM	CAH	surface water discharge	changes to stream discharge	groundwater withdrawal, surface disturbances	R	N	M	R	L	C		M
209	HKST	CUM	CAH	surface water discharge	changes to stream discharge	groundwater withdrawal, surface disturbances	R	N	L	R	M	C		L
210	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering, flow diversion	L		H					NO
211	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering, flow diversion	L		L					NO
212	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering, flow diversion	L		N					NO
213	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L		M					NO
214	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L		N					NO
215	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		L					NO
216	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		M					NO
217	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		H					NO
218	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		N					NO
219	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering	L		L					NO
220	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering	L		N					NO
221	SUVR	C	CAH	flow and water level of surface waterbodies	input of muskeg/overburden dewatering flows will increase flows in Unnamed Creek	North Steepbank mine - muskeg and overburden dewatering	L		H					NO
222	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L		N					NO
223	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L		L					NO
224	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		N					NO
225	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		L					NO
226	SUVR	C	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering	L		N					NO
227	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L		N					NO
228	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - closure landscape	L		N					NO
229	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flow inputs and natural drainage patterns	North Steepbank mine - Steepbank River crossing structure	L		M					NO
230	SUVR	C	CAH	flow and water level of surface waterbodies	changes to flows	upgrader - project footprint, muskeg dewatering	L							N
231	SUVR	O	CAH	flow and water level of surface waterbodies	changes to flows	upgrader - project footprint, closed circuit operation	L							N
232	SUVR	R	CAH	flow and water level of surface waterbodies	changes to flows	upgrader - closure landscape	L							N
233	SUVR	C	CAH	changes in channel geomorphology	changes in flow and in-channel erosion	muskeg and overburden dewatering	L	N	N	L			R	N
234	SUVR	O	CAH	changes in channel geomorphology	changes in flow and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L	N						NO
235	SUVR	C	CAH	changes in channel geomorphology	changes in flow and in-channel erosion	activities in the North Steepbank PDA	L							N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 7 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
236	SUVR	O	CAH	changes in channel geomorphology	changes in flow and in-channel erosion	activities in the North Steepbank PDA	L							N
237	SUVR	R	CAH	changes in channel geomorphology	changes in flow and in-channel erosion	activities in the North Steepbank PDA	L							N
238	SUVR	R	CAH	sustainability of closure landscape and drainage system	closure landscape and drainage system	creation of closure landscape/drainage system	L							N
239	SUML	C	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns, inflows from muskeg/overburden dewatering	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L							N
240	SUML	C	CAH	changes in surface water flows and levels	elimination of waterbodies in development area	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L	N	H	L	L			N
241	SUML	C	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns, inflows from muskeg/overburden dewatering	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L		H	L	L			N
242	SUML	C	CAH	changes in surface water flows and levels	changes in tributary flows	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	R	L			N
243	SUML	C	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns, inflows from muskeg/overburden dewatering	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L		N	L	L			N
244	SUML	O	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns, inflows from muskeg/overburden dewatering	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L		N	L	L			N
245	SUML	O	CAH	changes in surface water flows and levels	reduction of annual and flood flows to Shipyard Lake, mitigation by providing make-up flows from Athabasca River	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R							NO
246	SUML	O	CAH	changes in surface water flows and levels	diversion and disruption of natural drainage patterns, inflows from muskeg/overburden dewatering	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	L		H	L	S			N
247	SUML	O	CAH	changes in surface water flows and levels	changes in tributary flows	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	R	L			N
248	SUML	R	CAH	changes in surface water flows and levels	changes in drainage patterns	closure drainage systems, reclaimed landscape, EPL	L							N
249	SUML	R	CAH	changes in surface water flows and levels	changes in drainage patterns	closure drainage systems, reclaimed landscape, EPL	L		H	L	L			M
250	SUML	R	CAH	changes in surface water flows and levels	changes in drainage patterns of tributaries	closure drainage systems, reclaimed landscape, EPL	R		N	R	L			N
251	SUML	R	CAH	changes in peak flows	long-term impacts to creek channel from outflows from reclaimed landscape	closure drainage systems, reclaimed landscape, EPL	L							N
252	SUML	R	CAH	changes in peak flows	residual impact to 1 in 100 yr peak flows resulting from reclaimed landscape	closure drainage systems, reclaimed landscape, EPL	L							N
253	SUML	R	CAH	sustainability of closure landscape drainage systems	gully and channel erosion potential of reclaimed landscape	closure drainage systems, reclaimed landscape, EPL	L							L
592	ASJP	C	WAQ	change in basin sediment yield and sediment concentrations in receiving streams	change in basin sediment yield and sediment concentrations in receiving streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	L	N	N	L	M	H	R	N
593	ASJP	O	WAQ	change in basin sediment yield and sediment concentrations in receiving streams	change in basin sediment yield and sediment concentrations in receiving streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	L	N	N	L	M	H	R	N
594	ASJP	R	WAQ	change in basin sediment yield and sediment concentrations in receiving streams	change in basin sediment yield and sediment concentrations in receiving streams	infrastructure development, muskeg drainage and overburden dewatering, site clearing, diversion and disruption of natural drainages	L	N	N	L	M	H	R	N
595	ASJP	C	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	muskeg/overburden dewatering, stream diversions, disruption of natural drainage	L							NO
596	ASJP	O	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	mine operations, muskeg and overburden dewatering, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), stream diversions, disruption of natural drainage	L							NO
597	ASJP	R	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L							NO
598	ASJP	C	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	muskeg/overburden dewatering, stream diversions, disruption of natural drainage	L							NO
599	ASJP	O	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	mine operations, muskeg and overburden dewatering, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), stream diversions, disruption of natural drainage	L							NO
600	ASJP	R	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L							NO
601	ASJP	C	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	muskeg/overburden dewatering, stream diversions, disruption of natural drainage	L							NO
602	ASJP	O	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	mine operations, muskeg and overburden dewatering, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), stream diversions, disruption of natural drainage	L							NO
603	ASJP	R	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L							NO

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 8 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
604	ASJP	C	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	muskeg/overburden dewatering, stream diversions, disruption of natural drainage	L							NO
605	ASJP	O	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	mine operations, muskeg and overburden dewatering, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits), stream diversions, disruption of natural drainage	L							NO
606	ASJP	R	WAQ	changes in water quality	direct disturbance of natural watersheds affecting runoff and drainage patterns, in-stream flow, and assimilative capacity of receiving environment	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L							NO
607	ASJP	C	WAQ	changes in thermal regime of receiving waters	alteration of thermal regime of receiving waters	muskeg and overburden dewatering	L	N	N	L	S	L	R	N
608	ASJP	O	WAQ	changes in thermal regime of receiving waters	alteration of thermal regime of receiving waters	muskeg and overburden dewatering	L	N	N	L	S	L	R	N
609	ASJP	C	WAQ	dissolved oxygen levels	changes in dissolved oxygen levels	muskeg and overburden dewatering	L	N	N	L	S	L	R	N
610	ASJP	O	WAQ	dissolved oxygen levels	changes in dissolved oxygen levels	muskeg and overburden dewatering	L	N	N	L	S	L	R	N
611	ASJP	O	WAQ	ecological viability of End Pit Lakes	water quality of EPL discharge waters	mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits)	L							NO
612	ASJP	O	WAQ	ecological viability of End Pit Lakes	water quality of EPL discharge waters	End Pit Lake outflows	L							NO
613	PCMR	C	WAQ	changes in water quality	increased surface water runoff, increased sediment loading and transport of chemical contaminants	surface disturbances (land clearing, soil stripping, road cut and fill, stream crossings), exploratory driling, pipeline surveying	L	N	L	L	S	S	R	N
614	PCMR	O	WAQ	changes in water quality	increased surface water runoff, increased sediment loading and transport of chemical contaminants	surface disturbances (land clearing, road cut and fill, stream crossings, pad construction, camps, central plant facility), drilling of wells, ancillary facilities (disposal pits)	L	N	L	L	S			N
615	PCMR	O	WAQ	changes in water quality (total dissolved solids, conductivity, oil and grease)	small and infrequent releases of produced water to ground surface (may directly enter waterbody)	well servicing	L	N	L	L	S	S		N
616	PCMR	O	WAQ	changes in water quality	small releases of produced fluids and production chemicals, overflow of water from retention pond during flood circumstances	operation and maintenance of central plant facility and retention pond	L	N	L	L	S	S		N
617	PCMR	O	WAQ	changes in water quality	seepage from retention pond to subsurface (attenuation and dilution of leachate before reaching surface water)	retention pond	L	N	L		L			N
618	PCMR	R	WAQ	changes in water quality	potential increase in total suspended sediments	dismantling of facilities, removal of roads and contaminated soil, reclamation of sites	L	N	L	L	S			N
619	SUSB	O	WAQ	surface water quality	contamination from mine-related waters or accidental spills, increased sedimentation from erosion	processing and extraction activities	R	N	H	R	S			L
620	PCMC	O	WAQ	changes in surface water quality	runoff waters may contain suspended sediments and particulate-associated chemicals (metals, nutrients, organics)	discharge of surplus runoff from central facilities	L	N	N	L	M	M	R	N
621	ONLL	C	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
622	ONLL	O	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
623	ONLL	R	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	surface disturbance from project infrastructure and facilities	L	N	N	L	M	H	R	N
624	ONLL	C	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
625	ONLL	O	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
626	ONLL	R	WAQ	changes in basin sediment yield and sediment concentrations	changes in surface water and sediment runoff, channel erosion and pipeline exposure during floods	disturbance of stream channel bed and banks from road and pipeline crossing construction	L	N	L	L	S	L	R	N
627	ASMR	C	WAQ	changes in water quality during mean open-water flow	discharge of project waters to waterbodies	construction activities, muskeg drainage and overburden dewatering	R	N	N					N
628	ASMR	O	WAQ	changes in water quality during mean open-water flow	discharge and seepage of project waters to waterbodies	muskeg drainage and overburden dewatering, seepage	R	N	N					N
629	ASMR	R	WAQ	changes in water quality during mean open-water flow	discharge and seepage of project waters to waterbodies	seepage, EPL discharge	R	N	N					N
630	ASMR	C	WAQ	changes in water quality at annual 7Q10 flow	discharge of project waters to waterbodies	construction activities, muskeg drainage and overburden dewatering	R	N	N					N
631	ASMR	O	WAQ	changes in water quality at annual 7Q10 flow	discharge and seepage of project waters to waterbodies	muskeg drainage and overburden dewatering, seepage	R	N	N					N
632	ASMR	R	WAQ	changes in water quality at annual 7Q10 flow	discharge and seepage of project waters to waterbodies	seepage, EPL discharge	R	N	N					N
633	ASMR	C	WAQ	changes in water quality at mean open-water flow	discharge of project waters to waterbodies	construction activities, muskeg drainage and overburden dewatering	L	N	L	L	M	M	R	L
634	ASMR	O	WAQ	changes in water quality at mean open-water flow	discharge and seepage of project waters to waterbodies	muskeg drainage and overburden dewatering, seepage	L	N	L	L	M	M	R	L
635	ASMR	R	WAQ	changes in water quality at mean open-water flow	discharge and seepage of project waters to waterbodies	seepage, EPL discharge	L	N	L	L	M	M	R	L
636	ASMR	O	WAQ	changes in water quality (Whole Effluent Toxicity) at mean open-water flow	discharge and seepage of project waters to waterbodies	CT water seepage, sand seepage, tailings settling pond seepage	R	N	N					N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 9 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
637	ASMR	R	WAQ	changes in water quality (Whole Effluent Toxicity) at mean open-water flow	discharge and seepage of project waters to waterbodies	CT water seepage, sand seepage, tailings settling pond seepage, EPL discharge	R	N	N					N
638	ASMR	O	WAQ	changes in water quality (Whole Effluent Toxicity) at annual 7Q10 flow	discharge and seepage of project waters to waterbodies	CT water seepage, sand seepage, tailings settling pond seepage	R	N	N					N
639	ASMR	R	WAQ	changes in water quality (Whole Effluent Toxicity) at annual 7Q10 flow	discharge and seepage of project waters to waterbodies	CT water seepage, sand seepage, tailings settling pond seepage, EPL discharge	R	N	N					N
640	ASMR	C	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - cooling of waterbody in open-water season, slower seasonal warming and cooling	muskeg drainage and overburden dewatering	L	n	N					N
641	ASMR	O	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - cooling of waterbody in open-water season, slower seasonal warming and cooling	muskeg drainage and overburden dewatering	L	n	N					N
642	ASMR	R	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - cooling of waterbody in open-water season, slower seasonal warming and cooling	EPL discharge	L	n	N					N
643	ASMR	C	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - reduced diurnal fluctuation in waterbody temperature	muskeg drainage and overburden dewatering	L	n	N					N
644	ASMR	O	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - reduced diurnal fluctuation in waterbody temperature	muskeg drainage and overburden dewatering	L	n	N					N
645	ASMR	R	WAQ	changes in water quality (temperature regime)	discharge of project waters to waterbodies - reduced diurnal fluctuation in waterbody temperature	EPL discharge	L	n		L	M	L	R	NO
646	ASMR	C	WAQ	changes in dissolved oxygen concentration	discharge of organic-matter containing project waters into waterbodies	muskeg drainage and overburden dewatering	L	N	N					N
647	ASMR	O	WAQ	changes in dissolved oxygen concentration	discharge of organic-matter containing project waters into waterbodies	muskeg drainage and overburden dewatering	L	N	N					N
648	ASMR	R	WAQ	toxicity of EPL water	water quality of EPL prior to discharge to Muskeg River	drainage from mine-disturbed areas enters EPL	L	N	N					N
649	ASMR	C	WAQ	changes in water quality	introduction of contaminants into receiving waterbodies	accidental water releases and spills	R	N	N					N
650	ASMR	O	WAQ	changes in water quality	introduction of contaminants into receiving waterbodies	accidental water releases and spills	R	N	N					N
651	ASMR	O	WAQ	year-round acidification	deposition of acids or acid-forming substances	acidifying emissions, runoff containing acidifying substances released by the Project	R	N	N					N
652	CPSU	O	WAQ	changes in water quality	sediments or other chemical species in runoff entering creeks at creek crossings	crossings (roads, utility corridors) on creeks flowing into Engstrom Lake, tributaries to Meadow Creek, and Cottonwood Creek	L	N						N
653	CPSU	O	WAQ	changes in water quality	potential contamination of groundwater and interactions between groundwater and surface water	introduction of chemical species into groundwater from project facilities	L	N						N
654	CPSU	R	WAQ	changes in water quality	levels of suspended sediments affected by success of mitigation and reclamation landscape	mitigation, reclamation of surface disturbances	L	n	M	L				N
655	CPSU	O	WAQ	changes in water quality	interaction of groundwater and surface water - migration of chloride into Meadow Creek and exceedance of water quality guidelines	potential leak from lime sludge lagoon	L	N						NO
656	CPSU	R	WAQ	changes in water quality	levels of suspended sediments and chloride affected by success of mitigation and reclamation landscape	mitigation, reclamation of surface disturbances	L	N	M	L	L			N
657	CPSU	R	WAQ	changes in water quality	levels of suspended sediments and chloride affected by success of mitigation and reclamation landscape	mitigation, reclamation of surface disturbances	L	N	M	L	L			N
658	CPSU	R	WAQ	changes in water quality	levels of suspended sediments and chloride affected by success of mitigation and reclamation landscape	mitigation, reclamation of surface disturbances	L	N	M	L				N
659	CPSU	O	WAQ	changes in water quality	changes in water quality of tributaries flowing into the Christina River	surface disturbances in drainage area of tributaries	R							N
660	CPSU	O	WAQ	changes in water quality	interaction of groundwater and surface water	disposal of water into McMurray Formation discharge area along the Clearwater River	R							N
661	CPSU	R	WAQ	changes in water quality (suspended sediments, chloride, dissolved hydrocarbons)	changes in water quality of tributaries draining into the Christina River, interaction of groundwater and surface water	surface disturbances, disposal of wastewater into McMurray Formation	R							N
662	SYAN	C	WAQ	changes in water quality	changes in sediment yield from stream/river crossings	access corridor and bridge construction	R					N	L	L
663	SYAN	O	WAQ	changes in water quality	changes in sediment yield from stream/river crossings	access corridor and bridge construction	R					N	L	L
664	SYAN	C	WAQ	changes in water quality	changes in sediment yield from stream/river crossings	construction of drainage system	L					N	L	L
665	SYAN	O	WAQ	changes in water quality	changes in sediment yield from stream/river crossings	construction of drainage system	L					N	L	L
666	SYAN	C	WAQ	changes in water quality	changes in sediment loads	water diversions, construction of drainage system	L					N	L	L
667	SYAN	O	WAQ	changes in water quality	changes in sediment loads	water diversions, construction of drainage system	L					N	L	L
668	SYAN	C	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from CT flux, surface runoff, and groundwater	R					n	L	L
669	SYAN	O	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from CT flux, surface runoff, and groundwater	R					n	L	L

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 10 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
670	SYAN	C	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from CT flux, surface runoff, and groundwater	L					N	L-M	L
671	SYAN	O	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from CT flux, surface runoff, and groundwater	L					N	L-M	L
672	SYAN	R	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from mine (via Muskeg River, Fort Creek, outflow from west EPL)	R					n	L	L
673	SYAN	R	WAQ	changes in water quality	inflow of reclamation waters	release of reclamation waters from mine (seepage and discharge)	L					N	L-M	L
674	SYML	O	WAQ	water quality of regional lakes (metals, PAHs)	deposition of particulates containing metals and PAHs	emissions of particulates	R	N	L	R	L	C		N
675	SYML	O	WAQ	spring water quality of rivers tributary to Athabasca River (metals, PAHs)	deposition of particulates containing metals and PAHs onto snowpack, pulse of metals/PAHs during spring snowmelt	emissions of particulates	R	N	L	R	M	I		N
676	DCJS	C	WAQ	changes in water quality	increased sedimentation due to construction activities	surface disturbances	L							N
677	DCJS	O	WAQ	changes in water quality	increased sedimentation due to construction activities	surface disturbances	L							N
678	CNHZ	C	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	N					N
679	CNHZ	O	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	N					N
680	CNHZ	R	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N					N
681	CNHZ	C	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	L	L	M	H	R	N
682	CNHZ	O	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	infrastructure development, increased flow due to muskeg and overburden dewatering and site clearing	L	N	N					N
683	CNHZ	R	WAQ	changes in sediment concentration in receiving streams	Increased basin sediment loading from disturbed areas, increased channel flow and erosion rates	reclaimed landscape, closure drainage system, and end pit lakes	L	N	N					N
684	CNHZ	R	WAQ	changes in basin sediment yields to receiving streams and changes in sediment concentration in receiving streams	creation of closure landscape and drainage patterns vulnerable to erosion	potential increase in surface and gully erosion from the reclaimed landscape, and potential instability and erosion of closure drainage systems and end-pit lakes	L	N	L	L	L	H	I	M
685	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L		N					N
686	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L		N					N
687	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L		N					N
688	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L	N	L	L	M	M	T	N
689	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	L	L	M	M	T	N
690	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	L	L	M	M	T	N
691	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L							L
692	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							L
693	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							L
694	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L							N
695	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
696	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
697	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L							N
698	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
699	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
700	CNHZ	C	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	construction activities and accidential releases during construction, muskeg and overbudend dewatering,	L							L

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 11 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
701	CNHZ	O	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							L
702	CNHZ	R	WAQ	changes in water quality	reduction in assimilative capacity of receiving bodies	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							L
703	CNHZ	O	WAQ	changes in water quality	change in thermal regime	muskeg and overburden dewatering, release of EPL water	L		N					N
704	CNHZ	R	WAQ	changes in water quality	change in thermal regime	release of EPL water	L		N					N
705	CNHZ	C	WAQ	changes in water quality	lowered dissolved oxygen levels in receiving waterbodies	muskeg and overburden dewatering	L		N					N
706	CNHZ	O	WAQ	changes in water quality	lowered dissolved oxygen levels in receiving waterbodies	muskeg and overburden dewatering	L		N					N
707	CNHZ	O	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-1	L	N	L	L	L	H	R	L
708	CNHZ	R	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-1	L	N	L	L	L	H	R	L
709	CNHZ	O	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-2	L	N	L	L	L	H	R	L
710	CNHZ	R	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-2	L	N	L	L	L	H	R	L
711	CNHZ	O	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-2	L	N	M	L	L	H	R	M
712	CNHZ	R	WAQ	changes in water quality	release of EPL water may influence the water quality of receiving waterbodies	creation and operation of EPL-2	L	N	M	L	L	H	R	M
713	CNHZ	C	WAQ	changes in water quality	effects of all construction activities in planned development scenario on water quality	all construction activities associated with planned development scenario	C		N					N
714	CNHZ	O	WAQ	changes in water quality	effects of all operation activities in planned development scenario on water quality	all operation activities associated with planned development scenario	C		N					N
715	CNHZ	R	WAQ	changes in water quality	effects of all closure activities in planned development scenario on water quality	all closure activities associated with planned development scenario	C		N					N
716	SUFB	C	WAQ	sediment concentration in receiving streams	decreased permeability of plant area and will result in higher water and sediment runoff from these areas	plant, roads and pipelines, well pads	L	N	N	L	M	H	R	N
717	SUFB	O	WAQ	sediment concentration in receiving streams	decreased permeability of plant area and will result in higher water and sediment runoff from these areas	plant, roads and pipelines, well pads	L	N	N	L	M	H	R	N
718	SUFB	C	WAQ	sediment concentration in waterbodies downstream of stream crossings	effects on streambank and channel erosion	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	S	L	R	N
719	SUFB	O	WAQ	flows and water levels in streams	effects on streambank and channel erosion	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	S	L	R	N
720	SUFB	C	WAQ	water quality in receiving streams downstream of pipeline crossings	pipeline integrity during floods could be compromised by pipeline exposure due to natural sediment transport processes	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	M	L	R	N
721	SUFB	O	WAQ	water quality in receiving streams downstream of pipeline crossings	pipeline integrity during floods could be compromised by pipeline exposure due to natural sediment transport processes	pipeline to cross Steepbank River, North Steepbank River, Jackpine Creek and other small tributaries (5 main and 11 minor crossings)	L	N	L	L	M	L	R	N
722	SUFB	C	WAQ	water quality in receiving streams downstream of instream construction and bank excavation areas	release of hydrocarbons from banks of Steepbank River under Option A, and low level release of deleterious substances into aquatic environments under both Options	activities involving instream construction and bank excavation	L	N	N	L	S	L	R	N
723	SUFB	O	WAQ	water quality in receiving streams downstream of instream construction and bank excavation areas	release of hydrocarbons from banks of Steepbank River under Option A, and low level release of deleterious substances into aquatic environments under both Options	activities involving instream construction and bank excavation	L	N	N	L	S	L	R	N
724	SUST	C	WAQ	changes in TSS concentrations	reduction of TSS concentration	project activities	L	P						NO
725	SUST	O	WAQ	changes in TSS concentrations	reduction of TSS concentration	project activities	L	P						NO
726	SUST	R	WAQ	changes in TSS concentrations	reduction of TSS concentration	project activities	L	P						NO
727	SUST	R	WAQ	changes in surface water quality (benzo(a)anthracene, benzo(a)pyrene levels)	seepage of PAHs, changes in aquatic health	seepage from reclaimed STP Project area	L	N	L	L	M	L	R	N
728	SUST	R	WAQ	changes in surface water quality	aquatic health of McLean Creek	EPL discharge to McLean Creek	L	N	N					N
729	SUST	R	WAQ	changes in surface water quality	changes in aquatic health of Athabasca River due to changes in water quality of tributaries	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	R	N	N					N
730	SUST	R	WAQ	changes in water quality of Project Millenium End Pit Lake	input of additional tailings and process water to EPL	drainage of runoff and seepage from reclaimed STP Project area into Millenium EPL	L	N	N					N
731	TNFH	O	WAQ	changes in sediment concentrations and yields	changes in basin sediment runoff or channel erosion	muskeg drainage/overburden dewatering; drainage water from overburden disposal areas; runoff; construction at watercourse crossings	L	N	L					L
732	TNFH	R	WAQ	changes in sediment concentrations and yields	changes in basin sediment runoff or channel erosion	reclamation landscape	L	N	L					L
733	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	L	N	M					M
734	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	L	N	L					L

