OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) 2000

VOLUME I:

CHEMICAL AND BIOLOGICAL MONITORING

Golder Associates Ltd.

10th Floor, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

FINAL REPORT ON

OIL SANDS REGIONAL AQUATIC MONITORING PROGRAM (RAMP) 2000

Submitted to:

RAMP Steering Committee

2001 **002-2309**

Golder Associates Ltd.

10th Floor, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

March 26, 2001 002-2309

Attention: Distribution List

RE: Oil Sands Regional Aquatics Monitoring (RAMP) 2000 Report – Volume I

Attached is Volume I of the Oil Sands Regional Aquatics Monitoring (RAMP) 2000 Report. There are two volumes this year. Volume I includes the results of water quality, sediment quality, benthic invertebrate and fish monitoring. Volume II includes the results of the Climate and Hydrology Program.

Yours very truly,

GOLDER ASSOCIATES LTD.

Marie Lagimodiere, MES, P.Biol
Aquatic Biologist

Distribution

Brent Pasula	ExxonMobil – 2 copies
Andrew Cummins	Suncor Energy Inc., Oil Sands – 4 copies
Judy Smith	Shell Canada Limited
Noreen Easterbrook	Albian Sands Energy Inc. – 2 copies
Collin Cumberland	Petro-Canada Oil and Gas – 2 copies
Terry Van Meer	Syncrude Canada Ltd. - 2 copies
Bill Hunter	Syncrude Canada Ltd.
Geoff Chow	TrueNorth Energy – 2 copies
Mark Spafford	Alberta Pacific Forest Industries Inc.
Michael Burt	OPTI Canada Inc. – 2 copies
Brad Braun	Canadian Natural Resources Ltd. – 2 copies
Ken Shipley	Fort McKay Industry Relations Corporation
Bertha Ganter	Fort McKay Industry Relations Corporation
Bryan Kemper	Kemper^2 & Associates
Eric Davey	Athabasca Tribal Council – 5 copies
Scott Mackenzie	R.L.&L. Environmental Services Ltd.
Sonny Flett	Fort Chipewyan Metis
Margaret Fairbairn	Environment Canada – 2 copies
Marlene Evans	Environment Canada – 1 copy
Bev Ross	Department of Fisheries and Oceans
Fred Hnytka	Department of Fisheries and Oceans
Jay Nagendran	Alberta Environment
Anita Sartori	Alberta Environment – 2 copies
Larry Rhude	Alberta Environment
Leigh Noton	Alberta Environment
Jordan Sharon-Kuschminder	Toxics Watch Society
Gail MacCrimmon	Oil Sands Environmental Coalition

EXECUTIVE SUMMARY

Purpose and Scope

Northeastern Alberta is experiencing a large increase in oil sands development as well as other developments. To integrate monitoring activities in the Oil Sands Region, monitoring data pertaining to the aquatic environment are collected through the Oil Sands Regional Aquatics Monitoring Program (RAMP). RAMP is a multi-stakeholder initiative, currently funded by Albian Sands Energy Inc. (Albian), ExxonMobil, Petro-Canada Oil and Gas (Petro-Canada), Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), and TrueNorth Energy L.P. (TrueNorth).

RAMP is designed as a long-term monitoring program with sampling frequencies ranging from continuous or seasonal to once every few years. RAMP has been in place since 1997; hence, four years of sampling have been completed. The results of the 2000 RAMP are included in this volume; climate and hydrology are reported in Volume II.

The 2000 monitoring program included in this volume consists of the following main components:

- water and sediment quality in the Athabasca River, the Athabasca River Delta, and some tributaries to the Athabasca River;
- water quality in four wetlands;
- continuous temperature monitoring in some tributaries to the Athabasca River;
- benthic invertebrate communities in three tributaries to the Athabasca River and one wetlands;
- fish populations, including radiotelemetry in the Athabasca and Muskeg rivers, a spawning survey of Jackpine Creek and the lower Muskeg River and a reference site survey for sentinel species monitoring of tributaries of the Athabasca River;
- water quality in acid sensitive lakes; and
- a quality assurance/quality control program.

The study area for RAMP was recently revised to include the Regional Municipality of Wood Buffalo. Also, a focus area has been located within the RAMP study area, which includes rivers and lakes located south of Fort McMurray that have not been included in RAMP previously. OPTI Canada Inc., which joined RAMP in February 2001, conducted a baseline study located southeast of Fort McMurray in 2000. The study has been included in this report.

Water and Sediment Quality

The results of the 2000 program indicated that water and sediment quality in the Athabasca River and tributaries to the Athabasca River was generally consistent with historical data. Naphthenic acids were detected in the Athabasca River from upstream of Donald Creek to upstream of Fort Creek, and at eight of the ten sampling sites on the tributaries. PAH concentrations in sediments were higher than historic levels for sediment samples collected in the Athabasca River, upstream of Donald Creek, the Muskeg River and Fort Creek, and in McLean Creek. Sediments from the lower Athabasca River, including Athabasca Delta, were found to be toxic to several species of invertebrates.

Benthic Invertebrate Community

The benthic invertebrate data collected during the fall 2000 field program of RAMP represents the second year of monitoring the lower reaches of three tributaries of the Athabasca River (the MacKay, Steepbank and Muskeg rivers) and the first year of monitoring a wetlands (Shipyard Lake). The total abundances of benthic invertebrates were low in the erosional habitats of all three rivers and moderate to high in the depositional habitat found only in the Muskeg River. All three rivers supported diverse benthic faunas. The taxonomic richness was similar in all three rivers and both habitats (erosional and depositional). The erosional reach of the Muskeg River supported the highest number of taxa, as it did in 1998.

Fish Populations

A radiotelemetry study focussed on the mobility of longnose sucker, northern pike and Arctic grayling. The majority of radio-tagged longnose sucker known to spawn in the mainstem Athabasca River moved to Lake Athabasca within two to three weeks of spawning. However, only a small portion of tagged longnose sucker known to spawn in the Muskeg River migrated to Lake Athabasca. Most longnose sucker and northern pike tagged in the Muskeg River remained in the Athabasca River mainstem, the Muskeg River or other tributaries. It is believed that the presence of large beaver dams prevented the normal spawning run of Arctic grayling up the Muskeg River. Therefore, Arctic grayling could not be radio tagged.

A spawning survey of Jackpine Creek and the lower Muskeg River found that the availability and accessibility of suitable spawning habitat was greatly reduced in 2000 due to the presence of numerous beaver dams. Based on past studies, suitable habitat had been available in Jackpine Creek and the lower Muskeg River for Arctic grayling, sucker species and northern pike.

A survey of potential reference sites for future monitoring of sentinel fish species in the Muskeg and Steepbank rivers confirmed that slimy sculpin is the most abundant and widely distributed small-bodied fish species in the RAMP study area, and is best suited for sentinel species monitoring. Three of the nine potential reference sites investigated were suitable for monitoring. All three were recommended as reference sites to more accurately define natural variation in slimy sculpin populations.

Wetlands

Wetlands vegetation and sediment quality were not scheduled for study in 2000. Water quality in Kearl, Isadore's, Shipyard and McClelland lakes, and benthic invertebrate communities in Shipyard Lake were monitored in 2000. The results have been discussed above. The benthic invertebrate data collected during the fall 2000 field program of RAMP represents the first year of monitoring a wetland (Shipyard Lake). The survey of Shipyard Lake documented a relatively diverse lake community with low total abundance, in contrast to the impoverished fauna found in the previous survey of this lake. The available data for this lake suggest that benthic communities vary considerably among seasons and /or years.

Shipyard, Isadore's, McClelland and Kearl lakes were all included in the 2000 water sampling survey. Water quality in the four lakes sampled was generally consistent with historical data, with the exception of increased nutrient levels in Isadore's Lake. Toxicity (as defined by Microtox® testing) was observed for the first time in Shipyard Lake. Naphthenic acids were detected in McClelland Lake.

Acid Sensitive Lakes

Water samples were collected from 30 acid sensitive lakes in northeastern Alberta, as part of the second year of monitoring under RAMP. Comparison of lake-specific critical loads with potential acid input revealed that the critical loads were exceeded or nearly exceeded by the current acid deposition rates in three lakes away from sources of acidifying emissions and in three lakes close to oil sands development. These observations are of no immediate concern, because estimates of both critical loads and potential acid inputs are conservative. Acidity-related variables (pH and alkalinity) showed no substantial variation in 2000 compared to the 1999 and historical data. At this time, the available data are insufficient to evaluate trends over time.

Baseline South of Fort McMurray

OPTI Canada Inc. joined RAMP in February 2001. A baseline aquatic resources evaluation was completed in 2000 as part of the Environmental Impact Assessment of the OPTI Long Lake Project. Baseline surveys of water quality were carried out during the spring and fall of 2000. The Gregoire River and its tributaries, and Canoe, Long and Pushup lakes were sampled for detailed water chemistry. Two unnamed lakes were sampled in less detail. In water samples from the Gregoire River system, total phosphorus, sulphide, aluminum, iron and manganese in the spring samples, and lead and zinc in the fall samples exceeded chronic guidelines for the protection of aquatic life. Canoe, Long and Pushup lakes were similar in terms of water chemistry. Sulphide, aluminum, copper, iron, lead, manganese and zinc concentrations exceeded the chronic guidelines.

Quality Assurance/Quality Control

The results of the RAMP QA/QC assessment of field sampling and laboratory analysis indicate that water quality data analyzed by ETL, sediment quality data analyzed by AXYS and data analysis performed by Golder are valid.

ACKNOWLEDGEMENTS

This report documents the results of the fourth year of the Oil Sands Regional Aquatics Monitoring Program (RAMP). Funding and in-kind support was provided by Albian Sands Energy Inc, ExxonMobil, Petro-Canada Oil and Gas, Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd. and TrueNorth Energy L.P.

Ian Mackenzie was the Chairperson from 1999 to May 2000. Terry Van Meer took over as Chairperson in June 2000. Ken Shipley was the Vice Chairperson. John Gulley was the appointed Secretary during 2000. The Golder Associates Ltd. (Golder) Project Manager was Marie Lagimodiere and the Project Director was John Gulley.

RAMP is a multi-stakeholder program, and benefits from the active participation of its member organizations. Several positive collaborations were achieved in 2000 and are reviewed below.

Alberta Environment (AENV) and RAMP collaborated on aspects of the Muskeg River water quality program. RAMP purchased a DataSonde to install in the Muskeg River for continuous recording of dissolved oxygen, pH, temperature and conductivity. AENV installed the DataSonde and is providing on-going maintenance and downloading of the instrument. AENV also provided historical continuous monitoring data from the Muskeg River.

The spring fisheries program and radiotelemetry study was done by Chris Bjornson (Golder), Ken Allen (Golder), Terry Van Meer (Syncrude) and Melanie Ezekiel (Syncrude). Radiotelemetry tracking flights throughout the spring, summer, fall and winter were led by Melanie Ezekiel (Syncrude) with assistance from Neil Rutley (Syncrude) and Sid Gray (AENV). Melanie Ezekiel, Norm Jelfs and Bill Hunter (Syncrude) also conducted a radiotelemetry survey by canoe on the Muskeg River. Tony Calverley (Golder) and Scott Reid (Golder) conducted the fall fisheries reference site survey for sentinel species.

The spring water quality sampling was done by Chris Briggs (Golder) and Chris Bjornson (Golder). Jeff Brezenski (Golder) and Norm Boucher (Fort McKay) conducted the summer water quality sampling. The fall benthic, sediment and water sampling for the Athabasca River and tributaries was done by Tania Baxter and Jeff Brezenski (Golder) with the assistance of Neil Rutley (Syncrude) for the Athabasca River sampling.

Sampling in the Athabasca Delta channels and Flour Bay was done by Joe Adam (Athabasca Chipewyan First Nation), Charlie Mercredi (Athabasca Chipewyan

First Nation) and Marie Lagimodiere (Golder). Sampling of the lower Athabasca River at Embarras was done by Robert Grandjambe (Mikisew Cree First Nation), Steve Bourke (Fort Chipewyan) and Marie Lagimodiere (Golder).

The acid sensitive lake monitoring program was developed and implemented through a joint effort of RAMP, AENV and Alberta-Pacific Forest Industries Inc. (Al-Pac). AENV assisted by providing sampling equipment, training of field personnel, logistical support and field personnel. Al-Pac provided sampling equipment, field personnel and access to float plane services. Erin Sullivan (Al-Pac), William Donahue (University of Alberta) and Scott Flett (AENV) conducted the field survey.

The following Golder team members prepared sections of this report:

Introduction	Marie Lagimodiere John Gulley (technical review)
Climate and Hydrology Summary	Nathan Schmidt Dejiang Long (technical review)
Quality Assurance/Quality Control	Tanis Dirks J.P. Bechtold (technical review) Wade Gibbons (technical review) Zsolt Kovats (technical review)
Water and Sediment Quality	J.P. Bechtold (task manager) Lori Brewer Cherie Frick Pat Tones (technical review)
Fisheries	Wade Gibbons (task manager) Scott Reid Chris Bjornson Dave Fernet (technical review)
Benthic Invertebrates	Zsolt Kovats (task manager) Pat Tones (technical review)
Sampling South of Fort McMurray	Wade Gibbons Tanis Dirks Marie Lagimodiere (technical review)
Acid Sensitive Lakes	Zsolt Kovats (task manager) Mark Digel (technical review)

Pat Tones provided senior editorial review and Carole Collins formatted the report.

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1 INTRODUCTION

Northeastern Alberta is experiencing a large increase in oil sands development as well as other developments. Such growth highlights the need to integrate environmental monitoring activities so that potential cumulative effects can be identified and addressed. The coordination of monitoring data collection results in the development of a more complete, cost-effective database that is used by oil sands operators for their environmental management programs and by project proponents and reviewers for assessments of proposed oil sands developments.

Monitoring data pertaining to the aquatic environment are collected through the Oil Sands Regional Aquatics Monitoring Program (RAMP). RAMP is a multi-stakeholder initiative, currently funded by Albian Sands Energy Inc. (Albian), ExxonMobil, Petro-Canada Oil and Gas (Petro-Canada), Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), and TrueNorth Energy L.P. (TrueNorth).

The mandate of RAMP, as defined by its multi-stakeholder Steering Committee, is to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region. It is designed as a long-term monitoring program with sampling frequencies ranging from continuous or seasonal to once every few years.

The objectives of RAMP are to:

- monitor aquatic environments in the oil sands area to detect and assess cumulative effects and regional trends;
- collect baseline and historical data to characterize variability in the oil sands area;
- collect data against which predictions contained in environmental impact assessments (EIAs) can be verified;
- collect data that satisfies the monitoring required by regulatory approvals of oil sands developments;
- recognize and incorporate traditional knowledge into the monitoring and assessment activities;
- communicate monitoring activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies, environmental committees/organizations and other interested parties; and
- review and adjust the program to reflect monitoring results, technological advances and community concerns.

RAMP has been in place since 1997; hence, four years of sampling have been completed. The focus of monitoring has been on the following waterbodies:

- the Athabasca River and Peace Athabasca Delta;
- tributaries to the Athabasca River including the Steepbank, Muskeg and McKay rivers and McLean and Fort creeks;
- wetlands occurring in the vicinity of current and proposed oil sands developments; and
- acid-sensitive lakes in northeastern Alberta.

Sampling conducted to date includes surveys of water quality, sediment quality, benthic invertebrates, fish, wetlands vegetation, climate and hydrology. Climate and hydrology results are summarized in Section 2.4 of this volume and are reported in detail in Volume II of this report (Golder 2001a).

This report describes the results of the 2000 field program for water and sediment quality, benthic invertebrates and fish. Wetlands vegetation was not sampled in 2000. The results include data collected for RAMP but do not generally include data from other sampling programs in the region. This report also includes baseline aquatic data collected by OPTI Canada Inc. (OPTI) in the area south of Fort McMurray. Exceptions include information from Albian and Syncrude's joint monitoring program for the Muskeg River, continuous monitoring data from Alberta Environment (AENV) for the Muskeg River and AENV'S water quality data for selected sites, which are included.

The RAMP program design and rationale is described in the following document: "Oil Sands Regional Aquatic Monitoring Program (RAMP) Program Design and Rationale (Golder 2000a)". This document was developed by the RAMP Technical Subcommittee.

Other publications produced by RAMP in the past year include:

- Oil Sands Regional Aquatic Monitoring Program (RAMP) Fish Abnormalities (Golder 2000b);
- Oil Sands Regional Aquatic Monitoring Program (RAMP) Review of Historical Benthic Invertebrate Data in the Oil Sands Region (Golder 2001b); and
- Oil Sands Regional Aquatic Monitoring Program (RAMP) Newsletters: May 2000 (Volume 2, Issue 1) and February 2001 (Volume 3, Issue 1).

2 2000 MONITORING APPROACH

2.1 APPROACH

Historically, water quality monitoring and comparison to guidelines (e.g., chemical concentrations, toxicity testing) have been used to evaluate the potential impacts of human activities on aquatic systems. It is also beneficial to monitor biological communities that integrate the effects of complex and varied stressors on receptors (e.g., fish, benthic invertebrates, wetlands vegetation) to ensure there have been no adverse changes in the aquatic ecosystem due to human activities.

A receptor-oriented system stresses the collection of biological data relevant to the assessment of effects on the aquatic ecosystem. Sensitive, biological indicators were chosen in addition to traditional, chemistry-based monitoring to allow early detection of potential effects related to oil sands developments. The collection and analysis of data on these effects will allow the implementation of appropriate mitigation if effects that negatively impact aquatic ecosystems are detected.

The 2000 monitoring program was a continuation of long-term monitoring that began in 1997. It consisted of four main components:

- Water and sediment quality in rivers and some wetlands that are indicators of habitat quality and potential chemical exposure of fish and invertebrates. Water and sediment quality are assessed by chemical analyses and toxicity bioassays.
- Benthic invertebrate communities in tributaries and one lake, which are bioindicators of cumulative effects.
- Fish populations in rivers that are bioindicators of ecosystem integrity. Emphasis is on regional fish resources and sentinel species.
- Water quality in acid sensitive lakes that is used as an early indicator of potential effects from acid deposition.

To effectively evaluate aquatic ecosystems within the Oil Sands Region, RAMP has focused on four main aquatic systems potentially affected by development activities: 1) Athabasca River; 2) tributaries of the Athabasca River; 3) lakes and wetlands adjacent to developments; and 4) acid sensitive lakes.

Table 2.1 presents a summary of all geographic areas and aquatic components sampled by RAMP in 2000 and in previous years. Details on study design, sampling locations and methods are described in Section 3.

Table 2.1 Overview of RAMP Sampling from 1997 to 1999

Waterbody and Component	Sampling 1997	Sampling 1998	Sampling 1999	2000 Winter	2000 Spring	2000 Summer	2000 Fall
Athabasca River							
water quality	●	●	●				●
sediment quality	●	●					●
benthic invertebrates	●						
sentinel fish monitoring (longnose sucker)		●					
sentinel fish monitoring (trout-perch)			●				
radiotelemetry[(a)]	●	●			●	●	●
fish inventory	●	●	●		●		
fish tissue		●					
Athabasca River Delta							
water quality			●				●
sediment quality			●				●
McClelland Lake							
water quality					●		●
Fort Creek							
water quality					●		●
sediment quality							●
Unnamed Creek (drains Lease 52)							
water quality					●		●
Tar River							
water quality		●					
sediment quality		●					
Ells River							
water quality		●					
sediment quality		●					
sentinel fish monitoring (evaluated as reference area)		●					●
MacKay River							
water quality		●					●
sediment quality	●	●					
benthic invertebrates		●					●
fish inventory	●						
Muskeg River							
water quality	●	●	●	●[(b)]	●[(b)]	●[(b)]	●
toxicity testing		●	●				
sediment quality	●	●	●				●
temperature (continuous during open water)			●	●	●	●	●
benthic invertebrates		●					●
sentinel fish monitoring (slimy sculpin)			●				●[(c)]
spawning survey					●		
radiotelemetry[(a)]					●	●	●
fish inventory	●		●				
fish fence		●					
Alsands Drain							
temperature (continuous during open water)					●	●	●

Table 2.1 Overview of RAMP Sampling from 1997 to 1999 (continued)

Waterbody and Component	Sampling 1997	Sampling 1998	Sampling 1999	2000 Winter	2000 Spring	2000 Summer	2000 Fall
Jackpine Creek							
water quality		●	●				●
sediment quality	●						●
Muskeg Creek							
water quality			●				●
sediment quality							●
Shelley Creek							
water quality			●				
Wapasu Creek							
water quality			●				
Stanley Creek							
water quality			●				●
sediment quality							●
Kearl Lake							
water quality		●					●
vegetation	●	●					
Isadore's Lake							
water quality		●					●
vegetation	●	●					
Steepbank River							
water quality	●	●	●				●
sediment quality	●	●					
benthic invertebrates		●					●
fish inventory	●		●				
sentinel fish monitoring (slimy sculpin)			●				●[c]
Shipyard Lake							
vegetation	●	●					
water quality		●	●			●	●
benthic invertebrates							●
McLean Creek							
water quality			●				●
sediment quality			●				●
temperature (continuous during open water)			●				
Poplar Creek							
sediment quality	●						
water quality							●
Dover, Dunkirk, Horse and Hangingstone Rivers							
sentinel fish monitoring (evaluated as reference area)							●
Acid Sensitive Lakes							
water quality			●			●	

(a) Radiotelemetry is not part of the RAMP core sampling program. Radiotelemetry programs have been conducted to fill in baseline data gaps on fish movement patterns and to aid in study design. A radiotelemetry study of lake whitefish and walleye was conducted in 1998/99 and a radiotelemetry study of longnose sucker and northern pike was initiated in 2000 and is on-going.

(b) Data provided by Syncrude and Albian Sands from their joint monitoring program on the Muskeg River.

(c) Sentinel fish work on the Muskeg and Steepbank rivers in 2000 consisted of further definition of habitat and relative abundance. No lethal sampling of slimy sculpin was done in 2000 as would be done during a regular sentinel species sampling program.

2.1.1 Water and Sediment Quality

Analysis of water and sediment chemistry provides a direct measure of the suitability of a waterbody to support aquatic life. Changes in water and sediment quality may indicate chemical inputs from point and non-point sources. Measured concentrations of chemicals can be compared with water quality guidelines designed to protect aquatic life. Water and sediment quality surveys also provide valuable supporting data to interpret the results of biological surveys.

The scope of the 2000 water quality surveys was the following:

- to continue to monitor the same set of water quality parameters analyzed in 1999;
- to resample the mouths of McLean Creek, the Steepbank River and the Muskeg River;
- to resample Jackpine, Muskeg and Stanley creeks;
- to expand sampling to include Poplar, Fort and Unnamed creeks, and the MacKay River;
- to monitor seasonal water temperatures in the Muskeg River, McLean Creek, Fort Creek and the Alsands Drain;
- to sample Kearl, Isadore's, Shipyard and McClelland lakes;
- to resample the Athabasca River near the Embarras River and in the Athabasca River Delta, far downstream of current oil sands developments; and
- to expand sampling in the Athabasca River to include three cross-channel sample points upstream of Donald Creek, the Steepbank River, Muskeg River and Fort Creek.

The scope of the 2000 sediment quality survey was the following:

- to continue to monitor the same set of sediment quality parameters analyzed in 1999, including sediment toxicity (i.e., bioassays using benthic invertebrates: *Chironomus tentans*, *Hyalella azteca* and *Lumbriculus variegatus*);
- to resample the mouths of McLean Creek, Stanley Creek and the Muskeg River;
- to expand sampling in the Muskeg River to include five additional sites (i.e., 1 km upstream from the mouth and upstream of the Canterra Road crossing, Jackpine Creek, Muskeg Creek and Wapasu Creek);

- to expand sampling to include Jackpine, Fort and Muskeg creeks;
- to resample the Athabasca River Delta and at Big Point Channel and expand sampling to Flour Bay; and
- to expand sampling in the Athabasca River to include east bank and west bank samples upstream of Donald Creek, the Steepbank River, Muskeg River and Fort Creek, as well as a cross-channel composite upstream of the Embarras River.

2.1.2 Benthic Invertebrate Community

Benthic invertebrate (benthos) monitoring is an important component of aquatic monitoring programs because it provides an ecological indication of environmental effects. It complements surveys of fish populations, and water and sediment quality. Benthic invertebrates form communities that reflect the physical and chemical characteristics of their habitat and are sedentary, which render them useful as monitoring organisms. They also constitute a food source for many fish species, making them an important feature of fish habitat.

The RAMP benthic invertebrate component consists of periodic monitoring of the Athabasca River, at approximately 5-year intervals, and more frequent sampling of selected tributaries (MacKay, Muskeg and Steepbank rivers) and lakes (Kearl and Shipyard lakes). The sampling frequency in these waterbodies varies over time to allow the accumulation of adequate baseline data before the potential impacts of oil sands development appear. Initially, monitoring will be annual for five years and then the frequency will be reduced to once every two years, or as dictated by the development schedules of individual oil sands developments. The fall 2000 program included sampling of the above three tributaries and Shipyard Lake. Annual monitoring of Kearl Lake will begin in 2001.

The tributary monitoring approach adopted by RAMP focuses on the lower reach of each river to allow detection of the cumulative effects of all developments within their basins. To monitor lakes, sampling effort is distributed over the entire lake, but is restricted by depth to reduce variation in the data. Both river and lake sampling includes the collection of a full suite of supporting data to allow separation of the effects of natural variation on benthic community structure from the effects of oil sands developments.

The major objectives of the 2000 benthic surveys were to further characterize natural variability in the MacKay, Steepbank and Muskeg rivers before the commencement of intensive oil sands development within their basins, and to begin routine aquatic monitoring in waterbodies near oil sands developments. Some development has already occurred in the Muskeg River and Shipyard Lake basins, consisting of forest clearing, muskeg dewatering and construction of roads and camps. However, since the predicted impacts of these activities on water quality and benthic habitat are small (BOVAR 1996; Shell 1997), the 2000 monitoring results are tentatively considered part of the baseline data for these waterbodies.

In addition to routine monitoring in 2000, the Benthic Invertebrate Technical Subcommittee of RAMP has undertaken a review of all existing benthic invertebrate data in the RAMP study area (reported separately by Golder 2001b). The major objectives of this effort is to strengthen the baseline database for the region and make the data available for use during future monitoring. The historical data summarized by Golder (2001b) will be used in future RAMP cycles to describe natural variation and examine trends over time in benthic community variables in the waterbodies selected for monitoring, and to assess the effects of natural habitat variation on benthic community structure.

2.1.3 Fish Populations

Monitoring fish populations is a key component of RAMP for a variety of reasons. Fish integrate the effects of natural and anthropogenic factors and are, therefore, an important ecological indicator. Probably the most pertinent reason for evaluating fish populations is that fish are a highly valued component of the aquatic ecosystem. Hence, there is a public and regulatory expectation that fish will be monitored.

Within the Oil Sands Region there are two distinct yet related issues that need to be addressed by the fisheries component of RAMP. Firstly, it is necessary to ensure that fish populations are not adversely affected by increased oil sands development. The continued use of available fisheries resources for human consumption is of specific interest. Secondly, it is important to maintain the ecological integrity of aquatic ecosystems. With regards to fish, it is important to ensure that there are no adverse effects on ecological attributes such as growth, reproduction and survival. Early warning indicators are used to achieve this objective.

The scope and rationale of the fisheries component for the 2000 monitoring program have been outlined in detail in the Program Design and Rationale document (Golder 2000a). Generally, the 2000 program consists of the following:

- radiotelemetry study focussing on longnose sucker (*Catostomus catostomus*), northern pike (*Esox lucius*) and Arctic grayling (*Thymallus arcticus*);

- spawning survey of Jackpine Creek and the lower Muskeg River; and
- reference site survey for tributary sentinel species monitoring using slimy sculpin (*Cottus cognatus*).

The radiotelemetry study was initiated to: 1) evaluate the mobility of longnose sucker and its suitability as a sentinel species for the Athabasca River; 2) evaluate the mobility of northern pike and Arctic grayling within the Muskeg River system and Athabasca River; and 3) identify overwintering habitat for all three species. The spawning survey was conducted as part of the core monitoring program to evaluate potential changes in spawning habitat quality, quantity and utilization in the Muskeg River system (including Jackpine Creek) over time. Finally, a survey was conducted to identify additional reference sites for sentinel species monitoring of the Muskeg and Steepbank rivers. These sites will be used to provide a more accurate representation of the reference condition of slimy sculpin for comparison with potentially exposed populations monitored in the Muskeg and Steepbank rivers.

2.1.4 Acid Sensitive Lakes

The RAMP long-term acidification monitoring network was established in 1999. The objective of this component is to monitor the water chemistry of lakes as an early-warning indicator of effects caused by acidic deposition. Acid sensitive lake monitoring is a partnership between RAMP, Alberta-Pacific Forest Industries Inc. (Al-Pac) and AENV.

The monitoring network consists of 32 moderately to highly acid sensitive lakes in northeastern Alberta, including 22 lakes in the Oil Sands Region (expanded to 23 in 2000), five lakes in the Caribou Mountains and five lakes in the Canadian Shield. The lakes within the Oil Sands Region were selected to represent a gradient in acid deposition. Those in the Caribou Mountains and the Canadian Shield are distant from sources of acidifying emissions, and serve as reference lakes (i.e., spatial controls). The lakes are monitored annually for field parameters, acidity-related parameters, carbon parameters, major ions, nutrients and productivity indicators.

The lakes forming the network were selected to represent a cross-section of lake characteristics in northeastern Alberta. Primary criteria during lake selection included the following:

- moderate to high sensitivity to acidification, defined as total alkalinity <20 mg/L as $CaCO_3$;
- range in organic content, from clear water to brown water lakes;

- location along a gradient of acidic deposition radiating from the Oil Sands Region, as predicted in recent EIAs, or location away from the oil sands area (in the case of reference lakes); and
- access by float plane to ensure a cost-effective program.

The 2000 program represented the second year of monitoring under this component. The lakes monitored, sampling and analytical methods were similar to that established in 1999. Differences relative to the 1999 program included adding one new lake (E15), replacing two of the original lakes (O3, R3) that displayed only low acid sensitivity in 1999 with more sensitive lakes (E68, L107), and adding Gran alkalinity to the parameter list to obtain a more reliable indication of acid neutralizing capacity (ANC). Additionally, three lakes were not sampled in 1999 (L1, L30, R2) because of weather-related and logistical difficulties. In total, 30 lakes were monitored in 2000.

2.1.5 Vegetation

Aquatic vegetation communities in Isadore's, Kearl and Shipyard lakes are monitored on a regular basis as part of the RAMP core sampling program. The current RAMP sampling program includes airphoto interpretation and field sampling every three years. Field sampling was done in 1998 and is scheduled again for 2001. In years when field sampling is not scheduled, airphotos are assessed and compared to the previous years' photos if they are available. In 2000, airphotos were only available for Shipyard Lake. These were mapped and compared to previous years' airphotos and will be included in Suncor's Annual Wetlands Monitoring Report (Golder 2001c).

2.2 RAMP STUDY AREA

The study area for RAMP was recently revised by the Steering Committee to include the Regional Municipality of Wood Buffalo (Figure 2.1). This makes the RAMP study area consistent with the Cumulative Environmental Management Association, Water Working Group (CEMA WWG) study area.

A focus study area is located within the RAMP study area (Figure 2.1). The focus study area boundary is preliminary and is currently being updated by the RAMP Steering Committee. The focus area includes watersheds where oil sands development is occurring or planned. As well, areas downstream of the proposed developments, such as the lower Athabasca River and the Athabasca River Delta are also included. The Clearwater River and the Athabasca River upstream of Fort McMurray are included as reference areas. The focus study area includes rivers and lakes located south of Fort McMurray that have not previously been included in the RAMP sampling program.

Figure 2.1 RAMP Study Area and Focus Area

2.3 BASELINE SOUTH OF FORT MCMURRAY

OPTI Canada Inc. (OPTI) joined RAMP in February 2001. In 2000, OPTI conducted baseline water quality, and fish and fish habitat studies to provide information required for the Environmental Impact Assessment (EIA) of a Steam Assisted Gravity Drainage (SAGD) bitumen recovery and upgrading project, called the Long Lake Project. The Long Lake Project is located within the OPTI project boundary in northeastern Alberta, approximately 40 km southeast of Fort McMurray and approximately 8 km southeast of Anzac.

The water quality, and fish and fish habitat baseline data collected as part of the Long Lake Project were provided to RAMP. The data are detailed in OPTI (2000) and summarized in this report. The baseline surveys focused on waterbodies that were found in the defined Local Study Area (LSA). Waterbodies in the LSA were chosen because they may be directly or indirectly affected by infrastructure construction, groundwater withdrawal and air emissions (i.e., acidification) resulting from the Long Lake Project. Gregoire Lake was also investigated because of it is regionally important for recreational angling and locally important for subsistence fishing.

The specific objectives of the OPTI baseline water quality study were the following:

- to characterize baseline water quality in selected streams, rivers and lakes within the LSA;
- to evaluate acid sensitivity of lakes within the LSA so impacts due to acidic deposition can be identified; and
- to summarize available historical water quality data for Gregoire Lake.

The specific objectives of the OPTI fish and fish habitat study were the following:

- to collect information on fish and fish habitat to evaluate overwintering potential and spring and summer use of lakes, streams and rivers by fish in the LSA (i.e., use for spawning, rearing, migration and feeding);
- to collect information on fish and fish habitat in the immediate vicinity of potential watercourse crossings (i.e., pipeline and road crossings) in the LSA; and
- to summarize available historical fisheries data for Gregoire Lake.

2.4 CLIMATIC AND HYDROLOGIC CONDITIONS

The core components of the 2000 monitoring program (water and sediment quality, benthic invertebrate communities and fish populations) are all influenced by climatic conditions. In particular, changes that alter the quantity of water in the Athabasca River, the tributaries of the Athabasca River, wetlands and lakes will influence these core components.

Monitoring of climatic and hydrologic conditions in the Oil Sands Region is accomplished via the RAMP Climatic and Hydrologic Monitoring Program. This program, which is currently supported by Syncrude, Albian, Mobil, True North, Petro Canada, and Suncor, has been in place since 1995. An annual report on the program is issued as Volume II of the 2000 RAMP report. Summaries of historical information, as well as data collected during 2000, are included in Volume II. Since changes in flows and water levels may affect both the success and the results of RAMP sampling throughout the study area, a summary of the 2000 conditions is provided as background information in this section.

Field observations indicate that 2000 was a wetter than normal year in the Muskeg River and adjacent basins, in contrast to the dry conditions observed in 1998 and 1999. Heavy snowfall during November and December, 1999 was followed by light snowfall in early 2000. The resulting moderate snowpack (Figure 2.2), combined with dry muskeg, produced relatively low stream discharges during snowmelt in 2000. However, significant rainfall occurred in late May and late June, as shown in Figure 2.3. During the late June rainfall event, 63 mm of rain was measured at the Aurora Climate Station, and five-year flood events were measured on Jackpine Creek and the Muskeg and Firebag rivers. The total rainfall measured at the Aurora Climate Station in 2000 was 457 mm. This is similar to that measured in 1996 (472 mm) and significantly more than that measured in 1997, 1998 and 1999 (382 mm, 212 mm and 303 mm, respectively), as shown in Figure 2.3.

The analysis of available data indicates that maximum daily stream discharges in 2000 were slightly higher than the long-term mean of annual maximum daily values (Table 2.3). Minimum daily discharges were lower than the mean for most stations. Lower than normal minimum daily discharges occurred at the start of 2000 due to dry conditions occurring in 1999. The low of record on the Athabasca River, equal to the 50 year low flow, was recorded in January 2000, and a discharge equal to the 20 year low flow was recorded in the Muskeg River in January 2000. Minimum daily discharges during the latter half of 2000 were not representative of drought conditions.

Figure 2.2 Snow Accumulation in Muskeg River Basin, 1997 - 2000

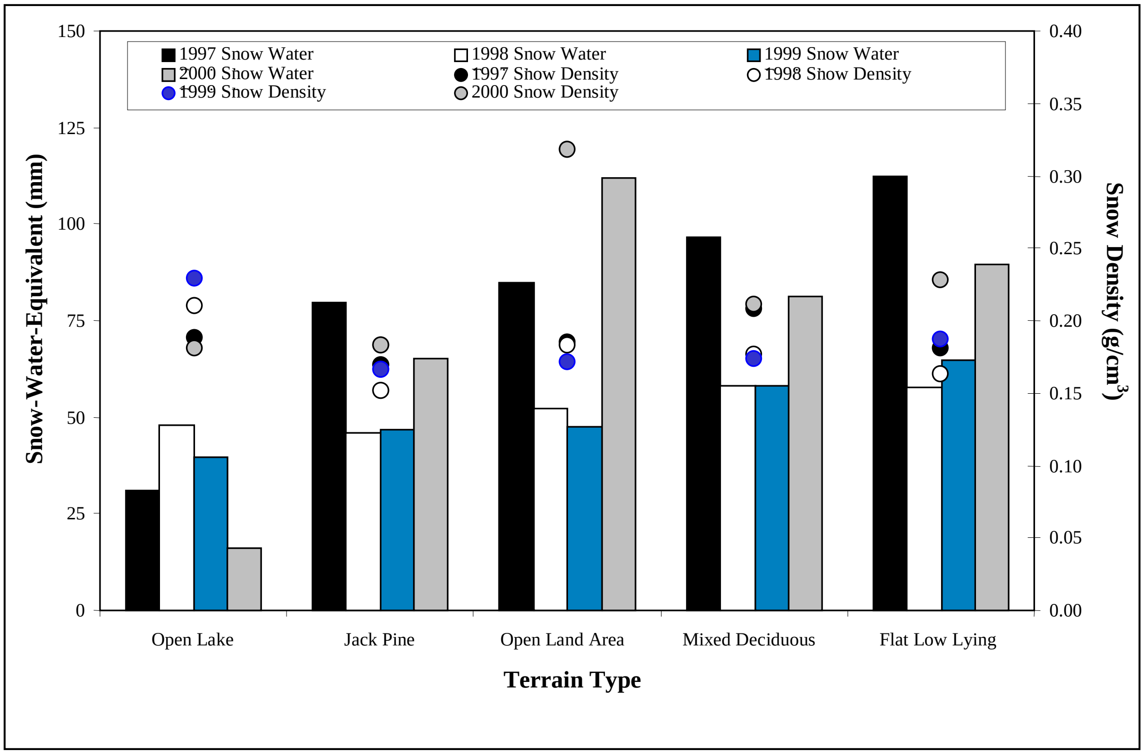
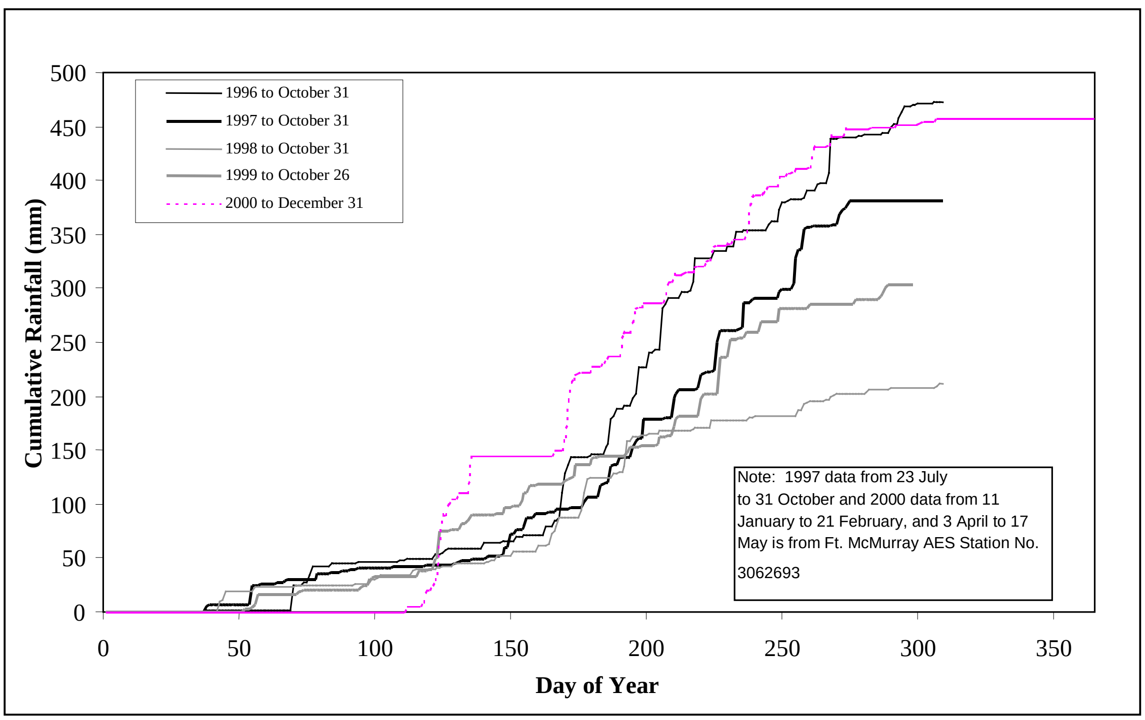


Figure 2.3 Cumulative Annual Rainfall at Aurora Climate Station, 1996 - 2000



The cumulative flow volume for the period from March to September 2000 (i.e., spring melt to late summer) was similar to average (Table 2.4) for local streams. However, the cumulative flow volume for the Athabasca River was the lowest recorded in 41 years of record. 1999 and 1998 were both dry years and the 2000 cumulative flow volumes were close to average. This indicates that dry muskeg areas observed in 1998 and 1999 may have recharged.

Table 2.2 Maximum and Minimum Mean Daily Discharges, RAMP Study Area

Stream Station ID Period of Record	Athabasca R. 07DA001 41 Years	Steepbank R. 07DA006 27 Years	Muskeg R. 07DA008 27 Years	Jackpine Cr. S2 24 Years	MacKay R. 07DB001 28 Years	Firebag R. 07DC001 25 Years
	Maximum Mean Daily Discharge					
2000 value (m^3/s)	1790	43.9	37.8	12.7	73.5	137
average recorded (m^3/s)	2460	35.6	26.5	7.54	126	104
maximum recorded (m^3/s)	4700	81.0	66.1	17.2	339	236
flood return period (yr)	< 2 years	3 years	5 years	5 years	< 2 years	5 years
	Minimum Mean Daily Discharge					
2000 value (m^3/s)	89	0.617	0.105	0.116	0.160	7.19
average recorded (m^3/s)	136	0.294	0.277	0.007	0.352	8.00
minimum recorded (m^3/s)	89	0.022	0.095	0.000	0.023	4.24
drought return period (yr)	50 years	< 2 years	20 years	n/a	7 years	4 years

Source: Environment Canada, Water Survey Branch; Golder (2000).

Table 2.3 Cumulative Streamflow Volumes, RAMP Study Area, March to September

Stream Station ID Period of Record	Athabasca R. 07DA001 41 Years	Steepbank R. 07DA006 27 Years	Muskeg R. 07DA008 27 Years	Jackpine Cr. S2 24 Years	MacKay R. 07DB001 28 Years	Firebag R. 07DC001 25 Years
2000 value (dam^3)	11,782,282	135,438	127,440	25,920	340,377	660,874
maximum recorded (dam^3)	25,279,862	273,634	187,146	59,051	904,734	903,836
average recorded (dam^3)	16,696,140	134,073	105,526	27,340	427,279	605,260
minimum recorded (dam^3)	11,782,282	36,587	18,151	1,000	28,526	344,469
drought return period (yr)	20 years	< 2 years	< 2 years	< 2 Years	3 years	< 2 Years

Source: Environment Canada, Water Survey Branch; Golder (2000).

3 METHODS

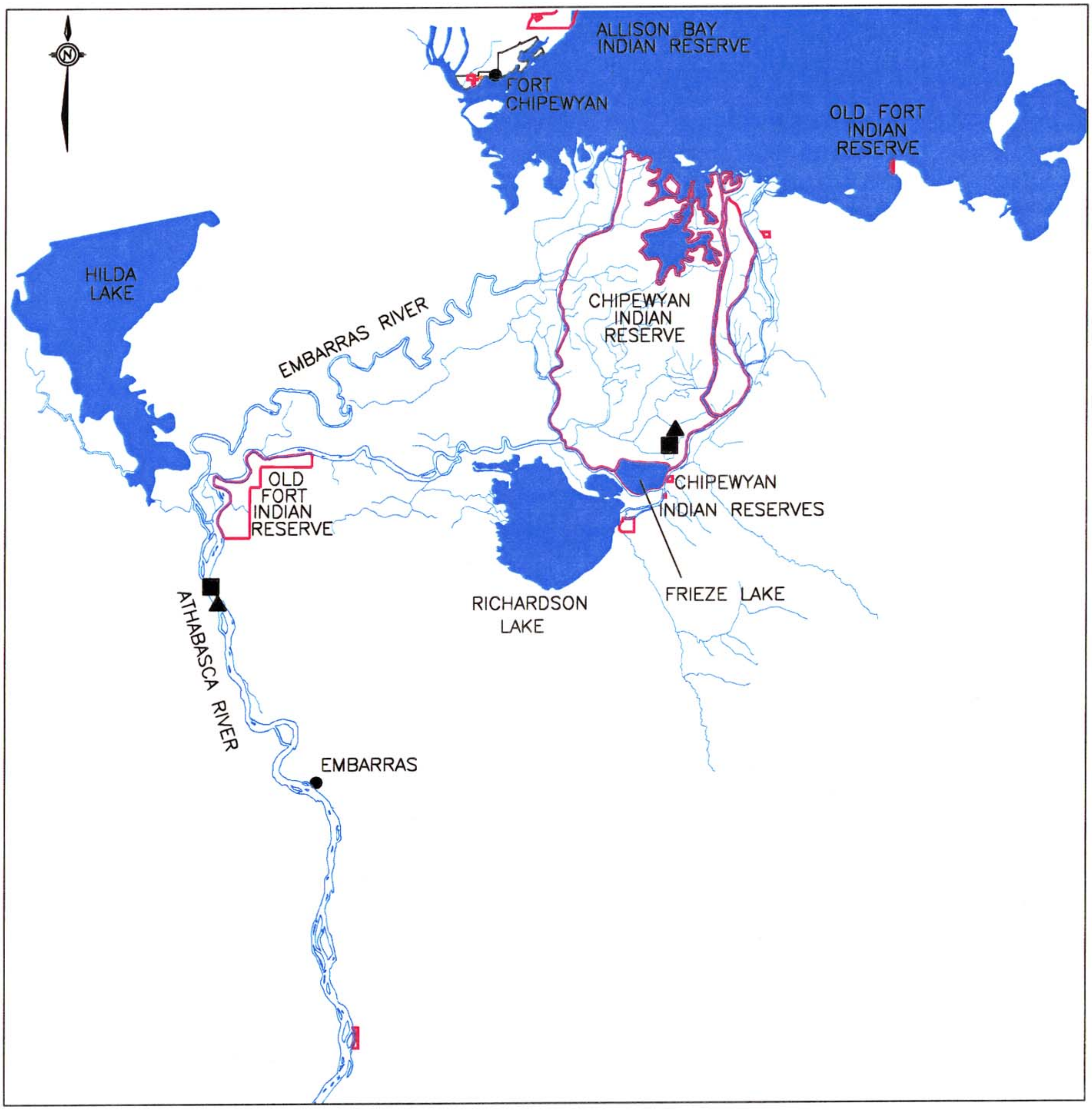
3.1 ATHABASCA RIVER

3.1.1 Water and Sediment Quality

In 2000, RAMP continued to monitor the Athabasca River upstream of the Embarras River and the Athabasca River Delta (Figure 3.1). RAMP also sampled along the east and west banks of the Athabasca River at three sites located upstream of Donald Creek, upstream of the Muskeg River and upstream of Fort Creek, as was done in 1998 (Figure 3.2). Each site was sampled at two points across the width of the river (i.e., along the east and west banks). A third sample point in the middle of the Athabasca River was added at the Donald Creek, Muskeg River and Fort Creek sites. Middle, west bank and east bank sample sites were also added upstream of the Steepbank River in 2000. Water and/or sediment samples were collected from each of the three points across the river at each site in accordance with the monitoring schedule summarized in Table 3.1.

Table 3.1 RAMP 2000 Water and Sediment Sampling Schedule for the Athabasca River

Sample Location		Short Title	Sample Media	Sample Date
Sampling Site	**Sampling Point**			
upstream of Donald Creek	west bank	ATR-DC-W	water / sediments	October 2 (fall)
	middle	ATR-DC-M	water	
	east bank	ATR-DC-E	water / sediments	
upstream of the Steepbank River	west bank	ATR-SR-W	water / sediments	October 2 (fall)
	middle	ATR-SR-M	water	
	east bank	ATR-SR-E	water / sediments	
upstream of the Muskeg River	west bank	ATR-MR-W	water / sediments	October 4 (fall)
	middle	ATR-MR-M	water	
	east bank	ATR-MR-E	water / sediments	
upstream of Fort Creek	west bank	ATR-FC-W	water / sediments	October 3 (fall)
	middle	ATR-FC-M	water	
	east bank	ATR-FC-E	water / sediments	
upstream of the Embarras River	cross channel	ATR-ER	water / sediments	September 15 (fall)
Delta	Big Point Channel	ARD-1	water / sediments	September 16 (fall)
	Flour Bay	FLB-1	sediments	September 15 (fall)



0 5 10 15 20 25km
SCALE 1:500,000

LEGEND

■ WATER QUALITY SAMPLING SITE

▲ SEDIMENT QUALITY SAMPLING SITE

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA
DIVISION ALBERTA ENVIRONMENTAL
PROTECTION, 1997. DATUM IS IN NAD83 UTM PROJECTION.

Golder Associates

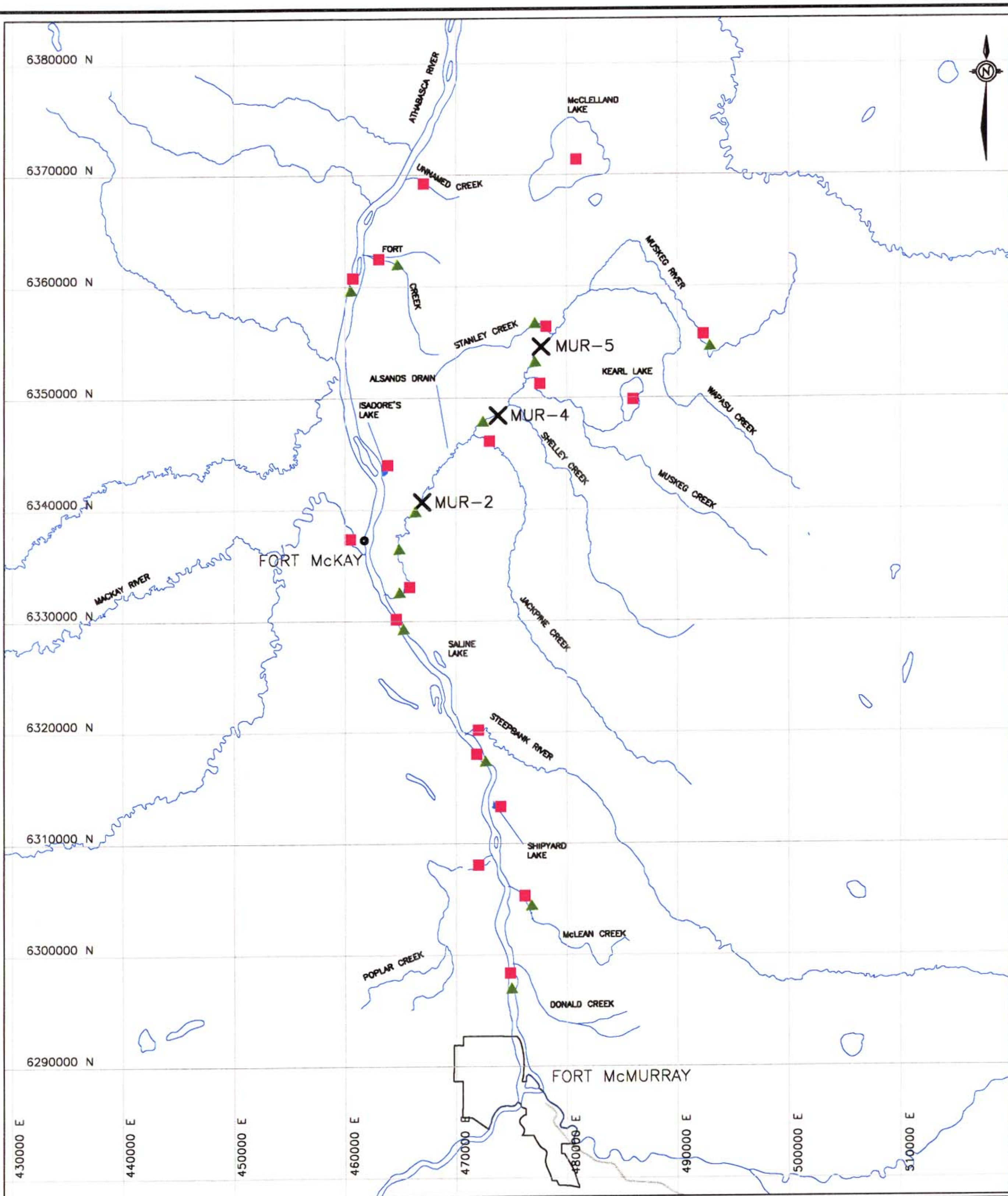
RAMP

RAMP 2000 WATER AND SEDIMENT SAMPLE SITES IN THE ATHABASCA RIVER NEAR EMBARRAS

DRAWN: TVS	APPROVED:	DATE:	14 Feb. 2001
PROJECT: 002-2309.3000		FIGURE: **3.1**	

Revision No.: 01

R:\Active\2300\002-2309\CAD\3000\AREA_SAMPLE_SITES.dwg



LEGEND

- ■ WATER QUALITY SAMPLING SITE
- ▲ SEDIMENT QUALITY SAMPLING SITE
- ✕ INDUSTRY SAMPLE SITE

0 5 10 15 20 25

SCALE (km)

Golder Associates

RAMP

RAMP 2000 WATER AND SEDIMENT SAMPLE SITES IN THE LOWER ATHABASCA RIVER WATERSHED

DRAWN: GMF	APPROVED:	DATE: 26 Mar. 2001	
PROJECT: 002-2309.3000		FIGURE: **3.2**	

Revision No.: 02

R:\Active\2300\002-2309\CAD\3000\ramp-2000-wq-New.dwg

3.1.1.1 Field Methods

Water Sampling

In the Athabasca River, composite samples were collected 50 to 100 m upstream of Donald Creek, the Steepbank River, the Muskeg River and Fort Creek. At each location, the east-bank composite sample was prepared by combining five, approximately equally-spaced, grab samples collected between the east bank of the river and 25% of the river width. A similar protocol was used to collect the west-bank composite sample. The mid-channel composite sample was prepared by collecting five grab samples from 40-60% across the river width.

Upstream of the Embarras River and in the Athabasca Delta (i.e., Big Point channel), a similar sampling technique was used, although the river grab samples were approximately equally spaced across the entire width of the river channel.

At each sampling point, the 10 L composite sample was prepared by combining 2 L grab samples in a clean, triple-rinsed 20 L pail. Each grab sample was collected using a clean, triple-rinsed 2 L plastic bottle. Water was collected from a depth of about 30 cm. Each sample was split into two parts. One part was shipped to Enviro-Test Laboratories (ETL) in Edmonton, Alberta, for analysis of conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons, chlorophyll *a* and naphthenic acids. The second portion was sent to HydroQual Laboratories (HydroQual) in Calgary, Alberta, for Microtox® analysis. Descriptions of the analytical methods used by each laboratory are provided in Appendix I. The dissolved metal samples were field filtered using 45 μm cartridge filters and a geopump.

Field measurements, including pH, conductivity, temperature and dissolved oxygen (DO) were monitored at each sampling point. However, field data for the Embarras River and Delta sites were lost in transit. All samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999a). All field probes were calibrated before use, and exact sample locations were determined by Global Positioning System (GPS).

Sediment Sampling

Composite sediment samples were collected along the east and west banks of the Athabasca River upstream of Donald Creek, the Steepbank River, the Muskeg River and Fort Creek. The east-bank composite sample was prepared by combining four to six grab samples taken from depositional areas located between the east bank of the river and 25% of the river width. A similar process was used to collect the west-bank composite samples. Composite sediment samples were also collected in the Athabasca River upstream of the Embarras River and in the Athabasca River Delta.

Sediments were taken from the top 3 cm of the river bottom using a Ponar grab sampler. Samples taken from the Athabasca River Delta and the Athabasca River upstream of the Embarras River were split into three parts. One part was shipped to ETL and analyzed for carbon content, particle size, recoverable hydrocarbons and total metals. Another part of the composite sample was sent to HydroQual for toxicity testing using midge larvae (*Chironomus tentans)*, amphipods (*Hyalella azteca*) and oligochaete worms (*Lumbriculus variegatus*). The final portion was sent to AXYS Analytical Services Ltd. (AXYS) in Sidney, B.C., and analyzed for polycyclic aromatic hydrocarbons (PAHs) and alkylated PAHs.

The eight other sediment samples collected from the lower Athabasca River were split into two parts and sent to ETL and AXYS for the same analyses described above; these samples were not submitted for toxicity testing. Descriptions of the methods used by each laboratory can be found in Appendix I. Sediments were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.2-2 (Golder 1999a).

3.1.1.2 Data Analysis

Qualitative comparisons were used to characterize water and sediment quality for the Athabasca River sample sites. Historical information, where available, was summarized, and historical median, minimum and maximum values were developed (Appendix II). Information collected in 2000 was then compared qualitatively to the historical median values associated with each of the 2000 sampling sites. The 2000 and historical median values were also compared to relevant water and sediment quality guidelines. Trends in the complete data set were examined, and differences between new information and historical data were identified using the following criteria:

- a pH change of greater than 0.5 pH units;
- a minimum of an order of magnitude change for parameters reported with only one significant digit (e.g., 0.1 mg/L in 2000 versus a historical median concentration of 1 mg/L);
- a relative change of greater than 100% for parameters with more than one significant digit (e.g., 180 mg/L in 2000 versus a historical median concentration of 90 mg/L); or
- a relative change of greater than 40% for parameters with more than one significant digit, where 2000 concentrations were higher or lower than historical maximum or minimum, respectively.

These criteria are based on professional judgement and serve as general guidelines by which potentially significant changes could be identified. Increased statistical analysis of the water quality data will be incorporated in future years, as the amount and number of years of data increases.

3.1.2 Fish Populations

The 2000 fisheries component for the Athabasca River focussed on developing a better understanding of the movements of longnose sucker within the Oil Sands Region. Longnose sucker has been selected as one of the sentinel monitoring species for the Athabasca River; however, there is some uncertainty as to their potential for large-scale movement. It is important to determine how long longnose sucker remain within the Oil Sands Region because potential effects on fish populations will be a function of exposure. A radiotelemetry study was initiated during the spring 2000 to follow the movements of sucker throughout the year. The study also provided important information regarding overwintering habits of longnose sucker within the Athabasca River.

3.1.2.1 Radiotelemetry Study

Existing studies of longnose sucker in the Athabasca River Basin (Bond and Machniak 1979; Tripp and McCart 1979) suggest that fish utilizing the river in the Oil Sands Region are part of the Lake Athabasca population which utilize the river basin for spawning and rearing activity. The residency period for adult longnose suckers in the Athabasca River and the extent to which the river basin is utilized during the open-water period is unknown, but it is believed that most of these fish overwinter in Lake Athabasca.

Based on previous studies, the longnose sucker population found in the lower Athabasca River consists of at least two “sub-populations” that exhibit different spawning/rearing strategies and, potentially, different patterns of use of the river basin. One segment of the population migrates in the spring from Lake Athabasca to Mountain and Cascade rapids of the Athabasca River located upstream of Fort McMurray. Spawning occurs in the mainstem of the Athabasca River (Tripp and McCart 1979). The second segment migrates from Lake Athabasca in the spring and enters tributary streams of the Athabasca River (e.g., Muskeg River) to spawn. The telemetry program included radio tagging 25 sucker that spawn in the mainstem and 25 sucker that spawn in the Muskeg River to determine if there was any difference in movement patterns and residency time between these sub-populations. An attempt was made to tag a similar number of male and female fish. Sex was determined prior to radio tagging by the presence (male) or absence (female) of spawning tubercles.

Athabasca River Spawners

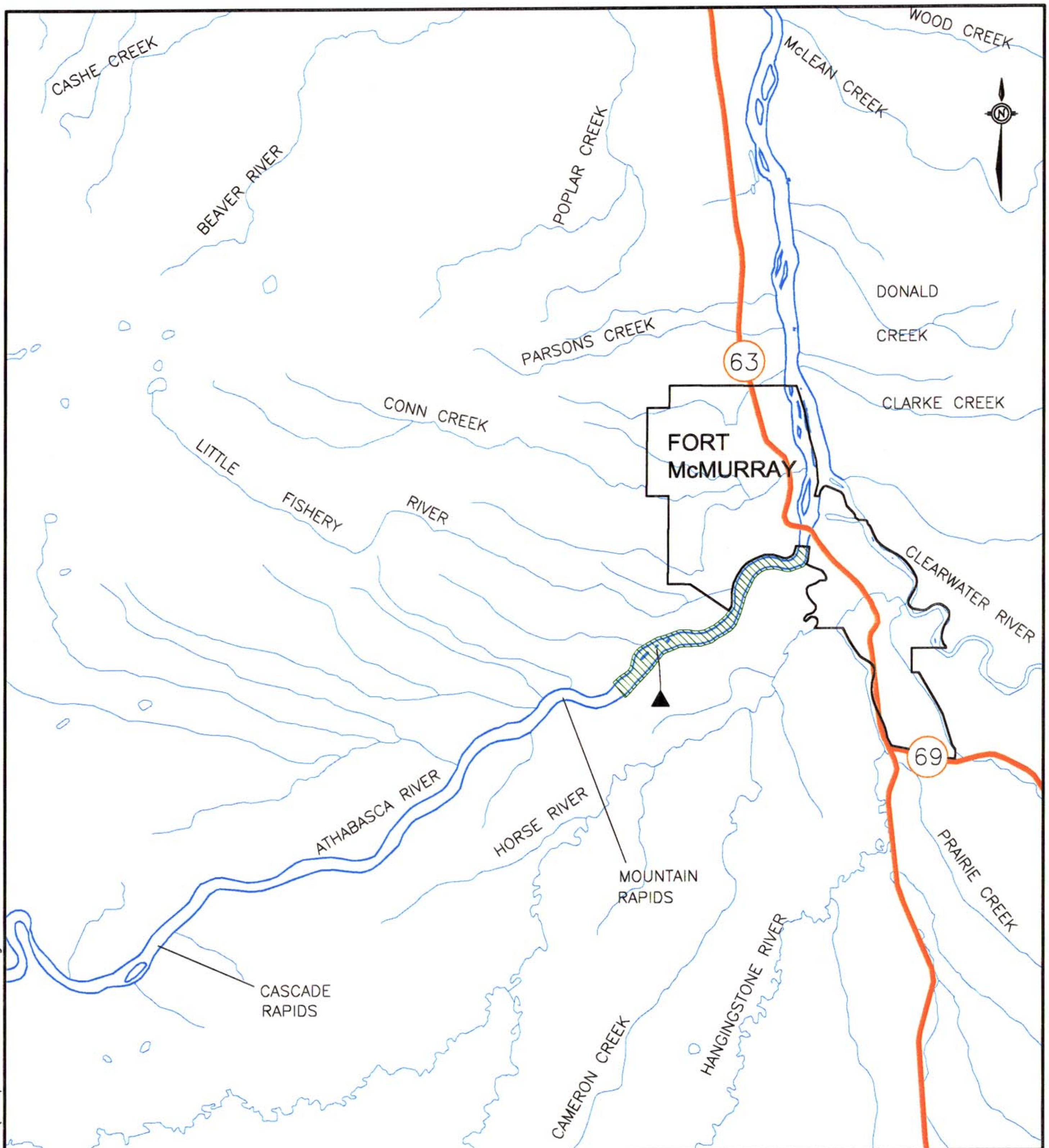
Concentrations of adult longnose sucker in major spawning areas were identified for the Athabasca River in the vicinity of Cascade and Mountain rapids by Tripp and McCart (1979). They found longnose sucker to be most abundant from early to mid May with the spawning period occurring from May 10-23. Therefore, the portion of the Athabasca River below Mountain Rapids was selected as the fish sampling area for the 2000 radiotelemetry study with sampling occurring over the period May 16-18. Fish were captured using a boat electrofisher (Smith-Root SR-18). The portion of the Athabasca River that was sampled for longnose sucker is presented in Figure 3.3. Fish were radio tagged and released at a site located 3 km downstream of Mountain Rapids (Figure 3.3).

All fish captured or observed during electrofishing operations were enumerated by species. All captured fish were measured for fork length (mm) and weight (g) and examined externally for any abnormalities. All longnose sucker and all incidental species that are included in the overall RAMP program (e.g., walleye [*Stizostedion vitreum*]) were fitted with brown external 'T'-bar anchor tags (Model FD-68B) that were manufactured by Floy Tag and Manufacturing Inc. for the RAMP program. Each Floy tag was marked with the letters "RAMP" and the phone number for the Alberta Environment, Fish and Wildlife Office in Fort McMurray. Fish were Floy tagged so that they could provide additional movement data in the event of capture by domestic, commercial or sport fishing activities. Adult longnose suckers to be radio tagged were retained in a holding facility for subsequent surgery. All other fish were released.

Pectoral fin rays were collected from a minimum of 100 adult longnose sucker, including all radio-tagged fish, for ageing analyses. This was done to compare the growth rates for the Athabasca River spawning sub-population to the existing data for the Muskeg River spawning sub-population. The fin rays were sectioned to allow age determination as per the methods described in Mackay et al. (1990).

Muskeg River Spawners

Spring spawning longnose sucker have been documented moving from the Athabasca River into the Muskeg River in early to mid May (Bond and Machniak 1977, 1979; Golder 1996). Portions of the Muskeg River from the vicinity of the Jackpine Creek confluence downstream to the river mouth were sampled for adult longnose sucker over the period May 26 to June 1, 2000 (Figure 3.4). A small portion of lower Jackpine Creek, extending for 0.5 km from the creek mouth upstream to an impassable beaver dam, was also sampled. The various release locations for radio-tagged fish are presented on Figure 3.4. Fish were captured using a portable boat electrofisher mounted in an inflatable boat. A fyke net (hoop trap) was also employed for a short time as a secondary sampling technique.



LEGEND

BOAT ELECTROFISHING AREA

▲ RELEASE SITE FOR RADIO-TAGGED FISH

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997. NAD 83 ZONE 12.

0 2 4 6 8 10

SCALE (km)

Golder Associates

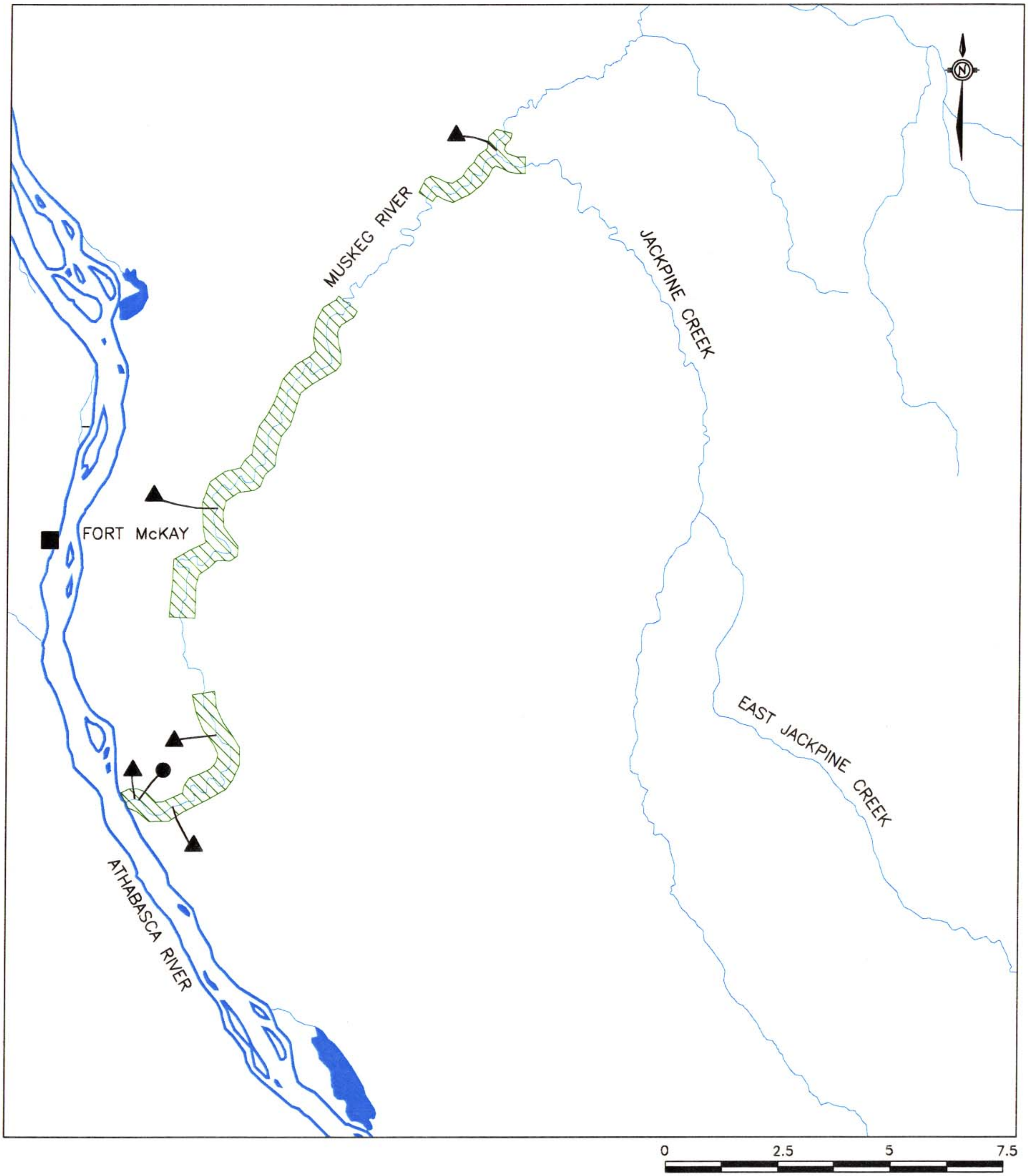
RAMP

FISH SAMPLING AREAS AND RELEASE SITES FOR THE RADIOTELEMETRY PROGRAM, ATHABASCA RIVER

DRAWN: VS	APPROVED:	DATE: 23 Feb. 2001	
PROJECT: 002-2309.6450		FIGURE: **3.3**	

Revision No.: 02

R:\Active\2300\002-2309\CAD\6050\Samp-AthabascaRiver.dwg



LEGEND

- BOAT ELECTROFISHING AREA
- ● FYKE NET LOCATION
- ▲ RELEASE SITE FOR RADIO TAGGED FISH

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

RAMP

FISH SAMPLING AREAS AND RELEASE SITES FOR THE RADIOTELEMETRY PROGRAM, MUSKEG RIVER

DRAWN: VS	APPROVED:	DATE: 16 Feb. 2001	
PROJECT: 002-2309.6450		FIGURE: **3.4**	

Revision No.: 02

R:\Active\2300\002-2309\CAD\6450\Samp-MuskegRiver.dwg

The fyke net was set 0.3 km upstream of the mouth of the Muskeg River (Figure 3.4) on May 28 and removed on May 29. It was hoped that the net would capture longnose sucker on the out-migration following spawning activity. However, examination of fish captured while electrofishing indicated that spawning activity was just underway. Based on this and the large amount of debris accumulating in the net, this sampling technique was abandoned.

All captured fish were processed as described in the previous section. Ageing structures were only collected from radio-tagged longnose sucker.

Radio Tagging Equipment and Procedures

Radio transmitters were surgically implanted into the body cavity. Coded microprocessor radio transmitters fitted with whip antennae (Lotek Engineering Inc. - Model MCFT-3EM) were used for the study. Transmitters weighed 8.9 g (weight in air) and emitted high frequency radio signals in the 149 MHz frequency range at a burst rate of 4 seconds. The inclusion of a microprocessor in each transmitter allowed them to operate on a programmed activation schedule. To save battery life, the transmitters automatically shut-off for a period of eight hours per twenty-four hour cycle (i.e., overnight) when telemetry surveys could not be conducted. The transmitters had a guaranteed life expectancy of 443 days.

Coded transmitters were used to accommodate the large number of fish included in the RAMP 2000 radiotelemetry program. Coded transmitters allow a number of transmitters to operate on the same frequency to make scanning for transmitters faster. This provides increased assurance of locating transmitter signals during the telemetry surveys. Each transmitter signal has a number encoded in the transmission that is identified by the telemetry receiver. The tracking receiver used was a Lotek Model SRX-400.

Following capture, adult longnose sucker were placed in a holding facility. Fish were selected for radio tagging based on size and physical condition. A minimum fish weight of 450 g was required to ensure that the transmitter did not weigh more than 2% of the fish’s body weight. Fish were radio tagged and released on the day they were captured.

For radio tagging, individual fish were removed from the holding facility and placed in an anaesthetic bath consisting of 1.0 ml of clove oil emulsified in 9.0 ml of ethanol and mixed in 20 L of river water. Fish were anaesthetized for a period of two to four minutes during which time the respiration rate and physical movements (coordination) of each fish was visually monitored until the fish was determined to be anaesthetized. The surgical implantation technique was modified from methods outlined by Bidgood (1980) and Knecht et al. (1981). A 3-4 cm longitudinal, abdominal incision was made slightly to one side of the mid-ventral line, anterior to the pelvic fins. A hypodermic needle (16 gauge) was inserted through the skin approximately 2 cm posterior to the incision, into the abdominal cavity and out through the incision. The radio transmitter's whip antennae was then inserted in the hypodermic needle and drawn out of the body cavity through the needle hole. The radio transmitter was positioned inside the body under the incision and an antibiotic (Lyquamycin) was injected intraperitoneally to reduce the possibility of infection. The incision was closed using dissolving sutures (polydioxanone), treated with a fungicide (methyl blue) and sealed with liquid tissue adhesive.

Fish were examined internally during surgery to determine sex, and the specific state-of-maturity (i.e., pre-spawning, spawning or post-spawning). Following surgery, the fish was placed in a holding facility with fresh river water for observation and recovery, then released.

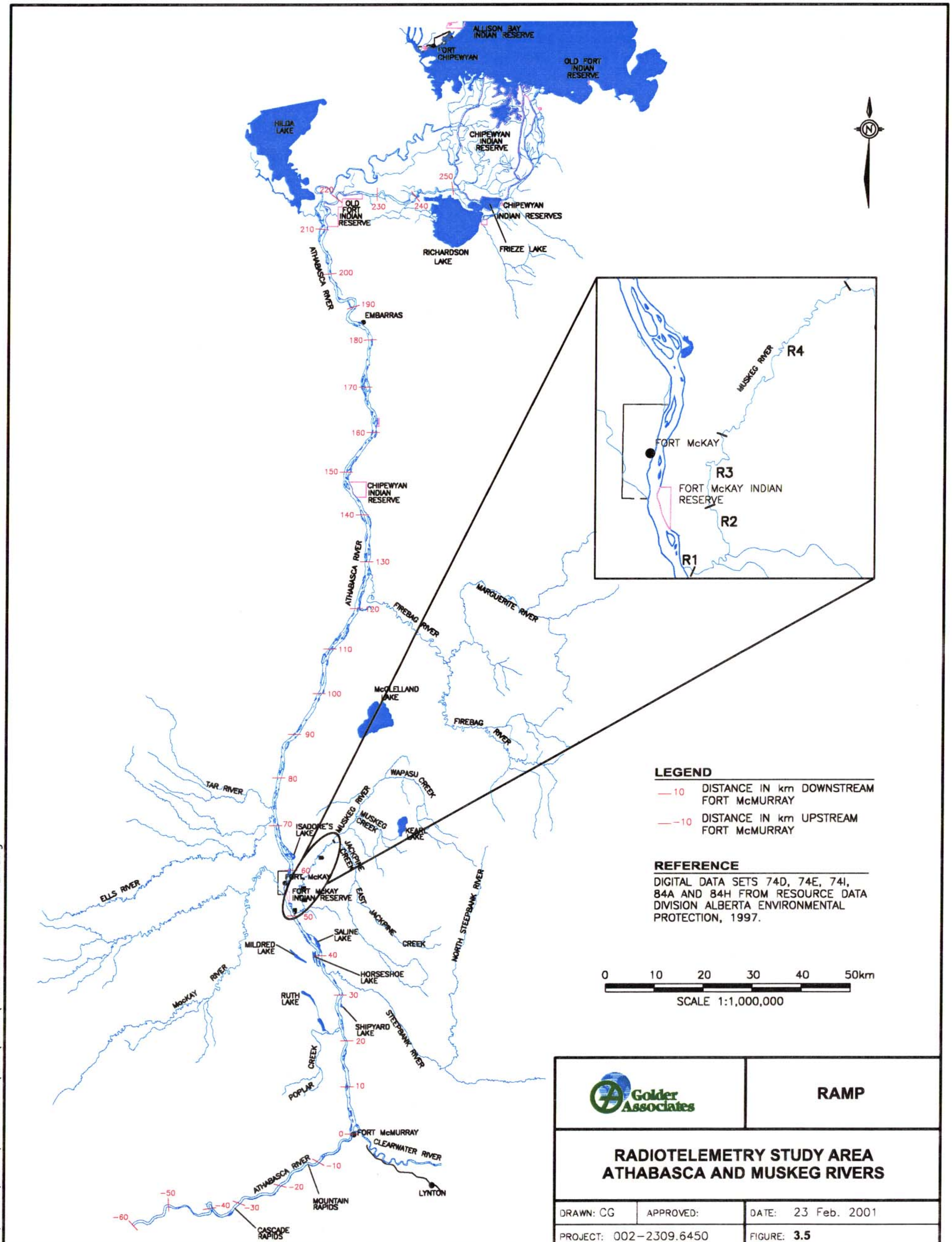
Radiotelemetry Surveys

Radio tracking surveys to monitor and record positions of radio-tagged fish were conducted by flying the telemetry study area with the tracking receiver mounted in a fixed-wing aircraft. The telemetry study area included the mainstem Athabasca River from Cascade Rapids downstream to Lake Athabasca, and the Muskeg River from the mouth upstream to the Jackpine Creek confluence (Figure 3.5). The area included approximately 335 km of the Athabasca River, including both the east (Fletcher) and west channels where the river divides near Lake Athabasca (Figure 3.5), and the lower 35 km of the Muskeg River. The Athabasca River study area was divided into kilometre posts centred on Fort McMurray and the Muskeg River study area was divided into river reaches (Figure 3.5).

Telemetry flights were initiated June 4, 2000 and were subsequently conducted approximately every two weeks, with the frequency increasing to once per week during the spring and fall when large scale fish movements were anticipated. At the time of writing this report, a total of 20 flights were flown between June 4, 2000 to January 24, 2001. The telemetry flights were conducted by Syncrude personnel and the specific flight dates (Appendix VI) were dependent on availability of personnel and aircraft, as well as weather conditions.

The telemetry flights are ongoing and will continue until the spring of 2001, providing a full year of monitoring data.

Telemetry flights were conducted using a two-person telemetry crew. One person operated the telemetry receiver and the other was responsible for navigation and marking fish locations. Fish positions were marked in-flight on 1:50,000 scale maps of the study area and also recorded by kilometre post (Athabasca River) or reach (Muskeg River).



Golder Associates

RAMP

RADIOTELEMETRY STUDY AREA ATHABASCA AND MUSKEG RIVERS

DRAWN: CG	APPROVED:	DATE: 23 Feb. 2001	
PROJECT: 002-2309.6450		FIGURE: **3.5**	

Revision No.: 01

In addition to the telemetry flights, a single ground-based survey was conducted for the Muskeg River by floating through the study area with the tracking receiver mounted in a canoe. The ground survey was conducted on August 23, 2000 for the purpose of providing more detailed fish positions than was possible using the aircraft and to assist in identifying individual signals for the large number of fish congregated in this watercourse.

3.2 TRIBUTARIES OF THE ATHABASCA RIVER

3.2.1 Water and Sediment Quality

In 2000, RAMP returned to McLean Creek, the Steepbank River, the Muskeg River, and Jackpine, Muskeg and Stanley creeks. Poplar Creek, Fort Creek and the Unnamed Creek draining Lease 52 were added to the RAMP program in 2000, along with the MacKay River (Figure 3.2). Water and/or sediment samples were collected from each sample site in accordance with the sampling schedule summarized in Table 3.2.

Table 3.2 RAMP 2000 Water and Sediment Sampling Schedule for Athabasca River Tributaries

Waterbody	Sample Location	Short Title	Sample Media	Sample Date
McLean Creek	mouth	MCC-1	water / sediments	October 2 (fall)
Poplar Creek	mouth	POC-1	water	October 2 (fall)
Steepbank River	mouth	STR-1	water	October 1 (fall)
MacKay River	mouth	MAR-1	water	October 7 (fall)
Fort Creek	mouth	FOC-1	water	May 24 (spring)
				September 7 (fall)[a]
			water / sediments	October 3 (fall)
Unnamed Creek (drains Lease 52)	mouth	UNC-1	water	May 24 (spring)
				September 7 (fall) [a]
				October 3 (fall)
Muskeg River	mouth	MUR-1	water / sediments	September 26 (fall)
	1 km upstream of mouth	MUR-1b	sediments	September 26 (fall)
	upstream of the Canterra Road crossing	MUR-2	sediments	September 26 (fall)
	upstream of Jackpine Creek	MUR-4	sediments	October 5 (fall)
	upstream of Muskeg Creek	MUR-5	sediments	October 5 (fall)
	upstream of Wapasu Creek	MUR-6	water / sediments	September 26 (fall)
Jackpine Creek	mouth	JAC-1	water / sediments	October 5 (fall)
Muskeg Creek	mouth	MUC-1	water / sediments	October 5 (fall)
Stanley Creek	mouth	STC-1	water / sediments	N/A [b]

[a] Originally intended to be summer samples. Mechanical difficulties delayed sample collection to early fall.

[b] No flowing water was observed, so no sample was taken.

3.2.1.1 Field Methods

Water Sampling

Water samples were collected from the centre of the Steepbank, MacKay and Muskeg rivers and McLean, Poplar, Fort and Unnamed creeks approximately 100 m upstream of their confluence with the Athabasca River. Water samples were also collected from Jackpine Creek, Muskeg Creek and the Muskeg River upstream of Wapasu Creek (Figure 3.2). At these last three sites, samples were taken 50 to 100 m upstream of the stream mouth and/or access road. Grab samples were collected at every site from a depth of approximately 30 cm.

All samples were preserved, stored and shipped to ETL for analysis of conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons, chlorophyll *a* and naphthenic acids. A portion of all of the fall samples were sent to HydroQual for Microtox® analysis. Toxicity testing with algae (*Selenastrum capricornutum*), water flea (*Ceriodaphnia dubia*) and fathead minnow (*Pimephales promelas*) was completed by HydroQual for fall samples collected from McLean Creek, Fort Creek and the upper Muskeg River.

Due to instrumentation problems, field measurements, including DO, pH, conductivity and temperature, could not be recorded at each sample site. A summary of available field data is provided in Table 3.3. Exact locations of sampling sites were determined using a GPS unit. All samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999a).

Thermographs

Thermographs were installed at the mouths of McLean and Fort creeks, the Alsands Drain and in the Muskeg River upstream of Jackpine and Wapasu creeks (Table 3.4). They were programmed to record water temperatures every 30 minutes, installed in the spring and left in situ. Thermographs were placed in areas where water depths exceeded 1 m at the time of installation and were covered with perforated PVC tubing. Thermographs were recovered between September 26 and October 5, 2000 (Table 3.4).

Two other thermographs, located in the Muskeg River upstream of the Canterra Road crossing and upstream of Muskeg Creek, were downloaded on June 2 and again between September 26 and October 5, 2000. These two thermographs were originally installed as part of RAMP's 1999 water quality program (Golder 2000c), and are left in place to record winter water temperatures.

Sediment Sampling

Sediment samples were collected from depositional areas close to the shore in the Muskeg River and Jackpine, Muskeg, McLean and Fort creeks (Table 3.2). Sediments were taken from the top 3 cm of the river bottom using an Eckman grab sampler. Four to six individual samples were collected at each sampling location and mixed to form one composite sample for the site. All composite samples were split into three parts and shipped to ETL, HydroQual and AXYS for analysis of the same parameters described in Section 3.1.1.1.

Table 3.3 Available Field Measurements for RAMP 2000

Waterbody	Sample Location	Short Title	Sample Date	Field Measurements
McLean Creek	mouth	MCC-1	October 2	all
Poplar Creek	mouth	POC-1	October 2	none
Steepbank River	mouth	STR-1	October 1	none
MacKay River	mouth	MAR-1	October 7	conductivity and temperature
Fort Creek	mouth	FOC-1	May 24	none
			September 7	all
			October 3	all
Unnamed Creek (drains Lease 52)	mouth	UNC-1	May 24	none
			September 7	all
			October 3	all
Muskeg River	mouth	MUR-1	September 26	all
	upstream of Wapasu Creek	MUR-6	September 26	no pH
Jackpine Creek	mouth	JAC-1	October 5	none
Muskeg Creek	mouth	MUC-1	October 5	none

Table 3.4 Thermograph Locations in 2000

Waterbody	Site	Short Title	Installation Date	Retrieval Date
Muskeg River	upstream of the Canterra Road crossing[(a)]	MUR-2	June 2	September 26
	upstream of Jackpine Creek	MUR-4	June 2	October 5
	upstream of Muskeg Creek[(a)]	MUR-5	June 2	October 5
	upstream of Wapasu Creek	MUR-6	June 2	September 26[(b)]
Alsands Drain	near mouth	ALD-1	June 2	September 26[(c)]
McLean Creek	near mouth	MCC-1	June 2	-[(d)]
Fort Creek	near mouth	FOC-1	May 24	October 3

(a) Thermograph was installed in 1999 and has not been removed; data downloaded on dates shown.
(b) Thermograph stopped recording water temperatures on September 10, 2000.
(c) Thermograph stopped recording water temperatures on September 16, 2000.
(d) Thermograph was never recovered and is presumed lost.

3.2.1.2 Data Analysis

Qualitative comparisons were used to characterize water and sediment quality in the Athabasca River tributaries. Historical information, where available, was summarized, and historical median, minimum and maximum values were developed (Appendix II). Information collected in 2000 was then compared qualitatively to the historical median values associated with each of the 2000 sampling sites. The 2000 and historical median values were also compared to relevant water and sediment quality guidelines. Trends in the complete data set were examined, and differences between new information and historical data were identified using the criteria described in Section 3.1.1.2. Increased statistical analysis of the water quality data will be incorporated in future years, as the amount and number of years of data increases.

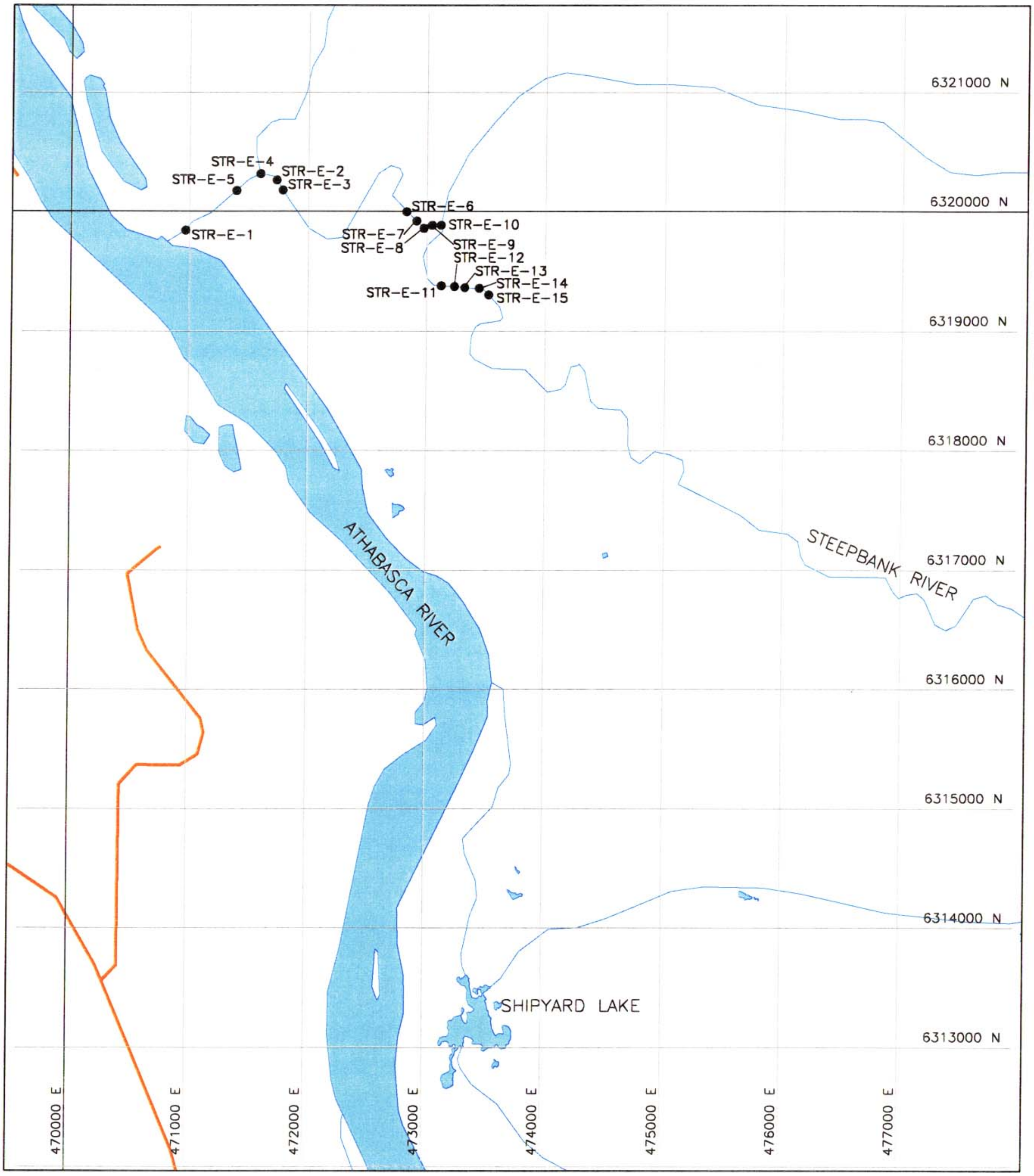
3.2.2 Benthic Invertebrate Community

3.2.2.1 Sampling Site Locations

The study design for each river consisted of collecting 15 individual samples within a 5 km erosional reach upstream from the mouth (Figures 3.6 and 3.7, Table 3.5). Additionally, 15 depositional samples were collected in the Muskeg River farther upstream, beginning about 10 km upstream from its mouth (Figure 3.7), above the abrupt change in the character of this river.

The dominant habitat types were monitored in each river. The MacKay and Steepbank rivers are largely erosional throughout their length, whereas the Muskeg River is mostly depositional with the exception of its lowest reach. Sampling both habitats in the Muskeg River increases the potential of detecting impacts. A sensitive monitoring design is particularly important in this river because of the large number of approved and planned oil sands developments in its basin.

Erosional sites consisted of shallow riffles, whereas depositional sites were located mostly in shallow run habitat. The objective of site selection in the field was to find locations representing "typical" erosional or depositional habitats within the lower reaches of each river, rather than to standardize the habitat sampled to within a narrow range. Although this approach may result in more variable data, it provides a better indication of the range of benthic communities inhabiting the sampling reaches.



R:\Active\2300\002-2309\CAD\6300\River-Sample Pts-Fall 2000 Data.dwg

LEGEND

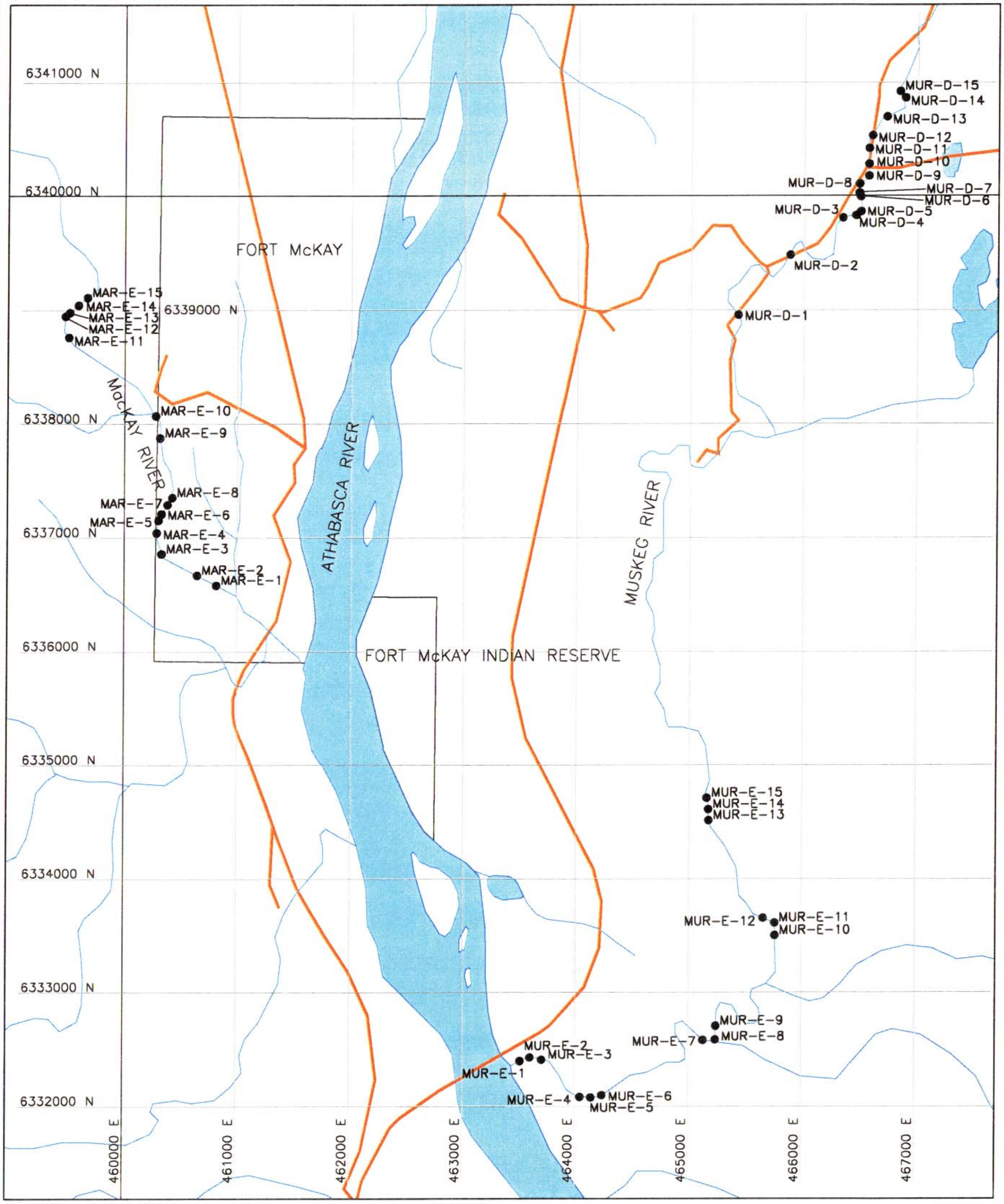
- ROADWAYS
- RIVERS AND STREAMS
- ● BENTHIC INVERTEBRATE SAMPLING SITE

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

Golder Associates	RAMP
RAMP 2000 BENTHIC INVERTEBRATE SAMPLING SITES IN THE STEEPBANK RIVER	
DRAWN: RFM APPROVED:	DATE: 21 Feb. 2001
PROJECT: 002-2309.6300	FIGURE: **3.6**

Revision No.: 01



LEGEND

ROADWAYS

RIVERS AND STREAMS

● BENTHIC INVERTEBRATE SAMPLING SITE

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

Golder Associates

RAMP

RAMP 2000
BENTHIC INVERTEBRATE SAMPLING SITES IN THE MACKAY AND MUSKEG RIVERS

DRAWN: RFM	APPROVED:	DATE: 21 Feb. 2001	
PROJECT: 002-2309.6300		FIGURE: 3.7	

Revision No.: 01

R:\Active\2300\002-2309\CAD\6300\River-Sample Pts-Fall 2000 Data.dwg

Table 3.5 Locations of Benthic Invertebrate Sampling Sites in the Rivers Sampled in Fall 2000

River	Site	UTM East	UTM North
MacKay (erosional)	MAR-E-1	460825	6336438
	MAR-E-2	460825	6336438
	MAR-E-3	460391	6336739
	MAR-E-4	460391	6336739
	MAR-E-5	460442	6337051
	MAR-E-6	460442	6337051
	MAR-E-7	460442	6337051
	MAR-E-8	460442	6337051
	MAR-E-9	460423	6337763
	MAR-E-10	460423	6337763
	MAR-E-11	459533	6338639
	MAR-E-12	459533	6338639
	MAR-E-13	459652	6338795
	MAR-E-14	459652	6338795
	MAR-E-15	459652	6338795
Steepbank (erosional)	STR-E-1	471071	6319616
	STR-E-2	471834	6320100
	STR-E-3	471896	6320035
	STR-E-4	471747	6320472
	STR-E-5	471455	6319960
	STR-E-6	473022	6319731
	STR-E-7	473091	6319755
	STR-E-8	473066	6319652
	STR-E-9	473106	6319671
	STR-E-10	473132	6319704
	STR-E-11	473308	6319163
	STR-E-12	473342	6319169
	STR-E-13	473404	6319167
	STR-E-14	473442	6319156
	STR-E-15	473491	6319186
Muskeg (erosional)	MUR-E-1	463675	6332260
	MUR-E-2	463675	6332260
	MUR-E-3	463675	6332260
	MUR-E-4	464203	6331838
	MUR-E-5	464203	6331838
	MUR-E-6	464203	6331838
	MUR-E-7	465325	6332659
	MUR-E-8	465325	6332659
	MUR-E-9	465325	6332659
	MUR-E-10	465849	6333433
	MUR-E-11	465849	6333433
	MUR-E-12	465849	6333433
	MUR-E-13	465230	6334393
	MUR-E-14	465230	6334393
	MUR-E-15	465230	6334393
Muskeg (depositional)	MUR-D-1	465427	6338742
	MUR-D-2	465983	6339249
	MUR-D-3	466394	6339624
	MUR-D-4	466588	6339572
	MUR-D-5	466575	6339613
	MUR-D-6	466603	6339794
	MUR-D-7	466470	6339790
	MUR-D-8	466551	6339893
	MUR-D-9	466698	6339918
	MUR-D-10	466675	6340049
	MUR-D-11	466639	6340204
	MUR-D-12	466688	6340295
	MUR-D-13	466779	6340490
	MUR-D-14	466949	6340650
	MUR-D-15	466809	6340680

Spacing of the individual samples in each river reach was dependent upon access (i.e., helicopter landing sites), habitat characteristics and time constraints. In areas where it was necessary to group samples within shorter reaches, spacing was about 50 to 100 m between samples to maximize spatial coverage.

3.2.2.2 Field Methods

Benthic samples were collected during 1 to 7 October, 2000 according to Golder Technical Procedure 8.6-1 (Golder 1999a). A Neill cylinder of 0.093 m^2 bottom area with a 210 µm mesh collecting net was used to sample benthic invertebrates in erosional habitat. A pole-mounted Ekman grab of 0.0232 m^2 bottom area was used in depositional habitat. A single sample was collected at each of the 15 locations selected within the sampling reach in each river. Depositional samples were sieved in the field prior to preserving, using a 250 µm mesh sieve. Benthic samples were preserved in 10% buffered formalin.

Physical characteristics of the sampling sites were recorded to allow an analysis of the influence of such variation on the invertebrate community. Supporting measurements are listed below and were measured at each sampling location using the following instruments:

- wetted and bankfull channel widths – visual estimate;
- field water quality: dissolved oxygen, conductivity, pH, water temperature – Multiline water quality meter;
- current velocity – Marsh-McBirney current velocity meter;
- water depth – wading rod of current velocity meter;
- amount of benthic algae at erosional sites – visual estimate as "none" to "high" and a quantitative benthic algae sample (2 x 2 cm scrapes from three cobbles at each sample location, combined into one composite sample per location);
- substrate particle size distribution and embeddedness at erosional sites – visual estimates of areal coverage by particles in standard size categories as a percentage and visual estimate of embeddedness as a percentage;
- bottom sediment texture at depositional sites (sand, silt, clay as weight percentages) and total organic carbon (TOC) content at depositional sites – quantified in the laboratory in sediment samples collected using the Ekman grab;
- exact position – Trimble GeoExplorer Global Positioning System (GPS) unit; and
- general site appearance – photograph.

Benthic algal scrapes for chlorophyll *a* analysis were stored and transported frozen. Sediment samples for determination of texture and TOC were stored on ice or in a refrigerator and were transported on ice. Both were submitted for analysis at Enviro-Test.

3.2.2.3 Laboratory Methods

Benthic invertebrate samples were first passed through a 250 µm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by this sieve was elutriated to separate organic material from sand and gravel.

The remaining organic material was separated into coarse and fine size fractions using a 1 mm sieve. The fine size fraction of large samples was subsampled using a method based on that described by Wrona et al. (1982). Invertebrates were removed from the detritus under a dissecting microscope. All sorted material was preserved for random checks of removal efficiency.

Invertebrates were identified using recognized taxonomic keys to the lowest practical level, typically genus with the exception of the Oligochaeta, which were identified to family. Small, early-instar or damaged specimens were identified to the lowest level possible, generally to family.

3.2.2.4 Data Analysis

The 2000 benthic survey results were summarized to describe community composition and natural variation in each waterbody. Non-benthic and terrestrial taxa were deleted from the data set. Community variables such as total abundance (number/m^2), taxonomic richness (total taxa) and community composition by major groups were examined as bar graphs of mean numbers per reach and corresponding standard errors. Mean abundances of common taxa, defined as those constituting ≥1% of total abundance at a site, were tabulated for each reach, to illustrate relative abundances and variability within sampling reaches.

The benthic invertebrate abundance data were also examined for relationships between key habitat variables and benthic community structure (summarized as total abundance, richness and abundances of common invertebrates). Spearman correlation coefficients were calculated to identify potential relationships, separately for each river (n=15 in each river). Significant correlations were examined visually as scatter-plots. Habitat variables were included in this analysis if they varied over a sufficient range to account for some variation in community structure. For this analysis, substrate composition was expressed as the Weighted Average Index (WAI; Fernet and Walder 1986). The WAI summarizes particle size as a single variable, which is useful to represent average particle size, provided that the size distribution is continuous.

3.2.3 Fish Populations

For tributaries of the Athabasca River, the fisheries program included three components. The first component was a fish movement (radiotelemetry) study for northern pike and Arctic grayling of the Muskeg River. The second component was a spawning survey of the lower Muskeg River and Jackpine Creek. The emphasis of this study was on identifying spawning habitat for Arctic grayling, but potential spawning habitats suitable for northern pike and longnose sucker were also evaluated. The third component was a survey of tributary streams in the Oil Sands Region to identify suitable reference sites for slimy sculpin for use in the tributary sentinel species monitoring study.

3.2.3.1 Radiotelemetry Study

The Muskeg River was selected for the radiotelemetry study because of its importance as a spawning, rearing and summer feeding stream for fish from the Athabasca River, and its location within the oil sands development area. Northern pike and Arctic grayling were target species because of their status as Key Indicator Resource species for the Muskeg River, and because of the continued uncertainty regarding the location of overwintering sites for these two species. The target number of fish to be radio tagged was 25 adults per species.

Sampling areas, capture techniques, fish processing methods and radio-tagging operations for northern pike and Arctic grayling were the same as described for longnose sucker from the Muskeg River (Section 3.1.2.1).

3.2.3.2 Spawning Survey

Limited baseline data are available concerning spawning activity for Arctic grayling, northern pike and longnose sucker in the Muskeg River drainage. Suspected spawning locations for these three species for the mainstem Muskeg River are mostly conjecture, based on known fish distribution and migration patterns, the presence of young-of-the-year fish, and the distribution of suitable habitats (Bond and Machniak 1979; Sekerak and Walder 1980; R.L.&L. 1989; Golder 1996). Although specific spawning areas in Jackpine Creek have been previously documented for Arctic grayling and longnose sucker (O'Neil et al. 1982), this spawning utilization information is dated and may not represent current use, particularly in view of apparent changes in spring spawning runs in this stream (Golder 1996). To provide further information on the spawning potential and use of Jackpine Creek and the Muskeg River by mainstem fishes, the following work was conducted: 1) summarize spawning habitat information from past studies; and 2) conduct a spring spawning survey to inventory current spawning sites/utilization.

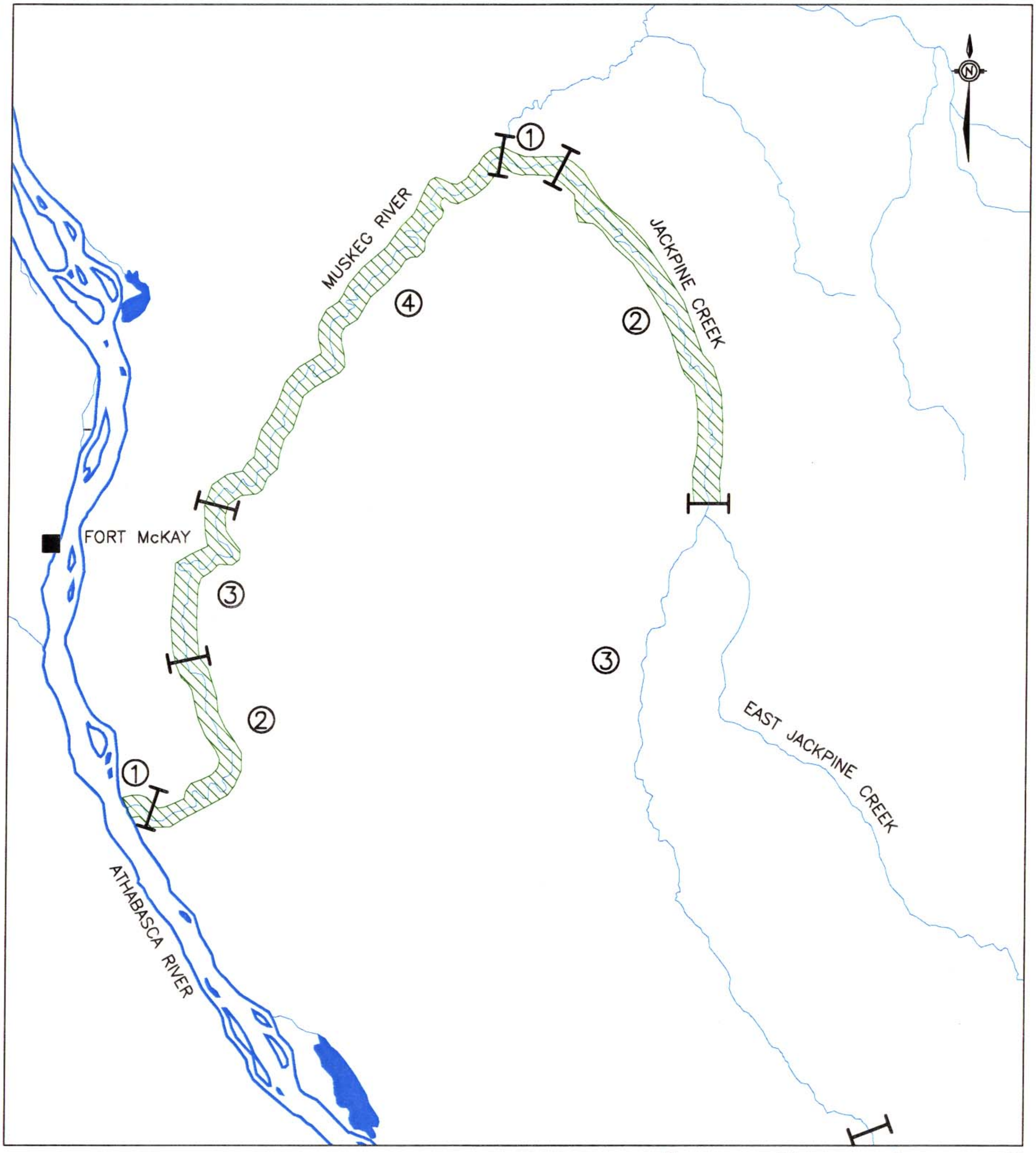
A spring spawning survey was conducted from May 20 to 25, 2000 for the lower reaches of Jackpine Creek and the Muskeg River. The specific areas surveyed were defined based on reaches previously described as having potential spawning habitat for Arctic grayling and longnose sucker (i.e., rocky substrates) (Bond and Machniak 1979; Sekerak and Walder 1980; O'Neil et al. 1982; R.L.&L. 1989; Golder 1996). The survey area on the Muskeg River included the lower 35 km of the river, extending from the Jackpine Creek confluence to the river mouth. This included Reaches 1, 2 and 3 and the lower portion of Reach 4. Similarly, the survey area for Jackpine Creek was to include Reaches 1, 2 and 3. However, aerial reconnaissance during a helicopter over-flight of Reach 3 (May 20) did not show any spawning potential due to excessive beaver activity resulting in several beaver impoundments dominated by fine, organic substrate. Therefore, the Jackpine Creek survey area extended from the top of Reach 2 to the confluence with the Muskeg River (approximately 21 km). Spawning survey areas and previously established reach boundaries are presented in Figure 3.8.

Both watercourses were surveyed for Arctic grayling and longnose sucker spawning activity. The Muskeg River was also surveyed for northern pike spawning. Access to Jackpine Creek was by helicopter. An egg survey was conducted by floating downstream in a 3.2 m inflatable boat (Zodiac) equipped with a 4 hp outboard motor and sampling potential spawning habitats for incubating eggs. Sampling focused on cobble/gravel substrates commonly used by Arctic grayling and longnose sucker, and areas of flooded vegetation potentially used by northern pike. Sampling was conducted using a fine mesh net. In rocky substrates, the net was held on the streambed into the current while the substrate upstream of the net was disturbed to dislodge incubating eggs so they floated downstream into the net. Areas of flooded vegetation were swept with the net to collect eggs attached to the vegetation. All eggs were enumerated, measured for diameter and checked for colour and any identifying features such as opaqueness or the presence of oil globules to allow species identification. A representative sample of eggs from each species was preserved in Gilson’s solution in the event species identification needed to be confirmed in the laboratory.

The location of all spawning sites was documented, by species, on 1:50,000 scale maps of the study area. Global Positioning System (GPS) coordinates for each site were also recorded using a Trimble Geo-Explorer rover unit. Habitat measurements at egg incubation sites included water depth, water velocity, water temperature and substrate particle size. As well, general habitat conditions and spawning suitability observations were recorded throughout the spawning survey areas.

3.2.3.3 Reference Site Survey

Fish communities of the Muskeg and Steepbank rivers may be influenced by potential changes in water quality and flow associated with oil sands development. In an effort to monitor potential impacts on fish in these river systems, a sentinel species monitoring program using slimy sculpin was initiated in the fall of 1999. Monitoring focused on three specific study areas: 1) an exposure area located on the Muskeg River downstream of current and future mining developments; 2) an exposure area located on the Steepbank River in the vicinity of the Steepbank Mine; and 3) a reference area located on the Steepbank River upstream of the Steepbank Mine and timber harvesting operations.



LEGEND

- REACH BOUNDARY
- ① REACH NUMBER
- SPAWNING SURVEY AREA

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

RAMP

REACH DESIGNATIONS AND SPAWNING SURVEY AREA, MUSKEG RIVER AND JACKPINE CREEK

DRAWN: VS	APPROVED:	DATE: 16 Feb. 2001	
PROJECT: 002-2309.6450		FIGURE: 3.8	

Revision No.: 02

R:\Active\2300\002-2309\CAD\6450\Reach-JackpineCk.dwg

Sufficient numbers of sculpin were collected in 1999 to detect differences in whole-organism parameters between exposure and reference sites. However, due to differences in sculpin abundance and habitat conditions between reference and exposure sites, it was uncertain whether measured differences were a function of habitat, anthropogenic influences or an interactive effect of both.

In response to this concern, the objectives of the current survey were the following:

- to describe habitat conditions at exposure and reference sites along the Muskeg and Steepbank rivers where slimy sculpin were collected in 1999. Habitat information would help to assess the influence of habitat conditions on sculpin characteristics and to ensure the selection of exposure and reference sites that are as similar as possible.
- to identify additional reference sites in other tributaries of the Athabasca River based on the presence of slimy sculpin and similarity in habitat conditions relative to exposure sites. Additional reference sites would help to more accurately define the full range of natural variability in sculpin characteristics.

The field survey occurred from September 18 to 22, 2000. The four sites along the Muskeg and Steepbank rivers sampled in 1999 were revisited. Additional reference sites outside the Muskeg and Steepbank drainages were selected by a review of habitat and fish collection information provided in Sekerak and Walder (1980) and Tripp and Tsui (1980). Reference site suitability was based on historical capture success of slimy sculpin and the similarity of habitat features (e.g., channel width, bed material) to exposure sites along the Muskeg and Steepbank rivers. Nine additional, potential reference sites were sampled along the Dover, Dunkirk, Ells, Hangingstone and Horse rivers (Figure 3.9, Table 3.6). Most sites are accessible only by helicopter. However, the Muskeg River sites and the Hangingstone River site immediately south of Highway 63 were accessed by vehicle.

Fish were sampled from areas of riffle and turbulent run habitat by a two-person field crew using a backpack electrofishing unit (Smith-Root Type 15-D). Stunned fish swept downstream by the current were collected with a pole seine (2 x 1.2 m, 0.5 cm mesh size) held downstream of the electrofishing unit. All fish collected were identified to species and enumerated. The total length (cm) and weight (g) of all slimy sculpin captured were measured and the state-of-maturity was assessed (i.e., juvenile, unknown, adult). Condition factor (100 x [body weight/total length^3]) was also calculated for sculpin from each site sampled.

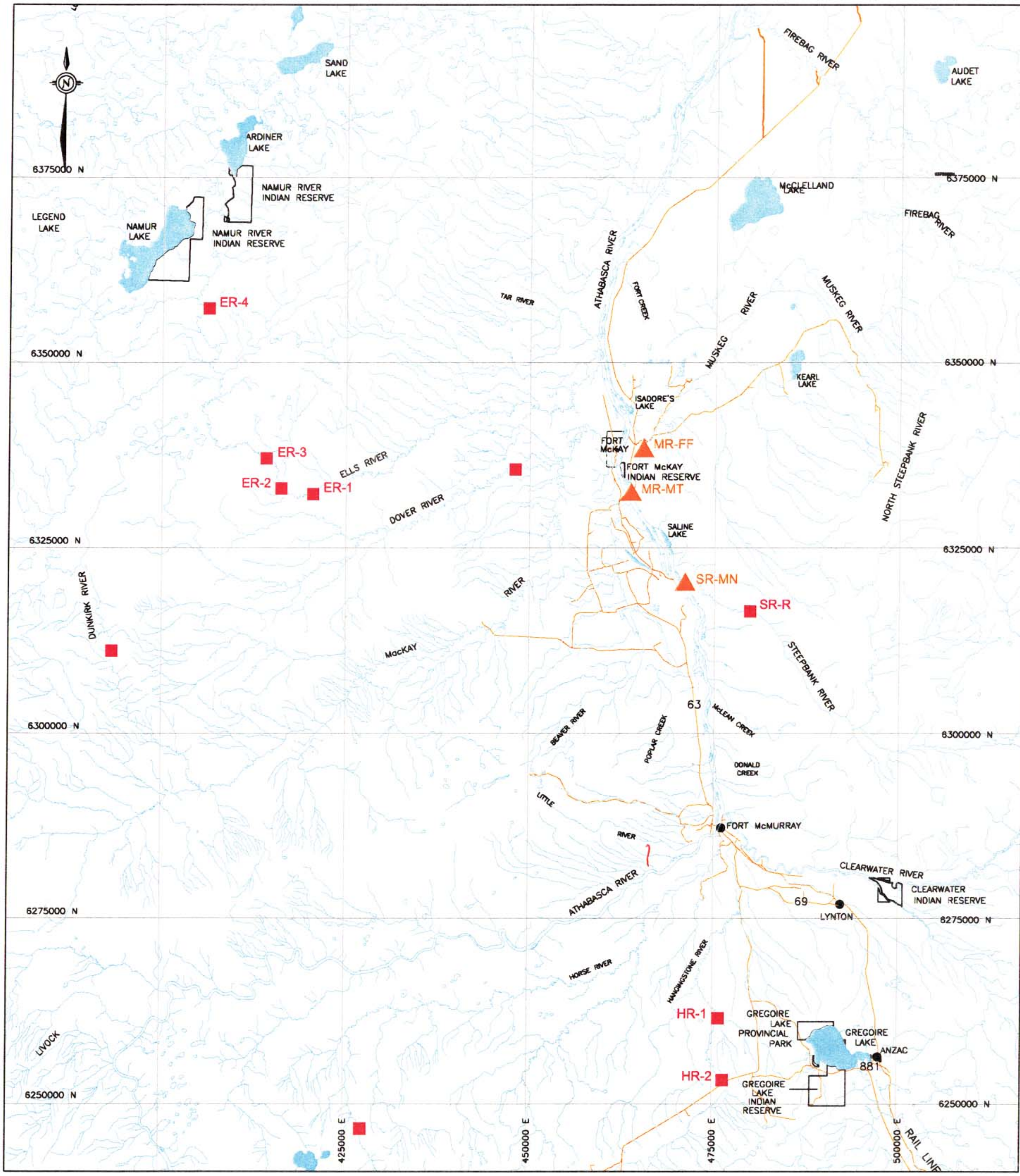


Image:Kos-bw.jpg Image:Mobil.tif

R:\Active\2300\002-2309\CAD\6450\Region.dwg

LEGEND

- REFERENCE SITE
- EXPOSURE SITES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997. DATUM IS IN NAD83 UTM PROJECTION.

0 10 20 30 40

SCALE (km)

Golder Associates

RAMP

REFERENCE SITES SURVEYED FOR THE SENTINEL SPECIES MONITORING PROGRAM

DRAWN: RFM	APPROVED:	DATE: 16 Feb. 2001
PROJECT: 002-2309.6450		FIGURE: 3.9

Revision No.: 02

Table 3.6 General Location and UTM Co-ordinates of Sampling Sites for Slimy Sculpin, Fall 2000

Site	General Location	UTMs of Sampling Reach
Muskeg River		
MR-FF	exposure site in the vicinity of past fish fence site, sampling area also extended approx. 750 m downstream to next available riffles	465521 E / 6338751 N
MR-MT	exposure site approx. 350 m upstream from the mouth of the Muskeg River (entering the Athabasca River)	463946 E / 6332040 N
Steepbank River		
SR-MN	exposure site in the vicinity of Steepbank Mine, approx. 650 m upstream of confluence with the Athabasca River	471221 E / 6319858 N
SR-R	reference site in the vicinity of Bitumen Heights approx. 16 km upstream of the confluence with the Athabasca River	479469 E / 6316259 N
Dover River	reference site approximately 15 km upstream of the confluence with the MacKay River	448378 E / 6335548 N
Dunkirk River	reference site approximately 25 km upstream of the confluence with the MacKay River	395884 E / 6302416 N
Ells River		
ER-1	reference site approximately 70 km upstream of the confluence with the Athabasca River	420355 E / 6332151 N
ER-2	reference site approximately 80 km upstream of the confluence with the Athabasca River	416270 E / 6332989 N
ER-3	reference site approximately 90 km upstream of the confluence with the Athabasca River	414179 E / 6336598 N
ER-4	reference site approximately 190 km upstream of the confluence with the Athabasca River	405409 E / 6357301 N
Hangingstone River		
HR-1	reference site approximately 42 km upstream of the confluence with the Clearwater River	475503 E / 6261000 N
HR-2	reference site approximately 59 km upstream of the confluence with the Clearwater River	476398 E / 6253114 N
Horse River	reference site approximately 140 km upstream of the confluence with the Athabasca River	427028 E / 624704 N

The following habitat characteristics were measured at all sites sampled in 1999 and those additional reference sites where slimy sculpin were captured:

- general habitat type (i.e., riffle, run, glide);
- bed material;
- discharge;

- channel width, water depth and velocity;
- bank stability;
- channel gradient;
- instream and overhanging cover; and
- water chemistry (dissolved oxygen, temperature, conductivity and pH).

Due to limited helicopter time, fewer detailed habitat observations were taken at potential reference sites where sculpin were not found, or were present in only limited numbers.

Channel gradient was surveyed using a survey tripod, level and rod. The length of channel surveyed at each site ranged from 16 to 44 m. The distance surveyed at some sites was restricted by high flows and channel morphology. Discharge was measured using a tagline, velocity meter (Marsh-McBirney Model 201) and wading rod in accordance to guidance provided by Terzi (1981). Five representative water depths and velocities were measured at those sites where either discharge was measured outside of the area sampled for sculpin, or when flows were too high to measure discharge safely. The surficial bed material of habitats sampled was characterized using the pebble count method (Kondolf 1997). Water chemistry was measured using a field water quality meter (Multi-line Model P4). Photographs of each reference and exposure site were also taken.

3.3 WETLANDS

3.3.1 Water and Sediment Quality

In 1999, water quality sampling of wetlands was restricted to Shipyard Lake. In 2000, RAMP collected water samples from Kearl, Isadore's, McClelland and Shipyard lakes. Sample locations are shown in Figure 3.2, and the 2000 wetlands sampling schedule is summarized in Table 3.7. During each sampling event, ten individual 1 L grab samples were collected and combined to form one composite sample. Sample bottles were placed approximately 30 cm below the water surface.

Each composite sample was divided into two parts, and one part was shipped to ETL and analyzed for conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons, chlorophyll *a* and naphthenic acids. The other part of the composite sample was sent to HydroQual for Microtox® analysis. Field measurements (i.e., DO, pH, conductivity and temperature) were taken at all sample sites. Unfortunately, spring and some of the fall field data from McClelland Lake were lost in the field.

Table 3.7 RAMP 2000 Water Sampling Schedule for the Wetlands

Waterbody	Short Title	Sample Media	Sample Date
Kearl Lake	KEL-1	water	September 27 (fall)
Isadore's Lake	ISL-1	water	September 30 (fall)
Shipyard Lake	SHL-1	water	August 11 (summer)
		water	September 28 (fall)
McClelland Lake	MCL-1	water	May 25 (spring)
		water	September 7 (fall)[a]
		water	September 29 (fall)

[a] Originally intended to be summer samples. Mechanical difficulties delayed sample collection to early fall.

Wetlands water quality data were analyzed by the same methods as those described in Section 3.2.1.2.

In 2000, no sediment samples were collected from the four wetlands currently included in the RAMP program.

3.3.2 Benthic Invertebrate Community

Benthic samples were collected in Shipyard Lake on September 28, 2000 according to Golder Technical Procedures 8.6-1. A pole-mounted Eckman grab of 0.02332 m^2 bottom area was used. The survey of Shipyard Lake included collection of ten grab samples positioned randomly in the lake, but within a restricted depth range of 1 to 2 m. Lake samples were sieved in the field prior to preserving, using a 250 µm mesh sieve. Benthic samples were preserved in 10% buffered formalin.

Physical characteristics of the sampling sites were recorded to allow an analysis of the influence of such variation on the invertebrate community. Supporting measurements are listed below and were measured at each sampling location using the following instruments:

- field water quality: dissolved oxygen, conductivity, pH, water temperature – Multiline water quality meter;
- water depth – wading rod of current velocity meter;
- bottom sediment texture (sand, silt, clay as weight percentages) and total organic carbon (TOC) content – quantified in the laboratory in sediment samples collected using the Ekman grab; and
- exact position – Trimble GeoExplorer Global Positioning System (GPS) unit.

A sediment sample was also collected at each lake sampling location and was analyzed for texture and TOC to aid in the interpretation of the benthic invertebrate data. Water transparency was measured as the Secchi depth.

Laboratory methods and data analysis described in Sections 3.2.2.3 and 3.2.2.4 were also used for the Shipyard Lake samples (n=10). Community variables such as total abundance (number/m^2), taxonomic richness (total taxa), community composition by major groups and mean abundance of common taxa were tabulated for Shipyard Lake.

Benthic invertebrate samples were submitted for taxonomy and enumeration to J. Zloty, Ph.D., Calgary, Alberta.

3.4 ACID SENSITIVE LAKES

3.4.1 Lakes Sampled

Thirty lakes were sampled in 2000, including 21 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and four lakes on the Canadian Shield (Table 3.8, Figure 3.10). In the Oil Sands Region, two of the original set of lakes (L1, L30) were not sampled because of difficulties with access via float plane. One lake (E15) was added to the 2000 program because it was found to be potentially at risk of acidification by the Firebag In-Situ Oil Sands Project EIA (Suncor 2000; this lake was identified in the EIA as L15b).

Slight modifications were also made to the set of reference lakes included in the 2000 program. Lakes O3 (Caribou Mountains) and R3 (Canadian Shield) were replaced with the more acid sensitive lakes E68 and L107, respectively (Figure 3.10). Lake R2 was not sampled in 2000 because it could not be located using the GPS coordinates available to the field crew.

3.4.2 Field Methods

Acid sensitive lakes were sampled during 29 August to 6 September, 2001, by Erin Sullivan (Al-Pac), William Donahue (University of Alberta), and Scott Flett (AENV; present during part of the survey). AENV field staff also assisted by providing sampling equipment, training of field personnel and logistical support. A float plane was used to access the study lakes.

Vertically integrated euphotic zone samples were collected from up to five sites in each lake using weighted Tygon tubing. Individual samples from one lake were then combined to form a single composite sample for chemical analysis.

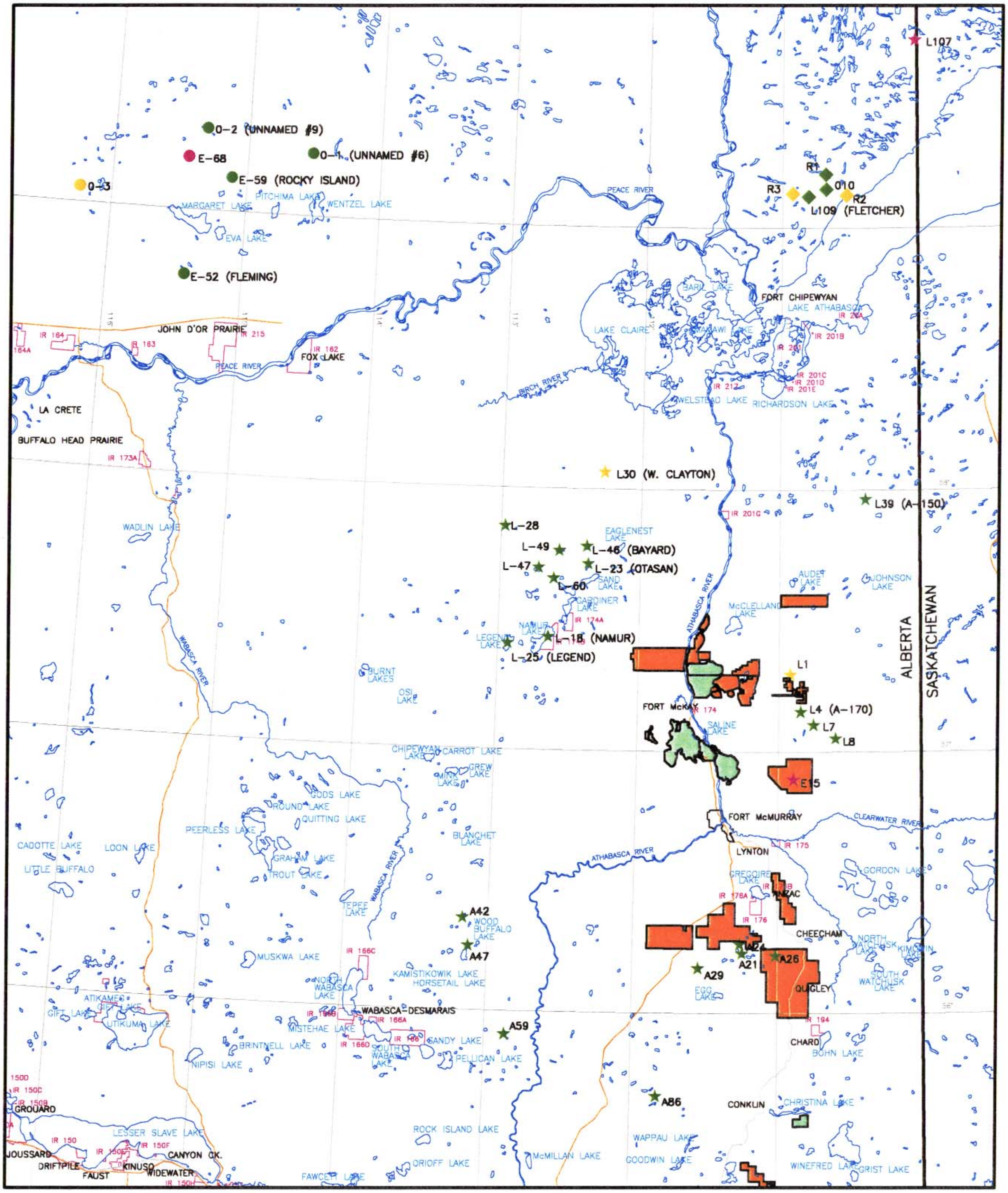
Table 3.8 Characteristics of the Lakes Selected for Long-term Acidification Monitoring

Lake	Sampled in 1999?	Sampled in 2000?	Latitude	Longitude	Altitude (m)	Max. Depth (m)	Alkalinity[a] (mg/L as $CACO_3$)
Oil Sands Region							
A21	Y	Y	56.2590	111.2600	719	1.2	0.8 - 2.0
A24	Y	Y	56.2219	111.2540	710	1.6	0 - 1.3
A26	Y	Y	56.2125	111.2028	712	1.3	1.7 - 9.3
A29	Y	Y	56.1685	111.5459	714	1.4	2.3 - 3.2
A42	Y	Y	56.3529	113.1753	643	1.3	9.2 - 11.3
A47	Y	Y	56.2440	113.1410	643	1.7	2.0 - 8.4
A59	Y	Y	55.9127	112.8622	555	2.0	2.1 - 3.5
A86	Y	Y	55.6833	111.8250	712	2.6	5.6 - 7.8
E15 (L15b)	N	Y (new)	56.8939	110.8980	457	1.7	20.0 - 21.3
L1	Y	N (too small)	57.2853	110.9239	--[b]	0.9	4.3 - 6.7
L4 (A-170)	Y	Y	57.1509	110.8469	549	2.1	4.7 - 10.4
L7	Y	Y	57.0913	110.7512	594	1.7	8.7 - 13.1
L8	Y	Y	57.0461	110.5895	610	2.0	14.2 - 21.7
L18 (Namur)	Y	Y	57.4444	112.6211	722	24.0	18.9 - 20.2
L23 (Otasan)	Y	Y	57.7020	112.3760	732	7.6	6.4 - 8.4
L25 (Legend)	Y	Y	57.4045	112.9294	789	10.2	9.0 - 10.2
L28	Y	Y	57.8526	112.9727	716	1.9	0 - 2.2
L30 (W. Clayton)	Y	N (fogged in)	58.0514	112.2669	--	0.9	0
L39 (A-150)	Y	Y	57.9590	110.3995	427	1.5	9.9 - 12.0
L46 (Bayard)	Y	Y	57.7700	112.3970	640	1.8	6.9 - 24.2
L47	Y	Y	56.2430	113.1400	643	1.3	7.9 - 16.0
L49	Y	Y	57.7600	112.5960	671	1.4	6.6 - 10.1
L60	Y	Y	57.6539	112.6167	671	2.7	9.6 - 15.7
Caribou Mountains							
E52 (Fleming)	Y	Y	58.7743	115.4432	853	>2	13.0 - 17.6
E59 (Rocky Island)	Y	Y	59.1350	115.1535	914	>6	9.0 - 15.0
E68 (Whitesand)	N	Y (new)	59.1905	115.4490	911	1.5	14.0 - 14.8
O1 (Unnamed #6)	Y	Y	59.2378	114.5200	823	1.8	3.9 - 4.5
O2 (Unnamed #9)	Y	Y	59.3140	115.3350	890	6.0	8.0 - 10.3
O3[c]	Y	N (not acid sens. in 1999)	59.0489	116.2556	--	--	10.0 - 35.5
Canadian Shield							
L107 (Weekes)	N	Y (new)	59.7093	110.0082	320	7.8	24.1 - 25.5
L109 (Fletcher)	Y	Y	59.1187	110.8252	268	13.7	18.2 - 23.0
O10	Y	Y	59.1429	110.6821	308	1.8	8.0 - 13.1
R1	Y	Y	59.1927	110.6792	305	13.1	13.5 - 15.8
R2	Y	N (not found)	59.1225	110.5142	--	--	11.0 (n=1)
R3[c]	Y	N (not acid sens. In 1999)	59.1268	110.9315	--	--	48.3 (n=1)

[a] Range based on all available data, including historical data (summarized by Saffran and Trew 1996) and RAMP data collected in 1999 and 2000.

[b] -- = not available.

[c] Lake was dropped from the monitoring network based on 1999 results.



LEGEND

SYMBOLS

- ● CARIBOU MOUNTAINS
- ★ OIL SANDS AREA
- ◆ CANADIAN SHIELD

- EXISTING OR APPROVED PROJECTS (green)
- PLANNED PROJECTS (orange)

COLOURS

- LAKES SAMPLED IN 1999 ONLY (yellow)
- LAKES SAMPLED IN 2000 ONLY (pink)
- LAKES SAMPLED IN BOTH YEARS (green)

REFERENCE

ORIGINAL BASE MAP OF ALBERTA WAS PRODUCED IN 10TM FORMAT. THE MAP WAS CONVERTED FROM DGN FORMAT TO DWG FORMAT IN NAD 83 ZONE 12 UTM PROJECTION.

Golder Associates	RAMP
LOCATIONS OF THE LAKES SURVEYED IN 2000	
DRAWN: GMF APPROVED:	DATE: 23 Feb. 2001
PROJECT: 012-2302.2600	FIGURE: **3.10**

Revision No.: 02

R:\Active\2300\012-2302\CAD\2600\LAKE_SAMPLE_LOCATIONS.dwg Exref:Exref-10TM-Develop-Hatch.dwg Exref:Exref-10TM-Develop-Outlines.dwg

The euphotic zone was defined as the depth of 1% of surface penetrating light, using a light meter. Vertical profiles of dissolved oxygen, temperature, conductivity and pH were measured at the deepest location using a field-calibrated water quality meter. Secchi depth was also recorded. Samples for chemical analysis were stored on ice and were shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection.

Subsamples of 150 mL volume were taken from the euphotic zone composite samples for phytoplankton taxonomy. These samples were preserved using Lugol's solution. One or two replicate zooplankton samples were also collected in each lake as vertical hauls through the euphotic zone, using a #20 mesh, conical plankton net. Zooplankton samples were preserved in approximately 5% formalin after anaesthetizing in Bromoseltzer or club soda. Plankton samples are being stored at AENV.

The water quality samples were analyzed for the following parameters:

- pH
- turbidity
- colour
- total suspended solids (TSS)
- total dissolved solids (TDS)
- dissolved organic carbon (DOC)
- dissolved inorganic carbon (DIC)
- particulate carbon (PC)
- total alkalinity (fixed point titration to pH 4.5)
- Gran alkalinity
- bicarbonate
- chloride
- sulphate
- calcium
- potassium
- sodium
- magnesium
- particulate nitrogen
- total dissolved nitrogen (TDN)
- ammonium
- nitrite + nitrate
- total phosphorus (TP)
- total dissolved phosphorus (TDP)
- chlorophyll *a*

As part of the QA/QC program for this component, one duplicate water sample was collected at Lake E68 and was analyzed for all parameters.

3.5 BASELINE SOUTH OF FORT MCMURRAY

3.5.1 OPTI Long Lake Project Local Study Area

The LSA for the water quality, and fish and fish habitat component was chosen to include waterbodies that may be directly or indirectly affected by the Long Lake Project (Figure 3.11). The LSA was defined as follows:

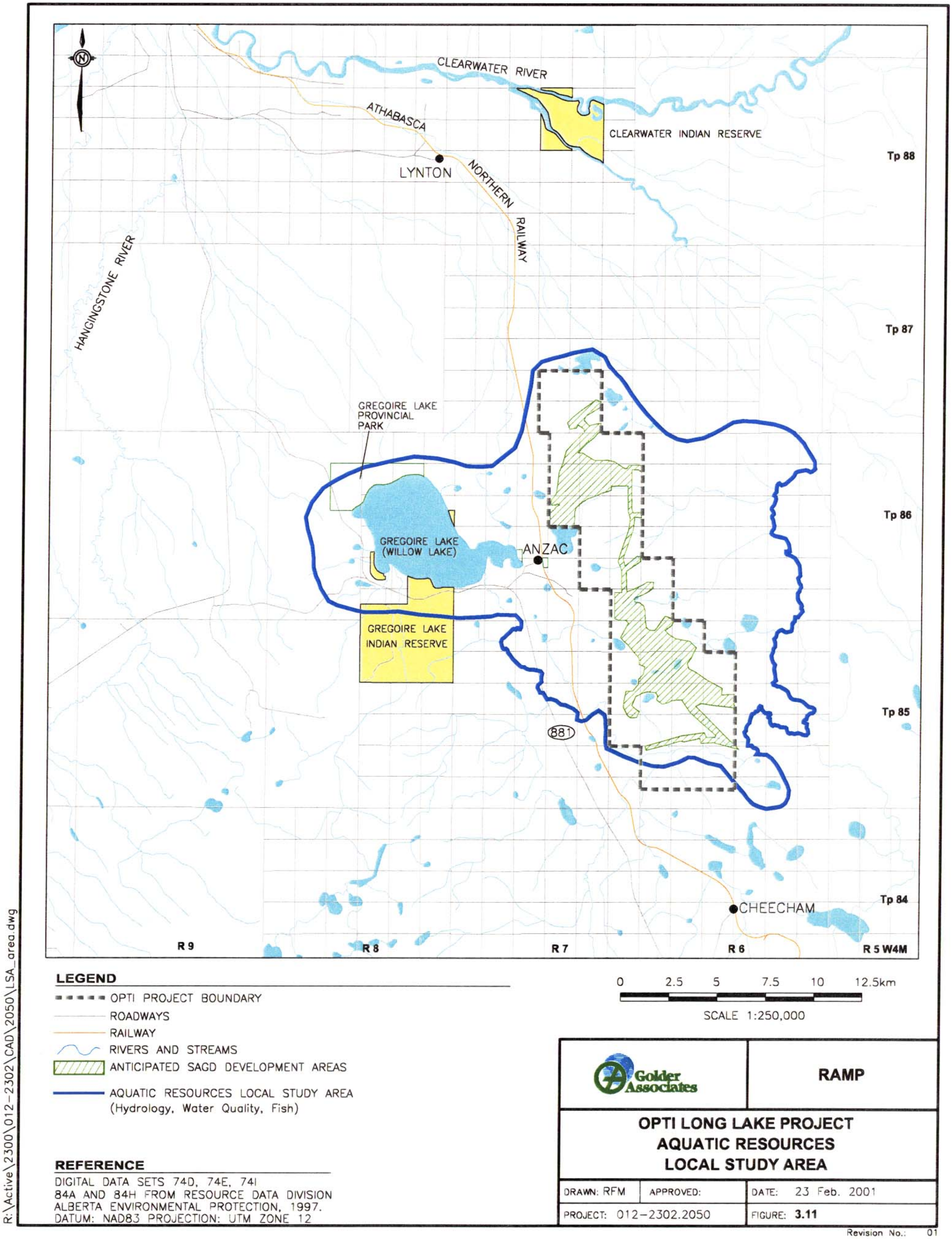
- north: the northerly extent of the Gregoire River watershed plus Caribou Horn Lake and Kiskatinaw Lake;
- northwest: Gregoire Lake and a buffer surrounding the lake to include existing development;
- west: the Gregoire River south from Gregoire Lake and east as it crosses the lease;
- south: along the Gregoire River as it crosses the lease in an east-west direction. A small area to the southeast includes the TransCanada pipeline metering station; and
- east: the Gregoire River to the Christina River confluence.

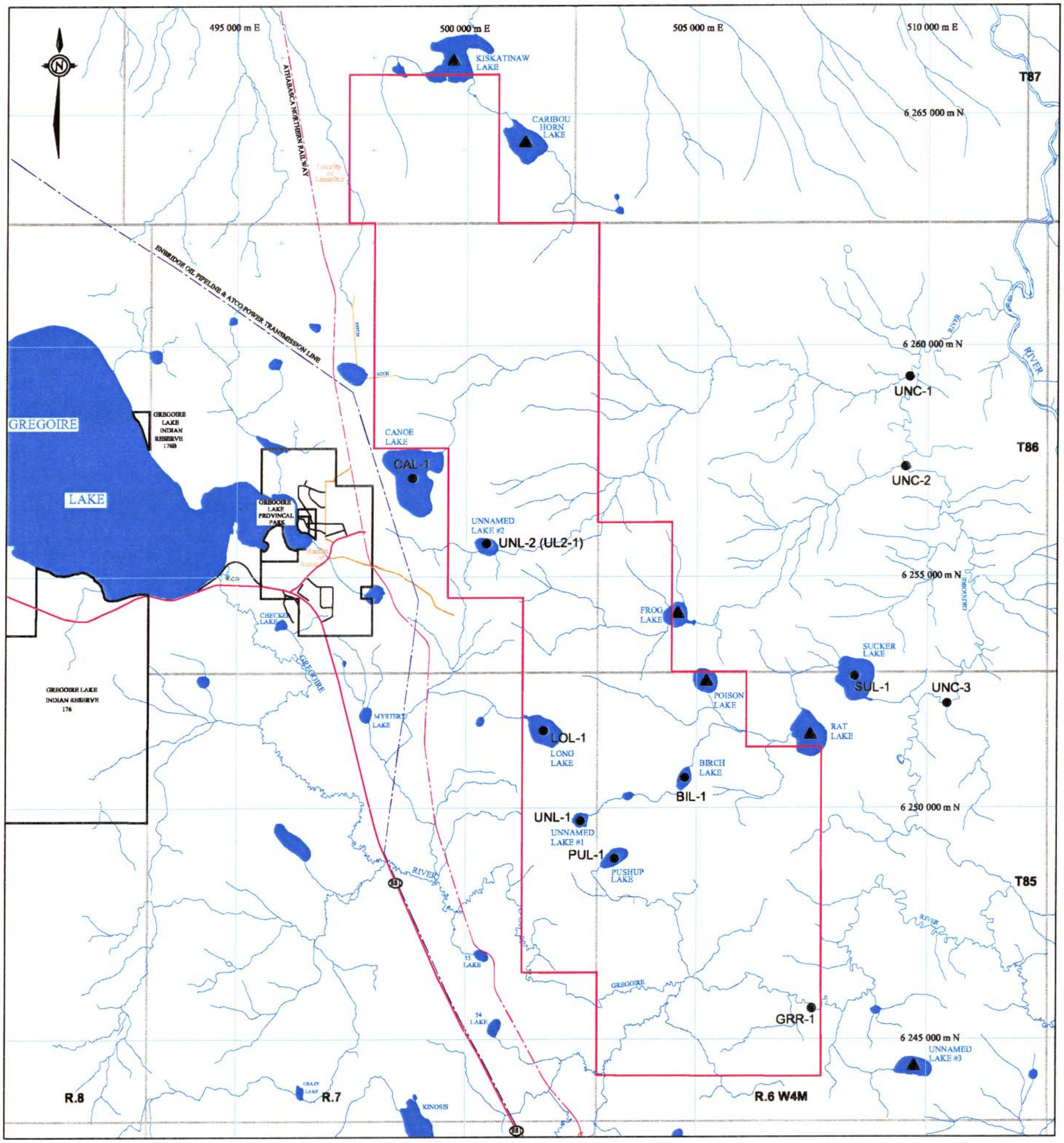
3.5.2 Water Quality

Water quality samples were collected in seven lakes and from the Gregoire River system (i.e., the Gregoire River and three tributaries to the Gregoire River) in spring and fall. The spring water quality surveys occurred from May 10 to 24 and the fall surveys were done from September 20 to 21 and November 1. Field parameters (i.e., temperature, conductivity, pH, dissolved oxygen) were measured in additional selected lakes during the winter and summer fisheries habitat baseline surveys. Locations of water quality sampling sites are shown in Figure 3.12.

3.5.2.1 Field Methods

Water samples were collected, preserved, stored and shipped in accordance with Golder Technical Procedure 8.3-1 (Golder 1999a). Single grab samples or composite samples were collected depending on the depth and size of the waterbody. Water quality field parameters were taken using a calibrated multi-meter (Hydrolab MiniSonde) at each sampling station. A Trimble GeoExplorer® Global Positioning System unit was also used to record the position of all sampling locations.


CLEARWATER RIVER
ATHABASCA
NORTHERN
RAILWAY
CLEARWATER INDIAN RESERVE
LYNTON
HANGINGSTONE RIVER
Tp 88
Tp 87
Tp 86
Tp 85
Tp 84
GREGOIRE LAKE PROVINCIAL PARK
GREGOIRE LAKE (WILLOW LAKE)
ANZAC
GREGOIRE LAKE INDIAN RESERVE
881
CHEECHAM
R 9
R 8
R 7
R 6
R 5 W4M
LEGEND
OPTI PROJECT BOUNDARY
ROADWAYS
RAILWAY
RIVERS AND STREAMS
ANTICIPATED SAGD DEVELOPMENT AREAS
AQUATIC RESOURCES LOCAL STUDY AREA (Hydrology, Water Quality, Fish)
0 2.5 5 7.5 10 12.5km
SCALE 1:250,000
REFERENCE
DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.
DATUM: NAD83 PROJECTION: UTM ZONE 12
Golder Associates
RAMP
OPTI LONG LAKE PROJECT
AQUATIC RESOURCES
LOCAL STUDY AREA
DRAWN: RFM
APPROVED:
DATE: 23 Feb. 2001
PROJECT: 012-2302.2050
FIGURE: 3.11
Revision No.: 01
R:\Active\2300\012-2302\CAD\2050\LSA_area.dwg



LEGEND

- OPTI PROJECT BOUNDARY
- ROAD, HARD SURFACE, ALL WEATHER, 2 OR MORE LANES
- ROAD, LOOSE OR STABILIZED SURFACE, ALL WEATHER
- RAILWAY
- PIPELINE
- ▲ FIELD PARAMETERS
- ● FIELD PARAMETERS AND DETAILED WATER QUALITY

NOTES

TOPOGRAPHY/CULTURE SUPPLIED UNDER LICENSE FROM AltaLIS LTD.
KEY MOOSE/CARIBOU ZONES FROM WATERWAYS FOREST AREA - NEB1 November 1998
CULTURE UPDATED FROM AERIAL PHOTOGRAPHY FLOWN IN 1992
DATA FROM OPTI CANADA INC. (CH11x17A.DWG) NAD83

Golder Associates

RAMP

OPTI LONG LAKE PROJECT
LOCATION OF WATER QUALITY SAMPLING SITES

DRAWN: GMF	APPROVED:
DATE: 23 Feb. 2001	
PROJECT: 012-2302.2050	FIGURE: **3.12**

Revision No.: 01

R:\Active\2300\012-2302\CAD\2050\WATER-QUAL_SAMPLING.dwg

Samples were shipped to ETL for chemical analysis. The Gregoire River system and three lakes (Canoe, Long and Pushup lakes) were analyzed in spring and fall for detailed water chemistry including conventional parameters, major ions, nutrients, total metals and organics (i.e., naphthenic acids, phenols, recoverable hydrocarbons). Samples collected from Unnamed Lakes 1 and 2 were analyzed for total alkalinity in the spring and major ions in the fall (to allow calculation of critical loads of acidity during the impact assessment). Birch Lake, Sucker Lake and Unnamed Lake 2 were analyzed for conventional parameters and major ions in November to fill data gaps.

3.5.2.2 Data Analysis

Water quality data were evaluated by comparing baseline concentrations of individual variables with published water quality guidelines for the protection of freshwater aquatic life and human health.

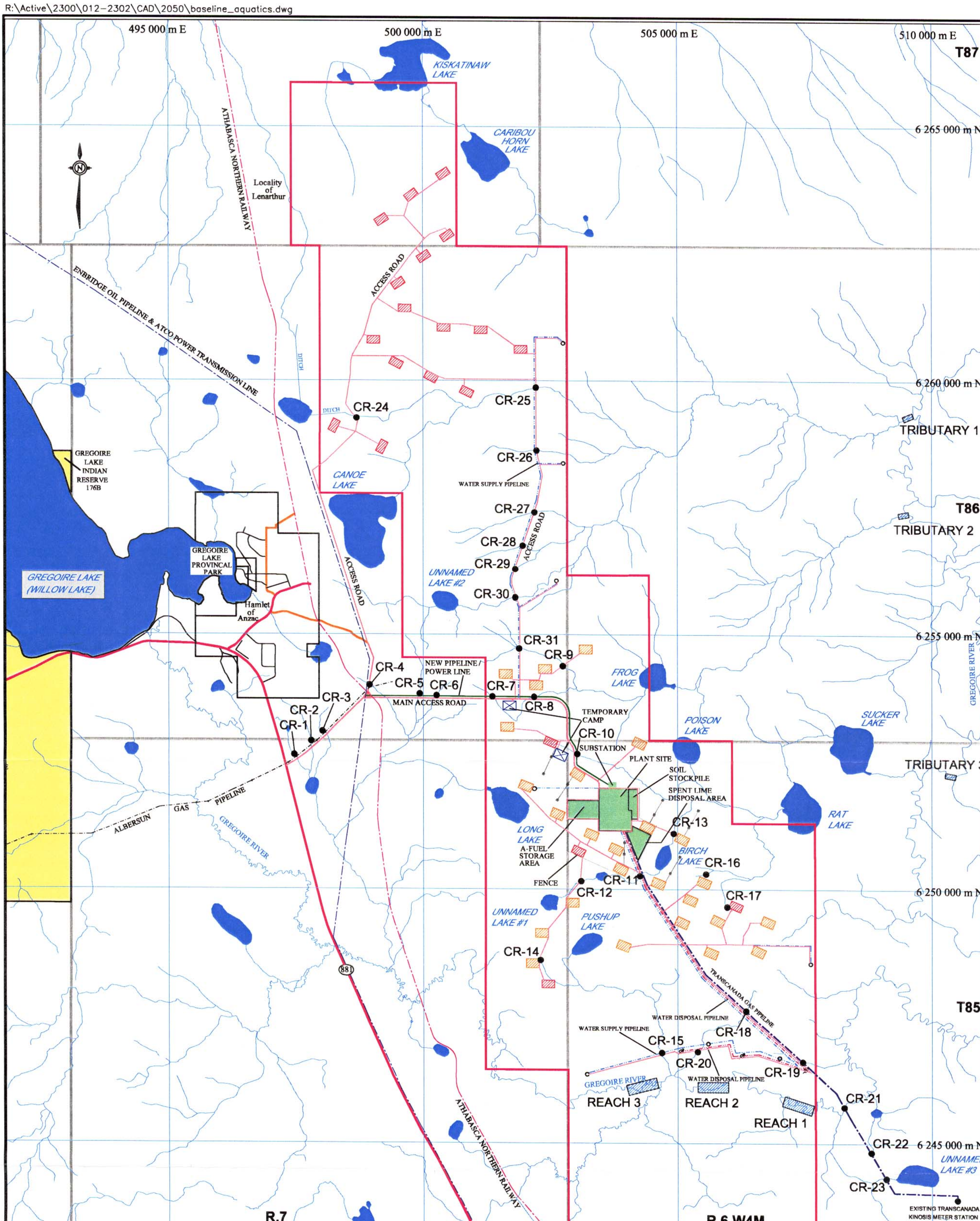
Historical data was used to describe baseline water quality in Gregoire Lake. Alberta Environment's Water Data System (WDS) provided information for a number of stations and sampling events between 1972 and 1997 (see OPTI 2000, Volume 5, Table VIII-1). In addition, limnological characteristics of Gregoire Lake, including the water quality data collected between 1976 and 1983, were summarized by Bradford (1990).

The formula used to calculate critical loads (i.e., acid sensitivity) for lakes in the LSA was adopted from Syncrude (1998) with two modifications. The critical load calculations are described in detail in OPTI 2000, Volume 2, Section F4.3.1.4.

3.5.3 Fish and Fish Habitat

Fish and fish habitat information was collected from 14 lakes, the Gregoire River system and at numerous potential pipeline/road watercourse crossings. The winter fish habitat surveys were conducted from March 20 to 22. The spring and summer fish habitat and inventory surveys were done from May 10 to 24 and July 31 to August 10, respectively. Road and pipeline watercourse crossings were evaluated in spring and summer. Additional watercourse crossing surveys were completed in the fall, from September 19 to 23 and October 31 to November 1. The sampling sites for the fisheries baseline survey are shown in Figure 3.13.

R:\Active\2300\012-2302\CAD\2050\baseline_aquatics.dwg



LEGEND

- OPTI LEASE 27 BOUNDARY
- ROAD, HARD SURFACE, ALL WEATHER, 2 OR MORE LANES
- ROAD, LOOSE OR STABILIZED SURFACE, ALL WEATHER
- RAILWAY
- PIPELINE
- UPLAND WELLPAD AND SOIL STORAGE AREA (175 x 250 m)
- PEAT WELLPAD (150 x 250 m)
- OBSERVATION WELL (45 x 45 m)
- WATER SUPPLY WELL
- WATER DISPOSAL WELL
- CR-1 WATERCOURSE CROSSINGS
- LONG LAKE — LAKE SURVEYS
- RIVER/TRIBUTARY SURVEYS

0 1000 2000 3000 4000m

SCALE 1:75,000

Golder Associates

RAMP

LOCATION OF BASELINE STUDY SITES IN THE OPTI LONG LAKE PROJECT LOCAL STUDY AREA

DRAWN: PSR	APPROVED:	DATE: 23 Feb. 2001	
PROJECT: 012-2302.2050		FIGURE: 3.13	

Revision No.:

3.5.3.1 Field Methods

Fish habitat mapping was conducted for lakes using the methods outlined in Golder Technical Procedures 8.19-0, “Lake Shoal and Shoreline Habitat Mapping” and for watercourses using Golder Technical Procedure 8.5-1, “Watercourse Habitat Mapping and Classification System” (Golder 1999a). Fish inventories were conducted in accordance to Golder Technical Procedure 8.1-3, “Fish Inventory Methods” (Golder 1999a). Fish were collected using gill nets, minnow traps or backpack electrofisher. A brief description of the field assessments conducted in the lakes, the Gregoire River system and the potential road/pipeline watercourse crossings are provided in the following sections.

Lakes

The field assessment of each lake included the following:

- winter habitat evaluation focusing on dissolved oxygen levels and depth;
- shoreline habitat map showing all relevant characteristics that may be used by resident fish, as well as depth characteristics. Photographs documenting shoreline habitat type were also included;
- field water quality measurements including pH, conductivity, temperature and dissolved oxygen concentrations; and
- fish inventory during the spring, summer and fall seasons to determine whether fish use these habitats for spawning, rearing or feeding.