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 12 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
735	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	L	N	M					M
736	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	L	N	L					L
737	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	L	N	H					M
738	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to McClelland Lake basin	release of operational and reclamation waters	L	N	M					M
739	TNFH	O	WAQ	predicted water quality under mean open water flow conditions	input of operational and reclamation waters to McClelland Lake basin	release of operational and reclamation waters	L	N	L					L
740	TNFH	O	WAQ	predicted water quality under low flow conditions	input of operational and reclamation waters to receiving waterbodies	release of operational and reclamation waters	R	N	L					L
741	TNFH	O	WAQ	changes in thermal regime	input of operational and reclamation waters to receiving waterbodies	muskeg drainage/overburden dewatering	L	N	L					L
742	TNFH	O	WAQ	changes in dissolved oxygen levels	input of operational and reclamation waters to receiving waterbodies	muskeg drainage/overburden dewatering	L							NO
743	TNFH	R	WAQ	viability of aquatic ecosystem	input of reclamation waters	reclamation landscape (end-pit lakes)	L	N	M					M
744	HKST	C	WAQ	water quality of local waterbodies	surface runoff and sedimentation	construction of roads, central plant, pads, pipelines, water crossings	L	N	N	L	S	I		L
745	HKST	O	WAQ	water quality of local waterbodies	surface runoff from plant site and well pads	project infrastructure (plant site, well pads)	L	N	N	L	L	S		L
746	HKST	O	WAQ	water quality of local waterbodies	surface runoff from roads and utility corridors	project infrastructure (roads, utility corridors)	L	N	N	L	L	S		L
747	HKST	O	WAQ	water quality of local waterbodies	input of waste water to waterbodies	discharge of waste water during operations	L	n	NO					L
748	HKST	O	WAQ	water quality of local waterbodies	impact from subsurface operations	subsurface operations	L	n	NO					L
749	HKST	O	WAQ	water quality of local waterbodies	water withdrawal and resulting changes in discharge affect concentrations of analytes	water withdrawal leading to reduced stream discharge	L	N, n	L	L	L	C		L
750	HKST	O	WAQ	water quality of local/regional waterbodies	effects of acidifying emissions on lake acid neutralizing capacity	acidifying emissions	R		NO					NO
751	HKST	C	WAQ	water quality of local/regional waterbodies	cumulative impacts on water quality	project activities and surface distrubances	L		NO					NO
752	SUVR	C	WAQ	concentrations/loads of sediment in surface waterbodies	changes in average flow and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering	L	N	H					NO
753	SUVR	O	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flood peak flow and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L	N	M					NO
754	SUVR	R	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - closure landscape	L	P	H					NO
755	SUVR	C	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering	L	N	N					NO
756	SUVR	O	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	L	N	N					NO
757	SUVR	R	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - closure landscape	L	P	N					NO
758	SUVR	C	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering	R		N					NO
759	SUVR	O	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - muskeg and overburden dewatering, runoff from external overburden disposal area, closed-circuit operations	R		N					NO
760	SUVR	R	WAQ	concentrations/loads of sediment in surface waterbodies	changes in flows and in-channel erosion	North Steepbank mine - closure landscape	R		N					NO
761	SUVR	C	WAQ	water quality and aquatic health	changes in surface water flows, input of project-related waters	North Steepbank mine - discharge of muskeg/overburden dewatering water, surface disturbances	L	N	N					N
762	SUVR	O	WAQ	water quality and aquatic health	changes in surface water flows, input of project-related waters	North Steepbank mine - discharge of muskeg/overburden dewatering water, surface disturbances	L	N	N					N
763	SUVR	R	WAQ	water quality and aquatic health	changes in surface water flows, input of project-related waters	North Steepbank mine - closure landscape, discharge from North Steepbank Pit Lake	L	N	N					N
764	SUVR	C	WAQ	water quality and aquatic health	changes in surface water flows, changes in water quality of Unnamed Creek	North Steepbank mine - discharge of muskeg/overburden dewatering water, surface disturbances	L	N	N					N
765	SUVR	O	WAQ	water quality and aquatic health	changes in surface water flows and water quality of Unnamed Creek, input of project-related waters	North Steepbank mine - depressurization of basal aquifer, seepage	L	N	N					N
766	SUVR	R	WAQ	water quality and aquatic health	changes in surface water flows and water quality of Unnamed Creek, input of project-related waters	North Steepbank mine - seepage	L	N	N					N
767	SUVR	O	WAQ	water quality (aluminum and iron concentrations)	changes in water quality due to altered surface flows	North Steepbank mine - closed circuit operations	L	N	L	L	M	H	R	N
768	SUVR	R	WAQ	water quality (strontium concentrations)	input of Pit Lake waters	North Steepbank mine - North Steepbank Pit Lake discharge	L	N	L	L	L	H	R	L
769	SUVR	C	WAQ	water quality	input of muskeg/overburden drainage waters	North Steepbank mine - muskeg and overburden dewatering	L	N	N					N
770	SUVR	R	WAQ	water quality	input of Pit Lake waters	North Steepbank mine - North Steepbank Pit Lake discharge	L	N	N					N
771	SUVR	C	WAQ	water quality (cadmium concentrations)	input of muskeg/overburden drainage waters	North Steepbank mine - muskeg and overburden dewatering	L	N	L	L	S	L	R	N
772	SUVR	R	WAQ	water quality (strontium concentrations)	input of Pit Lake waters	North Steepbank mine - North Steepbank Pit Lake discharge, seepage	L	N	L	L	L	H	R	L
773	SUVR	R	WAQ	water quality (sulphide concentrations)	input of Pit Lake waters	North Steepbank mine - seepage	L	N	L	L	L	H	R	L
774	SUVR	C	WAQ	water quality	input of muskeg/overburden waters	North Steepbank mine - muskeg and overburden dewatering	L	N	N					N
775	SUVR	O	WAQ	water quality	changes in water quality due to altered surface flows	North Steepbank mine - closed circuit operations	L	N	N					N
776	SUVR	O	WAQ	water quality	input of Pit Lake waters	North Steepbank mine - Pit Lake discharge, seepage	L	N	N					N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 13 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
777	SUVR	C	WAQ	concentrations/loads of sediment in surface waterbodies	changes to flows and sediment loading (in-channel erosion)	upgrader - project footprint, muskeg dewatering	L							N
778	SUVR	O	WAQ	concentrations/loads of sediment in surface waterbodies	changes to flows and sediment loading (in-channel erosion)	upgrader - project footprint, closed circuit operation	L							N
779	SUVR	R	WAQ	concentrations/loads of sediment in surface waterbodies	changes to flows and sediment loading (in-channel erosion)	upgrader - closure landscape	L							N
780	SUVR	O	WAQ	acidity of streams (spring acid pulse)	acid deposited onto snowpack released to stream during spring melt	acidifying emissions	R	N		R	L	H	R	NO
781	SUML	C	WAQ	changes in water quality	sediment load to Shipyard Lake reduced due to upstream ponds	interception drainage system	L		L	L	S			N
782	SUML	O	WAQ	changes in water quality	sediment load to Shipyard Lake reduced due to upstream ponds	interception drainage system	L		L	L	S			N
783	SUML	C	WAQ	changes in water quality	elimination of waterbodies in development area	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	L	L			N
784	SUML	O	WAQ	changes in water quality	elimination of waterbodies in development area	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	L	L			N
785	SUML	C	WAQ	changes in water quality	increased sediment yield	NE Dump, Reclamation Materials Stockpile	L		N	L	S		R	N
786	SUML	O	WAQ	changes in water quality	increased sediment yield	NE Dump, Reclamation Materials Stockpile	L		N	L	S		R	N
787	SUML	C	WAQ	changes in water quality	increased sediment yield in LSA	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	L	S			N
788	SUML	O	WAQ	changes in water quality	increased sediment yield in LSA	construction of infrastructure and interception drainage system, site clearing, muskeg/overburden dewatering	R		N	L	S			N
789	SUML	R	WAQ	changes in water quality	long-term sediment yield from reclaimed surface expected to be similar to natural basins	closure drainage systems, reclaimed landscape, EPL	L							N
790	SUML	C	WAQ	attainment of water quality and toxicity guidelines at mean open-water flow and annual 7Q10 flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering, seepage	R		N	R	L	M	I	L
791	SUML	O	WAQ	attainment of water quality and toxicity guidelines at mean open-water flow and annual 7Q10 flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering, seepage, CT flux	R		N	R	L	M	I	L
792	SUML	R	WAQ	attainment of water quality and toxicity guidelines at mean open-water flow and annual 7Q10 flow	discharge of mine-related waters to receiving waterbodies	seepage, EPL	R		N	R	L	M	I	L
793	SUML	C	WAQ	attainment of water quality and toxicity guidelines at average annual flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering	L		N	L	L	M	I	L
794	SUML	O	WAQ	attainment of water quality and toxicity guidelines at average annual flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering, CT flux	L		N	L	L	M	I	L
795	SUML	R	WAQ	attainment of water quality and toxicity guidelines at average annual flow	discharge of mine-related waters to receiving waterbodies	EPL outflow	L		N	L	L	M	I	L
796	SUML	C	WAQ	attainment of water quality and toxicity guidelines at low flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering	L		L	L	L	M	I	M
797	SUML	O	WAQ	attainment of water quality and toxicity guidelines at low flow	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering, CT flux	L		L	L	L	M	I	M
798	SUML	R	WAQ	attainment of water quality and toxicity guidelines at low flow	discharge of mine-related waters to receiving waterbodies	EPL outflow	L		L	L	L	M	I	M
799	SUML	C	WAQ	attainment of water quality and toxicity guidelines	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering	L		N	L	L	M	I	L
800	SUML	O	WAQ	attainment of water quality and toxicity guidelines	discharge of mine-related waters to receiving waterbodies	muskeg and overburden dewatering, CT flux	L		N	L	L	M	I	L
801	SUML	R	WAQ	attainment of water quality and toxicity guidelines	discharge of mine-related waters to receiving waterbodies	EPL outflow	L		N	L	L	M	I	L
802	SUML	C	WAQ	thermal regime of waterbodies	discharge of cooler mine-related waters to receiving waterbodies	muskeg and overburden dewatering	L		L	L	L	M	R	L
803	SUML	O	WAQ	thermal regime of waterbodies	discharge of cooler mine-related waters to receiving waterbodies	muskeg and overburden dewatering	L		L	L	L	M	R	L
804	SUML	R	WAQ	thermal regime of waterbodies	discharge of mine-related waters to receiving waterbodies	EPL discharge	L		L	L	L	M	R	L
805	SUML	C	WAQ	thermal regime of waterbodies	discharge of cooler mine-related waters to receiving waterbodies	muskeg and overburden drainage	L		N	L	M	M	R	N
806	SUML	O	WAQ	thermal regime of waterbodies	discharge of cooler mine-related waters to receiving waterbodies	muskeg and overburden drainage	L		N	L	M	M	R	N
807	SUML	C	WAQ	dissolved oxygen concentrations in small streams	discharge of mine-related waters containing elevated levels of organic matter	muskeg drainage	L		N	L	M	M	R	N
808	SUML	O	WAQ	dissolved oxygen concentrations in small streams	discharge of mine-related waters containing elevated levels of organic matter	muskeg drainage	L		N	L	M	M	R	N
809	SUML	R	WAQ	water quality of End Pit Lake	drainage of mine-disturbed areas into EPL - toxicity of EPL water as lake is filling	reclaimed landscape, creation of EPL	L		L	L	L	H	R	L
561	ASJP	C	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	muskeg and overburden dewatering	L	N	N	L	L	M	I	N
562	ASJP	C	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	muskeg and overburden dewatering	L	N	N	R	L	M	I	N
563	ASJP	O	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits)	L	N	N	L	L	M	I	N
564	ASJP	O	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	mine operations, seepage of process-affected waters (external tailings disposal, in-pit and external tailings deposits)	L	N	N	R	L	M	I	N
565	ASJP	R	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L	N	N	L	L	M	I	N
566	ASJP	R	SEQ	PAHs in sediments	accumulation of PAHs in sediments of receiving waterbodies	upward flux of process-affected water (in-pit and external tailings deposits), End Pit Lake Outflows	L	N	N	R	L	M	I	N

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
567	ASJP	R	SEQ		types of aquatic habitats that will develop in Project reclamation watercourses and waterbodies	constructed wetlands; stream development; End Pit Lakes	L							NO
568	PCMR	C	SEQ	changes in bogs and fens as represented by Muskeg and McLelland landforms	salinization, contamination, or changes in pH	potential spills and leaks	L	n	M	L	S-L			N
569	PCMR	O	SEQ	changes in bogs and fens as represented by Muskeg and McLelland landforms	salinization, contamination, or changes in pH	migration of solution from lime sludge pond, potential spills	L	n	M	L	S-L			N
570	PCMR	R	SEQ	changes in bogs and fens as represented by Muskeg and McLelland landforms	salinization, contamination, or changes in pH	residual project impacts, reclamation activities	L	n	M	L	S-L			N
571	ASMR	C	SEQ	accumulation of PAHs in aquatic sediments	mobilization of naturally-occuring PAHs and introduction of project-related PAHs into receiving waterbodies	surface disturbances	L	N	N-L	L	M	M	R	L
572	ASMR	O	SEQ	accumulation of PAHs in aquatic sediments	mobilization of naturally-occuring PAHs and introduction of project-related PAHs into receiving waterbodies	surface disturbances, release/seepage of project waters	L	N	N-L	L	M	M	R	L
573	ASMR	R	SEQ	accumulation of PAHs in aquatic sediments	mobilization of naturally-occuring PAHs and introduction of project-related PAHs into receiving waterbodies	surface disturbances, release/seepage of project waters	L	N	N-L	L	M	M	R	L
574	SYML	O	SEQ	water quality of regional lakes (metals, PAHs)	deposition of particulates containing metals and PAHs	emissions of particulates	R	N	L	R	L	C		N
575	SYML	O	SEQ	spring water quality of rivers tributary to Athabasca River (metals, PAHs)	deposition of particulates containing metals and PAHs onto snowpack, pulse of metals/PAHs during spring snowmelt	emissions of particulates	R	N	L	R	M	I		N
576	CNHZ	O	SEQ	changes in sediment quality	accumulation of PAHs in stream and river sediments	water from external tailings area, sand seepage from reclaimed land, CT and TT flux/seepage	L		N					N
577	CNHZ	R	SEQ	changes in sediment quality	accumulation of PAHs in stream and river sediments	water from external tailings area, sand seepage from reclaimed land, CT and TT flux/seepage	L		N					N
578	CNHZ	O	SEQ	changes in sediment quality	accumulation of PAHs in stream and river sediments	water from external tailings area, sand seepage from reclaimed land, CT and TT flux/seepage	L		N					N
579	CNHZ	R	SEQ	changes in sediment quality	accumulation of PAHs in stream and river sediments	water from external tailings area, sand seepage from reclaimed land, CT and TT flux/seepage	L		N					N
580	SUFB	C	SEQ	sedimentation of receiving streams	physical alteration of stream channels (lower Steepbank River plus three fish-bearing small streams under Option A and four fish-bearing streams under Option B pipeline route)	activities involving instream construction and bank excavation	L	N	L	L	S	L	R	N
581	SUFB	O	SEQ	sedimentation of receiving streams	physical alteration of stream channels (lower Steepbank River plus three fish-bearing small streams under Option A and four fish-bearing streams under Option B pipeline route)	activities involving instream construction and bank excavation	L	N	L	L	S	L	R	N
582	SUST	R	SEQ	changes in sediment quality	aquatic health	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	L	N	N					N
583	SUST	R	SEQ	changes in sediment quality	aquatic health	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	R	N	N					N
584	SUST	R	SEQ	changes in water quality of Project Millenium End Pit Lake	input of additional tailings and process water to EPL	drainage of runoff and seepage from reclaimed STP Project area into Millenium EPL	L	N	N					N
585	TNFH	O	SEQ	sediment PAH levels in receiving waterbodies	input of reclamation waters into receiving waterbodies	oil sands extraction and release into end-pit lake, seepage	L							NO
586	SUVR	C	SEQ	sediment quality	changes in sediment quality	North Steepbank mine - project construction	L	N	N					N
587	SUVR	O	SEQ	sediment quality	changes in sediment quality	North Steepbank mine - project operation	L	N	N					N
588	SUVR	R	SEQ	sediment quality	changes in sediment quality	North Steepbank mine - project closure	L	N	N					N
589	SUML	C	SEQ	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
590	SUML	O	SEQ	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
591	SUML	R	SEQ	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
25	ASJP	C	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
26	ASJP	O	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
27	ASJP	R	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
28	ASJP	C	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 15 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
29	ASJP	O	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N
30	ASJP	R	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N
31	ASJP	C	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
32	ASJP	O	BEI	ecosystem level diversity indicators, taxonomic richness of benthic invertebrate communities	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
33	CNHZ	C	BEI	levels of benthic invertebrates in Athabasca River	reduced benthic drift to Athabasca River	water diversions during construction phase	L		N					N
34	CNHZ	O	BEI	levels of benthic invertebrates in Athabasca River	reduced benthic drift to Athabasca River	water diversions during operation phase	L		N					N
35	CNHZ	R	BEI	levels of benthic invertebrates in Athabasca River	reduced benthic drift to Athabasca River	water diversions during closure phase	L		N					N
36	SUST	R	BEI	changes in toxic units	aquatic health of McLean Creek	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	L	N	N					N
37	SUST	R	BEI	changes in aquatic resources health	changes in aquatic health of Athabasca River due to changes in water quality of tributaries	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	R	N	N					N
38	SUST	R	BEI	changes in ecological viability of Project Millenium End Pit Lake	input of additional tailings and process water to EPL - direct and indirect exposure of aquatic orgnaisms to changes in water quality	drainage of runoff and seepage from reclaimed STP Project area into Millenium EPL	L	N	N					N
39	SUVR	R	BEI	benthic invertebrate community and habitat diversity	changes in habitat composition	North Steepbank mine - habitat compensation	L	n	N					NO
40	SUVR	R	BEI	benthic invertebrate community and habitat diversity	changes in habitat composition	North Steepbank mine - habitat compensation	R	n	N					NO
41	SUML	C	BEI	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
42	SUML	O	BEI	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
43	SUML	R	BEI	sediment quality	mobilization of naturally occurring PAHs, discharge of PAH-containing mine-related waters to receiving waterbodies	mining and processing activities	R		N	R	L	H	I	L
254	ASJP	C	FIP		disturbance, alteration, or loss of productive fish habitat within Project development area	positioning of dam on Khahago Creek and creek re-establishment on closure; elimination of Shelley Creek; diversion of Wesukemina Creek, elimination of lower reaches of Wesukemina Creek, creation of new exit route for Muskeg Creek from Kearl Lake by damming current outlet and creation of new channel; repositioning of Muskeg Creek; connection of West End Pit Lake	L							N
255	ASJP	O	FIP		disturbance, alteration, or loss of productive fish habitat within Project development area	positioning of dam on Khahago Creek and creek re-establishment on closure; elimination of Shelley Creek; diversion of Wesukemina Creek, elimination of lower reaches of Wesukemina Creek, creation of new exit route for Muskeg Creek from Kearl Lake by damming current outlet and creation of new channel; repositioning of Muskeg Creek; connection of West End Pit Lake	L							N
256	ASJP	R	FIP		disturbance, alteration, or loss of productive fish habitat within Project development area	positioning of dam on Khahago Creek and creek re-establishment on closure; elimination of Shelley Creek; diversion of Wesukemina Creek, elimination of lower reaches of Wesukemina Creek, creation of new exit route for Muskeg Creek from Kearl Lake by damming current outlet and creation of new channel; repositioning of Muskeg Creek; connection of West End Pit Lake	L							N
257	ASJP	C	FIP	changes in fish health	direct effects on fish health through changes in water quality, sediment quality, direct uptake of from water and sediments; indirect effects on fish health via direct effects on fish food organisms	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L							N
258	ASJP	O	FIP	changes in fish health	direct effects on fish health through changes in water quality, sediment quality, direct uptake of from water and sediments; indirect effects on fish health via direct effects on fish food organisms	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L							N
259	ASJP	R	FIP	changes in fish health	direct effects on fish health through changes in water quality, sediment quality, direct uptake of from water and sediments; indirect effects on fish health via direct effects on fish food organisms	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L							N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 16 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
260	ASJP	C	FIP	changes in fish tissue quality	linkage between changes in water quality and changes in fish tissue quality	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	S	L	R	N
261	ASJP	O	FIP	changes in fish tissue quality	linkage between changes in water quality and changes in fish tissue quality	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	S	L	R	N
262	ASJP	R	FIP	changes in fish tissue quality	linkage between changes in water quality and changes in fish tissue quality	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	S	L	R	N
263	ASJP	C	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
264	ASJP	O	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
265	ASJP	R	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	L	M	R	N
266	ASJP	C	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N
267	ASJP	O	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N
268	ASJP	R	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	L	L	S	L	R	N
269	ASJP	C	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
270	ASJP	O	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
271	ASJP	R	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: (i) direct effects of habitat changes; (ii) effects of habitat changes on benthic macroinvertebrate community diversity on fish habitat biodiversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
272	ASJP	R	FIP		types of aquatic habitats that will develop in Project reclamation watercourses and waterbodies	constructed wetlands; stream development; End Pit Lakes	L							NO
273	PCMR	C	FIP	changes in fish or aquatic resources	changes in natural drainage patterns	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
274	PCMR	O	FIP	changes in fish or aquatic resources	changes in natural drainage patterns	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
275	PCMR	C	FIP	changes in regional fish populations	changes in aquifer discharge to and flows in MacKay River, changes in overwintering fish habitat	groundwater pumping from Birch Channel aquifer	R	N	L					L
276	PCMR	O	FIP	changes in regional fish populations	changes in aquifer discharge to and flows in MacKay River, changes in overwintering fish habitat	groundwater pumping from Birch Channel aquifer	R	N	L					L
277	PCMR	C	FIP	changes in regional fish populations	changes in aquifer discharge to and flows in MacKay River, changes in overwintering fish habitat	groundwater pumping from Birch Channel aquifer	R	N	N					N
278	PCMR	O	FIP	changes in regional fish populations	changes in aquifer discharge to and flows in MacKay River, changes in overwintering fish habitat	groundwater pumping from Birch Channel aquifer	R	N	N					N
279	PCMR	C	FIP	changes in fish or aquatic resources	increased sediment or contaminant input to aquatic systems through surface run-off or sediment loadings	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
280	PCMR	O	FIP	changes in fish or aquatic resources, including tainting of fish	increased sediment or contaminant input to aquatic systems	project operation activities - well servicing, operation of the central plant	L		N					N
281	PCMR	R	FIP	changes in fish or aquatic resources	increased sediment input to aquatic systems	reclamation activities	L	N	N		S			N
282	PCMR	R	FIP	changes in fish or aquatic resources and habitats	post-closure conditions	reclamation and abandonment	L							N
283	PCMR	C	FIP	changes in fisheries resources	increase in fishing pressure and fish harvest	recreational angling by workforce	R		L					N
284	PCMR	O	FIP	changes in fisheries resources	increase in fishing pressure and fish harvest	recreational angling by workforce	R		L					N

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
285	SUSB	C	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality due to water releases	mine activities	R	N	L	L	S		R	N
286	SUSB	O	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality due to water releases	mine activities, drainage of Unnamed and Leggett Creeks	R	N	L	L	S		R	N
287	SUSB	C	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
288	SUSB	O	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
289	SUSB	R	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
290	SUSB	C	FIP	quality of fish flesh	changes in water quality	release of refinery wastewater effluent	R	N	M	L	M			M
291	SUSB	O	FIP	quality of fish flesh	changes in water quality	release of refinery wastewater effluent	R	N	M	L	M			M
292	SUSB	C	FIP	fish abundance	changes in aquatic habitat and/or aquatic health	mine activities	R	N		R				N
293	SUSB	O	FIP	fish abundance	changes in aquatic habitat and/or aquatic health	mine activities	R	N		R				N
294	SUSB	R	FIP	fish abundance	changes in aquatic habitat and/or aquatic health	mine activities	R	N		R				N
295	PCMC	C	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
296	PCMC	O	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
297	PCMC	R	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
298	PCMC	C	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat due to disturbance and changes in erosion/sediment loading	watercourse crossings	L	N	N	L	M	L	R	N
299	PCMC	O	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat due to disturbance and changes in erosion/sediment loading	watercourse crossings	L	N	N	L	M	L	R	N
300	PCMC	C	FIP	changes in forage fish health (acute or chronic effects)	increases in sediment loading, introduction of hydrocarbons	watercourse crossings	L	N	N	L	S	R	L	N
301	PCMC	O	FIP	changes in forage fish health (acute or chronic effects)	increases in sediment loading, introduction of hydrocarbons	watercourse crossings	L	N	N	L	S	R	L	N
302	ONLL	O	FIP	changes in fish habitat	changes in stream flow during open-water season and normal winter flows	groundwater withdrawal	L	N	N	L	M	R	H	N
303	ONLL	O	FIP	changes in fish habitat	changes in stream flow during periods of no winter outflow from Gregoire Lake	groundwater withdrawal	L	N	M	L	M	R	M	L
304	ONLL	O	FIP	changes in fish habitat	changes in stream flow	groundwater withdrawal	R	N	N	R	M	R	H	N
305	ONLL	C	FIP	changes in forage fish habitat	physical alteration to stream channel, increased sediment deposition	construction of road and pipeline stream crossings	L	N	N	L	S	R	L	N
306	ONLL	C	FIP	changes in fish habitat	physical alteration to stream channel, increased sediment deposition	construction of pipeline crossing (isolation technique requiring instream activity)	L	N	L	L	S	R	L	N
307	ONLL	C	FIP	acute or chronic changes in forage fish health	increased sediment loading, introduction of hydrocarbons	construction of watercourse crossing	L	N	N	L	S	L		N
308	ONLL	C	FIP	acute or chronic changes in fish health	increased sediment loading, introduction of hydrocarbons	construction of pipeline crossing (isolation technique requiring instream activity)	L	N	L	L	S	L	R	N
309	ONLL	O	FIP	acute or chronic changes in fish health	deposition of acids and acid-forming substances in regional lakes	acidifying emissions	R	N	N	L	M	H	R	N
310	ONLL	C	FIP	changes in fish abundance	changes in fishing pressure, changes in fish habitat, acute or chronic effects on fish health	development of infrastructure (increased access to fish-bearing waterbodies), groundwater withdrawal	L	N	M	L	M	M	R	L
311	ONLL	O	FIP	changes in fish abundance	changes in fishing pressure, changes in fish habitat, acute or chronic effects on fish health	development of infrastructure (increased access to fish-bearing waterbodies), groundwater withdrawal	L	N	M	L	M	M	R	L
312	ONLL	R	FIP	changes in fish abundance	changes in fishing pressure, changes in fish habitat, acute or chronic effects on fish health	development of infrastructure (increased access to fish-bearing waterbodies), groundwater withdrawal	L	N	M	L	M	M	R	L
313	ASMR	C	FIP	changes in forage fish habitat	changes in area of lakes/ponds, changes in flow regime	diversion and disruption of natural drainage patterns, inflows from project-related waters, mine facilities and infrastructure	L	N	N	L	M	once	R	N
314	ASMR	O	FIP	changes in forage fish habitat	changes in area of lakes/ponds, changes in flow regime	diversion and disruption of natural drainage patterns, inflows from project-related waters, mine facilities and infrastructure	L	N	N	L	M	once	R	N
315	ASMR	C	FIP	changes in habitat of longnose sucker, Arctic grayling, Northern Pike	changes in area of lakes/ponds, changes in flow regime	diversion and disruption of natural drainage patterns, inflows from project-related waters, mine facilities and infrastructure	L		N					N
316	ASMR	O	FIP	changes in habitat of longnose sucker, Arctic grayling, Northern Pike	changes in area of lakes/ponds, changes in flow regime	diversion and disruption of natural drainage patterns, inflows from project-related waters, mine facilities and infrastructure	L		N					N
317	ASMR	R	FIP	changes in fish habitat	creation of fish habitat in reclaimed landscape	reclamation and creation of streams, wetlands, and the EPL	L	P	N-H	L	L			N
318	ASMR	R	FIP	viability of end pit lake ecosystem	EPL will receive runoff from reclaimed landscape	creation of EPL at closure	L			L	L			NO
319	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	changes in drainage patterns	Surface disturbances	L	N	L	L	L			N
320	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	drawdown of water level	groundwater withdrawal	R	N	L	R	L			N
321	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	changes in water quality (suspended sediment and other contaminants)	surface disturbances	L	N	L	L	L			N
322	CPSU	O	FIP	changes in sport fishing pressure	changes in harvest of fish	sport fishing by workforce	R	N	L	R	L			N
323	SYAN	R	FIP	changes in walleye, goldeye, Arctic grayling, and longnose sucker	creation of possible fish habitat in EPLs	creation of end pit lakes	L					P		NO
324	SYAN	O	FIP	changes in forage fish abundance	increased sediment loads for one season	construction of drainage system	L					N	L	L
325	SYAN	O	FIP	changes in forage fish abundance	loss of forage fish habitat	mine development, dewatering	L					N	M	L
326	SYAN	O	FIP	changes in forage fish abundance	changes in water quality and forage fish habitat	water diversions	L					N	L	L