Gregoire River System

The field assessment for the Gregoire River system included the following:

- winter habitat evaluation focusing on dissolved oxygen levels;
- a spring, fish egg survey in three study reaches of the Gregoire River within the OPTI project boundary;
- a spring and summer detailed fish habitat and inventory survey in three study reaches of the Gregoire River within the OPTI project boundary;
- a spring and summer detailed fish habitat and inventory survey in one study reach within each of the three tributaries to the Gregoire River; and
- an aerial habitat evaluation and video tape of the Gregoire River from its confluence with the Christina River to the east OPTI project boundary.

Watercourse Crossings

Potential watercourse crossings were classified based on watercourse type, channel dimensions, flow volume and fish-bearing potential. Where the initial field assessment characterized the watercourse as having moderate or high potential for fish, a detailed assessment of a watercourse crossing was completed. Detailed assessment methods included:

- photographs of the proposed crossing point;
- completion of a standard Golder “Pipeline Crossing Habitat Evaluation Parameters (PCHEP)” form (see OPTI 2000, Volume 5, Appendix IX-J) at the crossing location;
- preparation of a fish habitat map for a distance of at least 100 m upstream and downstream of the crossing point;
- measurement of field water quality parameters; and
- completion of backpack electrofishing and minnow trapping to determine fish presence and species composition in the area of the proposed crossing.

If watercourses had low fish-bearing potential, a less detailed field assessment was conducted. A written description of the reach and crossing site was completed and photographs were taken in the vicinity of the proposed crossing point.

4 QA/QC

4.1 WATER AND SEDIMENT QUALITY

4.1.1 Field Sampling

4.1.1.1 Methods

Golder developed a water and sediment Quality Assurance/Quality Control (QA/QC) sampling program for the RAMP 2000 field season. It included the following:

- field blanks to detect potential sample contamination during sample collection, shipping and analysis;
- trip blanks to determine if sample contamination occurred during transport;
- split water and sediment samples to check intra-laboratory precision (i.e., repeatability of the result);
- duplicate sediment samples to check intra-site variability and the precision of field sampling methodology; and
- multiple composite sediment samples from a small area of the Athabasca River to examine local variability in sediment quality.

A detailed QA/QC field sampling schedule is provided in Table 4.1.

All water and sediment samples were collected in accordance with Golder Associates Technical Procedures 8.3-1 and 8.2-2, respectively (Golder 1999a). These procedures outline standard sample collection, preservation, storage and shipping protocols. They also provide specific guidelines for field record keeping and sample tracking.

In addition, all instruments and water quality meters used in the field were calibrated before use. The locations of each water and sediment sample site were recorded using a Global Positioning System (GPS) unit.

Table 4.1 RAMP 2000 QA/QC Water and Sediment Sampling Program Schedule and Description

Season	Sample Site	QA/QC Sample(s) [a]	Description
spring (May)	McClelland Lake	field blank	analyzed to detect potential sample contamination during collection, shipping and analysis
		split water sample	analyzed to determine intra-laboratory precision
	not site specific	trip blank	analyzed to determine if sample contamination occurred during transport
fall – Trip 1 (September 7 to 15)	McClelland Lake	field blank	analyzed to detect potential sample contamination during collection, shipping and analysis
		split water sample	analyzed to determine intra-laboratory precision
	Athabasca River, upstream of the Embarras River	split sediment sample	analyzed to determine intra-laboratory precision
		three additional composite sediment samples within 10 km upstream of the established RAMP sample site	analyzed to examine local variability in sediment quality
	not site specific	trip blank	analyzed to determine if sample contamination occurred during transport
fall – Trip 2 (September 27 to October 7)	McClelland Fen[c]	field blank	analyzed to detect potential sample contamination during collection, shipping and analysis
		split water sample	analyzed to determine intra-laboratory precision
	Athabasca River: • upstream of Donald Creek • upstream of Steepbank River • upstream of Fort Creek	split sediment sample	analyzed to determine intra-laboratory precision
	mouth of Fort Creek	duplicate sediment sample[b]	analyzed to check intra-site variation and precision of field sampling methodology
	not site specific	trip blank	analyzed to determine if sample contamination occurred during transport

(a) Split sample = one single sample is collected and split into two or more sample containers. They are labelled, preserved individually and submitted separately to the analytical laboratory or to two different laboratories for identical analyses.

(b) Duplicate sample = two samples are collected from one location using identical sampling procedures. They are labelled, preserved individually and submitted separately to the analytical laboratory for identical analyses.

(c) Although McClelland Fen was not included in the RAMP 2000 sample program, the QA/QC samples prepared at this site were analyzed at the same time as those collected during the second RAMP 2000 fall sampling trip.

4.1.1.2 Results

Field and Trip Blanks

Field and trip blanks were analyzed by ETL. Parameter concentrations in both field and trip blanks were considered significant if they were greater than five times the corresponding method detection limit (MDL). This threshold is based on the Practical Quantitation Limit defined by the U.S. EPA (1999). Water quality parameters that exceeded five times the MDL are listed in Tables 4.2 and 4.3. Raw data are presented in Appendix III, Table III-1.

Table 4.2 Summary of Water Quality Parameters in RAMP 2000 Field Blanks that Exceeded Five Times the Method Detection Limit

Parameter	Unit	Detection Limit	Season[a]			Comments[b]
			Spring	Fall Trip #1	Fall Trip #2	
Nutrients						
total phosphorus	µg/L	< 1	-	8	-	B
Total Metals						
barium (Ba)	µg/L	< 0.2	-	-	2	B
lead (Pb)	µg/L	< 0.1	-	1.1	-	C
manganese (Mn)	µg/L	< 0.2	2.9	-	-	A
nickel (Ni)	µg/L	< 0.2	1.2	2.7	-	A,C
potassium (K)	µg/L	< 20	-	140	-	B
zinc (Zn)	µg/L	< 4	11	73	-	A,C
Dissolved Metals						
aluminum (Al)	µg/L	< 10	-	90	-	A
barium (Ba)	µg/L	< 0.1	-	-	0.6	B
manganese (Mn)	µg/L	< 0.1	1.6	0.7	-	A,A
strontium (Sr)	µg/L	< 0.1	-	-	0.6	B

[a] - = parameter did not exceed five times the method detection limit.

[b] A = Sample concentrations from the relevant season were outside the historical range and greater than levels in the field blank; results are indicative of potential sample contamination during sampling, transport and/or analysis.

B = Sample concentrations from the relevant season generally contained levels consistent with historic data; therefore, this finding was assumed to be an isolated error.

C = Concentration in the field blank was higher than levels observed in the majority of the water samples collected in same season; therefore, this finding was assumed to be an isolated error.

Table 4.3 Summary of Water Quality Parameters in RAMP 2000 Trip Blanks that Exceeded Five Times the Detection Limit

Parameter	Units	Detection Limit	Season[a] Spring	Fall Trip #1	Fall Trip #2	Comments[b]
Nutrients						
total phosphorus	µg/L	< 1	-	-	19	A
Total Metals						
boron (B)	µg/L	< 2	-	-	14	A
zinc (Zn)	µg/L	< 4	-	36	-	B
Dissolved Metals						
aluminum (Al)	µg/L	< 10	130	-	-	C
barium (Ba)	µg/L	< 0.1	-	-	0.9	A
boron (B)	µg/L	< 2	-	-	11	A
manganese (Mn)	µg/L	< 0.1	2.2	0.6	-	D,D

(a) - = parameter did not exceed five times the method detection limit.

(b) A = Concentration in trip blank was higher than concentrations observed in the field blank, and water samples contained levels consistent with historical data; therefore, this findings was assumed to be an isolated error.

B = Concentration in trip blank was lower than concentrations observed in the corresponding field blank, but higher than levels observed in water samples collected from that season; therefore, this finding was assumed to be an isolated error.

C = Concentration in trip blank was higher than concentrations observed in either the field blank or the water samples collected during that season; therefore, this finding was assumed to be an isolated error.

D = Sample concentrations from the relevant season were outside the historical range and greater than levels in the trip blank; results are indicative of potential sample contamination during transport and/or analysis.

Split Water Samples

In general, ETL demonstrated high analytical precision. The variation among split samples was acceptable in all seasons in 2000, with the exception of total phosphorus, total phenols and several metals (e.g., nickel, aluminum, copper, lead and zinc) (Table 4.4). Most of these variations were small scale, isolated incidents that did not affect the interpretation of monitoring results for 2000.

Table 4.4 Water Quality of Split Samples, RAMP 2000 Field QA/QC Program

Parameter	Units	McClelland Lake Spring		McClelland Lake Fall Trip #1		McClelland Fen (Fall Trip #2)	
Conventional Parameters							
colour	T.C.U.	10	15	10	10	35	35
conductance	µS/cm	263	262	241	241	346	348
dissolved organic carbon	mg/L	10	10	12	12	11	17
hardness	mg/L	130	124	119	118	171	170
pH		8.3	8.3	8.4	8.4	7.8	7.9
total alkalinity	mg/L	137	137	127	128	177	175
total dissolved solids	mg/L	100	110	160	170	210	210
total organic carbon	mg/L	11	11	15	13	12	20
total suspended solids	mg/L	< 3	< 3	< 3	< 3	4	< 3
Major Ions							

Table 4.4 Water Quality of Split Samples, RAMP 2000 Field QA/QC Program (continued)

Parameter	Units	McClelland Lake				McClelland Fen (Fall Trip #2)	
		Spring		Fall Trip #1			
bicarbonate	mg/L	165	165	151	152	216	214
calcium	mg/L	27	26	22	22	45	44
carbonate	mg/L	< 5	< 5	< 5	< 5	< 5	< 5
chloride	mg/L	1	1	< 1	< 1	< 1	< 1
magnesium	mg/L	16	15	16	15	14	14
potassium	mg/L	3	3	3	3	2	2
sodium	mg/L	5	3	5	5	4	5
sulphate	mg/L	3	3	2	2	4	4
sulphide	µg/L	< 3	< 3	< 3	< 3	< 3	4
Nutrients and Chlorophyll *a*							
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen - ammonia	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
nitrogen - Kjeldahl	mg/L	0.6	0.7	0.8	0.8	0.3	0.5
phosphorus, total	µg/L	14	14	14	14	46	20
phosphorus, dissolved	µg/L	8	7	14	15	12	11
chlorophyll *a*	µg/L	2	2	4	1	< 1	2
Biological Oxygen Demand							
biochemical oxygen demand	mg/L	< 2	< 2	2	< 2	< 2	< 2
General Organics							
naphthenic acids	mg/L	< 1	< 1	broken	< 1	< 1	1
total phenolics	µg/L	< 1	< 1	2	2	< 1	10
total recoverable hydrocarbons	mg/L	0.7	1.3	broken	< 0.5	< 0.5	< 0.5
Toxicity							
Microtox IC_{50} @ 15 min	%	-	-	-	-	> 91	> 91
Microtox IC_{25} @ 15 min	%	-	-	-	-	> 91	> 91
Total Metals							
aluminum (Al)	µg/L	70	70	40	80	< 20	< 20
antimony (Sb)	µg/L	< 5	< 5	< 5	< 5	< 5	< 5
arsenic (As)	µg/L	< 1	< 1	< 1	< 1	< 1	< 1
barium (Ba)	µg/L	37.1	36.5	32.2	31.4	49.5	49.6
beryllium (Be)	µg/L	< 1	< 1	< 1	< 1	< 1	< 1
boron (B)	µg/L	56	57	69	68	46	46
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
calcium (Ca)	µg/L	26,000	25,700	21,600	21,500	44,200	44,600
chromium (Cr)	µg/L	2.2	2.4	< 0.8	1	< 0.8	< 0.8
cobalt (Co)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
copper (Cu)	µg/L	3	37	1	1	< 1	1
iron (Fe)	µg/L	40	40	< 20	< 20	100	100
lead (Pb)	µg/L	0.9	4.3	0.7	1.5	< 0.1	3.7
lithium (Li)	µg/L	19	19	20	20	26	26
magnesium (Mg)	µg/L	14,600	14,300	15,200	15,300	14,000	14,300
manganese (Mn)	µg/L	19.3	19.9	7.8	7.5	33.1	32.9
mercury (Hg)	µg/L	-	-	< 0.2	< 0.2	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.1	0.2	0.1	0.1	< 0.1	< 0.1
nickel (Ni)	µg/L	3.9	1.5	1.0	3.0	< 0.2	< 0.2
potassium (K)	µg/L	2,730	2,710	3,080	2,990	2,370	2,410

Table 4.4 Water Quality of Split Samples, RAMP 2000 Field QA/QC Program (continued)

Parameter	Units	McClelland Lake				McClelland Fen (Fall Trip #2)	
		Spring		Fall Trip #1			
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
sodium (Na)	µg/L	4,100	4,100	4,500	4,400	4,000	4,000
strontium (Sr)	µg/L	152	149	132	131	236	234
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.4	0.5	0.2	0.3	< 0.2	< 0.2
zinc (Zn)	µg/L	48	8	14	77	6	5
Dissolved Metals							
aluminum (Al)	µg/L	50	10	10	110	< 10	< 10
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	33.8	30.5	29.9	29.7	49.8	49.3
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
boron (B)	µg/L	90	-	59	60	45	45
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	3.6	< 0.4	< 0.4	1.3	< 0.4	< 0.4
cobalt (Co)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
copper (Cu)	µg/L	< 0.6	< 0.6	< 0.6	1.1	0.8	0.8
iron (Fe)	µg/L	< 10	< 10	10	10	40	40
lead (Pb)	µg/L	0.4	0.6	0.6	1.6	0.1	0.1
lithium (Li)	µg/L	25	20	22.3	22.2	26.3	25.7
manganese (Mn)	µg/L	3.4	< 0.1	2.2	2.1	32.5	32
mercury (Hg)	µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.1	< 0.1
molybdenum (Mo)	µg/L	0.1	< 0.1	0.1	0.2	2.1	< 0.1
nickel (Ni)	µg/L	0.8	0.2	0.4	2.7	0.9	< 0.1
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
strontium (Sr)	µg/L	146	147	132	133	234	232
thallium (Tl)	µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.2	-	< 0.1	< 0.1	0.1	< 0.1
zinc (Zn)	µg/L	< 2	5	< 2	83	14	< 2

- = No data.

Split Sediment Samples

Split sediment sample results indicate that AXYS has high analytical precision (Table 4.5). Although variations were observed in the reported concentrations of several parameters (including naphthalene, C1 and C3 substituted naphthalene, C3 and C4 substituted phenanthrene/anthracene and 1-methyl-7-isopropyl-phenanthrene), these variations were small scale, isolated incidents that did not affect the interpretation of monitoring results for 2000.

Table 4.5 Sediment Quality of Athabasca River Split Samples, RAMP 2000 Field QA/QC Program

Parameter	Units	Upstream Embarras River		Upstream Steepbank River		Upstream Donald Creek		Upstream Fort Creek	
Target PAHs and Alkylated PAHs									
naphthalene	ng/g	37	16	9	6	4	25	4	4
C1 subst'd naphthalenes	ng/g	31	25	11	11	6	16	6	5
C2 subst'd naphthalenes	ng/g	40	35	13	24	< 1	< 1	13	12
C3 subst'd naphthalenes	ng/g	29	21	5	17	< 1	< 4	5	6
C4 subst'd naphthalenes	ng/g	7	6	< 1	< 3	< 1	< 2	< 2	< 2
acenaphthene	ng/g	< 6	< 5	< 3	< 2	< 1	2	< 2	< 2
C1 subst'd acenaphthene	ng/g	3	3	< 1	1[(a)]	< 1	1.4	< 1	< 1
acenaphthylene	ng/g	< 5	< 6	< 1	< 1	< 0	< 1	< 1	< 2
anthracene	ng/g	< 2	< 5	< 2	< 2	< 1	< 1	< 2	< 2
dibenzo(a,h)anthracene	ng/g	< 4	< 5	< 4	< 2	< 6	< 5	< 2	< 2
benzo(a)anthracene / chrysene	ng/g	14	16	11[(a)]	10	2	4[(a)]	6	4
C1 subst'd benzo(a)anthracene / chrysene	ng/g	120	120	< 19	< 16	< 5	< 5	36	41
C2 subst'd benzo(a)anthracene / chrysene	ng/g	40	44	37	33	< 1	< 1	19	10
benzo(a)pyrene	ng/g	7	5[(a)]	4[(a)]	3[(a)]	< 2	< 2	< 3	< 2
C1 subst'd benzo(b&k) f/b(a)pyrene[(b)]	ng/g	< 2	< 8	< 5	< 4	< 2	< 1	< 4	< 4
C2 subst'd benzo(b& k) f/b(a)pyrene[(b)]	ng/g	< 4	< 2	< 3	< 5	< 2	< 2	< 3	< 3
benzofluoranthenes	ng/g	24	22	17	17[(a)]	< 1	< 2	5	2
benzo(g,h,i)perylene	ng/g	15	20	5	5	< 7	2[(a)]	< 2	< 1
biphenyl	ng/g	< 3	2	< 2	1[(a)]	< 1	2	< 1	< 1
C1 subst'd biphenyl	ng/g	< 2	< 3	< 2	< 1	< 3	< 2	< 2	< 3
C2 subst'd biphenyl	ng/g	< 4	< 2	< 1	< 1	< 1	< 1	< 1	< 1
dibenzothiophene	ng/g	< 1	< 6	< 2	< 1	< 1	< 1	< 1	< 2
C1 subst'd dibenzothiophene	ng/g	7	8	< 2	< 2	< 1	< 1	< 2	< 2
C2 subst'd dibenzothiophene	ng/g	17	26	< 2	< 2	< 3	< 1	< 3	< 3
C3 subst'd dibenzothiophene	ng/g	64	75	< 6	< 3	< 2	< 1	< 4	< 3
C4 subst'd dibenzothiophene	ng/g	< 3	< 4	< 3	< 2	< 1	< 2	< 2	< 2
fluoranthene	ng/g	4	4	3[(a)]	4	1	3	< 2	< 1
C1 subst'd fluoranthene / pyrene	ng/g	32	34	17	23	< 1	< 1	9	10
C2 subst'd fluoranthene / pyrene	ng/g	67	69	37	42	6	< 1	9	7
C3 subst'd fluoranthene / pyrene	ng/g	59	59	49	40	< 1	< 1	14	9
fluorene	ng/g	< 2	< 3	< 1	< 2	< 1	1[(a)]	< 1	< 2
C1 subst'd fluorene	ng/g	< 3	< 4	< 3	< 3	< 1	< 1	< 2	< 1
C2 subst'd fluorene	ng/g	< 3	< 5	< 1	< 4	< 1	< 1	< 2	< 2
C3 subst'd fluorene	ng/g	< 5	< 6	< 3	< 2	< 2	< 1	< 3	< 3
indeno(1,2,3,cd)pyrene	ng/g	11	12	5	5[(a)]	< 2	< 4	< 3	< 2
phenanthrene	ng/g	12	16	5	5	3	5	2	2
C1 subst'd phenanthrene / anthracene	ng/g	40	44	< 3	9	< 2	1	< 2	< 2
C2 subst'd phenanthrene / anthracene	ng/g	32	39	12	18	< 2	1	8	8
C3 subst'd phenanthrene / anthracene	ng/g	33	39	< 3	16	< 2	< 1	5	7
C4 subst'd phenanthrene / anthracene	ng/g	14	15	11	30	1	10	11	6
1-methyl-7-isopropyl-phenanthrene	ng/g	33	41	23	59	< 3	21	15	11
pyrene	ng/g	9	11	5	7	2[(a)]	3	4	2

[(a)] PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

[(b)] fluoranthene/benzo(a)pyrene.

Duplicate Sediment Samples

In general, duplicate sediment sample results from the mouth of Fort Creek indicate that intra-site variation was low and field sampling precision was high (Table 4.6). However, metal concentrations tended to vary between the two duplicate samples (e.g., aluminum, barium, manganese and zinc), as did those of several alkylated PAHs (e.g., C1, C2 and C3 dibenzothiophene). These variations did not affect the interpretation of monitoring results for 2000.

Table 4.6 Sediment Quality of Fort Creek Duplicate Samples, RAMP 2000 Field QA/QC Program

Parameter	Units	Mouth of Fort Creek	
Particle Size			
partice size - % sand	%	84	85
partice size - % silt	%	12	11
partice size - % clay	%	4	4
moisture content	%	21	21
Carbon Content			
total inorganic carbon	% dry wt	0.5	0.6
total organic carbon	% dry wt	3.2	3.2
Organics			
total recoverable hydrocarbons	mg/kg	9,200	9,700
total volatile hydrocarbons	mg/kg	0.7	< 0.5
total extractable hydrocarbons	mg/kg	970	1,000
Total Metals			
aluminum (Al)	µg/g	8,910	1,700
arsenic (As)	µg/g	5.9	1.5
barium (Ba)	µg/g	153	80
beryllium (Be)	µg/g	0.5	< 0.2
boron (B)	µg/g	7	5
cadmium (Cd)	µg/g	0.2	< 0.1
calcium (Ca)	µg/g	3,460	10,800
chromium (Cr)	µg/g	18.2	5.0
cobalt (Co)	µg/g	5.3	2.3
copper (Cu)	µg/g	12.2	6.2
iron (Fe)	µg/g	13,500	8,350
lead (Pb)	µg/g	9.7	4.2
magnesium (Mg)	µg/g	2,530	1,790
manganese (Mn)	µg/g	176	449
mercury (Hg)	µg/g	< 0.04	< 0.04
molybdenum (Mo)	µg/g	0.4	0.2
nickel (Ni)	µg/g	17.3	6.9
potassium (K)	µg/g	1,910	505
selenium (Se)	µg/g	0.7	< 0.2
silver (Ag)	µg/g	< 0.1	< 0.1
sodium (Na)	µg/g	103	69
strontium (Sr)	µg/g	27	27
thallium (Tl)	µg/g	0.16	< 0.05
uranium (U)	µg/g	0.8	0.3

Table 4.6 Sediment Quality of Fort Creek Duplicate Samples, RAMP 2000 Field QA/QC Program (continued)

Parameter	Units	Mouth of Fort Creek	
vanadium (V)	µg/g	26.7	10.3
zinc (Zn)	µg/g	83.1	25.1
Target PAHs and Alkylated PAHs			
naphthalene	ng/g	17	24
C1 subst'd naphthalenes	ng/g	54	77
C2 subst'd naphthalenes	ng/g	45	< 42
C3 subst'd naphthalenes	ng/g	< 32	< 22
C4 subst'd naphthalenes	ng/g	< 21	< 25
Acenaphthene	ng/g	< 12	< 24
C1 subst'd acenaphthene	ng/g	< 10	< 13
acenaphthylene	ng/g	< 15	< 14
anthracene	ng/g	< 25	< 24
dibenzo(a,h)anthracene	ng/g	< 68	< 100
benzo(a)anthracene / chrysene	ng/g	230	150
C1 subst'd benzo(a)anthracene / chrysene	ng/g	2,700	1,500
C2 subst'd benzo(a)anthracene / chrysene	ng/g	1,200	500
benzo(a)pyrene	ng/g	< 100	< 83
C1 subst'd benzo(b&k) f/b(a)pyrene[(a)]	ng/g	< 120	< 72
C2 subst'd benzo(b& k) f/b(a)pyrene[(a)]	ng/g	< 73	< 59
benzofluoranthenes	ng/g	76	44
benzo(g,h,i)perylene	ng/g	< 81	< 56
biphenyl	ng/g	< 14	< 17
C1 subst'd biphenyl	ng/g	< 7.6	< 14
C2 subst'd biphenyl	ng/g	< 9.4	< 6.7
dibenzothiophene	ng/g	< 15	< 19
C1 subst'd dibenzothiophene	ng/g	84	< 25
C2 subst'd dibenzothiophene	ng/g	570	210
C3 subst'd dibenzothiophene	ng/g	2,400	760
C4 subst'd dibenzothiophene	ng/g	< 35	< 29
fluoranthene	ng/g	< 23	< 34
C1 subst'd fluoranthene / pyrene	ng/g	460	220
C2 subst'd fluoranthene / pyrene	ng/g	1,200	410
C3 subst'd fluoranthene / pyrene	ng/g	1,700	670
fluorene	ng/g	< 18	< 16
C1 subst'd fluorene	ng/g	< 14	< 20
C2 subst'd fluorene	ng/g	< 12	< 27
C3 subst'd fluorene	ng/g	< 50	< 30
indeno(1,2,3,cd)pyrene	ng/g	< 59	< 60
phenanthrene	ng/g	37[(b)]	< 18
C1 subst'd phenanthrene / anthracene	ng/g	< 40	< 26
C2 subst'd phenanthrene / anthracene	ng/g	230	72
C3 subst'd phenanthrene / anthracene	ng/g	1,200	220
C4 subst'd phenanthrene / anthracene	ng/g	1,100	< 69
1-methyl-7-isopropyl-phenanthrene	ng/g	< 380	40
pyrene	ng/g	58	24

[(a)] fluoranthene/benzo(a)pyrene.

[(b)] PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

Local Variation in the Athabasca River

Three additional composite sediment samples were taken within a 10 km reach positioned just upstream of the established "Athabasca River, upstream of the Embarras River" RAMP sample site in the fall of 2000 to examine local variability in sediment quality in the Athabasca River. For almost every parameter, concentrations at the established sample site fell within the range defined by the three additional composite sediment samples (Table 4.7). These results suggest that sediment quality in the lower Athabasca River is relatively homogeneous and that composite sediment samples collected at the established site in the Athabasca River located upstream of the Embarras River are representative of sediment quality in the lower Athabasca River.

Table 4.7 Sediment Quality in the Lower Athabasca River, RAMP 2000 Field QA/QC Program

Parameter	Units	Athabasca River, Upstream of the Embarras River			
		Established RAMP Sample Site	Additional Samples Collected Within 10 km of the Established Sample Site		
Particle Size					
particle size - % sand	%	36	20	44	24
particle size - % silt	%	42	52	36	56
particle size - % clay	%	22	28	20	20
Carbon Content					
total inorganic carbon	% dry wt	0.8	0.9	0.8	0.9
total organic carbon	% dry wt	1.1	1.5	1.0	1.4
Organics					
total recoverable hydrocarbons	mg/kg	500	1200	600	600
total volatile hydrocarbons	mg/kg	< 0.5	< 0.5	0.5	0.6
total extractable hydrocarbons	mg/kg	59	180	69	130
Total Metals					
aluminum (Al)	µg/g	11,800	14,500	10,600	12,300
arsenic (As)	µg/g	4.6	5.9	4.8	5.3
barium (Ba)	µg/g	157	185	155	176
beryllium (Be)	µg/g	0.7	0.8	0.6	0.6
boron (B)	µg/g	20	25	18	20
cadmium (Cd)	µg/g	0.2	0.2	0.2	0.2
calcium (Ca)	µg/g	20,300	22,400	19,700	23,900
chromium (Cr)	µg/g	61.3	56.2	42.1	60.9
cobalt (Co)	µg/g	7.1	8.3	7.0	7.6
copper (Cu)	µg/g	12.7	19.1	14.2	15.9
iron (Fe)	µg/g	17,400	20,800	17,300	18,900
lead (Pb)	µg/g	7.2	9.5	7.7	8.3
magnesium (Mg)	µg/g	7,550	8,510	7,280	8,370
manganese (Mn)	µg/g	336	385	336	408
mercury (Hg)	µg/g	0.05	0.04	0.07	0.05
molybdenum (Mo)	µg/g	1.9	1.2	1.1	1.6
nickel (Ni)	µg/g	34.8	34.2	26.4	35.8
potassium (K)	µg/g	2,250	2,820	2,000	2,340
selenium (Se)	µg/g	0.6	0.9	0.8	0.6
silver (Ag)	µg/g	0.2	0.2	0.1	0.1
sodium (Na)	µg/g	257	272	231	246

Table 4.7 Comparison of Composite and Grab Sampling Techniques, RAMP 2000 Field QA/QC Program (continued)

Parameter	Units	Athabasca River, Upstream of the Embarras River			
		Established RAMP Sample Site	Additional Samples Collected Within 10 km of the Established Sample Site		
strontium (Sr)	µg/g	59	66	59	69
thallium (Tl)	µg/g	0.18	0.23	0.17	0.19
uranium (U)	µg/g	1.0	1.2	1.0	1.1
vanadium (V)	µg/g	33.9	40.0	30.7	34.3
zinc (Zn)	µg/g	60.8	61.3	48.3	53.3
Target PAHs and Alkylated PAHs					
naphthalene	ng/g	27	17	14	24
C1 subst'd naphthalenes	ng/g	28	31	25	36
C2 subst'd naphthalenes	ng/g	38	29	32	50
C3 subst'd naphthalenes	ng/g	25	76	34	39
C4 subst'd naphthalenes	ng/g	6	91	< 3	< 8
acenaphthene	ng/g	< 6	< 5	< 4	< 8
C1 subst'd acenaphthene	ng/g	3	< 3	< 3	2
acenaphthylene	ng/g	< 6	< 5	< 3	< 13
anthracene	ng/g	< 5	< 3	< 2	< 6
dibenzo(a,h)anthracene	ng/g	< 5	< 3	< 5	< 6
benzo(a)anthracene / chrysene	ng/g	15	32	19	22
C1 subst'd benzo(a)anthracene / chrysene	ng/g	120	300	140	190
C2 subst'd benzo(a)anthracene / chrysene	ng/g	42	130	45	55
benzo(a)pyrene	ng/g	6	9[a]	5[a]	8
C1 subst'd benzo(b&k) f/b(a)pyrene[b]	ng/g	< 8	< 9	< 4	< 8
C2 subst'd benzo(b& k) f/b(a)pyrene[b]	ng/g	< 4	< 5	< 4	< 6
benzofluoranthenes	ng/g	23	27	20	24
benzo(g,h,i)perylene	ng/g	18	24	16	17
biphenyl	ng/g	3	< 4	< 4	< 4
C1 subst'd biphenyl	ng/g	< 3	< 3	< 2	< 4
C2 subst'd biphenyl	ng/g	< 4	< 1	< 3	< 3
dibenzothiophene	ng/g	< 6	5	3[a]	< 2
C1 subst'd dibenzothiophene	ng/g	7	45	16	15
C2 subst'd dibenzothiophene	ng/g	22	310	51	57
C3 subst'd dibenzothiophene	ng/g	70	540	95	130
C4 subst'd dibenzothiophene	ng/g	< 4	< 7	< 3	< 4
fluoranthene	ng/g	4	7	4	5
C1 subst'd fluoranthene / pyrene	ng/g	33	93	40	61
C2 subst'd fluoranthene / pyrene	ng/g	68	180	82	91
C3 subst'd fluoranthene / pyrene	ng/g	59	190	71	74
fluorene	ng/g	< 3	4	< 2	< 4
C1 subst'd fluorene	ng/g	< 4	< 4	< 4	< 5
C2 subst'd fluorene	ng/g	< 5	< 5	< 4	< 8
C3 subst'd fluorene	ng/g	< 6	< 5	< 6	< 7
indeno(1,2,3,cd)pyrene	ng/g	12	18	12	13
phenanthrene	ng/g	14	28	15	20
C1 subst'd phenanthrene / anthracene	ng/g	42	140	55	62
C2 subst'd phenanthrene / anthracene	ng/g	36	200	63	59
C3 subst'd phenanthrene / anthracene	ng/g	36	220	58	70
C4 subst'd phenanthrene / anthracene	ng/g	15	160	56	69
1-methyl-7-isopropyl-phenanthrene	ng/g	37	57	48	56
pyrene	ng/g	10	18	15	16

[a] PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

4.1.2 Laboratory Analysis

4.1.2.1 Methods

As part of the laboratory QA/QC program, RAMP requested ETL and AXYS to provide the results of the internal quality control checks on their analytical equipment and sampling procedures. In 2000, ETL was implementing a new data management program that restricted access to lab QA/QC data; hence, some results could not be reported. This new data management program will be finalized prior to the start of the RAMP 2001 field program.

The laboratory QA/QC program included:

- using lab blanks to detect contamination from analytical equipment;
- using spiked samples to check for interference from the laboratory sample matrix by adding a specified amount of a chemical to the sample and measuring the percent recoveries; and
- re-analyzing a random sample (i.e., lab duplicate) to check accuracy of sampling procedures and stability of equipment.

4.1.2.2 Results

Lab Blanks

Levels of water and sediment quality parameters that were five times above the corresponding method detection limit in the spring and fall lab blanks are provided in Tables 4.8 and 4.9. Raw data are provided in Appendix III, Tables III-1 and III-2.

Spiked Samples

ETL spiked samples to check for interference from the laboratory sample matrix. Percentage recovery of spring, fall and late fall spiked samples are shown in Table 4.9 and 4.10. Water quality parameters that had less than 80% recovery were sulphide, total silver and total zinc (Table 4.10). Kjeldahl nitrogen was the only water quality parameter to have greater than 120% recovery. Sediment quality parameters that had less than 80% recovery included aluminum, lead, potassium, silver and thallium (Table 4.11). Total extractable hydrocarbons was the only sediment quality parameter that had a greater than 120% recovery.

Table 4.8 Summary of Water Quality Parameters in RAMP 2000 Lab Blanks That Exceeded Five Times the Detection Limit

Parameter	Units	Detection Limit	Season			Comments
			Spring	Fall		
				Trip #1	Trip #2	
Total Metals						
aluminum (Al)	µg/L	< 20	1,600	-	-	A
barium (Ba)	µg/L	<0.2	22.7	1.6	2.5	A ,A, A
calcium (Ca)	µg/L	< 100	2,300	-	-	A
chromium (Cr)	µg/L	< 0.8	5.1	-	-	A
iron (Fe)	µg/L	<20	2,230	-	110	A, A
lead (Pb)	µg/L	< 0.1	3.4	-	-	A
magnesium (Mg)	µg/L	< 20	750	-	-	A
manganese (Mn)	µg/L	<0.2	41.6	-	14.8	A, A
potassium (K)	µg/L	< 20	110	200	1340	A, A, A
strontium (Sr)	µg/L	< 0.2	5.6	-	1.7	A, A
vanadium (V)	µg/L	< 0.2	3.9	-	3	A, A
Dissolved Metals						
aluminum (Al)	µg/L	< 10	80	-	nd	A
boron (B)	µg/L	<2	17	-	nd	A
manganese (Mn)	µg/L	<0.1	0.8	2.4	nd	B, A

(a) - = parameter did not exceed five times the method detection limit; nd = no data.

(b) Two lab equipment blanks were analyzed in late fall.

(c) A = Concentration in lab blank was higher than concentrations observed in either the field blank, trip blank or the water samples collected during that season; therefore, this findings was assumed to be an isolated error.

B = Sample concentrations from the relevant season were outside the historical range and greater than levels in the lab blank; results are indicative of potential sample contamination during analysis.

Table 4.9 Summary of Sediment Quality Parameters in RAMP 2000 Lab Blanks That Exceed Five Times the Detection Limit

Parameter	Units	Detection Limit	ETL	AXYS	Comments
Total Metals					
aluminum (Al)	µg/g	< 1	47	n/a	A
copper (Cu)	µg/g	< 0.1	2	n/a	A
lead (Pb)	µg/g	< 0.1	0.7	n/a	A
zinc (Zn)	µg/g	< 0.2	8.2	n/a	A
Target PAHs and Alkylated PAHs					
naphthalene	ng/g	< 1.2	n/a	10[a]	B
C1 subst'd naphthalenes	ng/g	< 3.6	n/a	11	B

(a) PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

n/a = Not applicable.

(b) A = Concentration in lab blank was higher than concentrations observed in either the field blank, trip blank or the water samples collected during that season; therefore, this findings was assumed to be an isolated error.

B = Sample concentrations from the relevant season generally contained levels consistent with historical data; therefore, this finding was assumed to be an isolated error.

Table 4.10 Percent Recovery of Water Quality Parameters in Spiked Samples, RAMP 2000 Laboratory QA/QC Program

Parameter	Percent Recovery (%)			
	Spring	Fall Trip #1	Fall Trip #2	
Conventional Parameters				
dissolved organic carbon	-	100	95	-
total organic carbon	99	100	97	100
Major Ions				
calcium	-	103	98	100
chloride	109	102	105	104
magnesium	-	107	107	104
potassium	-	96	101	95
sodium	-	104	105	99
sulphate	-	106	100	103
sulphide	91	99	67	67
Nutrients				
nitrate + nitrite	99	106	101	98
nitrogen - ammonia	103	105	98	88
nitrogen - Kjeldahl	95	-	121	-
phosphorus, total	-	89	82	-
phosphorus, dissolved	-	-	-	110
General Organics				
naphthenic acids	-	94	113	90
total phenolics	94	96	97	92
Total Metals				
aluminum (Al)	108	97	94	96
antimony (Sb)	99	100	103	105
arsenic (As)	100	96	100	100
barium (Ba)	109	102	103	99
beryllium (Be)	106	106	100	103
boron (B)	104	106	105	100
cadmium (Cd)	102	94	101	102
calcium (Ca)	112	98	116	109
chromium (Cr)	102	94	100	101
cobalt (Co)	108	96	103	98
copper (Cu)	106	97	102	98
iron (Fe)	101	97	104	97
lead (Pb)	105	101	102	110
lithium (Li)	102	96	112	116
magnesium (Mg)	107	97	93	106
manganese (Mn)	113	103	105	100
mercury (Hg)	94	99	103	101
molybdenum (Mo)	108	92	106	104

Table 4.10 Percent Recovery of Water Quality Parameters in Spiked Samples, RAMP 2000 Laboratory QA/QC Program (continued)

Parameter	Percent Recovery (%)			
	Spring	Fall Trip #1	Fall Trip #2	
nickel (Ni)	107	96	103	97
potassium (K)	106	104	105	104
selenium (Se)	97	91	90	93
silver (Ag)	91	38	36	64
sodium (Na)	108	98	98	105
strontium (Sr)	112	98	106	101
thallium (Tl)	107	103	104	112
uranium (U)	108	110	104	104
vanadium (V)	113	93	104	102
zinc (Zn)	107	97	97	96
Dissolved Metals				
aluminum (Al)	115	-	-	-
antimony (Sb)	102	-	-	-
arsenic (As)	110	-	-	-
barium (Ba)	106	-	-	-
beryllium (Be)	101	-	-	-
boron (B)	104	-	-	-
cadmium (Cd)	108	-	-	-
chromium (Cr)	108	-	-	-
cobalt (Co)	108	-	-	-
copper (Cu)	107	-	-	-
iron (Fe)	106	-	-	-
lead (Pb)	108	-	-	-
lithium (Li)	105	-	-	-
manganese (Mn)	107	-	-	-
mercury (Hg)	100	-	-	-
molybdenum (Mo)	104	-	-	-
nickel (Ni)	109	-	-	-
selenium (Se)	112	-	-	-
silver (Ag)	101	-	-	-
strontium (Sr)	106	-	-	-
thallium (Tl)	108	-	-	-
uranium (U)	108	-	-	-
vanadium (V)	113	-	-	-
zinc (Zn)	114	-	-	-

- = No data.

Table 4.11 Percent Recovery of Sediment Quality Parameters in Spiked Samples, RAMP 2000 Laboratory QA/QC Program

Parameter	Percent Recovery (%) [a]
Organics	
total extractable hydrocarbons	150
Total Metals	
aluminum (Al)	33
arsenic (As)	102
barium (Ba)	87
beryllium (Be)	97
boron (B)	106
cadmium (Cd)	94
calcium (Ca)	98
chromium (Cr)	91
cobalt (Co)	98
copper (Cu)	87
iron (Fe)	97
lead (Pb)	78
magnesium (Mg)	80
manganese (Mn)	95
molybdenum (Mo)	108
nickel (Ni)	94
potassium (K)	72
selenium (Se)	103
silver (Ag)	34
sodium (Na)	93
strontium (Sr)	108
thallium (Tl)	77
uranium (U)	82
vanadium (V)	92
zinc (Zn)	102

[a] Sample from second fall sampling trip.

Lab Duplicates

ETL re-analyzed a random sediment sample and reported the results as a relative percent difference. The relative percent difference in all sediment quality parameters analyzed was less than 25% (Table 4.12).

Table 4.12 Relative Percent Difference of Sediment Quality Parameters in a Lab Duplicate, RAMP 2000 Laboratory QA/QC Program

Parameter	Relative Percent Difference (%) [(a)]
Organics	
total extractable hydrocarbons	23
Total Metals	
aluminum (Al)	2
arsenic (As)	6
barium (Ba)	2
beryllium (Be)	3
boron (B)	14
cadmium (Cd)	2
calcium (Ca)	3
chromium (Cr)	7
cobalt (Co)	5
copper (Cu)	1
iron (Fe)	1
lead (Pb)	0
magnesium (Mg)	3
manganese (Mn)	2
molybdenum (Mo)	17
nickel (Ni)	5
potassium (K)	6
sodium (Na)	2
strontium (Sr)	0
thallium (Tl)	16
uranium (U)	5
vanadium (V)	5
zinc (Zn)	11

[(a)] Sample from second fall sampling trip.

4.1.3 Data Analysis

Water quality and sediment data were entered into the project database from the electronic files and paper reports received from the analytical laboratories. All new data were verified against each laboratory's final reports to ensure data accuracy. Less than 5% of the values were found to be entered incorrectly. These mistakes were corrected.

4.2 BENTHIC INVERTEBRATE COMMUNITY

Laboratory analysis of benthic invertebrate samples incorporated an evaluation of invertebrate removal efficiency in six samples. Minimum removal efficiency of 95% was considered acceptable. Quality control results (Table 4.13) indicate that the data quality objective of minimum 95% removal of invertebrates from the sorted fractions of samples was achieved for all samples except one, which contained very low numbers of invertebrates.

The benthic invertebrate abundance data were received in electronic form from the taxonomist. Data entry was checked by the taxonomist by verifying each number entered. During data manipulation and analysis, backup files were generated prior to each major operation, and appropriate logic checks were performed to ensure the accuracy of calculations. Benthic invertebrate data and results of analyses are stored in printed and electronic format with appropriate documentation and backups to ensure that analyses may be reproduced if necessary.

Table 4.13 Quality Control Data for Re-sorted Benthic Invertebrate Samples

Taxon	MAR-E-6		MAR-E-11		MUR-E-15		MUR-D-11		STR-E-1		STR-E-5	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Nematoda	1			1				1		1		1
Ostracoda		1										
Hydracarina				3								
Capniidae					1							
Ephemeroptera					1							
Baetidae			1		5				1	1		3
Hydroptilidae										1		
Chironomini		3		2			1					
Tanytarsini		2						1			1	
Orthocladiinae				1								2
Total missed	1	6	1	7	7	0	1	2	1	3	1	6
Total in sample	274		580		343		454		41		166	
% missed[(a)]	4.7		2.6		2.0		4.6		9.8		4.2	
Sorting efficiency (%)[(a)]	95.3		97.4		98.0		95.4		90.2		95.8	

[(a)] Numbers of organisms were multiplied by the subsampling factor to calculate the % missed and sorting efficiency.

4.3 FISH POPULATIONS

4.3.1 Field Sampling

Fish collections for radiotelemetry studies and inventory work done as part of the reference site survey were conducted in accordance with Golder Technical Procedure 8.1-3 (Golder 1999a). The spawning survey also followed methods outlined in Technical Procedure 8.1-3. Detailed field notes were maintained in a bound notebook and fisheries data were recorded using appropriate capture data sheets.

Routine water quality data (pH, conductivity, temperature, dissolved oxygen) were collected at each site. Water quality instruments were calibrated at the start of each sampling day. The start and finish of each fisheries sampling reach was recorded using a GPS unit. A photograph of each fish collection site visited during the reference site survey was also taken.

For the radiotelemetry work a reference transmitter was used to: 1) ensure radiotelemetry equipment was working properly before each flight survey; 2) check the life expectancy of implanted transmitters; and 3) evaluate the range of the telemetry signal. The location of each tagged fish was identified using GPS coordinates as well as manually marking the location on 1:50,000 NTS base maps.

Fish ageing structures from longnose sucker (fin rays) and northern pike (scales) were stored in scale envelopes pending analysis by Syncrude Canada Ltd. A subsample of eggs found at each spawning site during the spawning survey was preserved in Gilson's solution. These samples were archived in the event species identification of eggs needed further confirmation.

4.3.2 Data Analysis

Fisheries data were entered into the project database from field and laboratory data sheets. All entries were independently checked for errors by a second person. For this report, no statistical analyses of the data were required.

4.4 ACID SENSITIVE LAKES

Water quality sampling in the field incorporated general QA/QC procedures to minimize sample contamination and ensure proper functioning of field instruments, as described in Golder Technical Procedure 3.1 (Golder 1999a). To evaluate intra-site variability, one duplicate sample was collected at Lake E68 and was analyzed for all parameters.

The Limnology Laboratory of the University of Alberta has an internal QA/QC program, which includes the use of standard reference samples, inter-laboratory comparisons and corrective actions, if QC objectives are not met. Standard QC samples are prepared for each analysis from analytical grade chemicals or certified standards. Inter-laboratory comparisons are performed twice a year against 10 samples supplied by National Water Research Institute (NWRI) and once a year against 2 samples provided by the Norwegian Institute for Water Research (NIVA).

Standards are run with every set of analyses to establish a standard curve, followed by QC samples, analyzed in duplicate. If the QC results are unacceptable at this point, corrective action is taken. If the analysis is deemed consistent over the length of the run, these are the only QC samples analyzed. For analyses where instrument drift may occasionally occur (e.g., DOC), QC samples are run as every 10th sample. Sulphate, chloride and alkalinity analyses also include analyzing QC samples at the end of a batch of samples. When a new QC sample is prepared, it is run with the previous QC sample to develop a new control chart.

Duplicate analytical results for Lake E68 indicate that intra-site variation was generally low and field sampling precision was high (Table 4.14). The percent difference between the two samples was <5% for most parameters. Exceptions included TSS, ammonia, chloride, DIC, PN, TDP and Chlorophyll *a*. The variation between duplicate samples in all but two of these was still below 10%. The variation in chloride was large when expressed as a percentage, but negligibly small in absolute terms (difference of 0.07 mg/L between samples). The variation in Chlorophyll *a* concentration was still relatively small (3.2 µg/L), but it may be of concern in ultra-oligotrophic lakes. Since both chloride and chlorophyll *a* are peripheral parameters in studies of acid sensitivity, these results are of no concern regarding the interpretation of the survey results.

Table 4.14 Duplicate Water Chemistry Results for Lake E68

Parameter	Units	Lake E68		% Difference Relative to Sample 1
		Sample 1	Sample 2	
lab pH	--	7.03	7.03	0.0
TDS	mg/L	72.0	71.0	1.4
TSS	mg/L	5.7	6.0	5.3
turbidity	NTU	3.6	3.7	2.8
total alkalinity	mg/L as $CaCO_3$	14.83	14.79	0.3
Gran alkalinity	mg/L as $CaCO_3$	14.50	14.49	0.1
calcium	mg/L	6.61	6.56	0.8
magnesium	mg/L	2.05	2.06	0.5
sodium	mg/L	1.03	1.05	1.9
potassium	mg/L	0.28	0.27	3.6
ammonia	µg/L	9.31	8.67	6.9
bicarbonate	mg/L	18.08	18.03	0.3
chloride	mg/L	0.14	0.07	50.0
sulphate	mg/L	3.59	3.57	0.6
nitrite + nitrate	µg/L	20.58	20.61	0.1
colour	PT units	311.7	310.7	0.3
DOC	mg/L	22.38	22.80	1.9
DIC	mg/L	2.34	2.19	6.4
PC	µg/L	1,904.6	1,891.3	0.7
TDN	µg/L	640.1	627.8	1.9
PN	µg/L	255.0	287.4	12.7
TP	µg/L	50.2	51.0	1.6
TDP	µg/L	26.6	24.9	6.4
chlorophyll *a*	µg/L	11.28	14.47	28.3

5 ATHABASCA RIVER - RESULTS AND DISCUSSION

5.1 WATER AND SEDIMENT QUALITY

5.1.1 Water Quality

Upstream of Donald Creek

Water quality in the Athabasca River at a site located upstream of Donald Creek was characterized in fall 2000 with water samples taken from three points on the west side, middle and east side of the river. Water from all three points was non-toxic to bacteria (Tables 5.1 and 5.2). Naphthenic acids were found in concentrations equal to the detection limit (i.e., 1 mg/L) on the west side. Several water quality guidelines were exceeded in 2000, including total phosphorus, aluminum, copper, iron and selenium (Table 5.3). Total phosphorus, aluminum and iron concentrations in previous sampling events have also exceeded water quality guidelines. Since mercury and silver detection limits in the 2000 samples were higher than Alberta surface water quality guidelines, it was not possible to determine if sample concentrations exceeded guideline levels.

In 2000, water quality did not vary substantially across the width of the Athabasca River at the site located upstream of Donald Creek, with the exception of hardness, chloride, total phosphorus, iron, aluminum, copper and zinc. Concentrations that were substantially different in 2000 from historical values are summarized in Table 5.4. Total organic carbon, total suspended solids and total nickel concentrations were lower in 2000 at all three sample points compared to historical data.

Upstream of the Steepbank River

Water in the Athabasca River upstream of the Steepbank River was non-toxic to bacteria in the fall of 2000 (Table 5.1). Naphthenic acids were found in concentrations equal to the detection limit (i.e., 1 mg/L) at the west, middle and east sampling points. Total nitrogen, total phosphorus, aluminum, iron, manganese and selenium levels exceeded relevant guidelines in 2000 (Table 5.3). With the exception of selenium, historical median concentrations also exceeded all of these guidelines.

Cross-river trends at this site were similar to those observed upstream of Donald Creek; parameter concentrations tended to be lowest in the mid-channel sample (Tables 5.1 and 5.2). Chloride and total aluminum concentrations were higher in 2000 at all three sampling points across the river compared to historical values, while dissolved organic carbon concentrations were lower in 2000 than in previous years (Table 5.4).

Table 5.1 Athabasca River Water Quality Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek (Fall)				Upstream of the Steepbank River (Fall)			
		2000			Historical Median[(a)]	2000			Historical Median[(b)]
		West	Middle	East		West	Middle	East	
Field Measured									
pH		7.9	8.0	8.2	6.5	8.0	8.0	8.0	8.0
specific conductance	µS/cm	225	229	271	320	253	247	244	190
temperature	^oC	4.3	5.4	4.7	11.0	4.3	4.0	4.4	5.6
dissolved oxygen	mg/L	12.9	-	13.2	10.5	12.7	12.8	12.8	11.7
Conventional Parameters									
dissolved organic carbon	mg/L	6	6	6	10	6	7	8	19
total alkalinity	mg/L	117	107	73	86	104	94	94	88
total dissolved solids	mg/L	180	170	160	114	190	160	170	142
total organic carbon	mg/L	7	7	7	23	8	9	10	20
total suspended solids	mg/L	6	12	10	50	54	10	69	106
Major Ions									
chloride	mg/L	3	3	25	3	8	11	11	3
sulphate	mg/L	34	32	12	15	32	23	22	16
Nutrients and Chlorophyll *a*									
nitrate + nitrite	mg/L	0.29	< 0.05	< 0.05	0.05	< 0.05	< 0.05	< 0.05	0.01
nitrogen – ammonia	mg/L	< 0.10	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10	< 0.10	< 0.01
nitrogen – total	mg/L	0.7	< 0.2	0.4	0.7	0.2	< 0.2	0.3	0.6
phosphorus, total	µg/L	34	29	384	100	54	30	70	95
chlorophyll *a*	µg/L	5	4	5	2	5	4	4	5
Biochemical Oxygen Demand									
biochemical oxygen demand	mg/L	< 2	< 2	< 2	3	< 2	< 2	< 2	< 0.1
Organics									
naphthenic acids	mg/L	1	< 1	< 1	< 1	1	1	1	-
total phenolics	µg/L	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1
Toxicity[(c)]									
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 91	> 91	-
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 91	> 91	-

(a) Based on information from Golder (1996, 1998, 1999b, 2000c) and AENV WDS stations AB07DA0020/0050/0090.

(b) Based on information from AENV WDS station AB07DA020.

(c) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 5.2 Metal Concentrations in Athabasca River Water Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek (Fall)				Upstream of the Steepbank River (Fall)			
		2000			Historical Median[a]	2000			Historical Median[b]
		West	Middle	East		West	Middle	East	
Total Metals									
aluminum (Al)	µg/L	540	30	680	700	2,430	680	2,770	660
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	< 0.8	< 5.0	< 5.0	< 5.0	-
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	1.3	3.0	< 1.0	< 1.0	1.0
barium (Ba)	µg/L	57	22	28	53	76	47	76	60
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.6	< 0.2	< 0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	< 1	< 1	< 1	2	5	< 1	8	3
copper (Cu)	µg/L	1	2	21	2	3	2	3	3
iron (Fe)	µg/L	540	410	1,170	705	2,490	920	3,040	2,220
lead (Pb)	µg/L	0.3	0.3	0.6	1.0	1.3	0.5	1.0	1.3
manganese (Mn)	µg/L	27	13	42	32	85	29	119	81
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1
molybdenum (Mo)	µg/L	0.7	0.4	0.4	1.1	5.3	0.5	0.4	< 3.0
nickel (Ni)	µg/L	0.8	0.2	1.8	5.1	8.2	1.1	2.8	13.4
selenium (Se)	µg/L	< 0.8	1.3	< 0.8	< 0.5	< 0.8	< 0.8	1.1	0.2
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.1
zinc (Zn)	µg/L	15	17	41	17	33	32	25	-
Dissolved Metals[c] [d]									
aluminum (Al)	µg/L	10	60	130	44	10	10	50	-
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	-
arsenic (As)	µg/L	**12.4**	**10.9**	**10.6**	< 0.5	**7.2**	**7.5**	< 0.4	-
barium (Ba)	µg/L	51	**48**	**52**	50	46	38	40	-
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	**0.3**	-
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 3.0	< 0.4	< 0.4	< 0.4	-
copper (Cu)	µg/L	**2.6**	1.6	0.8	1.9	0.8	0.7	1.9	-
iron (Fe)	µg/L	< 10	< 10	260	100	30	70	110	-
lead (Pb)	µg/L	0.4	0.3	0.2	0.2	0.2	0.1	**1.0**	-
manganese (Mn)	µg/L	14	4	19	5	25	9	51	-
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-
molybdenum (Mo)	µg/L	**0.8**	**1.0**	**0.7**	1.0	5.0	**0.6**	**1.7**	-
nickel (Ni)	µg/L	0.7	**0.6**	0.7	2.6	1.8	0.6	**5.9**	-
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	-
silver (Ag)	µg/L	0.4	0.3	0.2	< 0.2	< 0.2	< 0.2	< 0.2	-
zinc (Zn)	µg/L	9	6	6	5	7	5	**267**	-

[a] Based on information from Golder (1996, 1998, 1999b, 2000c) and AENV WDS stations AB07DA0020/0050/0090.

[b] Based on information from AENV WDS station AB07DA020.

[c] Occasionally, a dissolved metal level reported by ETL was higher than the respective total metal concentration (bolded numbers); this problem was detected too late for sample re-analysis; in future, lab results will be screened sooner to allow for sample re-analysis if required.

[d] Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

- = No data.

Table 5.3 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Guidelines for the Protection of			Upstream of Donald Creek (Fall)				Upstream of the Steepbank River (Fall)			
		Aquatic Life[(a)]		Human Health[(b)]	2000			Historical Median	2000			Historical Median
		Acute	Chronic		West	Middle	East		West	Middle	East	
Nutrients												
phosphorus, total	µg/L	-	50	-			C	C	C		C	C
Total metals												
aluminum (Al)	µg/L	750	100	-	C		C	C	A C	C	A C	C
copper (Cu)	µg/L	*	*	1300			A C					
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H	C H	C H	C H	C H
manganese (Mn)	µg/L	-	-	50					H		H	H
selenium (Se)	µg/L	-	1	170		C					C	

(a) Guidelines taken from AENV (1999).

(b) Guidelines taken from U.S. EPA (1999).

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Upstream of the Muskeg River

In 2000, Athabasca River water quality upstream of the Muskeg River was consistent across the width of the river (Tables 5.5 and 5.6). All three samples were non-toxic to bacteria, and naphthenic acids were detected at all three sampling points in 2000. Total aluminum and iron concentrations at each point also exceeded water quality guidelines in 2000, as they have in the past (Table 5.7). However, total aluminum concentrations were particularly high in the mid-channel sample.

Dissolved iron concentrations increased substantially at all three sampling points in 2000 compared to historical levels (Table 5.4). Conversely, dissolved aluminum, copper, lead and zinc levels at all three sampling points were lower in 2000 than in previous years.

Upstream of Fort Creek

Water quality was similar across the width of the Athabasca River upstream of Fort Creek in Fall 2000, except that metals tended to be found in greater concentrations mid-channel or on the east side of the river (Tables 5.5 and 5.6). All waters were non-toxic to bacteria, and naphthenic acids were detected at each sampling point in 2000. Total aluminum and iron concentrations in 2000 exceeded corresponding water quality guidelines, as they have in previous sampling events (Table 5.7).

Table 5.4 Site-specific Variations in Athabasca River Water Quality in 2000

Variations	Sampling Event	Affected Parameters at Sample Site: Upstream of Donald Creek	Upstream of Steepbank River	Upstream of Muskeg River	Upstream of Fort Creek	Upstream of Embarras River[a]
2000 levels **higher** than historical median values	west side	• sulphate • nitrate+nitrite • dissolved manganese	• sulphate • total aluminum	-	-	-
	middle	• sulphate	-	• total aluminum	• total aluminum • total iron • total & dissolved zinc	-
	east side	• chloride • total phosphorus • total copper • total zinc • dissolved aluminum • dissolved iron • dissolved manganese	• total aluminum • total selenium	-	• total suspended solids • total aluminum • total iron • total zinc	-
	every sampling event		• chloride	• dissolved iron	• total phosphorus	• total suspended solids • total zinc
2000 levels **lower** than historical median values	west side	• dissolved aluminum • dissolved iron	• total organic carbon	-	-	-
	middle	• total aluminum • dissolved iron	• total organic carbon • total suspended solids • total phosphorus • total iron • total manganese • total nickel	-	-	-
	east side	• dissolved copper	• total nickel	• total aluminum	-	-
	every sampling event	• total organic carbon • total suspended solids • total nickel	• dissolved organic carbon	• dissolved aluminum • dissolved copper • dissolved lead • dissolved zinc	• total nickel	-

[a] The was a single sampling point at the site upstream of the Embarras River.

Total phosphorus concentrations at the three sampling points across the width of the river were higher in 2000 compared to historical levels (Table 5.4). Total nickel levels were lower across the Athabasca River in 2000 than in previous years.

Table 5.5 Athabasca River Water Quality Upstream of the Muskeg River and Fort Creek

Parameter	Units	Upstream of the Muskeg River (Fall)				Upstream of Fort Creek (Fall)			
		2000			Historical	2000			Historical
		West	Middle	East	Median[(a)]	West	Middle	East	Median[(b)]
Field Measured									
pH		-	8.0	-	8.0	8.0	8.0	8.0	8.4
specific conductance	µS/cm	256	247	248	169	252	249	251	310
temperature	^{o}C	3.2	3.0	2.9	7.0	4.3	3.9	4.2	6.0
dissolved oxygen	mg/L	-	-	-	10.9	13.0	13.2	12.8	10.6
Conventional Parameters									
dissolved organic carbon	mg/L	7	8	8	14	8	8	8	4
total alkalinity	mg/L	103	101	100	100	100	99	100	99
total dissolved solids	mg/L	190	190	190	153	90	170	190	173
total organic carbon	mg/L	9	10	10	9	11	10	10	6
total suspended solids	mg/L	16	13	15	18	14	25	29	16
Major Ions									
chloride	mg/L	9	11	11	8	11	11	11	16
sulphate	mg/L	26	23	24	19	26	25	26	28
Nutrients and Chlorophyll *a*									
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen - ammonia	mg/L	< 0.10	0.10	< 0.10	0.01	< 0.10	< 0.10	< 0.10	0.17
nitrogen - total	mg/L	0.2	0.3	0.2	0.7	0.4	0.3	0.3	0.3
phosphorus, total	µg/L	32	30	31	42	32	42	39	18
chlorophyll *a*	µg/L	3	3	2	3	5	4	4	3
Biochemical Oxygen Demand									
biochemical oxygen demand	mg/L	< 2.0	< 2.0	< 2.0	1.8	< 2.0	< 2.0	< 2.0	< 2.0
Organics									
naphthenic acids	mg/L	2	2	1	< 1	1	2	2	< 1
total phenolics	µg/L	2	2	2	< 1	2	2	2	< 1
Toxicity[(c)]									
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	-	> 91	> 91	> 91	> 91
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	-	> 91	> 91	> 91	> 91

[(a)] Based on information from Golder (1997a) and AENV WDS station AB07DA0400.

[(b)] Based on information from Golder (1998, 1999b).

[(c)] Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 5.6 Metal Concentrations in Athabasca River Water Upstream of the Muskeg River and Fort Creek

Parameter	Units	Upstream of the Muskeg River (Fall)				Upstream of Fort Creek (Fall)			
		2000			Historical	2000			Historical
		West	Middle	East	Median[(a)]	West	Middle	East	Median[(b)]
Total Metals									
aluminum (Al)	µg/L	240	980	140	335	590	870	930	295
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	0.5	< 5.0	< 5.0	< 5.0	0.9
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	1.5	< 1.0	< 1.0	< 1.0	< 1.0
barium (Ba)	µg/L	50	50	47	63	47	55	54	54
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	2	3	2	3	1	2	3	1
copper (Cu)	µg/L	1	2	1	6	1	3	3	7
iron (Fe)	µg/L	860	1,360	840	2,600	810	1,350	1,340	440
lead (Pb)	µg/L	0.4	0.7	0.5	1.7	0.4	0.5	0.6	0.6
manganese (Mn)	µg/L	26	34	27	79	28	43	42	20
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.1	< 0.2	< 0.2	< 0.2	< 0.2
molybdenum (Mo)	µg/L	1.6	0.6	0.6	2.0	0.9	1.0	1.0	0.7
nickel (Ni)	µg/L	2.3	2.9	2.2	5.3	2.8	3.5	3.9	15.9
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	< 0.4	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.1	< 0.4	< 0.4	< 0.4	< 0.4
zinc (Zn)	µg/L	19	45	27	34	9	41	42	17
Dissolved Metals[(c) (d)]									
aluminum (Al)	µg/L	10	10	10	73	10	20	10	60
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	0.6	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	0.6	0.5	0.4	< 0.4	< 0.4
barium (Ba)	µg/L	46	43	42	40	44	44	44	39
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 3.0	< 0.4	< 0.4	< 0.4	< 0.4
copper (Cu)	µg/L	0.6	0.7	0.6	4.2	1.1	1.0	1.7	1.4
iron (Fe)	µg/L	120	110	140	< 10	150	130	170	175
lead (Pb)	µg/L	< 0.1	< 0.1	< 0.1	1.5	**0.6**	0.5	0.6	0.3
manganese (Mn)	µg/L	7	7	7	10	13	9	14	12
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.2	< 0.1	< 0.1	< 0.1	< 0.1
molybdenum (Mo)	µg/L	1.5	0.6	0.6	0.8	**2.2**	**2.2**	**1.5**	0.6
nickel (Ni)	µg/L	1.5	1.4	1.2	2.3	1.4	1.5	1.4	2.6
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.2	0.4	< 0.4	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	7.0	7.0	7.0	23	7.0	25	8.0	7.0

[(a)] Based on information from Golder (1997a) and AENV WDS station AB07DA0400.

[(b)] Based on information from Golder (1998, 1999b).

[(c)] Occasionally, a dissolved metal level reported by ETL was higher than the respective total metal concentration (bolded numbers); this problem was detected too late for sample re-analysis; in future, lab results will be screened sooner to allow for sample re-analysis if and when required.

[(d)] Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

- = No data.

Table 5.7 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Athabasca River Upstream of the Muskeg River and Fort Creek

Parameter	Units	Guidelines for the Protection of:			Upstream of the Muskeg River (Fall)				Upstream of Fort Creek (Fall)			
		Aquatic Life[a]		Human Health[b]	2000			Historical Median	2000			Historical Median
		Acute	Chronic		West	Middle	East		West	Middle	East	
Total Metals												
aluminum (Al)	µg/L	750	100	-	C	A C	C	C	C	A C	A C	C
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H	C H	C H	C H	C H
manganese (Mn)	µg/L	-	-	50				H				

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Upstream of the Embarras River

The cross-channel composite sample taken from the Athabasca River upstream of the Embarras River in 2000 was non-toxic to bacteria, and naphthenic acids were not detected (Table 5.8). Concentrations of aluminum, iron and manganese exceeded relevant guidelines in 2000 (Table 5.10). A limited amount of historical data was available for this location. However, the available data indicated that total suspended solids and total zinc increased in 2000 compared to previous sampling events (Tables 5.8 and 5.9).

Delta

A single composite water sample was collected from Big Point Channel in the Athabasca Delta in 2000. The water was non-toxic (based on Microtox® testing) and very similar to available historical data (Tables 5.8 and 5.9). Exceptions included total suspended solids, total aluminum and total zinc, which increased in 2000 compared to previous sampling events. Guidelines exceeded at this location in 2000 included total phosphorus, aluminum and iron (Table 5.10). In previous sampling events, total aluminum levels have been higher than the chronic aquatic guideline of 100 µg/L.

Table 5.8 Athabasca River Water Quality Upstream of the Embarras River and in the Delta

Parameter	Units	Upstream of the Embarras River (Fall)		Athabasca River Delta (Fall)	
		2000	Historical Median[a]	2000	Historical Median[b]
Field Measured					
pH		-	7.9	-	8.0
specific conductance	µS/cm	-	305	-	230
temperature	°C	-	11.0	-	9.0
dissolved oxygen	mg/L	-	9.7	-	9.5
Conventional Parameters					
dissolved organic carbon	mg/L	9	6	9	8
total alkalinity	mg/L	103	108	101	96
total dissolved solids	mg/L	180	164	170	157
total organic carbon	mg/L	12	17	13	11
total suspended solids	mg/L	44	8	58	21
Major Ions					
chloride	mg/L	7	12	7	9
sulphate	mg/L	22	20	22	18
Nutrients and Chlorophyll *a*					
nitrate + nitrite	mg/L	< 0.05	-	< 0.05	-
nitrogen – ammonia	mg/L	< 0.10	-	< 0.10	-
nitrogen – total	mg/L	0.6	-	0.8	-
phosphorus, total	µg/L	44	27	56	48
chlorophyll *a*	µg/L	2	5	4	5
Biochemical Oxygen Demand					
biochemical oxygen demand	mg/L	< 2.0	-	< 2.0	-
Organics					
naphthenic acids	mg/L	< 1	-	< 1	-
total phenolics	µg/L	2	4	2	4
Toxicity[c]					
Microtox IC_{50} @ 15 min	%	> 91	-	> 91	-
Microtox IC_{25} @ 15 min	%	> 91	-	> 91	-

[a] Based on information from AENV WDS stations AB07DD0130/0140/0150.

[b] Based on information from AENV WDS stations AB07DD0160/0170/0220/0230/0240.

[c] Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 5.9 Metal Concentrations in Athabasca River Water Upstream of the Embarras River and in the Delta

Parameter	Units	Upstream of the Embarras River (Fall)		Athabasca River Delta (Fall)	
		2000	Historical Median[(a)]	2000	Historical Median[(b)]
Total Metals					
aluminum (Al)	µg/L	1,670	-	2,570	350
antimony (Sb)	µg/L	< 5.0	-	< 5.0	-
arsenic (As)	µg/L	< 1.0	0.5	1.0	0.6
barium (Ba)	µg/L	62	56	69	55
cadmium (Cd)	µg/L	< 0.2	< 1.0	< 0.2	< 1.0
chromium (Cr)	µg/L	3	5	3	3
copper (Cu)	µg/L	3	< 1	5	< 1
iron (Fe)	µg/L	1,720	-	1,990	-
lead (Pb)	µg/L	1.4	-	1.7	-
manganese (Mn)	µg/L	54	-	49	-
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.2	< 0.1
molybdenum (Mo)	µg/L	0.9	-	0.9	-
nickel (Ni)	µg/L	4.5	-	5.4	-
selenium (Se)	µg/L	< 0.8	< 0.2	< 0.8	< 0.2
silver (Ag)	µg/L	< 0.4	-	< 0.4	-
zinc (Zn)	µg/L	33	4	58	4
Dissolved Metals					
aluminum (Al)	µg/L	280	-	310	-
antimony (Sb)	µg/L	< 0.8	-	< 0.8	-
arsenic (As)	µg/L	0.7	< 0.5	0.7	0.6
barium (Ba)	µg/L	49	-	49	-
cadmium (Cd)	µg/L	< 0.1	-	< 0.1	-
chromium (Cr)	µg/L	1.6	-	1.5	< 3.0
copper (Cu)	µg/L	1.6	-	1.7	-
iron (Fe)	µg/L	430	-	470	-
lead (Pb)	µg/L	0.3	-	0.3	-
manganese (Mn)	µg/L	10.0	-	10.8	-
mercury (Hg)	µg/L	< 0.1	-	< 0.1	-
molybdenum (Mo)	µg/L	0.8	-	0.9	-
nickel (Ni)	µg/L	2.4	-	2.4	-
selenium (Se)	µg/L	< 0.4	< 0.5	< 0.4	< 0.2
silver (Ag)	µg/L	< 0.2	-	< 0.2	-
zinc (Zn)	µg/L	< 2.0	-	< 2.0	-

[(a)] Based on information from AENV WDS stations AB07DD0130/0140/0150.

[(b)] Based on information from AENV WDS stations AB07DD0160/0170/0220/0230/0240.

- = No data.

Table 5.10 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Athabasca River Upstream of the Embarras River and in the Delta

Parameter	Units	Guidelines for the Protection of:			Upstream of the Embarras River (Fall)		Athabasca River Delta (Fall)	
		Aquatic Life[a]		Human Health[b]				
		Acute	Chronic		2000	Historical Median	2000	Historical Median
Nutrients								
phosphorus, total	µg/L	-	50	-			C	
Total Metals								
aluminum (Al)	µg/L	750	100	-	A C	-	A C	C
iron (Fe)	µg/L	-	300	300	C H	-	C H	-
manganese (Mn)	µg/L	-	-	50	H	-		-

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

- = No guideline / no data; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

5.1.2 Sediment Quality

Upstream of Donald Creek

Sediments collected in 2000 from the west and east banks of the Athabasca River upstream of Donald Creek contained primarily sand, with little silt and clay (Tables 5.11 and 5.12). Parameter concentrations in sediments collected along the west bank of the river did not exceed any Canadian sediment quality guidelines in 2000 (Table 5.13), and they were similar to or less than historical levels. A brief overview of previous sediment work completed in the lower Athabasca River watershed is included in Appendix IV.

Concentrations of several parameters in the east-bank sediment sample were greater in 2000 than in 1998 or in previous years, including a number of PAHs and alkylated PAHs (e.g., benzo(a)anthracene/chrysene, benzo(a)pyrene, benzofluoranthene, benzo(g,h,i)perylene and fluoranthene). Total recoverable hydrocarbon levels were particularly elevated in 2000 compared to previous sampling events. In 2000, east-bank sediment concentrations of benzo(a)anthracene/chrysene and pyrene exceeded Canadian sediment quality guidelines (Table 5.13). Since the detection limit for dibenzo(a,h,)anthracene in the 2000 east-bank sediment exceeded the relevant sediment quality guideline, it is not possible to determine whether the true concentration actually exceeded the guideline.

Table 5.11 Sediment Quality in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek					Upstream of Steepbank River		
		2000		1998[a]		Historical Median[b]	2000		Historical Median[c]
		West	East	West	East		West	East	
Particle Size									
particle size - % sand	%	98	85	83	70	56	71	89	66
particle size - % silt	%	1	9	10	20	24	21	6	26
particle size - % clay	%	2	7	7	10	20	8	5	8
Carbon Content									
total inorganic carbon	% dry wt	0.2	0.9	0.6	0.6	0.3	0.7	0.3	0.8
total organic carbon	% dry wt	0.1	2.5	0.4	0.9	0.4	2.1	0.5	0.9
Organics									
total recoverable hydrocarbons	mg/kg	300	14,600	214	653	423	800	500	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	-	-	-	< 0.5	< 0.5	-
total extractable hydrocarbons (C11-C30)	mg/kg	35	1,500	-	-	-	150	62	-
Total Metals									
aluminum (Al)	µg/g	2,500	3,920	5,990	8,080	19,250	5,160	2,600	33,000
arsenic (As)	µg/g	3.6	3.9	7.7	4.2	3.5	3.5	2.5	3.0
barium (Ba)	µg/g	67	109	132	106	319	180	64	411
cadmium (Cd)	µg/g	< 0.1	< 0.1	< 0.5	< 0.5	0.29	0.1	< 0.1	< 0.5
chromium (Cr)	µg/g	7.3	34.5	13.6	16.2	33.0	33.4	12.1	31.7
copper (Cu)	µg/g	6.0	6.9	9.0	10.0	12.0	8.5	3.7	13.2
iron (Fe)	µg/g	8,960	18,700	11,400	12,500	12,400	12,700	7,980	17,300
lead (Pb)	µg/g	3.2	4.2	8.0	8.0	3.8	5.4	3.0	7.2
manganese (Mn)	µg/g	261	315	251	283	248	276	188	335
mercury (Hg)	µg/g	< 0.04	0.07	0.03	0.04	0.02	0.1	< 0.04	0.023
molybdenum (Mo)	µg/g	0.4	1.2	< 1	< 1	< 1	0.7	0.3	< 1
nickel (Ni)	µg/g	9.1	23.9	14	13	16	20.2	8.8	21.35
selenium (Se)	µg/g	< 0.2	0.5	< 0.1	0.3	0.485	< 0.2	< 0.2	< 1
silver (Ag)	µg/g	< 0.1	< 0.1	< 1	< 1	< 1	0.1	< 0.1	< 0.5
zinc (Zn)	µg/g	26.15	26.6	48	46.2	32.1	30.6	22	48.55

(a) Based on information from Golder (1999b).

(b) Based on information from Allan and Jackson (1978) and Lutz and Hendzel (1977).

(c) Based on information from Allan and Jackson (1978) C.G.L. (1979), Beak (1988), Golder (1995) and Dobson et al. (1996).

- = No data.

Table 5.12 Concentration of Polycyclic Aromatic Hydrocarbons in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek					Upstream of Steepbank River		
		2000		1998[(a)]		Historical Median[(b)]	2000		Historical Median[(c)]
		West	East	West	East		West	East	
Target PAHs and Alkylated PAHs									
naphthalene	ng/g	15	13	25	12	< 10	18	7	-
C1 subst'd naphthalenes	ng/g	11	19	15	18	< 20	29	11	-
C2 subst'd naphthalenes	ng/g	< 1	< 7	26	25	20	46	19	-
C3 subst'd naphthalenes	ng/g	< 4	< 10	21	49	30	42	11	-
C4 subst'd naphthalenes	ng/g	< 2	< 9	< 2	57	< 20	< 9	< 3	-
acenaphthene	ng/g	1	< 5	< 2	< 3	< 10	< 7	< 3	-
C1 subst'd acenaphthene	ng/g	1	< 4	< 1	< 0	< 20	< 4	1	-
acenaphthylene	ng/g	< 1	< 5	< 1	< 1	< 10	< 6	< 1	-
anthracene	ng/g	< 1	< 12	< 2	< 4	< 10	< 4	< 2	-
dibenzo(a,h)anthracene	ng/g	< 6	< 10	< 4	< 6	< 10	< 4	< 4	-
benzo(a)anthracene / chrysene	ng/g	2	321*	8	21	20	43*	11	-
C1 subst'd benzo(a)anthracene / chrysene	ng/g	< 5	3,500	< 1	< 1	30	290	< 19	-
C2 subst'd benzo(a)anthracene / chrysene	ng/g	< 1	1,600	< 1	< 1	50	< 120	35	-
benzo(a)pyrene	ng/g	< 2	24*	< 6	11*	< 10	< 11	4	-
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 2	< 23	< 5	< 12	30	< 13	< 5	-
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 2	< 29	< 3	< 6	30	< 6	< 5	-
benzofluoranthenes	ng/g	< 2	88	6*	19*	10	28	17	-
benzo(g,h,I)perylene	ng/g	< 7	46	5*	13	< 10	< 33	5	-
biphenyl	ng/g	2	< 3	< 0	< 1	< 20	< 4	2	-
C1 subst'd biphenyl	ng/g	< 3	< 4	< 0	< 0	< 20	< 4	< 2	-
C2 subst'd biphenyl	ng/g	< 1	< 6	< 0	< 0	< 20	< 3	< 1	-
dibenzothiophene	ng/g	< 1	< 4	1	< 3	< 10	< 12	< 2	-
C1 subst'd dibenzothiophene	ng/g	< 1	< 12	7	23	< 20	20	< 2	-
C2 subst'd dibenzothiophene	ng/g	< 3	1,600	< 3	110	20	55	< 2	-
C3 subst'd dibenzothiophene	ng/g	< 2	4,400	< 2	< 3	40	79	< 6	-
C4 subst'd dibenzothiophene	ng/g	< 2	< 9	-	-	50	< 6	< 3	-
fluoranthene	ng/g	2	27	3	7	< 10	9	4	-
C1 subst'd fluoranthene / pyrene	ng/g	< 1	480	13	36	30	58	20	-
C2 subst'd fluoranthene / pyrene	ng/g	4	1,200	-	-	-	140	40	-
C3 subst'd fluoranthene / pyrene	ng/g	< 1	1,400	-	-	-	170	45	-
fluorene	ng/g	< 1	< 6	< 2	4	< 10	< 4	< 2	-
C1 subst'd fluorene	ng/g	< 1	< 4	< 1	< 1	< 20	< 5	< 3	-
C2 subst'd fluorene	ng/g	< 1	< 12	< 2	< 2	< 20	< 8	< 4	-

Table 5.12 Concentration of Polycyclic Aromatic Hydrocarbons in the Athabasca River, Upstream of Donald Creek and the Steepbank River (continued)

Parameter	Units	Upstream of Donald Creek					Upstream of Steepbank River		
		2000		1998[(a)]		Historical Median[(b)]	2000		Historical Median[(c)]
		West	East	West	East		West	East	
C3 subst'd fluorene	ng/g	< 2	< 14	-	-	-	< 6	< 3	-
indeno(1,2,3,cd)pyrene	ng/g	< 4	34	< 9	7*	< 10	12	5	-
phenanthrene	ng/g	4	14	7	17	10	15	5	-
C1 subst'd phenanthrene / anthracene	ng/g	2	18	19	64	< 20	65	6	-
C2 subst'd phenanthrene / anthracene	ng/g	1	400	23	86	30	37	15	-
C3 subst'd phenanthrene / anthracene	ng/g	< 2	1,000	< 3	140	40	39	9	-
C4 subst'd phenanthrene / anthracene	ng/g	6	700	27	710	40	51	21	-
1-Methyl-7-isopropyl-phenanthrene (retene)	ng/g	12	180	-	-	-	150	41	-
pyrene	ng/g	2	110	6	16	< 10	31	6	-

(a) Based on information from Golder (1999b).