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
327	SYAN	O	FIP	changes in forage fish abundance	changes in forage fish habitat at Aurora Mine South	water diversion, dewatering	L	1				N	H	L
328	SYAN	O	FIP	changes in forage fish abundance	changes in water quality (sediment load) and forage fish habitat	construction of drainage system	L					N	L	L
329	SYAN	R	FIP	changes in forage fish abundance	creation of new forage fish habitat	reclamation - restoration of drainage	L					P	H	L
330	SYAN	O	FIP	changes in aquatic ecosystem health and forage fish abundance	changes in water quality	release of reclamation waters - CT water flux	L							NO
331	SYAN	R	FIP	changes in aquatic ecosystem health and forage fish abundance	changes in water quality	release of reclamation waters	L							NO
332	SYML	O	FIP	effect of acidity on fish and aquatic biota	deposition of acids and acid-forming substances	acidifying emissions	R	N	N	R	L	C		N
333	SYML	O	FIP	effect on aquatic resources of particulate (metal/PAH-containing) deposition in regional lakes	deposition of particulates containing metals and PAHs	emissions of particulates	R	N	N	R	L	C		N
334	SYML	O	FIP	effect on aquatic resources of particulate (metal/PAH-containing) deposition in regional streams	deposition of particulates containing metals and PAHs onto snowpack, pulse of metals/PAHs during spring snowmelt	emissions of particulates	R	N	N-L	R	M	I		N
335	DCJS	C	FIP	changes in fish and fish habitat	generation of sediment by instream and upslope activities, interference with fish passage, direct alteration/loss of fish habitat	stream crossings (bridges, pipelines), water intake on Ells River and water withdrawal	L							N
336	DCJS	O	FIP	changes in fish and fish habitat	generation of sediment by instream and upslope activities, interference with fish passage, direct alteration/loss of fish habitat	stream crossings (bridges, pipelines), water intake on Ells River and water withdrawal	L							N
337	CNHZ	C	FIP	changes in fish habitat	loss of waterbodies and watercourses	water diversions during construction phase	L		N					N
338	CNHZ	O	FIP	changes in fish habitat	loss of waterbodies and watercourses	water diversions during operation phase	L		N					N
339	CNHZ	R	FIP	changes in fish habitat	loss of waterbodies and watercourses	water diversions during closure phase	L		N					N
340	CNHZ	C	FIP	changes in fish habitat	change in Athabasca River discharge and water level	water diversions during construction phase	L		N					N
341	CNHZ	O	FIP	changes in fish habitat	change in Athabasca River discharge and water level	water diversions during operation phase	L		N					N
342	CNHZ	R	FIP	changes in fish habitat	change in Athabasca River discharge and water level	water diversions during closure phase	L		N					N
343	CNHZ	C	FIP	changes in fish health	changes in water quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L							N
344	CNHZ	O	FIP	changes in fish health	changes in water quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
345	CNHZ	R	FIP	changes in fish health	changes in water quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
346	CNHZ	C	FIP	changes in fish health	changes in water quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	M	L	S	M	R	L
347	CNHZ	O	FIP	changes in fish health	changes in water quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	M	L	S	M	R	L
348	CNHZ	R	FIP	changes in fish health	changes in water quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	M	L	S	M	R	L
349	CNHZ	C	FIP	changes in fish health	changes in sediment quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
350	CNHZ	O	FIP	changes in fish health	changes in sediment quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
351	CNHZ	R	FIP	changes in fish health	changes in sediment quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
352	CNHZ	C	FIP	changes in fish health	changes in sediment quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
353	CNHZ	O	FIP	changes in fish health	changes in sediment quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
354	CNHZ	R	FIP	changes in fish health	changes in sediment quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
355	CNHZ	C	FIP	changes in fish health	changes in water quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L							N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 19 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
356	CNHZ	O	FIP	changes in fish health	changes in water quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
357	CNHZ	R	FIP	changes in fish health	changes in water quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
358	CNHZ	C	FIP	changes in fish health	changes in sediment quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
359	CNHZ	O	FIP	changes in fish health	changes in sediment quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
360	CNHZ	R	FIP	changes in fish health	changes in sediment quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
361	CNHZ	C	FIP	changes in fish health	changes in water quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L							N
362	CNHZ	O	FIP	changes in fish health	changes in water quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
363	CNHZ	R	FIP	changes in fish health	changes in water quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L							N
364	CNHZ	C	FIP	changes in fish health	changes in sediment quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
365	CNHZ	O	FIP	changes in fish health	changes in sediment quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
366	CNHZ	R	FIP	changes in fish health	changes in sediment quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
367	CNHZ	C	FIP	changes in fish health	changes in water quality	muskeg, drainage, overburden dewatering and runoff from the cleared plant site, ore preparation area, tailings dyke area, initial mining area (Cell 2) and overburden disposal areas	L	N	N					N
368	CNHZ	O	FIP	changes in fish health	changes in water quality	accidental releases during operation, muskeg and overburden dewatering, water from external tailings area, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	N					N
369	CNHZ	R	FIP	changes in fish health	changes in water quality	water from external tailings area, sand seepage from reclaimed land, in-pit seepage and runoff, CT flux/seepage, End-Pit Lake, re-injection or seepage of basal water and shallow groundwater	L	N	L	L	S	L	R	N
370	CNHZ	C	FIP	changes in fish abundance	changes in fish habitat from loss of watercourses and waterbodies	water diversions during construction phase	L	N	N					N
371	CNHZ	O	FIP	changes in fish abundance	changes in fish habitat from loss of watercourses and waterbodies	water diversions during operation phase	L	N	N					N
372	CNHZ	R	FIP	changes in fish abundance	changes in fish habitat from loss of watercourses and waterbodies	water diversions during closure phase	L	N	N					N
373	CNHZ	C	FIP	changes in fish abundance	changes in abundance of benthic invertebrates	water diversions during construction phase	L	N	N					N
374	CNHZ	O	FIP	changes in fish abundance	changes in abundance of benthic invertebrates	water diversions during operation phase	L	N	N					N
375	CNHZ	R	FIP	changes in fish abundance	changes in abundance of benthic invertebrates	water diversions during closure phase	L	N	N					N
376	CNHZ	C	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality	L	N	N					N
377	CNHZ	O	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality	L	N	N					N
378	CNHZ	R	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality	L	N	N					N
379	CNHZ	R	FIP	viability of aquatic ecosystems	ability of project reclamation watercourses and waterbodies to sustain viable aquatic ecosystems	project reclamation watercourses and waterbodies	L							N
380	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	L	N	N					N
381	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	L	N	N					N
382	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	L	N	N					N
383	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	L	L	L	H	I	M
384	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	L	L	L	H	I	M
385	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	L	L	L	H	I	M
386	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	N					N

Appendix A3 **Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 20 of 25).**

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
387	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	N					N
388	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	L	N	N					N
389	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	L	N	N					N
390	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	L	N	N					N
391	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	L	N	N					N
392	CNHZ	C	FIP	fish habitat and fish abundance	effect of planned development scenario on fish habitat and fish abundance	planned development scenario	C							N
393	CNHZ	O	FIP	fish habitat and fish abundance	effect of planned development scenario on fish habitat and fish abundance	planned development scenario	C							N
394	CNHZ	R	FIP	fish habitat and fish abundance	effect of planned development scenario on fish habitat and fish abundance	planned development scenario	C							N
395	CNHZ	C	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
396	CNHZ	O	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
397	CNHZ	R	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
398	CNHZ	C	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
399	CNHZ	O	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
400	CNHZ	R	FIP	fish health	effect of changes in water quality in planned development scenario	planned development scenario	C							N
401	CNHZ	C	FIP	fish health	effect of changes in sediment quality in planned development scenario	planned development scenario	C							N
402	CNHZ	O	FIP	fish health	effect of changes in sediment quality in planned development scenario	planned development scenario	C							N
403	CNHZ	R	FIP	fish health	effect of changes in sediment quality in planned development scenario	planned development scenario	C							N
404	CNHZ	C	FIP	changes in fish tissue quality	changes in fish tainting	changes in sediment quality under planned development scenario	C	N	N					N
405	CNHZ	O	FIP	changes in fish tissue quality	changes in fish tainting	changes in sediment quality under planned development scenario	C	N	N					N
406	CNHZ	R	FIP	changes in fish tissue quality	changes in fish tainting	changes in sediment quality under planned development scenario	C	N	N					N
407	CNHZ	C	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality under planned development scenario	C	N	N					N
408	CNHZ	O	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality under planned development scenario	C	N	N					N
409	CNHZ	R	FIP	changes in fish tissue quality	changes in fish tainting	changes in water quality under planned development scenario	C	N	N					N
410	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	C	N	N					N
411	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	C	N	N					N
412	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in fish habitat on fish habitat and fish diversity	changes in fish habitat	C	N	N					N
413	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	C	N	N					N
414	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	C	N	N					N
415	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in benthic invertebrate habitat on fish habitat and fish diversity	changes in benthic invertebrate habitat	C	N	N					N
416	CNHZ	C	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	C	N	N					N
417	CNHZ	O	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	C	N	N					N
418	CNHZ	R	FIP	fish and fish habitat biodiversity	effect of changes in river discharge and water level on fish habitat and fish diversity	changes in river discharge and water level	C	N	N					N
419	SUFB	C	FIP	amount of fish habitat available	physical alteration of stream channels (lower Steepbank River plus three fish-bearing small streams under Option A and four fish-bearing streams under Option B pipeline route)	activities involving instream construction and bank excavation	L	N	L	L	S	L	R	N
420	SUFB	O	FIP	sedimentation of receiving streams	physical alteration of stream channels (lower Steepbank River plus three fish-bearing small streams under Option A and four fish-bearing streams under Option B pipeline route)	activities involving instream construction and bank excavation	L	N	L	L	S	L	R	N
421	SUFB	C	FIP	decreases in fish health from changes in water quality in receiving streams downstream of instream construction and bank excavation areas	release of hydrocarbons from banks of Steepbank River under Option A, and low level release of deleterious substances into aquatic environments under both Options	activities involving instream construction and bank excavation	L	N	N	L	S	L	R	N
422	SUFB	O	FIP	decreases in fish health from changes in water quality in receiving streams downstream of instream construction and bank excavation areas	release of hydrocarbons from banks of Steepbank River under Option A, and low level release of deleterious substances into aquatic environments under both Options	activities involving instream construction and bank excavation	L	N	N	L	S	L	R	N
423	SUST	R	FIP	changes in toxic units, changes in tissue quality	aquatic health of McLean Creek	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	L	N	N					N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 21 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
424	SUST	R	FIP	changes in fish health index	aquatic health of McLean Creek	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	L	N	L	L	M	L	R	N
425	SUST	R	FIP	changes in aquatic resources health	changes in aquatic health of Athabasca River due to changes in water quality of tributaries	EPL discharge to McLean Creek, seepage from reclaimed STP Project Area	R	N	N					N
426	SUST	R	FIP	changes in ecological viability of Project Millenium End Pit Lake	input of additional tailings and process water to EPL - direct and indirect exposure of aquatic orgnaisms to changes in water quality	drainage of runoff and seepage from reclaimed STP Project area into Millenium EPL	L	N	N					N
427	SUST	C	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
428	SUST	C	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
429	SUST	O	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
430	SUST	O	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
431	SUST	R	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
432	SUST	R	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
433	SUST	C	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
434	SUST	C	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
435	SUST	O	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
436	SUST	O	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
437	SUST	R	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
438	SUST	R	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
439	SUST	C	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
440	SUST	C	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
441	SUST	O	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
442	SUST	O	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
443	SUST	R	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	L	n						NO
444	SUST	R	FIP	changes in aquatic biodiversity	changes in aquatic health	project activities, surface disturbances, release/seepage of project waters	R	n						NO
445	SUST	O	FIP	changes in fish tissue quality	direct and indirect exposure to tainting substances in water, sediment, and food organisms	seepage from STP Project	L	N	N					N
446	SUST	O	FIP	changes in fish tissue quality	direct and indirect exposure to tainting substances in water, sediment, and food organisms	seepage from STP Project	R	N	N					N
447	SUST	R	FIP	changes in fish tissue quality	direct and indirect exposure to tainting substances in water, sediment, and food organisms	seepage from STP Project, release of water from EPLs	L	N	N					N
448	SUST	R	FIP	changes in fish tissue quality	direct and indirect exposure to tainting substances in water, sediment, and food organisms	seepage from STP Project, release of water from EPLs	R	N	N					N
449	TNFH	R	FIP	changes in fish habitat in small streams and lakes	implementation of No Net Loss plan compensates for habitat loss during project construction/operation	No Net Loss Plan - reclamation landscape	L							NO
450	TNFH	O	FIP	changes in fish habitat in small streams and lakes	increase in flow due to water diversion to this channel	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	N					N

Appendix A3 **Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 22 of 25).**

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
451	TNFH	O	FIP	changes in fish habitat in small streams and lakes	changes in flow and water level	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	P	N		S			N
452	TNFH	R	FIP	changes in fish habitat in small streams and lakes	changes in flow and water level	reclamation landscape	L	N	N					N
453	TNFH	O	FIP	changes in fish habitat in small streams and lakes	changes in flow and water level	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	H		L			M
454	TNFH	R	FIP	changes in fish habitat	loss of tributaries to the Athabasca River; creation of new tributary habitat	diversion/disruption/loss of natural waterbodies and No Net Loss habitat creation	R							NO
455	TNFH	O	FIP	changes in fish and fish habitat	direct loss of habitat, introduction of sediment/deleterious substances, entrainment/impingement of fish at intake structure	construction and operation of Athabasca River water intake structure	R							NO
456	TNFH	O	FIP	changes in aquatic health	changes to flow and water quality	physical alteration of channel, input of operational and reclamation waters	L	N	N					N
457	TNFH	O	FIP	changes in aquatic health	changes to flow and water quality	physical alteration of channel, input of operational and reclamation waters	L	N	M					M
458	TNFH	O	FIP	changes in aquatic health	indirect impacts to flow and water quality via the creek connecting McClelland Lake and the Firebag River	diversion/disruption of natural drainage patternsin project area; input of operational and reclamation waters	L	N	L		S			L
459	TNFH	O	FIP	changes in aquatic health	indirect impacts to flow and water quality	seepage, release of operational/reclamation waters	R							NO
460	TNFH	O	FIP	changes in fish health	accumulation of metal or organic substances in fish tissue	release of operational and reclamation waters	R							NO
461	TNFH	O	FIP	impacts to fish from acidification	deposition of acidifying substances and exceedance of critical load	acidifying emissions	R	N	H					M
462	TNFH	O	FIP	changes in fish abundance	changes in fishing pressureand fish health	changes to access, direct/indirect impacts to fish habitat and health	L	N						NO
463	TNFH	R	FIP	changes in fish abundance	changes in fish habitat	No Net Loss Plan - reclamation landscape	L	P			L			NO
464	TNFH	O	FIP	changes in fish tissue quality	uptake of metals and organic compounds into fish tissue; impairment of flavour, aroma, or texture of edible fish tissue	release of operational and reclamation waters	R	N						NO
465	TNFH	R	FIP	aquatic biodiversity	direct and indirect impacts on fish habitat, fish species, and benthic invertebrates due to losses during construction/operation and compensation in No Net Loss plan	No Net Loss Plan - reclamation landscape	R							NO
466	HKST	C	FIP	fish and benthic invertebrate communities; habitat	change in sediment loading in streams	construction of stream crossings, buried pipeline crossings, and a single-span bridge	L	n	L	L	S	I		L
467	HKST	C	FIP	fish and benthic invertebrate communities; habitat	changes in stream flow due to altered infiltration and runoff patterns	construction of surface facilities	L	n	L	L	M	C		L
468	HKST	C	FIP	fish and benthic invertebrate communities; habitat	changes to stream discharge	groundwater withdrawal	L	n	L	L	M	C		L
469	HKST	O	FIP	fish and benthic invertebrate communities; habitat	acid deposition and acidification of waterbodies	acidifying emissions	R	n	L	R	L	C		L
470	HKST	C	FIP	fish populations (northern pike)	change in fishing pressure due to increased workforce numbers	increase in workforce in the area	L	n	L	L	M	S		L
471	HKST	O	FIP	fish populations (northern pike)	change in fishing pressure due to increased workforce numbers	increase in workforce in the area	L	n	L	L	M	S		L
472	HKST	C	FIP	abundance, habitat, or health of special status species (spoonhead sculpin)	project impacts on special status species	project activities	L	n	L	L	M	S		L
473	HKST	O	FIP	abundance, habitat, or health of special status species (spoonhead sculpin)	project impacts on special status species	project activities	L	n	L	L	M	S		L
474	HKST	CUM	FIP	changes in fish and aquatic resources	changes in acid deposition in lakes	acidifying emissions	R		NO					NO
475	HKST	CUM	FIP	changes in fish populations	change in fishing pressure due to increased workforce numbers	increase in workforce in the area	R		N					NO
476	HKST	CUM	FIP	changes in abundance, health, or habitat of special status species (spoonhead sculpin, northern redbelly dace, bull trout, Arctic grayling)	project impacts on special status species	project activities, increased workforce in area	R		NO					NO
477	SUVR	C	FIP	fish tissue quality, aquatic health	changes in surface water quality	North Steepbank mine - discharge of muskeg/overburden dewatering water, surface disturbances	L	N	N					N
478	SUVR	O	FIP	fish tissue quality, aquatic health	changes in surface water quality	North Steepbank mine - discharge of muskeg/overburden dewatering water, surface disturbances, depressurization of basal aquifer, seepage	L	N	N					N
479	SUVR	R	FIP	fish tissue quality, aquatic health	changes in surface water quality	North Steepbank mine - closure landscape, seepage, discharge from End Lake	L	N	N					N
480	SUVR	R	FIP	viability of Pit Lake aquatic ecosystem	water, sediment, and fish tissue quality affected by MFT and Pit Lake waters	North Steepbank mine - creation of Pit Lake	L	n	N					N
481	SUVR	C	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances, crossing structure, changes in flow regime of Unnamed Creek	L	N	N					NO
482	SUVR	O	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances, crossing structure, changes in flow regime of Unnamed Creek	L	N	N					NO
483	SUVR	R	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - closure landscape and habitat compensation	L	N	N					NO
484	SUVR	C	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances, changes in flow regime	L	n	N					NO
485	SUVR	O	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances, changes in flow regime	L	n	N					NO
486	SUVR	R	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - closure landscape and habitat compensation	L	n	N					NO
487	SUVR	C	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances and changes in flow regime of Steepbank River/Unnamed Creek	R	n	N					NO

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
488	SUVR	O	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - surface disturbances and changes in flow regime of Steepbank River/Unnamed Creek	R	n	N					NO
489	SUVR	R	FIP	fish habitat and fish abundance	direct and indirect impacts to fish habitat and fish abundance	North Steepbank mine - closure landscape and habitat compensation for North Steepbank mine	R	n	N					NO
490	SUVR	R	FIP	fish and fish habitat diversity	changes in habitat composition	North Steepbank mine - habitat compensation	L	n	N					NO
491	SUVR	R	FIP	fish and fish habitat diversity	changes in habitat composition	North Steepbank mine - habitat compensation	R	n	N					NO
492	SUVR	R	FIP	fish tainting	tainting of fish flesh due to direct exposure to process-affected water or indirect exposure to tainting compounds	North Steepbank mine - seepage and outflow from the North Steepbank Pit Lake	L	N	N					N
493	SUVR	R	FIP	fish tainting	tainting of fish flesh due to direct exposure to process-affected water or indirect exposure to tainting compounds	North Steepbank mine - seepage and outflow from the North Steepbank Pit Lake	R	N	N					N
494	SUVR	C	FIP	fish habitat and fish abundance	changes to flows, channel regime, and sediment loading (in-channel erosion)	upgrader - project footprint, muskeg dewatering	L	n	N					N
495	SUVR	O	FIP	fish habitat and fish abundance	changes to flows, channel regime, and sediment loading (in-channel erosion)	upgrader - project footprint, closed circuit operation	L	n	N					N
496	SUVR	R	FIP	fish habitat and fish abundance	changes to flows, channel regime, and sediment loading (in-channel erosion)	upgrader - closure landscape	L	n	N					N
497	SUVR	C	FIP	fish and fish habitat diversity	changes to fish habitat and fish abundance	upgrader - project footprint, muskeg dewatering	L	n	N					N
498	SUVR	O	FIP	fish and fish habitat diversity	changes to fish habitat and fish abundance	upgrader - project footprint, closed circuit operation	L	n	N					N
499	SUVR	R	FIP	fish and fish habitat diversity	changes to fish habitat and fish abundance	upgrader - closure landscape	L	n	N					N
500	SUST	C	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
501	SUST	C	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
502	SUST	O	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
503	SUST	O	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
504	SUST	R	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	L	n	N	L	S		R	N
505	SUST	R	FIP	changes in fish habitat and fish abundance	direct disturbance of habitat within project footprint, diversion and disruption of natural drainage patterns, changes in streamflow, sediment loadings, and channel morphology, and changes in water quality	surface disturbances, project activities	R	n	N	L	S		R	N
506	TNFH	R	FIP	changes in habitat in small streams and lakes	implementation of No Net Loss plan compensates for habitat loss during project construction/operation	No Net Loss Plan - reclamation landscape	L							NO
507	TNFH	O	FIP	changes in habitat in small streams and lakes	increase in flow due to water diversion to this channel	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	N					N
508	TNFH	O	FIP	changes in habitat in small streams and lakes	changes in flow and water level	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	N					N
509	TNFH	O	FIP	changes in habitat in small streams and lakes	changes in flow and water level	diversion/disruption of natural drainage patterns; muskeg drainage/overburden dewatering	L	N	H		L			M
510	HKST	C	FIP	fish and benthic invertebrate communities; habitat	change in sediment loading in streams	construction of stream crossings, buried pipeline crossings, and a single-span bridge	L	n	L	L	S	I		L
511	HKST	C	FIP	fish and benthic invertebrate communities; habitat	changes in stream flow due to altered infiltration and runoff patterns	construction of surface facilities	L	n	L	L	M	C		L
512	HKST	C	FIP	fish and benthic invertebrate communities; habitat	changes to stream discharge	groundwater withdrawal	L	n	L	L	M	C		L
513	HKST	O	FIP	fish and benthic invertebrate communities; habitat	acid deposition and acidification of waterbodies	acidifying emissions	R	n	L	R	L	C		L
514	SUVR	R	FIP	viability of Pit Lake aquatic ecosystem	water, sediment, and fish tissue quality affected by MFT and Pit Lake waters	North Steepbank mine - creation of Pit Lake	L	n	N					N
515	ASJP	R	FIP	fish habitat diversity, speces level fish biodiversity indicators, ecosystem level diversity indicators	linkage between: direct effects of habitat changes and benthic macroinvertebrate community diversity	releases of consolidated tailings water from the Project; releases of seepage water from the Project; introduction of substances to Project area watercourses from surface runoff and/or accidental spills	L	N	N	L	M	L	R	N
516	ASJP	R	FIP		types of aquatic habitats that will develop in Project reclamation watercourses and waterbodies	constructed wetlands; stream development; End Pit Lakes	L							NO

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
517	PCMR	C	FIP	changes in fish or aquatic resources	changes in natural drainage patterns	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
518	PCMR	O	FIP	changes in fish or aquatic resources	changes in natural drainage patterns	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
519	PCMR	C	FIP	changes in fish or aquatic resources	increased sediment or contaminant input to aquatic systems through surface run-off or sediment loadings	surface facilities and disturbances (well pads, roads, central plant site)	L		N					N
520	PCMR	O	FIP	changes in fish or aquatic resources, including tainting of fish	increased sediment or contaminant input to aquatic systems	project operation activities - well servicing, operation of the central plant	L		N					N
521	SUSB	C	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality due to water releases	mine activities	R	N	L	L	S		R	N
522	SUSB	O	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality due to water releases	mine activities, drainage of Unnamed and Leggett Creeks	R	N	L	L	S		R	N
523	SUSB	C	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
524	SUSB	O	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
525	SUSB	R	FIP	aquatic habitat	physical alterations to habitat, changes in hydrology, changes in water quality	mine activities	L	N	N					N
526	PCMC	C	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
527	PCMC	O	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
528	PCMC	R	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat through changes in surface water hydrology, sediment levels, and stream channels	surface disturbances (plant site, 49 wellpads, groundwater/wastewater wellpads)	L	N	N	L	M	L	R	N
529	PCMC	C	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat due to disturbance and changes in erosion/sediment loading	watercourse crossings	L	N	N	L	M	L	R	N
530	PCMC	O	FIP	changes in fish habitat (spawning, nursery, rearing, food supply, overwintering, migration areas)	alteration/loss of fish habitat due to disturbance and changes in erosion/sediment loading	watercourse crossings	L	N	N	L	M	L	R	N
531	ONLL	O	FIP	changes in fish habitat	changes in stream flow during open-water season and normal winter flows	groundwater withdrawal	L	N	N	L	M	R	H	N
532	ONLL	O	FIP	changes in fish habitat	changes in stream flow during periods of no winter outflow from Gregoire Lake	groundwater withdrawal	L	N	M	L	M	R	M	L
533	ONLL	O	FIP	changes in fish habitat	changes in stream flow	groundwater withdrawal	R	N	N	R	M	R	H	N
534	ONLL	C	FIP	changes in forage fish habitat	physical alteration to stream channel, increased sediment deposition	construction of road and pipeline stream crossings	L	N	N	L	S	R	L	N
535	ONLL	C	FIP	changes in fish habitat	physical alteration to stream channel, increased sediment deposition	construction of pipeline crossing (isolation technique requiring instream activity)	L	N	L	L	S	R	L	N
536	ONLL	C	FIP	acute or chronic changes in forage fish health	increased sediment loading, introduction of hydrocarbons	construction of watercourse crossing	L	N	N	L	S	L		N
537	ONLL	C	FIP	acute or chronic changes in fish health	increased sediment loading, introduction of hydrocarbons	construction of pipeline crossing (isolation technique requiring instream activity)	L	N	L	L	S	L	R	N
538	ONLL	O	FIP	acute or chronic changes in fish health	deposition of acids and acid-forming substances in acid-sensitive lakes	acidifying emissions	R	N	N	L	M	H	R	N
539	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	changes in drainage patterns	surface disturbances	L	N	L	L	L			N
540	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	drawdown of water level	groundwater withdrawal	R	N	L	R	L			N
541	CPSU	O	FIP	changes in quality and abundance of sport and non-sport fish resources	changes in water quality (suspended sediment and other contaminants)	surface disturbances	L	N	L	L	L			N
542	SYAN	O	FIP	changes in aquatic ecosystem health	changes in water quality	release of reclamation waters - CT water flux	L							NO
543	SYAN	R	FIP	changes in aquatic ecosystem health	changes in water quality	release of reclamation waters	L							NO
544	SYML	O	FIP	effect of acidity on fish and aquatic biota	deposition of acids and acid-forming substances	acidifying emissions	R	N	N	R	L	C		N
545	SUML	C	FIP	changes in habitat of walleye, lake whitefish, longnose sucker, goldeye, Arctic grayling	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	R		N					N
546	SUML	O	FIP	changes in habitat of walleye, lake whitefish, longnose sucker, goldeye, Arctic grayling	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	R		N					N
547	SUML	R	FIP	changes in habitat of walleye, lake whitefish, longnose sucker, goldeye, Arctic grayling	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	R		N					N
548	SUML	C	FIP	changes in habitat of mountain whitefish, northern pike, Arctic grayling, forage fish guild	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	L		N					N
549	SUML	O	FIP	changes in habitat of mountain whitefish, northern pike, Arctic grayling, forage fish guild	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	L		N					N
550	SUML	R	FIP	changes in habitat of mountain whitefish, northern pike, Arctic grayling, forage fish guild	potential impacts on habitat (area, water quality, hydrological characteristics) mitigated - no net loss	mining and processing activities, mitigation measures	L		N					N

Appendix A3 Compilation of residual impact assessments extracted from Athabasca oil sands EIAs (Page 25 of 25).

No.	Lease	Phase	RAMP Component	Assessment Endpoint	Issue	Activities	Scale	Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Overall
551	SUML	C	FIP	acute or chronic toxicity to fish	potential toxicity to fish from changes in sediment loading, thermal regime, or water quality	none (no valid linkages)	R		N					N
552	SUML	O	FIP	acute or chronic toxicity to fish	invalid linkages to toxicity from changes in sediment loading, thermal regime, or water quality	none (no valid linkages)	R		N					N
553	SUML	R	FIP	acute or chronic toxicity to fish	invalid linkages to toxicity from changes in sediment loading, thermal regime, or water quality	none (no valid linkages)	R		N					N
554	SUML	C	FIP	fish abundance	invalid linkages to abundance from changes in fishing access, acute/chronic effects, fish habitat	none (no valid linkages)	R		N					N
555	SUML	O	FIP	fish abundance	invalid linkages to abundance from changes in fishing access, acute/chronic effects, fish habitat	none (no valid linkages)	R		N					N
556	SUML	R	FIP	fish abundance	invalid linkages to abundance from changes in fishing access, acute/chronic effects, fish habitat	none (no valid linkages)	R		N					N
557	SUML	C	FIP	fish tissue quality (chemical concentrations, tainting)	discharge of mine-related waters and bioaccumulation of chemical species in fish tissue	mining and processing activities	R		N					N
558	SUML	O	FIP	fish tissue quality (chemical concentrations, tainting)	discharge of mine-related waters and bioaccumulation of chemical species in fish tissue	mining and processing activities	R		N					N
559	SUML	R	FIP	fish tissue quality (chemical concentrations, tainting)	discharge of mine-related waters and bioaccumulation of chemical species in fish tissue	mining and processing activities	R		N					N
560	SUML	R	FIP	aquatic ecosystem in reclamation streams, wetlands, EPL	reclamation of mine-disturbed areas, and drainage of reclaimed areas into EPL	reclaimed landscape, creation of EPL	L							NO
1	SYML	O	ASL	effect on aquatic resources of particulate (metal/PAH-containing) deposition in regional lakes	deposition of particulates containing metals and PAHs	emissions of particulates	R	N	N	R	L	C		N
2	SYML	O	ASL	effect on aquatic resources of particulate (metal/PAH-containing) deposition in regional streams	deposition of particulates containing metals and PAHs onto snowpack, pulse of metals/PAHs during spring snowmelt	emissions of particulates	R	N	N-L	R	M	I		N
3	ASJP	O	ASL	changes in acidity of RSA lakes	changes in acid deposition	air emissions for Jackpine mine - phase 1	R							NO
4	PCMR	O	ASL	changes in acidity of regional lakes (L10, L11, L12, A21, SUL, L8, A24, A26, 31, 25, 27, 30, 28, A29)	deposition of acids and acid-forming substances	acidifying emissions	R	N	potentially impacted	R	L	H	R	NO
5	PCMR	O	ASL	changes in acidity of 146 regional lakes	deposition of acids and acid-forming substances	acidifying emissions	R	N	N	R	M	H	R	N
6	PCMR	O	ASL	changes in wetlands exposed to acid input	deposition of acids and acid-forming substances	acidifying emissions	R	N	N	R	M	M	R	N
7	ONLL	O	ASL	changes in acidity of regional waterbodies	deposition of acids and acid-forming substances in acid-sensitive lakes	acidifying emissions	R	N	M	L	M	H	R	M
8	ONLL	O	ASL	changes in acidity of regional waterbodies	deposition of acids and acid-forming substances in acid-sensitive lakes	acidifying emissions	R	N	L	L	M	H	R	L
9	ONLL	O	ASL	changes in acidity of regional waterbodies	deposition of acids and acid-forming substances in acid-sensitive lakes	acidifying emissions	R	N	N	R	M	H	R	N
10	ASMR	O	ASL	changes in acidity	deposition of acids or acid-forming substances	acidifying emissions	R	N	N					N
11	SYAN	O	ASL	changes in acidity	deposition of acid-forming substances	acidifying emissions	R			1				NO
12	SYML	O	ASL	acidity of regional lakes	deposition of acids and acid-forming substances	acidifying emissions	R	N	N	R	L	C		N
13	CNHZ	O	ASL	changes in acidity of RSA lakes	changes in acid deposition	air emissions from project activities	R	N	N					N
14	CNHZ	O	ASL	changes in acidity of RSA lakes	changes in acid deposition	air emissions from project activities in planned development scenario	C	N	N	R	M	H	R	N
15	CNHZ	O	ASL	changes in acidity of RSA streams	changes in acid deposition	air emissions from project activities	R	N	N					N
16	SUFB	O	ASL	acid buffering capacity of acid-sensitive lakes	reduction in acid buffering capacity of acid-sensitive lakes from increased levels of NOx, SOx deposition	acidifying emissions from all Firebag Project operations	R	N	N	R	L	H	R	N
17	SUFB	C	ASL	acid buffering capacity of acid-sensitive lakes	reduction in acid buffering capacity of acid-sensitive lakes from increased levels of NOx, SOx deposition	acidifying emissions from all Firebag Project operations	C	N	N	R	L	H	R	N
18	SUFB	O	ASL	acid buffering capacity of acid-sensitive lakes	reduction in acid buffering capacity of acid-sensitive lakes from increased levels of NOx, SOx deposition	acidifying emissions from all Firebag Project operations	C	N	N	R	L	H	R	N
19	TNFH	O	ASL	changes in acidity of regional lakes	input of acidifying substances	acidifying emissions	R	N	H	R				M
20	TNFH	O	ASL	changes in acidity of regional lakes	input of acidifying substances	acidifying emissions	R	N	M	R				M
21	TNFH	O	ASL	changes in acidity of regional lakes	input of acidifying substances	acidifying emissions	R	N	L	R				L
22	SUVR	O	ASL	acidity of lakes	acid deposition and effect on water quality and aquatic life	acidifying emissions	R	N	N	R	L	H	R	N
23	SUML	O	ASL	acidity of regional waterbodies	deposition of acid-forming substances	acidifying emissions	R		L	R	L	H	R	L
24	SUML	O	ASL	spring acidity of regional streams/rivers	deposition of acid-forming substances in snowpack and acid pulse during snowmelt	acidifying emissions	R		L	R	L	M	R	L

Appendix A4

RAMP Standard Operating Procedures

Regional Aquatics Monitoring Program
2009 Standard Operating Procedures

VERSION 2

RAMP1467

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The following manual documents standard operating procedures (SOPs) specific to the Regional Aquatics Monitoring Program (RAMP) conducted in the oil sands region of northern Alberta. RAMP is a long-term program and the development and use of SOPs facilitates consistency in the quality, integrity and reliability of data collected from year to year, and is an important requirement in RAMP's overall quality control and assurance (QA/QC) procedures. This issue is particularly important for RAMP given the high number of scientific investigators participating in the program over time.

The procedures outlined in this manual focus on routine field sampling surveys associated with the major disciplines of RAMP including hydrology, water quality, sediment quality, benthic invertebrate communities, fish populations, and fish tissue analyses. The intent of the SOPs is to instruct field crews on how to prepare for and implement RAMP field surveys using scientifically defensible and consistent methods that maximize data quality. Additional information on field safety, QA/QC, and supplementary lab protocols is also presented. Procedures follow those used by provincial agencies (i.e., Alberta Environment, British Columbia Ministry of Environment), federal agencies (i.e., Environment Canada), and standardized methods/technical procedures outlined in past RAMP reports (Golder 1998, 1999, 2000, 2001, 2002, 2003a,b; RAMP 2004 to RAMP 2009).

The SOP manual is organized as follows:

- Section 2 – General Information;
- Section 3 – Hydrology Surveys;
- Section 4 – Water Quality Surveys (including sampling methods related to the Acid Sensitive Lakes component);
- Section 5 – Sediment Quality Surveys;
- Section 6 – Benthic Invertebrate Surveys;
- Section 7 – Fish Inventory, Sentinel Species, and Tissue Surveys;
- Section 8 – References; and
- Supporting Appendices.

2.0 GENERAL INFORMATION

2.1 FIELD CREWS

To ensure the collection of quality environmental data, it is important that all environmental consulting staff participating in RAMP field studies are professional biologists or technicians with experience in design and implementation of environmental monitoring programs. Professional crewmembers will have received training through traditional education (i.e., university or college), work experience, and professional development workshops or seminars. Crews typically include individuals with varying levels of expertise, including a field crew leader with a Bachelor's, Master's or Doctorate degree and environmental field technicians, each with a Bachelor's degree or a technical college diploma. Members from local First Nations and/or regional communities also participate in various field surveys, where their specific skills and traditional knowledge advance the progress of the field program (e.g., fish population studies). Where appropriate and/or necessary, all field crews are led by a registered professional biologist (P. Biol. in Alberta, R.P. Bio. in British Columbia).

2.2 FIELD WORKPLANS

Field crew responsibilities must be clearly established prior to beginning fieldwork through the use of Field Work Instructions (FWIs). FWIs, which are prepared by the component-specific manager or field crew leader, contain detailed information regarding sampling locations, inventory of the samples to be collected, and inventory of equipment and methods to be used. FWIs are prepared and discussed prior to beginning field sampling to ensure that the field crew is familiar with the work plan, and to address any foreseeable issues.

2.3 HEALTH AND SAFETY

All field programs must be conducted in accordance with recognized health and safety procedures. It is assumed that the environmental consulting company hired to implement the RAMP has developed a comprehensive health and safety plan to support their monitoring activities and, if possible, has received a Health and Safety Certificate of Recognition (COR). Accordingly, all consulting staff should possess training in Standard First Aid (Level 1), CPR and Workplace Hazardous Materials Information System (WHMIS) to ensure the safety of crewmembers and compliance with Workers' Compensation Board regulations. As well, all field crews that need to be on a oil sands mine site will be required to be in compliance with the industry's drug and alcohol testing program and undertake mine-specific safety training prior to entering a mine site.

Many field personnel may also require additional safety training in areas such as Transportation of Dangerous Goods (TDG), small boat safety (as required by the Coast Guard), all-terrain vehicle safety, snowmobile safety, bear awareness, and wilderness first aid.

To ensure the safety of field staff, a field safety plan is a mandatory component of the FWIs. Two forms must be filled out: a health and safety checklist and a field tailgate safety meeting form. The health and safety checklist must be filled out by the project manager/crew leader and reviewed and signed by all field crewmembers prior to starting the field program. This checklist provides an inventory of potential hazards, necessary safety equipment and safety training, including client-specific requirements, as well as important contact numbers. Prior to initiating fieldwork, potential safety issues, local emergency contacts, and necessary safety equipment are identified. The project manager/crew leader fills out the field tailgate safety meeting form each day of the field program, prior to initiating fieldwork. This form identifies hazards at the work site, protective equipment required, local emergency contacts, and evacuation route(s) to the hospital.

2.4 FIELD EQUIPMENT

Sampling gear and equipment required for field surveys should be regularly inspected and maintained according to manufacturers' instructions to ensure equipment is operating properly and safely. Equipment and materials that may be used during field surveys are listed below.

- **Fish Survey Equipment:** depth sounders, hipchains, range finders, gill nets, seine nets, pole seines, fyke nets, minnow traps, angling gear, backpack and boat electrofishers and related equipment, handsaws, gas powered ice augers, water aerator and holding containers, DNA sample kits, dissecting equipment, non-lethal tissue sampling equipment, acetone, hexane, formalin, ethanol, fish measuring boards, and balances;

- **Invertebrate Survey Equipment:** Ponar and/or Ekman grab, Hess or Neil-Hess samplers, sediment sieves, sample containers and preservative;

- **Periphyton and Plankton Survey Equipment:** periphyton samplers, rectangular and circular plankton tows, periphyton float samplers, phytoplankton filters, artificial substrates, sample containers;

- **Sediment Quality Survey Equipment:** Ponar and/or Ekman grabs, depth integrated sediment corer, sample containers, stainless steel equipment, acetone and hexane;

- **Water Quality Survey Equipment:** water samplers (e.g., Van Dorn sampler, Kemmerer sampler), sample bottles and preservatives, *in situ* monitoring equipment with associated manuals and calibration equipment for measuring temperature, dissolved oxygen, conductivity, pH, turbidity, current velocity, depth and Secchi depth;

- **General Electronic Equipment:** Global Positioning System (GPS) equipment, camera, laptop computer with Microsoft and datalogger specific software packages (DataDolphin and Lakewood Systems compatible);

- **Transportation Vehicles:** field truck, jet boat with electrfishing capability, other watercraft for smaller waterbodies;

- **Safety Gear and Equipment:** survival suits, life jackets, steel-toed footwear, chest waders, paddles, bailer, throw bag, painters, motorcycle helmets, hardhats, reflector vests, safety goggles, first aid kit, fire extinguisher, buggy whip; amber flashing vehicle light; bear spray, spinal board, blankets, etc.;

- **Reference Materials:** field data book, topographic maps, hydrographic charts, aerial photos of study sites, publications, and previous reports; and

- **Miscellaneous Field Equipment:** tarps, coolers, buckets, jerry cans, hoses, bottles, packing materials, assorted chemicals, waterproof pens and paper, generator, and power inverter.

More detailed information regarding field equipment for specific surveys is provided in the component-specific sections that follow.

2.5 SAMPLE COLLECTION AND ANALYSIS

Samples are to be collected in accordance with the sampling design established by the RAMP Technical Program Committee using scientifically defensible methods outlined in the SOP manual and FWIs. Approaches used for data collection incorporate a variety of QA/QC procedures to ensure data are of a high quality. These procedures are described in greater detail in the sections that follow on specific surveys. General information on data collection and sample handling is provided below.

2.5.1 Data Collection

Customized datasheets are created to increase efficiency in the field and reduce the likelihood of potential errors or omissions. The following general information should be recorded on datasheets during sample collection:

- Date and time of sampling;

- Station locations (UTM or latitude/longitude coordinates, including datum);

- Initials of field crew members;

- Sampling methods/gear used;

- Number of samples collected (water/sediment/benthos), number of specimens retained/released/dissected/archived (biota), or the number of measurements taken (climate and hydrology);
- Sample IDs/numbers;
- Volumes of samples collected (water/sediment);
- Number of samples included in composite samples;
- *In situ* measurements, where applicable;
- Qualitative site observations (e.g., weather, water turbidity) that may affect sample results;
- Handling techniques, preservation methods, sampling containers used; and
- Notes regarding photographs taken at sampling stations.

All of the above information is carefully recorded on field datasheets and/or field books and secured at the end of each day.

2.5.2 Sample Handling

Samples are collected, preserved, and stored in accordance with current standard technical guidance and QA/QC practices.

Prior to shipment to analytical laboratories, detailed lists of samples are made on chain of custody (COC) forms. These forms are used to notify the laboratory of the number and type of samples that are being shipped and type of analyses requested. In addition, these forms allow the samples to be tracked by the RAMP implementing consultant from the point of shipment to the laboratory. Information recorded on a COC form includes the date, project, sender's name, sample type (e.g., fish, sediment), sample ID number, sampling time and location, analyses requested, and preservatives added or required.

All samples must be carefully packaged with insulating materials and shipped to analytical laboratories for storage and subsequent analyses. Biota, sediment, and water samples are usually shipped either cool (on ice) or frozen (dry ice) in plastic insulated coolers via courier. Preserved biota (e.g., benthic invertebrates) are shipped in bins or coolers to the consulting taxonomist. The receiving laboratory checks the COC to ensure all samples are accounted for and in good condition, and confirms the samples received, date, and analyses to be performed. All regulations regarding the transportation of dangerous goods must be followed.

2.5.3 Laboratory Qualifications

Laboratories used to analyze water, sediment, and/or fish tissue samples must be accredited by the Canadian Association for Environmental Analytical Laboratories (CAEL). To obtain this accreditation, a laboratory must participate in an annual independently implemented performance evaluation assessment of its procedures, methods, and internal quality control.

Other analyses, such as benthic invertebrate sorting and taxonomy, and fish aging, are conducted by small independent laboratories or specialized consulting companies; these specialists follow standard QA/QC procedures for their respective disciplines.

2.6 DATA QUALITY, ANALYSIS AND MANAGEMENT

Results from field sampling, including information recorded on field datasheets and laboratory results, should be reviewed for potential errors or omissions and to identify any anomalies. Results are then entered into spreadsheets (if not already in that form) and checked for transcription errors. Original raw data files must be retained; duplicate files are used for data analysis and manipulation.

Data are then analyzed and used to produce tables and figures for reports. A log of statistical analyses performed and a hard copy of outputs should be retained by the consultant so that analyses may be reviewed and reproduced if needed.

All project-related documents, including datasheets, field notes, photographs, maps, and other supporting documentation, should be filed at the consultants office during their RAMP contract. Key data should be stored in a fireproof filing cabinet. All hard-copy field datasheets, laboratory reports, and final reports should be retained for up to six years after the sampling date.

3.0 HYDROLOGY SURVEYS

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. RAMP hydrology surveys are conducted to detect spatial and temporal changes in water flows and levels.

3.1 PREPARATION FOR FIELD PROGRAMS

General tasks to be completed in preparation for conducting a hydrology field survey are consistent with those previously outlined in Section 3.1 for Water Quality, with the exception of needing specific hydrologic equipment for measuring flow and water levels (see also Section 3.6).

3.2 DATA COLLECTION

Field notes and measurements should be recorded on the *RAMP Hydrology Data Sheet* (Figure 3.1) and/or in a waterproof field book. More information on data that should be recorded is provided in Section 2.5.1. Any modifications to permanent site equipment or measurement equipment should also be noted.

3.3 STREAMFLOW MEASUREMENTS

Streamflow measurement procedures follow those used previously by the RAMP program and guidance prepared by the Water Survey of Canada (2001), the United States Geological Survey (1982) and the BC Ministry of Environment, Lands and Parks (1998).

3.3.1 Safety

Prior to measuring streamflow, river conditions should be assessed to ensure that measurements can be taken safely. Generally, wading measurements can be taken safely if the depth (in meters) multiplied by velocity (m/s) does not exceed a value of 1.0. However, ice and benthic algae can make wading difficult at values < 1.0. At the discretion of the technician, measurements may be taken in more severe conditions provided appropriate safety equipment (e.g., a personal flotation device (PFD) or a safety line) is used. When measurements are taken from a bridge, boat, float tube, or belly-boat, the technician should use a PFD, guideline or safety line, or other necessary safety equipment to ensure measurements can be taken safely and comfortably.

3.3.2 Hydraulics

Whenever possible, measurements should be collected a specific measurement location or site. If no location is specified, or high discharges prevent metering at the specific site, choose a section of river where where there are no sharp irregularities in the bed, the bed is firm and well established, flow is well distributed across the width, turbulence and wave action are minimal, and the bed slope and water surface slopes are similar. In addition, the following factors should also be considered because they may adversely influence the accuracy and precision of streamflow measurements taken at a given river section:

- Weed growth in the metering section;
- Floating or lodged debris in proximity of the section;
- Beaver activity;
- Deposition of gravel or development of sand bars or obstructions;
- Erosion of the channel banks;
- Overflow channels that are bypassing the metering section;
- Exposure to high winds;
- River plan form alignment, bend radius, superelevation, or cross waves; and
- Ice conditions.

Methods and locations used to measure flows should be consistent over time.

3.3.3 Number of Verticals

Depth and velocity should be measured at a minimum of 20 verticals (i.e., stations along a transect that crosses the stream or river) distributed perpendicular to the direction of the flow; no single panel should capture more than 10% of the total river discharge. Typically, verticals will need to be more closely spaced near the thalweg. Where the stream width <2 m, fewer than 20 verticals are acceptable; measurements at intervals <0.1 m are impractical.

3.3.4 Depth Measurements

Flow depth (to the nearest centimeter) should be measured at each vertical station using a graduated wading rod or sounding reel. Where the flow is turbulent, the mean water level should be recorded. The measurement should account for any run-up on the measurement rod due to high flow velocity. When measurements are taken on a soft channel bed, care should be taken to ensure that the bottom of the wading rod does not sink into the bed material, resulting in an inaccurate measurement. When measurements are taken on coarse cobble beds, the observed depths should be adjusted to ensure they are representative of the tops of the boulders and the depths between them. Ice thickness should be measured by using a slush spoon or other rigid horizontal appendage that is firmly fixed on the ice wading rod.

Figure 3.1 RAMP hydrology data sheet.

Hatfield Consultants Hydrometric Site Visit Field Record

Project:	Project #
Site:	Date:
Personnel:	
Weather:	
Photos:	

Data Logger

Battery (Main):	Memory:	Logger#
Battery (Aux):	File Name:	PT#
Desiccant:	Transducer:	Air Temp:
Air Pressure:	RH:	Water Temp:
Count:	Datalogger Clock:	Laptop Clock:

Level Survey				Measurement
	Setup 1	Setup 2	Description	Start:
BM 1				End:
BM 2				Equipment ADV FlowMate Swoffer Dilution
Ice				Method Ice Wading Fishcat Boat
Water Level				River Condition:
Other				Quality/Error:

Mmt.	Offset (m)	Depth (m)	Ice (m)	V @ 0.6 D (m/s)	V @ 0.8 D (m/s)	V @ 0.2 D (m/s)		
1							LB Offset (m)	
2							RB Offset (m)	
3								
4							Velocity Profile	
5							Offset	
6							Total Depth	
7							Ice	
8								
9							Depth (m)	V (m/s)
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28							Entered by:	
29							Date:	
30							Checked by:	
31							Date:	

Notes:

Hydrometric Measurement Quality Assessment

Factor	Condition			
Channel alignment		Tight bend	Moderate bend	Straight or minor bends
Channel prism		Significant expansion or contraction or bars	Moderate expansion or contraction or bars	Prismatic (no or minor expansion or contraction)
Vegetation, debris, or damming	Vegetation, debris, or damming significantly affects the flow pattern	Vegetation, debris, or damming moderately affects the flow pattern	Vegetation, debris, or damming has a minor effect on the flow pattern	No or minimal instream vegetation, debris, or damming
Boulders	Boulders up to half of the flow depth	Boulders up to one quarter of the flow depth	Smaller boulders or cobbles	Plane bed
Wind (parallel to the channel		Strong Wind	Moderate Wind	Calm or breeze
Waves	Significant waves	Moderate Waves	Minor Waves	Ripples
Flow Velocities	Near lower detection limit of the meter	Reading precision generally within 10%	Reading precision generally within 5%	Three significant digits for most of the cross section
Ice	Severely broken and irregular	Partial or full ice cover; no velocity profile	Partial or full ice cover and a velocity profile taken	No Ice
Maximum panel discharge (% of total)	> 20%	15% - 20%	10% - 15%	< 10%
Resulting Quality	Poor	Fair	Good	Excellent

Select and circle one condition for each factor. The worst condition governs the overall quality assessment

Additional Notes:

3.3.5 Velocity Measurements

When wading, stand to the side and downstream from the meter so as not to influence the flow velocity measured by the meter.

Velocity Averaging

When an electromagnetic velocity sensor is used, linear averaging should be performed for at least 20 seconds. When the "RC" mode is used, the sensor should be allowed to stabilize for at least 5 time constants. When a mechanical "Price" meter is used, linear averaging should be performed for at least 45 seconds.

Depth of Mean or Index Velocity at Verticals

Velocity determinations are intended to provide the depth-averaged flow velocity. For depths of 1.1 m or less, velocity should be measured below the surface at 60% of the total depth. For depths greater than 1.1 m, velocity should be measured below the surface at 20% and 80% of the total depth. If an unusual vertical distribution of velocity is suspected, the velocity should be measured near the thalweg at 20%, 40%, 60%, and 80% of the depth to estimate the depth of mean velocity.

When measuring velocities through ice, measure the velocity at 60% of the depth for effective depths <1 m and apply a correction factor of 0.90. Alternatively (and more accurately), measure a vertical velocity profile to determine an appropriate correction factor. For depths >1 m, velocity should be measured at 20% and 80% of the effective depth (a correction is not necessary).

3.3.6 Water Level Measurement

When measuring water levels, the level and tripod should be secure, the level should be adjustable, and the base of the rod should be free of ice, mud, or other debris. To measure the water level, the rod should be held parallel to the direction of flow and pointing upstream. The rod should be slowly rotated so that the rod graduations directly face the level operator. A minimum of two local elevation reference benchmarks should be surveyed before the water level and river thalweg elevation are surveyed. When surveying the water level, the rod should be placed on the shore at the water's edge. Alternatively, the rod can be placed on a firm point located slightly below the water level, and the depth of water on the rod can be subtracted from the instrument reading. If the rod can be placed at the elevation of an installed depth sensor, its elevations also should be surveyed. Two separate determinations of each sighting should be taken and recorded.

3.3.7 Measurement Quality Assessment

The hydraulic conditions when measurements are taken should be categorized using the following criteria:

- **Excellent** – The reach is straight, with a prismatic section; no weeds, boulders, ice cover, slush, trash, or brush affecting flow; negligible wind; all equipment is operating properly; and no more than 10% of the discharge occurs in any single panel.
- **Good** – There is a slight irregularity in hydraulic conditions caused by the presence of a curved reach at, or upstream of, the measurement section; a non-prismatic channel; weeds, trash, brush, or boulders; an irregular bed; or upstream or downstream wind. No more than 15% of the discharge occurs in any single panel. These factors may result in a minimal reduction in the accuracy of the measurements.
- **Fair** - Minor reduction of measurement precision due to irregular hydraulic conditions caused by one or more of the factors listed above, or by ice cover. No more than 15% of the discharge occurs in any single panel.
- **Poor** - Significant reduction of measurement precision due to one or more of the factors listed above, or by velocities near the lower detection limit of the current meter.

3.3.8 Discharge Computation

The computation of discharge is performed as follows:

- Divide the stream cross-section into panels centered on each velocity measurement.
- Compute the discharge in each panel by multiplying the panel area by the effective panel-average velocity (the effective panel-average velocity is a product of the measured panel velocity and a velocity correction factor). For open water conditions, the velocity correction factor used is 1.0. For winter measurements, a velocity correction factor is computed by measuring the velocity profile at the thalweg and using this information to compute the average velocity. The average velocity is then compared to the velocity at 0.6 depth and a correction factor is obtained.
- Compute the panel-effective depth by subtracting the ice thickness (if applicable) from the measured panel depth.
- At the edge panels, the effective panel depth and effective panel average velocity are taken as ¼ of the values measured in the adjacent panel.

- The panel area is calculated by multiplying the effective panel depth by the length of the panel. The length of the panel is the distance between midpoints of adjacent verticals. The panel boundary nearest the banks is located halfway between the last measured vertical and the bank.

3.4 HYDROMETRIC STATION PERMITTING

Approvals, permits, or licenses are required by the agencies listed below to permit the permanent installation of a hydrometric station. Typically, the consultant prepares an application for a particular hydrometric station on behalf of the specific oil sands operator, and the oil sands operator becomes the holder of the license or permit.