(b) Based on information from Allan and Jackson (1978) and Lutz and Hendzel (1977).

(c) Based on information from Allan and Jackson (1978) C.G.L. (1979), Beak (1988), Golder (1995) and Dobson et al. (1996).

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a large degree of error than those produced from clearly defined spectra).

\- = No data.

Table 5.13 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Sediment Guidelines[(a)]		Upstream of Donald Creek					Upstream of the Steepbank River		
				2000		1998		Historical	2000		Historical
		ISQG[(b)]	PEL[(c)]	West	East	West	East	Median	West	East	Median
Total Metals											
arsenic (As)	µg/g	5.9	17			PEL					
Target PAHs and Alkylated PAHs											
C1 subst'd naphthalenes	ng/g	20	201						PEL		
benzo(a)anthracene / chrysene	ng/g	32	385		PEL				PEL		
pyrene	ng/g	53	875		PEL						

(a) Sediment guideline values taken from CCME (1999).

(b) ISQG = interim freshwater sediment quality guidelines.

(c) PEL = probable effect levels.

Upstream of the Steepbank River

The sediments collected from the west and east banks of the Athabasca River upstream of the Steepbank River in 2000 were predominantly sand, with the west bank sediment containing slightly more silt than the east bank (Tables 5.11 and 5.12). Metal concentrations were generally lower in 2000 than in previous sampling events. Parameter concentrations were also generally lower on the east side of the river in 2000. Concentrations of benzo(a)anthracene and C1 substituted naphthalene in the 2000 west-bank sediment exceeded Canadian sediment quality guidelines (Table 5.13). The detection limit for acenaphthene in the 2000 west-bank sediment sample was higher than the sediment quality guideline.

Upstream of the Muskeg River

Sand was the dominant constituent in sediments collected from the west and east banks of the Athabasca River upstream of the Muskeg River in 2000 (Tables 5.14 and 5.15). Aluminum, barium and strontium concentrations along both sides of the river were lower in 2000 than in previous years. Several PAHs and alkylated PAHs were present at higher concentrations in 2000 than in 1998 in both the west- and east-bank sediment samples, including C4 substituted naphthalene, C1 substituted acenaphthene, C1 and C2 substituted benzo(a)anthracene/chrysene, biphenyl, C2 and C3 substituted dibenzothiophene and fluoranthene.

Year 2000 concentrations of C2 substituted naphthalene and pyrene were greater than 1998 concentrations on the west bank of the river, while concentrations of C2 substituted fluorene and C3 substituted phenanthrene/anthracene were greater in the 2000 east-bank sediment sample than in previous years. The concentration of C1 substituted naphthalene in the sediments of both the west and east banks exceeded the Canadian sediment quality guideline in 2000, as did the concentration of arsenic in the east bank sediment sample (Table 5.16). In 1998, C1 substituted naphthalene levels along the east bank of the Athabasca River also exceeded the probable effect level of 201 ng/g.

Upstream of Fort Creek

Sediments in the Athabasca River upstream of Fort Creek were predominantly sand in 2000, with a greater percentage of sand being found in the sediment from the west bank of the river (Table 5.17 and 5.18). Aluminum, barium and chromium concentrations were lower in 2000 sediments from both banks compared to historical results.

Table 5.14 Sediment Quality in the Athabasca River Upstream of the Muskeg River

Parameter	Units	2000		1998[(a)]		Historical Median[(b)]
		West	East	West	East	
Particle Size						
particle size - % sand	%	76	48	71	60	79
particle size - % silt	%	14	36	17	22	16
particle size - % clay	%	11	16	12	18	4
Carbon Content						
total inorganic carbon	% dry wt	0.6	0.7	1.0	0.7	0.2
total organic carbon	% dry wt	0.7	0.8	0.7	1.6	0.3
Organics						
total recoverable hydrocarbons	mg/kg	500	700	406	555	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	140	32	-	-	-
Total Metals						
aluminum (Al)	µg/g	4,440	4,680	9,560	10,900	45,300
arsenic (As)	µg/g	3.8	6.4	4.8	5.5	1.7
barium (Ba)	µg/g	105	159	172	188	537
cadmium (Cd)	µg/g	0.1	0.2	< 0.5	< 0.5	< 0.5
chromium (Cr)	µg/g	12.9	20.7	18.1	21.2	31.3
copper (Cu)	µg/g	7.4	17.1	12.0	15.0	8.1
iron (Fe)	µg/g	12,200	19,700	14,500	16,200	13,600
lead (Pb)	µg/g	5.5	9.3	9.0	10.0	3.5
manganese (Mn)	µg/g	233	496	329	386	224
mercury (Hg)	µg/g	< 0.04	0.06	0.04	0.04	0.029
molybdenum (Mo)	µg/g	0.3	0.4	< 1	< 1	< 1
nickel (Ni)	µg/g	12.6	19.4	17	19	13.9
selenium (Se)	µg/g	0.7	1	0.4	< 0.1	< 1
silver (Ag)	µg/g	< 0.1	< 0.1	< 1	< 1	< 0.5
zinc (Zn)	µg/g	35.7	71.4	59.6	70.5	33.55

(a) Based on information from Golder (1999b).

(b) Based on information from Allan and Jackson (1978), C.G.L. (1979) and Beak (1988).

- = No data.

Table 5.15 Concentration of Polycyclic Aromatic Hydrocarbons in the Athabasca River Upstream of the Muskeg River

Parameter	Units	2000		1998[a]		Historical Median[b]
		West	East	West	East	
Target PAHs and Alkylated PAHs						
naphthalene	ng/g	10	8	17	34	-
C1 subst'd naphthalenes	ng/g	34	21	20	27	-
C2 subst'd naphthalenes	ng/g	62	35	30	32	-
C3 subst'd naphthalenes	ng/g	54	35	31	44	-
C4 subst'd naphthalenes	ng/g	34	33	< 2	< 5	-
acenaphthene	ng/g	< 3	< 2	< 2	4	-
C1 subst'd acenaphthene	ng/g	2	1	< 0	< 0	-
acenaphthylene	ng/g	< 1	< 1	< 1	< 1	-
anthracene	ng/g	< 1	< 4	< 1	< 4	-
dibenzo(a,h)anthracene	ng/g	< 3	< 3	< 2	< 5	-
benzo(a)anthracene / chrysene	ng/g	23*	31	13	23	-
C1 subst'd benzo(a)anthracene / chrysene	ng/g	190	410	< 1	< 1	-
C2 subst'd benzo(a)anthracene / chrysene	ng/g	64	150	< 1	< 1	-
benzo(a)pyrene	ng/g	8	8	5	10*	-
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 4	< 9	< 4	< 6	-
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 5	< 9	< 2	< 3	-
benzofluoranthenes	ng/g	32	28	11*	18	-
benzo(g,h,i)perylene	ng/g	9	15	6	10*	-
biphenyl	ng/g	4	3	< 1	< 1	-
C1 subst'd biphenyl	ng/g	< 2	< 3	< 1	< 1	-
C2 subst'd biphenyl	ng/g	< 1	< 3	< 0	< 1	-
dibenzothiophene	ng/g	< 1	3*	1	< 2	-
C1 subst'd dibenzothiophene	ng/g	5	27	9	15	-
C2 subst'd dibenzothiophene	ng/g	33	190	< 3	< 7	-
C3 subst'd dibenzothiophene	ng/g	42	300	< 1	< 3	-
C4 subst'd dibenzothiophene	ng/g	< 4	< 3	-	-	-
fluoranthene	ng/g	7	5	4	6*	-
C1 subst'd fluoranthene / pyrene	ng/g	49	89	16	31	-
C2 subst'd fluoranthene / pyrene	ng/g	82	150	-	-	-
C3 subst'd fluoranthene / pyrene	ng/g	78	160	-	-	-
fluorene	ng/g	2*	< 1	3	2*	-
C1 subst'd fluorene	ng/g	< 2	< 3	< 1	< 1	-
C2 subst'd fluorene	ng/g	< 2	41	< 1	< 1	-
C3 subst'd fluorene	ng/g	< 4	< 7	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	11	13	< 7	< 7	-
phenanthrene	ng/g	15	13	12	14	-
C1 subst'd phenanthrene / anthracene	ng/g	46	66	34	57	-
C2 subst'd phenanthrene / anthracene	ng/g	47	120	32	62	-
C3 subst'd phenanthrene / anthracene	ng/g	34	170	38	84	-
C4 subst'd phenanthrene / anthracene	ng/g	36	140	31	91	-
1-Methyl-7-isopropyl-phenanthrene (retene)	ng/g	90	63	-	-	-
pyrene	ng/g	15	11	7	13	-

(a) Based on information from Golder (1999b).

(b) Based on information from Allan and Jackson (1978), C.G.L. (1979) and Beak (1988).

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

- = No data.

Table 5.16 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in the Athabasca River Upstream of the Muskeg River

Parameter	Units	Sediment Guidelines[a]		2000		1998		Historical Median
		ISQG[b]	PEL[c]	West	East	West	East	
Total Metals								
arsenic (As)	µg/g	5.9	17		PEL			
Target PAHs and Alkylated PAHs								
C1 subst'd naphthalenes	ng/g	20	201	PEL	PEL		PEL	

[a] Sediment guideline values taken from CCME (1999).
[b] ISQG = interim freshwater sediment quality guidelines.
[c] PEL = probable effect levels.

Table 5.17 Sediment Quality in the Athabasca River Upstream of Fort Creek

Parameter	Units	2000		1998[a]		Historical Median[b]
		West	East	West	East	
Particle Size						
particle size - % sand	%	98	69	43	74	48
particle size - % silt	%	< 1	23	36	15	26
particle size - % clay	%	2	8	21	11	26
Carbon Content						
total inorganic carbon	% dry wt	0.1	0.4	1.0	0.8	0.8
total organic carbon	% dry wt	2.7	4.0	2.0	0.7	1.1
Organics						
total recoverable hydrocarbons	mg/kg	200	7,700	900	581	1,190
total volatile hydrocarbons (C5-C10)	mg/kg	0.6	0.8	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	7	1600	-	-	-
Total Metals						
aluminum (Al)	µg/g	1,850	3,440	9,440	7,630	31,900
arsenic (As)	µg/g	2.3	1.7	5.6	4.1	3.5
barium (Ba)	µg/g	43	95	178	138	560
cadmium (Cd)	µg/g	< 0.1	0.1	< 0.5	< 0.5	0.27
chromium (Cr)	µg/g	5.8	11.1	17.2	15.7	46.0
copper (Cu)	µg/g	4.3	7.9	16.0	10.0	8.9
iron (Fe)	µg/g	8,030	12,100	16,100	12,800	14,700
lead (Pb)	µg/g	3.7	5.0	9.0	8.0	4.0
manganese (Mn)	µg/g	184	261	419	293	259.5
mercury (Hg)	µg/g	< 0.04	< 0.04	0.06	0.03	0.045
molybdenum (Mo)	µg/g	0.2	0.3	< 1	< 1	< 1
nickel (Ni)	µg/g	7.9	12.9	20	14	15.95
selenium (Se)	µg/g	0.4	< 0.2	0.6	0.3	0.315
silver (Ag)	µg/g	< 0.1	< 0.1	< 1	< 1	< 1
zinc (Zn)	µg/g	58.8	41.9	71.1	52.7	34.25

[a] Based on information from Golder (1999b).
[b] Based on information from Golder (1998) and Crosley (1996).
- = No data.

Table 5.18 Concentration of Polycyclic Aromatic Hydrocarbons in the Athabasca River Upstream of Fort Creek

Parameter	Units	2000		1998[(a)]		Historical Median[(b)]
		West	East	West	East	
Target PAHs and Alkylated PAHs						
naphthalene	ng/g	4	24	28	23	10
C1 subst'd naphthalenes	ng/g	5	71	45	21	26
C2 subst'd naphthalenes	ng/g	13	65	72	28	35
C3 subst'd naphthalenes	ng/g	5	180	92	58	43
C4 subst'd naphthalenes	ng/g	< 2	760	< 4	< 5	39
acenaphthene	ng/g	< 2	< 22	4	4*	1
C1 subst'd acenaphthene	ng/g	< 1	< 5	< 1	< 0	< 20
acenaphthylene	ng/g	< 2	< 13	< 1	< 1	1
anthracene	ng/g	< 2	< 24	< 2	< 3	1
dibenzo(a,h)anthracene	ng/g	< 2	< 72	< 6	< 4	3
benzo(a)anthracene / chrysene	ng/g	5	410	46	27	25
C1 subst'd benzo(a)anthracene / chrysene	ng/g	39	4,300	< 2	< 1	35
C2 subst'd benzo(a)anthracene / chrysene	ng/g	14	1,800	< 2	< 1	85
benzo(a)pyrene	ng/g	< 3	< 62	16*	< 10	6
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 4	< 83	< 3	< 8	35
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 3	< 53	< 4	< 3	35
benzofluoranthenes	ng/g	5	130	31	14	17
benzo(g,h,i)perylene	ng/g	< 2	< 67	14	9*	12
biphenyl	ng/g	< 1	< 10	< 2	< 1	< 20
C1 subst'd biphenyl	ng/g	< 3	< 9	< 1	< 1	< 20
C2 subst'd biphenyl	ng/g	< 1	< 8	< 1	< 1	< 20
dibenzothiophene	ng/g	< 2	< 13	5	4	3
C1 subst'd dibenzothiophene	ng/g	< 2	210	50	53	8
C2 subst'd dibenzothiophene	ng/g	< 3	2,000	250	320	24
C3 subst'd dibenzothiophene	ng/g	< 4	5,300	< 3	< 2	200
C4 subst'd dibenzothiophene	ng/g	< 2	< 31	-	-	< 20
fluoranthene	ng/g	< 2	11*	11	5	6
C1 subst'd fluoranthene / pyrene	ng/g	10	570	50	33	45
C2 subst'd fluoranthene / pyrene	ng/g	8	890	-	-	-
C3 subst'd fluoranthene / pyrene	ng/g	14	1,100	-	-	-
fluorene	ng/g	< 2	< 19	7*	< 3	4
C1 subst'd fluorene	ng/g	< 2	< 9	< 3	< 2	< 20
C2 subst'd fluorene	ng/g	< 2	< 25	< 3	< 2	45
C3 subst'd fluorene	ng/g	< 3	< 49	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	< 3	< 35	< 11	< 12	8
phenanthrene	ng/g	2	< 23	32	21	15
C1 subst'd phenanthrene / anthracene	ng/g	< 2	190	110	98	46
C2 subst'd phenanthrene / anthracene	ng/g	8	1,200	140	150	100
C3 subst'd phenanthrene / anthracene	ng/g	6	2,800	230	210	160
C4 subst'd phenanthrene / anthracene	ng/g	9	2,300	720	57	230
1-Methyl-7-isopropyl-phenanthrene (retene)	ng/g	13	280	-	-	-
pyrene	ng/g	3	130	22	12	12

(a) Based on information from Golder (1999b).

(b) Based on information from Golder (1998) and Crosley (1996).

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

\- = No data.

In 2000, west bank sediments contained less chromium, copper, iron, lead, manganese, nickel, strontium and vanadium than in previous years. Similarly, total recoverable hydrocarbon and PAH concentrations were generally lower along the west bank of the river in 2000 than in 1999. However, C1 and C2 substituted benzo(a)anthracene/chrysene concentrations along the west bank were higher in 2000 than in 1998.

Total recoverable hydrocarbon and PAH concentrations were generally higher along the east bank of the river in 2000 than in previous years. Several PAHs from the 2000 east-bank sediment sample exceeded Canadian sediment quality guidelines, including C1 substituted naphthalene, benzo(a)anthracene/chrysene and pyrene (Table 5.19). In previous sampling events, chromium and C1 substituted naphthalene concentrations have exceeded sediment guidelines for the protection of aquatic life. In 2000, the detection limits for acenaphthene, acenaphthylene, benzo(a)pyrene, and dibenzo(a,h)anthracene in the east-bank sediment sample were higher than relevant sediment quality guidelines.

Table 5.19 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in the Athabasca River Upstream of Fort Creek

Parameter	Units	Sediment Guidelines[(a)]		2000		1998		Historical Median
		ISQG[(b)]	PEL[(c)]	West	East	West	East	
Total Metals								
chromium	µg/g	37	90					PEL
Target PAHs and Alkylated PAHs								
C1 subst'd naphthalenes	ng/g	20	201		PEL	PEL	PEL	PEL
benzo(a)anthracene / chrysene	ng/g	32	385		PEL	PEL		
pyrene	ng/g	53	875		PEL			

(a) Sediment guideline values taken from CCME (1999).
(b) ISQG = interim freshwater sediment quality guidelines.
(c) PEL = probable effect levels.

Athabasca River Delta and Flour Bay

Sediments collected from the Athabasca River Delta and Flour Bay in 2000 were both composed mainly of silt, followed by sand and then clay (Table 5.20). Both sediments were found to affect the growth and mortality of *Chironomus tentans* as well as the growth of *Lumbriculus variegatus*.

Table 5.20 Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Delta

Parameter	Units	Upstream of Embarras River		Delta		
				2000		Historical Median[b]
		2000	1995[a]	Big Point Channel	Flour Bay	
Particle Size						
particle size - % sand	%	36	99.4	10	16	14
particle size - % silt	%	42	0.01	58	52	64
particle size - % clay	%	22	0.54	32	32	22
Carbon Content						
total inorganic carbon	% dry wt	0.8	-	1.1	0.9	0.9
total organic carbon	% dry wt	1.1	0.3	1.7	1.9	1.6
Toxicity						
Chironomus tentans - 10d survival	% of control	84.1	-	86.4	88.6	42
Chironomus tentans - 10d growth	% of control	95.5	-	77.3	86.4	nt
Hyalella azteca - 10d survival	% of control	nt	-	nt	nt	72
Hyalella azteca - 10d growth	% of control	83.3	-	nt	nt	nt
Lumbriculus variegatus - 10d survival	% of control	nt	-	nt	nt	nt
Lumbriculus variegatus - 10d growth	% of control	68.4	-	52.6	57.9	62
Organics						
total recoverable hydrocarbons	mg/kg	500	-	700	700	800
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	< 0.5	< 0.5	-
total extractable hydrocarbons (C11-C30)	mg/kg	59	-	81	82	-
Total Metals						
aluminum (Al)	µg/g	11,800	-	18,700	14,700	48,100
arsenic (As)	µg/g	4.6	< 5	6.2	5.8	4.3
barium (Ba)	µg/g	157	-	215	187	710
cadmium (Cd)	µg/g	0.2	< 1	0.3	0.3	0.325
chromium (Cr)	µg/g	61.3	3	92	50.8	89
copper (Cu)	µg/g	12.7	4	20	18.6	14.4
iron (Fe)	µg/g	17,400	-	22,600	21,200	20,350
lead (Pb)	µg/g	7.2	4	10.2	10.2	7.5
manganese (Mn)	µg/g	336	-	523	403	381.5
mercury (Hg)	µg/g	0.05	-	0.08	0.09	0.0455
molybdenum (Mo)	µg/g	1.9	-	1.8	0.8	< 1
nickel (Ni)	µg/g	34.8	6	49.7	31.8	19.35
selenium (Se)	µg/g	0.6	-	0.8	0.8	0.425
silver (Ag)	µg/g	0.2	-	0.1	0.2	< 1
zinc (Zn)	µg/g	60.8	11	63.7	61.1	51.75

(a) Based on information from Dobson et al. (1996).

(b) Based on information from Golder (2000c), Allan and Jackson (1978) and Lutz and Hendzel (1977).

- = No data; nt = non-toxic.

Aluminum, barium, strontium, C4 substituted naphthalene and C4 substituted phenanthrene/anthracene were found in smaller concentrations in the 2000 Delta sediments compared to median historical concentrations (Tables 5.20 and 5.21). Nickel, and C1 and C2 substituted benzo(a)anthracene/chrysene concentrations were higher in 2000 Delta sediment samples than in previous sampling events. Arsenic, chromium and C1 substituted naphthalene concentrations in the 2000 Delta sediment samples exceeded sediment quality guidelines (Table 5.22). Historical median concentrations also exceed the chromium and C1 substituted naphthalene sediment quality guidelines.

Upstream of Embarras River

Particle distribution in 2000 was quite different than it was in an earlier sample collected in 1995 (Table 5.20); the 2000 sediments consisted of silt and sand, whereas the 1995 sample was almost all sand. A limited number of parameters were measured in the 1995 sediment sample (Tables 5.20 and 5.21). The 2000 sample contained higher levels of most comparable parameters. Chromium and C1-substituted naphthalene concentrations exceeded sediment quality guidelines in 2000 (Table 5.22). The 2000 sediment sample was also mildly toxic to *Chironomus tentans*, *Hyalella azteca* and *Lumbriculus variegatus*.

5.1.3 Summary

Water and sediment quality in the Athabasca River in 2000 was generally consistent with historical data, with a few exceptions. Naphthenic acids were detected in the Athabasca River from upstream of Donald Creek to upstream of Fort Creek. However, all sample waters, including those collected in the Athabasca River Delta were non-toxic (as defined by Microtox®). PAH levels in sediments collected upstream of Donald Creek, the Muskeg River and Fort Creek were higher than historical values, particularly for sediments from the east side of the river. C1 substituted naphthalene was the parameter that most frequently exceeded Canadian sediment quality guidelines, followed by benzo(a)anthracene/chrysene. Other parameters present at concentrations in excess of sediment guidelines included arsenic, chromium and pyrene. As well, sediments from the lower Athabasca River, including the Athabasca Delta, were found to be toxic to several species of invertebrates. A review of sediment toxicity will be initiated in 2001 to determine if the sediment toxicity observed in the lower Athabasca River is of concern and warrants further study.

Table 5.21 Concentration of Polycyclic Aromatic Hydrocarbons in the Athabasca River Upstream of the Embarras River and in the Delta

Parameter	Units	Upstream of Embarras River		Delta		
				2000		Historical Median[b]
		2000	1995[a]	Big Point Channel	Flour Bay	
Target PAHs and Alkylated PAHs						
naphthalene	ng/g	27	-	24	22	19
C1 subst'd naphthalenes	ng/g	28	-	40	47	35
C2 subst'd naphthalenes	ng/g	38	-	49	54	43
C3 subst'd naphthalenes	ng/g	25	-	48	50	54
C4 subst'd naphthalenes	ng/g	6	-	< 4	< 10	32
acenaphthene	ng/g	< 6	-	< 10	< 5	< 1
C1 subst'd acenaphthene	ng/g	3	-	4	3	3
acenaphthylene	ng/g	< 6	-	< 8	< 4	< 4
anthracene	ng/g	< 5	-	< 3	< 2	< 4
dibenzo(a,h)anthracene	ng/g	< 5	-	< 5	< 7	< 6
benzo(a)anthracene / chrysene	ng/g	15	-	26	31	31
C1 subst'd benzo(a)anthracene / chrysene	ng/g	120	-	250	230	36
C2 subst'd benzo(a)anthracene / chrysene	ng/g	42	-	63	< 140	15
benzo(a)pyrene	ng/g	6	-	6	9	13
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 8	-	< 11	< 7	< 15
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 4	-	< 4	< 3	< 13
benzofluoranthenes	ng/g	23	-	26	27	30
benzo(g,h,i)perylene	ng/g	18	-	20*	18	17
biphenyl	ng/g	3	-	5	6	8
C1 subst'd biphenyl	ng/g	< 3	-	< 5	< 3	< 2
C2 subst'd biphenyl	ng/g	< 4	-	< 2	< 2	< 2
dibenzothiophene	ng/g	< 6	-	3	< 5	< 3
C1 subst'd dibenzothiophene	ng/g	7	-	18	14	17
C2 subst'd dibenzothiophene	ng/g	22	-	70	< 8	75
C3 subst'd dibenzothiophene	ng/g	70	-	140	180	110
C4 subst'd dibenzothiophene	ng/g	< 4	-	< 5	< 4	-
fluoranthene	ng/g	4	-	8	6	7
C1 subst'd fluoranthene / pyrene	ng/g	33	-	59	63	43
C2 subst'd fluoranthene / pyrene	ng/g	68	-	110	110	-
C3 subst'd fluoranthene / pyrene	ng/g	59	-	100	89	-
fluorene	ng/g	< 3	-	4	5*	3
C1 subst'd fluorene	ng/g	< 4	-	< 3	< 4	< 4
C2 subst'd fluorene	ng/g	< 5	-	< 8	< 6	< 3
C3 subst'd fluorene	ng/g	< 6	-	< 8	< 4	-
indeno(1,2,3,cd)pyrene	ng/g	12	-	15	13	11
phenanthrene	ng/g	14	-	25	24	26
C1 subst'd phenanthrene / anthracene	ng/g	42	-	78	77	69
C2 subst'd phenanthrene / anthracene	ng/g	36	-	89	75	64
C3 subst'd phenanthrene / anthracene	ng/g	36	-	74	75	71
C4 subst'd phenanthrene / anthracene	ng/g	15	-	85	25	350
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	37	-	65	67	-
pyrene	ng/g	10	-	19	19	15

(a) Based on information from Dobson et al. (1996).
(b) Based on information from Golder (2000c), Allan and Jackson (1978) and Lutz and Hendzel (1977).
* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

- = No data.

Table 5.22 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in the Athabasca River Upstream of the Embarras River and in the Delta

Parameter	Units	Sediment Guidelines[a]		Upstream of Embarras River		Delta		
						2000		Historical Median
		ISQG[b]	PEL[c]	2000	1995	Big Point Channel	Flour Bay	
Total Metals								
arsenic (As)	μg/g	5.9	17			PEL		
chromium (Cr)	μg/g	37	90	PEL		PEL	PEL	PEL
Target PAHs and Alkylated PAHs								
C1 subst'd naphthalenes	ng/g	20	201	PEL		PEL	PEL	PEL

(a) Sediment guideline values taken from CCME (1999).
(b) ISQG = interim freshwater sediment quality guidelines.
(c) PEL = probable effect levels.

5.2 FISH POPULATIONS

5.2.1 Radiotelemetry Study

Results for the radiotelemetry study on longnose sucker from the Athabasca River and Muskeg River are preliminary. The study is ongoing and will continue to at least June 2001. A complete evaluation of the movement of radio-tagged longnose sucker will be provided in the 2001 RAMP report.

Table 5.23 presents the number of adult longnose sucker that were captured and radio tagged in the Athabasca and Muskeg rivers in the spring of 2000. For the Athabasca River spawners, 25 adult fish were radio tagged with a sex ratio of 12 males to 13 females. All 25 longnose sucker were spent, having recently completed spawning activities. Longnose sucker were common throughout the sampling area, and were particularly abundant in post-spawning congregations in areas of slow-moving water. For Muskeg River spawners, 25 adult fish were radio tagged with a sex ratio of 10 males to 15 females. The longnose suckers from the Muskeg River were a mix of pre-spawning, ripe and spent fish, indicating that spawning activity in the Muskeg River was still underway at the time of sampling. Detailed information for each radio-tagged fish and results of each tracking survey are presented in Appendix VI. Fish locations for the Athabasca River are presented as kilometre posts (KP), which indicate the distance in river kilometres upstream or downstream from Fort McMurray (the Highway 63 Bridge was designated KP 0.0, see Figure 3.5). Fish locations in the Muskeg River are presented by river reach (i.e., Reach 1-4, see Figure 3.5).

The following results describing the movements of longnose sucker assume that there were no problems with the transmitters or fish survivorship. However, it is recognized that signals may not be recorded for a variety of reasons including deep water, obstructions, battery failure, transmitter frequency shifts or the removal of the fish/tag from the study by anglers or predators. These potential issues will be easier to evaluate once the full year of tracking information is available.

Table 5.23 Fish Sampling Results for the Athabasca River Longnose Sucker Radiotelemetry Study, Spring 2000

Longnose Sucker Sub-population	Number Captured	Number Observed	Total Number	Number Floy Tagged	Number Radio Tagged		
					Male	Female	Total
Athabasca River	115	61	176	115	12	13	25
Muskeg River	27	14	41	27	10	15	25

Athabasca River Spawners

Of the 25 radio-tagged longnose suckers, 13 fish could not be located during any of the subsequent tracking flights. These fish presumably left the telemetry study area and moved upstream of Cascade Rapids, downstream to Lake Athabasca or entered tributaries other than the Muskeg River. As these fish are believed to originate from Lake Athabasca, it is likely that they returned to the lake soon after spawning, sometime during the 19 day period between radio tagging and the first tracking flight. It is less likely that they moved upstream of the rapids or into tributary streams since the fish were not recorded in the survey area at any time during the summer, fall or early winter, indicating they did not return from farther upstream or from tributary streams.

Three longnose sucker were found only during the first tracking flight and at varying distances downstream of Fort McMurray. Two fish were recorded moving downstream from the rapids (KP 13 and KP 17) and the third fish was found well downstream at KP 111. These fish then disappeared from the telemetry area and are believed to have returned to Lake Athabasca.

Two other radio-tagged fish also moved downstream from the rapids following spawning. These fish left the mainstem Athabasca River and were located in the Muskeg River for a short period of time in early June. These individuals then disappeared from the study area and may have returned to Lake Athabasca. It is also possible that these fish moved out of the study area by moving farther up the Muskeg River or into another tributary. However, if this was the case, it is expected that these fish would return to the study area prior to the winter period, but this was not observed.

Three other longnose sucker exhibited a different movement pattern. These fish could not be located following tagging on any of the initial tracking flights (from June through October), but returned to the telemetry study area in the late fall (November). One fish was located in the vicinity of KP 5-23, one in the area of KP 97-115 and one between KP 112-142. It is likely that these fish left the telemetry study area in the spring and, rather than returning to Lake Athabasca, moved upstream of the rapids or into tributaries other than the Muskeg River. Based on where these fish were found in November, it is believed that they represent a portion of the longnose sucker population that, following spawning activity in the mainstem river, utilize tributary streams in the Oil Sands Region for the remainder of the spring, summer and fall before returning to the Athabasca River. Two of these fish continue to remain in the Athabasca River (January 24, 2001) while the third individual has left the study area and may have returned to Lake Athabasca.

The final four radio-tagged longnose sucker represent a portion of the Athabasca River spawners that utilize the mainstem river for an extended period of time. These fish were recorded in the Athabasca River throughout the spring, summer and fall, and were still in the river during the January 24, 2001 tracking flight. None of these fish exhibited any large scale movements after their initial migration downstream from the rapids. After spawning, the four fish were located at KPs 17, 20, 43 and 215.

Although a few different movement patterns are evident from the telemetry results, the Athabasca River spawning sub-population of longnose sucker appears to use the mainstem river in the Oil Sands Region primarily as a spring migration route to and from spawning sites located upstream of Fort McMurray. The majority (18 out of 25) of radio-tagged fish are believed to have returned to Lake Athabasca either immediately or shortly after spawning at the rapids, although two of these fish did conduct some exploration of the Muskeg River. A smaller proportion (7 out of 25) of tagged fish are known, or believed, to have remained in the Athabasca River basin for a prolonged period of time. These fish either utilized specific locations in the mainstem river throughout the spring, summer and fall, or are believed to have used tributary streams other than the Muskeg River during the open-water period and returned to the mainstem river for the winter.

Muskeg River Spawners

A number of different movement patterns were recorded for the 25 radio-tagged longnose sucker that spawned in the Muskeg River (Appendix VI). Five radio-tagged fish were never located during any of the telemetry surveys and evidently left the telemetry study area shortly after spawning. These could have moved farther up the Muskeg River (i.e., upstream of Jackpine Creek), moved to Lake

Athabasca or returned to the Athabasca River to access other tributaries. As none of these fish were found to return to the study area for the winter period (i.e., leaving tributaries to overwinter in the Athabasca River), it is probable that they returned to Lake Athabasca in the spring. Two additional radio-tagged fish are believed to show the same movement pattern, but with a slightly longer delay before leaving the study area. One fish was located only during the first tracking flight and was recorded in the Athabasca River 5 km downstream of the Muskeg River mouth, presumably moving downstream to Lake Athabasca. The second fish was located in the Muskeg River on June 9, but was never recorded during subsequent flights.

Six other tagged sucker also left the Muskeg River in the spring immediately after spawning. One individual was recorded in the Athabasca River at KP 133 on June 9; however, the remaining five fish could not be located during the spring and summer flights. All six fish were later found in the Athabasca River during flights in the fall or early winter (October to January). Fall/winter locations in the Athabasca River for these fish include KPs 58, 88, 164, 165, 175 and 231. It is believed that after these fish left the Muskeg River they moved to other tributaries of the Athabasca River during the spring and summer, and returned to the mainstem river for the fall and winter. Five of these six fish continue to remain in the river (as of the last flight), while one has again left the study area and may have moved to Lake Athabasca.

Three longnose sucker left the Muskeg River soon after spawning, but remained in the mainstem Athabasca River throughout the spring, summer and fall. These fish were located primarily at KPs 14-19, 51-73 and 225-243. Within the Athabasca River, these three fish all showed relatively small-scale movements (5-22 km) over the duration of the telemetry study. At present, all three fish remain in the Athabasca River.

The remaining nine of 25 longnose sucker from the Muskeg River have remained primarily in the Muskeg River throughout the telemetry study. Four of these nine fish have been sporadically recorded in the Muskeg River, probably due to difficulties experienced with decoding the large number of transmitters that were present. The other five fish were consistently recorded in the Muskeg River. These fish have been utilizing this tributary for the entire open-water season. Seven of the nine fish remain in the Muskeg River to date, while the other two appear to have departed in early November. These two fish were not recorded in the Athabasca River and may have returned to Lake Athabasca.

Previous data (Bond and Machniak 1979) shows that a large number of longnose sucker that ascend the Muskeg River in the spring to spawn return to the Athabasca River later in the spring. Telemetry results show that some (nine out of 25) of the longnose sucker that were tagged while spawning in the Muskeg River remained in the Muskeg River, while the majority (16 out of 25) leave the tributary right after spawning or in early June. Just under half (seven out of 16) of the fish that left the Muskeg River are believed to have moved downstream to Lake Athabasca. The remainder either utilized the mainstem Athabasca River or appear to have utilized other tributaries of the Athabasca River throughout the open-water period, returning to the mainstem river in the fall/winter.

Comparison of Sub-populations

In general, the Athabasca River spawning and Muskeg River spawning longnose sucker sub-populations showed different levels of residency time in the Athabasca River basin. The majority of the Athabasca River spawners appear to return to Lake Athabasca within the first two or three weeks following spawning. A smaller portion of this sub-population remains in the mainstem Athabasca River or in unidentified tributary streams for the open-water period. Although most of the Muskeg River spawners left the Muskeg River following spawning, only a small portion of them returned to Lake Athabasca. The majority of the Muskeg River spawners remained in the Athabasca River basin, either in the mainstem river, the Muskeg River or other unidentified tributaries.

5.2.2 Summary

A radiotelemetry study of longnose sucker was initiated to evaluate their mobility and residency time within the Oil Sands Region. Based on previous studies, longnose sucker found in the lower Athabasca River consist of at least two sub-populations that exhibit different spawning/rearing strategies: 1) sucker that spawn in the mainstem Athabasca River at Mountain Rapids and Cascade Rapids upstream of Fort McMurray; and 2) sucker that spawn in tributaries of the Athabasca River such as the Muskeg River. Twenty-five sucker from each sub-population were radio tagged to determined whether they also exhibit different movement patterns. The majority of the Athabasca River spawners appeared to return to the Lake Athabasca within two to three weeks of spawning; whereas, only a small portion of the Muskeg River spawners migrated to the Lake Athabasca. Most of the Muskeg River spawners remained in the Athabasca River basin, either in the mainstem river, the Muskeg River or other unidentified tributaries. Further analyses of the movement patterns of longnose sucker will be conducted following the completion of the radiotelemetry study in 2001.

6 TRIBUTARIES - RESULTS AND DISCUSSION

6.1 WATER AND SEDIMENT QUALITY

6.1.1 Water Quality

McLean Creek

In 2000, conductivity, total dissolved solids (TDS), chloride, sulphate, total nickel, dissolved aluminum and dissolved nickel concentrations were lower than historical medians (Tables 6.1 and 6.2). Sample waters were non-toxic to bacteria, *Ceriodaphnia dubia* and fathead minnow. Total phosphorus, iron, manganese and aluminum concentrations exceeded Alberta water quality guidelines in the fall of 2000 (Table 6.3). Historically, total iron, manganese and aluminum concentrations tend to exceed water quality guidelines at the mouth of McLean Creek.

The analytical detection limits for total mercury and total silver reported in 2000 exceeded guideline levels. Thus, these elements could not be evaluated against regulatory objectives at any of the Athabasca River tributary sites.

Poplar Creek

In general, parameter concentrations at the mouth of Poplar Creek in the fall of 2000 were lower than in previous sampling events (Tables 6.1 and 6.2). Only total suspended solids and total aluminum levels were higher in 2000 than in previous years. Water collected from this site was non-toxic (as defined by Microtox® testing), and naphthenic acids were not detected.

Three parameters (i.e., total lead, manganese and phenolics) that historically exceeded water quality guidelines were below guidelines in 2000 (Table 6.3). Total aluminum and iron concentrations continued to exceed criteria in 2000.

Table 6.1 Water Quality in McLean and Poplar Creeks

Parameter	Units	McLean Creek (Fall)		Poplar Creek (Fall)	
		2000	Historical Median[a]	2000	Historical Median[b]
Field Measured					
pH		8.2	7.7	8.0	8.1
specific conductance	µS/cm	287	654	408	258
temperature	^{o}C	3.6	7.4	3.3	9.9
dissolved oxygen	mg/L	13.6	11.0	12.0	10.5
Conventional Parameters					
dissolved organic carbon	mg/L	21	14	24	26
total alkalinity	mg/L	146	195	166	156
total dissolved solids	mg/L	220	440	280	244
total organic carbon	mg/L	27	15	30	27
total suspended solids	mg/L	49	9	17	8
Major Ions					
chloride	mg/L	8	73	26	22
sulphate	mg/L	11	38	19	13
Nutrients and Chlorophyll *a*					
nitrate + nitrite	mg/L	< 0.05	0.05	0.07	0.04
nitrogen - ammonia	mg/L	< 0.1	< 0.05	< 0.1	0.1
total nitrogen	mg/L	1.0	0.7	1.0	0.9
total phosphorus	µg/L	53	14	31	48
chlorophyll *a*	µg/L	5	2	4	3
Biochemical Oxygen Demand					
biochemical oxygen demand	mg/L	< 2	< 2	< 2	0.3
Organics					
naphthenic acids	mg/L	2	2	2	< 1
total phenolics	µg/L	2	2	2	9
Toxicity[c]					
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91
Ceriodaphnia dubia 7 d mortality test - LC_{50}	%	> 100	-	-	-
Ceriodaphnia dubia 7 d reproduction test - IC_{25}	%	> 100	-	-	-
fathead minnow 7d growth - IC_{25}	%	> 100	-	-	-
fathead minnow 7d mortality test - LC_{50}	%	> 100	-	-	-

(a) Based on information from Golder (1996, 2000c) and unpublished data from Suncor Energy Inc.

(b) Based on information from Golder (1996) and AENV WDS station AB07DA0110.

(c) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 6.2 Metal Levels in McLean and Poplar Creeks

Parameter	Units	McLean Creek (Fall)		Poplar Creek (Fall)	
		2000	Historical Median[a]	2000	Historical Median[b]
Total Metals					
aluminum (Al)	µg/L	1,160	420	480	140
antimony (Sb)	µg/L	< 5.0	< 0.8	< 5	< 0.2
arsenic (As)	µg/L	< 1	< 1	< 1	0.6
barium (Ba)	µg/L	33	39	35	25
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 1
chromium (Cr)	µg/L	0.9	1.4	< 0.8	2.5
copper (Cu)	µg/L	2	2	2	2.7
iron (Fe)	µg/L	1,410	785	1,210	1,110
lead (Pb)	µg/L	0.7	1	0.4	10.2
manganese (Mn)	µg/L	96	65	46	139
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.1
molybdenum (Mo)	µg/L	0.2	0.35	0.3	< 3
nickel (Ni)	µg/L	1.4	4.5	0.4	7.25
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	< 0.2
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 2
zinc (Zn)	µg/L	26	14	46	38
Dissolved Metals[c]					
aluminum (Al)	µg/L	10	30	< 10	-
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	-
arsenic (As)	µg/L	0.4	0.4	0.7	0.7
barium (Ba)	µg/L	23	37	29	-
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	-
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	3
copper (Cu)	µg/L	< 0.6	1.1	0.8	-
iron (Fe)	µg/L	40	300	410	-
lead (Pb)	µg/L	0.2	0.2	0.1	-
manganese (Mn)	µg/L	39	64	29	-
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	-
molybdenum (Mo)	µg/L	0.2	0.2	0.3	-
nickel (Ni)	µg/L	0.4	3.5	< 0.1	-
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.2
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	-
zinc (Zn)	µg/L	6	3	5	-

(a) Based on information from Golder (1996, 2000c) and unpublished data from Suncor Energy Inc.

(b) Based on information from Golder (1996) and AENV WDS station AB07DA0110.

(c) Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

- = No data.

Table 6.3 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in McLean and Poplar Creeks

Parameter	Units	Guidelines for the Protection of Aquatic Life[a] Acute	Chronic	Human Health[b]	McLean Creek (Fall) 2000	McLean Creek (Fall) Historical Median	Poplar Creek (Fall) 2000	Poplar Creek (Fall) Historical Median
Nutrients								
total phosphorus	µg/L	-	50	-	C			
Total Phenolics								
total phenolics	µg/L	-	5	-				C
Total Metals								
aluminum (Al)	µg/L	750	100	-	A C	C	C	C
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H
lead (Pb)	µg/L	*	*	-				C
manganese (Mn)	µg/L	-	-	50	H	H		H

[a] Guidelines taken from AENV (1999).
[b] Guidelines taken from U.S. EPA (1999).
* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).
- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Steepbank River

At the mouth of the Steepbank River, total suspended solids and total nitrogen levels were higher than historical medians (Table 6.4). Dissolved aluminum and manganese levels were lower in 2000 than in previous years, and total aluminum, iron and nitrogen concentrations were higher in 2000 compared to historical levels (Table 6.5). Sample waters collected in the fall of 2000 were non-toxic to bacteria and contained detectable levels of naphthenic acids. Total aluminum, iron, phosphorous and nitrogen guidelines were exceeded in the Steepbank River in 2000 (Table 6.6). Historically, total aluminum and iron concentrations in the Steepbank River tend to exceed water quality guidelines.

MacKay River

Water quality in the MacKay River was generally consistent with historical data (Tables 6.4 and 6.5). Exceptions include total iron, manganese, nickel and zinc, as well as dissolved aluminum, iron and cadmium. Most of these parameters were more abundant in 2000 than in previous years. Sample waters from the mouth of MacKay River were non-toxic to bacteria and contained detectable levels of naphthenic acids. In 2000, total copper and manganese concentrations were higher than water quality guidelines (Table 6.6). Total phosphorus, iron and aluminum levels also exceeded guidelines in 2000, as they have in previous sampling events.

Table 6.4 Water Quality in the Steepbank and MacKay Rivers

Parameter	Units	Steepbank River (Fall)		MacKay River (Fall)	
		2000	Historical Median[(a)]	2000	Historical Median[(b)]
Field Measured					
pH		-	7.9	-	8.3
specific conductance	µS/cm	-	97	203	135
temperature	^{o}C	-	3.0	0.4	9.3
dissolved oxygen	mg/L	-	10.4	-	9.7
Conventional Parameters					
dissolved organic carbon	mg/L	19	20	24	30
total alkalinity	mg/L	86	109	100	121
total dissolved solids	mg/L	120	123	170	172
total organic carbon	mg/L	28	25	34	32
total suspended solids	mg/L	60	21	7	11
Major Ions					
chloride	mg/L	1	1	3	3
sulphate	mg/L	6	5	18	15
Nutrients and Chlorophyll *a*					
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	0.05
nitrogen - ammonia	mg/L	< 0.1	0.05	< 0.1	0.05
total nitrogen	mg/L	1.2	0.2	1.0	1.2
total phosphorus	µg/L	54	47	52	54
chlorophyll *a*	µg/L	2	2	< 1	2
Biochemical Oxygen Demand					
biochemical oxygen demand	mg/L	< 2	2	< 2	< 2
Organics					
naphthenic acids	mg/L	1	< 1	1	< 1
total phenolics	µg/L	< 1	1	4	3
Toxicity[(c)]					
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	-
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	-

(a) Based on information from Golder (1996, 1998, 1999b) and AENV WDS station AB07DA0260.

(b) Based on information from Golder (1999b) and AENV WDS station AB07DB0060/0070.

(c) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 6.5 Metal Levels in the Steepbank and MacKay Rivers

Parameter	Units	Steepbank River (Fall)		MacKay River (Fall)	
		2000	Historical Median[a]	2000	Historical Median[b]
Total Metals					
aluminum (Al)	µg/L	2,730	275	200	150
antimony (Sb)	µg/L	< 5	< 0.8	< 5	< 0.8
arsenic (As)	µg/L	< 1	0.8	< 1	1
barium (Ba)	µg/L	41	27	21	34
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	8.3	3	1.8	5.9
copper (Cu)	µg/L	2	2.8	12	1.75
iron (Fe)	µg/L	2,280	713	23,300	830
lead (Pb)	µg/L	0.8	1.1	0.5	0.4
manganese (Mn)	µg/L	48	36	442	40
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.1
molybdenum (Mo)	µg/L	0.2	1.8	0.6	1.8
nickel (Ni)	µg/L	2.2	3.4	20.7	1.6
selenium (Se)	µg/L	0.8	< 0.4	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	< 0.3	< 0.4	< 0.4
zinc (Zn)	µg/L	29	15	67	4
Dissolved Metals[c]					
aluminum (Al)	µg/L	30	68	20	10
antimony (Sb)	µg/L	< 0.8	0.7	< 0.8	< 0.8
arsenic (As)	µg/L	0.5	0.4	< 0.4	0.6
barium (Ba)	µg/L	20	34	15	47
cadmium (Cd)	µg/L	< 0.1	0.1	< 0.1	< 300
chromium (Cr)	µg/L	< 0.4	< 0.4	0.5	< 3
copper (Cu)	µg/L	1.7	1.9	0.9	1.9
iron (Fe)	µg/L	270	253	600	230
lead (Pb)	µg/L	0.2	1.1	0.2	0.1
manganese (Mn)	µg/L	1.6	15.5	12.9	10.6
mercury (Hg)	µg/L	< 0.1	< 0.2	< 0.1	< 0.1
molybdenum (Mo)	µg/L	0.2	0.4	0.3	0.5
nickel (Ni)	µg/L	0.5	2.4	1.2	2.3
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.2
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	5	13	< 2	5

[a] Based on information from Golder (1996, 1998, 1999b) and AENV WDS station AB07DA0260.

[b] Based on information from Golder (1999b) and AENV WDS station AB07DB0060/0070.

[c] Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

\- = No data.

Table 6.6 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Steepbank and MacKay Rivers

Parameter	Units	Guidelines for the protection of			Steepbank River (Fall)		MacKay River (Fall)	
		Aquatic Life[a]		Human Health[b]				
		Acute	Chronic		2000	Historical Median	2000	Historical Median
Nutrients								
total nitrogen	mg/L	-	1	-	C			C
total phosphorus	µg/L	-	50	-	C		C	C
Total Metals								
aluminum (Al)	µg/L	750	100	-	A C	C	C	C
copper (Cu)	µg/L	*	*	1,300			C	
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H
manganese (Mn)	µg/L	-	-	50			H	

(a) Guidelines taken from AENV (1999).
(b) Guidelines taken from U.S. EPA (1999).
* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).
- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Fort Creek

Three water samples were collected from Fort Creek in 2000. Water quality was generally consistent in all three samples (Tables 6.7 and 6.8). In comparison to available historical data, total aluminum and manganese concentrations were lower in 2000, and total suspended solids, zinc, dissolved copper and dissolved molybdenum levels were higher in the fall of 2000 than in previous years. Fort Creek waters were toxic to *Ceriodaphnia dubia* in the fall of 2000, although no toxic response was observed in the Microtox® test. These waters also contained detectable levels of naphthenic acids.

In 2000, water temperatures varied from 4.8 to 18.6 °C (Figure 6.1), and total aluminum (spring only), silver (spring only), iron and manganese concentrations were higher than relevant surface water quality guidelines (Table 6.9). With the exception of silver, historical median concentrations also exceeded all of these water quality guidelines.

Unnamed Creek

Limited seasonal variation was observed in the unnamed creek draining Lease 52 in 2000, although naphthenic acids were detected in one of the fall samples (Tables 6.7 and 6.8). All waters were non-toxic to bacteria. In Spring 2000, total aluminum, iron and silver concentrations in Unnamed Creek exceeded water quality guidelines (Table 6.9). In the fall of 2000, total aluminum was the only parameter found at concentrations in excess of water quality guidelines.

Table 6.7 Water Quality in Fort and Unnamed Creeks

Parameter	Units	Fort Creek				Unnamed Creek (2000)		
			Fall					
		Spring (2000)	2000		Historical Median[a]	Spring	Fall	
			Trip 1	Trip 2			Trip 1	Trip 2
Field Measured								
pH		-	8.2	8.1	8.2	-	8.1	7.9
specific conductance	µS/cm	-	458	417	368	-	289	289
temperature	^{o}C	-	11.9	3.0	1.5	-	7.2	8.1
dissolved oxygen	mg/L	-	11.6	13.0	13.4	-	11.1	12.9
Conventional Parameters								
dissolved organic carbon	mg/L	11	13	13	12	4	3	3
total alkalinity	mg/L	190	260	235	253	143	161	160
total dissolved solids	mg/L	200	320	270	322	130	200	180
total organic carbon	mg/L	14	17	15	14	6	4	5
total suspended solids	mg/L	18	10	61	11	14	< 3	6
Major Ions								
chloride	mg/L	2	2	2	2	1	< 1	< 1
sulphate	mg/L	10	8	8	6	9	9	9
Nutrients and Chlorophyll *a*								
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	0.06	< 0.05	< 0.05	< 0.05
nitrogen – ammonia	mg/L	< 0.10	< 0.10	< 0.10	0.04	< 0.10	< 0.10	< 0.10
total nitrogen	mg/L	0.5	0.6	0.4	0.5	< 0.2	0.2	< 0.2
total phosphorus	µg/L	33	29	19	26	24	14	16
chlorophyll *a*	µg/L	1	1	< 1	3	2	< 1	1
Biochemical Oxygen Demand								
biochemical oxygen demand	mg/L	< 2	< 2	< 2	1	< 2	< 2	< 2
Organics								
naphthenic acids	mg/L	< 1	< 1	2	1	< 1	< 1	2
total phenolics	µg/L	5	2	< 1	3	5	2	2
Toxicity[b]								
Microtox IC_{50} @ 15 min	%	-	-	> 91	> 91	-	-	> 91
Microtox IC_{25} @ 15 min	%	-	-	> 91	> 91	-	-	> 91
Ceriodaphnia dubia 7 d mortality test - LC_{50}	%	-	-	< 6.25	-	-	-	-
Ceriodaphnia dubia 7 d reproduction test - IC_{25}	%	-	-	no results	-	-	-	-
fathead minnow 7d growth - IC_{25}	%	-	-	> 100	-	-	-	-
fathead minnow 7d mortality Test - LC_{50}	%	-	-	> 100	-	-	-	-

(a) Based on unpublished data from TrueNorth Energy Inc. and information from AENV WDS station AB07DA2760.

(b) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 6.8 Metal Levels in Fort and Unnamed Creeks

Parameter	Units	Fort Creek				Unnamed Creek (2000)		
		Spring (2000)	Fall			Spring	Fall	
			2000 Trip 1	2000 Trip 2	Historical Median[a]		Trip 1	Trip 2
Total Metals								
aluminum (Al)	µg/L	320	50	50	240	280	110	130
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	< 0.8	< 5.0	< 5.0	< 5.0
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
barium (Ba)	µg/L	88	105	72	78	82	82	76
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	2	< 1	< 1	5	2	< 1	1
copper (Cu)	µg/L	1	< 1	< 1	1	< 1	< 1	< 1
iron (Fe)	µg/L	690	710	560	905	380	70	280
lead (Pb)	µg/L	0.3	0.6	< 0.1	0.4	0.2	1.0	0.4
manganese (Mn)	µg/L	78	98	62	102	43	18	21
mercury (Hg)	µg/L	-	< 0.2	< 0.2	< 0.05	-	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.2	0.1	< 0.1	< 3.0	0.3	0.2	0.3
nickel (Ni)	µg/L	1.7	1.1	1.2	1.4	1.5	0.6	2.1
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	0.6	< 0.4	< 0.4	< 0.4	0.8	< 0.4	< 0.4
zinc (Zn)	µg/L	13	14	19	5	5	< 4	29
Dissolved Metals[b][c]								
aluminum (Al)	µg/L	40	90	< 10	< 10	40	100	< 10
antimony (Sb)	µg/L	< 0.8	1.0	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	72	94	**74**	95	68	76	74
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	2	0.8	< 0.4	< 0.4	**3**	0.5	< 0.4
copper (Cu)	µg/L	< 0.6	1.0	**1.2**	< 0.6	0.7	0.7	**2.4**
iron (Fe)	µg/L	130	170	130	240	< 10	60	30
lead (Pb)	µg/L	**0.5**	0.3	0.5	< 0.1	**0.6**	0.5	**0.8**
manganese (Mn)	µg/L	32.8	80.0	49.5	71.4	4.9	13.3	10.4
mercury (Hg)	µg/L	< 0.02	< 0.02	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1
molybdenum (Mo)	µg/L	0.1	< 0.1	**1.2**	< 0.1	0.3	0.2	**1.4**
nickel (Ni)	µg/L	1.0	1.0	0.9	1.4	0.7	0.1	0.8
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	**0.9**	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	2	< 2	8	3	< 2	< 2	9

(a) Based on unpublished data from TrueNorth Energy Inc. and information from AENV WDS station AB07DA2760.

(b) Occasionally, a dissolved metal concentration reported by ETL was higher than the respective total metal concentration (bolded numbers); this problem was detected too late for sample re-analysis; in future, lab results will be screened sooner to allow for sample re-analysis if required.

(c) Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

- = No data.

Table 6.9 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in Fort and Unnamed Creeks

Parameter	Units	Guidelines for the Protection of Aquatic Life[a]		Human Health[b]	Fort Creek				Unnamed Creek (2000)		
					Spring (2000)	Fall 2000		Fall Historical Median	Spring	Fall	
		Acute	Chronic			Trip 1	Trip 2			Trip 1	Trip 2
Total Metals											
aluminum (Al)	µg/L	750	100	-	C			C	C	C	C
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H	C H		
manganese (Mn)	µg/L	-	-	50	H	H	H	H			
silver (Ag)	µg/L	*	0.1	-	C				C		

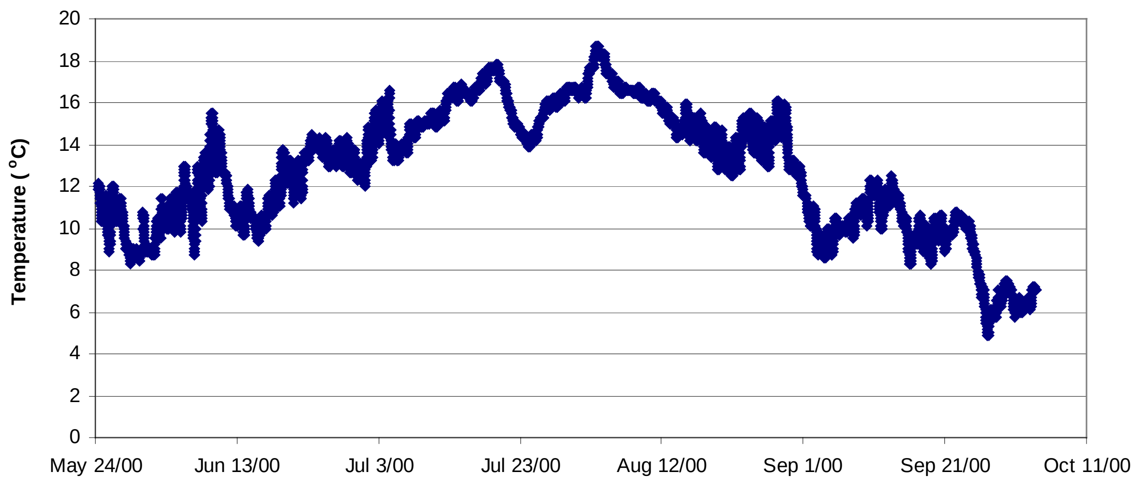
[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Figure 6.1 Water Temperature in Fort Creek



Muskeg River

Mouth

Water quality at the mouth of the Muskeg River in the fall of 2000 was generally consistent with historical data. Conductivity, as measured in the field, was lower in 2000 than in previous years, as were total manganese, nickel and dissolved aluminum concentrations (Tables 6.10a and 6.10b). Dissolved zinc concentrations were elevated in 2000 relative to historical medians. Sample waters taken from the mouth of the Muskeg River were non-toxic (as defined by Microtox® testing). Naphthenic acids were not detected, and iron levels were higher than surface water guidelines, as has been observed in previous sampling events (Table 6.11).

Table 6.10a Water Quality at Selected Locations in the Muskeg River

Parameter	Units	Mouth (MUR-1)		Upstream of Wapasu Creek (MUR-6)	
		2000	Historical Median[(a)]	2000	Historical Median[(b)]
Field Measured					
pH		8.1	8.2	7.5	7.8
specific conductance	µS/cm	250	610	211	352
temperature	^{o}C	5.1	4.3	3.8	4.0
dissolved oxygen	mg/L	11.4	12.3	9.5	7.6
Conventional Parameters					
dissolved organic carbon	mg/L	21	17	17	24
total alkalinity	mg/L	129	240	120	182
total dissolved solids	mg/L	220	288	210	189
total organic carbon	mg/L	26	22	22	23
total suspended solids	mg/L	3	3	3	4
Major Ions					
chloride	mg/L	2	5	< 1	1
sulphate	mg/L	13	16	5	2
Nutrients and Chlorophyll *a*					
nitrate + nitrite	mg/L	< 0.05	< 0.006	< 0.05	0.039
nitrogen - ammonia	mg/L	< 0.1	0.05	< 0.1	0.065
total nitrogen	mg/L	0.9	0.6	0.7	1.3
total phosphorus	µg/L	21	22	14	38
chlorophyll *a*	µg/L	< 1	< 1	< 1	< 1
Biochemical Oxygen Demand					
biochemical oxygen demand	mg/L	< 2.0	1	< 2.0	2.0
Organics					
naphthenic acids	mg/L	< 1	< 1	< 1	7
total phenolics	µg/L	< 1	1	< 1	4
Toxicity					
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91
Ceriodaphnia dubia 7 d mortality test - LC_{50}	%	-	-	> 100	> 100
Ceriodaphnia dubia 7 d reproduction test - IC_{25}	%	-	-	> 100	67.5
fathead minnow 7d growth - IC_{25}	%	-	-	> 100	56
fathead minnow 7d mortality test - LC_{50}	%	-	-	81	56.5

(a) Based on information from Golder (1996, 1998, 1999b, 2000c), R.L.&L. (1982) and AENV WDS stations AB07DA0620/0630.

(b) Based on information from Golder (1999b, 2000c), R.L.&L. (1989) and AENV WDS station AB07DA0440.

(c) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 6.10b Metal Concentrations at Selected Locations in the Muskeg River

Parameter	Units	Mouth (MUR-1)		Upstream of Wapasu Creek (MUR-6)	
		2000	Historical Median[a]	2000	Historical Median[b]
Total Metals					
aluminum (Al)	µg/L	90	95	90	50
antimony (Sb)	µg/L	< 5.0	< 0.7	< 5.0	< 0.8
arsenic (As)	µg/L	< 1.0	1.0	< 1.0	1.0
barium (Ba)	µg/L	42	34	34	65
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.6
chromium (Cr)	µg/L	1	4	4	< 1
copper (Cu)	µg/L	< 1	2	< 1	< 1
iron (Fe)	µg/L	540	800	190	1,780
lead (Pb)	µg/L	0.4	1.0	0.7	1.2
manganese (Mn)	µg/L	19	43	14	210
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.3	< 1.7	0.3	0.1
nickel (Ni)	µg/L	1.4	4.0	4.3	1.3
selenium (Se)	µg/L	< 0.8	< 0.4	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4
zinc (Zn)	µg/L	21	16	75	14
Dissolved Metals[c][d]					
aluminum (Al)	µg/L	< 10	27	< 10	10
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	25.7	79.3	16.8	36.9
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.0	< 0.1
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 3.0
copper (Cu)	µg/L	< 0.6	1.3	< 0.6	0.8
iron (Fe)	µg/L	220	250	40	855
lead (Pb)	µg/L	**0.8**	0.3	< 0.1	0.2
manganese (Mn)	µg/L	15.3	22.6	8.1	479
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1
molybdenum (Mo)	µg/L	0.2	0.1	0.1	0.1
nickel (Ni)	µg/L	0.5	2.8	0.4	2.1
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.3
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	13.0	3.0	10.0	6.0

[a] Based on information from Golder (1996, 1998, 1999b, 2000c), R.L.&L. (1982) and AENV WDS stations AB07DA0620/0630.

[b] Based on information from Golder (1999b, 2000c), R.L.&L. (1989) and AENV WDS station AB07DA0440.

[c] Occasionally, a dissolved metal concentration reported by ETL was higher than the respective total metal concentration (bolded numbers); this problem was detected too late for sample re-analysis; in future, lab results will be screened sooner to allow for sample re-analysis if required.

[d] Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

Table 6.11 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Muskeg River

Parameter	Units	Guidelines for the Protection of			Muskeg River (Fall)			
		Aquatic Life[a]		Human Health[b]	Mouth		Upstream of Wapasu Creek	
		Acute	Chronic		2000	Historical Median	2000	Historical Median
Nutrients								
total nitrogen	mg/L	-	1	-				C
Total Metals								
iron (Fe)	µg/L	-	300	300	C H	C H		C H
manganese (Mn)	µg/L	-	-	50				H

(a) Guidelines taken from AENV (1999).

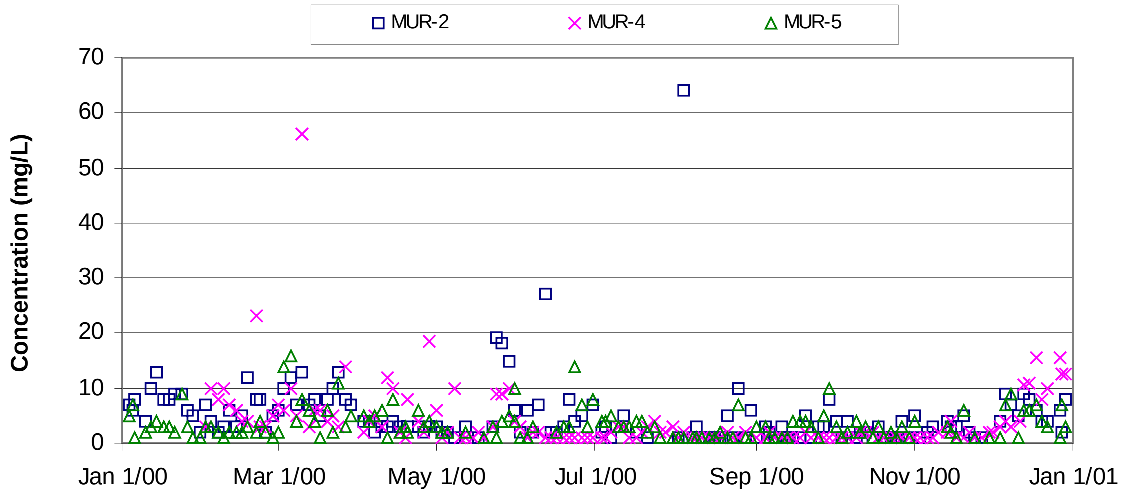
(b) Guidelines taken from U.S. EPA (1999).

- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

Mouth to Stanley Creek

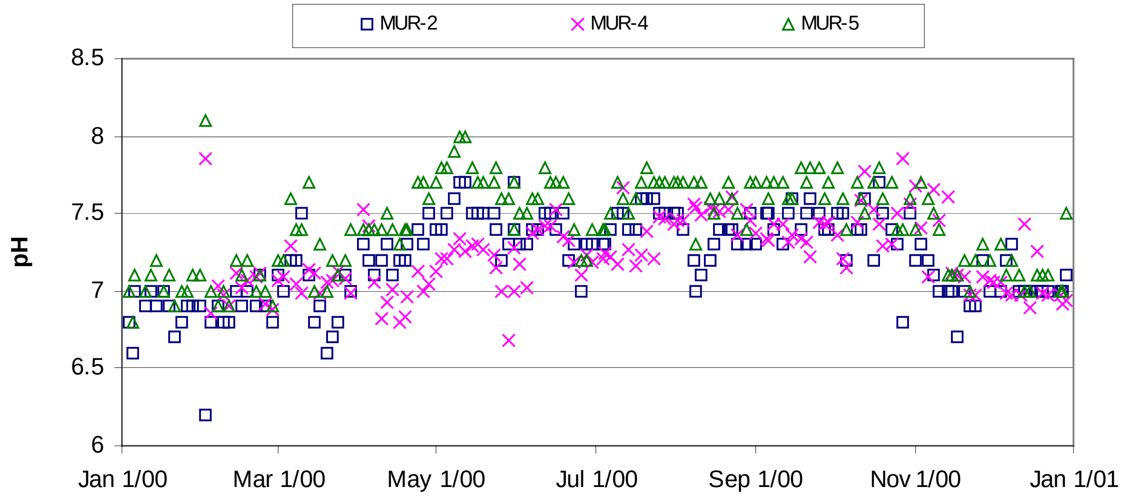
Together, Albian and Syncrude maintain three water quality monitoring stations in the Muskeg River between Stanley Creek and the confluence with the Athabasca River (see Figure 3.2). In 2000, total suspended solid, pH, dissolved oxygen, ammonia and biological oxygen demand samples were collected from each station at least once a week; sample results are shown in Figures 6.2 to 6.6, respectively. More extensive sampling and analysis was completed quarterly; sample results are summarized in Table 6.12. Water temperatures recorded by three thermographs installed in the Muskeg River between Stanley Creek and the mouth of the river are shown in Figure 6.7.

Figure 6.2 Total Suspended Solid Concentrations in the Muskeg River between Stanley Creek and the River Mouth



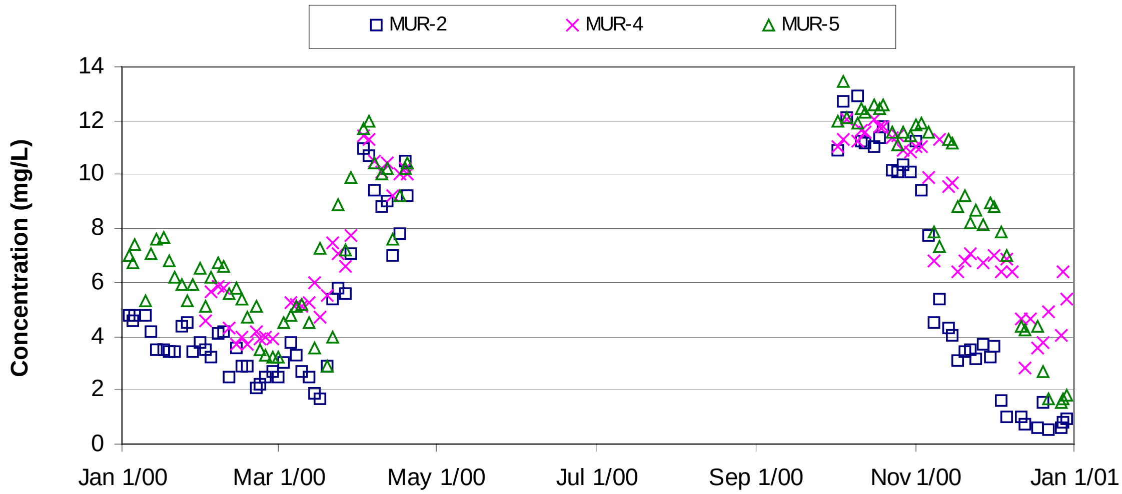
Sample locations are shown in Figure 3.2.

Figure 6.3 pH Levels in the Muskeg River between Stanley Creek and the River Mouth



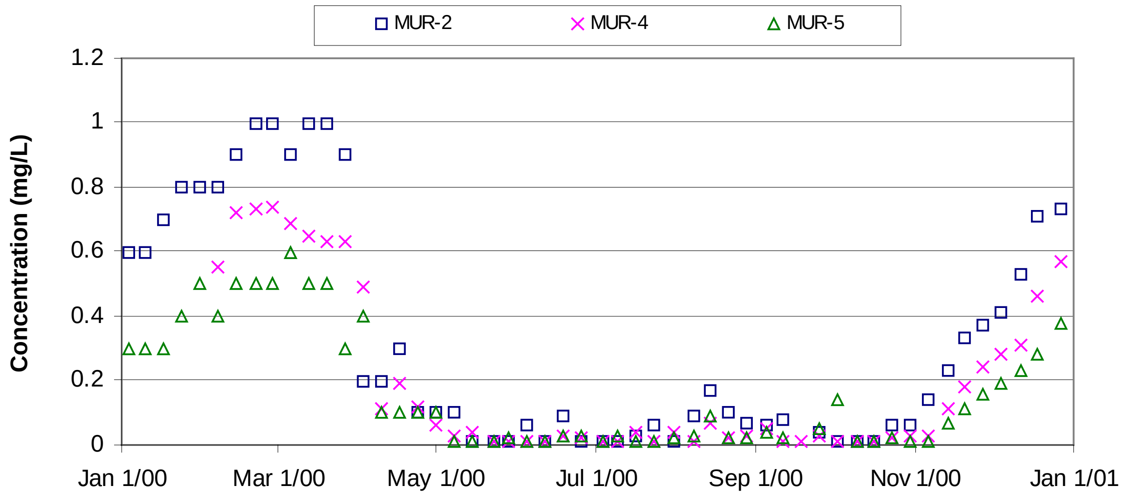
Sample locations are shown in Figure 3.2.

Figure 6.4 Dissolved Oxygen Concentrations in the Muskeg River between Stanley Creek and the River Mouth



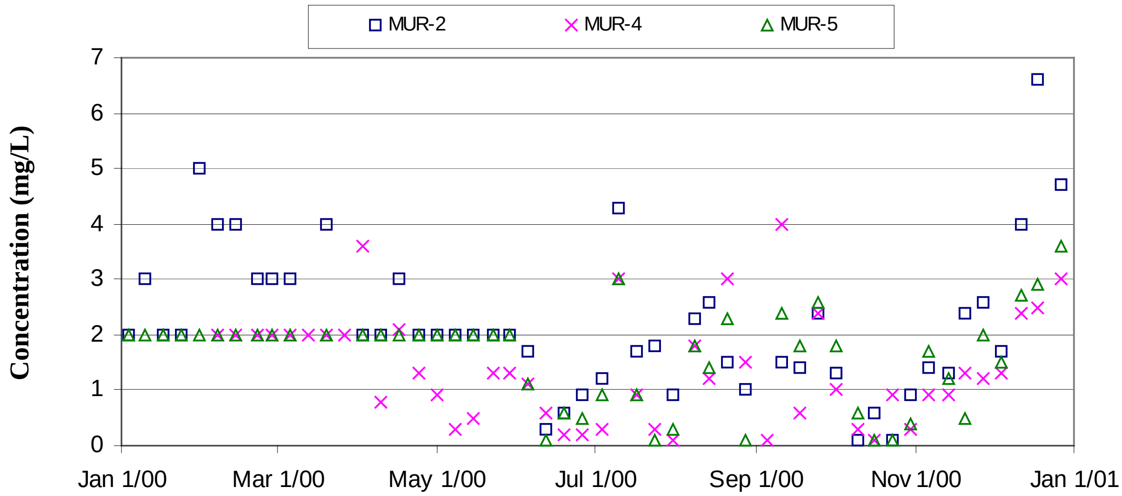
Sample locations are shown in Figure 3.2.

Figure 6.5 Ammonia Concentrations in the Muskeg River between Stanley Creek and the River Mouth



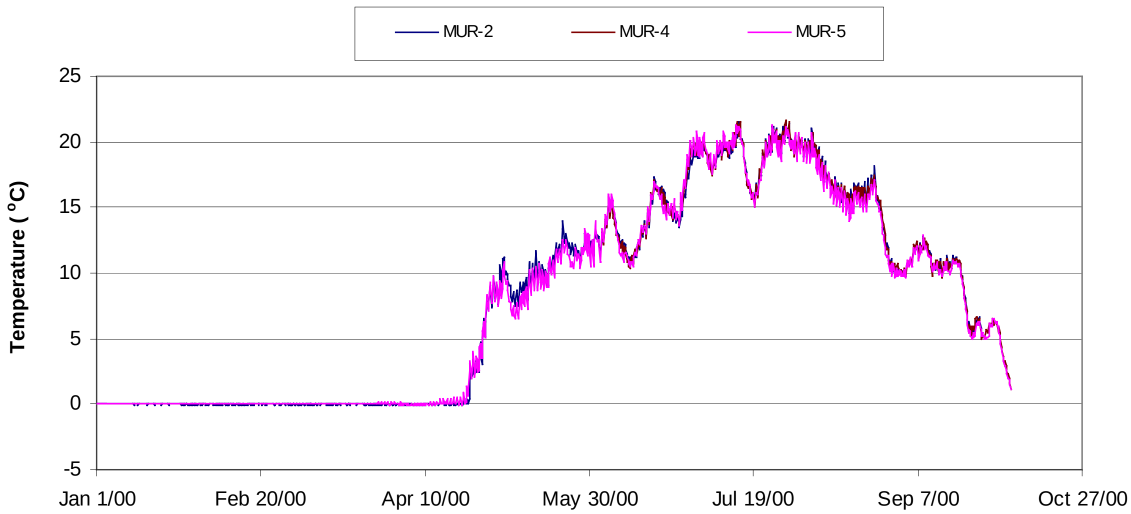
Sample locations are shown in Figure 3.2.

Figure 6.6 Biological Oxygen Demand Concentrations in the Muskeg River between Stanley Creek and the River Mouth



Sample locations are shown in Figure 3.2.

Figure 6.7 Water Temperature in the Muskeg River between Stanley Creek and the River Mouth



It is difficult to distinguish between the three individual datasets, because of extensive overlap; sample locations are shown in Figure 3.2.