- **Alberta Sustainable Resource Development** approves the disturbance of public land associated with the construction of a station. Their approval has historically been issued as a License of Occupation (LOC), but the use of Protection Notifications (PNs) is currently being considered. The submission requirements for an LOC are an application form, an Environmental Field Report form, an Environmental Field Report Supplement, and figures showing plans and a typical section of the site.

- **Alberta Environment** approves instream construction under the *Water Act*. Submission requirements are an Application under the *Water Act* for Approvals and/or Licenses and figures showing plans and a typical section of the site.

- **Department of Fisheries and Oceans** regulates activities that could potentially cause harmful alteration, disruption, or destruction of fish habitat in fish-bearing waters. No specific application form is used, but figures showing plans and a typical section of the site are required. An assessment of the fish habitat and potential fish passage concerns may also be necessary.

- **Navigable Waters Protection Program of Transport Canada** ensures the protection of the public right to navigation and the protection of the environment through the administration of the *Navigable Waters Protection Act*. They approve the construction of any work that could interfere with navigation within navigable waterways. Transport Canada determines whether a particular waterway is navigable or not. For installation of a typical RAMP hydrometric station, no official notice or correspondence is required or requested. However, if the proposed activity involves more significant instream construction (such as a weir), then their approval must be obtained. Application requirements include an application form with plans and details of the proposed work.

3.5 SNOWCOURSE SURVEYS

Snowcourse surveys provide an indication of the variation in snow accumulation on various terrain types in a study area. The information can be used to estimate the total snow water available for melt in a given catchment, to provide an estimate of spring runoff potential or for use in hydrologic modeling.

The following procedures should undertaken when conducting a snowcourse survey:

- Select plot size, shape, and orientation on a site-specific basis, typically incorporating a 10 m spaced regular grid pattern, with 50 m x 60 m dimensions. The plot size should be expanded to include up to 50 sampling points if snow conditions are unusually variable.

- Measure depth at a minimum of 30 locations within the plot. Depth is measured by inserting an Adirondack snow sampler into the snowpack and reading the depth from the outer graduations (depths should be measured to the nearest centimeter). Near tree wells, or in uneven terrain, select representative sampling locations reflecting the distribution of high or low catch micro-environments (assessed during a preliminary site assessment).

- Measure density by slowly twisting and pressing an Adirondack snow sampler through the snow column and into the ground, lodging a plug of substrate beneath the snow. Remove the debris plug and weigh the collected snow. Where lake or pond ice forms the substrate, ensure that snow confined within the sampler does not escape before weighing the plug. To ensure that no snow is lost, a trowel can be slid beneath the tube.

- Compute the sample water-equivalent based on the weight of the sample, and then use the measured snow depth to compute the snow density.

- Take a minimum of four density samples from representative locations within each plot. Note the vegetation cover type, snow color, snow texture and consistency, wind, and meteorological conditions. Photograph each plot and mark it with flagging tape; record its geographic coordinates.

3.6 GENERAL EQUIPMENT AND SUPPLIES FOR HYDROLOGY SURVEYS

The following is a list of sampling equipment and supplies generally recommended for collecting hydrologic data:

Sampling and Documentation

- Velocity meter and wading rod (including repair equipment, batteries);
- Tape measure or tag line, re-bar and hammer to position tag line;
- Level and tripod;
- Ice auger, blades and ice chisel in winter;
- Hydraulic weight and cable for deep water measurements;
- Snow sampler for snowcourse survey;
- Field logbooks/binders;
- Maps, air photos, GPS unit, compass;
- Written protocols and procedures for sample collection and equipment operation, including FWIs;
- Miscellaneous field equipment (e.g., shovel, water quality meters, spare parts etc.,);
- Laptop computer for downloading data from permanent hydrometric stations, climate stations;
- Camera or video equipment as required; and
- Transportation (truck, ATVs, boat, snowmobile, helicopter, belly boat).

Health and Safety

- Personal gear for all possible field and weather conditions (e.g., survival suits, rainjackets/rainpants, appropriate footwear, waders, gloves, hat, change of clothes);
- First aid kit and survival kit;
- Personal floatation device for each crew member for deep water or boat work;
- Boat safety equipment including paddles, painters, bailer, throw-bag and whistle;
- Communication device (satellite phone when access is other than helicopter) and list of emergency phone numbers;
- Three wool blankets and emergency food and clothing;
- Buggy whip, hard hats, blue light, reflective vests if accessing oil sands mine site; and
- Spare jerry can of fuel, tow-rope, shovel and pick if access is by truck.

4.0 WATER QUALITY SURVEYS

Water quality surveys are conducted to characterize and detect changes in environmental quality over time and/or space. Water quality surveys are often conducted concurrent with biological sampling to determine if there is a relationship between environmental quality and the health of resident biota.

4.1 PREPARATION FOR FIELD PROGRAMS

The following tasks must be completed prior to conducting work in the field (see also Section 4.7):

1. **Prepare Field Work Instructions (FWIs)** – The water quality manager or crew leader should generate FWIs and review them with crew members. The FWIs contain the following information:

    - Project scope and objectives;
    - Project personnel and responsibilities;
    - Sampling locations (including information on access, site descriptions, and coordinates);
    - Number and type of samples to be collected;
    - Required field measurements;
    - Detailed sample collection procedures;
    - Relevant health and safety information;
    - Required laboratory analyses;
    - Sample shipping/receiving instructions; and
    - Contact information for project manager/office staff, clients, and emergency services.

2. **Contact Analytical Laboratories** – Analytical laboratories are contacted to identify the necessary number and type of sampling containers, preservatives, handling requirements, and holding times for analyses requested, and to order supplies. Laboratories should also be notified as to when the samples will be arriving and to arrange for sample receiving and analysis.

3. **Assemble Equipment** – The component manager or crew leader generates an equipment list of required sample collection containers/bottles (pre-labeled), sampling equipment and spare parts/repair kits, field logbooks, and safety and personal equipment necessary to complete the field program. An example of a typical

checklist for water quality sampling is presented in Section 4.7. All equipment for collecting or measuring samples is cleaned and checked to ensure proper functioning prior to going into the field. A crew member familiar with the scope of the field program is responsible for assembling equipment. If necessary, transportation of the equipment to the site is arranged. Arrangements are also made to ensure there are proper facilities for storing samples prior to shipment to the analytical laboratories.

4. **Prepare Field Binder** – Field binders containing FWIs, all necessary data sheets (printed on waterproof paper), field book (if required) safety forms, chain of custody forms, labels for sample bottles and data sheets are prepared and assembled prior to field sampling.

4.2 DATA COLLECTION

Field notes and measurements are recorded on the *RAMP Water Quality Data Sheet* (Figure 4.1) and/or in a waterproof field book. Section 2.5.1 lists other information that could be recorded on each station field sheet. Details pertaining to unusual events that might have occurred during the operation of the sampler (e.g., possible sample contamination, equipment failure, unusual appearance, control of vertical descent of the sampler, etc.) and any deviations from standard operating procedures or FWIs should also be recorded.

4.3 SAMPLE COLLECTION PROTOCOL

Information on sample collection summarized below follows methods outlined in the initial RAMP report (Golder 1998) and sampling guidance described by Environment Canada (2002, 2005) and the Government of BC (2003). Sample QA/QC considerations are described in Section 4.6. Information on appropriate sample containers and sample preservation requirements is contained in Table 4.1.

4.3.1 Safety

Sampling is only conducted when conditions do not compromise the safety of the field crew. When safety may be compromised due to site conditions, sampling is relocated or postponed.

Figure 4.1 RAMP water quality data sheet.

2009 Water Quality Field Data Sheet

Regional Aquatics Monitoring Program

Location Information

Date: September _____ 2008

Site Name: ______________________ **Time:** ______________________

Site UTM E: ______________ **Crew:** ______________________

(NAD83): N: ______________ **Weather:** Clear Cloudy Rain Snow Windy

Access: ______________________ **Crew initials:** __________

Samples Collected

RAMP standard: ☐ Routine ☐ Nutrients ☐ TOC ☐ DOC ☐ BOD ☐ Oil & Grease

☐ U-T Hg ☐ TSS/TDS ☐ N. acids ☐ Sulphides ☐ T+D metals

Others: ☐ *Chlorophyll a* ☐ *Toxicity*

Sample Technique

Grab Van Dorn Composite Other:

In Situ Parameters

Diss. Oxygen:	________ mg/L	Sp Cond.	________ µS	pH:	________
Diss. Oxygen:	________ %	Conductivity	________ µS	Temp. (°C):	________
Winkler DO	________ mg/L	Turbidity	________ NTU	Odour	________

Water Surface Condition: Clear Turbid Foaming **Sampled @** Left Centre Right

Photo Record

Comments: ______________________________________

____

Habitat Observations

Morphology: Riffle Run Cascade Pool

Substrate

Dominant:	Organic	Clay	Silt	Sand	Gravel	Cobble	Boulder
Sub-Dominant:	Organic	Clay	Silt	Sand	Gravel	Cobble	Boulder

Channel Width: ________ m **Average Depth:** ________ m

Observations

____

____

____

____

(Office use only) Data Enty __________ Scanned __________ QA/QC Check __________

4.3.2 Sample Types

Two types of water samples can be collected: grab and composite samples. Grab samples are collected by filling a container held beneath the surface of the water at a single location and time. Grab samples can be collected from specified depths using a deep-water sampler (e.g., Van Dorn or Kemmerer bottle), or are collected directly by submerging the sample bottle to a depth of 30cm, then uncapping and recapping at depth. Composite samples are used to assess average water quality conditions and are collected by mixing equal volumes of a number of grab samples collected from multiple locations (e.g., at specified distances across a river) or from the same location over time. Composite samples are poured into a triple-rinsed bucket and transferred to appropriate sample bottles using a clean glass vessel/funnel. During collection of composite samples, the composite container is kept covered.

The number of grabs collected from a river to prepare a composite sample is determined using the following wetted width designations:

- Wetted width > 50 m: Three grabs at each of five equally spaced sample locations along a river cross-section.
- Wetted width 20-50 m: Four grabs at each of three equally spaced sample locations along a river cross-section.
- Wetted width < 20 m: Ten grabs from a single centre-channel position.

Composite samples from lakes are collected using five randomly selected grabs collected at 30 cm depth. Spacing of the individual grabs is dependent on the lake area, but where possible, grab samples used to form the lake composite should include near-shore and mid-lake samples.

4.3.3 General Sampling Considerations

The following protocols should be followed to prevent sample contamination:

- Sampling is conducted sequentially from the least to the most contaminated sites (degree of contamination is estimated by site conditions, professional knowledge, etc.).
- Sampling equipment must be cleaned appropriately before and after use. This may involve rinsing with ambient water or cleaning/rinsing with soap and water, acid, organic solvents, or pure water.
- Powder-free latex gloves are worn during sample collection.
- Field measurements are conducted *in situ* or on subsamples, but are never conducted on samples submitted to the laboratory for analysis.

- If samples are collected from a boat, samples are collected upstream of the boat.

- If samples are collected on foot, the individual collecting the sample wades in downstream from the station and avoids disturbing the substrate.

- Samples are collected in the container appropriate for the specified analysis (Table 4.1).

- For analyses requiring pre-cleaned bottles and reagents/preservatives, sample containers are cleaned according to certified methods, and are certified by the laboratory as contamination-free.

- Sample containers are filled by submerging the bottle to a depth of 30 cm, uncapping and filling the bottle, and recapping at depth (to avoid surface contamination). Oil and grease samples are collected at the surface. Sample bottles are not triple-rinsed if they are certified clean by the analytical laboratory. Samples for ultra-trace mercury analysis are triple-rinsed using ultra-clean techniques, following guidance from the analytical laboratory.

- Sample containers should be capped at all times except for sample collection. Sample containers should be stored in a clean shipping container (cooler). Vehicle (boat, truck) cleanliness should be maintained at all times to avoid potential sources of contamination.

- Reagents and preservatives are certified as contaminant-free by the laboratory; sample containers containing reagents/preservatives are clearly labeled and include the reagent/preservative expiry date. Expired reagents/preservatives are never used to preserve samples.

4.3.4 Water Samples for Metal Analyses

Samples collected for metals analysis must not come into contact with any metal objects. Other specifications for collection of samples for metals analysis, including preservation of samples, are listed in Table 4.1. Field crews need to be aware of these restrictions to ensure samples are collected and preserved, stored and shipped correctly. This information should be included in the FWIs.

4.3.5 Water Samples for Organic Compounds

Collecting samples for the analysis of organic compounds must follow the following protocols:

- Sample bottles are NOT rinsed with ambient water prior to sample collection;

- Sample bottles should be completely filled to avoid volatilization of organic compounds into the overlying air space; and
- Proper bottles must be used when sampling for organic compounds to prevent the release or absorption of organic compounds to/from the sample container when filled with water.

4.3.6 Collection of Water Samples at Depth

A deep-water sampler, such as a Van Dorn or Kemmerer bottle, allows water samples to be collected from depths greater than 2 m. A general description of how to use these samplers is provided below and an illustration of the samplers is provided in Figure 4.2:

1. Ensure the sampler is clean.
2. Open the sampler by raising the end seals and set the trip mechanism.
3. Lower the sampler to the desired water depth and send the messenger down to "trip" the mechanism that closes the sampler seals. When sampling water immediately above the river or lakebed, care must be made not to disturb any sediment.
4. Bring the sampler to the surface.
5. Transfer the water sample from the sampler to a clean, pre-labeled container (grab) or clean intermediary vessel (composite) using the drain valve. Avoid contact with the drain spout when filling containers to prevent sample contamination.
6. Filter and/or preserve the samples immediately or as soon as possible after sample collection.

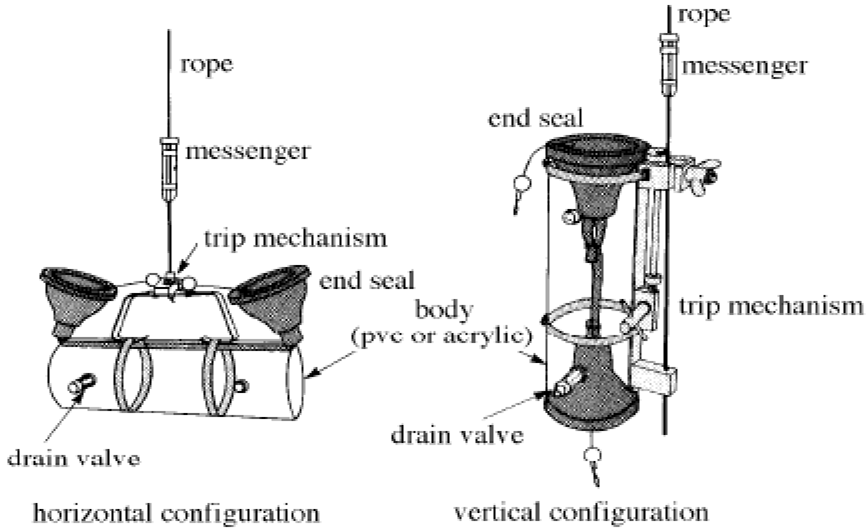
Table 4.1 Summary of sample collection, preservation, and storage requirements.

Parameters	Container Type	Preservative	Holding Time*	Min. Volume	Note
Conventional Chemistry					
pH, Conductivity, Bicarbonate, Carbonate, Hydroxide, Total Alkalinity (as $CaCO_3$)	0.5-1 L plastic	Chill 4°C	0.25 hours	50 mL	1
Dissolved Organic Carbon	100 mL amber glass	1 mL 1:1 Hydrochloric Acid	28 days	50 mL	2
Total Organic Carbon	100 mL amber glass	1 mL 1:1 Hydrochloric Acid	28 days	50 mL	
Total Dissolved Solids	0.5-1 L plastic	Chill 4°C	7 days	200 mL	1
Total Suspended Solids	0.5-1 L plastic	Chill 4°C	7 days	200 mL	1
True Colour	0.5-1 L plastic	Chill 4°C	48 hours	100 mL	1
Major Ions					
Calcium, Potassium, Magnesium, Sodium	250 mL plastic	3 mL 1:3 Nitric Acid	6 months	200 mL	2
Sulphate	0.5-1 L plastic	Chill 4°C	28 days	50 mL	1
Sulphide	125 mL plastic	2mL 2N Zn Acetate/1mL 6N NaOH	28 days	100 mL	
Chloride					
Nutrients					
Ammonia-N	250 mL plastic/glass	1 mL 1:1 Sulfuric Acid	28 days	100 mL	
Nitrate+Nitrite-N	0.5-1 L plastic	Chill 4°C	48 hours	50 mL	1
Total Kjeldahl Nitrogen	250 mL plastic/glass	1 mL 1:1 Sulfuric Acid	28 days	200 mL	
Total Dissolved Phosphorus	250 mL plastic	1 mL 1:1 Sulfuric Acid	28 days	100 mL	2, 7
Total Phosphorus	250 mL plastic	1 mL 1:1 Sulfuric Acid	28 days	100 mL	
Biological					
Biochemical Oxygen Demand (BOD)	0.5-1 L plastic	Chill 4°C	48 hours	500 mL	1
Other					
Naphthenic Acids	250 mL amber glass	Chill 4°C	14 Days	250 mL	
Recoverable Hydrocarbons	1 L amber glass	2 mL 1:1 HCl	28 days	1 Litre	
Phenols (4AAP)	100 mL amber glass	1 mL 1:1 Sulfuric Acid	28 days	50 mL	
Metals (Total and Dissolved)					
Aluminum to Zinc	500 mL plastic	1% nitric acid (lab preserved)	5-7 days (unpreserved)	500 mL	
Mercury	250 mL plastic	1% nitric acid (lab preserved)	5-7 days (unpreserved)	250 mL	

* All water samples should be kept cool (4°C).

1. All these parameters may be analyzed from a single unpreserved bottle.
2. Samples must be field filtered before preservation.
7. If field filtering is not possible, or poses unacceptable risks for sample contamination, then send the samples unfiltered and unpreserved to the laboratory within 48 hours of sampling.

Figure 4.2 Illustration of a Van Dorn water sampler (taken from Government of BC 2003).



4.3.7 Habitat-Specific Sampling Considerations

Sampling considerations specific to different types of aquatic habitats include:

Lakes and Ponds

- A personal flotation device should be worn at all times.
- To avoid sample contamination from suspended sediments, it is preferable to collect the sample from a boat or dock. If that is not possible, samples can be collected by wading out past the point where wave action affects the lake bottom (usually this distance is close to the shore).
- The collection of deep-water samples requires that at least one member of the sampling group be very familiar with boat operation and safety. If the sampling trip involves the use of a boat, then the weather forecast should be obtained prior to departure; if conditions are poor, the sampling trip should be postponed.
- After returning to shore, preserve and filter the sample (if required), and store the sample in a cooler. If conditions do not permit preservation or filtering, complete these tasks as soon as soon as possible following sample collection.
- Deep-water sampling sites can be marked with a buoy or referenced by easily identifiable features (preferably two) on shore. Reference points should be described (both in writing and with photographs) on datasheets or in a logbook. Once at the site, anchor the boat (or tie it to the buoy) if depth permits and wait until it settles with the bow facing

into the wind before collecting the sample. If the water is too deep to anchor, then one person will have to maintain the location (with either the motor or with paddles) while the other person collects the sample and takes the field measurements.

- The person at the bow should always collect the samples because the bow is the anchor point and the boat will drift so that the bow is pointing into the wind. In quiet waters, the samples should be collected prior to anchoring and while the boat is slowly moving forward to reduce the potential of contamination from the boat or motor. The person in the stern is responsible for holding the boat's position (when not anchored) and taking/recording field measurements and notes.

Rivers and Streams

- A personal flotation device should be worn when water or substrate conditions pose a potential risk to personal safety.

- Samples from rivers and streams should be collected from mid-stream whenever possible to avoid potential contamination from shoreline areas (e.g., back eddies, seepage).

- When flow and/or water depth are too high to permit safe sampling, samples can be collected from shore. A safety line should be used to secure the person collecting the sample if conditions pose any risk. Precautions should be taken if the benthic surface is covered with ice or algae.

- When collecting samples from rivers or streams, take necessary equipment (e.g., sample bottles, syringe) and wade into the river downstream from the point where samples will be collected, then wade upstream. This ensures that sediments upstream of where the sample is to be collected will not be disturbed. Stand perpendicular to the flow, facing upstream and rinse/collect sample as appropriate.

- Collecting river samples from a boat should ideally utilize three people: one to operate the boat and maintain the position during sampling, one to collect the sample from the bow, and one to collect field measurements and take field notes. Samples should be collected from the most downstream to upstream sites.

4.3.8 Winter Water Sampling

Safety

Collection of water quality samples in winter requires extra planning to ensure safety of all crew members. Winter safety precautions to follow include:

- When walking on ice, check ice thickness with a rod or ice chisel every few steps (ice should be a minimum of 3 to 4 inches thick). Ice over flowing waters, at lake outlets, and on reservoirs may be of variable thickness due to fluctuating water levels and complex flow patterns.

- A minimum of two people should be present during sample collection.

- Wear a life jacket when walking on spring ice (or during first freeze-up), and carry a length of rope (tied around your waist) to use as a lifeline. Use extra caution because ice at this time may not be strong enough to bear your weight or the weight of a snowmobile.

- Never collect a sample when conditions are unsafe.

Methods

A number of important protocols must be followed when collecting water samples in the winter. Stations for winter water quality sampling should be located as close as possible to the open-water stations. Precautions should be taken to ensure that samples do not freeze following sample collection. The following steps should be followed when collecting winter water quality samples (Government of BC 2003):

- Clear loose ice and snow from the estimated stream thalweg; drill through the ice with a hand or motorized auger. Keep the area around the hole clear of potential contamination (e.g., dirt, fuel, oil, etc.).

- Remove all ice chips and slush from the hole using a plastic sieve. Samples should be collected approximately 0.2 m below the bottom of the river/lake ice using a depth sampler (e.g., Van Dorn sampler) to minimize the possibility of contaminant introduction associated with augering.

4.3.9 Sample Shipping

In most cases, samples should be kept cool (e.g., on ice, 4°C) and dark. Samples should not be allowed to freeze and should be shipped in coolers (with ice-packs) as soon as possible to the appropriate laboratory (keeping in mind appropriate holding times). If possible, avoid use of cube or block ice; the water that leaks with melting may ruin sample labels.

Chain of Custody (COC) and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document and are available in triplicate. The form should be completed and one copy be retained by the field personnel (after the shipper has signed the COC) and the remaining two copies sent with the water samples, either inside the shipping container or attached firmly to the outside of the container. The COC forms should be enclosed in a sealed waterproof bag.

It is important that each person having custody or control of the samples is identified on the COC forms. Typically, this will include the crew who collected the sample, any intermediate persons involved in storing, packaging or transporting the sample, the shipper and the analytical laboratory that will receive the samples.

4.4 FIELD MEASUREMENTS

Field water quality measurements can be collected by immersing the probe of a water quality meter directly into the water column, or in water collected using a deep-water sampler or sample container. Field measurements are never taken on samples collected for submission to the laboratory (to avoid contaminating the sample). The number of field measurements taken depends on water depth, as follows (Environment Canada 2005):

- Depth ≤ 2 m – one set of measurements at mid-depth;
- Depth between 2 and 4 m – two sets of measurements collected at 25 cm above the bottom, and 25 cm below the surface; and
- Depth > 4 m – multiple sets of measurements collected throughout the water column.

Dissolved oxygen, temperature, and specific conductivity are commonly measured in the field using a multi-variable probe (e.g., YSI 85 meter); pH is measured using a pH meter (e.g., Piccolo ATC pH meter [HI 1280]). Dissolved oxygen can also be measured by Winkler titration. The LaMott portable Winkler titration kit has been used often in the field by RAMP technicians. This field titration kit only provides 0.1 mg/L accuracy, but the data is often more reliable than those provided by electronic DO probes rated at 0.01 mg/L accuracy. Electronic equipment is calibrated prior to sample collection and periodically throughout a day of sampling (e.g., after every five samples or if water quality changes dramatically from site to site).

The recommended accuracy of *in situ* field measurements is as follows:

- Dissolved Oxygen (± 0.2 mg/L);
- Temperature (± 0.4 °C);
- Conductivity (± 0.05 µS/cm);
- pH (± 0.02 units);
- Water Depth (± 1 cm);
- Current Velocity (± 1 m/s);
- Turbidity (± 0.01 NTU);

- Salinity (± 0.1 ppt); and
- Clarity (Secchi disk, ± 1 cm).

4.5 WATER SAMPLING FOR ACID SENSITIVE LAKES SURVEYS

Water quality monitoring in acid sensitive lakes is conducted to assess changes in acidification and other indicators of water quality.

Water samples are collected from the euphotic zone (defined as twice the Secchi disk depth) and are combined to form a composite sample. Where the euphotic zone extends to the lake bottom, sampling is conducted at a maximum depth of 1 m above the lake bottom. In shallow lakes (< 3 m deep), 1 L samples are collected at 0.5 m depth from five to ten locations along a transect dictated by wind direction (upwind to downwind shore).

Samples are collected using weighted Tygon© tubing. *In situ* dissolved oxygen, temperature, conductivity, and pH are measured at the deepest location using a field-calibrated meter (see Section 4.4). Samples are kept on ice and shipped for chemical analysis within 48 hours of collection.

Subsamples for phytoplankton taxonomy can be taken from euphotic zone composite samples. The subsamples are preserved using Lugol's solution. Zooplankton samples can also be collected in each lake as vertical hauls through the euphotic zone using a #20 mesh (63 µm) plankton net. Organisms are anaesthetized in soda water prior to sample preservation in approximately 5% formalin.

All composite or grab samples collected for laboratory analysis are transferred into clean, pre-labeled containers and shipped to the laboratory as described in Section 4.3.9. Samples for the Acid Sensitive Lakes component should arrive at the laboratory within 24 hours of sampling.

4.6 SAMPLE QA/QC

Sample QA/QC protocols are based on those presented by the Government of BC (2003b) and Environment Canada (2002; 2005).

The goal of sample QA/QC is to monitor for potential contamination of field samples during the collection, transport and analyses of the samples. This process includes the use of field blanks, trip or travel blanks and field duplicates. Table 4.2 summarizes sample QA/QC requirements.

Field blanks are used to detect potential contamination during sample collection and transport. They are prepared in the field by filling the appropriate container with de-ionized water provided by the laboratory. The sample is handled in the same way as other field samples and shipped to the laboratory for identical analyses.

Trip or travel blanks are used to detect potential contamination during transport. Trip blanks consist of pre-filled bottles of de-ionized water provided by the analytical lab. Theses blanks accompany empty bottles to the field site, where they are left intact and unopened inside the travel and shipping container. The unopened trip blanks are then returned to the lab to be analyzed with the other samples. Note: chemistry labs will often only provide trip blanks for select analyte groups unless otherwise requested.

Field duplicates are collected by filling multiple sample containers of ambient water at a single site, and are collected to evaluate within-site and analytical variability. Each replicate sample is submitted separately to the analytical laboratory.

The number of trip blanks, field blanks and field duplicates that are commonly used for a given survey is approximately 10% of the total number of sites sampled (e.g., one set of QA/QC samples for every ten sites sampled). Station(s) used for collection of QA/QC samples are randomly selected. All QA/QC samples are analyzed as complete sets, incorporating the total suite of standard RAMP variables.

To identify potentially contaminated samples, field and trip blanks are compared to analytical detection limits. Blanks with analyte concentrations below or near the detection limits represent samples that were collected and handled properly. Blanks with contaminant concentrations greater than 5 times the detection limits are identified as potentially contaminated during sample collection, shipping, or analysis.

Table 4.2 QA/QC considerations for field blanks, trip blanks and field replicate samples (adapted from BC WLAP 2003).

QA/QC Sample Type	Objective	Frequency of Collection	Acceptability Criteria	Action for Failed Criteria
Field Blanks	To assess potential contamination from sample containers, preservatives, or other sources during sample collection, handling, and transport.	10% of samples (i.e., one field blank for every 10 samples collected), or a minimum of one per sample set.	Analyte concentrations greater than 5 times the analytical detection limits may indicate contamination.	Check field notes to determine potential source of contamination. Assess impact of contamination on sample data. Analyze additional blank samples. Reject/qualify sample results if necessary. Do not subtract field blank results from reported sample results.
Trip Blanks	To assess the efficacy of storage conditions and potential contamination during transport.	One per sample set.	Analyte concentrations greater than 5 times the analytical detection limits may indicate contamination.	Check field notes to determine potential source of contamination. Assess impact of contamination on sample data. Analyze additional blank samples. Reject/qualify sample results if necessary. Do not subtract trip blank results from reported sample results.
Field Duplicates	To evaluate precision of sampling and analysis, and to evaluate within-station variability.	10% of samples (i.e., one field blank for every 10 samples collected), or a minimum of one per sample set.	If analytical values exceed 5 times the analytical detection limit in at least one of the samples, relative percent difference values[1] greater than 20% may indicate a problem with sampling/analytical precision or the representativeness of the sample. Relative percent difference values greater than 50% indicate likely contamination or lack of sample representativeness.	Determine source of problem and impact on sample data. Check field notes for possible sources of heterogeneity.

[1] For two samples, A and B, Relative Percent Difference is calculated as: RPD = 2*(A-B)/(A+B)*100%.

4.7 GENERAL EQUIPMENT AND SUPPLIES FOR WATER QUALITY SURVEYS

The following is a list of sampling equipment and supplies generally recommended for collecting surface water samples:

Sampling and Documentation

- Pre-cleaned field sample bottles (obtained from the analytical lab) of appropriate type and number for desired analyses;
- Latex gloves;
- Sample preservatives;
- Filtration apparatus if required;
- Ice packs/coolers;
- Waterproof labels, permanent markers and pencils;
- Field logbooks/binders;
- Maps, air photos, GPS unit, compass;
- Written protocols and procedures for sample collection and equipment operation, including FWIs;
- Water quality meters, including calibration fluid, spare parts, and repair equipment (duct-tape, silicon lubricant, tool box, socket set) and other sampling tools, e.g., Secchi Disk, flow meter, sounding line or pole, tape measure, flagging tape, rope, water samplers (Van Dorn, Kemmerer);
- Ice auger, blades and ice chisel in winter;
- Camera or video equipment as required;
- Laboratory Chain of Custody/Analytical Request forms; and
- Transportation (truck, ATVs, boat, snowmobile, helicopter).

Health and Safety

- Personal gear for all possible field and weather conditions (e.g., survival suits, rainjackets/rainpants, appropriate footwear, waders, gloves, hat, change of clothes);
- First aid kit and survival kit;

- Personal floatation device for each crew member for deep water, spring ice or boat work;
- Boat safety equipment including paddles, painters, bailer, throw-bag and whistle;
- Communication device (satellite phone when access is other than helicopter) and list of emergency phone numbers;
- Three wool blankets and emergency food and clothing;
- Buggy whip, hard hats, blue light, reflective vests, and other required gear if accessing oil sands mine site; and
- Spare jerry can of fuel, tow-rope, shovel and pick if access is by truck.

5.0 SEDIMENT QUALITY SURVEYS

Aquatic bottom sediment is collected for analysis of physical, chemical or toxicological characteristics in order to assess sediment quality. Sediment quality surveys are often conducted concurrently with water quality surveys and biological monitoring to determine if there is a relationship between environmental quality and the health of resident biota. In addition, sediment quality surveys are conducted to evaluate changes in environmental quality over time and/or space.

5.1 PREPARATION FOR FIELD PROGRAMS

General tasks to be completed in preparation for conducting a sediment quality field survey are consistent with those previously outlined in Section 3.1 for Water Quality, with the exception of needing specific sediment sample containers and sampling equipment (see also Section 5.6).

5.2 DATA COLLECTION

Field notes and measurements should be recorded on the *RAMP Benthic Invertebrate and Sediment Data Sheet* (Figure 6.1) and/or in a waterproof field book. A detailed list of data that should be recorded at each site is provided in Section 2.5.1. The following supplemental information should also be recorded:

- Details pertaining to unusual events that might have occurred during the operation of the sampler (e.g., possible sample contamination, equipment failure, unusual appearance, control of vertical descent of the sampler, etc.);
- Any deviations from standard operating procedures or FWIs;
- Sediment characteristics, such as texture, color, biological components and structure (e.g., shells, tubes, macrophytes), debris (e.g., wood chips, plant fibers), presence of oily sheen and obvious odors;
- Characteristics of the vertical profile, including the presence and depth of distinct layers (more appropriate for core samplers);
- Depth of penetration of the sediment sampler and/or fullness of sediment of grab; and
- Supporting *in situ* field water quality data.

5.3 SAMPLE COLLECTION

Sediment sampling methods follow those used throughout the RAMP program (i.e., Golder 1998) and guidance prepared by federal and provincial agencies (Environment Canada 2002, 2005; Government of BC 2003).

5.3.1 Safety

Sample and data collection are always determined by site conditions that might affect the safety of the field crew. When safety may be compromised due to site conditions, sampling is relocated or postponed.

5.3.2 Sediment Samplers

Two types of sediment samplers are used by RAMP for sediment surveys of lotic and lentic depositional habitats: a) grab samplers or dredges; and b) sediment core samplers. Grab samplers, such as an Ekman or Ponar grab (Figure 5.2), are used for the majority of samples, and are used to collect surface sediments to assess the horizontal distribution of sediment quality/characteristics. These grabs are also used for the collection of benthic invertebrate samples from depositional habitats. Core samplers (Figure 5.2) are used to collect a depth profile of sediments, allowing assessment of vertical distribution of variables and long-term changes in sediment quality/characteristics. To date, core samplers have been used infrequently in RAMP, but were useful for studies conducted in the Athabasca River Delta (2005 program) focusing on time trends in chemicals and sedimentation rates. Sampling equipment should be chosen based on survey objectives, site conditions and the volume of sediment required for analysis. The advantages and disadvantages of common grab devices are outlined in Table 5.1 (Environment Canada 2005). All equipment used for RAMP should be stainless steel, particularly when sampling for the analyses of metals or organic compounds.

Step-by-step instructions for the collection of grab samples (using an Ekman or Ponar grab) are as follows:

1. Prior to collecting the sample, rinse/clean the grab sampler (jaws open) and all other equipment (i.e., stainless steel pans and spoon) that will contact the sample (see Section 5.3.3) to prevent contamination.

2. Set the grab into the open position. Using a graduated rope attached to the top of the sampler, slowly lower the grab until it touches the bottom. If using an Ekman grab, ensure the messenger (small weight used to trigger the sampler) remains at the surface.

3. Trigger the sampler. The Ponar grab will trigger automatically as soon as it contacts the sediment bed; however, for the Ekman grab, release the messenger while ensuring the graduated line is as vertical as possible; maintain some tension in the line so that the messenger falls freely and trips the jaws of the grab.

4. Once the jaws of the sampler have been triggered close, begin to slowly raise the sampler off the bottom (fine sediments may be lost if the sampler is raised too quickly).

5. Ensure the sample meets acceptability criteria (e.g., desired depth of penetration has been achieved, no loss of sediment sample due to incomplete closure or tilting of the grab sampler). If the criteria are not met, the sample should be discarded in a bucket and another sample collected from the site.

6. If the sample is acceptable, completely open the jaws and put the sample into a flat-bottomed stainless steel pan. Repeat the collection process until sufficient sediment volume has been collected. All sediment material is mixed to obtain a homogenous sample for placement into labeled, sterilized glass jars and/or re-sealable plastic bags (depending on analyses).

Figure 5.1 Diagrams of an Ekman and a Ponar sediment grab and a sediment corer (Government of BC 2003c).

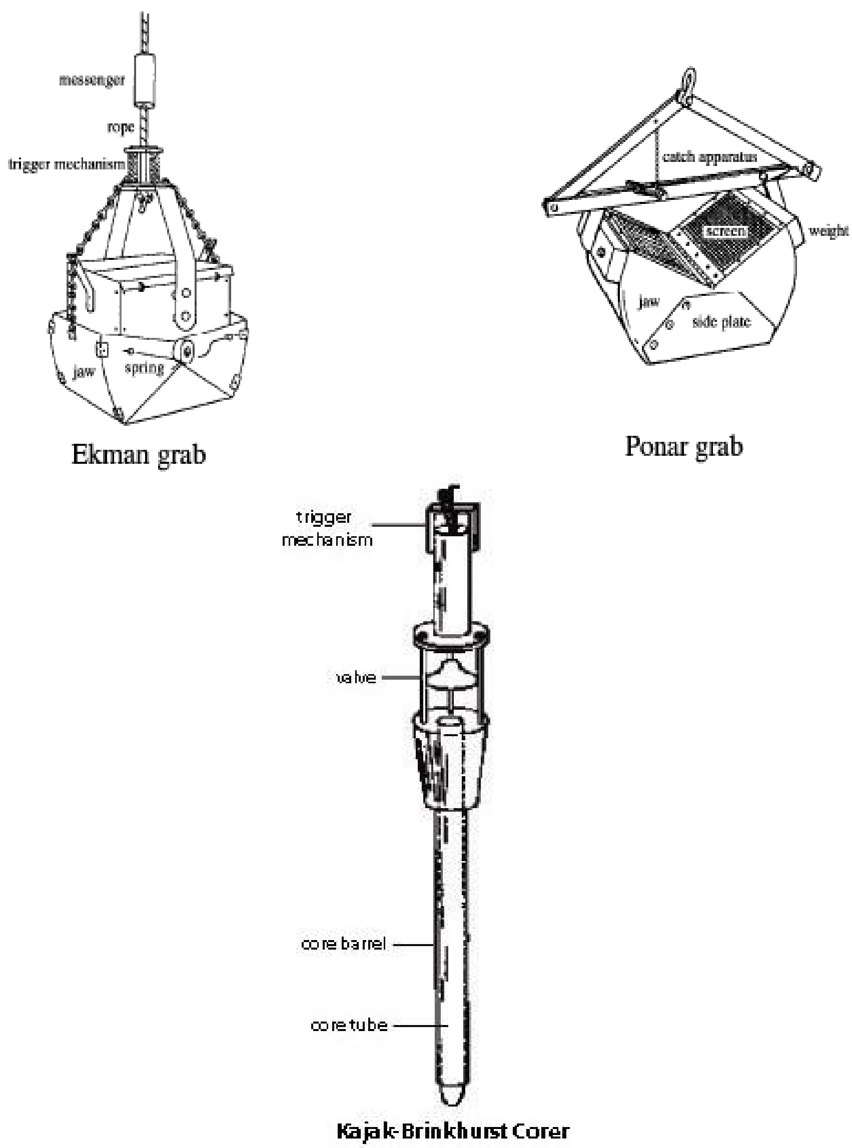


Table 5.1 Characteristics, advantages, and disadvantages of grab devices used for sediment sample collection.

Grab Sampler/ Dimension	Use	Sediment Depth Sampled (cm)	Volume of Sediment Sample (cm^3)	Advantages	Disadvantages
Smith-McIntyre Grab	Deep Lakes Rivers Estuaries	0-30	10,000-20,0000	Designed for sampling hard substrates (rubble or coarse/very coarse unconsolidated bottom).	Loss of fine-grained sediment; heavy (requires motorized winch); possible metal contamination.
Ekman Grab – Small	Lakes Marine Areas Soft Sediments Silt Sand	0-10	≤ 3,400	Designed for fine-grained soft sediments and mixtures of silt and sand; lightweight and therefore easy to operate manually.	Restricted to low current conditions.
Ekman Grab – Large	Lakes Marine Areas Soft Sediments Silt Sand	0-30	≤ 13,300	Designed for fine-grained soft sediments and mixtures of silt and sand; large sample obtained, permitting subsampling.	Restricted to low current conditions; penetration depth exceeded by weight of sampler in very soft sediment.
Ponar Grab – Standard	Deep Lakes Rivers Estuaries Useful for sand, silt, and clay	0-10	7,250	Most universal grab sampler; adequate on most substrates; large sample obtained intact, permitting subsampling; good for coarse and firm bottom sediments.	Shock wave from descent may disturb fine-grained sediment; possible incomplete closure of jaws results in sample loss; possible contamination from metal frame construction.
Petersen Grab	Deep Lakes Rivers Estuaries Useful on most substrates	0-30	9,450	Large sample; can penetrate most substrates.	Heavy, likely requires winch; no cover/lid to permit subsampling; all other disadvantages of Ekman and Ponar.

5.3.3 General Sampling Considerations

The following protocols should be followed to prevent sample contamination:

- Sampling is conducted sequentially from the least to the most contaminated sites (degree of contamination is estimated by site conditions, professional knowledge, etc.).
- All sampling equipment (spoons, pans, grab sampler) are cleaned before use, following three steps:
  - Equipment is cleaned with a solvent, metal-free soap (e.g., Liquinox) to remove any metal residues;
  - Equipment is rinsed with environmental grade hexane and environmental grade acetone (to remove any organic residues); and
  - Equipment is rinsed three times with ambient water downstream of the sampling site.
- Sampling equipment for organics analyses must not be plastic; the container must be a glass bottle provided by the laboratory. Sampling equipment for metals analyses must be stainless steel or plastic (for sample homogenization.
- Disposable non-powdered latex gloves are worn throughout the sample collection process.
- Only grab samples that do not contain large, foreign objects, obtain an adequate penetration depth, and are not overfilled or leaking are used.
- Sediments are transferred from the grab sampler to a cleaned stainless steel pan for compositing using a clean, stainless steel spoon. Direct contact between sediments and gloves is avoided.
- During collection of composite samples, the composite container is kept covered between grab collections.
- Sample containers are stored appropriately (i.e., capped, away from potential contamination) in office or storage facilities.
- Sample containers are capped at all times except during sample collection. Sample containers are stored in a clean shipping container (e.g., cooler); vehicle (boat, truck) cleanliness is maintained at all times to avoid potential sources of contamination.

5.3.4 Depositional Habitats

When sediment samples are being collected for benthic invertebrate, toxicity, and/or chemical analysis, the top 2 to 5 cm of each grab sample are collected and transferred to a stainless steel tray using a stainless steel spoon. If required, additional grab samples are collected until a sufficient volume of surficial sediment is collected (approximately 1 L of sediment). The number of grab samples collected for composite samples should be recorded on the field datasheet; the general appearance of the sediments, including grain size, presence of a hydrocarbon or biogenic sheen, and presence of debris, plant material, or biota, is recorded, along with other general information described in Section 5.2. The collection of water quality samples from a monitoring site should be completed PRIOR to sediment sampling to avoid disturbing overlying waters.

Sediments are homogenized, and transferred to heat-treated, wide-mouth glass jars with Teflon® lids lined with aluminum foil as needed. Typically, a small jar (125 mL) is collected for analysis of total organic carbon and pH analyses, and a larger jar (250 mL) of sediment is collected for grain size and chemical analyses. For toxicity samples, a larger volume of sediment is collected (approximately 3 L of sediment). Sediments for toxicity testing are transferred to two 1 L jars or laboratory-supplied sealable plastic bags; sediments for concurrent chemical and grain size analyses are transferred to 125 mL and 250 mL glass jars, as described above. Each analytical laboratory will have its own protocols, and it is advisable to confirm specifications with each laboratory prior to conducting the sediment survey.

An adhesive label with the sample ID is placed on each jar and secured with clear tape. Sample IDs and other relevant information (e.g., type of analyses requested, station ID) are also written on the lid of the jar using a waterproof marker. Toxicity samples are double bagged and labeled (both bags) with an indelible marker. A duplicate ID label is attached to the datasheet for each sample collected. All samples are stored in a cooler with ice packs to avoid exposure to heat and light, and shipped to the appropriate laboratory for analysis.

5.3.5 Erosional Habitats

In erosional habitats, where substrates with large particle sizes are present (e.g., large gravel, cobble, or boulder), sediments generally are not collected for chemical analyses due to particle size limitations. However, information regarding the bed structure can be collected, including the dominant particle size, degree of embeddedness, matrix, and texture of the substrate. A substrate score, which takes into consideration the particle type/size and degree of embeddedness, is derived using criteria described in Table 5.2.

Table 5.2 Criteria used to characterize substrates (adapted from Reynoldson *et al.* 1998).

Particle Type/Size		Embeddedness	
Category	**Score**	**Category**	**Score**
Organic cover (>50% of surface)	1	Completely embedded	1
<0.1 to 0.2 cm	2	¾ embedded	2
0.2 to 0.5 cm	3	½ embedded	3
0.5 to 2.5 cm	4	¼ embedded	4
2.5 to 5 cm	5	Unembedded	5
5 to 10 cm	6		
10 to 25 cm	7		
>25 cm	8		

The substrate score is derived by summing the scores for:

- Size of predominant particle;
- Size of 2nd most predominant particle;
- Size of remaining material; and
- Embeddedness score.

In addition, a photographic record is taken at each station to illustrate the substrate within a 30 x 30 cm grid

5.3.6 Sampling From a Boat

The collection of deep-water samples requires that at least one member of the sampling group be very familiar with boat operation and safety. If the sampling trip involves the use of a boat, then the weather forecast should be obtained prior to departure; if conditions are poor, the sampling trip should be postponed. Each crew member should wear a personal flotation device at all times.

Collecting river samples from a boat should ideally utilize three people: one to operate the boat and maintain the position during sampling, one to collect the sample from the bow, and one to collect field measurements and take field notes. Samples should be collected moving from the least to the most contaminated sites and from downstream to upstream sites. Samples are collected using methods described above.

5.3.7 Sample Shipping

In most cases, samples should be kept cool (e.g., on ice, 4°C) and dark. Samples should be shipped in coolers (with ice-packs) as soon as possible to the laboratory (keeping in mind appropriate holding times). If possible, avoid use of cube or block ice; the water that leaks with melting may ruin sample labels.

Chain of Custody (COC) and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document and are available in triplicate. The form should be completed and one copy be retained by the field personnel (after the shipper has signed the COC) and the remaining two copies sent with the water samples, either inside the shipping container or attached firmly to the outside of the container. The COC forms should be enclosed in a sealed waterproof bag.

It is important that each person having custody or control of the samples is identified on the COC forms. Typically, this will include the crew who collected the sample, any intermediate persons involved in storing, packaging or transporting the sample, the shipper and the analytical laboratory that will receive the samples.

5.4 FIELD MEASUREMENTS

Routine field water quality measurements should be taken at each sampling station. Dissolved oxygen, temperature, and specific conductivity are commonly measured in the field using a multi-variable probe (e.g., YSI 85 meter); pH is measured using a pH meter (e.g., Piccolo ATC pH meter [HI 1280]). Dissolved oxygen can also be measured by Winkler titration. The LaMott portable Winkler titration kit has been used often in the field by RAMP technicians.

Additional information on water quality field measurements can be found in Section 3.4 (water quality procedures).

5.5 SEDIMENT QA/QC SAMPLES

QA/QC samples are collected in order to evaluate environmental heterogeneity and to assess potential contamination from sample preparation, handling, or analysis. Sediment QA/QC samples include cross-contamination samples and field duplicates. Gloves are changed prior to collection of QA/QC samples (as well as between stations). A complete set of QA/QC samples is collected from a randomly selected station(s). The number of QA/QC samples collected is equal to 5% to 10% of the total number of composite samples collected (e.g., one set of QA/QC samples is collected for every 5 or 10 stations sampled).

Cross-contamination blanks are used to ensure that procedures used to clean equipment between stations are effective. Two different methods are used for cross-contamination blanks depending on the size of the grab sampler used for sample collection.

- **Small grab samplers (e.g., Ekman or Petite Ponar)** – Equipment is cleaned as described in Section 5.3.3. Sampling equipment, including the grab sampler and spoon, are placed in a metal tray and rinsed a fourth time with de-ionized, distilled water. Rinsate in the tray is collected for analysis to evaluate possible cross-contamination between stations. Rinsate samples are treated and analyzed as water samples.

- **Large grab samplers (e.g., Standard Ponar, Smith-McIntyre)** – Equipment is cleaned as described above. The entire inside and outside of the grab sampler and spoon are swiped with 2"X 2" cotton gauze pads (i.e., swabs). For PAH or dioxin and furan samples, the swab is presoaked in a 1:1 acetone/hexane mixture. The swab is placed in a sample container and treated like a sediment sample. Samples collected for PAH or dioxin and furan analysis are placed in an amber glass jar.

- **Rinsate blanks**, comprised of de-ionized, distilled water, **or swab blanks**, comprised of a clean swab placed in a sample container, are collected prior to sample collection (analogous to trip blanks). The number of cross-contamination samples and blanks collected should be equal to 5% to 10% of the total number of stations.

To identify potentially contaminated samples, the cross-contamination swab/rinsate and swab/rinsate blanks are compared to each other. Concentrations of analytes in the cross-contamination blanks and filter blanks should be similar. Analyte concentrations in these blanks are also compared to detection limits; however, the swabs may contain some analytes at concentrations greater than detection limits. For most analytes, blanks with contaminant concentrations greater than 5 times the detection limits represent samples that were potentially contaminated during sample collection, shipping, or analysis.

Field duplicates are used to assess the precision of the field sampling and heterogeneity of sediments collected from the same location by collecting a replicate sample. The relative percent difference (RPD) between field duplicates is determined to assess the precision of the analyses and heterogeneity of the sample. Relative percent difference is calculated as:

$$|(A - B) / [(A+B)/2] * 100\%|$$

Analyte concentrations differing by more than 20% between samples and at least five times above detection limits are considered to exhibit higher variability than expected due to analytical error.

5.6 GENERAL EQUIPMENT AND SUPPLIES FOR SEDIMENT QUALITY SURVEYS

The following is a list of sampling equipment and supplies generally recommended for collecting sediment samples:

Sampling and Documentation

- Pre-cleaned field sample containers (obtained from the analytical lab) of appropriate type and number for desired analyses, including containers for cross-contamination samples and blanks;
- Latex gloves;
- Sample preservatives;
- Ice packs/coolers;
- Waterproof labels, permanent markers and pencils;
- Field logbooks/binders;
- Maps, air photos, GPS unit, compass;
- Written protocols and procedures for sample collection and equipment operation, including FWIs;
    - Field equipment (e.g., grab sampler or corer, sampling tools, water quality meters), spare parts, and repair equipment (duct tape, silicon lubricant, toolbox, socket set, etc.);
- Camera or video equipment as required;
- Laboratory Chain of Custody/Analytical Request forms; and
- Transportation (truck, ATVs, boat, snowmobile, helicopter).

Health and Safety

- Personal gear for all possible field and weather conditions (e.g., survival suits, rainjackets/rainpants, appropriate footwear, waders, gloves, hat, change of clothes);
- First aid kit and survival kit;
- Personal floatation device for each crew member for deep water or boat work;
- Boat safety equipment including paddles, painters, bailer, throw-bag and whistle;
- Communication device (satellite phone when access is other than helicopter) and list of emergency phone numbers;
- Three wool blankets and emergency food and clothing;
- Buggy whip, hard hats, blue light, reflective vests if accessing oil sands mine site; and
- Spare jerry can of fuel, tow-rope, shovel and pick if access is by truck.

6.0 BENTHIC INVERTEBRATE COMMUNITY SURVEYS

Invertebrate animals (various life stages of insects, crustaceans, worms, and molluscs) that inhabit the bottom of a body of water make are referred to as aquatic benthic invertebrates. A benthic community consists of an assemblage of benthic invertebrates at a given location and time. The composition (abundance, diversity) of benthic communities provides information regarding the quality of the aquatic habitat in which they reside.

Benthic invertebrate community surveys are conducted for the Regional Aquatic Monitoring Program (RAMP) to assess and detect spatial and/or temporal changes in freshwater benthic communities. This component is often conducted concurrent with water and sediment quality surveys to determine if there is a relationship between environmental quality and the health of the resident biota.

This section details the methodologies used by field crews to conduct benthic invertebrate community surveys.

6.1 PREPARATION FOR FIELD PROGRAMS

General tasks to be completed in preparation for conducting a benthic invertebrate community survey are consistent with those previously outlined in Section 3.1 for Water Quality, with the exception of needing specific benthos sample containers and sampling equipment (see also Section 6.5). In addition, a benthic taxonomist (Jack Zloty or alternate) should be contacted so they know how many and when samples are to be expected and to ensure sample sieving, sorting and taxonomic analysis can be completed in a timely manner.

6.2 DATA COLLECTION

Field notes and measurements should be recorded on the *RAMP Benthic Invertebrate Data Sheet* (Figure 6.1) and/or in a waterproof field book. Section 2.5.1 lists other information that could be recorded on each station field sheet. Details pertaining to unusual events that might have occurred during the operation of the sampler (e.g., equipment failure, unusual appearance, control of vertical descent of the sampler, site characteristics, etc.) and any deviations from standard operating procedures or FWIs should also be recorded.

Table 6.1 provides a summary of the data to be collected for erosional and depositional benthic invertebrate surveys. Methods for each component are provided in subsequent sections.

Figure 6.1 RAMP benthic invertebrate and sediment data sheet.

Watercourse Name		**Reach ID**	
Reach (circle one)	Upper / Middle / Lower	**Sample Date**	
Habitat (circle one)	River / Lake	**Field Crew** (circle)	
General Habitat Type (circle one)	Erosional / Depositional	**Weather** (circle)	Clear Cloudy Rain Snow Windy
Access (describe)		**Crew Initials** (sign)	

Station Number (*#1 is downstream*)	**1** (d/s)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** (u/s)
UTM E (Zone 12, NAD83)										
UTM N										
Sample Label										
Sample Time (24 hr clock)										
Dissolved Oxygen (mg/L)		-	-	-	-	-	-	-	-	
Conductivity (µS/cm)		-	-	-	-	-	-	-	-	
pH		-	-	-	-	-	-	-	-	
Water Temperature (^oC)		-	-	-	-	-	-	-	-	
Water Depth (m)										
Macrophyte cover (vis. % cover)										
Macrophyte Species (list)										
All Rivers										
Current Velocity (sec/2m) Rep 1										
Rep 2										
Rep 3										
Conversion to m/s										
Bankfull Channel Width (m)										
Wetted Channel Width (m)										
Erosional Rivers										
Benthic Chlorophyll *a* **sample?** (check)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sand/ Silt/ Clay (%) (Visual Estimate)										
Small Gravel (%)										
Large Gravel (%)										
Small Cobble (%)										
Large Cobble (%)										
Boulder (%)										
Bedrock (%)										
Depositional Rivers and Lakes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sediment Grain Size, TOC sample (check)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sediment Chemistry (@ #1 only)	☐ TOC	☐ PAH	☐ PSA/Metals		☐ CCME Hydrocarbons			☐ Toxicity		☐ *Gear cleaned*
Sed. Chem. QA/QC set?	Y / N		If yes, QA/QC sample ID:							

Plant Species: VA = *Vallisneria americana* (tapegrass), PO=*Potamogeton* (pondweed), COON = *Ceratophyllum demersum* (coontail)
CH=*Chara*, CL = *Cladophora*, EL - *Elodea canadensis* (Canada waterweed), MIL = *Myriophyllum spicatum* (millfoil), UNK = unknown

Table 6.1 Data to be collected for RAMP erosional and depositional benthic invertebrate surveys.