Table 6.12 Water Quality in the Muskeg River Between Stanley Creek and the River Mouth

Parameter	Units	MUR-2				MUR-4				MUR-5			
		Feb	May	Aug	Oct	Feb	May	Aug	Oct	Feb	May	Aug	Oct
Conventional Parameters													
specific conductance	µS/cm	596	295	367	242	546	300	334	243	-	-	-	-
total alkalinity	mg/L	320	169	186	132	317	174	186	133	-	-	-	-
total dissolved solids	mg/L	343	175	210	136	307	175	188	134		171	218	150
total hardness	mg/L	300	160	180	110	270	170	170	110	-	-	-	-
Major Ions													
chloride	mg/L	5.1	2.7	2	2.3	4.2	2.5	2.1	2.1	2.9	1.4	1.1	1.7
sulphate	mg/L	25.2	4.4	17.3	3.7	1.2	1.6	0.5	1.4	0.4	1	0.3	0.7
Toxicity													
Ceriodaphnia dubia 7d survival - LC_{50}	%	-	-	-	-	< 100	< 100	< 100	< 100	-	-	-	-
fathead minnow 7d survival - LC_{50}	%	-	-	-	-	< 100	< 100	< 100	< 100	-	-	-	-
Total Metals													
aluminum (Al)	µg/L	18	10	22	35	18	8	12	18	19	8	32	17
antimony (Sb)	µg/L	1.2	< 0.2	< 0.2	1.7	0.4	< 0.2	< 0.2	1.7	22.1	< 0.2	< 0.2	1.7
arsenic (As)	µg/L	< 0.2	< 0.2	< 0.2	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
barium (Ba)	µg/L	75.2	35.4	50.7	27.8	79.4	< 5	40.3	26.5	-	-	-	-
cadmium (Cd)	µg/L	< 0.2	< 0.2	0.4	< 0.2	< 0.2	< 0.2	0.4	< 0.2	3.2	< 0.2	0.5	< 0.2
chromium (Cr)	µg/L	3	< 1	4	3	3	< 1	3	3	7	1	3	3
copper (Cu)	µg/L	< 0.2	1	1.2	1.8	0.4	0.6	1.1	1.9	2.9	1.8	1.7	2.4
iron (Fe)	µg/L	930	940	820	720	300	1,100	1,000	780	3,690	1,420	2,080	1,090
lead (Pb)	µg/L	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	4.8	< 0.4	< 0.4	< 0.3
manganese (Mn)	µg/L	703	47	68	43	1220	35	50	44	-	-	-	-
molybdenum (Mo)	µg/L	0.7	< 0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	< 0.2	-	-	-	-

Table 6.12 Water Quality in the Muskeg River Between Stanley Creek and the River Mouth (continued)

Parameter	Units	MUR-2				MUR-4				MUR-5			
		Feb	May	Aug	Oct	Feb	May	Aug	Oct	Feb	May	Aug	Oct
nickel (Ni)	µg/L	< 0.5	2.2	4.4	4.6	< 0.5	2.6	2.9	3.1	< 0.5	2.5	3.9	4.9
selenium (Se)	µg/L	< 0.2	< 0.2	< 0.2	< 0.1	-	-	-	-	< 0.2	< 0.2	< 0.2	< 0.1
silver (Ag)	µg/L	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.4	< 0.1	0.2	< 0.1
zinc (Zn)	µg/L	7.2	2.5	< 0.6	7.1	7.3	14.7	< 0.6	9.5	21	16.1	2.6	35.6
Organics													
naphthenic acids	mg/L	< 1	< 1	8	< 1	< 1	< 1	8	< 1	1	< 1	< 1	< 1
total phenolics	µg/L	4	6	9	6	< 4	6	12	8	4	5	8	5
benzene	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
ethylbenzene	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
m & p-xylene	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
o-xylene	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0	< 0.4	< 0.4	< 0.4
toluene	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Polycyclic Aromatic Hydrocarbons													
acenaphthene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.5	< 0.03	< 0.05	< 0.05
acenaphthylene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.03	< 0.05	< 0.05
anthracene	µg/L	< 0.01	< 0.005	< 0.005	0.03	< 0.01	< 0.005	< 0.005	< 0.01	< 0.1	< 0.01	< 0.005	< 0.005
benzo(a)anthracene	µg/L	< 0.01	< 0.005	< 0.005	0.09	< 0.01	< 0.005	< 0.005	< 0.01	< 0.01	< 0.3	< 0.005	< 0.005
benzo(a)pyrene	µg/L	< 0.01	< 0.005	< 0.005	< 0.01	< 0.01	< 0.005	< 0.005	< 0.01	< 0.5	< 0.05	< 0.005	< 0.009
benzo(b&j)fluoranthene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.03	< 0.05	< 0.05
benzo(c)phenanthrene	µg/L	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.03	< 0.03	< 0.03
benzo(g,h,i) perylene	µg/L	< 0.05	< 0.03	< 0.03	< 0.07	< 0.05	< 0.03	< 0.03	< 0.05	< 0.1	< 0.03	< 0.03	< 0.03
benzo(k)fluoranthene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.005	< 0.05	< 0.05
chrysene	µg/L	< 0.05	< 0.03	< 0.03	< 0.07	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.03	< 0.03
dibenz(a,h)anthracene	µg/L	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.04	< 0.05	< 0.05	< 0.05

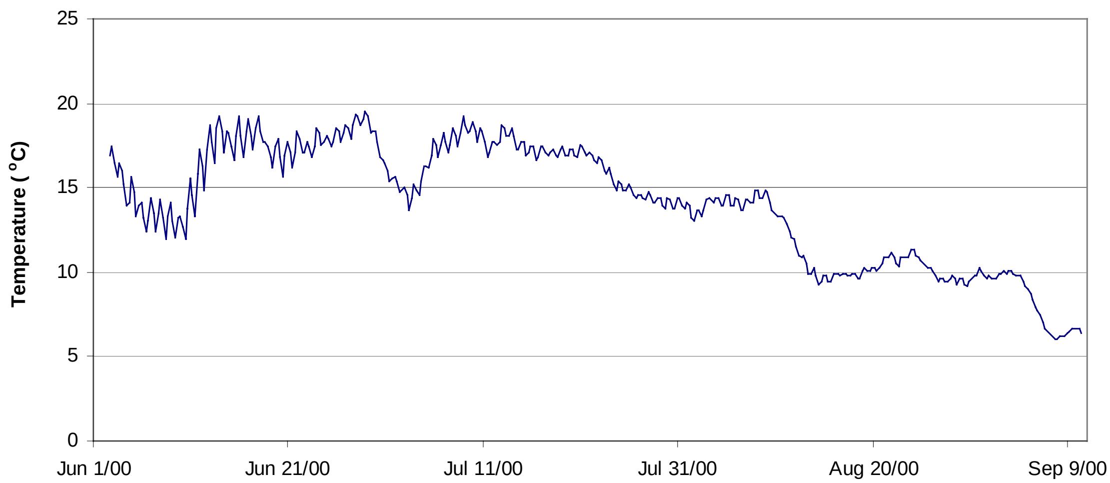
Table 6.12 Water Quality in the Muskeg River Between Stanley Creek and the River Mouth (continued)

Parameter	Units	MUR-2				MUR-4				MUR-5			
		Feb	May	Aug	Oct	Feb	May	Aug	Oct	Feb	May	Aug	Oct
dibenzo(a,h)pyrene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05
dibenzo(a,i)pyrene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.05
dibenzo(a,i)pyrene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05
dimethylbenz(a)anthracene (7,12)	µg/L	< 0.5	< 0.3	< 0.3	< 0.5	< 0.5	< 0.3	< 0.3	< 0.5	< 0.05	< 0.05	< 0.3	< 0.3
fluoranthene	µg/L	< 0.04	< 0.02	< 0.02	< 0.09	< 0.04	< 0.02	< 0.02	< 0.04	< 0.1	< 0.03	< 0.02	< 0.02
fluorene	µg/L	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.01	< 0.005	< 0.03	< 0.03
indeno(1,2,3-cd)pyrene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.05	< 0.03	< 0.05	< 0.05
3-methylcholanthrene	µg/L	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.1	< 0.05	< 0.03	< 0.03
naphthalene	µg/L	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.05
phenanthrene	µg/L	< 0.05	< 0.03	< 0.03	0.15	< 0.05	< 0.03	< 0.03	< 0.05	< 0.01	< 0.02	< 0.03	< 0.15
pyrene	µg/L	< 0.02	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01	< 0.01	< 0.02	< 0.05	< 0.005	< 0.01	< 0.01

Upstream of Wapasu Creek

Upstream of Wapasu Creek, parameter concentrations were generally lower in the fall of 2000 than in previous years (Tables 6.10a and 6.10b). Naphthenic acids were not detected, and the sample was non-toxic to bacteria. However, sample waters were found to significantly affect the survival of fathead minnows. All parameter levels, with the possible exception of mercury and silver, were below guidelines in 2000 (Table 6.11). Water temperatures in the Muskeg River upstream of Wapasu Creek experienced limited diurnal fluctuation and ranged from 6 to 19.5 ^{o}C (Figure 6.8).

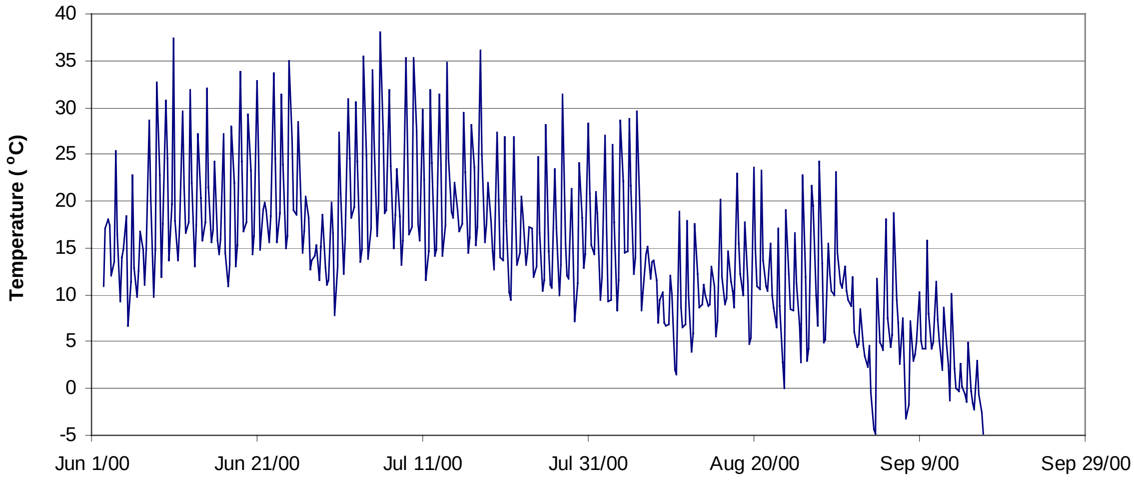
Figure 6.8 Water Temperature in the Muskeg River, Upstream of Wapasu Creek



Alsands Drain

Although no water samples were collected from the Alsands Drain in 2000, a thermograph was installed in the drain during the open-water season. The resulting temperature measurements suggest that the thermograph may not have been completely submerged while in the field; hence apparent summer water temperatures approaching 40 ^{o}C (Figure 6.9).

Figure 6.9 Water Temperature in the Alsands Drain



Jackpine Creek

In the fall of 2000, sample waters taken from the mouth of Jackpine Creek were non-toxic, but they contained detectable levels of naphthenic acids (Table 6.13). Total lead, manganese and barium, as well as dissolved aluminum and manganese, concentrations were lower than historical medians (Table 6.14). Total iron was the only element, with the possible exception of mercury and silver, to be present in 2000 at concentrations greater than guideline levels (Table 6.15). Historically, total iron and aluminum concentrations tend to exceed water quality guidelines.

Muskeg Creek

In the fall of 2000, total copper, chromium, molybdenum, nickel and zinc concentrations were higher than historical medians (Tables 6.13 and 6.14). Total and dissolved barium, dissolved iron and dissolved manganese levels were lower in 2000 than in previous years. Sample waters also contained detectable levels of naphthenic acids. No toxic response was observed (based on Microtox® testing). Total copper, iron and manganese concentrations in the fall of 2000 were higher than surface water quality guidelines (Table 6.15). Historical median concentrations also exceeded total iron and manganese guidelines.

Table 6.13 Water Quality in Jackpine and Muskeg Creeks

Parameter	Units	Jackpine Creek (Fall)		Muskeg Creek (Fall)	
		2000	Historical Median[(a)]	2000	Historical Median[(b)]
Field Measured					
pH		-	7.8	-	7.7
specific conductance	µS/cm	-	413	-	333
temperature	^{o}C	-	6.5	-	9.5
dissolved oxygen	mg/L	-	9.8	-	7.2
Conventional Parameters					
dissolved organic carbon	mg/L	22	24	20	24
total alkalinity	mg/L	93	113	123	155
total dissolved solids	mg/L	110	127	150	166
total organic carbon	mg/L	29	26	26	27
total suspended solids	mg/L	< 3	8	3	3
Major Ions					
chloride	mg/L	2	2	2	1
sulphate	mg/L	4	4	5	5
Nutrients and Chlorophyll *a*					
nitrate + nitrite	mg/L	< 0.05	< 0.005	< 0.05	< 0.05
nitrogen - ammonia	mg/L	< 0.1	0.04	< 0.1	0.18
total nitrogen	mg/L	0.8	0.8	0.7	1.1
total phosphorus	µg/L	21	35	24	42
chlorophyll *a*	µg/L	1	< 1	7	1
Biochemical Oxygen Demand					
biochemical oxygen demand	mg/L	< 2	2	< 2	5
Organics					
naphthenic acids	mg/L	1	< 1	1	< 1
total phenolics	µg/L	2	1	2	5
Toxicity[(c)]					
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91

(a) Based on information from Golder (1996, 1998, 2000c), R.L.&L. (1982, 1989) and AENV WDS station AB07DA0600.

(b) Based on information from Golder (1996, 1999b, 2000c) and AENV WDS station AB07DA0500.

(c) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = No data.

Table 6.14 Metal Concentrations in Jackpine and Muskeg Creeks

Parameter	Units	Jackpine Creek (Fall) 2000	Jackpine Creek (Fall) Historical Median[a]	Muskeg Creek (Fall) 2000	Muskeg Creek (Fall) Historical Median[b]
Total Metals					
aluminum (Al)	µg/L	100	115	50	40
antimony (Sb)	µg/L	< 5.0	< 0.6	< 5.0	< 0.8
arsenic (As)	µg/L	< 1.0	1.0	< 1.0	< 1.0
barium (Ba)	µg/L	13	22	22	51
cadmium (Cd)	µg/L	< 0.2	0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	< 1	1	76	< 1
copper (Cu)	µg/L	< 1	< 1	11	< 1
iron (Fe)	µg/L	380	580	1,160	1,750
lead (Pb)	µg/L	0.2	< 2.6	0.3	0.2
manganese (Mn)	µg/L	17	50	92	350
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.2	0.3	6.4	< 0.1
nickel (Ni)	µg/L	3.9	3.3	36.3	4.2
selenium (Se)	µg/L	< 0.8	< 0.4	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	0.4	< 0.4	< 0.4
zinc (Zn)	µg/L	27	25	32	7
Dissolved Metals[c]					
aluminum (Al)	µg/L	20	45	< 10	20
antimony (Sb)	µg/L	< 0.8	0.6	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	0.4	< 0.4	< 0.4
barium (Ba)	µg/L	12.1	31.7	19.1	55.6
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	0.9	3.0	0.5	< 1.9
copper (Cu)	µg/L	< 0.6	1.3	< 0.6	0.7
iron (Fe)	µg/L	190	280	210	685
lead (Pb)	µg/L	0.1	0.5	0.1	0.1
manganese (Mn)	µg/L	12.1	48.9	9.6	421
mercury (Hg)	µg/L	< 0.1	0.1	< 0.1	< 0.1
molybdenum (Mo)	µg/L	0.1	0.1	< 0.1	< 0.1
nickel (Ni)	µg/L	0.9	0.9	0.6	2.3
selenium (Se)	µg/L	< 0.4	< 0.2	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	8.0	9.0	7.0	3.0

[a] Based on information from Golder (1996, 1998, 2000c), R.L.&L. (1982, 1989) and AENV WDS station AB07DA0600.

[b] Based on information from Golder (1996, 1999b, 2000c) and AENV WDS station AB07DA0500.

[c] Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

Table 6.15 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in Jackpine and Muskeg Creeks

Parameter	Units	Guidelines for the Protection of			Jackpine Creek (Fall)		Muskeg Creek (Fall)	
		Aquatic Life[a]		Human		Historical		Historical
		Acute	Chronic	Health[b]	2000	Median	2000	Median
Nutrients								
total nitrogen	mg/L	-	1	-				C
Total Metals								
aluminum (Al)	µg/L	750	100	-		C		
copper (Cu)	µg/L	*	*	1300			C	
iron (Fe)	µg/L	-	300	300	C H	C H	C H	C H
manganese (Mn)	µg/L	-	-	50			H	H
silver (Ag)	µg/L	*	0.1	-		C		

[a] Guidelines taken from AENV (1999).
[b] Guidelines taken from U.S. EPA (1999).
* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).
- = No guideline; A = acute guideline exceeded; C = chronic guideline exceeded; H = human health guideline exceeded.

6.1.2 Sediment Quality

6.1.2.1 McLean and Fort Creeks

Sediments collected from the mouths of McLean and Fort creeks were primarily composed of sand in 2000 (Table 6.16). This differed from the sediment collected from McLean Creek in 1999, which was predominantly silt, followed by clay and then sand.

Metal concentrations in McLean Creek were generally lower in 2000 than in 1999, as were total inorganic carbon and C1 substituted phenanthrene/anthracene concentrations (Tables 6.16 and 6.17). Total recoverable hydrocarbon concentrations and PAHs levels were generally higher in 2000 than in 1999. C1 substituted naphthalene, benzo(a)anthracene, phenanthrene and pyrene concentrations in McLean Creek sediments exceeded Canadian sediment quality guidelines in 2000 (Table 6.18). All of these parameters, with the exception of pyrene, were also present at concentrations in excess of guideline levels in 1999. The detection limits for acenaphthene, acenaphthylene, anthracene, dibenzo(a,h)anthracene and benzo(a)pyrene in the 2000 McLean Creek sediment sample were greater than the corresponding sediment guidelines.

Table 6.16 Sediment Quality in McLean and Fort Creeks

Parameter	Units	McLean Creek		Fort Creek
		2000	1999[(a)]	(2000)
Particle Size				
particle size - % sand	%	84	10	85
particle size - % silt	%	12	60	12
particle size - % clay	%	4	30	4
Carbon Content				
total inorganic carbon	% dry wt	< 0.1	1.1	0.6
total organic carbon	% dry wt	5.6	2.3	3.2
Organics				
total recoverable hydrocarbons	mg/kg	43,900	900	9,450
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	0.6
total extractable hydrocarbons (C11-C30)	mg/kg	5800	-	985
Total Metals				
aluminum (Al)	μg/g	3,500	15,500	5,305
arsenic (As)	μg/g	3.4	6.4	3.7
barium (Ba)	μg/g	49.7	205	116.5
boron (B)	μg/g	< 5	15	6
cadmium (Cd)	μg/g	< 0.1	< 0.5	0.15
chromium (Cr)	μg/g	31.8	29.4	11.6
copper (Cu)	μg/g	10.5	24.0	9.2
iron (Fe)	μg/g	10,100	24,600	10,925
lead (Pb)	μg/g	4.4	12.0	6.95
manganese (Mn)	μg/g	188	682	312.5
mercury (Hg)	μg/g	< 0.04	0.04	< 0.04
molybdenum (Mo)	μg/g	1.5	< 1	0.3
nickel (Ni)	μg/g	23.2	33.0	12.1
selenium (Se)	μg/g	< 0.2	0.4	0.45
silver (Ag)	μg/g	< 0.1	< 1	< 0.1
zinc (Zn)	μg/g	24.7	81.1	54.1

[(a)] Based on information from Golder (2000c).

\- = No data.

Table 6.17 Concentration of Polycyclic Aromatic Hydrocarbons in McLean and Fort Creeks

Parameter	Units	McLean Creek		Fort Creek
		2000	1999[(a)]	(2000)
Target PAHs and Alkylated PAHs				
naphthalene	ng/g	16	27	21
C1 subst'd naphthalenes	ng/g	24	64	66
C2 subst'd naphthalenes	ng/g	100	81	44
C3 subst'd naphthalenes	ng/g	310	92	< 32
C4 subst'd naphthalenes	ng/g	< 30	51	< 25
acenaphthene	ng/g	< 17	< 3	< 24
C1 subst'd acenaphthene	ng/g	< 4	8	< 13
acenaphthylene	ng/g	< 7	< 4	< 15
anthracene	ng/g	< 58	< 3	< 25
dibenzo(a,h)anthracene	ng/g	< 100	< 10	< 100
benzo(a)anthracene/chrysene	ng/g	1,200	61	190
C1 subst'd benzo(a)anthracene/chrysene	ng/g	14,000	56	2,100
C2 subst'd benzo(a)anthracene/chrysene	ng/g	6,200	10	850
benzo(a)pyrene	ng/g	< 45	< 14	< 100
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	< 5	< 31	< 120
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	< 18	< 14	< 73
benzofluoranthenes	ng/g	410*	38	60
benzo(g,h,i)perylene	ng/g	210*	24	< 81
biphenyl	ng/g	7	11	< 17
C1 subst'd biphenyl	ng/g	< 4	< 3	< 14
C2 subst'd biphenyl	ng/g	< 5	< 3	< 9
dibenzothiophene	ng/g	< 26	4	< 19
C1 subst'd dibenzothiophene	ng/g	740	23	55
C2 subst'd dibenzothiophene	ng/g	4,000	76	390
C3 subst'd dibenzothiophene	ng/g	20,000	130	1,580
C4 subst'd dibenzothiophene	ng/g	< 47	-	< 35
fluoranthene	ng/g	60	10	< 34
C1 subst'd fluoranthene/pyrene	ng/g	2,400	65	340
C2 subst'd fluoranthene/pyrene	ng/g	5,300	-	805
C3 subst'd fluoranthene/pyrene	ng/g	7,400	-	1,185
fluorene	ng/g	14	6	< 18
C1 subst'd fluorene	ng/g	< 11	< 4	< 20
C2 subst'd fluorene	ng/g	< 8	< 3	< 27
C3 subst'd fluorene	ng/g	< 17	-	< 50
indeno(1,2,3,cd)pyrene	ng/g	160	14*	< 60
phenanthrene	ng/g	87*	45	28
C1 subst'd phenanthrene/anthracene	ng/g	< 28	120	< 40
C2 subst'd phenanthrene/anthracene	ng/g	2,100	96	151
C3 subst'd phenanthrene/anthracene	ng/g	7,800	120	710
C4 subst'd phenanthrene/anthracene	ng/g	4,500	420	585
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	1,100	-	210
pyrene	ng/g	490	26	41

[(a)] Based on information from Golder (2000c).

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

\- = No data.

Table 6.18 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in McLean and Fort Creeks

Parameter	Units	Sediment Guidelines[a]		McLean Creek		Fort Creek
		ISQG[b]	PEL[c]	2000	1999	(2000)
Total Metals						
arsenic (As)	µg/g	5.9	17		ISQG	
Target PAHs and Alkylated PAHs						
C1 naphthalene	ng/g	20	201	ISQG	ISQG	ISQG
benzo(a)anthracene/chrysene	ng/g	32	385	PEL	ISQG	ISQG
phenanthrene	ng/g	42	515	ISQG	ISQG	
pyrene	ng/g	53	875	ISQG		

[a] Sediment guideline values taken from CCME (1999).
[b] ISQG = interim freshwater sediment quality guidelines.
[c] PEL = probable effect levels.
- = No data.

Comparisons between McLean Creek and Fort Creek sediments collected in 2000 indicated that, when concentrations differed between the two creeks, McLean Creek tended to have higher concentrations. This was true for total recoverable hydrocarbons, total extractable hydrocarbons, chromium, molybdenum and a number of PAHs (e.g., benzo(a)anthracene/chrysene, benzofluoranthene, phenanthrene/anthracene and pyrene). Exceptions included barium, zinc and C1 substituted naphthalene. C1 substituted naphthalene and benzo(a)anthracene levels in Fort Creek sediments exceeded Canadian sediment quality guidelines in 2000 (Table 6.18). As well, the detection limits for acenaphthene, acenaphthylene, dibenzo(a,h)anthracene and benzo(a)pyrene in the 2000 Fort Creek sediment sample were greater than the corresponding sediment guidelines.

6.1.2.2 Muskeg River

In 2000, sediments were collected from six locations along the Muskeg River. With the exception of MUR-5 and MUR-6, which contained comparable proportions of sand, silt and clay, the remaining Muskeg River locations exhibited a predominance of sand (Table 6.19).

Historical data were only available for MUR-1, MUR-4 and MUR-6. There were few differences between the 2000 MUR-1 concentrations and historical median concentrations (Tables 6.19 and 6.20). Exceptions included concentrations of C1 and C2 benzo(a) anthracene/chrysene, which were higher in 2000 than in the past, and C2 and C3 substituted naphthalene and C4 substituted dibenzothiophene levels, which were lower in 2000 than in previous years.

Table 6.19 Sediment Quality in the Muskeg River

Parameter	Units	MUR-1		1 km Upstream (2000)	MUR-2 (2000)	MUR-4		MUR-5 (2000)	MUR-6	
		2000	Historical Median[(a)]			2000	1997[(b)]		2000	1998[(c)]
Particle Size										
particle size - % sand	%	90	70	88	72	75	64	43	28	-
particle size - % silt	%	4	20	8	16	11	18.3	21	46	-
particle size - % clay	%	6	10	4	12	15	17.7	36	26	-
Carbon Content										
total inorganic carbon	% dry wt	0.9	1.3	1.7	0.1	0.1	-	0.1	0.1	-
total organic carbon	% dry wt	0.5	1.5	1.1	2.8	4.5	4.5	13.6	21.2	-
Organics										
total recoverable hydrocarbons	mg/kg	1,900	2,040	1,800	11,300	9,800	3,690	3,400	2,200	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5	-
total extractable hydrocarbons (C11-C30)	mg/kg	72	-	47	370	140	-	270	130	-
Total Metals										
aluminum (Al)	µg/g	4,180	7,480	9,440	2,000	9,040	5,820	6,230	15,600	-
arsenic (As)	µg/g	1.9	2.865	2.1	0.6	1.2	2.4	1.4	2	-
barium (Ba)	µg/g	116	113	78.5	50.4	89	118	106	151	-
boron (B)	µg/g	20	14	26	< 2	14	-	13	27	-
cadmium (Cd)	µg/g	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	0.3	-
chromium (Cr)	µg/g	36.8	19.55	17.1	4.5	12.2	12.3	8.8	98.1	-
cobalt (Co)	µg/g	4.4	5	3.4	1.5	2.9	4	2.3	5.1	-
copper (Cu)	µg/g	7.8	9.5	6.5	3.8	7	10	8.8	14.6	-
iron (Fe)	µg/g	16,000	18,650	15,400	5,370	12,400	23,000	20,400	12,500	-
lead (Pb)	µg/g	6.1	7.5	5.3	2.5	5.1	< 5	3.5	5.7	-
manganese (Mn)	µg/g	756	474.5	346	225	314	620	288	116	-
mercury (Hg)	µg/g	< 0.04	0.04	0.04	< 0.04	< 0.04	0.04	< 0.04	0.08	-

Table 6.19 Sediment Quality in the Muskeg River (continued)

Parameter	Units	MUR-1		1 km Upstream (2000)	MUR-2 (2000)	MUR-4		MUR-5 (2000)	MUR-6	
		2000	Historical Median[(a)]			2000	1997[(b)]		2000	1998[(c)]
molybdenum (Mo)	µg/g	1.3	< 1	0.6	0.1	0.3	< 1	0.1	5.5	-
nickel (Ni)	µg/g	26.9	16	12.7	4.6	10.3	9	6.1	59.4	-
selenium (Se)	µg/g	< 0.2	0.25	< 0.2	< 0.2	0.4	0.6	0.6	< 0.2	-
silver (Ag)	µg/g	< 0.1	< 1	< 0.1	< 0.1	< 0.1	< 1	< 0.1	< 0.1	-
zinc (Zn)	µg/g	28.0	42.0	23.7	19.1	39.9	37.9	28.7	38.7	-

[(a)] Based on information from Golder (1998, 1999b, 2000c) and Lutz and Hendzel (1977).

[(b)] Based on information from Golder (1998).

[(c)] Based on information from Golder (1999b).

- = No data.

Table 6.20 Concentration of Polycyclic Aromatic Hydrocarbons in the Muskeg River

Parameter	Units	MUR-1		1 km Upstream (2000)	MUR-2 (2000)	MUR-4		MUR-5 (2000)	MUR-6	
		2000	Historical Median[(a)]			2000	1997[(b)]		2000	1998[(c)]
Target PAHs and Alkylated PAHs										
naphthalene	ng/g	8.5	14	7.3	20*	10	3	7.1	10	6.29
C1 subst'd naphthalenes	ng/g	< 10	15	8.1	< 19	15	< 3	12	10	20.82
C2 subst'd naphthalenes	ng/g	< 4.4	20	14	< 6	21	30	16	21	97
C3 subst'd naphthalenes	ng/g	< 9.8	23	8.7	< 12	6.8	30	14	8.7	27.4
C4 subst'd naphthalenes	ng/g	< 6.7	4.5	< 2.8	1,200	< 3.2	160	34	< 2.3	17.6
acenaphthene	ng/g	< 6.1	< 3	< 2.2	< 8.4	< 3.1	< 3	2*	< 3	0.41
C1 subst'd acenaphthene	ng/g	< 1.8	< 2.8	< 0.87	< 6.8	< 0.54	< 20	1.5	3	-
acenaphthylene	ng/g	< 5.6	< 3	< 1.3	< 4.9	< 1.2	4	< 1.4	< 2.7	0.42
anthracene	ng/g	< 2.4	< 3	< 2.3	< 14	< 1.7	< 3	< 3.5	< 0.98	0.4
dibenzo(a,h)anthracene	ng/g	< 21	< 3.7	< 2.5	< 20	< 11	< 3	< 9.2	< 3.6	-
benzo(a)anthracene/chrysene	ng/g	17	16.5	16.5*	259*	64	57	40.8*	12	12.39
C1 subst'd benzo(a)anthracene/chrysene	ng/g	120	17	< 17	3,600	630	120	440	230	5
C2 subst'd benzo(a)anthracene/chrysene	ng/g	52	9.2	58	1,600	320	200	130	16	5.2
benzo(a)pyrene	ng/g	< 3.9	< 10	3*	< 34	< 6.9	16	< 6.8	15	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	< 5.2	< 12	< 4.9	< 27	< 18	120	< 6.1	< 2	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	< 5.7	< 9.2	< 5	< 29	< 16	190	< 8.5	< 2.5	-
benzo(b&k)fluoranthene	ng/g	7.8	12	9.7*	62*	18	34	13	13	5.64
benzo(g,h,i)perylene	ng/g	12	12	6.9*	34	30*	10	16	< 16	13.94
biphenyl	ng/g	< 4.3	< 4.4	< 1.5	< 4.3	< 1.9	< 20	2.3	2.6	-
C1 subst'd biphenyl	ng/g	< 2.4	< 2.3	< 1.7	< 2.1	< 2.8	< 20	0.27	< 3	-
C2 subst'd biphenyl	ng/g	< 2.4	< 1.6	< 0.97	< 6.9	< 0.68	< 20	< 1.1	< 0.95	-
dibenzothiophene	ng/g	< 2.4	< 1.9	0.92*	< 14	2.7*	5	< 1.7	< 1.8	2.59

Table 6.20 Concentration of Polycyclic Aromatic Hydrocarbons in the Muskeg River (continued)

Parameter	Units	MUR-1		1 km Upstream (2000)	MUR-2 (2000)	MUR-4		MUR-5 (2000)	MUR-6	
		2000	Historical Median[(a)]			2000	1997[(b)]		2000	1998[(c)]
C1 subst'd dibenzothiophene	ng/g	16	< 11	< 2.7	200	< 4.7	30	14	< 1.5	52.8
C2 subst'd dibenzothiophene	ng/g	44	42	4	2,800	81	300	100	< 2.2	97.6
C3 subst'd dibenzothiophene	ng/g	72	82	79	7,600	180	580	310	< 1.5	26.6
C4 subst'd dibenzothiophene	ng/g	44	240	< 2.3	< 14	< 7.3	560	< 4.6	< 1.4	-
fluoranthene	ng/g	< 2.5	2.8	1.9	< 22	< 1.9	6	2.7	5.9	1.86
C1 subst'd fluoranthene/pyrene	ng/g	21	17	13	510	100	70	50	7.1	163.8
C2 subst'd fluoranthene/pyrene	ng/g	64	-	51	1,400	250	-	120	16	-
C3 subst'd fluoranthene/pyrene	ng/g	78	-	47	1,900	340	-	130	< 3.6	-
fluorene	ng/g	< 3	2.7	< 0.8	< 2.5	< 1	< 3	< 2.8	3.1	2.82
C1 subst'd fluorene	ng/g	< 2.9	< 2.2	< 1.4	< 10	< 2.3	20	< 1.8	< 1.3	29.4
C2 subst'd fluorene	ng/g	< 4.1	< 3	< 2.8	< 43	< 1.9	150	< 2.3	< 1.8	69.6
C3 subst'd fluorene	ng/g	< 6.8	-	< 2.9	2,300	< 6.9	-	< 4	< 3	-
indeno(c,d-123)pyrene	ng/g	11	6.4	6.8*	23*	17*	9	7.2*	4.5*	-
phenanthrene	ng/g	5.700	9.800	4.7*	58	5.9	9	9.5	10	10.94
C1 subst'd phenanthrene/anthracene	ng/g	22	40	14	464	23	90	46	5.2	42.4
C2 subst'd phenanthrene/anthracene	ng/g	42	40	34	2,000	51	260	83	20	59.6
C3 subst'd phenanthrene/anthracene	ng/g	44	51	36	2,900	84	600	130	6	-
C4 subst'd phenanthrene/anthracene	ng/g	46	110	10	1,100	130	210	63	140	-
1-Methyl-7-isopropyl-phenanthrene (retene)	ng/g	13	-	16	< 210	17	-	170	280	362
pyrene	ng/g	7.6	6	3.5	110	13	15	11*	4.5	3.7

(a) Based on information from Golder (1998, 1999b, 2000c) and Lutz and Hendzel (1977).

(b) Based on information from Golder (1998).

(c) Based on information from Golder (1999b).

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a large degree of error than those produced from clearly defined spectra).

\- = No data.

At MUR-4, total recoverable hydrocarbons, naphthalene, C1 substituted naphthalene, C1 substituted benzo(a)anthracene/chrysene and benzo(g,h,i)perylene concentrations were higher in 2000 than in 1997. However, C3 and C4 substituted naphthalene, C1 and C2 substituted benzo(b&k)fluorene/ benzo(a)pyrene, dibenzothiophene, C1 and C2 substituted fluorene and C1, C2 and C3 substituted phenanthrene/anthracene concentrations were lower in 2000 than in 1997.

Historical sediment data at MUR-6 is limited to PAHs (Table 6.20). Concentrations were generally comparable between 1998 and 2000, with several exceptions. Fluoranthene, C1 and C2 substituted benzo(a)anthracene/chrysene and benzo(b&k)fluorene were found in greater concentrations in 2000 than in 1998, while C1, C2, C3, and C4 substituted naphthalene, C1, C2, and C3 substituted dibenzothiophene, C1 substituted fluoranthene/pyrene, C1 and C2 substituted fluorene and C1 and C2 phenanthrene/anthracene were found in lower concentrations in 2000 than in 1998.

Several parameters in the 2000 Muskeg River sediment samples exceeded sediment quality guidelines. These parameters included benzo(a)anthracene/ chrysene at MUR-2, MUR-4 and MUR-5, chromium at MUR-6, as well as phenanthrene and pyrene at MUR-2 (Table 6.21). The detection limit for dibenzo(a,h)anthracene was greater than the sediment quality guideline at MUR-1, MUR-2, MUR-4 and MUR-5. The detection limit for acenaphthene was greater than the relevant guideline at MUR-2.

6.1.3 Summary

Although water quality in the Athabasca River tributaries was generally consistent with historical data, naphthenic acids were detected at eight of the ten sample sites. Sample waters from Fort Creek and the upper Muskeg River were also found to be toxic to *Ceriodaphnia dubia* and fathead minnows, respectively. Toxicity, assessed by Microtox®, was not observed in the other tributaries. Microtox® has been included in the 2000 RAMP because historical Microtox® data are available. However, Microtox® may not be as good an indicator of toxicity as *C. dubia* and fathead minnows, since no effect was observed in the Microtox® tests completed with sample waters from Fort Creek and the upper Muskeg River.

Sediment quality in tributaries of the Athabasca River was comparable to historical data. However, total recoverable hydrocarbon and PAH concentrations in McLean Creek were generally higher in 2000 than in 1999. PAH and total recoverable hydrocarbon concentrations also tended to be higher in McLean Creek than at the mouth of Fort Creek.

Table 6.21 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in the Muskeg River in 2000

Parameter	Units	Sediment Guidelines[a]		MUR-1		1 km Upstream of Mouth (2000)	MUR-2 (2000)	MUR-4		MUR-5 (2000[a])	MUR-6	
		ISQG[b]	PEL[c]	2000	Historical Median			2000[a]	1997[b]		2000[c]	1998
Total Metals												
chromium (Cr)	μg/g	37	90								PEL	
Target PAHs and Alkylated PAHs												
C1 naphthalene	ng/g	20	201									ISQG
benzo(a)anthracene/ chrysene	ng/g	32	385				ISQG	ISQG	ISQG	ISQG		
phenanthrene	ng/g	42	515				ISQG					
pyrene	ng/g	53	875				ISQG					

[a] Sediment guideline values taken from CCME (1999).
[b] ISQG = interim freshwater sediment quality guidelines.
[c] PEL = probable effect levels.
- = No data.

In the Muskeg River, the one parameter that was consistently elevated in 2000 compared to historical data was C1 substituted benzo(a)anthracene/chrysene. The parameter that most frequently exceeded guidelines in the 2000 tributary sediments was benzo(a)anthracene/chrysene. Other parameters that exceeded guidelines included chromium, C1 substituted naphthalene, phenanthrene and pyrene.

6.2 BENTHIC INVERTEBRATE COMMUNITY

6.2.1 Benthic Habitat

The MacKay, Steepbank and Muskeg rivers are of medium size, with wetted channel widths generally between 15 and 40 m at the time of sampling, which corresponded to the fall low-flow period (Table 6.22). Erosional reaches were characterized by similar ranges in current velocity (0.5 to 1 m/s) and depth (20 to 40 cm). As expected, the depositional reach in the Muskeg River was slower and deeper. The variation in depth in this reach was considerably greater (25 to 200 cm) than in the erosional reaches.

The substratum was dominated by gravel and cobble in the erosional reaches, with the highest within-reach variability in the Steepbank River and lowest variability in the MacKay River (Table 6.22). The degree of embeddedness was generally low. The mean benthic algal biomass on cobble surfaces was similar in the Steepbank and Muskeg rivers, but was about 50% lower in the MacKay River. Depositional sediments in the Muskeg River were composed mostly of sand (about 80% on average); silt and clay accounted for the remainder (Table 6.22). Sediment TOC was relatively low (≤6%), considering the abundant aquatic plant flora observed in this river. Aquatic macrophyte cover was highly variable among depositional sampling locations, ranging from 0 to 90%.

Based on field water quality measurements, conductivity was similar in the MacKay and Muskeg rivers, and was somewhat lower in the Steepbank River (Table 6.22). Water temperature was in the “normal” range for the time of year sampled in all rivers. Dissolved oxygen (DO) and pH were only measured in the Steepbank River due to failure of the water quality meter while sampling the other rivers. In this river, DO was near saturation and pH was in the typical range for moderate-sized rivers in the Oil Sands Region in the fall.

The habitat data collected during the benthic surveys indicates that habitat differences within and among the erosional sampling reaches were minor. Habitat variation was greater in the depositional reach sampled in the Muskeg River, as exemplified by the wide ranges in water depth and aquatic macrophyte cover.

Table 6.22 Habitat Characteristics of the Benthic Invertebrate Sampling Reaches in the MacKay, Steepbank and Muskeg Rivers in Fall 2000

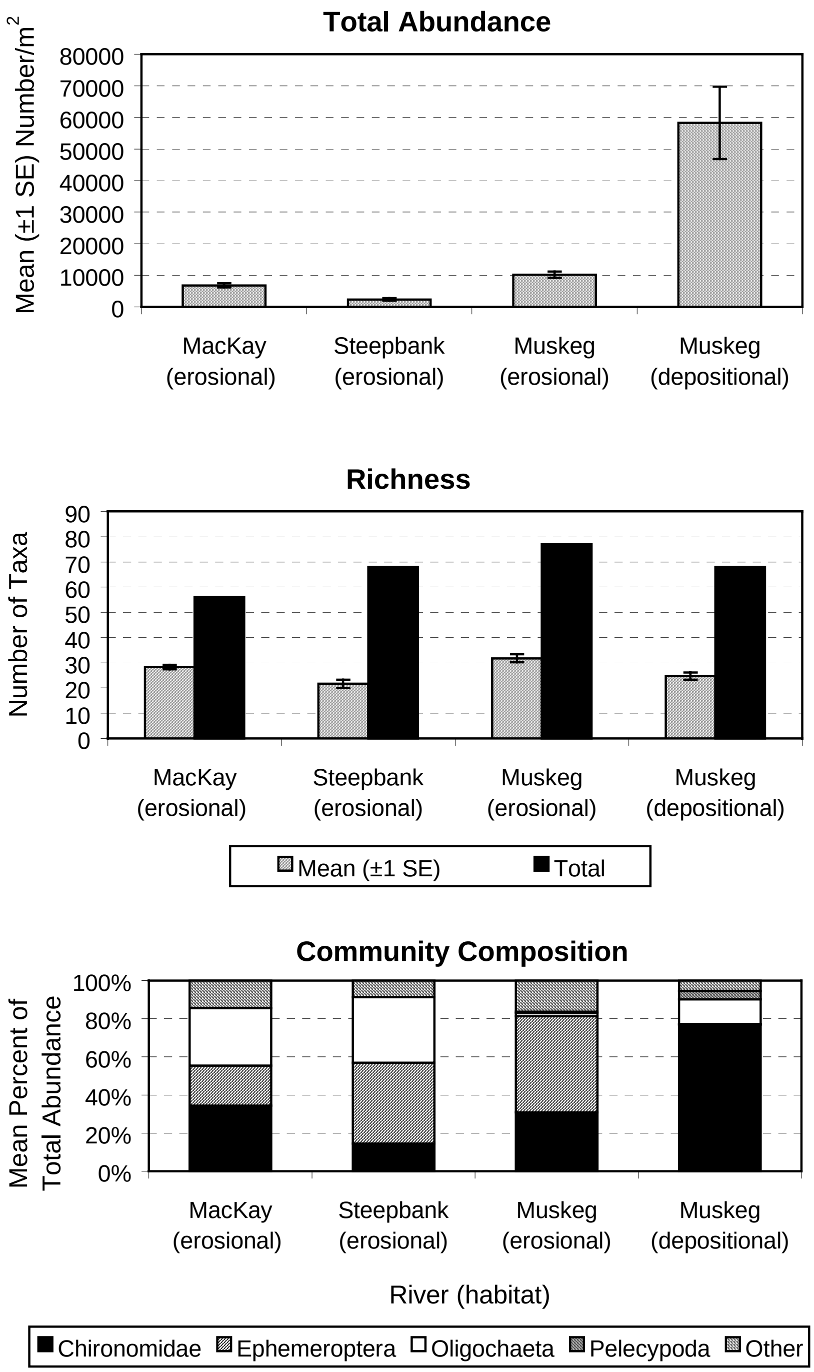
Variable	Units	MacKay River (erosional) Mean (range)	Steepbank River (erosional) Mean (range)	Muskeg River (erosional) Mean (range)	Muskeg River (depositional) Mean (range)
sample date	-[(a)]	October 7, 2000	October 1, 2000	October 6, 2000	October 6, 2000
habitat	-	riffle	riffle	riffle	run/backwater/pool
wetted channel width	m	36 (30 - 42)	23 (17 - 31)	21 (17 - 25)	20 (14 - 28)
bankfull channel width	m	43 (38 - 52)	33 (23 - 40)	25 (22 - 27)	23 (17 - 31)
water depth	cm	30 (25 - 37)	35 (23 - 46)	31 (26 - 38)	127 (25 - 200)
current velocity	m/s	0.74 (0.51 - 0.99)	0.73 (0.60 - 0.98)	0.76 (0.51 - 0.97)	0.20 (0.10 - 0.45)
Field Water Quality					
dissolved oxygen	mg/L	-	12.5 (12.1 - 13.1)	-	-
conductivity	µS/cm	205 (202 - 210)	148 (143 - 151)	210 (208 - 211)	207 (200 - 209)
pH	-	-	8.1 (7.7 - 8.1)	-	-
water temperature	^{o}C	0.4 (-0.1 - 1.0)	4.7 (4.1 - 4.9)	1.1 (0.9 - 1.3)	0.3 (0.2 - 0.4)
Benthic Algae and Aquatic Macrophytes					
amount of benthic algae	visual est.[(b)]	L-M	L-H	H	-
benthic algal chlorophyll *a* (15 samples/river)	mg/m^2	23 (3 - 59)	41 (<1 - 183)	44 (19 - 80)	-
aquatic macrophyte cover	%	-	-	-	43 (0 - 90)
Substrate (erosional habitat)					
sand/silt/clay	%	8 (0 - 20)	6 (0 - 20)	3 (0 - 10)	-
small gravel	%	39 (25 - 50)	13 (0 - 40)	12 (0 - 25)	-
large gravel	%	33 (20 - 45)	23 (0 - 50)	38 (15 - 60)	-
small cobble	%	19 (5 - 30)	25 (10 - 50)	47 (25 - 80)	-
large cobble	%	2 (0 - 5)	26 (0 - 70)	<1 (0 - 5)	-
boulder	%	0	4 (0 - 30)	0	-
bedrock	%	0	2 (0 - 35)	0	-
weighted average index	-	4.2 (3.7 - 4.9)	5.6 (3.6 - 7.1)	5.1 (4.4 - 5.7)	-
embeddedness	%	13 (5 - 30)	10 (0 - 25)	14 (5 - 25)	-
Bottom Sediments (depositional habitat)					
sand	%	-	-	-	81 (71 - 95)
silt	%	-	-	-	8 (2 - 14)
clay	%	-	-	-	11 (3 - 20)
total organic carbon	%	-	-	-	3 (0 - 6)

[(a)] - = Not applicable or no data.
[(b)] Categories: N = none; L = low; M = moderate; H = high.

6.2.2 Benthic Communities

Total benthic invertebrate abundance was generally low (means of ≤10,000 organisms/m^2) in erosional reaches in the MacKay, Steepbank and Muskeg rivers (Figure 6.10). The depositional reach in the Muskeg River supported larger numbers of invertebrates, in the moderate to high range in absolute terms (Figure 6.10). Total abundance was most variable in the depositional reach, where the greatest among-site variation in habitat features was also observed (Table 6.22).

Figure 6.10 Total Invertebrate Abundance, Richness and Community Composition in the Rivers Sampled in Fall 2000 (SE = standard error, n = 15)



Taxonomic richness (total number of taxa at the lowest taxonomic level) was less variable and similar in all rivers and habitats sampled (Figure 6.10; Mean = mean value based on 15 samples, Total = total taxa in 15 samples combined). Richness values were average to above average relative to Alberta rivers in general. As in 1998 (Golder 1999b), the Muskeg River supported the most diverse benthic fauna of the three tributaries, with a total of 77 taxa in all samples combined.

Taxonomic composition at the level of major taxon was similar in the MacKay and Steepbank rivers. Here, the benthic communities were dominated by chironomids (Chironomidae), mayflies (Ephemeroptera) and oligochaete worms (Oligochaeta) (Figure 6.10). The erosional reach of the Muskeg River differed from these by a more pronounced dominance of mayflies and a substantially lower proportion of oligochaetes. The depositional fauna of the Muskeg River consisted mostly of chironomids and oligochaete worms.

At a finer taxonomic resolution, the benthic fauna of the MacKay River was numerically dominated by the oligochaete families Naididae and Enchytraeidae, the mayfly genus *Baetis* and a number of common chironomid genera (Table 6.23). Water mites (Hydracarina), other mayflies (*Tricorythodes* and the family Ephemerellidae), nematode worms and stoneflies (Chloroperlidae, *Taeniopteryx*, *Isoperla*) were also common in this river. All of these taxa or groups except the stoneflies were also common in the Steepbank River. The erosional reach of the Muskeg River was strongly dominated by *Baetis*, which accounted for 45% of total abundance (Table 6.23). The remainder of common taxa in this river were similar to those in the other erosional reaches, with the exception of oligochaetes, which were absent.

The depositional reach sampled in the Muskeg River shared some common taxa with the erosional reaches (*Micropsectra*, Tubificidae, *Tanytarsus*, *Polypedilum*, Naididae, Nematoda) (Table 6.23). The chironomid genus *Micropsectra* accounted for nearly 50% of total abundance in all depositional samples combined. Other common depositional taxa included a number of additional chironomid genera, fingernail clams (Sphaeriidae) and seed shrimps (Ostracoda).

There were a number of significant correlations between habitat variables, and richness and/or abundances of common invertebrates in the Steepbank and Muskeg rivers (Table 6.24). Total abundance was not significantly correlated with any of the habitat variables in any of the rivers sampled. The lack of significant correlations in the MacKay River data set may reflect in part the lower variation in substrate characteristics among the sampling locations in this river (Table 6.22). Significant correlations between habitat variables and richness and/or abundance occurred mainly in the erosional habitats which had greater variation in both abundances (Table 6.23) and habitat variables (Table 6.22) than the depositional reach of the Muskeg River.

Table 6.23 Abundances of Common Invertebrates (number/m^2), Total Abundance and Taxonomic Richness in the Lower Reaches of the MacKay, Steepbank and Muskeg Rivers in Fall 2000

MacKay River – Erosional Habitat					Steepbank River - Erosional Habitat				
Taxon	Major Group	Mean	Standard Error	% of Total Abundance	Taxon	Major Group	Mean	Standard Error	% of Total Abundance
Naididae	Oligochaeta	1187	216	17.4	*Baetis*	Ephemeroptera	579	202	24.6
Baetis	Ephemeroptera	1041	215	15.3	Naididae	Oligochaeta	507	87	21.5
Enchytraeidae	Oligochaeta	840	122	12.3	*Ephemerella*	Ephemeroptera	326	73	13.8
Polypedilum	Chironomidae	508	141	7.5	Enchytraeidae	Oligochaeta	270	31	11.5
Rheotanytarsus	Chironomidae	507	105	7.4	*Micropspectra*	Chironomidae	96	31	4.1
Micropspectra	Chironomidae	435	125	6.4	Hydracarina	Hydracarina	67	12	2.9
Hydracarina	Hydracarina	245	41	3.6	*Polypedilum*	Chironomidae	51	10	2.2
Tanytarsus	Chironomidae	185	36	2.7	*Tricorythodes*	Ephemeroptera	50	11	2.1
Thienemannimyia complex	Chironomidae	184	45	2.7	Nematoda	Nematoda	44	8	1.9
Tricorythodes	Ephemeroptera	179	48	2.6	*Thienemannimyia* complex	Chironomidae	40	11	1.7
Nematoda	Nematoda	150	49	2.2	Tubificidae	Oligochaeta	31	7	1.3
Chloroperlidae	Plecoptera	150	36	2.2	*Cricotopus/Orthocladius*	Chironomidae	26	10	1.1
Lopescladius	Chironomidae	139	36	2.0	*Hemerodromia*	Other Diptera	25	10	1.1
Saetheria	Chironomidae	138	60	2.0					(89.7)
Taeniopteryx	Plecoptera	92	22	1.3					
Ephemerellidae	Ephemeroptera	85	14	1.2					
Isoperla	Plecoptera	73	21	1.1					
				(90.0)					
Total abundance		6,817	677		Total abundance		2,355	381	
Richness		28.3	0.9		Richness		21.7	1.6	
Total richness		56			Total richness		68		

Muskeg River - Erosional Habitat					Muskeg River - Depositional Habitat				
Taxon	Major Group	Mean	Standard Error	% of Total Abundance	Taxon	Major Group	Mean	Standard Error	% of Total Abundance
Baetis	Ephemeroptera	4540	617	44.6	*Micropspectra*	Chironomidae	27,881	5,976	47.8
Lopescladius	Chironomidae	1621	518	15.9	Tubificidae	Oligochaeta	5,871	3,048	10.1
Hydracarina	Hydracarina	584	62	5.7	*Tanytarsus*	Chironomidae	4,297	1,493	7.4
Ephemerellidae	Ephemeroptera	417	104	4.1	*Larsia*	Chironomidae	3,884	957	6.7
Thienemannimyia complex	Chironomidae	340	135	3.3	*Pisidium/Sphaerium*	Pelecypoda	2,612	553	4.5
Micropspectra	Chironomidae	313	101	3.1	*Procladius*	Chironomidae	1,201	297	2.1
Chloroperlidae	Plecoptera	282	52	2.8	*Polypedilum*	Chironomidae	1,069	248	1.8
Plecoptera	Plecoptera	251	78	2.5	Naididae	Oligochaeta	1,009	432	1.7
Tanytarsus	Chironomidae	225	52	2.2	*Heterotrissocladius*	Chironomidae	980	258	1.7
Naididae	Oligochaeta	131	36	1.3	Nematoda	Nematoda	900	361	1.5
Optioservus	Coleoptera	119	24	1.2	*Paratendipes*	Chironomidae	863	226	1.5
Rheotanytarsus	Chironomidae	113	34	1.1	*Paratanytarsus*	Chironomidae	831	242	1.4
				(87.8)	*Stempellinella*	Chironomidae	745	286	1.3
					Parakiefferiella	Chironomidae	605	118	1.0
					Candona	Ostracoda	591	210	1.0
									(91.5)
Total abundance		10,180	988		Total abundance		58,297	11,418	
Richness		31.8	1.6		Richness		24.7	1.5	
Total richness		77			Total richness		68		

Table 6.24 Significant Correlations Between Habitat Variables and Biological Variables in the Steepbank and Muskeg River Data Sets, Fall 2000

River	Habitat	Variable	Depth	Current Velocity	Chloro-phyll *a*	Substrate WAI[(a)]	Substrate TOC[(b)]	Comment (based on scatterplot)
Steepbank	erosional	Richness	N/T[(c)]	-[(d)]	0.76**	0.60*[(e)]	N/T	
		Nematoda	N/T	-	0.56*	-	N/T	very weak relationship
		Enchytraeidae	N/T	-	-	-0.57*	N/T	
		Baetis	N/T	-	0.54*	-	N/T	
		Tricorythodes	N/T	-	0.66*	-	N/T	
		Thienemannimyia complex	N/T	-	0.82***	-	N/T	
		Micropsectra	N/T	-	0.64*	0.65*	N/T	
		Cricotopus/Orthocladius	N/T	-	-	0.65*	N/T	
Muskeg	erosional	Richness	N/T	-	0.52*	-	N/T	very weak relationship
		Naididae	N/T	-	-	-0.54*	N/T	
		Ephemerella	N/T	-	-	0.73**	N/T	
		Plecoptera (unidentified)	N/T	-0.68**	-	-	N/T	
		Micropsectra	N/T	-	0.55*	-	N/T	very weak relationship
		Rheotanytarsus	N/T	-0.53*	0.54*	-	N/T	very weak relationships
		Tanytarsus	N/T	-0.73**	-	-	N/T	
	depositional	Tubificidae	-0.52*	-	N/T	N/T	-	very weak relationship
		Procladius	-	-0.52*	N/T	N/T	-	

(a) WAI = weighted average index of particle size.
(b) TOC = total organic carbon in bottom sediment.
(c) N/T = not tested; data were not available or habitat variable had limited range.
(d) - = no significant correlation (P>0.05; Spearman rank correlation; n=15).
(e) Significant correlation (* = P<0.05, ** = P<0.01, *** = P<0.001; Spearman rank correlation coefficient [r_S] shown; n=15).

The directions of the significant correlations were generally consistent with the habitat associations of the taxa involved. All correlations with chlorophyll *a* were positive, likely reflecting greater food availability in areas of greater algal growth. Oligochaete (typically depositional taxa) abundances were negatively correlated with mean substrate size, whereas mayfly (erosional taxa) numbers were positively correlated with this variable. Four significant correlations were contrary to expectations: the abundance of the depositional chironomid genus *Micropsectra* was positively correlated with mean substrate size and abundances of stoneflies (Plecoptera), and two erosional chironomid genera (*Rheotanytarsus*, *Tanytarsus*) were negatively correlated with current velocity.

These results suggest that the variation among sites in current velocity, and potentially other habitat features, are not consistently reflected in the biological data. This may be a consequence of sampling a relatively small number of sites, which does not allow a sensitive analysis, or the large natural variation in benthic community characteristics (i.e., patchiness), which may obscure true habitat associations. Additionally, if significant changes in flows occurred in the weeks preceding the field program, instantaneous habitat measurements may not yield an accurate reflection of the physical conditions that shaped the benthic communities.

6.2.3 Summary

Benthic invertebrates were collected during fall 2000 in the lower reaches of the MacKay, Steepbank and Muskeg rivers. Erosional habitat was sampled in the MacKay and Steepbank rivers and both erosional and depositional habitats were sampled in the Muskeg River. The major objective of the surveys was to strengthen the baseline database for these waterbodies and begin routine monitoring in the Muskeg River, which has operating oil sands developments in its basin.

All rivers and habitats supported diverse benthic faunas, with low total abundances in erosional reaches and moderate to high abundances in the depositional reach sampled in the Muskeg River. Taxonomic richness was less variable among rivers and habitats. As in 1998, the erosional reach in the Muskeg River supported the highest number of taxa.

Erosional communities comprised mostly chironomid midges, mayflies and oligochaetes in the MacKay and Steepbank rivers, and chironomids and mayflies in the Muskeg River. Aquatic mites, nematodes and stoneflies were also common in this habitat. The depositional reach of the Muskeg River was dominated by chironomids and oligochaetes, though fingernail clams, nematode worms and seed shrimps were also common. Some of the variation in richness and abundances of common invertebrates within the erosional reaches appeared related to habitat variation (e.g., benthic algal biomass), but relationships contrary to expectations were also found (e.g., erosional taxa negatively correlated with current velocity).

6.3 FISH POPULATIONS

6.3.1 Radiotelemetry Study

Results for the radiotelemetry study on northern pike from the Muskeg River are preliminary. The study is ongoing and will continue to at least June 2001. A complete evaluation of the movement of radio-tagged northern pike will be provided in the 2001 RAMP report.

Table 6.25 presents the number of fish captured and radio tagged in the Muskeg River in the spring of 2000. A total of 25 northern pike was radio tagged, which included 22 adult fish and three juveniles. Juvenile fish were included due to low capture success of adult pike in the Muskeg River. The sex ratio for the radio-tagged fish was 13 males to 12 females. The adult northern pike that were captured in the Muskeg River were a mix of pre-spawning and post-spawning fish, indicating that spawning activity was underway at the time of sampling. No Arctic grayling were captured and it is believed that this species was absent from the Muskeg River during the spring of 2000 (see Section 6.3.2).

Table 6.25 Fish Sampling Results for the Muskeg River Radiotelemetry Study, Spring 2000

Species	Number Captured	Number Observed	Total Number	Number Floy Tagged	Number Radio Tagged		
					Male	Female	Total
northern pike	29	10	39	28	13	12	25
Arctic grayling	0	0	0	-	-	-	-

Detailed information for each radio-tagged fish and results of each tracking survey are presented, in order of transmitter frequency and code, in Appendix VI. Two of the radio-tagged northern pike were captured and removed by anglers at the mouth of the Muskeg River immediately after tagging, reducing the total number of radio-tagged pike to 23.

The following results describing the movements of the remaining northern pike assume that there were further problems with fish survivorship or problems with transmitter function. However, it is recognized that signals may not be recorded for a variety of reasons including deep water, obstructions, battery failure, transmitter frequency shifts or the removal of the fish/tag from the study by anglers or predators. These potential issues will be easier to evaluate once the full year of tracking information is available.

Five northern pike were never located during any of the telemetry surveys and obviously left the telemetry study area immediately after spawning. These fish may have moved farther up the Muskeg River or returned to the Athabasca River and then to Lake Athabasca or to other tributary streams. It is likely that these fish returned to the lake since they were never recorded in the study area during the fall or early winter, as would be expected if they were utilizing the Muskeg River or other tributaries during the open-water period. One additional fish is also suspected to have returned to Lake Athabasca after initially staying in the Muskeg River for a few weeks after the spawning season. Before leaving the study area, this fish was recorded in the Muskeg River or at the river mouth until the end of June.

Four northern pike left the Muskeg River and were absent from the study area for most of the survey period, then returned to the telemetry study area in the fall or early winter. Two of these fish were not recorded in the telemetry study area following tagging until early November, when they were found in the Athabasca River (one at KP 1-9 and one at KP 29). These fish may have utilized other tributaries for the open-water period and returned again to the mainstem river in the fall. The other two fish remained in the Muskeg River until the early summer before leaving the telemetry study area for the remainder of the summer and fall. They were recorded again in the Athabasca River in December/January at KP 37 and KP 239. It is likely these fish also moved to other Athabasca River tributaries during the open-water period and returned to the mainstem river for the winter. Potential movement of pike to other tributaries was confirmed for at least one radio-tagged pike that had remained in the Muskeg River until early June, disappeared from the telemetry study area during the summer and fall and was accidentally found again in the lower Clearwater River during a November flight (the Clearwater River was not included in the tracking survey area, but is located close to the Fort McMurray airport from which the telemetry flights were based).

Six other northern pike were observed to leave the Muskeg River to take up residence in the mainstem Athabasca River. Two of these fish left the Muskeg River immediately after spawning, one left in mid-June and the other three left in September. All six fish then remained in the Athabasca River for the remainder of the survey period with their positions centred at KP 9, KP 10, KP 12, KP 45, KP 137 and KP 195.

The final six radio-tagged fish were found to utilize the Muskeg River for an extended period. All of these fish remained in the Muskeg River throughout the telemetry study period and were still present in the Muskeg River when this report was completed.

The majority (17 out of 23) of the northern pike that were radio tagged in the Muskeg River in the spring are known or believed to have remained in the Athabasca River basin throughout the telemetry study. Following spring spawning activities in the Muskeg River, these 17 fish, in approximately equal proportions, either remained in the Muskeg River, moved to the mainstem Athabasca River or are believed to have utilized other tributaries during the open-water period and returned to the mainstem river in the fall or winter. The remaining fish (6 out of 23) are believed to have returned to Lake Athabasca following the spawning season.

6.3.2 Spawning Survey

6.3.2.1 Historical Habitat Information

Jackpine Creek

Potential spawning habitat in Jackpine Creek was initially described based on available habitats in the various reaches of the watercourse and the distribution of young-of-the-year fish. Hard substrates were observed in small amounts (5-10%) and were limited primarily to Reaches 2 and 3 (Figure 3.6) (Sekerak and Walder 1980). However, only Reach 2 has been described as providing suitable habitat for spawning by species requiring rocky substrates such as Arctic grayling and longnose sucker (Bond and Machniak 1979). This type of spawning habitat was said to be limited to Reach 2 where the gradient is high and there are riffle and pool habitats providing a mix of fine sediments and coarser substrates. Overall, the spawning potential of Reach 2 was described as limited due to the large size of the substrate (i.e., cobbles and boulders), but riffle areas were considered to provide good spawning potential where gravels occur, particularly in the middle portions of the reach (Bond and Machniak 1979). Farther downstream in Reach 1 the spawning potential was considered poor due to reduced gradient and a greater proportion of sand substrate. Areas upstream of Reach 2 were also described as unsuitable due to several beaver dams resulting in sediment and organic deposits. Spawning habitat in upstream areas was described as sporadic and limited to scour areas below beaver dams (R.L.&L. 1989).

Significant spawning migrations and spawning activities have been documented in Jackpine Creek for Arctic grayling and longnose sucker, as well as a small number of northern pike (O'Neil et al. 1982). At that time, spawning was recorded for Arctic grayling and longnose sucker in the high gradient section of Reach 2, from 7.4 to 14.9 km and 5.5 to 14.2 km upstream of the creek mouth for Arctic grayling and longnose sucker, respectively. Limited northern pike spawning occurred closer to the creek mouth in Reach 1. More recent studies have shown that access to Jackpine Creek for these three migrant species is variable, based on beaver activity. These species were not believed to have been able to spawn in Jackpine Creek during the spring of 1995 (Golder 1996) due to impassable beaver dams located near the creek mouth. It is thought that dry weather in recent years has allowed an increased number of beaver dams to be established, resulting in an apparent decline in Arctic grayling numbers in Jackpine Creek since the 1981 survey (Golder 1997a).

Muskeg River

Potential spawning habitat for Arctic grayling, longnose sucker and northern pike in the Muskeg River has been described by various researchers, based on habitat characteristics and the distribution of adult and young-of-the-year fish. The portion of the river upstream of the Jackpine Creek confluence was described as having low gradient, pool habitat with weed growth, several beaver dams that severely restricted fish movement (Griffiths 1973; Sekerak and Walder 1980; Golder 1996) and limited spawning habitat potential for northern pike (R.L.&L. 1989).

Potential spawning habitat for Arctic grayling, longnose sucker and northern pike was recorded in the lower 35 km of the river downstream of Jackpine Creek. The portion of Reach 4 located below Jackpine Creek (Figure 3.6) was thought to have limited spawning potential for all three fish species. At this location the channel consisted primarily of low gradient pool habitat with fine sediments (Sekerak and Walder 1980). Approximately 5% of the reach consisted of boulder/cobble/gravel areas associated with isolated riffle habitats providing low quality spawning habitat for Arctic grayling and longnose sucker (Bond and Machniak 1979; Golder 1996). Small amounts of aquatic vegetation in the lower portion of Reach 4 was thought to provide widespread, but low quality, spawning habitat for northern pike (Sekerak and Walder 1980).

Reach 3 has been described as having a moderate gradient and a uniform mix of fines and gravel, with some cobble/boulder areas; substrate coarseness increases towards the bottom of the reach (Bond and Machniak 1979). The habitat consists of a mix of runs, pools and riffles, with run habitats being deep and slow (Golder 1996). The spawning potential for Arctic grayling and longnose sucker was described as excellent in the gravel areas and low in other areas. Potential northern pike spawning areas in slower flowing habitats and backwater areas were listed as good but uncommon (Bond and Machniak 1979).

Reach 2 flows through an area of cliffs and has been described as the canyon section. It is a high gradient section of the river with a good mix of riffle:pool sequences and a range of different habitat types. It has rocky substrate throughout (50% gravel, 10-30% cobble) providing high quality spawning habitat for Arctic grayling and longnose sucker (Bond and Machniak 1979; Golder 1996). Northern pike spawning habitat is limited to a small number of side slough areas that have minimum flow and aquatic vegetation.

Reach 1 includes a short (0.5 km) section of river near the confluence with the Athabasca River. It is lower gradient than Reach 2 and consists mostly of shallow run habitat with some riffles and pools (Golder 1996). The substrate is composed of fines and gravels, providing limited spawning potential (Bond and Machniak 1979).

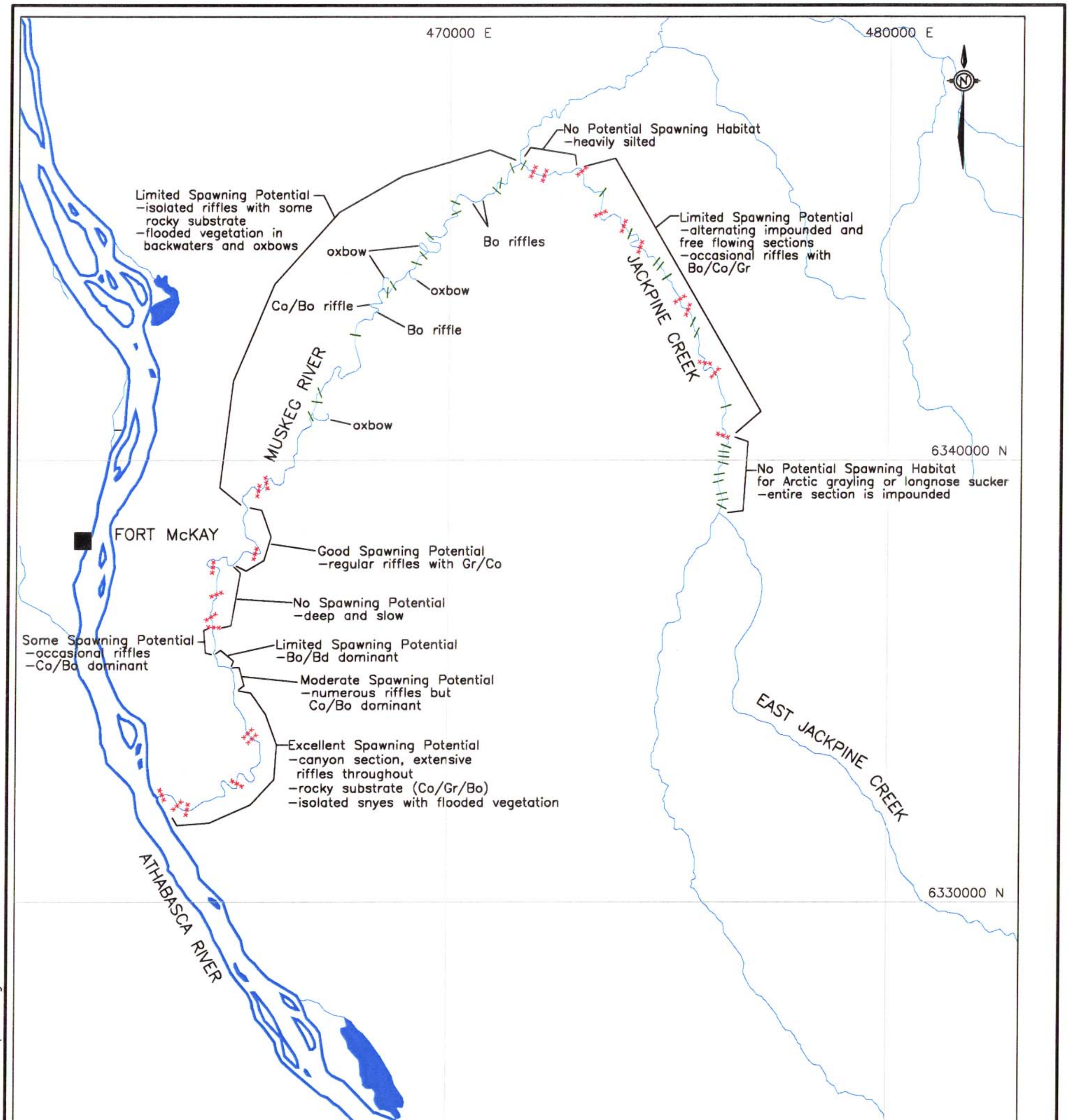
A detailed spawning survey has not been conducted for the Muskeg River in the past. Limited spawning activity of northern pike is thought to occur in Reach 4, upstream of the confluence with Jackpine Creek. These fish are believed to be part of a resident population isolated in this section of river by numerous beaver dams and periodically supplemented by upstream migrants during high water years (R.L.&L. 1989). In general, the Muskeg River is considered a minor spawning area for northern pike (Bond and Machniak 1979). Actual spawning sites for Arctic grayling and longnose sucker have not been documented, but spawning is believed to occur in suitable habitats, as described above, in the portion of the river downstream of Jackpine Creek. White sucker (*Catostomus catostomus*) spawning activity has been observed in the lower few kilometres of the river (Bond and Machniak 1979).

6.3.2.2 2000 Spawning Survey

Jackpine Creek

Current habitat conditions in the surveyed portion of Jackpine Creek (Reaches 1 and 2) relative to spawning potential for Arctic grayling and longnose sucker are presented in Figure 6.11. Also presented is the location of existing beaver dams. For Figure 6.11, large dams are those which were considered impassable and small dams are those which appeared to allow upstream and downstream fish movements.

The initial overflight of Jackpine Creek indicated no spawning potential in Reach 3 or the upper portion of Reach 2. However, the entire length of Reach 2 was included in the ground survey to confirm this observation. The upper portion of Reach 2 was completely impounded by a continuous series of beaver dams and the substrate consisted of fine sediments and organic material, providing little to no potential as spawning habitat (Figure 6.11). Farther downstream, the remainder of Reach 2 consisted of alternating sections of free-flowing stream and sections impounded by beaver dams. Most of the channel in this area consisted of slow pool habitat, but free-flowing sections had some spawning potential associated with riffle habitats. However, the riffle sections were short and dominated by boulder and cobble with very little gravel, limiting their suitability for spawning. The frequency of riffle habitat and availability of rocky substrates increased downstream through Reach 2. Reach 1 did not exhibit any potential spawning habitat as it is heavily dominated by silt laden pools and embedded riffle areas.



0 2.5 5 7.5

SCALE (km)

LEGEND

—	SMALL BEAVER DAM
xxx	LARGE BEAVER DAM
Bo	BOULDER (SUBSTRATE >256mm)
Co	COBBLE (SUBSTRATE 64-256mm)
Gr	GRAVEL (SUBSTRATE 2-64mm)
Bd	BEDROCK

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

RAMP

GENERAL HABITAT CONDITIONS FOR SPAWNING, MUSKEG RIVER AND JACKPINE CREEK

DRAWN: VS	APPROVED:	DATE: 26 Mar. 2001
PROJECT: 002-2309.6450		FIGURE: **6.11**

Revision No.: 02

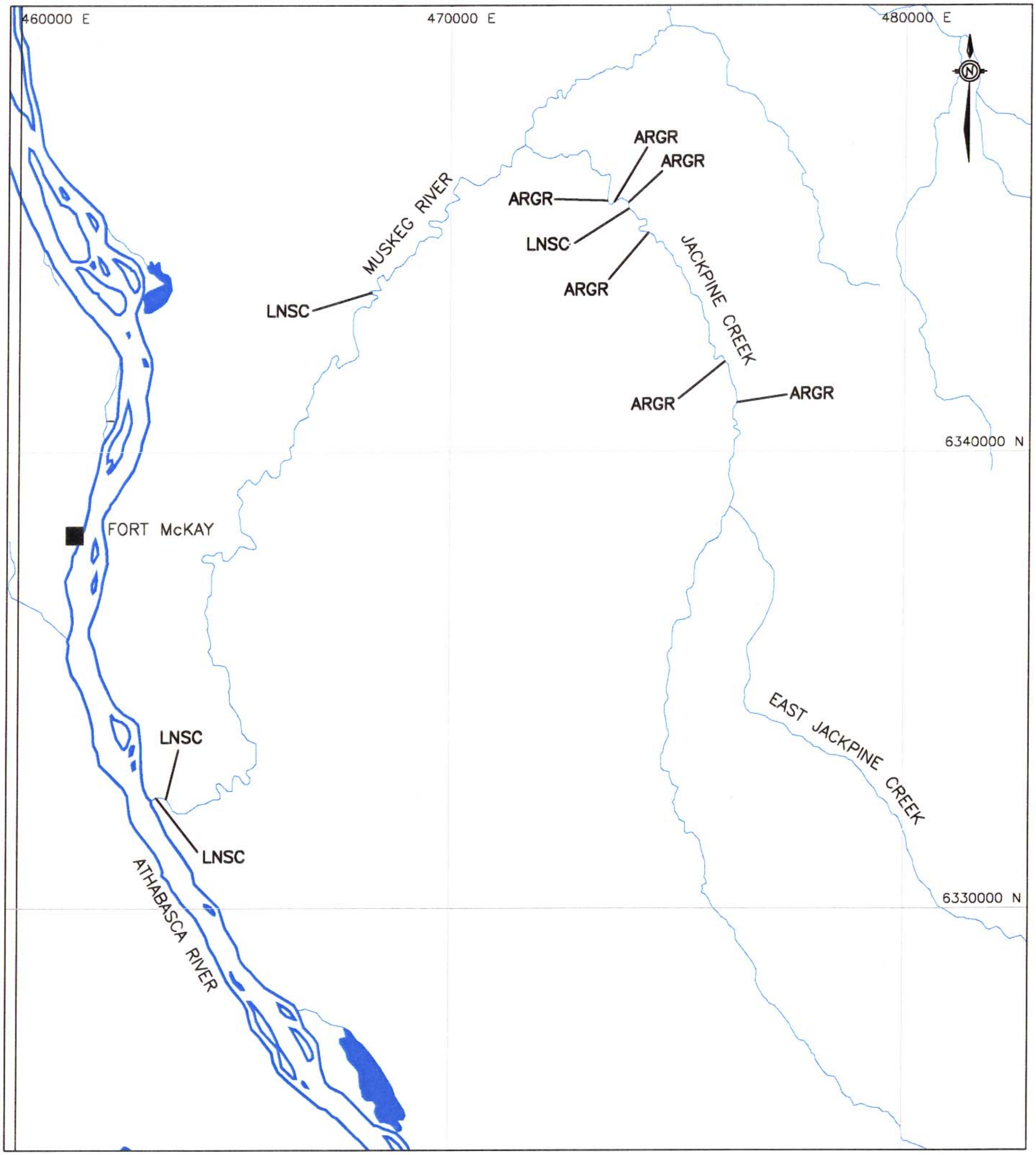
R:\Active\2300\002-2309\CAD\6450\General-Jackpine.dwg

Throughout Jackpine Creek, impounded areas have a firm rocky substrate overlaid by fine sediments and algae. This suggests that available spawning habitat has been reduced as a result of increased beaver activity, the interruption of stream flow and the accumulation of silt and organic material. There is also a large number of beaver dams that have created barriers to fish movement, particularly in the lower portion of the creek (Figure 6.11).

Seven spawning sites were identified in Jackpine Creek in the spring of 2000 by the recovery of incubating eggs: six sites for Arctic grayling and one site for longnose sucker (Figure 6.12). All of the spawning sites were located in Reach 2 and occurred in higher frequency towards the bottom of the reach where the incidence of riffle habitats and coarse substrates was highest. Arctic grayling eggs were identified relative to longnose sucker eggs due to their smaller size (Scott and Crossman 1998). The average diameter for incubating Arctic grayling eggs was 2.0-2.2 mm, compared to 2.8-3.1 mm for longnose sucker.

Habitat characteristics measured at each spawning site are presented in Table 6.26. Almost all incubation sites were situated in areas of gravel substrate, typically in small isolated gravel patches among boulder/cobble riffle habitat. In general, fish were found to use any of the limited spawning habitat that was available.

Although spawning sites identified in the spring of 2000 occurred within the same section of Jackpine Creek as previously documented (O'Neil et al. 1982), the number of spawning sites and the extent of the creek utilized for spawning was notably less than previously recorded. Based on the identification of 13 impassable beaver dams in the surveyed portion of Jackpine Creek, including six large dams in the lower-most section, it was considered unlikely that a spawning run of Arctic grayling or longnose sucker could have accessed Jackpine Creek from the Muskeg River in the spring of 2000. It is also unlikely that the spawning run was able to ascend the Muskeg River from the Athabasca River (see following section). It is believed that the fish spawning in Jackpine Creek represent a portion of the Arctic grayling and longnose sucker populations that have been stranded in the creek by the construction of the dams. These fish would have had to survive the winter in the creek, likely in deeper impoundment areas where water was found to be up to 2.3 m deep. Adult Arctic grayling are known to be summer residents in Jackpine Creek, whereas most longnose sucker are thought to be more transitory and leave the watercourse during the spring following spawning. As such, more Arctic grayling are susceptible to being trapped in the creek, which may explain why a larger number of spawning sites was recorded for this species.



0 2.5 5 7.5
SCALE (km)

LEGEND

ARGR ARCTIC GRAYLING SPAWNING SITE
LNSC LONGNOSE SUCKER SPAWNING SITE

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

RAMP

SPRING 2000 SPAWNING SITES, MUSKEG RIVER AND JACKPINE CREEK

DRAWN: VS	APPROVED:	DATE: 26 Mar. 2001	
PROJECT: 002-2309.6450		FIGURE: **6.12**	

Revision No.: 02

R:\Active\2300\002-2309\CAD\6450\Spr2000-JackpineCk.dwg

Table 6.26 Habitat Data from Spawning Sites in the Muskeg River and Jackpine Creek, Spring 2000

Species	Watercourse	Water Depth (m)	Velocity (m/s)	Substrate Size	General Habitat Type
Arctic Grayling	Jackpine Creek	0.26	0.45	gravel patch	riffle dominated by boulder/cobble with gravel patches
		0.10	0.51	gravel/cobble	riffle below beaver dam with cobble/gravel/boulder substrate
		0.14	0.62	gravel patch	riffle below large dam; boulder/cobble with gravel patches
		0.30	0.41	gravel patch	riffle dominated by boulder/cobble with gravel patches
		0.22	0.41	small cobble	riffle with cobble/boulder/gravel substrate
		0.24	0.59	gravel	riffle with cobble/gravel substrate
Longnose Sucker	Jackpine Creek	0.32	0.53	gravel patch	riffle with cobble/bolder/gravel substrate
	Muskeg River	0.30	0.59	small cobble	riffle dominated by cobble with some boulder/gravel
		0.38	0.48	gravel	riffle with cobble/gravel substrate
		0.35	0.61	gravel	riffle with gravel substrate

Muskeg River

Figure 6.11 presents the general habitat conditions for the surveyed portion of the Muskeg River with respect to potential spawning habitat for Arctic grayling, longnose sucker and northern pike. Figure 6.11 also shows the locations of large (impassable) and small (passable) beaver dams.

The portion of Reach 4 (Figure 6.12) located downstream of Jackpine Creek has very limited spawning potential for fish such as Arctic grayling and longnose sucker that require rocky substrates. A small number of riffles occur in this area; however, the substrate is usually dominated by boulders too large to provide good spawning habitat. The remainder of this section is deep and slow with fine substrate material. Northern pike spawning habitat is available in backwater habitats where flooded vegetation is present, and in oxbow areas that can be accessed from the river (Figure 6.11). Northern pike spawning habitat was considered to be of good quality, but localized and limited in extent.

The gradient of the river increases moderately in Reach 3 and this section of the river is transitional between the slower Reach 4 and the high gradient Reach 2. As such, the availability and quality of spawning habitats in this reach is highly variable. For Arctic grayling and longnose sucker, portions of the reach offer good spawning potential with regular riffles of gravel/cobble substrate. Other sections are slow and deep with no spawning potential for either fish species. The remainder of Reach 3 offers some spawning potential, but the quality is limited either by the low frequency of riffle habitat, or by substrate too large for spawning. Northern pike spawning potential is very limited.

In Reach 2 the gradient of the river increases noticeably. Throughout the reach there is an extensive amount of swift flowing, riffle habitat and rocky substrate. The habitat at the top end of the reach has poor spawning potential because it is dominated by bedrock; however, the majority of Reach 2 consists of cobble/gravel/boulder substrate providing excellent spawning potential for Arctic grayling and longnose sucker. There are also a small number of low velocity snye habitats with aquatic vegetation that provide potential spawning areas for northern pike. These habitats provide moderate quality spawning potential, but they are not numerous.

Reach 1 encompasses only the lower 0.5 km of the river. This area has a moderate gradient and contains riffle habitats with rocky substrates. The substrate size is somewhat smaller than in Reach 2 and this section provides good spawning potential for Arctic grayling and longnose sucker. There is no potential spawning habitat for northern pike.

Specific egg incubation sites located during the spawning survey are presented in Figure 6.12. The only sites recorded were three longnose sucker spawning areas; one located in one of the few riffle areas with cobble and gravel substrate in Reach 4, and two located in Reach 1 near the river mouth. The number of spawning sites identified was much less than expected based on the spring spawning runs of Arctic grayling and longnose sucker that have been documented in the Muskeg River in the past (Bond and Machniak 1977, 1979; Sekerak and Walder 1980; Golder 1996). It is believed that the spawning survey results for spring 2000 do not indicate the typical spawning utilization of this river. Due to the presence of a number of large beaver dams (Figure 6.11), including three in the vicinity of the river mouth, it is suspected that fish were not able to ascend the river during the typical spring migration period. However, heavy rains resulted in increasing water levels and flow of the Muskeg River during the spring such that many of these dams were breached and starting to wash out by the end of the spawning survey (May 25, 2000).

The timing of the spring spawning runs in the Muskeg River is known from the results of past counting fence studies (Bond and Machniak 1977, 1979; Golder 1996). Upstream movements were largely completed by early May for Arctic grayling and mid-May for longnose sucker and northern pike. Small numbers of longnose sucker and northern pike, and very small numbers of Arctic grayling continue to ascend the Muskeg River later in the spring in some years. Spawning activity, based on the capture of ripe and spent fish, has been estimated to be completed by early to mid May for Arctic grayling and early to late May for longnose sucker and northern pike. If fish passage up the Muskeg River was blocked by beaver dams until late May, most of the fish attempting to ascend the river would have been prevented or delayed in completing their spawning run in 2000. Fish would then have either moved on to other areas, possibly ascending other tributaries, or waited at the Muskeg River mouth for an opportunity to continue upstream.

During fish collections for the radiotelemetry study, extensive sampling was conducted on the Muskeg River between Jackpine Creek and the river mouth. Sampling occurred after the beaver dams had been breached and access to the river was possible for migrating fish; however, the numbers of adult longnose sucker and northern pike captured were extremely low and no Arctic grayling were encountered. Based on the known timing of the migrations, it appears that Arctic grayling, which were blocked for an extended period, did not utilize the Muskeg River basin in the spring of 2000. The small number of longnose sucker and northern pike present in the Muskeg River suggests that these fish represent late spring migrants and the majority of the spawners for these species did not wait at the river mouth.

Adult longnose sucker and northern pike that were captured in late May consisted of a mix of pre-spawning, spawning, and post-spawning fish, indicating that spawning activity for both species was underway at the time of sampling. Spawning activity primarily occurred in the lower Muskeg River as fish distribution in the spring of 2000 was limited almost entirely to Reaches 1, 2 and 3. No northern pike and only a very small number of longnose sucker were captured in Reach 4. Small spawning groups of longnose sucker were encountered in suitable habitat in riffle areas throughout Reaches 1, 2 and 3. Spawning groups of northern pike were recorded in large backwater areas and snye habitats, primarily in Reach 2.

It is apparent that the spring spawning survey, although conducted during the typical spawning season, occurred prior to when migrating fish could access the Muskeg River from the Athabasca River. The longnose sucker egg incubation site located in Reach 4 could have been the result of adult fish that overwintered in the Muskeg River because they had been trapped by the construction of numerous beaver dams. The remaining incubation sites were located near the river mouth and were recorded following the washout of the dams and, therefore, could represent spawning activity by migrant fish. It was noted that the dams on Jackpine Creek remained intact following the spawning survey and that access to this watercourse by spawning fish was still not possible. Spawning activity in the Muskeg River for the spring of 2000 is better represented by the distribution of spawning groups observed during fish sampling activities rather than the survey for incubating eggs.

6.3.3 Reference Site Survey

6.3.3.1 Physical Habitat Conditions

The 13 sites sampled along the seven rivers visited represent a range of channel widths (13.5-34.9 m) and flow levels (1.3-9.1 m^3/s). Areas sampled for slimy sculpin were riffle and turbulent run habitats with vegetated and generally stable banks. Bank instability was, however, noted at the exposure site at the Steepbank River and sites along the Hangingstone and Ells rivers. Surficial bed material consisted of cobble with varying proportions of either boulder, or gravel-sized material. Mean water velocities ranged between 0.45 and 0.95 m/s, with mean water depths generally less than 0.35 m. The following text describes physical habitat conditions at exposure and potential reference sites in greater detail. Tables 6.27 and 6.28 summarize habitat characteristics measured at each site. Photos of each site are provided in Appendix VII.

Table 6.27 Flow Characteristics of Exposure and Reference Sites, September 18-23, 2000

Site	Channel Width	Mean Water Velocity (m/s)	Mean Water Depth (m)	Discharge (m^3/s)
Exposure Sites				
Muskeg River (MR-FF)	21	0.45	0.63	6.0
Muskeg River (MR-MT)	18.9	0.95	0.33	6.0
Steepbank Mine (SR-MN)	n/m	0.89	0.28	n/m
Reference Sites				
Steepbank River (SR-R)	33.9	0.82	0.33	9.1
Dover River	15.1	0.52	0.2	1.6
Dunkirk River	34.9	0.61	0.28	6.0
Ells River (ER-3)	30.2	0.55	0.41	6.8
Hangingstone River (HR-1)	13.5	0.63	0.15	1.3
Hangingstone River (HR-2)	8.54	0.75	0.2	1.3
Horse River	17.8	0.48	0.29	2.5

Note: n/m: not measured.

Table 6.28 Summary of Channel Characteristics and Surficial Bed Material at Exposure and Reference Sites, Fall 2000

Site	River Length (km)	Pattern	Confinement	Gradient (m/m)	Bed Material
Exposure Sites					
Muskeg River (MR-FF)	110	irregular meander	occasionally confined	0.008	4% fines 76% gravel 20% cobble
Muskeg River (MR-MT)	110	irregular meander	entrenched	0.003	2% fines 45% gravel 47% cobble 6% boulder
Steepbank River (SR-MN)	120	irregular	occasionally confined	0.004	32% gravel 67% cobble 1% boulder
Reference Sites					
Steepbank River (SR-R)	120	irregular meander	occasionally confined	0.006	4% fines 8% gravel 66% cobble 22% boulder
Dover River	146	irregular meander	frequently confined	n/m	5% fines 5% gravel 40% cobble 50% boulder
Dunkirk River	80	irregular meander	occasionally confined	0.005	3% fines 17% gravel 40% cobble 40% boulder
Ells River (R-3)	193	irregular meander	confined	0.023	18% gravel 66% cobble 16% boulder
Ells River (R-4)	193	irregular meander	confined	n/m	5% fines 10% gravel 55% cobble 30% boulder
Hangingstone River (HR-1)	98	irregular meander	unconfined	0.010	5% fines 27% gravel 67% cobble 1% boulder
Hangingstone River (HR-2)	98	irregular	occasionally confined	0.007	33% gravel 66% cobble 1% boulder
Horse River	200	irregular meander	unconfined	0.016	4% fines 35% gravel 48% cobble 13% boulder

n/m: not measured.

Exposure Sites

Exposure sites along the Muskeg River were similar with respect to channel width, discharge and gradient (Tables 6.27 and 6.28). Channel gradient at the exposure site MR-MT was the shallowest of all the sites visited (0.003 m/m). Habitat sampled for sculpin were turbulent runs and riffles with stable and well vegetated banks. Flows were fast and shallow at both sites although the MR-FF was deeper and slower flowing. The surficial bed material at both sites consisted of gravel and cobble with a greater proportion of cobble found at MR-MT.

SR-MN was a mixture of turbulent run and riffle habitats with well vegetated banks. Channel width and discharge was not measured due to unsafe flow conditions across the channel. Discharge was measured upstream at SR-RF to be 9.1 m^3/s. Channel width has been previously measured in this reach to be 20 m. (Sekerak and Walder 1980). Mean water depth and velocity from point measurements were 0.28 m and 0.89 m/s, respectively. Surficial bed material was a mix of gravel (32%) and cobble (67%). Bank erosion and exposed gravel bars occurred along both sides of the reach investigated. SR-MN was the only site where bitumen was found in the floodplain or channels.

Reference Sites

Habitat at each of the potential reference sites sampled for sculpin was a mix of turbulent run/riffle habitat with vegetated banks. Channel widths and flow levels were between 8.5 and 34.9 m, and 1.58 and 9.1 m^3/s, respectively. Channel gradients ranged from 0.0054 to 0.023 m/m. Detailed habitat descriptions are only provided for sites where there was at least moderate capture success for slimy sculpin (i.e., Dunkirk, Hangingstone, Horse, and Steepbank rivers). Detailed habitat measurements were not done along the Ells River because of poor sculpin capture success and limited helicopter time.

The smallest watercourse investigated was the Hangingstone River. Channel width at both sites on this river was less than 14 m and discharge was only 1.3 m^3/s. Flows through riffle habitats were both shallow (<0.2 m) and fast (0.63 to 0.75 m/s). The presence of side channels, instream islands, unstable banks and gravel bars along the channel edges suggest that the channel is more active than the other sites visited. Surficial bed material at the two sites was similar, one third gravel and two thirds cobble.

The Horse River site was steep compared to the other sites where sculpin were abundant (0.016 m/m). Surficial bed material was a mix of gravel, cobble and boulder. Surficial bed material, channel width (17.8 m) and mean water depth (0.29 m) were similar to MR-MT, although discharge and mean water velocity were much lower.

Velocities through the Steepbank River reference site (SR-R) were fast (0.82 m/s) and the discharge was the highest of the reference sites visited. Surficial bed material of riffle and run habitats sampled can be characterized as mainly cobble with some boulder. Generally, the banks were stable and well vegetated although some undercutting was visible along the right downstream bank.

The Dunkirk River site was similar to the Steepbank River reference site. Channel width was 34.9 m, gradient was 0.0054 m/m and surficial bed material was dominated by cobble and boulder. The discharge was lower (6.0 m^3/s), but mean water velocity and depth were similar. Riverbanks were stable and well vegetated.

6.3.3.2 Water Quality

Dissolved oxygen concentrations ranged between 9.09 and 12.97 mg/L (Table 6.29) and above the CCME guideline of 6.5 mg/L for coldwater biota (CCME 1999). The lowest concentration (9.09 mg/L) was measured at MR-FF and was slightly below the CCME guideline of 9.5 mg/L stipulated to protect early life-stages of coldwater biota. Except for the Dover and Muskeg River sites, dissolved oxygen concentrations were all above 11 mg/L.

Table 6.29 Summary of Water Quality Data Collected From Exposure and Reference Sites, September 18-23, 2000

Waterbody	pH	Temperature (ºC)	DO (mg/L)	Conductivity (µS/cm)
Exposure Sites				
Muskeg River (MR-FF)	8.24	11.4	9.09	267
Muskeg River (MR-MT)	8.54	11.0	10.75	273
Steepbank River (SR-MN)	8.69	5.9	12.46	174
Reference Sites				
Steepbank River (SR-R)	8.51	8.1	11.36	166
Dover River	8.53	10.3	9.98	348
Dunkirk River	8.63	7.4	11.31	187
Ells River (ER-1)	8.62	9.1	11.35	173
Ells River (ER-2)	8.66	9.3	11.56	174
Ells River (ER-3)	8.65	8.8	11.4	166
Ells River (ER-4)	8.56	5.6	12.97	130
Hangingstone River (HR-1)	8.38	3.5	12.85	254
Hangingstone River (HR-2)	8.35	3.5	11.71	228
Horse River	8.37	4.6	11.67	92

There was a general trend of decreasing water temperature at sites sampled over the course of the fieldwork (Table 6.29). This coincided with a period of cooler weather (single digit temperatures and light snow) that began on September 18. Conductivity measurements ranged between 92 and 348 µS/cm with the Horse and Dover rivers at either end of this range (Table 6.29). Most sites were between 130 and 267 µS/cm. pH measurements taken at each site were very similar (8.24 – 8.69).

6.3.3.3 Fish Inventory

Eight different species were collected from the 13 sites sampled (Table 6.30). Generally, only four or five species were collected from each site. Lake chub (*Couesius plumbeus*) was the only species collected from the Dover River. Slimy sculpin were collected from all sites except the Dover River and ER-4. All fish collected were either small-bodied species or juvenile longnose sucker and burbot (*Lota lota*). Except for sites on the Ells and Dover rivers, slimy sculpin was the most frequently collected species from riffles. Slimy sculpin made up 41 to 96% of the total number of fish collected from the Steepbank, Muskeg, Horse, Dunkirk and Hangingstone rivers. The high numbers of sculpin may reflect the capture method and habitat type which were specifically selected to collect slimy sculpin. Longnose dace (*Rhinichthys cataractae*) was the most frequently collected species from three of the four sites sampled along the Ells River. Data on slimy sculpin collected during the survey are presented in Appendix VII.

Catch per unit effort (CPUE) at the 13 sites sampled ranged from 1.7 to 18.1 fish/100 seconds of electrofishing. At most sites, CPUE was less than 6 fish/100 seconds; however, at the Horse River, the reference site on the Steepbank River (SR-R) and the lower exposure site on the Muskeg River (MR-MT), CPUE was greater than 10 fish/100 seconds. Abundance of slimy sculpin (mature plus immature) was greatest at reference sites on the Steepbank (SR-R) and Horse rivers, although the abundance of adult sculpin was highest at the Dunkirk and Hangingstone (HR-2) rivers.

The mean total length of slimy sculpin captured from Athabasca River tributary sites ranged between 5.5 and 7.4 cm. The average weight and condition of slimy sculpin ranged between 2.04 and 5.11 g, and 1.03 and 1.23, respectively (Table 6.31). Sculpin condition was greatest at those sites with low sculpin abundance (ER-2, ER-3 and MR-FF). Most sculpin captured from these sites were of adult size (>6.7 cm TL). Most of the sculpin captured from sites with the lowest condition factors (SR-MN and MR-MT) were either juveniles or of unknown maturity. Intermediate levels of condition were calculated for sites with the highest sculpin abundance (Horse River and SR-R).

Table 6.30 Total Number of Each Fish Species Collected at Each Sampling Site, September 2000

Fish Species	Muskeg River		Steepbank River		Ells River				Horse River	Dunkirk River	Dover River	Hangingstone River	
	MR-FF	MR-MT	SR-MN	SR-R	ER-1	ER-2	ER-3	ER-4	1	1	1	HG-2	HG-1
slimy sculpin	13	28	17	57	1	4	8	0	77	25	0	27	18
spoonhead sculpin[(a)]	0	10	9	0	0	0	0	0	0	0	0	0	0
pearl dace[(b)]	7	2	0	5	0	5	0	2	0	12	0	1	0
longnose dace	1	7	8	21	14	9	26	0	2	1	0	9	7
trout-perch	0	0	0	0	1	0	0	0	0	0	0	0	0
lake chub	2	2	2	4	2	8	7	7	0	3	14	1	2
longnose sucker	9	0	0	0	0	8	3	1	1	1	0	0	7
burbot	0	0	0	0	0	0	0	3	0	0	0	0	0
total	32	49	36	87	18	34	44	13	80	42	14	38	34
effort (seconds)	536	480	696	569	489	652	775	766	443	852	265	536	1,035
CPUE (fish/100 sec)	5.9	10.2	5.2	15.3	3.7	5.2	5.7	1.7	18.1	4.9	5.3	7.1	3.3
number of species	5	5	4	4	4	5	4	4	3	5	1	4	4

[(a)] *Cottus ricei.*
[(b)] *Margariscus margarita.*

Table 6.31 Summary of Length, Weight and Condition Measurements of Sculpin Captured from Reference and Exposure Sites, September 18-23, 2000

Site	Total Length (cm)	Weight (g)	Condition
Exposure Sites			
Muskeg River (MR-FF)	7.38 (0.17)	5.11 (0.48)	1.23 (0.05)
Muskeg River (MR-MT)	5.70 (0.24)	2.24 (0.31)	1.06 (0.02)
Steepbank River (SR–MN)	5.94 (0.18)	2.27 (0.19)	1.03 (0.03)
Reference Sites			
Steepbank River (SR-R)	5.71 (0.10)	2.19 (0.13)	1.14 (0.02)
Dunkirk River	6.92 (0.23)	3.91 (0.28)	1.13 (0.03)
Ells River (ER-2)	7.33 (0.27)	4.93 (0.67)	1.24 (0.10)
Ells River (ER-3)	6.25 (0.53)	3.21 (0.56)	1.23 (0.08)
Hangingstone River (HR-1)	6.88 (0.28)	4.08 (0.49)	1.14 (0.03)
Hangingstone River (HR-2)	6.24 (0.26)	2.94 (0.31)	1.08 (0.02)
Horse River	5.47 (0.08)	2.04 (0.39)	1.09 (0.12)

6.3.3.4 Reference Site Suitability

The response of slimy sculpins at exposure sites on the Steepbank and Muskeg rivers to oil sands development is defined relative to sculpin collected at reference sites. Differences in sculpin abundance and habitat conditions can make the interpretation of differences in whole-organism characteristics between reference and exposure sites less clear. One of the objectives of the study was to identify additional reference sites with similar habitat characteristics and sculpin abundance to exposure sites on the Steepbank and Muskeg rivers. The advantage of sampling several reference sites is that the range of natural variability in whole-organism characteristics of slimy sculpin in the Oil Sands Region can be more accurately defined. The comparability of different reference sites to exposure sites along the Steepbank and Muskeg rivers is discussed below.

Sculpin abundance and habitat characteristics at reference and exposure sites indicate that reference sites for the Steepbank River could be established upstream of oil sands development (SR-R) and in other drainages (Dunkirk River). Reference sites of comparable channel size to SR-MN include SR-R, and sites on the Dunkirk and Ells River. SR-R is similar in size and gradient to SR-MN although surficial bed material is larger with more boulders. Sculpin abundance at SR-R was three times greater than that reported for the fall of 1999 (10 vs. 3.3 fish per 100 sec.) but, of the 57 sculpin captured, only six were adult sized. Low adult abundance may reflect the removal of 80 adult sculpin from SR-R as part of the 1999 sentinel species monitoring program. Physical habitat characteristics and water quality parameters measured at the Dunkirk River site were similar to SR-MN although surficial bed material was larger with more boulder. A large number of adult-sized sculpin (20) were captured within a relatively short period of electrofishing (852 seconds). Water quality parameters measured at both reference sites were very similar to that measured at the Steepbank Mine site. Despite an abundance of clean, gravel/cobble riffle areas, few to no sculpin were captured at the four sites sampled along the Ells River. Bitumen out-croppings found at SR-MN were not identified at any of the reference sites.

The Horse River site (HR-1) was the only site of comparable channel size to the Muskeg River sites. A large number of sculpin were electrofished from the Horse River (CPUE 17.4 sculpin per 100 sec) although only six of 77 sculpin captured were adult sized. The CPUE for sculpin from the Horse River was several times greater than sculpin CPUE from the Muskeg River sites in both the fall of 1999 and 2000. Key habitat differences between the Horse and Muskeg River sites included a steeper channel gradient, larger bed material, lower discharge and relatively low water conductivity. Although located within a smaller watercourse, riffle habitat sampled on the Hangingstone River less than a kilometre downstream of the Highway 63 Bridge provided good sculpin habitat and sculpin abundance was equal to, or greater than, the Muskeg River sites. Secondly, 14 of the 27 sculpin captured were adult. While the Hangingstone River is smaller than the Muskeg River, water quality parameters, the size of bed material and channel gradient were more similar to the Muskeg River than the values measured at the Horse River site.

Reference sites visited during the fall of 2000 do not provide perfect matches with exposure sites. However, physical habitat characteristics and water quality parameters are reasonably similar (i.e., riffle habitat with cobble dominated substrates). Sampling reference sites on the Dunkirk, Horse and Hangingstone rivers in addition to SR-R is recommended as part of future sentinel species monitoring programs. These reference sites will provide a more accurate description of the natural variation in whole-organism characteristics between slimy sculpin populations.

Although the collection method is somewhat biased to their capture, slimy sculpin abundance at exposure and reference sites indicate that the species is best suited for sentinel species monitoring. No other species was collected from riffle habitats in comparable numbers. Recent work with slimy sculpin populations in New Brunswick has also helped to validate assumptions regarding limited home ranges and for organismic parameters to reflect local conditions (M. Gray, University of New Brunswick, Fredericton, NB, unpubl. data). Additionally, the low number of fish species captured during this and past field studies limits the utility of alternate bioassessment approaches (e.g., IBI) to monitor ecosystem health of Athabasca River tributaries (Bramblett and Fausch 1991; Selong and Helfrich 1998).

Four of the nine reference sites visited outside of the Steepbank and Muskeg drainages supported sufficiently large slimy sculpin populations for sentinel species monitoring. Measurements of physical habitat characteristics and water quality identified several differences between exposure and these potential reference sites. Except for channel width and flow volume, most differences are considered minor. It is recommended that instead of direct comparisons with exposure sites, evaluations of whole organism characteristics at exposure sites should be done relative to:

- a regional level of variation defined by sculpin populations within the Steepbank, Dunkirk, Horse and Hangingstone river drainages; and
- past sampling events (i.e., sentinel species monitoring done in 1999).

Our current understanding of the ecology of slimy sculpin (and other fish species residing in riffle habitats) in Athabasca River tributaries is limited. Several reference sites will more accurately define natural variation in the growth, reproduction and survivorship of slimy sculpin populations.

6.3.4 Summary

A radiotelemetry study of northern pike and Arctic grayling was initiated to evaluate their mobility and residency time within the Muskeg River basin and Athabasca River. Twenty-five northern pike captured in the Muskeg River were radio tagged. Unfortunately, no Arctic grayling were found in the Muskeg River during the study. It is believed the normal spawning run of Arctic grayling in 2000 in the Muskeg River was prevented by the presence of numerous large beaver dams. A majority of radio-tagged northern pike was believed to remain in the Athabasca River basin utilizing the Muskeg River, the mainstem Athabasca River and other tributaries (e.g., Clearwater River) during the open-water period. Six northern pike were believed to move to Lake Athabasca following spring spawning season. Further analyses of the movement patterns of northern pike will be conducted following the completion of the radiotelemetry study in 2001.

A spawning survey was conducted on Jackpine Creek and the lower portion of the Muskeg River to evaluate spawning habitat quality/quantity and utilization. Based on past studies, suitable habitat was available for Arctic grayling, sucker species and northern pike. However, during the 2000 survey the availability and accessibility of suitable spawning habitat was greatly reduced due to the presence of numerous beaver dams on Jackpine Creek and the Muskeg River. Only seven spawning sites were identified in Jackpine Creek by recovery of incubating eggs;

six sites for Arctic grayling and one site for longnose sucker. Similarly, only three sites for longnose sucker were found in the Muskeg River. It is likely that access to spawning habitat in the Muskeg River system was greatly reduced by large beaver dams. As such, it is believed that the results of the 2000 spawning survey do not represent the typical spawning use of these watercourses when beaver activity is less prevalent.

A survey was conducted to identify additional reference sites for sentinel species monitoring of the Muskeg and Steepbank rivers. Nine sites along the Dover, Dunkirk, Ells, Hangingstone and Horse rivers were evaluated based on capture success of slimy sculpin (sentinel species) and similarity of habitat to previously identified exposure sites. Four of nine reference sites support sufficiently large slimy sculpin populations for sentinel species monitoring. Habitat conditions at these sites were not identical to exposure sites; however, physical characteristics and water quality parameters were reasonably similar. In particular, the site on the Dunkirk River was most similar to the exposure site on the Steepbank River; whereas sites on the Horse and Hangingstone (HR-1) rivers were most similar to the exposure site on the Muskeg River. Regardless, it is recommended that all reference sites be used in comparisons with each exposure site in an effort to more accurately define natural reference variation in growth, reproduction and survivorship of slimy sculpin populations.

7 WETLANDS – RESULTS AND DISCUSSION

7.1 WATER QUALITY

7.1.1 Kearl Lake

Kearl Lake water quality in Fall 2000 was similar to historical water quality (Table 7.1). However, there were several exceptions. Parameter concentrations that increased in 2000 compared to historical levels included pH, total dissolved solids and dissolved zinc. Parameter concentrations that decreased included total phosphorus, cobalt, manganese, molybdenum and nickel, as well as dissolved copper, iron and nickel.

The 2000 Kearl Lake water sample was found to be non-toxic (as defined by Microtox® testing), and naphthenic acids were not detected. In 2000, silver and mercury detection limits were higher than Alberta surface water quality guidelines (Table 7.2). In previous sampling events, silver concentrations in Kearl Lake have exceeded the chronic guideline of 0.1 mg/L.

7.1.2 Isadore's Lake

Fall water quality in Isadore's Lake changed little from 1997 to 2000 (Table 7.1). In both years, sample waters were non-toxic (as defined by Microtox® testing), and naphthenic acids were not detected. Notable differences between the two sampling events included increased concentrations of total nitrogen, total phosphorus, chlorophyll *a*, biological oxygen demand and total chromium, iron, selenium and zinc (Table 7.1). Total aluminum, copper, manganese and nickel concentrations, as well as dissolved aluminum, arsenic, copper, manganese and molybdenum concentrations, were lower in 2000 than in 1997. Total nitrogen, total phosphorus and selenium concentrations in the 2000 sample exceeded corresponding chronic guidelines for the protection of aquatic life (Table 7.2). As with Kearl Lake, the detection limits for mercury and silver exceeded guidelines.

Table 7.1 Wetlands Water Quality

Parameter	Units	Kearl Lake (Fall) 2000	Kearl Lake (Fall) Historical Median[(a)]	Isadore's Lake (Fall) 2000	Isadore's Lake (Fall) 1997[(b)]	Shipyard Lake Summer 2000	Shipyard Lake Summer H. Median[(c)]	Shipyard Lake Fall 2000	Shipyard Lake Fall 1999[(d)]	McClelland Lake Spring 2000	McClelland Lake Fall 2000 Trip 1	McClelland Lake Fall 2000 Trip 2
Field Measured												
pH		8.1	7.4	-	-	-	8.9	7.7	8.7	-	9.0	8.6
specific conductance	µS/cm	159	170	-	-	-	264	346	333	-	234	220
temperature	^{o}C	6.3	2.0	-	-	-	22.8	7.3	2.2	-	13.0	7.2
dissolved oxygen	mg/L	11.0	13.7	-	-	-	14.0	9.0	8.2	-	10.7	11.5
Conventional Parameters												
dissolved organic carbon	mg/L	17	19	9	9	17	16	18	17	10	12	17
total alkalinity	mg/L	92	85	173	136	142	135	159	165	137	128	129
total dissolved solids	mg/L	220	94	250	220	220	149	200	240	105	165	140
total organic carbon	mg/L	22	25	11	12	19	24	21	19	11	14	20
total suspended solids	mg/L	4	2	5	6	6	175	15	5	< 3	< 3	5
Major Ions												
chloride	mg/L	< 1	1	4	2	13	5	18	11	1	< 1	< 1
sulphate	mg/L	6	4	64	38	5	2	11	6	3	2	2
Nutrients and Chlorophyll *a*												
nitrate + nitrite	mg/L	< 0.05	0.02	< 0.05	0.07	< 0.05	0.03	< 0.05	< 0.10	< 0.05	< 0.05	< 0.05
nitrogen – ammonia	mg/L	< 0.10	0.08	< 0.10	0.11	< 0.10	0.07	< 0.10	< 0.05	< 0.10	< 0.10	< 0.10
nitrogen – total	mg/L	0.4	1.0	1.2	0.5	1.1	0.8	1.2	0.8	0.7	0.8	0.5
phosphorus, total	µg/L	11	27	75	12	20	31	16	17	14	14	15
chlorophyll *a*	µg/L	2	3	10	< 1	2	5	-	-	2	3	1
Biochemical Oxygen Demand												
biochemical oxygen demand	mg/L	< 2	2	6	2	< 2	3	-	< 2	< 2	2	< 2
Organics												
naphthenic acids	mg/L	< 1	< 1	< 1	1	< 1	< 1	2	< 1	< 1	-	2
total phenolics	µg/L	< 1	5	< 1	< 1	< 1	3	< 1	6	< 1	2	3

Table 7.1 Wetlands Water Quality (continued)

Parameter	Units	Kearl Lake (Fall)		Isadore's Lake (Fall)		Shipyard Lake				McClelland Lake		
						Summer		Fall		Spring	Fall 2000	
		2000	Historical Median[(a)]	2000	1997[(b)]	2000	H. Median[(c)]	2000	1999[(d)]	2000	Trip 1	Trip 2
Toxicity[(e)]												
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 91	> 91	> 91	-	-	> 91
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91	68	> 91	> 91	> 91	-	-	> 91
Total Metals												
aluminum (Al)	µg/L	20	< 10	< 20	62	160	50	140	30	70	60	< 20
antimony (Sb)	µg/L	< 5.0	2.3	< 5.0	0.7	< 5.0	0.2	< 5.0	< 0.8	< 5.0	< 5.0	< 5.0
arsenic (As)	µg/L	< 1.0	< 0.3	< 1.0	1.8	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
barium (Ba)	µg/L	20	68	82	55	42	30	32	27	37	32	31
cadmium (Cd)	µg/L	< 0.2	< 1.0	< 0.2	0.3	< 0.2	< 3.0	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
chromium (Cr)	µg/L	< 1	< 2	3	< 0.4	< 1	4	4	2	2	1	< 1
copper (Cu)	µg/L	2	< 1	< 1	7	< 1	1	4	< 1	20	1	< 1
iron (Fe)	µg/L	50	90	130	< 10	4,660	2,220	420	270	40	< 20	< 20
lead (Pb)	µg/L	0.8	< 2.0	< 0.1	0.9	1.3	< 20.0	< 0.1	< 0.1	2.6	1.1	0.3
manganese (Mn)	µg/L	7	16	13	43	79	179	6	15	20	8	7
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.2	< 0.1	< 0.2	< 50.0	< 0.2	< 0.2	-	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.2	2.0	< 0.1	0.8	< 0.1	< 3.0	< 0.1	0.2	0.2	0.1	< 0.1
nickel (Ni)	µg/L	0.8	3.0	< 0.2	1.2	1.5	8.0	< 0.2	1.6	2.7	2.0	1.0
selenium (Se)	µg/L	< 0.8	< 0.7	1.1	< 0.4	< 0.8	< 1.0	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	1.7	< 0.4	< 0.1	< 0.4	< 2.0	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
zinc (Zn)	µg/L	15	9	32	12	12	12	31	< 4	28	46	5
Dissolved Metals[(f)(g)]												
aluminum (Al)	µg/L	< 10	30	< 10	35	110	35	< 10	< 10	30	60	< 10
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	0.5	1.0	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	1.6	0.6	0.9	0.4	< 0.4	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	17	18	80	54	28	25	27	28	32	30	31

Table 7.1 Wetlands Water Quality (continued)

Parameter	Units	Kearl Lake (Fall)		Isadore's Lake (Fall)		Shipyard Lake				McClelland Lake		
						Summer		Fall		Spring	Fall 2000	
		2000	Historical Median[a]	2000	1997[b]	2000	H. Median[c]	2000	1999[d]	2000	Trip 1	Trip 2
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	0.3	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.5	0.8	2.0	0.9	< 0.4
copper (Cu)	µg/L	< 0.6	1.4	< 0.6	1.5	< 0.6	1.1	1.5	0.9	< 0.6	0.9	**3.0**
iron (Fe)	µg/L	< 10	90	< 10	**20**	280	805	< 10	220	< 10	10	< 10
lead (Pb)	µg/L	< 0.1	0.3	0.1	0.3	0.9	0.2	0.1	< 0.1	0.5	1.1	0.2
manganese (Mn)	µg/L	4	4	**15**	34	33	51	3	3	2	2	1
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.2	< 0.1	0.2	< 0.1	0.03	< 0.02	< 0.02	< 0.1
molybdenum (Mo)	µg/L	0.2	< 0.1	< 0.1	0.7	< 0.1	< 0.9	**0.2**	0.2	0.1	**0.2**	**0.2**
nickel (Ni)	µg/L	0.2	1.6	0.2	0.8	**1.6**	0.4	0.4	**1.8**	0.5	1.6	< 0.1
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	11	5	11	**17**	**15**	< 2	6	3	4	43	**13**

(a) Based on information from Golder (1996, 1999b) and R.L.&L. (1989).

(b) Based on information from Golder (1997a).

(c) Based on information from Golder (1996, 1999b, 2000c).

(d) Based on information from Golder (2000c).

(e) Results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms used in the Microtox® test live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

(f) Occasionally, a dissolved metal level reported by ETL was higher than the respective total metal concentration (bolded values); this problem was detected too late for sample re-analysis; in future, lab results will be screened sooner to allow for sample re-analysis if and when required.

(g) Historical total and dissolved metal concentrations may differ, because of varying sample size (e.g., four total metal readings compared with only two dissolved metal values).

\- = No data.

Table 7.2 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in RAMP Wetlands

		Guidelines for the protection of			Kearl Lake (Fall)		Isadore's Lake (Fall)		Shipyard Lake				McClelland Lake		
		Aquatic Life[(a)]		Human		Historical			Summer		Fall		Spring	Fall 2000	
Parameter	**Units**	**Acute**	**Chronic**	**Health[(b)]**	**2000**	**Median**	**2000**	**1997**	**2000**	**H. Median**	**2000**	**1999**	**2000**	**Trip 1**	**Trip 2**
Nutrients															
nitrogen – total	mg/L	-	1	-			C		C		C				
phosphorus, total	µg/L	-	50	-			C								
Total Phenolics															
total phenolics	µg/L	-	5	-								C			
Total Metals															
aluminum (Al)	µg/L	750	100	-					C		C				
copper (Cu)	µg/L	*	*	1300									A C		
iron (Fe)	µg/L	-	300	300					C H	C H	C H				
manganese (Mn)	µg/L	-	-	50					H	H					
selenium (Se)	µg/L	-	1	170			C								
silver (Ag)	µg/L	*	0.1	-		C									

(a) Guidelines taken from AENV (1999).

(b) Guidelines taken from U.S. EPA (1999).

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

- No guideline.

7.1.3 Shipyard Lake

Summer and fall water quality in Shipyard Lake in 2000 was generally comparable with historical data (Table 7.1). Exceptions included increased chloride, sulphate, aluminum, total iron, dissolved nickel and dissolved zinc concentrations in the summer of 2000 compared to historical data. Parameters observed at lower concentrations in Summer 2000 included total suspended solids, total chromium, manganese and nickel. The Summer 2000 sample was identified as being toxic to bacteria (i.e., Microtox® IC_{25} = 68%).

Total suspended solids, total and dissolved zinc, and total aluminum concentrations increased in Fall 2000 compared to Fall 1999. Parameters that decreased in concentration in Fall 2000 were pH, total phenolics, nickel and dissolved iron. Naphthenic acids were detected for the first time in Shipyard Lake in fall 2000, although the concentration is close to the detection limit.

Water quality guidelines were exceeded in both the summer and fall of 2000 (Table 7.2). They included chronic guidelines for the protection of aquatic life for total nitrogen, aluminum and iron. Total iron and manganese concentrations were higher than human health guidelines in the summer and/or fall in 2000.

7.1.4 McClelland Lake

Water samples were obtained from McClelland Lake on three separate occasions in 2000: once in the spring and twice in the fall. Water quality was generally consistent across all three sampling events (Table 7.1). Total copper, lead, manganese and dissolved chromium concentrations were greatest in the spring and decreased through the fall. Dissolved zinc levels were higher in fall.

Naphthenic acids were detected in the second fall sampling event. Toxicity testing indicated that these waters were non-toxic to bacteria. Total copper concentrations in spring exceeded both the acute and chronic guidelines for the protection of aquatic life (Table 7.2).

7.1.5 Summary

In 2000, water quality in Kearl and Isadore’s lakes was generally consistent with historical data, with the exception of increased nutrient levels in Isadore’s Lake. Toxicity (as defined by Microtox® testing) was observed for the first time in Shipyard Lake, and naphthenic acids were detected in McClelland Lake.

7.2 BENTHIC INVERTEBRATE COMMUNITY

7.2.1 Shipyard Lake

Shipyard Lake sampling locations were one to two metres deep (Table 7.3). Secchi depth was greater than the water depth at all sites. Conductivity was in the moderate range for lakes in the Oil Sands Region and DO was close to saturation. Water temperature was within the expected range for this lake during the fall season, but pH was lower than the previously measured value in fall 1999 (8.7; Golder 2000c).

Bottom sediments were dominated by fine sediments (silt and clay) and contained moderate amounts of organic material (Table 7.3). The lake bottom was completely covered by aquatic vegetation (macrophytes or macrophytic algae) in the depth range sampled. The deeper, central part of the open-water zone in Shipyard Lake is devoid of submergent vegetation.

Table 7.3 Habitat Characteristics of the Benthic Invertebrate Sampling Reaches in Shipyard Lake in Fall 2000

Variable	Units	Mean (range)
sample date	-	September 28, 2000
water depth	m	1.6 (1.2 - 1.9)
Secchi depth	m	>1.9
Field Water Quality		
dissolved oxygen	mg/L	9.0 (7.4 - 10.3)
conductivity	µS/cm	346 (321 - 378)
pH	-	7.6 (7.0 - 7.9)
water temperature	^{o}C	7.3 (7.2 - 7.4)
Bottom Sediments and Macrophyte Cover		
sand	%	2 (1 - 6)
silt	%	43 (40 - 48)
clay	%	55 (51 - 59)
total organic carbon	%	9 (7 - 12)
aquatic macrophyte cover	%	100

Shipyard Lake benthic communities were characterized by low total abundance and moderate richness in absolute terms for lakes, with a total of 31 taxa identified from all samples combined (Table 7.4). However, the communities were reasonably diverse, without dominance by any single group. All common lake-dwelling groups were represented. Chironomid midges, mayflies and snails

(Gastropoda) each accounted for >15% of total abundance. At the level of individual taxon, the lake-dwelling mayfly *Caenis* was the most numerous, though its abundance varied widely among samples (as shown by the large standard error in Table 7.4). Amphipods (*Hyalella azteca*), fingernail clams (Sphaeriidae), seed shrimps, snails (*Gyraulus* and *Armiger crista*) and chironomids were also very common.

Table 7.4 Benthic Community Characteristics in Shipyard Lake in Fall 2000

Variable	Mean	Standard Error	% of Total Abundance
Abundances (number/m^2) of Common Invertebrates			
Caenis	933	365	22.0
Hyalella azteca	387	139	9.1
Sphaeriidae	366	121	8.6
Ostracoda	297	108	7.0
Gyraulus	280	166	6.6
Dero	267	135	6.3
Armiger crista	258	86	6.1
Glyptotendipes	211	102	5.0
Paratanytarsus	211	83	5.0
Enallagma	194	136	4.6
Valvata	125	51	2.9
Psectrocladius	112	50	2.6
Dicrotendipes	95	52	2.2
Endochironomus	95	50	2.2
Procladius	69	37	1.6
Chironomus	65	34	1.5
Ablabesmyia	56	38	1.3
(total %)			(94.5)
Total Abundance and Richness			
Total abundance	4,248	945	--
Number of taxa	11.7	1.4	--
Total taxa in all samples	31	--	--
Composition by Major Groups			
Oligochaeta	301	133	7.1
Ostracoda	297	108	7.0
Amphipoda	387	139	9.1
Pelecypoda	366	121	8.6
Gastropoda	662	225	15.6
Ephemeroptera	933	365	22.0
Odonata	211	137	5.0
Chironomidae	985	201	23.2
Other	108	48	2.5

Correlation analysis found few significant relationships between depth, sediment TOC and biological variables. Depth was negatively correlated with TOC (r_S = -0.81, $P<0.01$, n=10), which may reflect a decline in the density of plant cover with depth due to declining light level. Abundances of *Caenis* and *Paratanytarsus* (chironomid midge) were significantly but weakly positively correlated with total organic carbon in the sediment (r_S=0.67 and 0.64, $P<0.05$, n=10).

The 2000 benthic survey of Shipyard Lake documented a relatively diverse community of low total abundance. These results differ from the findings of the only previous benthic survey of this lake (Golder 1996; August 1996 survey), which reported an impoverished community consisting mostly of oligochaete worms and chironomids tolerant of low dissolved oxygen concentration (*Chironomus* sp.). The differences between these results may be indicative of pronounced seasonal variation (late summer vs. fall) or among-year differences in dissolved oxygen deficit during the summer months.

7.2.2 Summary

Benthic invertebrates were collected in Shipyard Lake during fall 2000. The major objective of the survey was to begin routine monitoring in this lake. The survey documented a relatively diverse community of low total abundance, in contrast with the impoverished fauna documented by the previous survey of this lake. The available data for this lake suggest that benthic communities vary considerably among seasons and/or years.

8 ACID SENSITIVE LAKES – RESULTS AND DISCUSSION

8.1 BACKGROUND INFORMATION

Acid deposition has been modelled in the Oil Sands Region in a number of recent EIAs (Shell 1997, Suncor 1998, Syncrude 1998, Suncor 2000, OPTI 2000). The most useful variable in assessing the effects of acid deposition on lakes is the Potential Acid Input (PAI, in units of keq/ha/yr). PAI considers wet and dry deposition by sulphur and nitrogen compounds, and the mitigating effect of base cations. It is calculated as the sum of sulphur and nitrogen deposition rates from sources within the area being evaluated, plus the background PAI for the region.

The estimated PAI values for the acid-sensitive lakes monitored by RAMP are provided in Table 8.1, using data from Suncor (2000) and OPTI (2000). The PAI values shown in this table represent combined acid deposition from all existing and approved oil sands developments at the time these EIAs were prepared (i.e., baseline scenario). All projects were considered "fully developed" for modelling purposes, which means that the modelled PAI are higher than the existing level of acid deposition to these lakes. Therefore, for the purpose of this document, the modelled PAI are considered to represent "near-future" deposition rates.

As can be expected based on the positions of the RAMP lakes relative to existing and approved oil sands developments (Figure 3.10), only a handful are close to the area of highest acid deposition (E15, L1, L4, L7 and L8). Accordingly, these lakes have the highest modelled PAI values (Table 8.1). There are relatively few acid sensitive lakes in the most heavily developed part of the Oil Sands Region, which limits the spatial resolution of this monitoring program. However, as the number of developments increases in the region (see Figure 3.10 for planned developments), the area of elevated acid deposition is also expected to expand, resulting in the exposure of a larger number of sensitive lakes to acid deposition.

To allow assessment of the potential for acidification in Alberta, the Target Loading Subgroup of the Clean Air Strategic Alliance (CASA) established guidelines for acid deposition rates, including the critical load (CL), target load and monitoring load (CASA 1996, 1999). Of these, the CL is the most useful for aquatic assessments focussing on sensitive lakes. It is defined as the highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems. The CL was set at 0.25 keq/ha/yr for highly sensitive soils in Alberta, and was subsequently extended to sensitive aquatic systems based on a review by Schindler (1996). It is applicable at the spatial resolution of 1° latitude by 1° longitude cells and is not intended for evaluating the effects of acid deposition on individual lakes.

Table 8.1 Modelled "Near-future" Acid Deposition Rates to Acid Sensitive Lakes Monitored by RAMP and Available Lake-Specific Critical Loads

Lake	Modelled PAI (existing and approved developments)		
	Suncor Firebag EIA[a] (keq/ha/yr)	OPTI Long Lake EIA[b] (keq/ha/yr)	Critical Load (keq/ha/yr)[b]
A21	(<0.15)[c]	0.14	0.11
A24	(<0.15)	0.14	0.03
A26	(<0.15)	0.15	0.27
A29	(<0.14)	0.12	0.06
A42	(<0.12)	(<0.12)	--[d]
A47	(<0.12)	(<0.12)	--
A59	(<0.12)	(<0.11)	--
A86	(<0.12)	0.11	0.16
E15 (L15b)	0.18	0.31	0.19
L1	0.17	0.21	0.20
L4 (A-170)	0.16	0.20	0.24
L7	0.15	0.18	0.41
L8	0.15	0.18	0.63
L18 (Namur)	(<0.17)	(0.13)	--
L23 (Otasan)	0.14	(0.12-0.13)	--
L25 (Legend)	(<0.16)	(0.12-0.13)	--
L28	(<0.13)	(<0.12)	--
L30 (W. Clayton)	(<0.13)	(0.13-0.15)	--
L39 (A-150)	(<0.13)	(0.12-0.13)	--
L46 (Bayard)	0.13	(0.12-0.13)	--
L47	(0.13)	(0.12)	--
L49	(0.13)	(0.12)	--
L60	(0.14)	(0.12-0.13)	--

[a] Data from Firebag In-Situ Oil Sands Project EIA (Suncor 2000).
[b] Data from Long Lake Project EIA (OPTI 2000).
[c] PAI values in parentheses are visual estimates based on positions of PAI contours on deposition maps.
[d] -- = not available.

Recent oil sands EIAs have adopted the use of the lake-specific CL, which allows assessment of the potential effects of acid deposition on individual lakes by comparison with modelled PAI values (Syncrude 1998, Suncor 2000, OPTI 2000). This approach takes into account the buffering capacity of each lake being evaluated and inputs of base cations from the lake's catchment area to estimate the critical load for individual lakes. The critical load corresponds to a deposition rate (keq/ha/yr) below which adverse effects are not expected on the lake's ecosystem. In other words, the CL corresponds to the amount of acid deposition below which acid neutralizing capacity (ANC) or pH remain above specified threshold values (e.g., ANC of 75 µeq/L was used by OPTI (2000), approximately corresponding to pH 6).

Lake specific CLs have been calculated for those lakes monitored by RAMP that are located within the regional study areas of recent EIAs (Table 8.1) (Syncrude 1998; Suncor 2000; refined by OPTI (2000) based on information from Andrews [unpubl. manuscript]). Refined CLs are currently being calculated for the entire set of lakes monitored by RAMP, as part of an effort funded by the NO_x and SO_x Management Committee, and will be included in forthcoming RAMP reports.

The most recent lake-specific CLs available for lakes in the Oil Sands Region (Table 8.1) are more conservative than those used elsewhere, because they incorporate a higher threshold ANC value (0 to 50 µeq/L was used in Europe; Kamari et al, 1992; Harriman et al. 1995). In addition, CLs do not incorporate the effects of naturally occurring organic acids on buffering capacity. Organic acids can impart some buffering capacity to brown water lakes, in addition to the carbonate-bicarbonate buffering system (Sullivan 2000).

The lake-specific CLs available for RAMP lakes at this time range from 0.03 to 0.63 keq/ha/yr (Table 8.1). The modelled "near-future" PAIs exceeded the CLs in three lakes located at some distance from sources of acidifying emissions (A21, A24, A29). Of the lakes located close to oil sands developments (E15, L1, L4, L7 and L8), three lakes have CLs that are exceeded or nearly exceeded by the PAI, suggesting there is already some concern regarding acidification in the Oil Sands Region in the foreseeable future.

These observations should be tempered by the conservative nature of this technique. The modelled PAI values in Table 8.1 are believed to be conservative (OPTI 2000). Additionally, lake-specific CLs may be underestimated for reasons outlined above. Comparing these parameters yields a conservative evaluation regarding the potential for acidification, which is subject to future refinement. Refinement of this technique is under way, as part of the efforts of the NO_x and SO_x Management Committee.

In this report, the 2000 data are examined as a "snapshot in time", to provide an evaluation of the current status of each lake with regard to acidification, with special attention to four of the five lakes closest to the area of elevated acid deposition (L1 was not sampled in 2000). Time trends will be evaluated once sufficient data are available for all lakes, likely in about 5-10 years. In the meantime, the data for lakes with longer-term data sets (L4, L7, L25, L18) will be examined periodically for trends related to acidification.

8.2 FIELD PARAMETERS

The field data collected during the survey are provided in Appendix VIII. The correspondence between field and lab pH is examined in the following section. The field parameter data were not analyzed further.

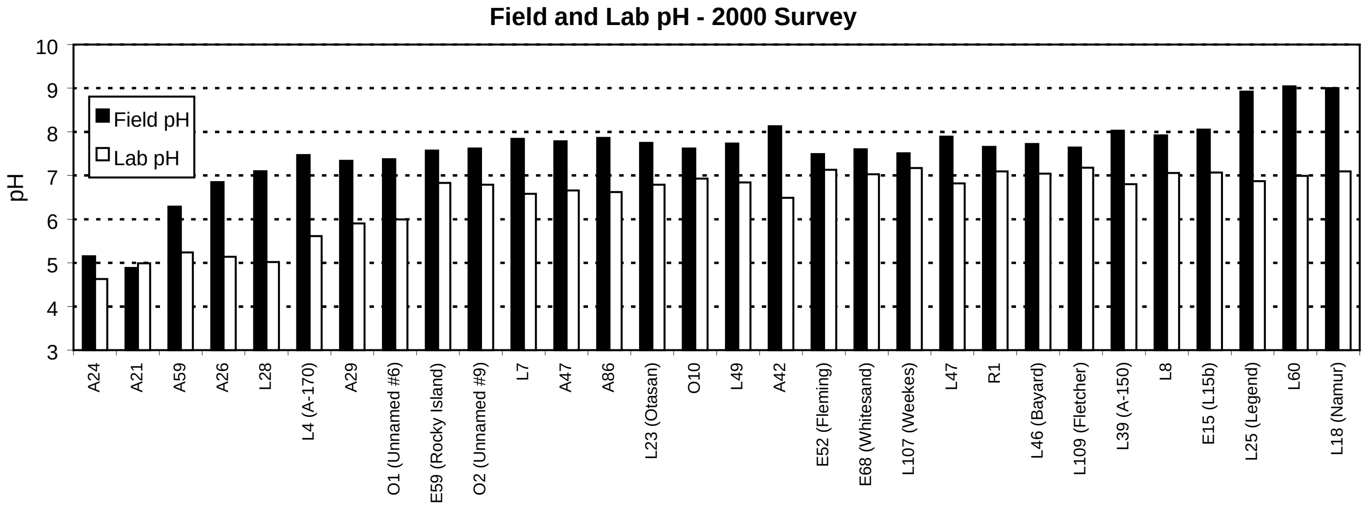
8.3 pH AND ALKALINITY

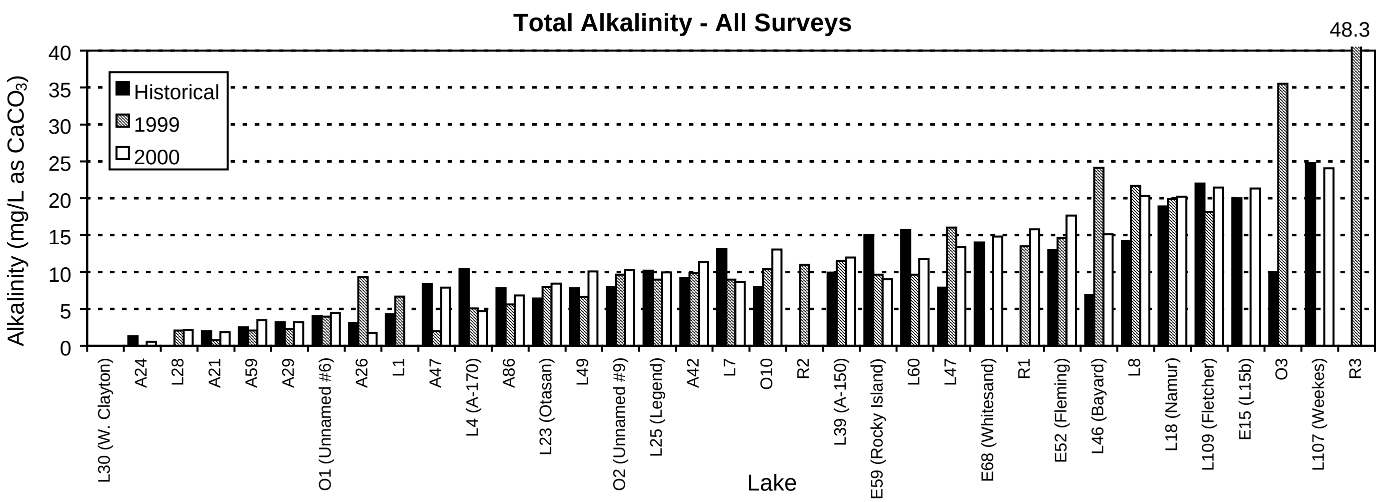
Field pH ranged between 4.9 and 9.0 in 2000, with only four of the 30 lakes having pH <7 (Figure 8.1). As expected, lab pH measurements were lower than field measurements, with one exception (A21). The differences between field and lab pH were close to two pH units for five lakes (L28, L4, L25, L60, L18), and greater than one unit for ten lakes. Differences of one to two units between field and lab measurements are unusual, suggesting they may have resulted from a faulty field pH meter.

The pH data were compared between 1999 and 2000 to determine which measurements (lab or field) were more reliable. Both field and lab pH were generally higher in 2000 than in 1999, but the among-year differences were substantially lower for lab pH (Appendix VIII, Figure VIII-1). Since there were no data quality concerns regarding pH in 1999 and the 2000 lab pH data matched the 1999 data reasonably well, lab pH was again used as the primary measure of acidity in this document. This is consistent with the 1999 RAMP data summary for acid sensitive lakes (Golder 2000c) and previous descriptions of acid sensitivity in Alberta (e.g., Saffran and Trew 1996).

Total alkalinity varied moderately among lakes, with an overall range of 0.55 to 24.06 mg/L as $CaCO_3$ in 2000 (Figure 8.1). Excluding the two lakes (O3 and R3) that were not resampled in 2000 because of insufficient level of acid sensitivity in 1999, the variation in alkalinity among years was relatively low for most lakes. Moderate variation (2-fold or greater) among years was observed for a small number of lakes (A26, A47, L4, L46), but are of no concern regarding data quality or acidification. An examination of time series data for selected lakes during the 1999 RAMP survey (Golder 2000c) found that total alkalinity may vary up to 2.5-fold between consecutive years and up to 5.6-fold from the minimum to the maximum value for the period of record in lakes where acidification has not occurred.

Figure 8.1 Comparisons of Field and Lab pH in the Lakes Sampled in 2000 (top) and Total Alkalinity Data Available for the Lakes Monitored (bottom)





Notes: Historical and 1999 alkalinity measurements were 0 mg/L in Lake L30 (W. Clayton); this lake was not sampled in 2000 because it was fogged in.
Historical alkalinity measurement was 0 mg/L in Lake L28.
1999 alkalinity measurement was 0 mg/L in Lake A24.

Gran alkalinity was highly correlated with total alkalinity, but tended to be slightly lower in lakes with very low alkalinity (Figure 8.2). Gran alkalinity differs from total alkalinity in the titration endpoint during laboratory analysis. Total alkalinity is measured by titration to a fixed pH of 4.5, whereas the endpoint for Gran alkalinity is determined using a graphical method (Gran 1952). Gran alkalinity is the method of choice for waters that have low ANC and elevated concentrations of organic compounds (Sullivan 2000). Overall, the two measures of alkalinity used in this survey provided a consistent indication of ANC in the lakes monitored.

There was a strong, non-linear relationship between log-alkalinity and pH (Figure 8.2). As in 1999, the “steepest” part of the curve was below the alkalinity value of 10 mg/L as $CaCO_3$. The lakes in this category are particularly susceptible to acidification, because even small changes in alkalinity will result in rapid changes in pH. pH was also positively correlated with total alkalinity, bicarbonate, DIC and concentrations of base cations (Ca^{2+} and Mg^{2+}) (Pearson correlations, $r>0.7$, $P<0.001$).

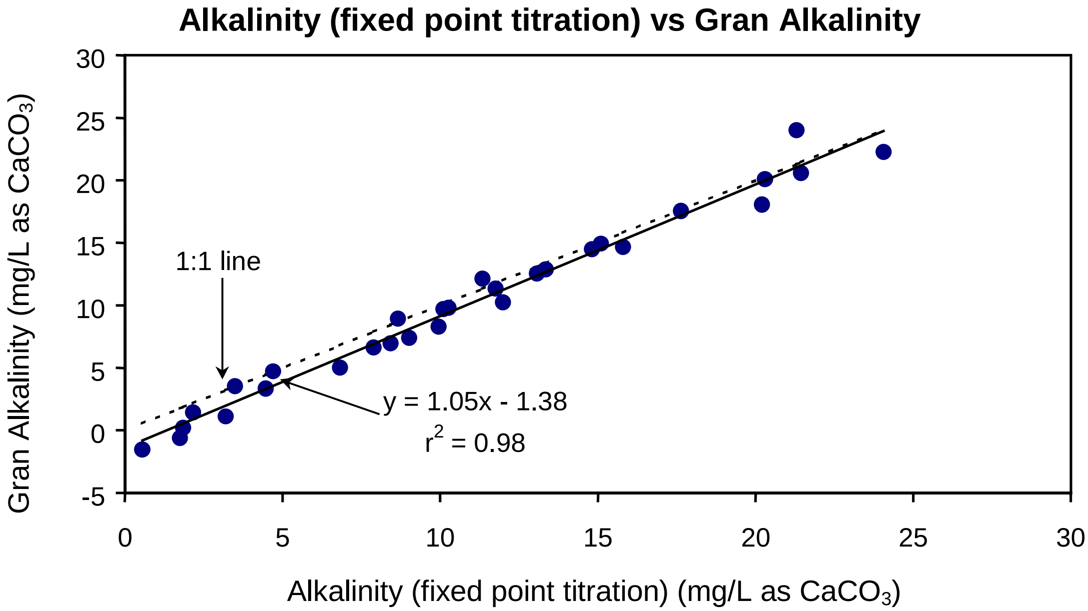
On the basis of the 2000 alkalinity data, 16 of the 30 lakes were highly sensitive to acidic deposition (alkalinity of 0 to 10 mg/L as $CaCO_3$) using the sensitivity categories described by Saffran and Trew (1996). Nine (total alkalinity) to 11 (Gran alkalinity) lakes were moderately sensitive (11 to 20 mg/L). Four (Gran alkalinity) to five lakes (total alkalinity) showed only low sensitivity in 1999 (>20 mg/L). However, the maximum alkalinity measurement was still below 25 mg/L as $CaCO_3$ in these lakes. Therefore, based on alkalinity, the set of lakes monitored in 2000 was appropriate for the objectives of this monitoring program.

The lakes located close to current sources of acidifying emissions (E15, L4, L7 and L8) showed no substantial deviation from 1999 or previous data in terms of pH or alkalinity.

8.4 MAJOR IONS, COLOUR AND DOC

Concentrations of dissolved ions were low to moderate in the lakes monitored in 2000. TDS ranged between 36 and 115 mg/L, with one outlier (E15, with 179 mg/L) (Figure 8.3). Conductivity, TDS and concentrations of most ions varied among lakes without obvious grouping of lakes at any level (calcium and TDS in Figure 8.3; conductivity and other major ions in Table VIII-1, Appendix VIII). As in 1999, the variation in sulphate concentration was discontinuous, with higher levels observed in a cluster of lakes in the Birch Mountains (L18, L46, L47, L49, L60) relative to the other lakes (Figure 8.3).

Figure 8.2 The Relationships Between Total Alkalinity, Gran Alkalinity and pH in the 2000 Data Set



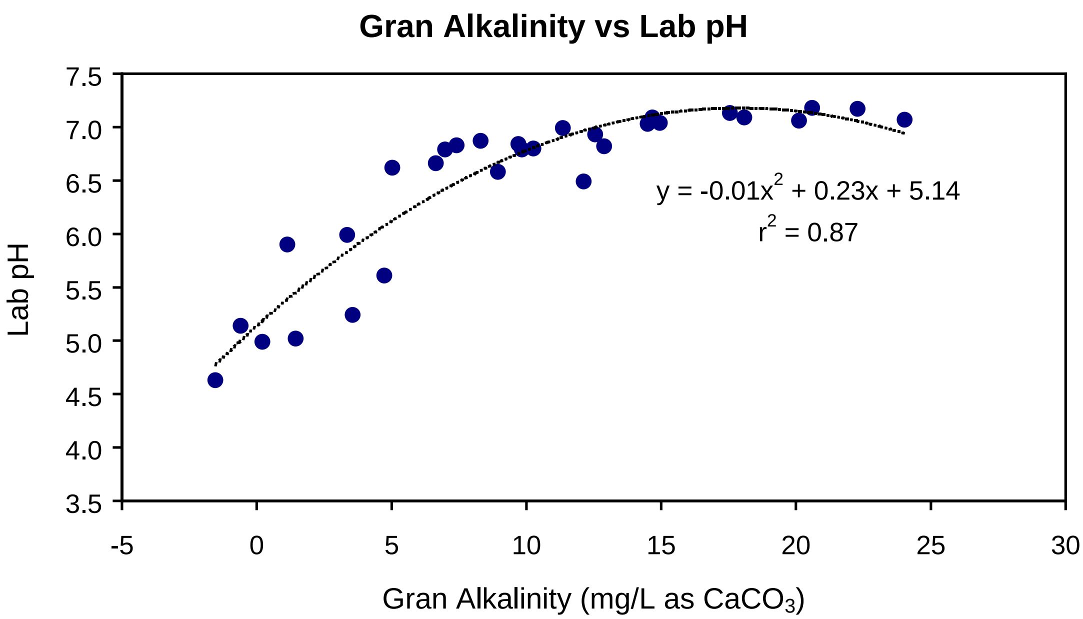
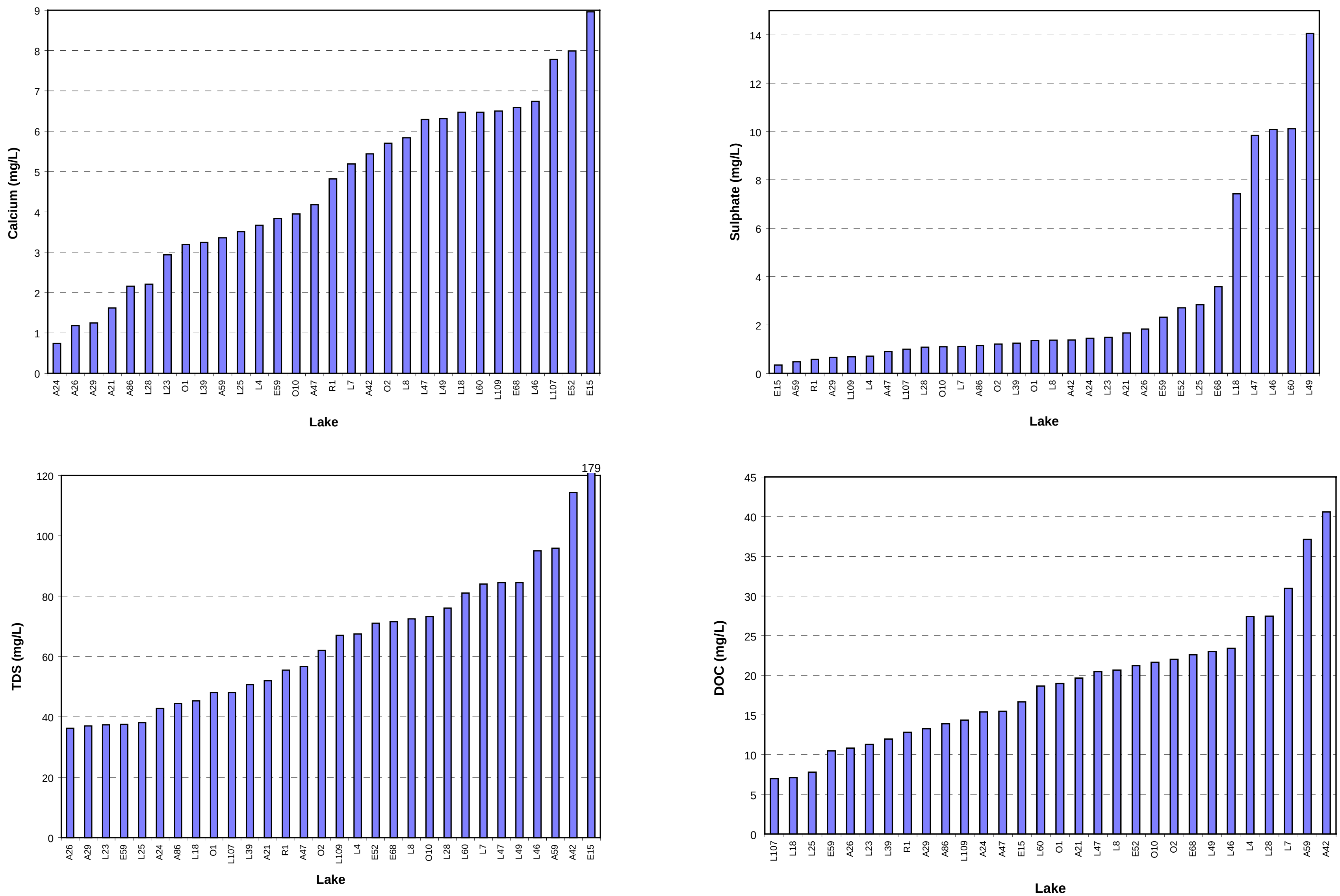


Figure 8.3 Calcium, Sulphate, Total Dissolved Solids (TDS) and Dissolved Organic Carbon (DOC) in the Lakes Sampled in 2000



Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic acid anions. The ratio of (total cations)/(total anions) ranged from 1.09 to 3.30 on an equivalent basis; about half of the lakes had ratios >1.5 (Table VIII-1, Appendix VIII). The differences between total cations and total anions were linearly related to DOC (Figure 8.4), with one outlier (E15, with an elevated TSS concentration of 56 mg/L). Since DOC concentration is related to the concentration of organic acids in surface waters (Sullivan 2000), this relationship suggests that the excess cations were balanced by acid groups on organic substances.

Colour and DOC concentration spanned wide ranges in the study lakes, as intended during the selection of lakes for this monitoring program (DOC in Figure 8.4; colour in Table VIII-1, Appendix VIII). There was no obvious break-point between clear water and brown water lakes in terms of either parameter. Caribou Mountains lakes tended to have higher colour (283 to 312 Pt units, with one exception) than Canadian Shield Lakes (8 to 112 Pt units), but a similar trend was not apparent in DOC concentration. The lakes in the Oil Sands Region spanned the full range of the colour and DOC data. Colour was significantly correlated with DOC, with only one conspicuous outlier (A42) (Pearson's $r=0.84$, $P<0.001$, A42 removed). The sample from Lake A42 had by far the highest TSS concentration in the 2000 data set (175 mg/L), which probably accounted for the unusual combination of DOC (maximum in 2000) and colour (low to moderate).

The sum of base cations was highly correlated with both measures of ANC. Figure 8.5 shows the relationship with Gran alkalinity on an equivalent basis. In lakes with low DOC content, a 1:1 relationship would be expected between these variables (Sullivan 2000). In the case of the RAMP lakes (characterized by elevated DOC), the deviation from this relationship in Figure 8.5 is most likely due to the presence of organic acids, which tend to lower ANC relative to base cation concentrations (Sullivan 2000). Therefore, these data by themselves are not useful to assess acidification, but tracking the ANC / sum of base cations ratio over time may be a useful exercise during future assessments.

The bicarbonate / divalent cations ratio was also calculated for each lake monitored by RAMP (Table 8.2). This is a simplified version of the above ratio and is also expected to equal one under pristine conditions, unless organic acids are present in elevated concentrations, or the lakes being evaluated are located in unusual geological settings (Schindler 1996). Acidification causes a decline in bicarbonate and an increase in divalent cations by increased leaching from soils and lake sediments. As a result, the ratio is more sensitive to acidification than either the numerator or the denominator, and a declining ratio over time may indicate progressive acidification.

Figure 8.4 The Relationship Between Dissolved Organic Carbon (DOC) and (Sum of Cations) – (Sum of Anions) in the 2000 Data Set

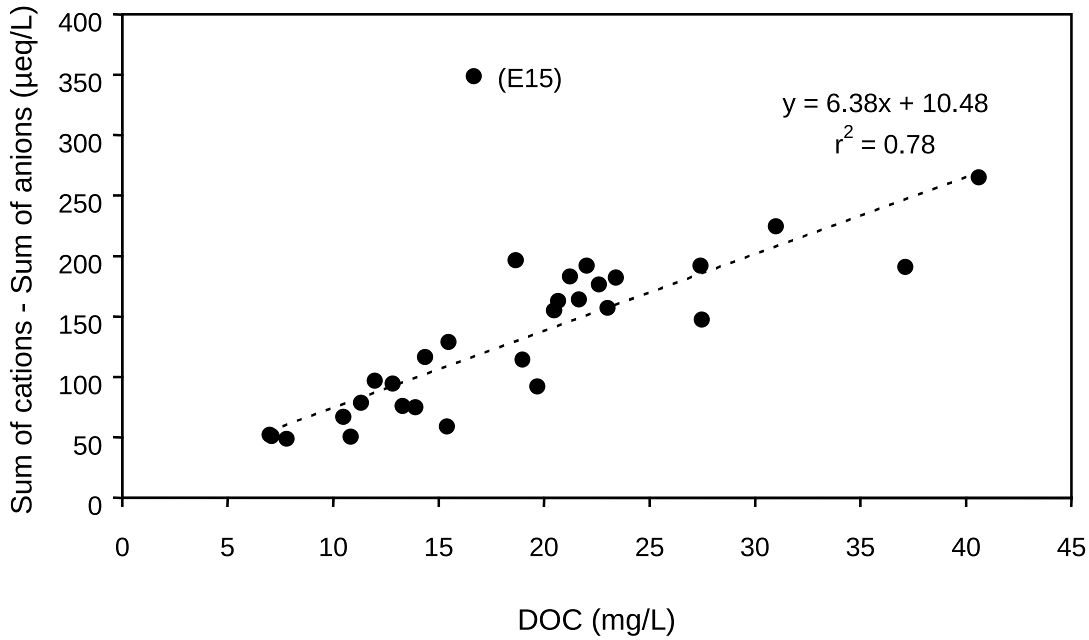


Figure 8.5 The Relationship between the Sum of Base Cations and Gran Alkalinity in the Lakes Sampled in 2000

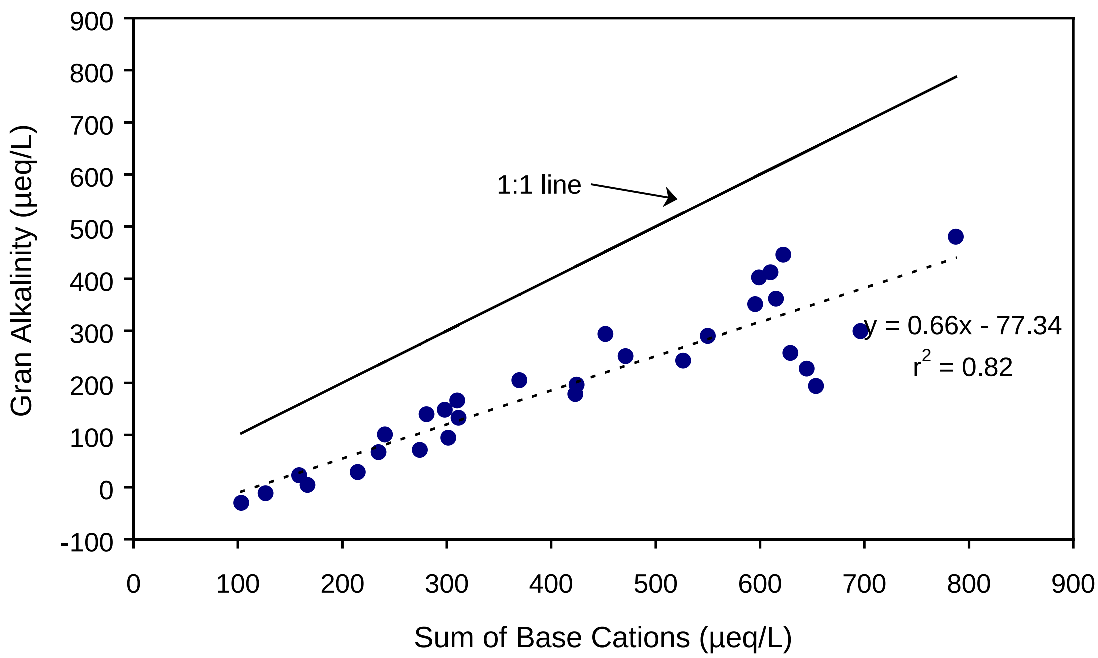


Table 8.2 Bicarbonate/Divalent Cations Ratios for the Acid Sensitive Lakes Monitored by RAMP in 1999 and 2000

Lake	$HCO_3^- / (Ca^{2+}+Mg^{2+})$ (equivalents)	
	1999	2000
Oil Sands Region		
A21	0.12	0.30
A24	--	0.16
A26	0.64	0.40
A29	0.46	0.63
A42	0.58	0.60
A47	0.39	0.57
A59	0.20	0.30
A86	0.67	0.76
E15 (L15b)	--	0.70
L1	0.55	--
L4 (A-170)	0.39	0.34
L7	0.56	0.45
L8	0.84	0.80
L18 (Namur)	0.84	0.83
L23 (Otasan)	0.67	0.72
L25 (Legend)	0.75	0.77
L28	0.25	0.26
L39 (A-150)	0.82	0.86
L46 (Bayard)	0.77	0.57
L47	0.57	0.56
L49	0.31	0.42
L60	0.47	0.46
Caribou Mountains		
E52 (Fleming)	0.59	0.65
E59 (Rocky Island)	0.64	0.66
E68	--	0.59
O1 (Unnamed #6)	0.35	0.41
O2 (Unnamed #9)	0.50	0.51
O3	1.12	--
Canadian Shield		
L107 (Weekes)	--	0.93
L109 (Fletcher)	0.75	0.84
O10	0.66	0.80
R1	0.76	0.84
R2	0.61	--
R3	1.00	--

The bicarbonate / divalent cations ratio is shown in Table 8.2 for each lake using the 1999 and 2000 RAMP data sets. Considerably more data are available for lakes L4, L7, L18 and L25, as discussed by Schindler (1996). The ratios were <1 for all lakes in 1999 and 2000 due to elevated organic acid concentrations, which is a characteristic of the RAMP data set (as discussed above). At this time, the available data are insufficient to evaluate trends over time using this approach for most RAMP lakes. Schindler (1996) examined trends over time in this ratio and available water chemistry data for Lakes L4, L7, L18 and L25 and concluded that there was no evidence of acidification at that time. The changes in this ratio relative to the previous year in lakes located close to current sources of acidifying emissions (L4, L7 and L8; E15 was only sampled in 2000) are within the year-to-year variation documented by Schindler (1996). Future RAMP assessments will track this ratio as part of the annual data summary.