Component	Habitats		
	River or Stream Erosional	River or Stream Depositional	Pond or Lake Depositional
Geographic position	✓	✓	✓
General Appearance	✓	✓	✓
Benthos	✓	✓	✓
Total organic carbon		✓	✓
Grain size	✓	✓	✓
Wetted and Bankfull Channel Width	✓	✓	
Water quality (D.O., conductivity, temperature, pH)	✓	✓	✓
Current Velocity	✓	✓	
Water Depth	✓	✓	✓
Chlorophyll *a*	✓		
Macrophytes	✓	✓	✓

6.3 SAMPLE COLLECTION

6.3.1 General Methods

Methods for collecting benthic invertebrate samples from rivers, streams, and lakes are described in the following sections. Approximate site locations should be identified prior to each field survey. However, exact site locations should be selected in the field to ensure that sites are similar in terms of physical characteristics (particularly current velocity, depth, and substratum composition).

Invertebrate freshwater habitat may be broadly classified as erosional and depositional for the purposes of benthic sampling. Erosional habitats include wave-washed areas of lakes and moderate- to fast- running rivers and streams. These habitats are typically characterized by harder substrates that are usually dominated by gravel and/or other larger sediment fractions. Erosional sites are sampled using a Hess or Neil-Hess cylinder. Depositional habitats are areas of standing or slow-moving water (e.g., lakes, deltas, streams, rivers) and are typically characterized by softer substrates that are usually dominated by sand and/or other smaller particulates. Depositional sites are sampled using an Ekman or Ponar grab. Detailed methods for sampling each habitat are presented in this section and follow those used previously in RAMP (Golder 1998) and federal EEM guidance (Environment Canada 2002; 2005).

6.3.2 Safety

The decision to undertake benthic sampling on a given waterbody should always be determined by site-specific conditions that might affect the safety of the field crew. When safety may be compromised or is uncertain, sampling is relocated or postponed.

6.3.3 RAMP Sampling Design

RAMP benthic monitoring occurs in tributaries to the lower Athabasca River, the Athabasca River Delta and specific lakes in the oil sand region.

River Reaches

RAMP collects several benthic samples within a specific river reach to quantify the overall benthic community. A reach is a relatively homogenous (in terms of physical features) section of river, typically 2 to 5 km long. Sampling sites are somewhat randomly selected within reaches. Through reconnaissance of a reach, the reach length is determined, and samples sites are selected within the reach at the time of sampling, in such a way as to ensure that sites are distributed roughly evenly throughout the reach. Individual sites are not necessarily re-visited from year to year. This is justified because the habitats (riffles and pools) within a river are mobile both longitudinally, and side to side.

Sites are classified as either erosional or depositional, depending on which is the dominant habitat type within the tributary. Habitat types are specified, *a priori*, before the execution of the field program.

Single samples from 15 sites were collected from each reach in 2004 and earlier RAMP collections. From the 2005 season and forward, 10 sites are to be sampled within each reach (provides adequate statistical power).

Lakes

Ten sites are sampled within each lake, with sites allocated haphazardly to ensure about equal distribution in the lake. Sites are restricted to a narrow range in water depth (1 to 2 m) to minimize natural variations in benthos communities. Single benthic samples are collected at each site.

Athabasca River Delta

Five samples have historically been collected within the Athabasca River Delta, from each of three Channels (Fletcher, Goose Island, Big Point).

Timing

Benthic sampling is conducted in **September** of each year to limit potential season-associated variability in composition of the benthic community.

6.3.4 Erosional Habitat (River Reaches, Streams)

At each erosional site within a reach, one sample of benthic invertebrates is collected within gravel to cobble-sized substrates using a Hess or Neil-Hess cylinder, as follows:

- Sampling should be initiated at the downstream limit of the sampling site.
- Place the Hess cylinder at mid-riffle, ensuring that the top of the cylinder is not below the water's surface (< 60 cm deep). If water is too deep, re-locate the cylinder until water is shallow enough for proper sampling.
- In order to minimize risk of dislodging important large organisms prior to sampling, do not disturb the substrate before inserting the cylinder.
- Ensure that the seal at the bottom of the cylinder is adequate to prevent benthos from escaping during sampling.
- Drive the bottom of the cylinder into the substratum and hold it there for the duration of sampling.
- Orient the cylinder so that the "window" is facing upstream, and trailing net is downstream. Water should be flowing through the cylinder, entering through a mesh window at the front and exiting through the sampling net.
- Reach inside the cylinder and manually dislodge invertebrates from rocks and pebbles in order to ensure that they move into the trailing net of the cylinder and into the cod end of the sampler. Larger substrates (e.g., rocks) can be sampled by gently rubbing them to remove invertebrates; rocks can then be removed from the sampler. A trowel can be used to stir up additional coarse substrate to approximately the depth of the "pavement" layer (the top 5 cm layer of rocks, cobbles, and pebbles which typically forms a contiguous layer over finer substrate). Ensure that caddisflies, which are attached to the sides/surfaces of rocks, are removed and washed into the collection net. The sample should take between 1 and 3 minutes to collect, once the sampler has been placed on the bottom.
- Allow suspended material to be transported into the net or to settle. Lift the cylinder with the net pointing down and dip it into the water a few times to transport all invertebrates clinging to the inside of the sampling net into the cod end of the sampler.
- Remove the cod end of the sampler and wash contents into a 1-L plastic jar. Contents could be washed in a box sieve to facilitate transfer to a jar. In this case, the mesh of the box should be the same or finer as the mesh in the Hess Sampler.

- Insert into the sample jar a piece of “Rite-in-Rain” paper labeled in pencil with the station ID.

- Preserve sample with buffered formalin to a final concentration of 5% to 10% buffered formalin. The proper dilution (5-10%) can be achieved by either:
  - Adding 50 and 100 ml of 100% buffered formalin for every 1000 ml of sample (more formalin is preferable over less, particularly if the sampled sediment is dominated by clay or organic matter); or
  - Adding 10% buffered solution to a “dry” sample (minimum amount of water remaining in the sample).
  - Formalin is buffered by adding baking soda to 100% formalin (37% formaldehyde). Enough baking soda has been added when there is a precipitate on the bottom. Roughly 100 g of baking soda per 4 L of formaldehyde/formalin should be sufficient

- Cap the sample container, check the label, gently agitate the sample to distribute preservative, and wash the surface of the container to remove excess formalin. Place sample container in transport device (backpack/cooler).

- After the sample is collected thoroughly rinse the cylinder and net in river water to remove any residual sediment, invertebrates and plant material.

6.3.5 Depositional Habitat (River Reaches, Lakes, Delta)

At each depositional site, one sample of benthic invertebrates is collected from soft substrates using an Ekman grab, as follows:

- In order to ensure accurate sampling, select an area of undisturbed sediment for sampling.

- Open grab, set triggering mechanism and slowly lower the grab (e.g., 0.5 m/s) to substrate.

- Deploy a messenger in deep water (> 2 m) or use pole or hand to trip the jaw mechanism.

- Lift the sample out of/off the substrate. Ensure the sample meets acceptability criteria (e.g., desired depth of penetration has been achieved, no loss of sediment sample due to incomplete closure or tilting of the grab sampler). If the criteria are not met, the sample should be discarded in a bucket and another sample collected from the site.

- Open jaws of the Ekman over a 250 µm mesh box sieve. Gently wash the sample using the box sieve, and transfer the contents to a 1-L plastic jar.

- Preserve sample with buffered formalin to a final concentration of 5% to 10% buffered formalin (see Section 6.3.4 for instructions on preparing 10% buffered formalin).

- The container must be externally labeled with a sample ID on the side and on the lid. Cap the sample container, double check the label, gently agitate the sample to distribute preservative throughout the sample, and wash the container to remove any excess formalin. Place sample container in transport device (backpack/cooler).

- Rinse the Ekman grab and sieve in ambient water to thoroughly remove any sediment, clinging invertebrates, or plant material.

6.4 SUPPORTING DATA

In addition to sampling benthic invertebrates at each site, a number of parameters are required to characterize the habitat in order to enable a more detailed analysis and facilitate interpretation:

- **Substrate Characterization -**
  - Depositional Sites – collect a separate grab/site for grain size analysis and total organic carbon content. Place one or more sediment samples in plastic a wash tub and decant off as much water as possible while maintaining sediment and silt. Collect enough sediment to fill each of the required sediment jars. Using a spoon, homogenize the sample and transfer sediment to appropriate containers provided by analytical laboratory and store them in a cooler.
  - Erosional Sites - Sediment grain size at erosional sites will be characterized by visually estimating percent areal substrate coverage according to standard size categories stipulated by the modified Wentworth classification system (Cummins 1962). See also the Field Data Sheet (Figure 6.1).

- **Routine field water quality** – measure dissolved oxygen, conductivity, temperature, and pH at each site (see Section 3.0 for details). Measurements should be made immediately upstream of the benthic sample to avoid measuring water quality overtop of or downstream from disturbed substrate.

- **Water Depth** - using a sounding line or velocity meter rod, measure the water depth for each site at the approximate location that the benthic invertebrate sample was collected.

- **Wetted and Bankfull Channel Width** - at the same riverine cross-section used to collect benthic invertebrates, use a tape measure or "range-finder" to measure the following:

- o Wetted Width - distance across channel from wetted perimeter to wetted perimeter; and
- o Bankfull Width - distance across channel from top-of-bank to top-of-bank, where the top-of-bank is normally demarked by vegetative growth (e.g., grasses, weeds, shrubs).

- **Flow Velocity** - use an electronic meter to record flow velocities at each site (repeat measurements 2 to 4 times, and calculate average). Alternatively, record the time for a partially submerged object to travel a 2 m distance (see field data sheet, Figure 6.1), and convert the time to a flow velocity. Velocity should be measured over the location that the benthic sample was collected.

- **Macrophyte Cover** - at all sites, as per the Site Characterization Form, estimate macrophyte cover (defined as the percentage of the site covered by macrophytes). Also list the dominant species.

- **Chlorophyll *a*** - at each replicate erosional site collect one sample of periphyton for analysis of chlorophyll *a* (i.e., 10 periphyton samples per erosional reach).
  - o Close to where the benthic invertebrate sample was collected, select three undisturbed rocks that have been exposed to the water's surface. Rocks with flat surfaces are preferable when available.
  - o Use a plastic template with a 2 cm x 2 cm square cutout in the center. Place the template on each rock and scrape periphyton and other materials (e.g., detritus, scum, etc.) from within the 4 cm^2 area with a scalpel or knife, and transfer to a 5 cm diameter filter paper. Combine the scrapings from all three rocks onto one filter paper to make one composite sample.
  - o Preserve the sample by sprinkling and covering the scrapings with magnesium carbonate powder.
  - o Fold the filter paper to enclose the scrapings, and wrap it in aluminum foil.
  - o Place the sample in a plastic bag with a label indicating the site and date.
  - o Keep the sample in cool, dark location (i.e., refrigerate) and then submit to the laboratory for analysis of chlorophyll *a*.

6.5 GENERAL EQUIPMENT AND SUPPLIES FOR BENTHIC INVERTEBRATE COMMUNITY SURVEYS

The following is a list of sampling equipment and supplies generally recommended for collecting benthic invertebrate community samples:

Sampling and Documentation

- Benthos sampling equipment (Hess sampler, Ekman grab, box sieve, rope, messenger, etc.);
- Field sample containers (obtained from the analytical lab) of appropriate type and number for desired analyses (grain size, total organic carbon, chlorophyll *a*, benthos taxonomy);
- Latex gloves;
- Sample preservatives;
- Ice packs/coolers;
- Waterproof labels, permanent markers and pencils;
- Field logbooks/binders;
- Maps, air photos, GPS unit, compass;
- Written protocols and procedures for sample collection and equipment operation, including FWIs;
- Supporting field equipment (e.g., water quality meters, measuring tape line, velocity meter and wading rod, periphyton sampling equipment, spare parts, and repair equipment, etc.);
- Camera or video equipment as required;
- Laboratory Chain of Custody/Analytical Request forms; and
- Transportation (truck, ATVs, boat, snowmobile, helicopter).

Health and Safety

- Personal gear for all possible field and weather conditions (e.g., survival suits, rain jackets/rain pants, appropriate footwear, waders, gloves, hat, change of clothes);
- First aid kit and survival kit;
- Personal floatation device for each crew member for deep water or boat work;
- Boat safety equipment including paddles, painters, bailer, throw-bag and whistle;
- Communication device (satellite phone when access is other than helicopter) and list of emergency phone numbers;
- Three wool blankets and emergency food and clothing;
- Buggy whip, hard hats, blue light, reflective vests if accessing oil sands mine site; and
- Spare jerry can of fuel, tow-rope, shovel and pick if access is by truck.

7.0 FISH SURVEYS

RAMP monitors fish populations in the Athabasca oil sands region because they are a good ecological indicator and a highly valued resource. Monitoring is conducted in the Athabasca River mainstem, tributary streams and regional lakes to evaluate whether fish populations are being affected by oil sands development and to ensure they are safe to eat for local residents. RAMP field studies conducted to address these issues include:

- Fish population inventories;
- Sentinel fish species inventories; and
- Fish tissue monitoring.

These surveys were designed to assess spatial and temporal changes in fish populations, health, and tissue concentrations of chemicals. Each of these surveys is described further below.

Key species of interest for the RAMP program include walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), lake whitefish (*Coregonus clupeaformis*), goldeye (*Hiodon alosoides*), longnose sucker (*Catostomus catostomus*), slimy sclupin (*Cottus cognatus*), longnose dace (*Rhinichthys catarctae*) and trout-perch (*Percopsis omiscomaycus*). With the exception of slimy sculpin and longnose dace, all species have been identified as key fish indicators for the Athabasca River by CEMA (2001).

Methods for fish surveys follow those used in previous RAMP programs (Golder 1998) and federal EEM guidance developed for the pulp and paper and metal mining industries (Environment Canada 2002; 2005).

7.1 PREPARATION FOR FIELD PROGRAMS

General tasks to be completed in preparation for conducting a fish population surveys are consistent with those previously outlined in Section 3.1 for Water Quality. Other equipment that will be needed includes:

- Equipment to capture fish, including electrofishing equipment, minnow traps, seine nets, fish fences, set lines and angling gear;
- Scale(s) to weigh fish (more than one scale may be needed depending on the size ranges targeted or if organ weights are required);
- Length board(s) to measure fish;
- Instructional binder on conducting internal and external fish health assessments;
- Appropriate sample containers, metal-free detergent, acetone, hexane, and non-chlorinated, non-powdered latex examination gloves for tissue sampling;

- Dissection kit for tissues collected using lethal methods;
- Solvent-rinsed foil (request from analytical chemistry lab) and plastic wrap for storing tissues for metals and organics analyses collected using lethal methods;
- Balance (± 0.001 or 0.0001 g), biopsy needles or tissue plugs, rubbing alcohol to disinfect plugs/needles between fish, tissue adhesive for sealing wounds, and screw-top cryovials for tissues collected using non-lethal methods; and
- Dry ice and coolers for storing tissue samples.

7.1.1 Collection Permits

Fishing permits should be obtained from provincial or federal agencies at least one month (if possible) in advance of the field program. In Alberta, permit applications for freshwater fish are obtained from the Sustainable Resource Department (SRD). Applications can be obtained from the SRD website (http://www.srd.alberta.ca/ManagingPrograms/FishWildlifeManagement/FisheriesWildlifeManagementInformationSystem/Default.aspx).

If anadromous fish are being targeted, or if fish are being collected from areas where anadromous fish reside, then a permit may also be required from the Department of Fisheries and Oceans (DFO). Refer to the DFO website for more information (http://www.pac.dfo-mpo.gc.ca/pages/default_e.htm).

Dates on permit applications should allow for unforeseen scheduling changes; if multiple sampling events are required within a given year, permits can be obtained that are valid for one year. Conditions associated with the permit are provided on the permit application.

7.2 FISH POPULATION INVENTORIES

Fish population inventories utilize non-lethal methods to assess various whole organisms metrics in target species.

7.2.1 Data Collection

Field notes and measurements should be recorded on the *RAMP Fish Population Data Sheet* (Figure 7.1) and/or in a waterproof field book. More information on data that should be recorded is provided in Section 2.5.1. The following information is typically collected during a fish survey:

- Electrofishing: upstream and downstream extent of electrofishing (UTM or latitude/longitude), and electrofishing time (seconds) and settings (amperes, voltage, pulse rate);
- All other fishing methods (i.e., beach seining, angling): method used, shore distance or area seined and station location (UTM or lat/long);

- Date and time of sampling or net set and retrieval;
- Field crewmembers;
- Number of samples collected;
- Photograph of sampling station; and
- Supporting data (e.g., water quality data, weather, current velocity, etc.).

7.2.2 Sample Collection

Fish Collection Methods

Fish can be collected using a variety of non-lethal methods, which are described below (modified from Golder 1998).

Electrofishing

Electrofishing refers to the use of electricity to stun and capture fish. An electrical current is passed between electrodes placed in the water and the resulting electrical field attracts nearby fish to the positive electrode (anode). The current gradient acts as a narcotic and stuns the fish, allowing them to be easily netted from the water. Fish captured by electrofishing revive quickly when returned to water. Electrofishing requires experience, trained operators to reduce injury to the fish and injury to field personnel.

Boat Electrofishing

Boat electrofishing can be used to effectively collect fish in moderately shallow water of larger streams, rivers, and lakes. Two types of boat electrofishers are available: a portable boat electrofisher used with an inflatable (e.g., Zodiac) or aluminum boat and an electrofishing boat. Both systems consist of an electrofishing control box powered by a 5,000-watt generator. The portable electrofisher has a free control box and generator that can be loaded into a small boat and is ideal for small or intermediate sized rivers. The electrofishing boat consists of an 18 ft aluminum river boat with a built-in electrofishing control box and generator. Boat electrofishers are designed for intermediate and large rivers systems that are deep enough to allow the boat and that have a suitable boat launch. These units are capable of generating the largest electrical field and highest current outputs.

Typically, the electrofisher is set to an average of 600 volts and 5 amps to attract and stun fish in select areas. However, electrofisher settings (voltage, current, and pulse rates) are selected based on water chemistry (especially conductivity), river conditions, and desired size range for target fish species. Boat electrofishing is typically conducted while floating downstream. Immobilized fish are collected at the surface using dip nets with 2 m insulated handles. A general description of electrofishing techniques is presented in Reynolds (1996). Electrofisher settings, the number of seconds of electrofishing, and the geographic coordinates of the area fished should be recorded.

Figure 7.1 RAMP fish inventory data sheet.

Oilsands Regional Aquatic Monitoring Program (RAMP)

FISH SAMPLE RECORD

Page _____ of _______

Date: dd mm yy   Stream/Waterbody: ____________________   Sampling Technique: ______________________________

Sample Identification Location	Page	Fish	Species Code	Fork Length (mm)	Weight (g)	Stage Code	Sex	Maturity Code	Age Structure	Tag Type	Tag Number	Capt/Ret Code	Comments or External Pathology (class/cond)
		01											
		02											
		03											
		04											
		05											
		06											
		07											
		08											
		09											
		10											
		11											
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		21											
		22											
		23											
		24											
		25											

Oilsands Regional Aquatic Monitoring Program (RAMP)
Codes For Fish Sample Record Form

Capture Method

	Electrofisher- Boat
	Electrofisher-Backpack
N	Gill Net
N	Beach Seine
T	Minnow Trap
T	Fry Trap
E	Post-Emergent Fry Drift Trap
N	Drift Net
U	Trap - Fish Moving Upstream
D	Trap - Fish Moving Downstream
T	Other -specify

Sex Code

	Female
	Male
	Unknown

Stage Code

	Fry
	Juvenile
	Adult
	Unknown

Age Structure

FR	Fin Ray
SC	Scales
SF	Scales + Finray
OT	Other (specify)

Tagging/Marking

F	Floy Tag
C	Fin Clip
OT	Other (specify)

Capture Release

0	First Capture - Released
1	First Capture - Sacrificed
2	Recapture - Released
3	Recapture - Sacrificed
4	Incidental Recapture

Maturity codes

IM	Immature
MA	Maturing
SD	Seasonally Developing
PR	Pre-spawning
RP	Ripe
SP	Spent
RS	Resting
RB	Resorbing
UN	Unknown

Species Codes

ARGR	Arctic grayling
BRST	Brook stickleback
BURB	Burbot
EMSH	Emerald shiner
FLCH	Flathead chub
FTMN	Fathead minnow
GOLD	Goldeye
LKCH	Lake chub
LKTR	Lake trout
LKWH	Lake Whitefish
LNDC	Longnose dace
LNSC	Longnose sucker
MNWH	Mountain whitefish
NRPK	Northern pike
RDSH	Redside shiner
RNTR	Rainbow trout
RVSH	River shiner
SLSC	Slimy sculpin
SPSC	Spoonhead sculpin
SPSH	Spottail shiner
SUSP.	Sucker spp.
TRPR	Trout perch
WALL	Walleye
WHSC	White sucker
YLPR	Yellow perch

External Pathology Codes

BOF Body Form	EM	Emaciated
	TR	Truncate
	SC	Scoliosis
	LO	Lordosis
	OT	Other (specify)
BOS Body Surface	LE	Lesion
	RM	Raised Missing Scales
	RS	Reoriented scales
	SW	Swollen
	EX	Excess Mucus
	GR	Growths &/or tumors
	PA	Parasites
	WO	Wounds &/or scars
	OT	Other (specify)
OPR Opercle	IN	Incomplete
	OT	Other (specify)
IST Isthmus	EN	Enlarged
	HM	Hemorrhagic
	OT	Other (specify)
PSD Psuedobranch	SW	Swollen
	LI	Lithic
	OT	Other (specify)
THY Thymus	HM	Hemorrhagic
	OT	Other (specify)
EYE Eyes	EX	Exopthalmia (Popeye)
	HM	Hemorrhagic
	CC	Cloudy cornea
	LD	Lens deformed
	LP	Lens parasites
	LC	Lens cataract
	BL	Blind
	MI	Missing
	OT	Other (specify)
LAJ Lips and Jaws	DE	Deformed
	GR	Growths &/or tumors
	OT	Other (specify)
SNT Snout	PN	Pugnose
	GR	Growths &/or tumors
	AB	Abrasions
	OT	Other (specify)
BAR Barbels if present	DE	Deformed
	MI	Missing
	OT	Other (specify)
ANU Anus	IN	Inflamed
	OT	Other (specify)
FIN Fins	FE	Frayed-eroded
	PA	Parasites
	HM	Hemorrhagic
	GB	Gas Bubbles
	OT	Other (specify)
GIL Gills	FR	Frayed
	CL	Clubbed
	MA	Marginate
	DI	Discoloured
	PA	Parasites
	GB	Gas Bubbles
	OT	Other (specify)
URO Urogenital	IN	Inflamed
	OT	Other (specify)

Location (Body Surface): 1-fins, 2-head, 3-eyes, 4-mouth, 5-peduncle, 6-ventral, 7-dorsal, 8-lateral

Location (Eyes): 1-right, 2-left

Location (Fins)	Severity
1-dorsal 2-pectoral	a-not active/healed
3-pelvic 4-anal	b-mild active no bleeding
5-adipose 6-caudal	c-bleeding infection

Backpack Electrofishing

Backpack electrofishing is used on small streams that can be safely waded. A backpack electrofisher (e.g., Smith Root Model Type 12B) consists of a portable electrofishing unit and a power source (12 V battery or mini gas generator) attached to a pack frame. It is equipped with a hand-held, button-operated anode pole and a cable or "rat tail' cathode that is left trailing in the water. The operator wears the pack unit and uses the switch to activate the submerged anode while wading in the stream. One or more assistants wading next to the operator will monitor and adjust the electrical current output, as well as capture stunned fish with a dip net. Sampling is normally conducted while moving upstream so that fish are not disturbed prior to being sampled. In faster currents, a pole seine (e.g., 2 x 1.2 m, 6 mm mesh size) positioned approximately 2 m downstream of the electrofisher can be used to collect stunned fish that are swept downstream too quickly to be seen an captured using a dip net (as described in Gibbons *et al.* 1998). Electrofisher settings, the number of seconds of electofishing, and the geographic coordinates of the area fished should be recorded.

Seine Netting

Seine nets consist of netting suspended between a float line and a lead line and are used to catch fish by dragging it through the water along the substrate. It is commonly used in areas along shorelines of streams, rivers, or lakes, where the substrate is smooth and the habitat is suitable for walking. Small meshed seines are used to capture small-bodied species and small life stages of larger fish species, while larger mesh seines are available for sampling large fish.

Beach seining is accomplished by two people dragging the net through the water while wading shallow water areas. Each person grabs one end of the net by placing their foot through a loop on the lead line and holding a loop at the end of the float line in their hands. One person walks out from shore to a suitable depth and both people walk parallel to the shore dragging the net between them. Care is made to ensure the lead line of the net is in contact with the substrate to prevent fish from escaping under the net. After a set distance, the outer person curves back into shore meeting the near shore person at the waters, pursing the two ends of the net together forming a pen holding the capture fish. Keeping the two lead lines together, the net is pulled up on shore with the fish.

A boat can also be used to pull the offshore end of the net when seining deeper water. A pole may be attached between the float and lead line of the boat end of the net to ensure separation of the net and contact of the lead line with bottom.

The geographic coordinates of the area fished, dimensions of the seine net (e.g., mesh size, length), number of hauls made, and the distance/area seined per haul should be recorded.

Angling

A rod, reel, and bait can also be used to capture fish for scientific purposes. The number of hours spent angling, equipment used, and type and number of hooks used should be recorded. Habitat descriptions and the length of shoreline covered while trolling should also be recorded.

Minnow Trapping

Minnow traps (e.g., Gee minnow traps) are used to capture small-bodied fish species or small life stages of larger species from shallow areas of lakes, ponds and streams. Traps are usually placed with the long axis parallel to the shore and tied to a stake, tree or anchor with sideline. The traps can be baited (e.g., open tin of cat food) to attract fish or unbaited if the objective is to capture fish moving through the area. The number of traps used and duration the traps were in place should be recorded as an estimate of fishing effort.