8.5 SUSPENDED SOLIDS, NUTRIENTS AND TROPHIC STATUS

Suspended sediment levels were elevated in a number of lakes (Figure 8.6), and appeared linked to lake depth. All measurements above 10 mg/L were in samples from lakes with maximum depths <2 m. The possible reasons for this observation include wind-induced mixing in shallow lakes or potentially, mixing caused by landing of the aircraft before sampling. The elevated TSS concentrations are of some concern in this program, because they may result in atypical concentrations of parameters associated with particulate material (e.g., nutrients, carbon parameters, chlorophyll *a*).

The lakes varied widely in nutrient and chlorophyll *a* concentrations. TP concentration ranged from 4.2 to 299.1 µg/L (Figure 8.6). Based on chlorophyll *a* concentration (Figure 8.6), one lake was oligotrophic (<2.5 µ/L), 11 lakes were mesotrophic (2.5 to 8 µg/L), 11 lakes were eutrophic (8 to 25 µ/L) and seven lakes were hyper-eutrophic (>25 µg/L) (trophic categories from Mitchell and Prepas 1990).

The lakes with elevated TSS were all in the hyper-eutrophic category which implies that the samples collected from these lakes in 2000 may not yield a reliable indication of trophic status. Three of these lakes (A42, A59, L39) were also hyper-eutrophic in 1999 (Golder 2000c), when two (A42, A59) had elevated TSS concentrations or turbidity. Three of the other four lakes found hyper-eutrophic in 2000 (L46, L49, O10; E15 was not sampled in 1999) had widely varying chlorophyll *a* concentrations in 1999, when the corresponding TSS concentrations were lower. Therefore, elevated suspended solids was reflected in the measured chlorophyll *a* concentrations for subsets of the lakes sampled in both years, resulting trophic status designations that are potentially incorrect.

There was a linear relationship between log TP and log chlorophyll *a* (Figure 8.7). Concentrations of phosphorus and nitrogen variables were significantly inter-correlated (Pearson correlations; P<0.05) with the exception of TDP and nitrite+nitrate. The chlorophyll *a* / TP ratio was not related to pH, but was weakly positively correlated with TSS, PC, and PN (Pearson correlations excluding lakes E15 and A42; P<0.05).

Figure 8.6 Total Suspended Solids (TSS), Total Phosphorus (TP), Total Dissolved Nitrogen (TDN) and Chlorophyll *a* in the Lakes Sampled in 2000

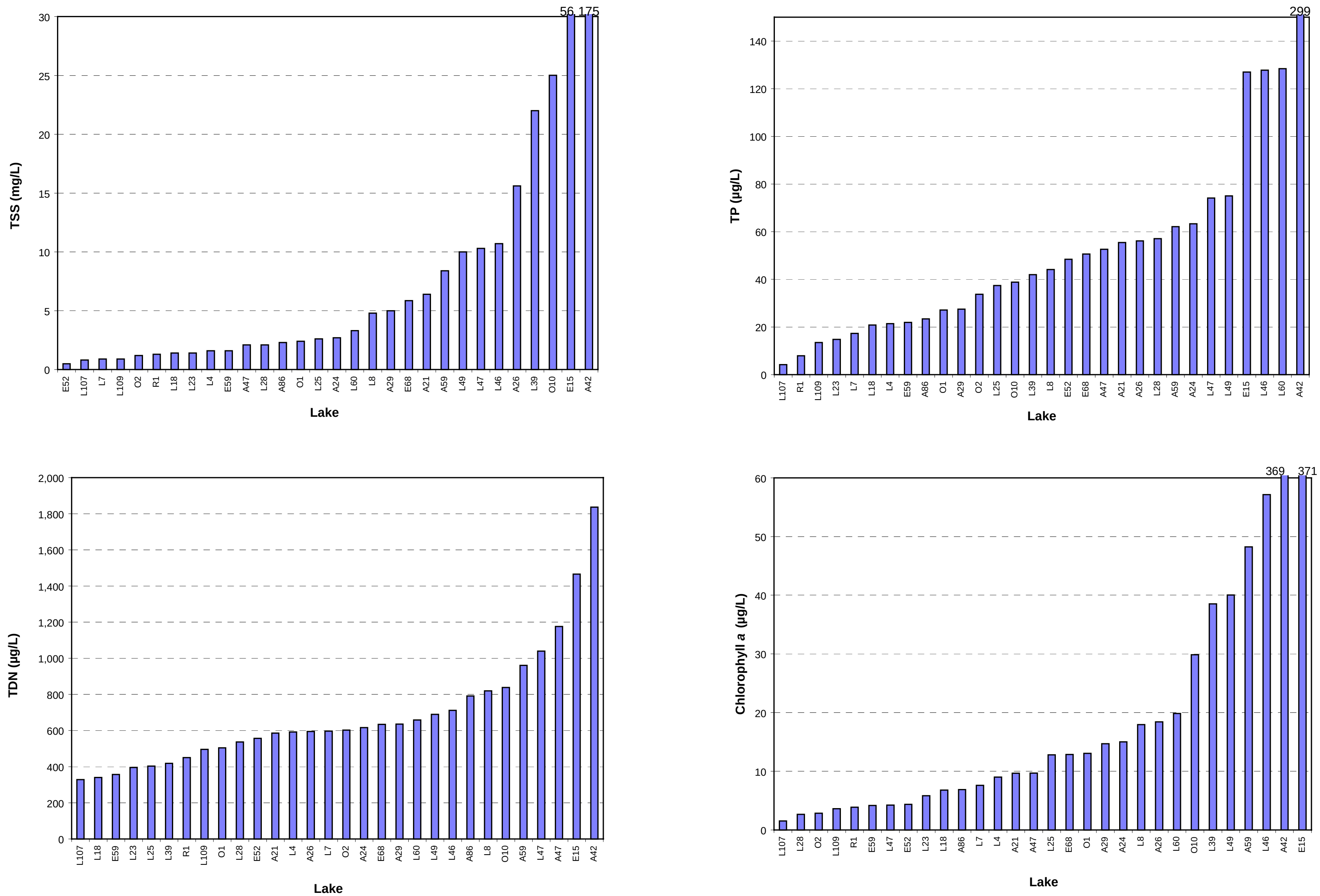
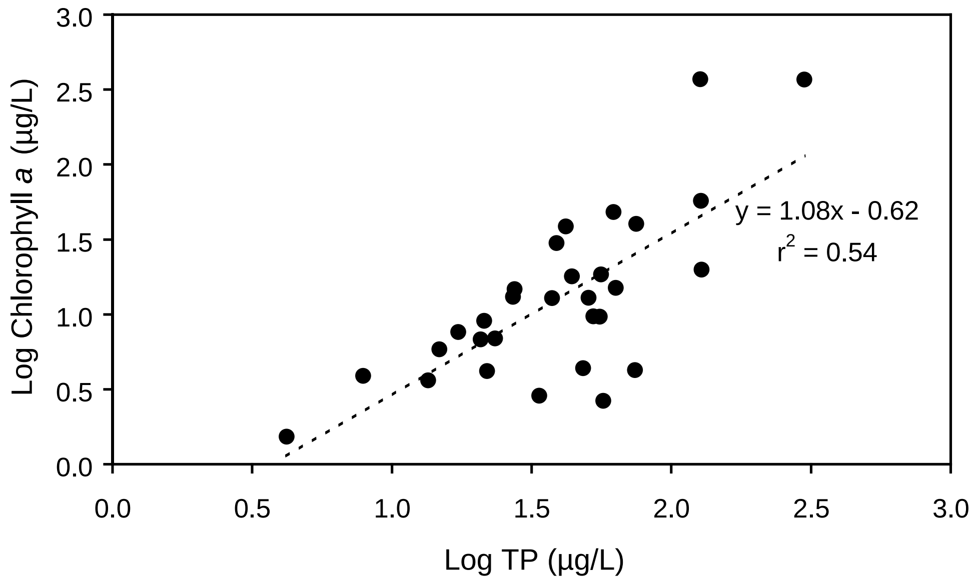


Figure 8.7 The Relationship Between Total Phosphorus (TP) and Chlorophyll *a* in the Lakes Sampled in 2000



8.6 SUMMARY

The RAMP long-term acidification monitoring network was established in 1999. It consists of 33 moderately to highly acid sensitive lakes in north-eastern Alberta. Water chemistry is evaluated annually, with special attention to indicators of acidification. Thirty lakes were sampled in 2000, including 21 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and four lakes on the Canadian Shield.

The most recent estimates of acid deposition rates, corresponding to full operation by existing and approved oil sands developments (as the PAI), and lake-specific CLs were summarized for the lakes in the RAMP monitoring network. As expected, the five lakes located close to the area of highest acid deposition (E15, L1, L4, L7 and L8) have the highest PAI values. Comparison of lake-specific CLs with PAI revealed that the CLs are exceeded or nearly exceeded by the modelled acid deposition rates in three lakes away from sources of acidifying emissions and in three of the lakes close to oil sands developments. This technique is currently being refined by the NO_x and SO_x Management Committee.

The quality of the water chemistry data collected in 2000 was acceptable. Minor concerns included higher field pH measurements relative to the 1999 data and elevated suspended sediment levels in a subset of the lakes monitored. Since the evaluation of lake sensitivity and acidification-related changes in water chemistry rely mostly on alkalinity, major ion concentrations and DOC, these data quality concerns did not interfere with the interpretation of the data.

Acidity-related variables (pH and alkalinity) showed no substantial deviation in 2000 compared to the 1999 and historical data. Concentrations of dissolved ions were low to moderate. Colour and DOC spanned wide ranges in the study lakes. Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic acid anions.

The bicarbonate / divalent cations ratio was <1 for all lakes in 1999 and 2000, probably due to elevated organic acid concentrations. At this time, the available data are insufficient to evaluate trends over time using this approach for most RAMP lakes. However, Schindler (1996) examined trends over time in this ratio for a subset of lakes with available long-term data (L4, L7, L18 and L25) and concluded that there was no evidence of acidification at that time.

Suspended sediment levels were elevated in a number of lakes and appeared linked to lake depth. The elevated TSS concentrations are of some concern in this program, because they may result in atypical concentrations of parameters associated with particulate material (e.g., nutrients, carbon parameters, chlorophyll *a*).

The 30 lakes varied widely in nutrient and chlorophyll concentrations. Based on chlorophyll *a* concentration, one lake was oligotrophic, 11 lakes were mesotrophic, 11 lakes were eutrophic and seven lakes were hyper-eutrophic. There was a weak linear relationship between log TP and log chlorophyll *a*. Concentrations of phosphorus and nitrogen variables were significantly inter-correlated with the exception of TDP and nitrite+nitrate. The chlorophyll *a* / TP ratio was not related to pH.

Data collected during the second year of acid sensitive lake monitoring under RAMP fulfilled the objectives of this component. Relative to 1999 and the historical data, no substantial changes were found in 2000 in acidity-related variables in the lakes monitored. As this component is still in its initial phase of implementation, it is expected to evolve as new information and needs dictate. Potential changes to the program include addition of acid sensitive lakes close to sources of acidifying emissions (i.e., if they are located as part of ongoing baseline studies) and use of CLs to assess acid-sensitivity.

9 BASELINE SOUTH OF FORT MCMURRAY - RESULTS AND DISCUSSION

9.1 WATER QUALITY

Water quality results of the seven lakes, Gregoire River system and Gregoire Lake are summarized in the following sections. Further details are presented in the Long Lake Project EIA (OPTI 2000, Volume 5, Appendix VIII).

9.1.1 Lakes

Canoe, Long and Pushup lakes were similar in terms of water chemistry (Tables 9.1 and 9.2). All were slightly alkaline (pH between 7.3 and 8.5), with alkalinity near 40 mg/L. Conductivity and total dissolved solids were relatively low in these lakes; suspended solids concentration was occasionally elevated. Total and dissolved organic carbon and colour were in the characteristic ranges for brown water lakes. Limited data collected from Unnamed Lakes 1 and 2 indicated that these lakes had lower concentrations of major ions and were probably more acid-sensitive than the other lakes sampled. Sulphide concentrations exceeded the chronic aquatic life guideline in all three lakes in the spring and in Canoe Lake in the fall.

Nutrient concentrations were sufficient in Canoe, Long and Pushup lakes to support productive plankton communities (Tables 9.1 and 9.2). However, the chlorophyll *a* data indicated that these lakes are oligotrophic (unproductive; Long Lake) or mesotrophic (moderately productive; Canoe and Pushup lakes). Metal concentrations were generally low, but aluminum, copper, iron, lead and zinc exceeded chronic aquatic life guidelines and manganese exceeded human health guidelines under baseline conditions. Organic chemicals (i.e., phenols, naphthenic acids, recoverable hydrocarbons) were occasionally detectable, but only at very low concentrations.

There were some consistent seasonal differences in the lake water quality data (Tables 9.1 and 9.2). The pH was generally lower, whereas the nutrients total Kjeldahl nitrogen and total phosphorus were higher in the fall samples. Among the metals, concentrations of lead and zinc were occasionally higher in fall samples. In addition, hydrocarbons were only detected in the samples collected in the spring.

Table 9.1 Water Quality of Selected Rivers, Streams and Lakes in the Local Study Area, May 10 to 24, 2000

Parameter	Units	Gregoire River (GRR-1)	Tributary 1 (UNC-1)	Tributary 2 (UNC-2)	Tributary 3 (UNC-3)	Canoe Lake (CAL-1)	Long Lake (LOL-1)	Pushup Lake (PUL-1)
Conventional Parameters								
pH (field)	-	8.3	--	--	5.4[(a)]	8.5	8.1	8.1
pH (lab)	-	8.1	8.1	7.9	7.9	7.2	7.7	7.2
conductivity	µS/cm	364	390	346	639	88	88	86
total dissolved solids	mg/L	240	90	170	350	120	80	70
total suspended solids	mg/L	3	38	<3	3	22	<3	6
hardness	mg/L	168	122	127	215	39	33	33
alkalinity	mg/L	173	196	156	279	40	37	39
dissolved organic carbon	mg/L	11	13	13	8	18	15	14
total organic carbon	mg/L	13	16	17	11	21	18	16
colour	TCU	50	60	60	50	50	50	30
chlorophyll *a*	µg/L	1	6	1	2	12	6	10
Nutrients								
ammonia	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.57
nitrate + nitrite	mg/L	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	-
total Kjeldahl nitrogen	mg/L	0.5	0.8	0.8	0.6	1.3	1.0	1.5
total phosphorus	mg/L	**0.053**[(C)]	**0.072**[(C)]	0.040	**0.063**[(C)]	0.048	0.028	0.036
dissolved phosphorus	mg/L	0.029	0.029	0.023	0.024	0.015	0.020	0.008
Major Ions								
bicarbonate	mg/L	210	239	190	341	48	45	48
calcium	mg/L	47.1	31.0	32.1	50.9	10.2	9.1	9.4
chloride	mg/L	<1	1	2	<1	1	<1	<1
magnesium	mg/L	12.3	10.9	11.3	21.4	3.2	2.6	2.3
potassium	mg/L	2.7	2.1	1.7	2.7	1.0	0.6	2.4
sulphide	mg/L	0.010	<0.003	<0.003	<0.003	**0.013**[(C)]	**0.022**[(C)]	**0.020**[(C)]
sodium	mg/L	16.5	43.2	26.5	63.9	3.1	4.0	2.0
sulphate	mg/L	21.4	13.2	23.0	70.1	1.6	3.6	<0.5
Total Metals								
aluminum	mg/L	0.03	**1.90**[(A,C)]	0.07	0.06	**0.15**[(C)]	0.03	<0.02
antimony	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
arsenic	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
barium	mg/L	0.0363	0.0555	0.0346	0.0486	0.0171	0.0083	0.0097
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
bismuth	mg/L	0.0001	<0.0001	<0.0001	0.0001	0.0002	0.0001	<0.0001
boron	mg/L	0.066	0.259	0.168	0.432	0.021	0.021	0.013
cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
chromium	mg/L	<0.0008	0.0029	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
cobalt	mg/L	<0.0002	0.0008	0.0005	0.0002	<0.0002	<0.0002	<0.0002
copper	mg/L	0.003	0.002	0.001	0.002	**0.005**[(C)]	<0.001	<0.001

Table 9.1 Water Quality of Selected Rivers, Streams and Lakes in the Local Study Area, May 10 to 24, 2000 (continued)

Parameter	Units	Gregoire River (GRR-1)	Tributary 1 (UNC-1)	Tributary 2 (UNC-2)	Tributary 3 (UNC-3)	Canoe Lake (CAL-1)	Long Lake (LOL-1)	Pushup Lake (PUL-1)
iron	mg/L	**0.71**(C,H)	**1.94**(C,H)	**0.3**(C,H)	**0.67**(C,H)	**0.48**(C,H)	0.11	0.27
lead	mg/L	0.0007	0.0006	0.0001	0.0015	**0.0096**(C)	0.0001	<0.0001
lithium	mg/L	0.02	0.025	0.018	0.056	<0.006	<0.006	<0.006
manganese	mg/L	**0.0773**(H)	**0.2720**(H)	**0.3070**(H)	**0.2220**(H)	0.0416	0.0060	**0.0656**(H)
mercury	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
molybdenum	mg/L	0.0015	0.0004	0.0002	0.0002	0.0001	<0.0001	<0.0001
nickel	mg/L	0.0042	0.0056	0.0004	0.0016	0.0010	0.0007	0.0003
selenium	mg/L	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
silver	mg/L	<0.0004(D)	<0.0004(D)	<0.0004(D)	<0.0004(D)	<0.0004(D)	<0.0004(D)	<0.0004(D)
strontium	mg/L	0.19	0.1880	0.1460	0.3500	0.0315	0.0436	0.0274
thallium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
tin	mg/L	0.0006	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
titanium	mg/L	0.0034	<0.0006	0.0025	0.0018	0.0039	<0.0006	<0.0006
uranium	mg/L	0.0003	0.0003	0.0005	0.0008	<0.0001	<0.0001	<0.0001
vanadium	mg/L	0.0005	0.0033	<0.0002	<0.0002	0.0004	<0.0002	<0.0002
zinc	mg/L	0.008	0.008	0.033	0.047	0.018	<0.004	<0.004
Organics								
phenols	mg/L	0.001	<0.001	<0.001	<0.001	0.002	0.004	0.003
naphthenic acids	mg/L	<1	<1	<1	<1	2	1	1
hydrocarbons, recoverable	mg/L	1.3	2.0	1.4	1.0	2.7	2.6	1.9

Note: Water Quality guideline exceedances are identified by bold font.

-- = No data.

(a) Likely erroneous measurement; lab pH was used to evaluate ammonia guideline exceedance.

(A) Acute aquatic life guideline exceeded.

(C) Chronic aquatic life guideline exceeded.

(D) Detection limit exceeds chronic aquatic life guideline.

(H) Human health guideline exceeded.

Table 9.2 Water Quality of Selected Rivers, Streams and Lakes in the Local Study Area, September 20 to 21, 2000

Parameter	Units	Gregoire River (GRR-1)	Tributary 1 (UNC-1)	Tributary 2 (UNC-2)	Tributary 3 (UNC-3)	Canoe Lake (CAL-1)	Canoe Lake (duplicate)	Long Lake (LOL-1)	Pushup Lake (PUL-1)	Unnamed Lake 1 (UNL-1)	Unnamed Lake 2 (UNL-2)
Conventional Parameters											
pH (field)	-	7.9	7.7	7.9	7.8	8.4	--	7.3	7.4	8.1	8.0
pH (lab)	-	7.9	7.4	--	7.9	6.8	6.5	7.1	7.2	6.4	--
conductivity	µS/cm	246	110	--	805	83.3	84.8	86.7	85.4	39.2	--
total dissolved solids	mg/L	190	180	--	530	100	120	140	110	100	--
total suspended solids	mg/L	6	3	--	<3	19	13	9	10	5	--
hardness	mg/L	115	65	--	263	37	38	38	35	11	--
alkalinity	mg/L	123	48	--	409	36	37	32	40	15	--
dissolved organic carbon	mg/L	14	46	38	14	20	20	24	16	22	25
total organic carbon	mg/L	17	47	52	14	26	25	32	17	30	34
colour	TCU	80	175	--	30	70	80	125	30	125	--
chlorophyll *a*	µg/L	1	--	<1	--	10	11	--	16	--	--
Nutrients											
ammonia	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.25	--	--
nitrate + nitrite	mg/L	<0.1	<0.1	--	<0.1	<0.1	<0.1	<0.1	<0.1	--	--
total Kjeldahl nitrogen	mg/L	0.6	0.8	1.1	0.6	1.3	1.7	2.1	1.8	--	--
total phosphorus	mg/L	**0.060**(C)	0.018	0.050	0.029	**0.091**(C)	**0.089**(C)	**0.064**(C)	**0.055**(C)	--	0.11
dissolved phosphorus	mg/L	0.060	0.012	--	0.019	0.065	0.060	0.044	0.034	--	--
Major Ions											
bicarbonate	mg/L	150	58	--	499	44	45	39	48	18	--
calcium	mg/L	32.2	16.6	--	63.1	9.6	9.8	9.8	9.8	3.1	--
chloride	mg/L	3	1	--	1	1	1	<1	<1	<1	--
magnesium	mg/L	8.4	5.7	--	25.7	3.2	3.3	3.4	2.5	0.9	--

Table 9.2 Water Quality of Selected Rivers, Streams and Lakes in the Local Study Area, September 20 to 21, 2000 (continued)

Parameter	Units	Gregoire River (GRR-1)	Tributary 1 (UNC-1)	Tributary 2 (UNC-2)	Tributary 3 (UNC-3)	Canoe Lake (CAL-1)	Canoe Lake (duplicate)	Long Lake (LOL-1)	Pushup Lake (PUL-1)	Unnamed Lake 1 (UNL-1)	Unnamed Lake 2 (UNL-2)
potassium	mg/L	1.9	0.8	--	3.7	0.7	0.9	0.6	2.6	1.3	--
sulphide	mg/L	0.004	**0.012**(C)	**0.025**(C)	<0.003	0.017	**0.055**(C)	0.005	0.007	0.004	0.005
sodium	mg/L	9	4	--	97	3	4	5	2	<1	--
sulphate	mg/L	7.9	6.5	--	49.3	2.5	2.7	7.8	1.4	2.4	--
Total Metals											
aluminum	mg/L	**0.14**(C)	**0.38**(C)	0.09	0.05	**0.11**(C)	0.08	0.09	0.07	--	**0.23**(C)
antimony	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	--	<0.005
arsenic	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	--	<0.001
barium	mg/L	0.0261	0.0192	0.0176	0.0529	0.0186	0.0180	0.0114	0.0157	--	0.0266
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	--	<0.001
bismuth	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	--	<0.0001
boron	mg/L	0.032	0.013	0.061	0.499	0.018	0.017	0.019	0.012	--	0.030
cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	--	<0.0002
chromium	mg/L	0.0009	0.0018	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	--	<0.0008
cobalt	mg/L	0.0002	0.0004	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	--	0.0002
copper	mg/L	0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.002	--	**0.003**(A,C)
iron	mg/L	**0.71**(C,H)	**0.38**(C,H)	**0.98**(C,H)	0.12	**0.37**(C,H)	**0.35**(C,H)	0.24	0.29	--	**0.85**(C,H)
lead	mg/L	0.0001	**0.0049**(C)	**0.0048**(C)	0.0013	**0.0016**(C)	0.0009	**0.0016**(C)	**0.0026**(C)	--	**0.0026**(C)
lithium	mg/L	0.009	<0.006	0.012	0.065	<0.006	<0.006	<0.006	<0.006	--	0.009
manganese	mg/L	0.0206	0.0254	0.0453	**0.207**(H)	0.0326	0.0314	0.0219	**0.0886**(H)	--	0.0326
mercury	mg/L	**<0.0002**(C,H)	**<0.0002**(C,H)	**<0.0002**(C,H)	**<0.0002**(C,H)	**<0.0002**(C,H,)	**<0.0002**(C,H)	**<0.0002**(C,H)	**<0.0002**(C,H)	--	**<0.0002**(C,H)
molybdenum	mg/L	0.0010	0.0003	0.0002	0.0004	<0.0001	0.0001	0.0002	<0.0001	--	0.0009

Table 9.2 Water Quality of Selected Rivers, Streams and Lakes in the Local Study Area, September 20 to 21, 2000 (continued)

Parameter	Units	Gregoire River (GRR-1)	Tributary 1 (UNC-1)	Tributary 2 (UNC-2)	Tributary 3 (UNC-3)	Canoe Lake (CAL-1)	Canoe Lake (duplicate)	Long Lake (LOL-1)	Pushup Lake (PUL-1)	Unnamed Lake 1 (UNL-1)	Unnamed Lake 2 (UNL-2)
nickel	mg/L	0.0047	0.0069	0.0054	0.0018	0.0019	0.0015	0.0051	0.0034	--	0.0074
selenium	mg/L	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	--	<0.0008
silver	mg/L	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	<0.0004 (D)	--	<0.0004 (D)
strontium	mg/L	0.136	0.0498	0.116	0.431	0.0371	0.0368	0.0523	0.0327	--	--
thallium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	--	<0.0001
tin	mg/L	<0.0004	0.0013	0.0012	0.0005	0.0004	0.0048	0.0023	0.0012	--	0.0022
titanium	mg/L	0.0026	0.0521	0.0026	0.0020	0.0021	0.0017	0.0020	0.0017	--	0.0037
uranium	mg/L	0.0001	<0.0001	<0.0001	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	--	0.0001
vanadium	mg/L	0.0003	0.0006	<0.0002	<0.0002	0.0003	0.0003	0.0004	0.0002	--	0.0005
zinc	mg/L	0.090	**0.298** (A,C)	**0.195** (A,C)	0.049	0.030	0.045	**0.190** (A,C)	**0.119** (A,C)	--	**0.160** (A,C)
Organics											
phenols	mg/L	0.001	**0.006** (C)	0.001	0.003	<0.001	0.002	<0.001	<0.001	--	0.002
naphthenic acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	--	--
hydrocarbons, recoverable	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	--	<0.5	<0.5	--	--

Note: Water Quality guideline exceedances are identified by bold font.

-- = No data.

(A) Acute aquatic life guideline exceeded.

(C) Chronic aquatic life guideline exceeded.

(D) Detection limit exceeds chronic aquatic life guideline.

(H) Human health guideline exceeded.

Acid sensitivity of lakes in the LSA was evaluated based on total alkalinity and lake-specific CLs (use of CLs is described in Section 8.1). Total alkalinity was available for eight of the 14 lakes and indicate that two lakes (Unnamed Lakes 1 and 2) are moderately to highly acid sensitive (alkalinity ≤10 mg/L as $CaCO_3$ are considered highly sensitive according to Saffran and Trew 1996). The remaining six lakes with no alkalinity data are unlikely to be acid sensitive based on the field conductivity data collected in 2000. Conductivity is typically positively correlated with alkalinity and was >100 µS/cm in these lakes. Moderately to highly acid sensitive lakes (i.e., those with alkalinity ≤20 mg/L as $CaCO_3$) typically have conductivity values ≥60 µS/cm, based on data summarized by Saffran and Trew (1996) for a large number of lakes in north-eastern Alberta.

Critical loads calculated for the lakes in the LSA are shown in Table 9.3. Exact critical loads calculated could not be calculated for six lakes in the LSA (Caribou Horn, Frog, Kiskatinaw, Poison and Rat lakes, and Unnamed Lake 3) because only field parameter data were available for these lakes. A linear regression equation was used to estimate critical loads for these lakes, using the strong statistical relationship between field conductivity and critical load.

The CLs estimated for the lakes in the LSA also suggest that only two of the lakes are acid sensitive. Unnamed Lakes 1 and 2 had the lowest CLs (Table 9.3). The other lakes in the LSA had CLs that were at least three times higher than the those calculated for Unnamed Lakes 1 and 2, suggesting they are considerably less sensitive to acid deposition.

Table 9.3 Water Chemistry Variables Related to Acid Sensitivity for the Lakes in the Long Lake Project Local Study Area

Lake	Distance (km)[(a)]	Critical Load (keq/ha/yr)[(b)]	Conductivity (µS/cm)	pH	Alkalinity (mg/L)
Lakes in LSA					
Birch	1.9	1.02	95	8.1	46.0
Canoe	7.6	0.85	84	8.4	37.7
Caribou Horn	12.7	(1.60)	175	8.3	-
Frog	2.4	(1.22)	133	8.4	-
Gregoire	15.0	1.12	175	7.3	54.3
Kiskatinaw	5.9	(1.68)	184	8.2	-
Long	1.6	0.86	75	8.2	34.5
Poison	1.9	(2.50)	275	8.6	-
Pushup	3.3	0.75	72	8.1	39.5
Rat	4.1	(1.81)	198	8.5	-
Sucker	5.5	2.21	218	8.1	106.0
Unnamed 1	2.5	0.21	26	8.2	10.0
Unnamed 2	2.4	0.25	35	7.5	10.5
Unnamed 3	10.0	(1.50)	164	7.6	-

(a) Distance from Long Lake Project central facility.

(b) Critical loads in parentheses were estimated based on conductivity.

9.1.2 Gregoire River System

Water samples collected from the Gregoire River and its three tributaries were slightly alkaline (Tables 9.1 and 9.2). Dissolved oxygen concentration was typically near saturation and dissolved salt concentrations were in the low to moderate range. Hardness and alkalinity were generally >100 mg/L. Major ions and related parameters were generally present in lower concentrations in fall samples. Colour and carbon parameters were elevated in all stream samples. Nutrient concentrations were moderate and total phosphorus occasionally exceeded the chronic aquatic life guideline. Sulphide concentrations exceeded the chronic aquatic life guideline in the fall in tributaries 1 and 2. Most metals were either below detection limits or, if detectable, were present in concentrations below guidelines for the protection of aquatic life and human health. Exceptions included aluminum, iron and manganese in the spring samples plus lead and zinc in the fall samples. Organic chemicals were occasionally detectable, but only at very low concentrations.

9.1.3 Gregoire Lake

Based on available historical data (1972 to 1997), alkalinity, hardness, total dissolved solids and pH are relatively low in Gregoire Lake compared to other Alberta lakes and vary little among seasons (Table 9.4). Elevated concentrations of total and dissolved organic carbon are consistent with the largely brown-water tributary inputs to Gregoire Lake. Nutrient concentrations in Gregoire Lake are sufficient to support a productive aquatic ecosystem. However, the most recent nutrient data suggest that the lake is oligo-mesotrophic (unproductive to moderately productive).

Concentrations of metals are generally low or below detection limits in all seasons. In some cases, guideline exceedances cannot be determined because detection limits are above current guidelines. Phenols, and oil and grease are detectable but at low concentrations in all seasons.

9.2 FISH AND FISH HABITAT

Fish and fish habitat information collected from fourteen lakes, the Gregoire River system and thirty-one watercourse crossings are summarized in the following sections. Historical information from Gregoire Lake is also presented below. Further details are presented in the Long Lake Project EIA (OPTI 2000, Volume 5, Appendix VIII).

9.2.1 Lakes

Habitat maps and photographs of the lakes sampled are found in OPTI 2000, Volume 5, Appendix IX-E and IX-F respectively. Table 9.5 summarizes the fish and fish habitat information collected during the baseline survey.

Table 9.4 Water Quality of Gregoire Lake

Parameter	Units	Winter (1976-81)				Spring (1977-83, 1994, 1996-97)				Summer (1972-83, 1989-97)				Fall (1972, 1976-82, 1989-92, 1994-95, 1997)			
		median	min	max	n	median	min	max	n	median	min	max	n	median	min	max	n
Conventional Parameters																	
pH (field)	-	7.6	6.8	8.3	36	7.5	6.6	8.2	20	7.6	6.9	8.6	68	7.5	6.7	8.7	24
conductivity	µS/cm	134	86	200	36	109	15	147	20	115	87	171	68	109	48	131	24
total dissolved solids	mg/L	84	53	121	36	76	53	95	18	70	57	108	53	67	60	92	22
total suspended solids	mg/L	3	<0.4	21	36	4	<0.4	6	11	5	1	23	36	6	1	16	17
hardness	mg/L	67	57	72	6	54	26	71	9	59	42	69	23	56	51	63	11
alkalinity	mg/L	59	38	93	36	52	22	66	20	50	30	105	68	50	42	56	24
dissolved organic carbon	mg/L	14	7	24	36	12	4	22	12	12	7	25	30	13	10	17	15
total organic carbon	mg/L	15	7	24	36	12	4	30	12	12	7	25	42	13	10	17	16
chlorophyll *a*	µg/L	3	<1	20	30	3	<1	7	12	5	<1	130	60	9	<1	31	21
Nutrients																	
ammonia	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	0.070	--	--	1
nitrate + nitrite	mg/L	0.036	<0.003	0.580	36	0.017	<0.003	0.210	13	0.007	<0.003	<0.1	47	0.008	<0.003	<0.1	18
total Kjeldahl nitrogen	mg/L	0.935	0.420	2.080	36	0.720	0.085	1.020	12	0.900	0.280	1.640	31	0.800	<0.1	1.960	15
total phosphorus	mg/L	0.024	0.013	**0.074**[(C)]	36	0.025	0.018	0.050	15	0.035	0.016	**0.600**[(C)]	76	0.037	0.019	**0.100**[(C)]	26
orthophosphate	mg/L	0.007	0.003	0.035	36	0.010	0.003	0.025	12	0.010	<0.003	0.029	42	0.010	0.005	0.018	16
Major Ions																	
bicarbonate	mg/L	--	--	--	--	59	26	69	5	67	37	85	16	65	62	68	6
calcium	mg/L	18.6	11.4	28.6	36	15.4	7.0	21.5	20	15.2	9.0	20.0	67	15.3	13.2	17.5	24
chloride	mg/L	1.0	0.5	2.2	36	0.9	0.5	2.0	20	0.8	<0.1	6.0	62	0.8	0.4	4.0	24
magnesium	mg/L	5.0	3.1	8.7	35	4.3	2.0	5.5	20	4.0	2.0	7.0	62	4.0	2.0	5.0	24
potassium	mg/L	1.0	0.6	1.8	36	0.9	0.2	1.3	20	0.9	0.1	1.5	61	0.8	0.1	1.1	24
silica	mg/L	0.8	<0.02	1.9	35	2.2	0.4	11.0	19	2.7	0.3	10.7	47	2.9	<0.02	8.8	17
sodium	mg/L	2.8	1.5	4.2	35	2.4	1.9	10.0	20	2.3	<1	11.0	62	2.3	0.8	3.0	24
sulphate	mg/L	8.0	5.3	13.8	36	7.3	2.9	29.0	20	7.0	<0.5	36.0	56	6.0	4.3	11.0	22
sulphide	mg/L	<0.01	<0.01	<0.05[(D>C)]	21	<0.01	<0.01	<0.01	5	<0.01	<0.01	**0.07**[(C)]	15	<0.01	<0.01	<0.01	12

Table 9.4 Water Quality of Gregoire Lake (continued)

Parameter	Units	Winter (1976-81)				Spring (1977-83, 1994, 1996-97)				Summer (1972-83, 1989-97)				Fall (1972, 1976-82, 1989-92, 1994-95, 1997)			
		median	min	max	n	median	min	max	n	median	min	max	n	median	min	max	n
Total Metals																	
aluminum	mg/L	0.05	<0.01	**0.36**(C)	32	0.05	0.02	**0.40**(C)	12	**0.14**(C)	<0.01	**0.70**(C)	28	**0.15**(C)	0.04	**0.35(C)**	13
arsenic	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	0.001	**0.01(C)**	2
beryllium	mg/L	<0.001	--	--	1	<0.001	--	--	1	<0.001	<0.001	<0.001	4	--	--	--	--
cadmium	mg/L	<0.001	<0.001	<0.001	26	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	20	<0.001	<0.001	**0.004**(A,C)	12
chromium	mg/L	--	--	--	--	--	--	--	--	<0.001	<0.001	<0.006	5	0.003	--	--	1
chromium, hexavalent	mg/L	<0.003	<0.003	0.006	32	<0.003	<0.003	<0.003	11	<0.003	<0.003	<0.003	26	<0.003	<0.003	<0.003	13
cobalt	mg/L	<0.001	<0.001	0.009	17	<0.001	<0.0001	<0.002	7	<0.001	<0.001	0.019	18	<0.0015	<0.001	0.004	10
copper	mg/L	0.004	<0.001	**0.05**(A,C)	33	0.002	<0.001	**0.069**(A,C)	12	0.002	<0.001	**0.093**(A,C)	39	**0.01**(A,C)	<0.001	**0.011**(A,C)	16
iron	mg/L	0.16	0.05	**1.1**(C,H)	33	0.17	0.06	**0.46**(C,H)	14	0.17	<0.01	**2**(C,H)	45	0.28	0.02	**0.55**(C,H)	19
lead	mg/L	<0.002(D>C)	<0.002(D>C)	**0.016**(C)	34	<0.002(D>C)	<0.001(D>C)	**0.005**(C)	14	<0.002(D>C)	<0.001(D>C)	**0.025**(C)	37	**0.007**(C)	<0.002(D>C)	**0.069**(A,C)	15
manganese	mg/L	0.050	<0.001	**0.370**(H)	33	**0.058**(H)	0.012	**0.276**(H)	12	**0.093**(H)	0.013	**0.270**(H)	36	**0.066**(H)	0.016	**0.126**(H)	15
mercury	mg/L	<0.0001(D>H)	<0.0001(D>H)	**0.0006**(C,H)	33	<0.0001(D>H)	<0.0001(D>H)	**0.0006**(C,H)	12	<0.0001(D>H)	<0.0001(D>H)	**0.0044**(A,C,H)	32	<0.0001(D>H)	<0.0001(D>H)	<0.0005(D>C,H)	14
nickel	mg/L	<0.001	<0.001	0.025	33	<0.001	<0.0001	<0.002	12	<0.001	<0.001	0.030	33	<0.001	<0.001	0.005	14
selenium	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	<0.0005	--	--	1
silver	mg/L	<0.005(D>A,C)	<0.001(D>C)	<0.005(D>A,C)	7	<0.001(D>C)	<0.001(D>C)	**0.004**(A,C)	5	<0.001(D>C)	<0.001(D>C)	**0.015**(A,C)	7	<0.005(D>A,C)	<0.001(D>C)	<0.005(D>A,C)	3
titanium	mg/L	--	<0.01	<0.01	2	--	<0.01	<0.01	2	--	<0.01	<0.01	2	<0.05	--	--	1
vanadium	mg/L	<0.001	<0.001	0.001	27	<0.001	<0.001	<0.001	9	<0.001	<0.001	0.002	20	<0.001	<0.001	0.002	13
zinc	mg/L	0.011	<0.001	0.075	33	0.006	<0.001	**0.15**(C)	12	0.012	<0.001	0.063	38	0.011	<0.001	**0.39**(C)	16
Dissolved Metals																	
arsenic	mg/L	0.0008	0.0001	**0.0070**(C)	33	0.0011	<0.0002	0.0018	12	0.0009	0.0002	0.0019	28	0.0009	0.0005	**0.0070**(C)	12
selenium	mg/L	<0.0002	0.0001	0.0005	33	<0.0002	<0.0002	**0.0011**(C)	12	<0.0002	<0.0002	<0.0005	28	<0.0002	<0.0002	<0.0005	12
boron	mg/L	0.05	<0.01	0.10	27	0.03	<0.01	0.08	7	0.025	<0.01	0.06	16	0.06	0.01	0.12	12
Organics																	
oil and grease	mg/L	7	2	11	19	7	4	9	5	4	<1	5	17	4	3	9	6
phenolics	mg/L	0.003	<0.001	**0.013**(C)	33	0.002	<0.001	0.004	10	0.003	<0.001	**0.062**(C)	40	0.003	<0.001	**0.016**(C)	13

Source: AENV WDS.

Note: Water quality guideline exceedances are identified by bold font.

-- = No data.

Table 9.4 Water Quality of Gregoire Lake (continued)

(A) Acute aquatic life guideline exceeded.

(C) Chronic aquatic life guideline exceeded.

(H) Human health guideline exceeded.

(D>A,C,H) Detection limit exceeds guideline shown in superscript; exceedance cannot be evaluated.

Table 9.5 Fish and Fish Habitat Summary of Lakes within the Local Study Area

Lake	Habitat Quality					Fish Species Collected	Reported Fish Assemblage
	Spawning	Rearing	Feeding	Overwintering	Migration[a]		
Birch Lake	moderate	moderate-high	moderate-high	low	moderate	392 brook stickleback	none reported
Canoe Lake	moderate	moderate	moderate	low	low	164 lake chub	none reported
Caribou Horn Lake	high	high	high	moderate	low-moderate	22 white sucker 17 northern pike	none reported
Frog Lake	low-moderate	low-moderate	low-moderate	low	low-nil	12 brook stickleback	none reported
Gregoire (Willow) Lake	high	high	high	moderate	high	n/s	Arctic grayling, burbot, cisco, lake whitefish, longnose sucker, northern pike, walleye, trout-perch, yellow perch[b]
Kiskatinaw Lake	high	high	high	moderate	low-moderate	48 white sucker 55 northern pike	none reported
Long Lake	low-moderate	low-moderate	low-moderate	low-nil	low-nil	0	northern pike[c]
Poison Lake[b]	low-nil	low-nil	low-nil	nil	low-nil	0	none reported
Pushup Lake	low-moderate	high	high	low	low	917 brook stickleback	none reported
Rat Lake	moderate	moderate	moderate	low	low-moderate	768 brook stickleback 20 lake chub	Arctic grayling[c]
Sucker Lake	high	high	high	moderate-high	low	n/s	white sucker, northern pike, yellow perch[d] Arctic grayling, lake chub[c]
Unnamed Lake 1	low	low	low	low-nil	low-nil	0	none reported
Unnamed Lake 2	low	low	low	low-nil	low-nil	0	none reported
Unnamed Lake 3	low	low	low	low-nil	nil	0	none reported

(a) Refers to potential for fish to migrate via inlet/outlet creeks as per conditions observed during 2000 baseline survey.
(b) Sources: Bradley (1969), Griffiths (1973), Tripp and Tsui (1980), Sullivan (1985), Mitchell and Prepas (1990).
(c) Source: Volume 7, Appendix XVI.
(d) Source: M. van den Heuvel and T. Van Meer, (1997, unpubl. data).
n/s = Not surveyed during 2000 baseline survey.

Kiskatinaw, Caribou Horn and Sucker lakes were inhabited by sport and forage fish species including northern pike, white sucker and yellow perch. These lakes provide habitat for spawning, rearing, feeding and likely overwintering.

Canoe, Rat, Pushup, Frog and Birch lakes provided moderate habitat potential for spawning, rearing and feeding, but had limited to no capacity for overwintering due to low levels of dissolved oxygen during the winter. Forage fish (i.e., brook stickleback and lake chub) were the only kinds of fish found in these lakes.

Long Lake, Poison Lake and Unnamed Lakes 1, 2 and 3 were all shallow (<1.5 m deep) and provided only limited spawning, rearing and feeding habitat for fish. None were likely to provide overwintering habitat. No fish species were found in these lakes during the spring, summer or fall inventories.

9.2.2 The Gregoire River System

Habitat maps and photographs of the lakes are found in OPTI 2000, Volume 5, Appendix IX-H and IX-I respectively. Table 9.6 summarizes the fish and fish habitat information collected during the baseline survey.

The Gregoire River within the OPTI project boundary was divided into three sampling reaches for assessment. Reaches 1 (west side of lease) and 2 (middle of lease) are similar, consisting of a series of riffle/run habitat units suitable for spawning, rearing and feeding. Reach 3 (east side of lease) is dominated by placid, deep runs suitable for rearing, feeding and perhaps overwintering. Forage fish were the only fish captured in the baseline study including longnose and white sucker, spoonhead sculpin, lake chub, pearl dace and trout-perch. Sport fish (i.e., Arctic grayling, northern pike and walleye) have been documented in the Gregoire River (Tripp and Tsui, 1980; Golder 1997b; FRM Environmental Consulting Ltd. 1996, 1998). In general, the Gregoire River is considered an important migration route and spawning area for northern pike, longnose sucker and white sucker. However, no eggs were recovered from the spring egg survey in 2000.

Three tributaries of the Gregoire River were evaluated. Tributaries 1 and 2 were frozen to the bottom during the spring survey. Hence, neither stream provides accessible spawning habitat. Tributary 3 is a small stream dominated by shallow riffle/run habitat. Habitat quality is considered low and no fish species were captured during baseline work.

9.2.3 Watercourse Crossings

A total of 31 potential road and/or pipeline watercourse crossings were evaluated during the baseline assessment. PCHEP forms and photographs are located in OPTI 2000, Volume 5, Appendix IX-J and IX-K respectively. Table 9.7 summarizes the fish and fish habitat information collected during the baseline survey.

Table 9.6 Fish and Fish Habitat Summary of the Gregoire River System within the Local Study Area

Watercourse	Habitat Quality					Fish Species Collected	Reported Fish Assemblage[b]
	Spawning	Rearing	Feeding	Overwintering	Migration[a]		
Gregoire River							
Reach 1 (east)	high	moderate-high	moderate-high	low	high	38 longnose sucker 9 spoonhead sculpin 11 pearl dace 2 trout-perch	Arctic grayling, longnose dace, longnose sucker, northern pike, slimy sculpin, spoonhead sculpin, spottail shiner, trout-perch, walleye, white sucker, yellow perch
Reach 2 (middle)	high	moderate-high	moderate-high	low	high	59 longnose sucker 10 spoonhead sculpin 9 pearl dace 5 trout-perch 9 lake chub	
Reach 3 (west)	low-nil	moderate	moderate	moderate	moderate-high	1 white sucker	
Tributaries							
Tributary 1	nil	low	low	nil	low	n/s	none reported
Tributary 2	nil	low	low	nil	low	n/s	none reported
Tributary 3	low-nil	low	low	nil	low	0	none reported

[a] Refers to use of river for migration.

[b] Sources: Tripp and Tsui (1980); Golder (1997b); FRM Environmental Consulting Ltd. (1996, 1998).

n/s = Not surveyed during 2000 baseline survey.

Table 9.7 Summary of Proposed Road and Pipeline Watercourse Crossing Assessments

Crossing Site	Watercourse	Crossing Type	Time of Assessment	Habitat Condition	Class	Habitat Potential at Crossing	Fish Species at Crossing	Fisheries Potential
CR-1	tributary to Mystery Lake	road	August	dry peatlands, no defined channel	n/a	none	n/s	no
CR-2	tributary to Mystery Lake	road	August	dry, low-lying catchment, no defined channel	n/a	none	n/s	no
CR-3	tributary to Mystery Lake	road	August	dry, no defined channel, small pockets of standing water	n/a	none	n/s	no
CR-4	unnamed tributary	road/pipeline	August	peatlands, no defined channel, small pockets of standing water	n/a	none	n/s	no
CR-5	unnamed tributary	road/pipeline	August, September	30 cm culvert created length of defined channel in peatlands habitat	C-D[(a)]	limited to forage fish use	none	low-nil
CR-6	unnamed tributary	road/pipeline	August	dry, no defined channel, aspen peatlands/forest	n/a	none	n/s	no
CR-7	tributary to Frog Lake	road/pipeline	August	dry, no defined channel, aspen/spruce forest	n/a	none	n/s	no
CR-8	tributary to Frog Lake	road/pipeline	May	no defined channel, muskeg peatlands, small pockets of standing water	n/a	none	n/s	no
CR-9	tributary to Frog Lake	road	September	no defined channel, muskeg peatlands	n/a	none	n/s	no
CR-10	tributary to Poison Lake	road/pipeline	May, August	no defined channel, small pockets of standing water, peatlands-like	n/a	none	n/s	no
CR-11	tributary to Birch Lake	pipeline	August, September	narrow channel downstream of crossing, peatlands upstream of crossing	C	limited to forage fish use	none	low
CR-12	outlet of Unnamed Lake 1	road	September	no defined channel, muskeg peatlands	n/a	none	n/s	none
CR-13	tributary to Rat Lake	road	September	no defined channel, muskeg peatlands, pockets of standing water	n/a	none	n/s	none
CR-14	tributary to Gregoire River	road	September	dry, no defined channel, aspen/spruce forest	n/a	none	n/s	none
CR-15	tributary to Gregoire River	road/pipeline	November	large beaver pond, defined channel 100 m upstream of Gregoire River	C	rearing, feeding and spawning in lower 100 m	6 pearl dace (lower 100 m)	moderate (lower 100 m)
CR-16	tributary to Rat Lake	road	September	dry, no defined channel, aspen/spruce forest	n/a	none	n/s	none
CR-17	tributary to Rat Lake	road	September	no watercourse, spruce/aspen forest	n/a	none	n/s	none

Table 9.7 Summary of Proposed Road and Pipeline Watercourse Crossing Assessments (continued)

Crossing Site	Watercourse	Crossing Type	Time of Assessment	Habitat Condition	Class	Habitat Potential at Crossing	Fish Species at Crossing	Fisheries Potential
CR-18	tributary to Gregoire River	road/pipeline	September	dry, no defined channel, muskeg peatlands and spruce/aspen forest	n/a	none	n/s	none
CR-19	tributary to Gregoire River	road/pipeline	September	no defined channel, muskeg peatlands	n/a	none	n/s	none
CR-20	tributary to Gregoire River	road/pipeline	August	no defined channel, muskeg peatlands	n/a	none	n/s	no
CR-21	Gregoire River	pipeline	September	well defined, flowing river	C	rearing, feeding, migration	sport and forage species	high
CR-22	tributary to an unnamed lake	pipeline	September	dry, no defined channel, black spruce peatlands	n/a	none	n/s	none
CR-23	outlet of Unnamed Lake 3	pipeline	September	defined channel through muskeg peatlands	C-D[a]	limited to forage fish use	none	low-nil
CR-24	outlet of an unnamed lake	road	September	no defined channel, muskeg peatlands, pockets of standing water	n/a	none	n/s	none
CR-25	outlet of an unnamed lake	road/pipeline	November	no defined channel, muskeg peatlands, pockets of standing water	n/a	none	none	none
CR-26	unnamed tributary	road/pipeline	November	no defined channel, small isolated pockets of standing water	n/a	none	n/s	none
CR-27	unnamed tributary	road/pipeline	November	dry, no defined channel	n/a	none	n/s	none
CR-28	unnamed tributary	road/pipeline	November	no defined channel, muskeg peatlands	n/a	none	n/s	none
CR-29	unnamed tributary	road/pipeline	November	dry, no defined channel	n/a	none	n/s	none
CR-30	tributary to Unnamed Lake 2	road/pipeline	November	flooded muskeg peatlands, beaver impoundments	n/a	none	none	none
CR-31	tributary to Frog Lake	road/pipeline	November	dry, no defined channel, muskeg peatlands	n/a	none	n/s	none

[a] Classified as a Class "C" waterbody, but a strong case can be made to classify it as a Class "D" waterbody (i.e., no fish present, not sensitive from a fisheries perspective).

n/a = Not applicable, the Alberta Codes of Practice (AENV 2000a, 2000b) define a waterbody as having "defined bed and banks" (i.e., defined channel); a fen or a muskeg without a defined channel is not captured by the Codes of Practice.

n/s = Not surveyed for fish because it was dry or lacked a defined channel (e.g., peatlands).

Most watercourses at the proposed crossing sites lacked any defined channel and were either dry, or consisted of pockets of standing water or peatlands habitat. These watercourses were classed as having no habitat potential for fish. Unnamed watercourses at crossings sites CR-5, CR-11 and CR-23 were more defined and considered to have limited habitat potential, probably for forage fish species. The crossing at CR-21 is considered sensitive from a fisheries perspective.

9.2.4 Gregoire Lake

Gregoire Lake was not included in the field component of the baseline assessment due to the availability of existing information describing this lake.

Eleven fish species are known to inhabit Gregoire Lake including Arctic grayling, northern pike, walleye, longnose and white sucker, yellow perch, longnose dace, spoonhead sculpin, slimy sculpin, spottail shiner, trout-perch (Table 9.5).

Gregoire Lake is regarded as an important recreational lake for residents of Fort McMurray and an important subsistence fishery for local communities. Recreational angling focuses on walleye, northern pike and yellow perch (in order of importance). Regionally Gregoire Lake is important for walleye; harvest per unit effort is more than twice the regional average (Sullivan 1985; Larry Rhude, AENV, pers. comm.). Local Aboriginal communities are also known to use Gregoire Lake for subsistence fishing, including an annual fall harvest of lake whitefish (Larry Rhude, AENV, pers. comm.).

9.3 SUMMARY

OPTI baseline water quality and fish and fish habitat studies focused on:

- characterizing water quality and fisheries resources in selected streams, rivers and lakes within the LSA, and in Gregoire Lake;
- evaluating acid sensitivity of lakes within the LSA; and
- evaluating the sensitivity of watercourses to potential road/pipeline crossings.

In general, the seven lakes studied in the water quality field assessment had unproductive or moderately productive nutrient concentrations and similar water chemistry. Three of the thirteen lakes studied in the fisheries field assessment had satisfactory habitat potential and were inhabited by a few species of sport fish (i.e., northern pike, white sucker and yellow perch). The remainder of the lakes studied had moderate to poor habitat potential and were only inhabited by forage fish.

Water samples collected from the Gregoire River system were slightly alkaline and a few parameters exceeded water quality guidelines. The Gregoire River had higher nutrient concentrations than the lakes sampled. Fish habitat in the Gregoire River was suitable for rearing, feeding and perhaps overwintering. Historical information indicates that the Gregoire River is an migration route and spawning area for northern pike, longnose sucker and white sucker.

Based on available historical data (1972 to 1997), Gregoire Lake has a slightly different water quality that other lakes in Alberta. Concentrations of alkalinity, hardness, total dissolved solids and pH are relatively low compared to other Alberta Lakes. However, nutrient concentrations are sufficient to support a productive aquatic ecosystem. Gregoire Lake is also regarded as an important recreational lake for Fort McMurray residents and an important subsistence fishery for local communities. The most common fish species captured for these purposes are walleye, lake whitefish, northern pike and yellow perch.

The critical loads estimated for the lakes in the LSA suggest that only two of the lakes are acid sensitive (Unnamed Lakes 1 and 2).

One potential road/pipeline watercourse crossing was considered sensitive from a fisheries perspective.

10 SUMMARY AND CONCLUSIONS

10.1 SUMMARY

10.1.1 Water and Sediment Quality

In 2000, water and sediment samples were collected from the Athabasca River and several tributaries of the Athabasca River. Shipyard, Isadore's, McClelland and Kearl lakes were all included in the 2000 water sampling survey. The results of the 2000 program indicate that:

- Water and sediment quality in the Athabasca River in 2000 was generally consistent with historical data.
- Naphthenic acids were detected in the Athabasca River from upstream of Donald Creek to upstream of Fort Creek.
- PAH levels in sediments collected upstream of Donald Creek, the Muskeg River and Fort Creek were higher than historical values, particularly for sediments from the east side of the river.
- Sediments from the lower Athabasca River, including the Athabasca Delta, were found to be toxic to several species of invertebrates.
- Although water quality in the Athabasca River tributaries was generally consistent with historical data, naphthenic acids were detected at eight of the ten sample sites.
- Water from Fort Creek was found to be toxic to *Ceriodaphnia dubia*; toxicity was not observed in the other tributaries.
- PAH concentrations in McLean Creek were generally higher in 2000 than in 1999.
- The parameter that most frequently exceeded guidelines in the 2000 tributary sediments was benzo(a)anthracene/chrysene; other parameters that exceeded guidelines included chromium, C1 substituted naphthalene, phenanthrene and pyrene.
- Water quality in Kearl and Isadore's lakes was generally consistent with historical data, with the exception of increased nutrient levels in Isadore's Lake.
- Toxicity (as defined by Microtox® testing) was observed for the first time in Shipyard Lake.
- Naphthenic acids were detected in McClelland Lake.

10.1.2 Benthic Invertebrate Community

The benthic invertebrate data collected during the fall 2000 field program of RAMP represents the second year of tributary monitoring and the first year of lake monitoring for this component. The lower reaches of the MacKay (erosional), Steepbank (erosional) and Muskeg (erosional and depositional) rivers, and Shipyard Lake were sampled in late September to early October, 2000. The results of the 2000 surveys can be summarized as follows:

- All three rivers and both habitat types (erosional and depositional) supported diverse benthic fauna, with low total abundances in erosional reaches and moderate to high abundances in depositional habitat.
- Taxonomic richness was similar in all rivers and both habitats. As in 1998, the erosional reach in the Muskeg River supported the highest number of taxa.
- Erosional communities comprised mostly chironomid midges, mayflies and oligochaete worms in the MacKay and Steepbank rivers, and chironomids and mayflies in the Muskeg River. Aquatic mites, nematodes and stoneflies were also common in this habitat.
- The depositional reach of the Muskeg River was dominated by chironomids and oligochaetes, though fingernail clams, nematode worms and seed shrimps were also common.
- Some of the variation in richness and abundances of common invertebrates within the erosional reaches appeared related to habitat variation (e.g., benthic algal biomass), but relationships contrary to expectations were also found (e.g., erosional taxa negatively correlated with current velocity).
- The survey of Shipyard Lake documented a relatively diverse community with low total abundance, in contrast with the impoverished fauna documented by the previous survey of this lake. The available data for this lake suggest that benthic communities vary considerably among seasons and/or years in this lake.

10.1.3 Fish Populations

The fisheries component of the 2000 RAMP focussed mainly on the mainstem Athabasca River and the Muskeg River basin. Fisheries work included: 1) a radiotelemetry study focusing on the mobility of longnose sucker, northern pike and Arctic grayling; 2) a spawning survey of Jackpine Creek and lower Muskeg River; and 3) a survey of potential reference sites for future sentinel species monitoring on the Muskeg and Steepbank rivers using slimy sculpin. Results of the 2000 fisheries component of RAMP include the following:

- A majority of radio-tagged longnose sucker known to spawn in the mainstem Athabasca River moved to Lake Athabasca within two to three weeks of spawning.
- Only a small portion of radio-tagged longnose sucker known to spawn in the Muskeg River migrated to Lake Athabasca. Most remained in the Athabasca River basin, either in the mainstem river, the Muskeg River or other unidentified tributaries.
- Most northern pike from the Muskeg River were believed to remain in the Athabasca River basin utilizing the Muskeg River, the mainstem Athabasca River and other tributaries (e.g., Clearwater River) during the open water period. Only six of 23 radio-tagged pike appeared to move downstream to Lake Athabasca following the spring spawning season.
- Arctic grayling were not radio tagged due to poor capture success in the Muskeg River. The presence of numerous large beaver dams in 2000 may have prevented the normal spawning run of Arctic grayling up the Muskeg River.
- Based on past studies, suitable spawning habitat was available in Jackpine Creek and the lower Muskeg River for Arctic grayling, sucker species and northern pike.
- During the 2000 spawning survey, the availability and accessibility of suitable spawning habitat was greatly reduced due to the presence of numerous beaver dams on Jackpine Creek and the Muskeg River. The number of actual spawning sites as identified by the presence of incubating eggs was very limited (a total of 10 sites confirmed).
- It is believed that the results of the 2000 spawning survey do not represent the typical spawning use of these watercourses when beaver activity is less prevalent.
- The reference site survey confirmed that slimy sculpin is the most abundant and widely distributed small-bodied species in the study area and is best suited for sentinel species monitoring.
- Three of nine potential reference sites were found to be suitable for sentinel species monitoring. It was recommended that all three reference sites be used in comparisons with each exposure site in an effort to more accurately define natural reference variation in slimy sculpin populations.

10.1.4 Acid Sensitive Lakes

Water samples were collected from 30 acid sensitive lakes in northeastern Alberta, as part of the second year of acid sensitive lake monitoring under RAMP. Results of the 2000 program indicate the following:

- Comparison of lake-specific CLs with acid deposition rates modelled for existing and approved oil sands developments revealed that the CLs are exceeded or nearly exceeded by the "near-future" acid deposition rates in three lakes away from sources of acidifying emissions and in three lakes close to oil sands developments.
- The quality of the water chemistry data collected in 2000 was acceptable. Minor concerns included higher field pH measurements relative to the 1999 data, and elevated suspended sediment levels and concentrations of particulate-related parameters in a subset of the lakes monitored.
- Acidity-related variables (lab pH and alkalinity) showed no substantial deviation in 2000 compared to the 1999 and historical data. Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic acid anions.
- The bicarbonate/divalent cations ratio was <1 for all lakes in 1999 and 2000 due to elevated organic acid concentrations. At this time, the available data are insufficient to evaluate trends over time using this approach for most RAMP lakes.
- Suspended sediment levels were elevated in a number of lakes and appeared linked to lake depth. Based on chlorophyll *a* concentration, one lake was oligotrophic, 11 lakes were mesotrophic, 11 lakes were eutrophic and seven lakes were hyper-eutrophic. There was a weak linear relationship between log TP and log chlorophyll *a*. The chlorophyll *a*/TP ratio was not related to pH.

In summary, the second year of acid sensitive lake monitoring under RAMP generated data that fulfilled the objectives of this component. Relative to 1999 and the available historical data, no substantial changes were found in 2000 in acidity-related variables in the lakes monitored. Since this component is still in its initial phase of implementation, it is expected to evolve as new information and needs dictate. Potential changes to the program include addition of acid sensitive lakes close to sources of acidifying emissions and use of CLs to assess acid-sensitivity.

10.1.5 Baseline South of Fort McMurray

OPTI Canada Inc. (OPTI) is in the process of joining RAMP. OPTI is planning to construct and operate a bitumen recovery and upgrading project, the Long Lake Project, within Lease 27 in northeastern Alberta. A baseline aquatic resources evaluation was completed to collect water quality and fish and fish habitat information that would be required to conduct an Environmental Impact Assessment (EIA) of the Long Lake Project.

Baseline surveys of water quality were carried out in the Local Study Area (LSA) during the spring and fall of 2000. The Gregoire River system (i.e., the Gregoire River and its three tributaries) and Canoe, Long and Pushup lakes were sampled for detailed water chemistry. Unnamed Lakes 1 and 2 were sampled for less detailed water chemistry. Water quality results indicate the following:

- Water samples collected from the Gregoire River system were slightly alkaline.
- Chronic aquatic life guideline exceedances for the Gregoire River system water samples included total phosphorus and sulphide. Most metals were either below detection limits or, if detectable, were present in concentrations below guidelines for the protection of aquatic life and human health. Exceptions included aluminum, iron and manganese in the spring samples plus lead and zinc in the fall samples. Organic chemicals were occasionally detectable, but only at very low concentrations.
- Canoe, Long and Pushup lakes were similar in terms of water chemistry. All were slightly alkaline (pH between 7.3 and 8.5), with alkalinity near 40 mg/L. Sulphide concentrations exceeded the chronic aquatic life guideline in all three lakes in the spring and in Canoe Lake in the fall. Metal concentrations were generally low, but a few metals exceeded guidelines under baseline conditions. These included aluminum, copper, iron, lead, manganese and zinc. Organic chemicals were occasionally detectable, but only at very low concentrations.
- Limited data collected from Unnamed Lakes 1 and 2 indicated that these lakes had lower concentrations of major ions and were probably more acid-sensitive than the other lakes sampled.
- The critical loads estimated for the lakes in the LSA suggested that only two of the lakes (Unnamed Lakes 1 and 2) were acid sensitive.

Historical information (1972 to 1997) collected for Gregoire Lake indicated the following:

- Alkalinity, hardness, total dissolved solids and pH are relatively low in Gregoire Lake compared to other Alberta lakes and vary little among seasons.
- Nutrient concentrations in Gregoire Lake are sufficient to support a productive aquatic ecosystem. However, the most recent nutrient data suggest that the lake is oligo-mesotrophic (unproductive to moderately productive).
- Concentrations of metals are generally low or below detection limits in all seasons. In some cases, guideline exceedances cannot be determined

because detection limits are above current guidelines. Phenols, and oil and grease are detectable but at low concentrations in all seasons.

Fish and fish habitat field studies were done during the winter, spring, summer and fall of 2000 to evaluate seasonal habitat quality and fish utilization. Assessments of all potential road and/or pipeline watercourse crossings were done as details of the Long Lake Project infrastructure became available. Results from the fish and fish habitat baseline survey indicate the following:

- Gregoire, Kiskatinaw, Caribou Horn and Sucker lakes are inhabited by sport and forage fish species. These four lakes provide habitat for spawning, rearing, feeding, and likely overwintering.
- Lakes such as Canoe, Rat, Pushup, Frog and Birch lakes provide moderate habitat potential for spawning, rearing and feeding, but have limited to no capacity for overwintering due to low winter oxygen levels. Fish assemblages at these lakes consist of brook stickleback and/or limited numbers of lake chub.
- Long, Poison and Unnamed Lakes 1, 2 and 3 are all shallow (<1.5 m deep) and provide only limited spawning, rearing and feeding habitat for fish. None of these lakes were found to support fish species during the baseline assessment.
- The fish assemblage in the Gregoire River includes sport and forage fish species. In general, the Gregoire River is considered an important migration route and spawning area for northern pike, longnose sucker and white sucker.
- Tributaries 1 and 2 of the Gregoire River do not provide accessible spawning habitat. Habitat quality of tributary 3 of the Gregoire River is considered low and no fish species were captured during baseline work.
- Most road and/or pipeline watercourse crossings at the proposed crossing sites were classed as having no habitat potential for fish. Unnamed watercourses at crossings sites CR-5, CR-11 and CR-23 were more defined and considered to have limited habitat potential, probably for forage fish species. The crossing at CR-21 is considered sensitive from a fisheries perspective.
- Gregoire Lake is also regionally important for recreational angling and locally important for subsistence fishing.

10.1.6 Quality Assurance/Quality Control

The results of the RAMP QA/QC assessment of field sampling and laboratory analysis indicate that water quality data analyzed by ETL, sediment quality data analyzed by AXYS and data analysis performed by Golder are valid. A summary of the QA/QC assessment is provided below:

- Only a few water quality parameters were five times above the corresponding method detection limits in the field and trip blanks analyzed by ETL.
- ETL and AXYS have high analytical precision.
- Intra-site variation of sediment quality was low and field sediment sampling precision was high at the mouth of Fort Creek.
- Analysis of lab equipment blanks and spiked samples from AXYS and ETL indicate that the laboratory sampling procedures are satisfactory.
- The relative percent difference from ETL's re-analysis of a random sediment sample (i.e., lab duplicate) was low (i.e., less than 25%).
- Less than 5% of the values from the laboratory reports were entered into the Golder database incorrectly. These mistakes were corrected.

10.2 DISCUSSION AND CONCLUSIONS

RAMP is based on monitoring the potential effects of oil sands developments on the whole river ecosystem including changes in fish populations and benthic invertebrate communities. The key to RAMP's success is to select and verify monitoring methods that will differentiate effects of oil sands development from natural variability. One of the major achievements in 1999 and 2000 is that the studies have verified that RAMP now has an assessment tool in the form of small-bodied fish that has more precision (i.e., it can separate potential mining effects from general oil sands effects) and statistical strength (i.e., it can identify differences if they are present) than previous monitoring.

Small-bodied species in the Athabasca River (trout-perch) and its tributaries (slimy sculpin) were selected because of their reduced potential for large-scale movement, increasing the likelihood that the fish being sampled have been exposed to the potential effects of development (exposure sites) or have not been exposed (reference sites).

The 2000 field program was a continuation of the evaluation of small-bodied fish begun in 1999. The 1999 field program demonstrated that adequate numbers of male and female trout-perch could be collected in the Athabasca River to detect at least a 30% difference among sites, and in some cases a 20% difference. Slimy sculpin was selected as the sentinel species on the Muskeg and Steepbank rivers in 1999; however, more effort was needed to collect higher numbers and additional reference sites were needed to ensure the full range of natural variability in fish characteristics within the Oil Sands Region. The 2000 survey confirmed that slimy sculpin is the most abundant and widely distributed small-bodied species in the study area and is best suited for sentinel species monitoring. Three of nine potential reference sites were found to be suitable for monitoring sentinel species. When all three sites are used in comparisons with each exposure site, the effects due to natural variation in slimy sculpin populations will be better understood. The monitoring program now has confirmed that suitable species and suitable exposure and reference sites are present to provide a clearer separation of natural effects and potential effects due to oil sands developments.

The same cannot be said for the second sentinel species, longnose sucker. The results of the 2000 radiotelemetry study confirmed that individuals within this species will have a variable and often transient exposure to the potential effects of oil sands development. The majority of radio-tagged longnose sucker known to spawn in the mainstem Athabasca River moved to Lake Athabasca within two to three weeks of spawning, while only a small portion of tagged longnose sucker known to spawn in the Muskeg River migrated to Lake Athabasca. Those that remained exhibited a variety of movements either in the mainstem river, the Muskeg River or other tributaries. Again 2000 has been a confirmatory year demonstrating that a mobile, large-bodied fish species such as longnose sucker will have highly variable exposure to oils sands developments. It is quite literally not a sentinel (i.e., it does not stand guard).

Field observations indicated that 2000 was a wetter than normal year in the Muskeg River and adjacent basins, in contrast to the dry conditions observed in 1998 and 1999. Maximum daily stream discharges and the cumulative flow volume (from spring melt to late summer) were much lower than normal in 1999. For all gauged stations, 1999 was dryer than 1998, and for several streams it was the driest year on record. Although 2000 began as a dry year and stream discharges were relatively low during snowmelt, significant rainfall occurred in late May and early June. During the late June rainfall, five-year flood events were measured in Jackpine Creek, the Muskeg River and Firebag River. The number of actual spawning sites identified by the presence of incubating eggs was very limited in 2000. The presence of numerous large beaver dams constructed during the previous low flow years may have prevented the normal spawning run of Arctic grayling and other species up the Muskeg River in the spring 2000 and reduced spawning use of the Muskeg River. Based on past studies, suitable spawning habitat was available in Jackpine Creek and the lower Muskeg River for Arctic grayling, sucker species and northern pike. The 2000 data demonstrated the wide natural variation in spawning success that occurs naturally. This range of wet and dry years strengthens the RAMP database by better reflecting the effects of this variation.

The results for the fall benthic invertebrate monitoring in three tributaries were similar to the 1999 results even though the hydrologic conditions changed from dry-year to wet-year conditions in June of 2000. The 2000 results confirm that benthic invertebrate monitoring is a relatively robust tool providing similar results under naturally varying conditions.

Benthic invertebrate monitoring of wetlands began in 2000 with the monitoring of Shipyard Lake. The available data for this lake suggests that benthic communities vary considerably among seasons and/or years, possibly due to changes in dissolved oxygen concentrations.

As 2000 is only the fourth year of water quality monitoring in a long-term program, it is too early to draw many conclusions. The 2000 water quality data were generally consistent with historical data on both the Athabasca River and the tributaries, although some values were higher or lower than before. As more data are added each year, the data set will continue to expand towards the full range of historical and natural variation. Water quality sampling has been expanded to improve the resolution of data across the width of the Athabasca River which is now sampled at three points across the river using composite samples.

Some of the conclusions made in 1998 and 1999 have been confirmed with more data. Water quality guidelines cannot be met for all parameters and will not be suitable as a simplistic test for potential effects of the development. Tests of significant change, based on adequate data are the primary tool for assessment of potential effects related to oil sands development. Some guidelines are likely exceeded due to natural and historic conditions. A number of additional detection's were reported for organic compounds in 2000. For example, naphthenic acids were detected in water samples from eight of the ten tributary sites and the Athabasca River upstream of Donald Creek to upstream of Fort Creek. PAH levels in sediments from three tributary locations were higher than historical values.

A long-term acidification monitoring network formed a new component of RAMP in 1999. The objective of this component is to monitor lake water chemistry as an early-warning indicator of excessive acidic deposition. The field program was implemented to collect baseline water chemistry data and to verify that the lake selection criteria were satisfied by the candidate lakes. The network was monitored in 2000. No substantial changes were found in 2000 in acidity-related variables in the lakes monitored. Since this component is still in its initial phase of implementation, it is expected to evolve with the addition of more acid sensitive lakes close to sources of acidifying emissions and improved assessment methods.

The spatial extent of monitoring data increased substantially in 2000 with the addition of baseline information collected in 2000 provided by OPTI Canada Inc. Up to this year, RAMP did not extend southward beyond the Athabasca River and its tributaries. These new data provide a broader view of baseline conditions in the Oil Sands Region.

In summary, the 2000 RAMP continued to expand our knowledge of aquatic resources in the Oil Sands Region. New data were added that expanded the extent of variation in water and sediment quality, fish populations and benthic invertebrate communities due to natural and historic causes, and the natural processes that appear to initiate this variation. The process of confirming the validity of the methods being used has progressed. Small-bodied fish and benthic invertebrates appear to be useful, while evidence is mounting that longnose sucker is not appropriate as a sentinel species. The program is continuing to expand with OPTI data, new wetland data for benthic invertebrates, the identification of new tributary reference sites for slimy sculpin and better water quality information across the width of the Athabasca River.

11 CLOSURE

Respectfully submitted,

GOLDER ASSOCIATES LTD.

Written by:

Marie Lagimodiere, MES, P.Biol.
Aquatic Biologist

Wade N. Gibbons, Ph.D.,
Senior Aquatic Biologist

Jean-Philippe Bechtold, M.A.Sc., P.Biol.
Water Quality Specialist

Zsolt Kovats, M.Sc.
Aquatic Ecologist

Reviewed by:

John Gulley, M.Sc., P.Biol.
Associates, Oil Sands Market Director

David A. Fernet, M.Sc., P.Biol.
Principal

Pat Tones, Ph.D.
Associate

12 REFERENCES

AENV (Alberta Environment). 1999. Surface water quality guidelines for use in Alberta. Environmental Service, Environmental Sciences Division. Edmonton, Alberta.

AENV. 2000a. Code of Practice for Pipelines and Telecommunication Lines Crossing a Water Body. Water Act - Water (Ministerial) Regulation.

AENV. 2000b. Code of Practice for Watercourse Crossings. Water Act - Water (Ministerial) Regulations.

Allan, R. and T. Jackson. 1978. Heavy metals in bottom sediments of the mainstem Athabasca River system in the AOSERP study area. Prepared for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 34.

Andrews, D. Unpublished manuscript. Calculation of critical loads of acidity to Alberta lakes. Manuscript submitted to Can. J. Fish. Aquat. Sci.

Beak Consulting Ltd. 1988. 1983 Trace Element Concentrations in Benthic Invertebrates and Sediments in the Athabasca River near the Suncor Tar Island Plant Site. Prepared for Suncor Energy Inc., Fort McMurray, Alberta. June 1988.

Bidgood, B.F. 1980. Field surgical procedure for implantation of radio tags in fish. Alberta and Wildlife Div., Fish. Res. Rep. 20, Edmonton, Alberta.

Bond, W.A. and K. Machniak. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Department of Fisheries, Winnipeg, Manitoba. AOSERP Report 26. 137 pp.

Bond, W.A. and K. Machniak. 1979. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 76. 180 pp.

BOVAR (BOVAR Environmental Ltd). 1996. Environmental impact assessment for the Syncrude Canada Limited Aurora Mine. Prepared for Syncrude Canada Ltd., Fort McMurray, AB.

Bradford, M.E. 1990. Gregoire Lake. In: Atlas of Alberta Lakes. P. Mitchell and E. Prepas (eds). University of Alberta Press.

Bradley, G.M. 1969. Preliminary Biological Survey of Six Lakes in Northern Alberta. Fish and Wildlife Division, Alberta Dept. Lands and Forests. 14 pp.

Bramblett, R.G. and K.D. Fausch. 1991. Variable fish communities and the index of biotic integrity in a western Great Plains river. Transactions of the American Fisheries Society: 120:752-769.

C.G.L. (Chemical and Geological Laboratories Ltd.). 1979. A Survey of Benthic Invertebrates and Sediment Chemistry of the Athabasca River near Great Canadian Oil Sands Ltd. Prepared for Great Canadian Oil Sands Ltd., Fort McMurray, Alberta. January 1979.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

CASA (Clean Air Strategic Alliance). 1996. Final Report of the Target Loading Subgroup on Critical and Target Loading in Alberta. CASA SO_2 Management Project Team.

CASA. 1999. Application of Critical, Target, and Monitoring Loads for the Evaluation and Management of Acid Deposition. Prepared by the Target Loading Subgroup.

Crosley, R.W. 1996. Environmental contaminants in bottom sediments: Peace and Athabasca River Basins, October 1994 and May 1995. NRBS Project Report No. 106. NRBS. Edmonton

Dobson, E., K. Day and T.B. Reynoldson. 1996. Ecotoxicology of suspended and bottom sediments: Athabasca, Smoky and Peace Rivers, June 1995. NRBS Project Report No. 135. NRBS. Edmonton.

Fernet, D.A. and G.L. Walder. 1986. The development of habitat suitability criteria for use with the instream flow incremental methodology. Prepared for Habitat Branch, Fish and Wildlife Division, Edmonton, Alberta. 141 pp.

FRM Environmental Consulting Ltd. 1996. Stream Inventory of Alberta's Northeast Boreal Forest. Prepared for Alberta Pacific Forest Industries Inc.

FRM Environmental Consulting Ltd. 1998. Stream Inventory of Alberta's Northeast Boreal Forest, 1997. Prepared for Alberta Pacific Forest Industries Inc. and Alberta Conservation Association.

Golder (Golder Associates Ltd.). 1995. Tar Island dyke seepage environmental risk assessment. Prepared for Suncor Energy Inc., Fort McMurray, Alberta.