Fish Fence

RAMP has deployed fish counting fences to enumerate fish use of river systems during specific time periods. The most common objective is to document the number and species of fish entering a river as part of seasonal spawning runs. They consist of one or more trap boxes with fences (wings), which stretch out in front of the entrance of the boxes to lead fish into the trap. The fence extends the full width of the stream to intercept all fish moving through the stream. Either a one-way or two-way fence can be deployed. The one-way fence has only one trap box and one set of wings and is used to capture fish moving in one direction. A two-way fence has two trap boxes facing in opposite directions, each with its own set of wings, to capture fish moving in both directions. Fences should be place in easily accessible areas of low to moderate current velocity (i.e., < 9 m^3/s), stable substrate (i.e., not easily eroded) and at a depth that can be safely waded. Figure 7.2 shows set-up of the RAMP two-way counting fence deployed on the Muskeg River in 2003. Traps should be checked a minimum of twice a day; once in the morning and again in the evening. It is recommended that traps be checked more frequently during active spawning runs. Fish can be removed from the trap using a dip net. Once data from each fish are collected, the fish should be released beyond the fence to allow it to continue migration in the direction it was originally traveling.

If spring flow measurements, estimated from snow pack levels and late winter discharge conditions, are predicted to exceed a discharge threshold of 9 m^3/s, the RAMP Fisheries Sub-group may determine that the fence operation should be re-scheduled for the following year. Similarly, if actual discharge conditions immediately prior to fence installation exceed 9 m^3/s, installation of the fence will be postponed until conditions recede below the threshold, or it will be cancelled if it is felt that a significant portion of the spawning runs has already been missed (depends on flow and water temperature conditions). Based on knowledge gained from past fencing studies, a discharge of 9 m^3/s was the highest the fence could sustain for an extended period of time, and provided conditions suitable for the crew to safely install, maintain and monitor the fence.

Figure 7.2 View of Muskeg River fish fence looking upstream from right bank, May 2003.

7.2.3 Catch-Per-Unit-Effort (CPUE)

Catch-per-unit-effort (CPUE) is a measure of the number of fish captured per unit of sampling effort using a particular type of fishing gear. Results can be given for a particular species or the entire fishing reach. CPUE can be used to define the relative abundance of fish species and to compare abundances between sites and/or seasons. For all fish inventory surveys, sampling effort must be recorded so that CPUE can be calculated. The unit of sampling effort is specific to gear type. CPUE calculations for fishing methods commonly used during RAMP include:

- Electrofishing – number of fish/100 seconds of electrofishing;
- Seining – number of fish/area (m^2) or length of shoreline seined (m);
- Angling – number of fish/angler or rod hour;
- Minnow Trapping – number of fish/hour or trap-hour; and
- Fish Fence – number of fish/hour or day.

7.2.4 Fish Holding

When non-lethal sampling methods are used, live fish (target species and others) may be temporarily placed into a 45 gallon, plastic holding tank in the boat containing approximately 25 gallons of ambient water. The status of fish in the holding tanks should be monitored continuously to ensure that holding stress is minimized. An aerator is used to maintain oxygen levels in the holding tank;

fresh ambient water is regularly added to refresh water in the holding tank. Alternatively, many electrofishing boats are equipped with a live-well holding tank with water circulation where fish can be held until processing. If fish are to be processed on shore while the boat continues fishing, fish can also be held in a live car or fish cage placed in shallow water of the river or lake.

7.2.5 Fish Processing

Typically, fish are processed on shore in a mobile laboratory or appropriate facility. Fish are transferred by dip net and field crew that handle the fish wear disposable non-powdered latex gloves.

7.2.6 Measurements

Whole Organism Metrics

a) Fish Size

The following data are collected to assess fish size:

- Fork Length – length measured from the most anterior part of the fish to the tip of the median caudal fin rays (+1 mm) using a standard measuring board; and
- Whole Weight – total weight will be recorded using either an electronic scale with digital readout (+10 g). The balance should be calibrated daily to ensure accuracy.

Some species such as burbot, sculpins or darters do not have a forked caudal fin. For these species, the standard measurement is total length defined as the distance from the most anterior part of the head to the distal tip of the longest caudal fin ray.

b) Fish Health Assessment

Fish captured during inventory surveys undergo a non-lethal external examination for signs of injury, abnormalities, parasitism, or disease. The assessment of external abnormalities follows methods outlined by Adams *et al*. (1993) and Environment Canada (2005). In addition to noting obvious lesions or tumors, the examination notes health status of a specific organs or structures:

- Skin – discoloration, modified scale pattern, lesions;
- Skeletal Structure - abnormal curvature of spine, jaw deformation;
- Fins – deformation, frayed rays, missing fins, erosion;
- Eyes – opaque, swollen, protruding, bleeding, missing;
- Opercles – missing, shortened or abnormal shape;
- Gills – pale, clubbed, marginate, frayed;

- Pseudobranchs – swollen, lithic, inflamed; and
- Thymus – hemorrhages.

c) Other Variables

Sex and state of maturity are recorded when discernable by external examination. The sex of pre-spawning fish can often be identified externally when eggs or milt (sperm) are exuded with the application of light pressure on the abdomen. As well, some fish species exhibit external secondary sex characteristics that facilitate sexing of fish. Sucker species are a good example in that the males often have tubercles (small bumps) along the rays of the anal fin. Other species may show differences in coloration or external structures throughout the year or immediately prior to spawning.

d) Fish Age

Ageing structures are bony parts of the fish that are taken for ageing analysis. In fish from temperate zones such as Canada, these structures contain annual bands or annuli that represent seasonal variation in growth and can be counted to estimate the age of the fish. The primary ageing structures for non-lethal surveys include scales, fin rays and spines. Scales from each fish should be removed from the left side of the fish, above the lateral line, between the dorsal and adipose/caudal fins (Devries and Frie 1996). Following the removal from the fish, ageing structures should be placed in a small coin or "scale envelope" with, as a minimum, the date, fish number, species, sampling location, type of ageing structure and the project number written on the outside. Adding information such as the fork length, weight, sex and life history stage may also be useful when identifying the fish at a later date. Scale envelopes should be allowed to dry overnight before being stored then archived frozen in a freezer.

With respect to fish ageing, all ageing structures collected and methods used to determine age follow procedures described in the manual of Fish Ageing Methods for Alberta (Mackay *et al.* 1990).

e) Anchor or Floy Tagging

Larger fish species captured by RAMP are often marked with a floy tag. The tag aids in the identification of individual fish or simply fish that have been captured by RAMP. The tag is shaped like an inverted "T" and is most commonly inserted through the back of the rear portion of the dorsal fin and anchored between the bones of the dorsal fin using a special tagging gun. The colorful posterior portion of the tag remains outside of the fishes' body and is marked with the RAMP acronym as well as the phone number of the ASRD contact (to date, Sara Bumstead).

7.3 SENTINEL SPECIES MONITORING

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, 2005) and metal mining (Environment Canada 2002) effluent regulations.

For the RAMP, operational or exposure sites are located immediately downstream of oil sands developments. Reference sites are located either in the same watercourses, upstream of the development, or in other watercourses of similar habitat and beyond the influence of oil sands operations.

In 2004, the sentinel-species monitoring program switched from lethal to non-lethal sampling techniques. The rationale for the change in the program approach was to reduce the pressure of annual sampling on fish populations. Detailed methods for conducting a non-lethal sentinel species survey are presented in Gray *et al.* (2002). Methods used previously for lethal sampling were based on those used in the federal EEM program (Environment Canada 2002; 2005). Emphasis has been placed on using small-bodied sentinel species due to their short life span (i.e., responsive to current conditions), limited home range and mobility (i.e., greater exposure potential), and high abundance relative to large species. As of 2005, RAMP has focused on slimy sculpin (*Cottus cognatus*) at the Muskeg and Steepbank rivers, longnose dace (*Rhinichthys cataractae*) at the Ells River and trout-perch (*Percopsis omiscomaycus*) at the Athabasca River.

7.3.1 Fish Collections

The non-lethal sampling program includes two sampling trips: 1) a mid to late summer trip (August) that focuses on non-lethal collection of all size classes of the sentinel species from a defined area along the watercourse; and 2) a late fall trip (October) to collect sentinel fish from the same sampling areas to evaluate growth. For streams and small rivers, an area is defined by placing two small-mesh, full span block nets approximately 50 to 80 m apart to stop upstream/downstream movement of fish. Crews of two or three people using a backpack electrofishing unit and a portable pole seine fitted with a 1/8" net systematically electrofish the enclosed area. If possible, multiple passes of the enclosed area are conducted to ensure all sentinel fish have been captured. This information is used to estimate the density of the sentinel species. A target of 100 fish is the recommended sample size. If necessary, additional sampling outside the enclosed area is conducted until 100 fish have been captured. In October, blocking nets are not used, but 100 fish are again collected from the general sampling area. All fish captured during the survey are held temporarily in a bucket of freshwater. Field notes and measurements should be recorded on the *RAMP Sentinel Fish Collection Sheet* (Figure 7.3) and/or in a waterproof field book. Once the fish have been processed, all fish are released to the same area of the stream from which they were caught.

7.3.2 Measurements

Data on fish lengths (± 1.0 mm), weights (± 0.01 g), and external appearance are collected in accordance with methods described in Section 7.2.6. To provide supplemental data on age classes, ageing structures from ten individuals per sampling area may also be collected to facilitate the interpretation of future length-frequency analyses and the identification of cohorts.

During each sampling trip, supporting habitat information is collected at each site including channel morphology, cross-sectional current velocity measurements, water depth, *in situ* water quality measurements and vegetative cover.

7.4 FISH TISSUE SURVEY

The RAMP fish tissue program is conducted to measure the concentrations of chemicals present in muscle tissue of fish and to identify any potential consumption risk to humans, fish, and wildlife. Historically, the program has used lethal sampling methods to collect muscle tissue; however, in 2004 non-lethal methods (i.e., biopsy needles or tissue plugs) were found to be successful. Both methods are described below.

7.4.1 General

For each selected fish species, up to 25 individuals from five size classes are targeted for mercury analyses. The target size classes used for monitoring programs in the Athabasca River, Clearwater River, Muskeg River, and select lakes within the RAMP regional study area are summarized in Table 7.1.

Mercury is measured in all fish selected for tissue analyses, while a more comprehensive suite of metals and tainting compounds is completed on composite samples (n = 5 fish per composite for each sex and species combination).

Figure 7.3 RAMP Sentinel Species Collection Sheet.

Creek: ______________________ **Start Date/Time:** ______________________ **Start UTM (D/S): E** __________ **N** __________

Batch: ______________________ **End Date/Time:** ______________________ **End UTM (U/S): E** __________ **N** __________

Crew: ______________________ **Photos:** Roll#: Photo #s: ______________ **Weather:** ______________________

Fishing Gear: **EF MT AG SN** **Net/Pass No.:** ______________________ **Effort:** ______________ Open Closed

Net/Mesh Size: __________ **EF Settings:** ______________________ **EF seconds:** #1: #2: #3:

Habitat type (%): Riffle:______ Pool:______ Glide:______ **Gradient (%):** __________ **W width (m):** __________ **Habitat comments:** ______________________

Pass#	**Fish ID**	**Species**	**Fork Length** (mm)	**Weight** (g)	**Stage Code**	**Aging Structure**	**External Fish Health Assessment Checklist**					**Comments**
							Fin Erosion	Skin Abberations	Bleeding/ Swollen Eye	Clubbed or Frayed Gills	Shortened Opercles	
						Y N						
						Y N						
						Y N						
						Y N						
						Y N						
						Y N						
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Stage: F=fry, J=Juvenile, A=Adult, U=Unknown **Aging Structure:** OT=Otolith, FR=Fin Ray, SC=Scales, CL=Cleithra

Comments:

Table 7.1 Target fork length classes for the RAMP fish tissue sampling program.

Species	Target Size Classes for Mercury Analysis (mm) (5 fish per class)					Target Size Classes for Composite Samples	
	1	2	3	4	5	Female	Male
Walleye	200-300	301-400	401-500	501-600	601-700	500-550	450-500
Northern pike	200-300	301-400	401-500	501-600	601-700	500-550	450-500
Lake whitefish (Athabasca River)	350-400	401-450	451-500	501-550	551-600	400-450	400-450
Lake whitefish (regional lakes)	200-300	301-400	401-500	501-600	601-700	400-450	400-450

7.4.2 Preparation for Dissections

The chemical compounds of interest dictate the equipment used for tissue dissection. Disposable aprons or clean lab coats and gloves should be worn during all dissections.

Metals – Special care is required to minimize the chance of contaminating samples for metals analyses. Dissections should be done on a washable plastic surface covered with a **disposable plastic sheet** that can be changed after each dissection. The use of high quality, corrosion resistant stainless steel dissecting instruments is often acceptable (unless low level chromium and nickel analyses are being conducted), otherwise, knives of titanium blades can be used. All dissecting equipment should be cleaned/washed before and between fish with a **metal-free detergent** solution and rinsed with distilled water.

Organic compounds – Ensure tissues are dissected on a clean, washable surface covered in **solvent-rinsed or combusted aluminum foil** that is changed after each dissection. The use of clean high quality stainless dissecting instruments is acceptable. All dissecting equipment should be cleaned/washed before and between fish with distilled water, cleaned with a metal-free detergent, rinsed with distilled water, rinsed with **acetone and hexane**, and then allowed to dry. Non-chlorinated, non-powdered latex gloves should be worn when cleaning equipment, and changed prior to starting dissections.

7.4.3 Lethal Sampling Methods

7.4.3.1 Prior to Dissection

As mentioned above, muscle tissue is collected from each fish for mercury analyses. Additional muscle tissue is collected from five males and females for composite samples. Lethal sampling is conducted in accordance with previous protocols followed by RAMP (Golder 1998).

Each fish is rendered unconscious by concussion and measured for fork length and total body weight. An external health examination is also conducted following methods outlined in Section 7.2.6. Prior to dissection, fish are sacrificed by spinal severance and placed on a dissection pan.

7.4.3.2 Collection of Muscle for Chemical Analyses

The left side of the fish, which will be filleted to collect a sample for organics analysis, should be placed on the solvent-rinsed aluminum foil. The right side of the fish, which will be filleted to collect a sample for metals analysis, should be facing up and not come into contact with the foil. Muscle tissue samples should be collected prior to internal dissection of the fish. Muscle should be collected above the lateral line and posterior to the dorsal fin. Skin or bone should be removed from the muscle tissue, unless the sampling program requires them. Minimum muscle tissue requirements per fish are 20 g for organic compound analyses and 2 g for metals analyses (for most fish these minimum weights will be exceeded). Muscle samples collected for **organics analyses** should be individually **wrapped in solvent-rinsed (hexane and acetone) aluminum foil (<u>not plastic</u>)** and samples collected for **metals analyses** must be individually **wrapped in plastic wrap (<u>not foil</u>).** All samples must be labeled with the fish ID, sampling location, date, and analyses requested, stored on dry ice, and shipped to analytical lab.

7.4.3.3 Assessment of Internal Structures

The body cavity of the fish is opened on the ventral surface by cutting from the anus up to a point posterior to the pelvic fins. The intestine can be closed off with a clamp to avoid any tissue contamination. Tissues are removed from the organism using forceps. Contact between gloves and tissue is avoided. The gonads are removed and weighed. The liver is removed from the fish using forceps or by hand (depending on liver size) and weighed. In the event that the liver is collected for tissue analysis then care should be taken to remove the gall bladder from the liver without contaminating the liver tissue with bile. If the gall bladder is punctured, the liver should be rinsed with saline solution or distilled water.

During dissections, internal organs and structures are examined for potential anomalies using a modification of the approach described in Adams *et al.* (1993). Organs and structures examined include:

- Kidney – swollen, mottled, granular;
- Spleen – color, granular, nodular, enlarged;
- Mesenteric fat – amount of fat associated with the gut and intestines;
- Hindgut – occurrence of inflammation;
- Gall bladder – color, fullness;
- Incidence of parasites – level of infestation.

7.4.3.4 Collection of Ageing Structures

Following removal of muscle tissue, ageing structures should be collected. The preferred ageing structures (lethal and non-lethal) for select freshwater species are summarized in Table 7.2. These structures contain bands or annuli that represent seasonal variation in growth and can be used to estimate the age of the fish. The structure that is the best indicator of fish age varies from species to species.

Structures most commonly used to age fish include scales, otoliths, and fin rays/spines. Scales are usually removed with a knife from the left side of the fish, above the lateral line, between the dorsal and adipose/caudal fins (Devries and Frie 1996). Saggital otoliths are removed by placing the fish species on its dorsal side, removing the gills with a knife, and then severing the spinal column between the second and third vertebrae; exposed otoliths are then removed with forceps. Otoliths and scales are stored dry in labeled envelopes (indicating species, location, sample number, date captured, and other relevant data). Otoliths for some species may also be stored in glycerin.

7.4.3.5 Assessing Fish Maturity

The following codes are used for assessing maturity of fish (Golder 1998):

- **Unknown** – State of maturity cannot be determined.
- **Immature** – Fry or juvenile fish with undeveloped, string-like gonads that are small and transparent. Fish has never spawned and will not spawn in the coming season. Male gonads will be smooth yellow, pink, or white structures. Female gonads will be granular yellow or pink structures.
- **Maturing** – Adult fish with developed gonads (i.e., enlarged, sperm or egg development apparent). Posterior end of the gonad may thin and undeveloped (similar to gonad from an immature fish). Fish has not spawned before but will spawn in the coming season. Male testes and female ovaries will be larger than those observed in immature fish but smaller and paler than fully developed males.
- **Ripe** – Sexually mature adults in spawning condition with loose semen and eggs in the gonads. Semen (milt) and eggs will be extruded with application of slight pressure on the abdomen, which will be distended. In males, testes will be large and white. In females, yellow/orange large ovaries with large and transparent eggs will be apparent.
- **Spent** – Sexually mature adults in post-spawning condition. In males and females, the abdomen will be flaccid, and it may be possible to extrude small amounts of watery semen or eggs. The testes will be reduced in size, gray to creamy white in color, and blood vessels may be apparent on the surface. Ovaries will be reduced in size, dark orange to brown in color, and may contain residual eggs.

Table 7.2 Preferred ageing structures for select freshwater fish species (adapted from MacKay *et al.* 1990).

Species	Sampling Method			
	Lethal		Non-Lethal	
	Primary	Secondary	Primary	Secondary
Lake sturgeon	Otoliths	-	**First pectoral fin rays**[1]	-
Arctic graying	Sagittal otoliths	-	Scales[2]	Pectoral fin rays
Cisco	**Sagittal otoliths**	-	**Scales**[2,6]	-
Lake whitefish	**Sagittal otoliths**	-	**Scales**[2,6]	Pelvic fin rays
Mountain whitefish	Sagittal otoliths	-	Scales[4]	-
Lake trout	**Sagittal otoliths**	-	**First three pelvic fin rays**[1]	Scales
Bull trout	**Sagittal otoliths**	-	**First three pelvic fin rays**[1]	-
Brook trout	**Sagittal otoliths**	-	Scales[3,7]	-
Brown trout	**Sagittal otoliths**	-	Scales[4,7]	-
Rainbow trout	**Sagittal otoliths**	-	Scales[5,6]	
Cutthroat trout	**Sagittal otoliths**	-	Scales	-
Northern pike	**Cleithrum (freeze)**	Opercular bones and vertebrae	**First three pelvic fin rays**[1]	Scales[4,7]
Goldeye	**Operculum**	-	First three pelvic fin rays[1]	Scales[3,8]
Mooneye	**Operculum**	-	First three pelvic fin rays[1]	Scales[3,8]
Yellow perch	Opercular bone	-	**Pelvic spine and first 2 fin rays**[1]	Anal spines (2)[1]
Walleye	Opercular bone	Otoliths	**Pelvic spine and first 2 fin rays**[1]	Dorsal spine
Sauger	Opercular bone	Otoliths	**Pelvic spine and first 2 fin rays**[1]	Dorsal spine
Burbot	**Sagittal otoliths**	-	-	-
Suckers spp.	-	Otoliths	**Pectoral fin rays**[1]	Scales[8]
Trout-perch	Otoliths	-	-	-
Sculpin spp.	**Otoliths**	-	Length-frequency analysis	-
Cyprinid spp.	**Otoliths**	-	Scales	Length-frequency analysis
Flathead chub	Otoliths	-	**Pectoral fin rays**[1]	Scales
Stickleback spp.	Otoliths	-	Length-frequency analysis	-

Bolded structures represent the preferred aging structure for that species.

[1] Collect proximal end.

[2] Collect a minimum of 10 to 15 scales from the left side of the fish between the front edge of the dorsal fin and the lateral line.

[3] Collect a minimum of 10 to 15 scales from between the dorsal fin and lateral line.

[4] Collect a minimum of 10 to 15 scales posterior to the dorsal fin and above the lateral line.

[5] Collect a minimum of 10 to 15 scales immediately dorsal to the lateral line, between the posterior edge of the dorsal fin and origin of the anal fin.

[6] Preferred for fast-growing fish.

[7] Preferred for fish < 3 years old.

[8] Preferred for fish < 5 years old.

7.4.3.6 Collection of Muscle for Tainting Assessments

Fish tissues may also be collected to assess the tainting of fish tissues, which affects the palatability and odor of the flesh. Fish are dissected using methods described for organics analyses; however, additional care is taken to ensure that fish are not exposed solvents or other chemicals during sampling.

7.4.3.7 Sample Shipping and Analysis

Samples to be analyzed for standard mercury analyses (CVAAS) are shipped frozen to ALS Laboratories in Fort McMurray (Bay1-245 Macdonald Crescent Fort McMurray, AB T9H 4B5). Analyses should be conducted in accordance with methods used previously (Lab work order # L692585; job # 1393-3106). However, a note should be included on the chain of custody (COC) that composite samples should be analyzed using lower detection limits (mg/kg) for the following metals: As - 0.006; Al – 2; Cd - 0.01; Se - 0.06; Ag - 0.02; and V - 0.006.

7.4.4 Non-Lethal Sampling Methods for Tissue Mercury Analyses

7.4.4.1 General Information

Muscle tissue plugs can be used to assess contaminant concentrations (for RAMP it is used for mercury analyses) in fish populations without having to sacrifice large numbers of fish. Plugs of muscle can be collected from fish using biopsy needles or dermal punches. Non-lethal sampling using this approach is particularly advantageous in situations where target fish species are rare or threatened. Mortalities and long-term sublethal effects on fish associated with this approach have been found to be low (Baker *et al*. 2004). More detailed information on the methodology of this approach is provided in Baker *et al.* (2004).

7.4.4.2 Sampling Considerations

- Fish must be of sufficient size (fork length greater than 180 mm) to remove a tissue plug without causing mortality.
- Tissue biopsy needles are less invasive and collect a smaller amount of tissue. Dermal punches are more invasive and collect a larger amount of tissue. A study conducted by Baker indicated that a mean weight of 47 mg of tissue (two composite plugs) was collected using a 3" long biopsy needle and 126 mg of tissue (two composite plugs) was collected using dermal punches. RAMP has used both procedures in the past. The biopsy needle used by RAMP was 4.5 in long collected slightly more tissue. At the time of writing, the dermal punch has been easier to acquire from the supplier relative to the biopsy needles. A veterinarian is also required to order the biopsy needle.
- On live fish, all wounds must be sealed with a tissue adhesive.

- The estimated time of collection is 30 to 45 seconds for the dermal punch and 10 seconds for the tissue biopsy needle (trained technician).
- The number of plugs collected from each fish will depend on analytical requirements. For mercury analysis described in Baker *et al*. (2004), composites of two plugs were collected to ensure tissue weights met analytical requirements. Flett Research has refined its methodology to measure samples from one plug.

7.4.4.3 Prior to Collecting the Tissue Sample

- It is recommended that the sampling technique be practiced in advance of field sampling on fish (with skin) purchased from grocery store.
- All dissecting equipment must be cleaned appropriately prior to sampling (washed with Liquinox then rinsed with deionized, distilled water).
- Analytical labs should be notified of number of samples that will be sent and date of sample arrival. For the smaller tissue weights associated with non-lethal tissue sampling, Flett Research should be used for sample analyses. Flett recommends shipping samples early on in the week (by Wednesday at the latest), to ensure that samples are not stored improperly while in the care of the courier.
- Prior to sampling, sample vials can be labeled and then weighed. Vial weights should be recorded so wet weights can be estimated.

7.4.4.4 Collecting the Tissue Sample

Details on methods are taken with permission from Baker *et al.* (2004).

- Fish should be anaesthetized with clove oil prior to being handled.
- Information of the water body sampled, date and time of sampling, and fish species, weight (g), length (mm), and sex should be recorded. An external examination for abnormalities should also be conducted.
- **Using a biopsy needle** – The True-Cut tissue biopsy needle is a 14-gauge double-barreled device with a cannula for contained harvested muscle. Estimated time of sample collection is 10 seconds. To collect a tissue sample:
    - A needle should be inserted forward at an oblique angle beneath a scale into the dorsal musculature (i.e., needle should run along muscle wall, not go through the fish cavity). If inserted improperly the needle can penetrate the swim bladder.
    - The outer barrel, which possesses a sharp leading edge, should be extended over the inner needle to cut and capture a small tissue plug within the cannula.

  - o The needle should then be withdrawn and opened, and the tissue sample removed with clean tweezers.

- **Using a dermal punch** – A 4 mm diameter Acu-Punch biopsy punch measuring 4 inches in length is used to collect tissue plugs. Estimated time of sample collection is 30 to 40 seconds. To collect a tissue sample:
  - o Several scales should be removed using the tip of the punch.
  - o The punch is placed against the exposed epidermis and a downward twisting motion is used to penetrate several millimeters into the tissue.
  - o The punch then is rotated parallel to the fish and twisted to cut and capture a small piece of muscle and skin in the punch.
  - o The plug is blown onto a clean glass slide and the skin is removed from the plug with a scalpel.
- The tissue plugs should be placed in the pre-weighed vial and weighed immediately after collection to obtain a wet tissue weight. The minimum tissue weight required is 40 mg; however, efforts should be made to collect closer to 50 mg from each fish.
- The vial should be placed on dry ice then transferred to a freezer at the end of the day to eliminate potential effects of moisture loss on Hg concentrations. Care should be taken to ensure that the vial is completely sealed.
- The wound left from the plug should be sealed with a tissue adhesive.
- Dissecting equipment should be cleaned with detergent and rinsed with distilled water between fish to avoid cross-contamination.
- The biopsy needle should be rinsed in deionized distilled water between fish. When sampling live fish, the needle should be rinsed with rubbing alcohol to avoid transmitting diseases between fish.
- Fish should be allowed to recover prior to being released.

7.4.4.5 Sample Shipping and Analysis

Samples shipped on dry ice to Flett Research for low-level mercury analyses should be sent by courier on a Monday, Tuesday, or Wednesday at the latest to avoid problems with sample handling. Samples should be shipped by courier to the attention of Bob Flett at Flett Research (440 DeSalaberry Ave., Winnipeg, Manitoba, R2L 0Y7) for CVAFS analyses. A request should be made on the COC for determination of wet and dry weights for tissue plug samples.

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