Golder. 1996. Aquatic baseline report for the Athabasca, Steepbank and Muskeg rivers in the vicinity of the Steepbank and Aurora mines. Final report for Suncor Inc., Oil Sands Group. Fort McMurray, Alberta.

Golder. 1997a. Aquatic resources baseline study for the Muskeg River Mine Project. Final report to Shell Canada Limited, Calgary, Alberta.

Golder. 1997b. Assessment of Potential Impacts to Fisheries Resources Associated with the Proposed Athabasca Pipeline. Prepared for Upside Engineering Ltd., Calgary, Alberta.

Golder. 1998. Oil Sands Regional Aquatics Monitoring Program (RAMP) 1997. Final report for Suncor Energy Inc., Oil Sands Group, Syncrude Canada Ltd., and Shell Canada Ltd.

Golder. 1999a. Oil Sands Regional Monitoring Program: Field technical procedures. Final report submitted to the RAMP Steering Committee.

Golder. 1999b. Oil Sands Regional Aquatics Monitoring Program (RAMP) 1998. Final report for the RAMP Steering Committee. 183 p. +App.

Golder. 2000a. Oils Sands Regional Aquatic Monitoring Program - Program design and rationale. Prepared for the Regional Aquatic Monitoring Program Steering Committee.

Golder. 2000b. Oil Sands Regional Aquatics Monitoring Program (RAMP) - Fish abnormalities. Prepared for the RAMP Steering Committee. 30 pp.

Golder. 2000c. Oil Sands Regional Aquatics Monitoring Program (RAMP) 1999. Annual report prepared for the RAMP Steering Committee.

Golder. 2001a. Oil Sands Regional Aquatics Monitoring Program (RAMP) 2001, Volume II: Climate and Hydrology. Annual report prepared for the RAMP Steering Committee. 165 pp. + App.

Golder. 2001b. Oil Sands Regional Aquatics Monitoring Program (RAMP) - Review of historical benthic invertebrate data in the Oil Sands Region. Draft in preparation for the RAMP Steering Committee.

Golder. 2001c. Suncor's annual wetlands monitoring report. In preparation for Suncor Energy Inc., Oil Sands.

Gran, G. 1952. Determination of the equivalence point in potentiometric titrations. Analyst, 77:661.

Griffiths, W.E. 1973. Preliminary fish survey of the Fort McMurray tar sands area. Alberta Dept. of Lands and Forests, Fish and Wildlife Div., Edmonton, Alberta. 618 pp.

Griffiths, W.G. 1973. Preliminary Fisheries Survey of the Fort McMurray Tar Sands Area. Fish and Wildlife Division, Alberta Dept. Lands and Forests. 618 p.

Harriman, R., T.E.H. Allott, R.W. Battarbee, C. Curtis, J. Hall and K. Bull. 1995. Critical load maps for UK freshwaters. DOE Report, 19.

Kamari, J., M. Amann, Y.-W. Brodin, M.J. Chadwick, A. Henriksen, J.P. Hettelingh, J.C.I. Kuylenstierna, M. Posch and H. Sverdup. 1992. The use of critical loads for the assessment of future alternatives to acidification. Ambio, 21:377.

Knecht, C.D., A.R. Allen, D.J. Williams and J.H. Johnson. 1981. Fundamental techniques in veterinary surgery, 2nd edition. W.B. Saunders Co., Philadelphia, PA.

Kondolf, G.M. 1997. Application of the pebble count: Notes on purpose, method, and variants. Journal of the American Water Resources Association 33:79-87.

Lutz, A. and M. Hendzel. 1977. A survey of baseline levels of contaminates in aquatic biota of the AOSERP study area. Prepared for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 17.

Mackay, W.C., G.R. Ash and H.J. Norris (eds). 1990. Fish ageing methods for Alberta. R.L.&L. Environmental Services Ltd. in assoc. with Alberta Fish and Wildl. Div. and Univ. of Alberta, Edmonton. 113 p.

Mitchell P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

O'Neil, J., L. Noton and T. Clayton. 1982. Aquatic investigations in the Hartley Creek area, 1981 (SandAlta Project). Prep. for Gulf Can. Resour. Inc. by R.L.&L. Env. Serv. Ltd. 159 p + App.

OPTI Canada Inc. 2000. Long Lake Project Application for Approval to Alberta Energy and Utilities Board and to Alberta Environment. Volumes 1 – 7. December 2000.

R.L.&L. (R.L.&L. Environmental Services Ltd.). 1982. Aquatic investigations in Hartley Creek area, 1981 (SandAlta Project). Report No. Phase II-18.

R.L.&L. 1989. OSLO Project: Water quality and fisheries resource baseline studies. Prepared for the OSLO Joint Venture Oil Sands Project.

Rhude, Larry. (Alberta Environment). 2000. Personal Communication. Fisheries Biologist with the Fish and Wildlife Division.

Saffran, K.A. and D.O. Trew. 1996. Sensitivity of Alberta Lakes to Acidifying Deposition: An Update of Maps with Emphasis on 109 Northern Lakes. Water Management Division, Alberta Environmental Protection, Edmonton, AB. 70 p.

Schindler, D.W. 1996. The Response of Aquatic Ecosystems in Alberta to Acidifying Deposition. I n: Scientific Appendix to the Final Report of the Target Loading Subgroup on Critical and Target Loading in Alberta. Clean Air Strategic Alliance. Edmonton AB. 48 p.

Scott, W.B. and E.J. Crossman. 1998. Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa. Bulletin 184.

Sekerak, A.D. and G.L. Walder. 1980. Aquatic biophysical inventory of major tributaries in the AOSERP study area. Volume I: Summary report. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Limited, Environmental Research Associates. AOSERP 114. 100 pp.

Selong, J.H. and L.A. Helfrich. 1998. Impacts of Trout Culture Effluent on Water Quality and Biotic Communities in Virginia Headwater Streams. Progressive Fish-Culturist 60:247-262.

Shell Canada Limited (Shell). 1997. Muskeg River Mine Project. Vol. 2. Environmental impact assessment – biophysical and historical resources impact assessment. Prepared by Golder Associates. Submitted to Alberta Energy and Utilities Board and Alberta Environmental Protection.

Sullivan, M.G. 1985. Characteristics and Impact of the Sports Fishery at Gregoire Lake During May-August 1984. Alberta Natural Resources, Fish and Wildlife Division, Unpublished Report, St. Paul.

Sullivan, T.J. 2000. Aquatic Effects of Acidic Deposition. CRC Press LLC. Boca Raton, Florida.

Suncor Energy Inc. (Suncor). 1998. Project Millennium Application. Volumes 1 and 2. Prepared by Golder Associates Ltd., Calgary AB.

Suncor. 2000. Firebag In-Situ Oil Sands Project Application. Volumes 1, 2a, 2b, 3, 4a and 4b. Submitted to Alberta Energy and Utilities Board and Alberta Environment. Prepared by Golder Associates. May 2000.

Syncrude Canada Ltd. (Syncrude). 1998. Mildred Lake Upgrader Expansion Environmental Impact Assessment. Application to the Alberta Energy and Utilities Board. Prepared by Conor Pacific Environmental Technologies Inc. Calgary, AB.

Terzi, R.A. 1981. Hydrometric field manual measurement of streamflow. Environment Canada, Inland Waters Directorate, Water Resources Branch, Ottawa. 37 pp.

Tripp, D.B. and P.J. McCart. 1979. Investigations of the spring spawning fish populations in the Athabasca and Clearwater rivers upstream from Fort McMurray: Volume I. Prepared for the Alberta Oil Sands Environmental Research Program. AOSERP Report 84.

Tripp, D.B. and P.T.P. Tsui. 1980. Fisheries and Habitat Investigations of Tributary Streams in the Southern Portion of the AOSERP Study Area. Volume I: Summary and Conclusions. AOSERP Report No. 92.

U.S. EPA (United States Environmental Protection Agency). 1999. National recommended water quality criteria - Correction. Report No. EPA 822-Z-99-001.

Wrona, F.J., M. Culp and R.W. Davies. 1982. Macroinvertebrate subsampling: a simplified apparatus and approach. Can. J. Fish. Aquat. Sci. 39:1051-1054.

13 GLOSSARY AND LIST OF ACRONYMS

13.1 GLOSSARY

Acute	Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Baseline	A surveyed condition which serves as a reference point to which later surveys are compared.
Benthic Invertebrates	Invertebrate organisms living on the bottom of lakes, ponds and streams. Examples of benthic invertebrates include the aquatic insects such as caddisfly larvae, which spend at least part of their life on or in bottom sediments. Many benthic invertebrates are major food sources for fish.
Biological Indicator (Bioindicator)	Any biological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomonitoring	The use of living organisms as indicators of the quality and integrity of aquatic or terrestrial systems in which they reside.
Chronic	Defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduce reproduction, etc., in addition to lethality.
Community	Plant or animal species living in close association in a defined location (e.g., fish community of a lake).
Concentration	Quantifiable amount of a chemical in environmental medium, expressed as mass of a substance per unit volume (e.g., mg/L), or per unit sample mass (e.g., mg/g).
Conductivity	A measure of a water's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.

Detection Limit (DL)	the lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Discharge	In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).
Diversity	The variety, distribution and abundance of different plant and animal communities and species within an area.
Ecological Indicator	Any ecological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress.
Environmental Impact Assessment (EIA)	A review of the effects that a proposed development will have on the local and regional environment.
Fauna	A term referring to an association of animals living in a particular place or at a particular time.
GPS	Global Positioning System. This system is based on a constellation of satellites which orbit the earth every 24 hours. GPS provides exact position in standard geographic grid (e.g., UTM).
Lethal	Causing death by direct action.
m^3/s	Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.
Microtox®	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Oil sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 μm) and a fines (<44 μm) fraction, consisting of silts and clays.
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCo_3$).

PAH	Polycyclic Aromatic Hydrocarbon. A chemical by-product of petroleum-related industry and combustion of organic materials. PAHs are composed of at least two fused benzene rings. Toxicity increases with molecular size and degree of alkylation.
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
QA/QC	Quality Assurance and Quality Control refers to a set of practices that ensure the quality of a product or a result. For example, "Good Laboratory Practice" is part of QA/QC in analytical laboratories and involves proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.
Reach	A comparatively short length of river, stream channel or shore. The length of the reach is defined by the purpose of the study.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Relative Abundance	The proportional representation of a species in a sample or a community.
Riffle Habitat	Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.
Run Habitat	Areas of swiftly flowing water, without surface waves, that approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Sediments	Solid fragments of inorganic or organic material that fall out of suspension in water, wastewater, or other liquid.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Sport/Game Fish	Large fish that are caught for food or sport (e.g., northern pike, trout).
Stressor	An agent, a condition, or another stimulus that causes stress to an organism.

Transect	A line drawn perpendicular to the flow in a channel along which measurements are taken.
Toxic	A substance, dose, or concentration that is harmful to a living organism.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Wetlands	Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskeg, potholes, swales, glades, slashes and overflow land of river valleys.

13.2 LIST OF ACRONYMS

µg/kg	microgram/kilogram
µS/cm	micro Siemans/centimetre
ACFN	Athabasca Chipewyan First Nation
AENV	Alberta Environment
AEP	Alberta Environmental Protection
Al-Pac	Alberta Pacific Forest Industries Inc.
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
AOSERP	Alberta Oil Sands Environmental Research Program
ARCV	Alberta Research Council-Vegreville
ATC	Alberta Tribal Council
AXYS	AXYS Analytical Services Ltd.
CCME	Canadian Council of Ministers of the Environment
CPUE	Catch-per-unit-effort
DFO	Department of Fisheries and Oceans
DO	Dissolved oxygen
DOC	Dissolved organic carbon
D/S	Downstream
EEM	Environmental Effects Monitoring

EIA	Environmental Impact Assessment
ETL	Enviro-Test Laboratories
EUB	Alberta Energy and Utilities Board
GPS	Global Positioning System
IRC	Industry Relations Corporation
ISQG	Interim Freshwater Sediment Quality Guidelines
KIR	Key Indicator Resource
km	kilometre
m	metre
m^3/s	cubic metres per second
MDL	Method detection limit
MFO	Mixed function oxygenase
mg/kg	milligram/kilogram
mg/L	milligram/litre
MSE	Mean Squared Error
NRBS	Northern Rivers Basins Program
NREI	Northern Rivers Ecosystem Initiative
PAH	Polycyclic aromatic hydrocarbons
PEL	Probable Effect Level
PERD	Environment Canada's Program on Energy Research and Development
QA/QC	Quality assurance/Quality control
RAMP	Regional Aquatics Monitoring Program
SR	Studentized Residuals
T.C.U.	True colour units
TDS	Total dissolved solids
TOR	Terms of Reference
TSS	Total suspended solids
U/S	Upstream
U.S. EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WBEA	Wood Buffalo Environmental Association
Yr	Year

APPENDIX I

LABORATORY METHODS

Table I-1 Analytical Methods used by EnviroTest Labs when Analyzing RAMP Water Samples

Parameter	Units	Detection Limits	Analytical Methods[a]
Conventional Parameters			
bicarbonate (HCO3)	mg/L	5	APHA 2320B
calcium	mg/L	0.5	APHA 3120 B
carbonate (CO3)	mg/L	5	APHA 2320 B
chloride	mg/L	1	APHA 4500
colour	T.C.U.	3	APHA 2120B
conductance	µS/cm	0.2	APHA 2510 B
dissolved organic carbon	mg/L	1	APHA 5310 B
hardness	mg/L	1	APHA 2340 B
magnesium	mg/L	0.1	APHA 3120 B
pH		0.1	APHA 4500-H
potassium	mg/L	0.1	APHA 3120 B
sodium	mg/L	1	APHA 3120 B
sulphate	mg/L	0.5	APHA 4110 B
sulphide	µg/L	3	AEP
total alkalinity	mg/L	5	APHA 2320 B
total dissolved solids	mg/L	10	APHA 2540 c
total organic carbon	mg/L	1	APHA 5310 B
total suspended solids	mg/L	3	APHA 2540-D
Nutrients			
nitrate + nitrite	mg/L	0.1	APHA 4500NO3H
nitrogen - ammonia	mg/L	0.05	APHA 4500NH3F
nitrogen - kjeldahl	mg/L	0.2	APHA 4500N-C
phosphorus, total	µg/L	2	APHA 4500-PBE
phosphorus, total dissolved	µg/L	2	APHA 4500-PBE
Biochemical Oxygen Demand			
biochemical oxygen demand	mg/L	2	APHA 5210 B
Organics			
naphthenic acids	mg/L	1	FTIR
total phenolics	µg/L	1	EPA 420.2
total recoverable hydrocarbons	mg/L	0.5	APHA 5520 F
Metals (Total)			
aluminum (Al)	µg/L	20	SW6010
antimony (Sb)	µg/L	0.8	SW 3015
arsenic (As)	µg/L	1	ICP-MS
barium (Ba)	µg/L	0.2	SW6010
beryllium (Be)	µg/L	1	SW6010
boron (B)	µg/L	4	SW6010
cadmium (Cd)	µg/L	0.2	SW6010
calcium (Ca)	µg/L	100	APHA 3120 B
chromium (Cr)	µg/L	0.8	SW6010
cobalt (Co)	µg/L	0.2	SW6010
copper (Cu)	µg/L	1	SW6010
iron (Fe)	µg/L	20	SW6010
lead (Pb)	µg/L	0.1	SW6010
lithium (Li)	µg/L	6	SW3015
magnesium (Mg)	µg/L	20	APHA 3120 B

Parameter	Units	Detection Limits	Analytical Methods[a]
manganese (Mn)	µg/L	0.2	SW6010
mercury (Hg)	µg/L	0.2	APHA 3112 B
molybdenum (Mo)	µg/L	0.1	SW6010
nickel (Ni)	µg/L	0.2	SW6010
potassium (K)	µg/L	20	APHA 3120 B
selenium (Se)	µg/L	0.8	SW 3015
silver (Ag)	µg/L	0.4	SW6010
sodium (Na)	µg/L	200	APHA 3120 B
strontium (Sr)	µg/L	0.2	SW6010
titanium (Ti)	µg/L	0.6	SW 3015
uranium (U)	µg/L	0.1	SW 3015
vanadium (V)	µg/L	0.2	SW6010
zinc (Zn)	µg/L	4	SW6010
Metals (Dissolved)			
aluminum (Al)	µg/L	10	APHA 3120 B
antimony (Sb)	µg/L	0.8	ICP-MS
arsenic (As)	µg/L	0.4	ICP-MS
barium (Ba)	µg/L	0.1	APHA 3120 B
beryllium (Be)	µg/L	0.5	APHA 3120 B
boron (B)	µg/L	2	APHA 3120 B
cadmium (Cd)	µg/L	0.1	APHA 3120 B
chromium (Cr)	µg/L	0.4	APHA 3120 B
cobalt (Co)	µg/L	0.1	APHA 3120 B
copper (Cu)	µg/L	0.6	APHA 3120 B
iron (Fe)	µg/L	10	APHA 3120 B
lead (Pb)	µg/L	0.1	APHA 3120 B
lithium (Li)	µg/L	3	APHA 3120 B
manganese (Mn)	µg/L	0.1	APHA 3120 B
mercury (Hg)	µg/L	0.01 - 0.1	ICP-MS
molybdenum (Mo)	µg/L	0.1	APHA 3120 B
nickel (Ni)	µg/L	0.1	APHA 3120 B
selenium (Se)	µg/L	0.4 - 0.8	ICP-MS
silver (Ag)	µg/L	0.2	APHA 3120 B
strontium (Sr)	µg/L	0.1	APHA 3120 B
titanium (Ti)	µg/L	0.3	APHA 3120 B
uranium (U)	µg/L	0.1	ICP
vanadium (V)	µg/L	0.1	APHA 3120 B
zinc (Zn)	µg/L	2	APHA 3120 B

[a] APHA = Protocols developed by the American Public Health Association.

EPA and SW = Protocols established by the United States Environmental Protection Agency.

AEP = Protocol developed by Alberta Environment Protection.

ICP = Inductively Coupled Plasma.

MS = Mass spectrometry.

FTIR = Fourier Transform Infrared Spectroscopy.

Table I-2 Analytical Methods used by EnviroTest Labs when Analyzing RAMP Sediment Samples

Parameter	Units	Detection Limits	Analytical Methods[(a)]
Conventional Parameters			
particle size - % sand	%	1	gravimetric
particle size - % silt	%	1	gravimetric
particle size - % clay	%	1	gravimetric
total inorganic carbon	% by wt	0.01	combustion/acid reaction
total organic carbon	% by wt	0.01	combustion/acid reaction
total carbon	% by wt	0.01	combustion/acid reaction
General Organics			
total recoverable hydrocarbons	µg/g	100	APHA 5520 C
Metals (Total)			
aluminum (Al)	µg/g	10	SW 3051/6010
antimony (Sb)	µg/g	0.02	APHA 3114 C
arsenic (As)	µg/g	0.05	APHA 3114 C
barium (Ba)	µg/g	0.5	SW 3051/6010
beryllium (Be)	µg/g	1	SW 3051/6010
cadmium (Cd)	µg/g	0.5	SW 3051/6010
calcium (Ca)	µg/g	100	SW 3051/6010
chromium (Cr)	µg/g	0.5	SW 3051/6010
cobalt (Co)	µg/g	1	SW 3051/6010
copper (Cu)	µg/g	1	SW 3051/6010
iron (Fe)	µg/g	1	SW 3051/6010
lead (Pb)	µg/g	5	SW 3051/6010
magnesium (Mg)	µg/g	10	SW 3051/6010
manganese (Mn)	µg/g	0.1	SW 3051/6010
mercury (Hg)	µg/g	0.04	APHA 3114 C
molybdenum (Mo)	µg/g	1	SW 3051/6010
nickel (Ni)	µg/g	2	SW 3051/6010
potassium (K)	µg/g	20	SW 3051/6010
selenium (Se)	µg/g	0.1	APHA 3114 C
silver (Ag)	µg/g	1	SW 3051/6010
sodium (Na)	µg/g	100	SW 3051/6010
strontium (Sr)	µg/g	1	SW 3051/6010
sulphur (S)	µg/g	100	SW 3051/6010
titanium (Ti)	µg/g	5	SW 3051/6010
vanadium (V)	µg/g	1	SW 3051/6010
zinc (Zn)	µg/g	0.5	SW 3051/6010

[(a)] APHA = Protocols developed by the American Public Health Association.
SW = Protocols established by the United States Environmental Protection Agency.

Table I-3 Analytical Methods used by HydroQual Labs when Analyzing RAMP Water and Sediment Samples

Parameter	Analytical Methods
Water	
Microtox®	Toxicity testing using luminescent bacteria (*Vibrio fischeri*). 1992. Environment Canada. EPS 1/RM/24.
chlorophyll *a*	Spectrophotometric determination of chlorophyll. Standard methods for the examination of water and wastewater, 18th ed. 1992. American Public Health Association.
Selenastrum capricornutum	Growth inhibition test using the freshwater alga *Selenastrum capricornutum*. 1992. Environment Canada. EPS 1/RM/25. Amended November 1997.
Ceriodaphnia dubia (growth and survival)	Test of reproduction and survival using the Cladoceran *Ceriodaphnia dubia*. 1992. Environment Canada. EPS 1/RM/21. Amended November 1997.
fathead minnow (growth and survival)	Test of larval growth and survival using fathead minnow. 1992. Environment Canada. EPS 1/RM/22. Amended November 1997.
Sediments	
Chironomus tentans (growth and survival)	Test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus tentans* or *Chironomus riparius*). 1997. Environment Canada. EPS 1/RM/32.
Hyalella azteca (growth and survival)	Test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*. 1997. Environment Canada. EPS 1/RM/33.
Lumbriculus variegatus (growth and survival)	Standard test methods for measuring the toxicity of sediment-associated contaminant with freshwater invertebrates. 1995. ASTM E 1706-98a.

SUMMARY OF THE ANALYTICAL PROTOCOL USED BY AXYS LABS TO ANALYZE FOR POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) IN RAMP SEDIMENT SAMPLES

Summary

Sediments were analyzed for a suite of polycyclic aromatic hydrocarbons (PAHs), including alkylated PAHs. All samples were spiked with an aliquot of surrogate standard solution containing perdeuterated analogues of acenaphthene, chrysene, naphthalene, 2-methylnaphthalene, perylene, phenanthrene, pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene and benzo(a)pyrene prior to analysis. Sediment samples were extracted by elution through a chromatographic column. Each extract was cleaned up on silica gel prior to analysis of PAHs by high resolution gas chromatography with low resolution (quadrupole) mass spectrometric detection (HRGC/MS).

Extraction Methods

A sub-sample of homogenized sediment was dried overnight at 105°C to determine moisture content.

Homogenized sediment sample was dried by grinding with anhydrous sodium sulphate. The mixture was transferred to a glass chromatographic column containing methanol. An aliquot of surrogate standard solution was added and the column was eluted with dichloromethane. The eluate was backwashed by shaking with potassium hydroxide solution followed by solvent extracted distilled water. The extract was dried over anhydrous sodium sulphate and concentrated. Activated copper was added to the extract to remover sulphur. The extract was ready for chromatographic cleanup procedures.

Chromatographic Cleanup Procedures

The extract was loaded onto a silica gel column (5% deactivated) and eluted with pentane (F1, discarded) followed by dichloromethane (F2, retained). The F2 fraction was concentrated and an aliquot of recovery standard, containing perdeuterated analogues of benzo(b)fluoranthene, fluoranthene and acenaphthylene was added. The extract was transferred to an autosampler vial in preparation for GC/MS analysis.

GC/MS Analysis

Analysis of the extract for PAHs was carried out using a Finnigan INCOS 50 mass spectrometer equipped with a Varian 3400 gas chromatograph with CTC autosampler and a Prolab Envirolink data system for MS control and data acquisition. The mass spectrometer was operated at unit mass resolution, in the

EI mode (70 Ev), using Multiple Ion Detection (MID) to enhance sensitivity. At least two characteristic ions for each target analyte and surrogate standard were monitored. A Restek Rtx-5 capillary chromatography column (30 m, 0.25 mm i.d. x 0.25 mm film thickness), used for chromatographic separation, was coupled to the MS source. A splitless/split injection sequence was used.

Quantitation Procedures

Concentrations of PAHs were calculated using the internal standard (isotope dilution) method of quantitation, comparing the area of the quantitation ion to that of the corresponding deuterated standard and correcting for response factors. Response factors were determined daily using authentic PAHs. Quantification was carried out using HP EnviroQuant and Prolab MS Extend software.

Concentrations of analytes were corrected based on the percent recovery of surrogate standards. Concentrations were reported on a dry weight basis.

APPENDIX II

WATER AND SEDIMENT DATA

Table II-1

Water Quality in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek (Fall)							Upstream of the Steepbank River (Fall)						
		2000			Historical (1976 - 1998)[(a)]				2000			Historical (1996)[(b)]			
		West	Middle	East	median	min	max	n	West	Middle	East	median	min	max	n
Field Measured															
pH		7.9	8.0	8.2	6.5	-	-	1	8.0	8.0	8.0	8.0	7.9	8.1	3
specific conductance	µS/cm	225	229	271	320	190	340	3	253	247	244	190	129	202	3
temperature	^oC	4.3	5.4	4.7	11.0	6.0	11.7	3	4.3	4.0	4.4	5.6	4.6	5.6	3
dissolved oxygen	mg/L	12.9	n/a	13.2	10.5	9.8	11.0	3	12.7	12.8	12.8	11.7	11.7	11.9	3
Conventional Parameters															
colour	T.C.U.	30	35	60	37	15	60	5	40	55	55	80	-	-	1
conductance	µS/cm	302	282	254	199	132	310	13	305	272	272	279	-	-	1
dissolved organic carbon	mg/L	6	6	6	10	4	23	10	6	7	8	19	-	-	1
hardness	mg/L	138	127	78	91	64	122	13	121	103	101	101	-	-	1
pH		7.9	8.0	7.7	7.6	6.8	8.2	13	7.9	7.8	7.8	7.7	-	-	1
total alkalinity	mg/L	117	107	73	86	67	107	13	104	94	94	88	-	-	1
total dissolved solids	mg/L	180	170	160	114	84	220	12	190	160	170	142	-	-	1
total organic carbon	mg/L	7	7	7	23	4	70	10	8	9	10	20	-	-	1
total suspended solids	mg/L	6	12	10	50	4	386	13	54	10	69	106	-	-	1
Major Ions															
bicarbonate (HCO3)	mg/L	143	130	88	123	113	130	4	127	115	115	108	-	-	1
calcium	mg/L	38	35	21	25	18	34	13	32	28	27	27	-	-	1
carbonate (CO3)	mg/L	< 5.0	< 5.0	< 5.0	< 2.8	0.0	< 5.0	6	< 5.0	< 5.0	< 5.0	< 0.5	-	-	1
chloride	mg/L	3	3	25	3	1	15	13	8	11	11	3	2	8	3
magnesium	mg/L	11	10	6	6	5	9	13	10	8	8	8	-	-	1
potassium	mg/L	1.0	0.8	0.8	1.0	0.4	1.4	13	1.0	1.0	0.8	1.1	-	-	1
sodium	mg/L	10	10	21	9	7	17	13	13	14	14	0.4	0.4	8	3
sulphate	mg/L	34	32	12	15	4	31	13	32	23	22	16	-	-	1
sulphide	µg/L	< 3	< 3	3	< 2	< 2	< 2	3	9	< 3	< 3	< 5	-	-	1
Nutrients and Chlorophyll *a*															
nitrate + nitrite	mg/L	0.29	< 0.05	< 0.05	0.05	0.01	0.05	4	< 0.05	< 0.05	< 0.05	0.01	-	-	1
nitrogen - ammonia	mg/L	< 0.10	< 0.10	< 0.10	< 0.05	< 0.01	< 0.05	4	< 0.10	< 0.10	< 0.10	< 0.01	< 0.01	0.03	3
nitrogen - kjeldahl	mg/L	0.4	< 0.2	0.4	0.6	< 0.2	2.0	10	0.2	< 0.2	0.3	0.6	-	-	1
phosphorus, total	µg/L	34	29	384	100	14	550	13	54	30	70	95	-	-	1
phosphorus, total dissolved	µg/L	23	19	29	10	7	22	5	18	21	22	92	-	-	1
chlorophyll *a*	µg/L	5	4	5	2	< 1	6	6	5	4	4	5	-	-	1
Biochemical Oxygen Demand															
biochemical oxygen demand	mg/L	< 2.0	< 2.0	< 2.0	3.0	2.0	8.0	3	< 2.0	< 2.0	< 2.0	< 0.1	-	-	1
Organics															
naphthenic acids	mg/L	1	< 1	< 1	< 1	< 1	20	4	1	1	1	-	-	-	-
total phenolics	µg/L	< 1	< 1	< 1	2	< 1	7	6	< 1	< 1	< 1	< 1	-	-	1
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.6	< 0.5	< 1.0	4	< 0.5	< 0.5	< 0.5	-	-	-	-
Toxicity															
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 100	3	> 91	> 91	> 91	-	-	-	-
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 100	3	> 91	> 91	> 91	-	-	-	-
Metals (Total)															
aluminum (Al)	µg/L	540	30	680	700	110	4500	11	2430	680	2770	660	-	-	1
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	< 0.8	< 0.2	1.2	4	< 5.0	< 5.0	< 5.0	-	-	-	-
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	1.3	0.5	9.0	13	3.0	< 1.0	< 1.0	1.0	-	-	1
barium (Ba)	µg/L	57	22	28	53	40	67	4	76	47	76	60	-	-	1
beryllium (Be)	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	4	< 1	< 1	< 1	< 1	-	-	1
boron (B)	µg/L	20	24	25	43	25	90	4	23	19	24	30	-	-	1
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.6	< 0.2	< 3.0	6	< 0.2	< 0.2	< 0.2	< 0.2	-	-	1
calcium (Ca)	µg/L	35400	19300	19700	34600	30100	34900	3	35900	28600	32600	-	-	-	-
chromium (Cr)	µg/L	< 1	< 1	< 1	2	< 1	6	6	5	< 1	8	3	-	-	1
cobalt (Co)	µg/L	0.3	< 0.2	0.3	1.0	0.4	3.0	6	1.3	0.4	0.7	1.3	-	-	1
copper (Cu)	µg/L	1	2	21	2	< 1	6	5	3	2	3	3	-	-	1
iron (Fe)	µg/L	540	410	1170	705	400	2190	4	2490	920	3040	2220	-	-	1
lead (Pb)	µg/L	0.3	0.3	0.6	1.0	0.5	< 20.0	4	1.3	0.5	1.0	1.3	-	-	1
lithium (Li)	µg/L	< 6	6	7	6	< 6	8	4	7	6	< 6	7	-	-	1
magnesium (Mg)	µg/L	9880	6120	6220	9290	8790	9330	3	10400	8240	8880	-	-	-	-
manganese (Mn)	µg/L	27	13	42	32	23	71	4	85	29	119	81	-	-	1
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 50.0	13	< 0.2	< 0.2	< 0.2	< 0.1	-	-	1

Table II-1

Water Quality in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek (Fall)							Upstream of the Steepbank River (Fall)						
		2000			Historical (1976 - 1998)[(a)]				2000			Historical (1996)[(b)]			
		West	Middle	East	median	min	max	n	West	Middle	East	median	min	max	n
molybdenum (Mo)	µg/L	0.7	0.4	0.4	1.1	0.8	< 3.0	4	5.3	0.5	0.4	< 3.0	-	-	1
nickel (Ni)	µg/L	0.8	0.2	1.8	5.1	3.0	9.8	4	8.2	1.1	2.8	13.4	-	-	1
potassium (K)	µg/L	1290	1010	1180	1100	1100	2060	3	1770	1210	1840	-	-	-	-
selenium (Se)	µg/L	< 0.8	1.3	< 0.8	< 0.5	< 0.2	< 0.8	6	< 0.8	< 0.8	1.1	0.2	-	-	1
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.1	< 2.0	4	< 0.4	< 0.4	< 0.4	< 0.1	-	-	1
sodium (Na)	µg/L	10000	20400	20300	14400	8400	14500	3	11900	13300	12800	-	-	-	-
strontium (Sr)	µg/L	254	121	123	229	171	258	4	241	201	211	159	-	-	1
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0.1	-	-	-	-	< 0.1	< 0.1	< 0.1	-	-	-	-
uranium (U)	µg/L	0.4	0.1	0.1	0.4	0.4	0.4	3	0.5	0.3	0.1	-	-	-	-
vanadium (V)	µg/L	1.3	0.6	1.7	1.9	0.7	5.9	4	14.2	1.9	7.6	5.0	-	-	1
zinc (Zn)	µg/L	15	17	41	17	4	58	6	33	32	25	-	-	-	-
Metals (Dissolved)															
aluminum (Al)	µg/L	10	60	130	44	40	120	3	10	10	50	-	-	-	-
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	0.6	< 0.8	3	< 0.8	< 0.8	< 0.8	-	-	-	-
arsenic (As)	µg/L	12.4	10.9	10.6	< 0.5	< 0.4	< 5.0	5	7.2	7.5	< 0.4	-	-	-	-
barium (Ba)	µg/L	51	48	52	50	42	51	3	46	38	40	-	-	-	-
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3	< 0.5	< 0.5	< 0.5	-	-	-	-
boron (B)	µg/L	31	24	24	27	10	450	10	28	26	27	-	-	-	-
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	3	< 0.1	< 0.1	0.3	-	-	-	-
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 3.0	< 0.4	5.0	9	< 0.4	< 0.4	< 0.4	-	-	-	-
cobalt (Co)	µg/L	0.1	0.1	0.2	0.3	0.1	0.8	3	0.2	0.1	0.1	-	-	-	-
copper (Cu)	µg/L	2.6	1.6	0.8	1.9	1.3	< 3.0	4	0.8	0.7	1.9	-	-	-	-
iron (Fe)	µg/L	< 10	< 10	260	100	100	140	3	30	70	110	-	-	-	-
lead (Pb)	µg/L	0.4	0.3	0.2	0.2	0.1	0.5	3	0.2	0.1	5.9	-	-	-	-
lithium (Li)	µg/L	6	6	6	6	-	-	1	6	6	6	-	-	-	-
manganese (Mn)	µg/L	13.9	3.7	18.5	4.7	4.5	11.4	3	25.4	8.6	51.3	-	-	-	-
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	3	< 0.1	< 0.1	< 0.1	-	-	-	-
molybdenum (Mo)	µg/L	0.8	1.0	0.7	1.0	0.6	1.0	3	5.0	0.6	1.7	-	-	-	-
nickel (Ni)	µg/L	0.7	0.6	0.7	2.6	1.6	2.7	3	1.8	0.6	5.9	-	-	-	-
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.8	5	< 0.4	< 0.4	< 0.4	-	-	-	-
silver (Ag)	µg/L	0.4	0.3	0.2	< 0.2	< 0.2	< 0.2	3	< 0.2	< 0.2	< 0.2	-	-	-	-
strontium (Sr)	µg/L	262	250	250	241	179	242	3	240	208	195	-	-	-	-
thallium (Tl)	µg/L	< 0.1	< 0.05	< 0.1	-	-	-	-	< 0.1	< 0.05	< 0.1	-	-	-	-
uranium (U)	µg/L	0.4	0.4	0.4	0.4	0.3	0.4	3	0.4	0.3	0.3	-	-	-	-
vanadium (V)	µg/L	0.1	0.2	0.4	< 0.1	< 0.1	< 0.1	3	6.7	0.3	0.3	-	-	-	-
zinc (Zn)	µg/L	9.0	6.0	6.0	5.0	4.0	14.0	3	7.0	5.0	267	-	-	-	-

(a) Based on information from Golder (1996, 1998, 1999b, 2000c) and NAQUADAT stations AB07DA0020/0050/0090.

(b) Based on information from NAQUADAT station AB07DA020.

Table II-2
Water Quality in the Athabasca River Upstream of Fort Creek and the Muskeg River

		Upstream of the Muskeg River (Fall)							Upstream of Fort Creek (Fall)						
		2000			Historical (1976 - 1997)[a]				2000			Historical (1997 - 1998)[b]			
Parameter	**Units**	**West**	**Middle**	**East**	**median**	**min**	**max**	**n**	**West**	**Middle**	**East**	**median**	**min**	**max**	**n**
Field Measured															
pH		-	8.0	-	8.0	7.9	8.1	3	8.0	8.0	8.0	8.4	-	-	1
specific conductance	µS/cm	256	247	248	169	145	197	3	252	249	251	310	160	360	3
temperature	^{o}C	3.2	3.0	2.9	7.0	0.0	15.0	13	4.3	3.9	4.2	6.0	4.0	11.0	3
dissolved oxygen	mg/L	-	-	-	10.9	9.6	13.6	12	13.0	13.2	12.8	10.6	10.3	10.8	3
Conventional Parameters															
colour	T.C.U.	35	40	40	50	< 5	70	5	50	50	40	-	15	25	2
conductance	µS/cm	285	283	283	269	188	362	12	288	280	280	-	290	328	2
dissolved organic carbon	mg/L	7	8	8	14	4	20	5	8	8	8	-	3	4	2
hardness	mg/L	110	107	106	-	84	101	2	113	113	113	-	101	127	2
pH		7.8	7.9	7.8	7.7	7.4	8.0	11	7.9	7.9	7.9	-	8.1	8.2	2
total alkalinity	mg/L	103	101	100	100	75	135	12	100	99	100	-	90	107	2
total dissolved solids	mg/L	190	190	190	153	120	213	12	90	170	190	-	162	184	2
total organic carbon	mg/L	9	10	10	9	3	19	12	11	10	10	-	5	6	2
total suspended solids	mg/L	16	13	15	18	8	68	12	14	25	29	-	14	17	2
Major Ions															
bicarbonate (HCO3)	mg/L	125	123	122	91	-	-	1	122	121	122	-	110	130	2
calcium	mg/L	30	29	29	29	23	40	12	31	31	31	-	27	35	2
carbonate (CO3)	mg/L	< 5.0	< 5.0	< 5.0	< 0.5	-	-	1	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	3
chloride	mg/L	9	11	11	8	3	16	14	11	11	11	-	3	30	2
magnesium	mg/L	9	8	8	8	6	12	12	9	9	9	-	8	10	2
potassium	mg/L	0.9	1.0	1.0	0.6	0.1	1.1	12	0.9	0.9	1.0	-	1.0	1.1	2
sodium	mg/L	11	12	12	10	9	18	14	12	13	13	-	9	26	2
sulphate	mg/L	26	23	24	19	14	31	11	26	25	26	-	23	34	2
sulphide	µg/L	< 3	6	< 3	< 5	-	-	1	5	3	6	-	< 2	< 2	2
Nutrients and Chlorophyll *a*															
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	0.03	-	-	1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.08	3
nitrogen - ammonia	mg/L	< 0.10	0.10	< 0.10	0.01	0.01	0.17	3	< 0.10	< 0.10	< 0.10	0.17	< 0.05	0.34	3
nitrogen - kjeldahl	mg/L	0.2	0.3	0.2	0.7	0.4	0.9	5	0.4	0.3	0.3	-	< 0.2	0.4	2
phosphorus, total	µg/L	32	30	31	42	18	101	13	32	42	39	-	15	20	2
phosphorus, total dissolved	µg/L	17	20	20	-	< 10	18	2	20	17	18	-	9	14	2
chlorophyll *a*	µg/L	3	3	2	3	< 1	5	4	5	4	4	-	2	3	2
Biochemical Oxygen Demand															
biochemical oxygen demand	mg/L	< 2.0	< 2.0	< 2.0	1.8	-	-	1	< 2.0	< 2.0	< 2.0	-	< 2.0	< 2.0	2
Organics															
naphthenic acids	mg/L	2	2	1	< 1	-	-	1	1	2	2	< 1	< 1	< 1	3
total phenolics	µg/L	2	2	2	-	< 1	< 1	2	2	2	2	< 1	< 1	< 1	3
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	-	-	1	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5	2
Toxicity															
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	-	-	-	-	> 91	> 91	> 91	-	> 91	> 91	2
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	-	-	-	-	> 91	> 91	> 91	-	> 91	> 91	2
Metals (Total)															
aluminum (Al)	µg/L	240	980	140	335	30	3890	12	590	870	930	-	50	540	2
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	0.5	-	-	1	< 5.0	< 5.0	< 5.0	-	< 0.8	0.9	2
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	1.5	1.1	4.0	3	< 1.0	< 1.0	< 1.0	-	< 1.0	< 1.0	2
barium (Ba)	µg/L	50	50	47	-	50	76	2	47	55	54	-	52	56	2
beryllium (Be)	µg/L	< 1	< 1	< 1	-	< 1	1	2	< 1	< 1	< 1	< 1	< 1	< 1	3
boron (B)	µg/L	15	17	17	-	30	33	2	20	19	20	-	19	35	2
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	-	< 0.2	< 0.2	2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	3
calcium (Ca)	µg/L	30400	29700	30000	29600	-	-	1	29400	31900	31500	-	28200	35100	2
chromium (Cr)	µg/L	2	3	2	-	< 2	4	2	1	2	3	-	< 1	1	2
cobalt (Co)	µg/L	0.4	0.5	0.4	-	1.2	2.1	2	0.3	0.6	0.5	-	0.4	1.3	2
copper (Cu)	µg/L	1	2	1	-	4	8	2	1	3	3	-	6	7	2
iron (Fe)	µg/L	860	1360	840	-	2220	2980	2	810	1350	1340	-	170	710	2
lead (Pb)	µg/L	0.4	0.7	0.5	-	1.6	1.7	2	0.4	0.5	0.6	-	0.2	1.0	2
lithium (Li)	µg/L	6	7	7	-	4	11	2	6	6	6	-	< 6	6	2
magnesium (Mg)	µg/L	8080	8090	7970	8740	-	-	1	8350	8970	8860	-	8360	9540	2
manganese (Mn)	µg/L	26	34	27	-	74	84	2	28	43	42	-	5	36	2
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.2	< 0.1	< 0.1	0.3	12	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.2	3
molybdenum (Mo)	µg/L	1.6	0.6	0.6	-	0.9	< 3.0	2	0.9	1.0	1.0	-	0.6	0.8	2
nickel (Ni)	µg/L	2.3	2.9	2.2	-	3.4	7.1	2	2.8	3.5	3.9	-	15.4	16.4	2
potassium (K)	µg/L	1200	1260	1200	2300	-	-	1	1210	1340	1320	-	1130	1290	2
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	-	< 0.2	< 0.4	2	< 0.8	< 0.8	< 0.8	-	< 0.8	< 0.8	2
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	-	< 0.1	< 0.1	2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.1	< 0.4	3

Table II-2

Water Quality in the Athabasca River Upstream of Fort Creek and the Muskeg River

Parameter	Units	Upstream of the Muskeg River (Fall)							Upstream of Fort Creek (Fall)						
		2000			Historical (1976 - 1997)[a]				2000			Historical (1997 - 1998)[b]			
		West	Middle	East	median	min	max	n	West	Middle	East	median	min	max	n
sodium (Na)	µg/L	10800	12400	12500	9700	-	-	1	13000	13300	13400	-	9200	25500	2
strontium (Sr)	µg/L	208	201	200	-	147	192	2	193	207	206	-	244	297	2
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0.1	-	-	-	-	< 0.1	< 0.1	< 0.1	-	-	-	-
uranium (U)	µg/L	0.3	0.4	0.3	0.4	-	-	1	0.3	0.3	0.3	-	0.2	0.4	2
vanadium (V)	µg/L	3.6	2.5	1.8	-	< 2.0	9.7	2	2.3	2.9	3.0	-	0.2	1.2	2
zinc (Zn)	µg/L	19	45	27	34	-	-	1	9	41	42	-	8	26	2
Metals (Dissolved)															
aluminum (Al)	µg/L	10	10	10	73	-	-	1	10	20	10	-	30	90	2
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	0.6	-	-	1	< 0.8	< 0.8	< 0.8	-	< 0.8	< 0.8	2
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	0.6	0.4	6.0	10	0.5	0.4	< 0.4	-	< 0.4	< 0.4	2
barium (Ba)	µg/L	46	43	42	40	-	-	1	44	44	44	-	37	42	2
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	-	-	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3
boron (B)	µg/L	15	16	14	95	26	100	4	19	17	17	-	12	19	2
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	0.1	-	-	1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	2
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	< 3.0	< 0.4	3.0	5	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	3
cobalt (Co)	µg/L	0.2	0.1	0.1	0.3	-	-	1	0.1	0.1	0.1	-	0.2	0.6	2
copper (Cu)	µg/L	0.6	0.7	0.6	4.2	-	-	1	1.1	1.0	1.7	-	1.1	1.6	2
iron (Fe)	µg/L	120	110	140	< 10	-	-	1	150	130	170	-	100	250	2
lead (Pb)	µg/L	< 0.1	< 0.1	< 0.1	1.5	-	-	1	0.6	0.5	0.6	-	0.2	0.3	2
lithium (Li)	µg/L	4	5	4	7	-	-	1	5	4	4	-	4	6	2
manganese (Mn)	µg/L	7.0	6.9	6.8	10.2	-	-	1	12.5	8.7	14.4	-	4.8	18.1	2
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.2	-	-	1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	3
molybdenum (Mo)	µg/L	1.5	0.6	0.6	0.8	-	-	1	2.2	2.2	1.5	-	0.5	0.7	2
nickel (Ni)	µg/L	1.5	1.4	1.2	2.3	-	-	1	1.4	1.5	1.4	-	2.3	2.8	2
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.2	< 0.2	< 0.4	4	0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	3
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	-	-	1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	3
strontium (Sr)	µg/L	195	183	178	175	-	-	1	182	187	185	-	201	255	2
thallium (Tl)	µg/L	< 0.1	< 0.05	< 0.1	-	-	-	-	< 0.1	< 0.05	< 0.1	-	-	-	-
uranium (U)	µg/L	0.3	0.3	0.3	0.3	-	-	1	0.3	0.3	0.3	-	0.2	0.4	2
vanadium (V)	µg/L	1.6	0.2	0.3	0.2	-	-	1	0.8	0.6	0.6	< 0.1	< 0.1	< 0.1	3
zinc (Zn)	µg/L	0.01	0.01	0.01	0.02	-	-	1	7.0	25.0	8.0	-	5.0	9.0	2

[a] Based on information from Golder (1997a) and NAQUADAT station AB07DA0400.

[b] Based on information from Golder (1998, 1999b).

Table II-3
Water Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca River Delta

Parameter	Units	Upstream of the Embarras River (Fall)					Delta (Fall)				
			Historical (1976 - 1987)[(a)]					Historical (1976 - 1987)[(b)]			
		2000	median	min	max	n	2000	median	min	max	n
Field Measured											
pH		-	7.9	7.9	8.0	3	-	8.0	7.8	8.6	4
specific conductance	µS/cm	-	305	262	328	3	-	230	196	2000	11
temperature	^{o}C	-	11.0	2.2	14.7	4	-	9.0	2.3	14.7	17
dissolved oxygen	mg/L	-	9.7	8.9	12.2	3	-	9.5	6.0	14.0	9
Conventional Parameters											
colour	T.C.U.	75	23	23	36	3	100	35	10	70	9
conductance	µS/cm	263	285	197	338	4	257	240	180	338	17
dissolved organic carbon	mg/L	9	6	6	8	3	9	8	4	20	11
hardness	mg/L	119	120	89	129	4	114	108	12	129	8
pH		7.9	8.3	7.9	8.4	4	7.9	7.9	7.5	8.4	17
total alkalinity	mg/L	103	108	79	118	4	101	96	77	117	17
total dissolved solids	mg/L	180	164	137	181	3	170	157	118	186	14
total organic carbon	mg/L	12	17	-	-	1	13	11	4	21	14
total suspended solids	mg/L	44	8	6	17	5	58	21	7	50	16
Major Ions											
bicarbonate (HCO3)	mg/L	125	134	126	141	3	123	129	127	143	3
calcium	mg/L	33	34	25	37	4	31	29	24	37	17
carbonate (CO3)	mg/L	< 5.0	-	< 5.0	< 5.0	2	< 5.0	-	< 5.0	< 5.0	2
chloride	mg/L	7	12	7	21	4	7	9	5	24	17
magnesium	mg/L	9	9	7	9	4	9	8	6	9	17
potassium	mg/L	1.0	0.9	0.7	1.0	4	0.9	0.8	0.1	1.3	17
sodium	mg/L	13	12	9	19	4	11	12	8	19	17
sulphate	mg/L	22	20	12	23	4	22	18	3	28	17
sulphide	µg/L	< 3	-	-	-	-	< 3	-	-	-	-
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.05	-	-	-	-	< 0.05	-	-	-	-
nitrogen - ammonia	mg/L	< 0.10	-	-	-	-	< 0.10	-	-	-	-
nitrogen - kjeldahl	mg/L	0.6	-	-	-	-	0.8	0.6	0.3	1.0	8
phosphorus, total	µg/L	44	27	21	140	6	56	48	17	220	19
phosphorus, total dissolved	µg/L	15	-	-	-	-	15	-	-	-	-
chlorophyll *a*	µg/L	2	5	4	5	3	4	5	< 1	7	4
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2.0	-	-	-	-	< 2.0	-	-	-	-
Organics											
naphthenic acids	mg/L	< 1	-	-	-	-	< 1	-	-	-	-
total phenolics	µg/L	2	4	3	5	3	2	4	4	5	3
total recoverable hydrocarbons	mg/L	< 0.5	-	-	-	-	< 0.5	-	-	-	-
Toxicity											
Microtox IC_{50} @ 15 min	%	> 91	-	-	-	-	> 91	-	-	-	-
Microtox IC_{25} @ 15 min	%	> 91	-	-	-	-	> 91	-	-	-	-
Metals (Total)											
aluminum (Al)	µg/L	1670	-	-	-	-	2570	350	40	520	11
antimony (Sb)	µg/L	< 5.0	-	-	-	-	< 5.0	-	-	-	-
arsenic (As)	µg/L	< 1.0	0.5	0.5	0.8	3	1.0	0.6	0.5	1.0	3
barium (Ba)	µg/L	62	56	55	57	3	69	55	52	65	3
beryllium (Be)	µg/L	< 1	-	-	-	-	< 1	-	-	-	-
boron (B)	µg/L	16	-	-	-	-	16	-	-	-	-
cadmium (Cd)	µg/L	< 0.2	< 1.0	< 1.0	< 1.0	3	< 0.2	< 1.0	< 1.0	< 1.0	3
calcium (Ca)	µg/L	32700	-	-	-	-	32500	-	-	-	-

Table II-3

Water Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca River Delta

Parameter	Units	Upstream of the Embarras River (Fall)					Delta (Fall)				
			Historical (1976 - 1987)[(a)]					Historical (1976 - 1987)[(b)]			
		2000	median	min	max	n	2000	median	min	max	n
chromium (Cr)	µg/L	3	5	< 1	7	3	3	3	2	5	3
cobalt (Co)	µg/L	0.6	< 1.0	< 1.0	< 1.0	3	0.8	< 1.0	< 1.0	< 1.0	3
copper (Cu)	µg/L	3	< 1	< 1	3	3	5	< 1	< 1	< 1	3
iron (Fe)	µg/L	1720	-	-	-	-	1990	-	-	-	-
lead (Pb)	µg/L	1.4	-	-	-	-	1.7	-	-	-	-
lithium (Li)	µg/L	7	-	-	-	-	7	-	-	-	-
magnesium (Mg)	µg/L	8660	-	-	-	-	9850	-	-	-	-
manganese (Mn)	µg/L	54	-	-	-	-	49	-	-	-	-
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.1	< 0.1	3	< 0.2	< 0.1	< 0.1	0.9	14
molybdenum (Mo)	µg/L	0.9	-	-	-	-	0.9	-	-	-	-
nickel (Ni)	µg/L	4.5	-	-	-	-	5.4	-	-	-	-
potassium (K)	µg/L	1410	-	-	-	-	1650	-	-	-	-
selenium (Se)	µg/L	< 0.8	< 0.2	< 0.2	< 0.2	3	< 0.8	< 0.2	< 0.0	< 0.2	3
silver (Ag)	µg/L	< 0.4	-	-	-	-	< 0.4	-	-	-	-
sodium (Na)	µg/L	11600	-	-	-	-	12000	-	-	-	-
strontium (Sr)	µg/L	210	-	-	-	-	206	-	-	-	-
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	0.4	-	-	-	-	0.5	-	-	-	-
vanadium (V)	µg/L	4.3	-	-	-	-	5.3	-	-	-	-
zinc (Zn)	µg/L	33	4	2	5	3	58	4	2	8	3
Metals (Dissolved)											
aluminum (Al)	µg/L	280	-	-	-	-	310	-	-	-	-
antimony (Sb)	µg/L	< 0.8	-	-	-	-	< 0.8	-	-	-	-
arsenic (As)	µg/L	0.7	< 0.5	-	-	1	0.7	0.6	0.3	2.6	14
barium (Ba)	µg/L	49	-	-	-	-	49	-	-	-	-
beryllium (Be)	µg/L	< 0.5	< 1.0	< 1.0	< 1.0	3	< 0.5	< 1.0	< 1.0	< 1.0	3
boron (B)	µg/L	25	-	-	-	-	23	40	20	100	7
cadmium (Cd)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
chromium (Cr)	µg/L	1.6	-	-	-	-	1.5	< 3.0	< 3.0	10.0	8
cobalt (Co)	µg/L	0.2	-	-	-	-	0.2	-	-	-	-
copper (Cu)	µg/L	1.6	-	-	-	-	1.7	-	-	-	-
iron (Fe)	µg/L	430	-	-	-	-	470	-	-	-	-
lead (Pb)	µg/L	0.3	-	-	-	-	0.3	-	-	-	-
lithium (Li)	µg/L	6	-	-	-	-	6	-	-	-	-
manganese (Mn)	µg/L	10.0	-	-	-	-	10.8	-	-	-	-
mercury (Hg)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
molybdenum (Mo)	µg/L	0.8	-	-	-	-	0.9	-	-	-	-
nickel (Ni)	µg/L	2.4	-	-	-	-	2.4	-	-	-	-
selenium (Se)	µg/L	< 0.4	< 0.5	-	-	1	< 0.4	< 0.2	< 0.2	0.5	11
silver (Ag)	µg/L	< 0.2	-	-	-	-	< 0.2	-	-	-	-
strontium (Sr)	µg/L	206	-	-	-	-	197	-	-	-	-
thallium (Tl)	µg/L	< 0.05	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	0.3	-	-	-	-	0.3	-	-	-	-
vanadium (V)	µg/L	1.1	-	-	-	-	1.3	-	-	-	-
zinc (Zn)	µg/L	< 2.0	-	-	-	-	< 2.0	-	-	-	-

[(a)] Based on information from NAQUADAT stations AB07DD0130/0140/0150.

[(b)] Based on information from NAQUADAT stations AB07DD0160/0170/0220/0230/0240.

Table II-4

Sediment Quality in the Athabasca River Upstream of Donald Creek and the Steepbank River

		Upstream of Donald Creek								Upstream of the Steepbank River					
		2000		1998[a]		Historical (1975 - 1997)[b]				2000		Historical (1975 - 1995)[c]			
Parameter	**Units**	**West**	**East**	**West**	**East**	**Median**	**Min**	**Max**	**n**	**West**	**East**	**Median**	**Min**	**Max**	**n**
Particle Size															
partice size - % sand	%	98	85	83	70	56	-	-	1	71	89	66	37	94	8
partice size - % silt	%	1	9	10	20	24	-	-	1	21	6	26	2	41	8
partice size - % clay	%	2	7	7	10	20	-	-	1	8	5	8	0.3	22	8
moisture content	%	23	21	-	-	-	-	-	-	29	25	-	-	-	-
Carbon Content															
total inorganic carbon	% by wt	0.2	0.9	0.6	0.6	0.3	-	-	1	0.7	0.3	0.8	-	-	1
total organic carbon	% by wt	0.1	2.5	0.4	0.9	-	0.2	0.7	2	2.1	0.5	0.9	0.2	6.6	22
total carbon	% by wt	0.3	3.4	1.1	1.5	-	-	-	-	2.8	0.8	-	-	-	-
Organics															
total recoverable hydrocarbons	mg/kg	300	14600	214	653	423	-	-	1	800	500	-	-	-	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	-	-	-	-	-	-	< 0.5	< 0.5	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	35	1500	-	-	-	-	-	-	150	62	-	-	-	-
Metals (Total)															
aluminum (Al)	ug/g	2500	3920	5990	8080	-	10700	27800	2	5160	2600	33000	4250	87600	13
arsenic (As)	ug/g	3.6	3.9	7.7	4.2	3.5	2.7	5.6	3	3.5	2.5	3.0	1.3	8.4	17
barium (Ba)	ug/g	67	109	132	106	-	168	470	2	180	64	411	88	780	13
beryllium (Be)	ug/g	0.2	0.4	< 1	< 1	-	< 1	1	2	0.4	< 0.2	0.45	0.15	2.4	13
boron (B)	ug/g	5	6	-	-	-	-	-	-	13	< 5	16	14	18	5
cadmium (Cd)	ug/g	< 0.1	< 0.1	< 0.5	< 0.5	-	0.08	< 0.5	2	0.1	< 0.1	< 0.5	0.06	7.37	23
calcium (Ca)	ug/g	7600	17900	15400	14200	-	12000	17500	2	21400	10100	28500	5900	71000	13
chromium (Cr)	ug/g	7.3	34.5	13.6	16.2	33.0	19.0	75.0	3	33.4	12.1	31.7	10.3	587.0	24
cobalt (Co)	ug/g	4.4	4.9	6.0	5.0	-	4.0	7.0	2	5.4	3.7	13.7	5.0	25.2	22
copper (Cu)	ug/g	6.0	6.9	9.0	10.0	12.0	1.9	15.0	3	8.5	3.7	13.2	2.5	27.7	24
iron (Fe)	ug/g	8960	18700	11400	12500	12400	10900	15000	3	12700	7980	17300	10200	27800	14
lead (Pb)	ug/g	3.2	4.2	8.0	8.0	3.8	< 1	9.0	3	5.4	3.0	7.2	< 1	121.0	24
magnesium (Mg)	ug/g	1975	4700	5100	5390	-	3200	5680	2	5840	2980	6544	1512	13650	22
manganese (Mn)	ug/g	261	315	251	283	248	232	381	3	276	188	335	213	425	14
mercury (Hg)	ug/g	0	0.07	0.03	0.04	0.02	0.01	0.05	3	0.1	0	0.023	0.01	0.07	14
molybdenum (Mo)	ug/g	0.4	1.2	< 1	< 1	< 1	-	-	1	0.7	0.3	< 1	0.9	1.4	12
nickel (Ni)	ug/g	9.1	23.9	14	13	16	6.8	33.9	3	20.2	8.8	21.35	7.7	44.6	24
potassium (K)	ug/g	645	1280	1060	1640	1990	-	-	1	1970	570	7750	580	11300	12
selenium (Se)	ug/g	< 0.2	0.5	< 0.1	0.3	-	0.17	0.8	2	< 0.2	< 0.2	< 1	0.18	2.96	15
silver (Ag)	ug/g	< 0.1	< 0.1	< 1	< 1	< 1	-	-	1	0.1	< 0.1	< 0.5	< 0.2	< 0.5	12
sodium (Na)	ug/g	100	100	112	215	-	244	7400	2	200	< 100	5500	40	11500	13
strontium (Sr)	ug/g	27	45	44	40	-	52	155	2	55	25	100	30.7	205	13
thallium (Tl)	ug/g	< 0.1	0.08	-	-	-	-	-	-	0.12	< 0.1	-	-	-	-
uranium (U)	ug/g	0.35	0.6	-	-	-	-	-	-	0.8	0.4	< 50	< 50	< 50	5
vanadium (V)	ug/g	11.05	17.6	18	22	32	28	39	3	30.4	11.4	46.5	14	118	23
zinc (Zn)	ug/g	26.15	26.6	48	46.2	32.1	16	53	3	30.6	22	48.55	13.9	110	24
Target PAHs and Alkylated PAHs															
naphthalene	ng/g	15	13	25	12	< 10	-	-	1	18	7	-	-	-	-
C1 subst'd naphthalenes	ng/g	11	19	15	18	< 20	-	-	1	29	11	-	-	-	-
C2 subst'd naphthalenes	ng/g	< 1	< 7	26	25	20	-	-	1	46	19	-	-	-	-
C3 subst'd naphthalenes	ng/g	< 4	< 10	21	49	30	-	-	1	42	11	-	-	-	-
C4 subst'd naphthalenes	ng/g	< 2	< 9	< 2	57	< 20	-	-	1	< 9	< 3	-	-	-	-
acenaphthene	ng/g	1	< 5	< 2	< 3	< 10	-	-	1	< 7	< 3	-	-	-	-
C1 subst'd acenaphthene	ng/g	1	< 4	< 1	< 0.2	< 20	-	-	1	< 4	1	-	-	-	-
acenaphthylene	ng/g	< 1	< 5	< 1	< 1	< 10	-	-	1	< 6	< 1	-	-	-	-
anthracene	ng/g	< 1	< 12	< 2	< 4	< 10	-	-	1	< 4	< 2	-	-	-	-
dibenzo(a,h)anthracene	ng/g	< 6	< 10	< 4	< 6	< 10	-	-	1	< 4	< 4	-	-	-	-
benzo(a)anthracene / chrysene	ng/g	2	321	8	21	20	-	-	1	43	11	-	-	-	-
C1 subst'd benzo(a)anthracene / chrysene	ng/g	< 5	3500	< 1	< 1	30	-	-	1	290	< 19	-	-	-	-
C2 subst'd benzo(a)anthracene / chrysene	ng/g	< 1	1600	< 1	< 1	50	-	-	1	< 120	35	-	-	-	-
benzo(a)pyrene	ng/g	< 2	24	< 6	11	< 10	-	-	1	< 11	4	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene / benzo(a)py	ng/g	< 2	< 23	< 5	< 12	30	-	-	1	< 13	< 5	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene / benzo(a)py	ng/g	< 2	< 29	< 3	< 6	30	-	-	1	< 6	< 5	-	-	-	-
benzofluoranthenes	ng/g	< 2	88	6	19	10	-	-	1	28	17	-	-	-	-
benzo(g,h,i)perylene	ng/g	< 7	46	5	13	< 10	-	-	1	< 33	5	-	-	-	-
biphenyl	ng/g	2	< 3	< 0	< 1	< 20	-	-	1	< 4	2	-	-	-	-

Table II-4

Sediment Quality in the Athabasca River Upstream of Donald Creek and the Steepbank River

Parameter	Units	Upstream of Donald Creek								Upstream of the Steepbank River					
		2000		1998[(a)]		Historical (1975 - 1997)[(b)]				2000		Historical (1975 - 1995)[(c)]			
		West	East	West	East	Median	Min	Max	n	West	East	Median	Min	Max	n
C1 subst'd biphenyl	ng/g	< 3	< 4	< 0	< 0	< 20	-	-	1	< 4	< 2	-	-	-	-
C2 subst'd biphenyl	ng/g	< 1	< 6	< 0	< 0	< 20	-	-	1	< 3	< 1	-	-	-	-
dibenzothiophene	ng/g	< 1	< 4	1	< 3	< 10	-	-	1	< 12	< 2	-	-	-	-
C1 subst'd dibenzothiophene	ng/g	< 1	< 12	7	23	< 20	-	-	1	20	< 2	-	-	-	-
C2 subst'd dibenzothiophene	ng/g	< 3	1600	< 3	110	20	-	-	1	55	< 2	-	-	-	-
C3 subst'd dibenzothiophene	ng/g	< 2	4400	< 2	< 3	40	-	-	1	79	< 6	-	-	-	-
C4 subst'd dibenzothiophene	ng/g	< 2	< 9	-	-	50	-	-	1	< 6	< 3	-	-	-	-
fluoranthene	ng/g	2	27	3	7	< 10	-	-	1	9	4	-	-	-	-
C1 subst'd fluoranthene / pyrene	ng/g	< 1	480	13	36	30	-	-	1	58	20	-	-	-	-
C2 subst'd fluoranthene / pyrene	ng/g	4	1200	-	-	-	-	-	-	140	40	-	-	-	-
C3 subst'd fluoranthene / pyrene	ng/g	< 1	1400	-	-	-	-	-	-	170	45	-	-	-	-
fluorene	ng/g	< 1	< 6	< 2	4	< 10	-	-	1	< 4	< 2	-	-	-	-
C1 subst'd fluorene	ng/g	< 1	< 4	< 1	< 1	< 20	-	-	1	< 5	< 3	-	-	-	-
C2 subst'd fluorene	ng/g	< 1	< 12	< 2	< 2	< 20	-	-	1	< 8	< 4	-	-	-	-
C3 subst'd fluorene	ng/g	< 2	< 14	-	-	-	-	-	-	< 6	< 3	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	< 4	34	< 9	7	< 10	-	-	1	12	5	-	-	-	-
phenanthrene	ng/g	4	14	7	17	10	-	-	1	15	5	-	-	-	-
C1 subst'd phenanthrene / anthracene	ng/g	2	18	19	64	< 20	-	-	1	65	6	-	-	-	-
C2 subst'd phenanthrene / anthracene	ng/g	1	400	23	86	30	-	-	1	37	15	-	-	-	-
C3 subst'd phenanthrene / anthracene	ng/g	< 2	1000	< 3	140	40	-	-	1	39	9	-	-	-	-
C4 subst'd phenanthrene / anthracene	ng/g	6	700	27	710	40	-	-	1	51	21	-	-	-	-
1-Methyl-7-isopropyl-phenanthrene (Retene)	ng/g	12	180	-	-	-	-	-	-	150	41	-	-	-	-
pyrene	ng/g	2	110	6	16	< 10	-	-	1	31	6	-	-	-	-

[(a)] Based on information from Golder (1999b).
[(b)] Based on information from Allan and Jackson (1978) and Lutz and Hendzel (1977).
[(c)] Based on information from Allan and Jackson (1978) C.G.L. (1979), Beak (1988), Golder (1995) and Dobson et al. (1996).

Table II-5

Sediment Quality in the Athabasca River Upstream of the Muskeg River

Parameter	Units	2000		1998[a]		Historical (1976 - 1983)[b]			
		West	East	West	East	Median	Min	Max	n
Particle Size									
partice size - % sand	%	76	48	71	60	-	64	94	2
partice size - % silt	%	14	36	17	22	-	3	30	2
partice size - % clay	%	11	16	12	18	-	1	6	2
moisture content	%	28	34	-	-	-	-	-	-
Carbon Content									
total inorganic carbon	% by wt	0.6	0.7	1.0	0.7	0.2	-	-	1
total organic carbon	% by wt	0.7	0.8	0.7	1.6	-	0.2	0.4	2
total carbon	% by wt	1.3	1.6	1.4	2.2	-	-	-	-
Organics									
total recoverable hydrocarbons	mg/kg	500	700	406	555	-	-	-	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	-	-	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	140	32	-	-	-	-	-	-
Metals (Total)									
aluminum (Al)	ug/g	4440	4680	9560	10900	45300	22200	78600	3
arsenic (As)	ug/g	3.8	6.4	4.8	5.5	-	1.6	1.9	2
barium (Ba)	ug/g	105	159	172	188	537	443	540	3
beryllium (Be)	ug/g	0.4	0.6	< 1	< 1	0.33	0.3	1.1	3
boron (B)	ug/g	< 2	18	-	-	-	-	-	-
cadmium (Cd)	ug/g	0.1	0.2	< 0.5	< 0.5	< 0.5	< 0.5	1.76	3
calcium (Ca)	ug/g	15300	19200	24700	17600	15600	8900	34000	3
chromium (Cr)	ug/g	12.9	20.7	18.1	21.2	31.3	11.3	36.0	4
cobalt (Co)	ug/g	5.6	8.1	7.0	8.0	12.5	2.0	18.5	4
copper (Cu)	ug/g	7.4	17.1	12.0	15.0	8.1	2.6	26.5	4
iron (Fe)	ug/g	12200	19700	14500	16200	13600	10900	25400	3
lead (Pb)	ug/g	5.5	9.3	9.0	10.0	3.5	< 1	7.8	4
magnesium (Mg)	ug/g	4690	6530	7400	6700	4677.5	2700	13100	4
manganese (Mn)	ug/g	233	496	329	386	224	189	353	3
mercury (Hg)	ug/g	< 0.04	0.06	0.04	0.04	0.029	0.011	0.029	3
molybdenum (Mo)	ug/g	0.3	0.4	< 1	< 1	-	< 1	< 1	2
nickel (Ni)	ug/g	12.6	19.4	17	19	13.9	7.1	22.2	4
potassium (K)	ug/g	1250	1910	1840	2040	-	9000	12700	2
selenium (Se)	ug/g	0.7	1	0.4	< 0.1	< 1	-	-	1
silver (Ag)	ug/g	< 0.1	< 0.1	< 1	< 1	-	< 0.5	< 0.5	2
sodium (Na)	ug/g	121	169	186	216	7600	5200	9200	3
strontium (Sr)	ug/g	41	58	65	57	128	126	155	3
thallium (Tl)	ug/g	0.09	0.2	-	-	-	-	-	-
uranium (U)	ug/g	0.7	1.1	-	-	-	-	-	-
vanadium (V)	ug/g	19.1	28.8	24	28	34.9	24.9	65.7	4
zinc (Zn)	ug/g	35.7	71.4	59.6	70.5	33.55	16.8	48.5	4
Target PAHs and Alkylated PAHs									
naphthalene	ng/g	10	8	17	34	-	-	-	-
C1 subst'd naphthalenes	ng/g	34	21	20	27	-	-	-	-
C2 subst'd naphthalenes	ng/g	62	35	30	32	-	-	-	-
C3 subst'd naphthalenes	ng/g	54	35	31	44	-	-	-	-
C4 subst'd naphthalenes	ng/g	34	33	< 2	< 5	-	-	-	-
acenaphthene	ng/g	< 3	< 2	< 2	4	-	-	-	-
C1 subst'd acenaphthene	ng/g	2	1	< 0	< 0	-	-	-	-
acenaphthylene	ng/g	< 1	< 1	< 1	< 1	-	-	-	-
anthracene	ng/g	< 1	< 4	< 1	< 4	-	-	-	-
dibenzo(a,h)anthracene	ng/g	< 3	< 3	< 2	< 5	-	-	-	-
benzo(a)anthracene / chrysene	ng/g	23	31	13	23	-	-	-	-
C1 subst'd benzo(a)anthracene / chrysene	ng/g	190	410	< 1	< 1	-	-	-	-
C2 subst'd benzo(a)anthracene / chrysene	ng/g	64	150	< 1	< 1	-	-	-	-
benzo(a)pyrene	ng/g	8	8	5	10	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 4	< 9	< 4	< 6	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 5	< 9	< 2	< 3	-	-	-	-
benzofluoranthenes	ng/g	32	28	11	18	-	-	-	-

Table II-5

Sediment Quality in the Athabasca River Upstream of the Muskeg River

Parameter	Units	2000		1998[(a)]		Historical (1976 - 1983)[(b)]			
		West	East	West	East	Median	Min	Max	n
benzo(g,h,i)perylene	ng/g	9	15	6	10	-	-	-	-
biphenyl	ng/g	4	3	< 1	< 1	-	-	-	-
C1 subst'd biphenyl	ng/g	< 2	< 3	< 1	< 1	-	-	-	-
C2 subst'd biphenyl	ng/g	< 1	< 3	< 0	< 1	-	-	-	-
dibenzothiophene	ng/g	< 1	3	1	< 2	-	-	-	-
C1 subst'd dibenzothiophene	ng/g	5	27	9	15	-	-	-	-
C2 subst'd dibenzothiophene	ng/g	33	190	< 3	< 7	-	-	-	-
C3 subst'd dibenzothiophene	ng/g	42	300	< 1	< 3	-	-	-	-
C4 subst'd dibenzothiophene	ng/g	< 4	< 3	-	-	-	-	-	-
fluoranthene	ng/g	7	5	4	6	-	-	-	-
C1 subst'd fluoranthene / pyrene	ng/g	49	89	16	31	-	-	-	-
C2 subst'd fluoranthene / pyrene	ng/g	82	150	-	-	-	-	-	-
C3 subst'd fluoranthene / pyrene	ng/g	78	160	-	-	-	-	-	-
fluorene	ng/g	2	< 1	3	2	-	-	-	-
C1 subst'd fluorene	ng/g	< 2	< 3	< 1	< 1	-	-	-	-
C2 subst'd fluorene	ng/g	< 2	41	< 1	< 1	-	-	-	-
C3 subst'd fluorene	ng/g	< 4	< 7	-	-	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	11	13	< 7	< 7	-	-	-	-
phenanthrene	ng/g	15	13	12	14	-	-	-	-
C1 subst'd phenanthrene / anthracene	ng/g	46	66	34	57	-	-	-	-
C2 subst'd phenanthrene / anthracene	ng/g	47	120	32	62	-	-	-	-
C3 subst'd phenanthrene / anthracene	ng/g	34	170	38	84	-	-	-	-
C4 subst'd phenanthrene / anthracene	ng/g	36	140	31	91	-	-	-	-
1-Methyl-7-isopropyl-phenanthrene (retune)	ng/g	90	63	-	-	-	-	-	-
pyrene	ng/g	15	11	7	13	-	-	-	-

[(a)] Based on information from Golder (1999b).
[(b)] Based on information from Allan and Jackson (1978), C.G.L. (1979) and Beak (1988).

Table II-6
Sediment Quality in the Athabasca River Upstream of Fort Creek

Parameter	Units	2000		1998[a]		Historical (1975 - 1997)[b]			
		West	East	West	East	Median	Min	Max	n
Particle Size									
partice size - % sand	%	98	69	43	74	-	30	66	2
partice size - % silt	%	< 1	23	36	15	-	14	37	2
partice size - % clay	%	2	8	21	11	-	20	33	2
moisture content	%	21	23	-	-	1	-	-	1
Carbon Content									
total inorganic carbon	% by wt	0.1	0.4	1.0	0.8	0.8	0.5	2.1	4
total organic carbon	% by wt	2.7	4.0	2.0	0.7	1.1	0.3	1.7	5
total carbon	% by wt	2.9	4.4	3.0	1.4	-	2.1	3.2	2
Organics									
total recoverable hydrocarbons	mg/kg	200	7700	900	581	1190	-	-	1
total volatile hydrocarbons (C5-C10)	mg/kg	0.6	0.8	-	-	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	7	1600	-	-	-	-	-	-
Metals (Total)									
aluminum (Al)	ug/g	1850	3440	9440	7630	31900	7790	49800	3
arsenic (As)	ug/g	2.3	1.7	5.6	4.1	3.5	2.6	5.1	4
barium (Ba)	ug/g	43	95	178	138	560	145	680	3
beryllium (Be)	ug/g	< 0.2	0.4	< 1	< 1	1.3	< 1	1.9	3
boron (B)	ug/g	5	8	-	-	-	-	-	-
cadmium (Cd)	ug/g	< 0.1	0.1	< 0.5	< 0.5	-	0.04	< 0.5	2
calcium (Ca)	ug/g	8070	16500	24400	19400	18550	17200	20400	3
chromium (Cr)	ug/g	5.8	11.1	17.2	15.7	46.0	20.2	72.0	4
cobalt (Co)	ug/g	4.0	5.4	8.0	6.0	12.0	7.0	13.0	3
copper (Cu)	ug/g	4.3	7.9	16.0	10.0	8.9	3.5	15.0	4
iron (Fe)	ug/g	8030	12100	16100	12800	14700	10700	20800	4
lead (Pb)	ug/g	3.7	5.0	9.0	8.0	4.0	2.5	8.0	4
magnesium (Mg)	ug/g	2410	5020	7530	6500	6365	6300	8300	3
manganese (Mn)	ug/g	184	261	419	293	259.5	101	382	4
mercury (Hg)	ug/g	< 0.04	< 0.04	0.06	0.03	0.045	0.011	< 0.1	6
molybdenum (Mo)	ug/g	0.2	0.3	< 1	< 1	< 1	-	-	1
nickel (Ni)	ug/g	7.9	12.9	20	14	15.95	8.1	23.5	4
potassium (K)	ug/g	355	948	1690	1420	1395	-	-	1
selenium (Se)	ug/g	0.4	< 0.2	0.6	0.3	-	0.13	0.5	2
silver (Ag)	ug/g	< 0.1	< 0.1	< 1	< 1	< 1	-	-	1
sodium (Na)	ug/g	61	105	146	384	6700	137	8100	3
strontium (Sr)	ug/g	21	46	73	52	153	53	190	3
thallium (Tl)	ug/g	< 0.05	0.07	-	-	-	-	-	-
uranium (U)	ug/g	0.3	0.6	-	-	-	-	-	-
vanadium (V)	ug/g	8.9	15.9	22	20	38	18.5	95	4
zinc (Zn)	ug/g	58.8	41.9	71.1	52.7	34.25	22.9	57.4	4
Target PAHs and Alkylated PAHs									
naphthalene	ng/g	4	24	28	23	10	6	21	3
C1 subst'd naphthalenes	ng/g	5	71	45	21	26	15	27	3
C2 subst'd naphthalenes	ng/g	13	65	72	28	35	23	35	3
C3 subst'd naphthalenes	ng/g	5	180	92	58	43	26	55	3
C4 subst'd naphthalenes	ng/g	< 2	760	< 4	< 5	39	14	55	3
acenaphthene	ng/g	< 2	< 22	4	4	1	1	< 3	3
C1 subst'd acenaphthene	ng/g	< 1	< 5	< 1	< 0	< 20	-	-	1
acenaphthylene	ng/g	< 2	< 13	< 1	< 1	1	0	< 3	3
anthracene	ng/g	< 2	< 24	< 2	< 3	1	1	< 3	3
dibenzo(a,h)anthracene	ng/g	< 2	< 72	< 6	< 4	3	2	< 3	3
benzo(a)anthracene / chrysene	ng/g	5	410	46	27	25	20	31	3
C1 subst'd benzo(a)anthracene / chrysene	ng/g	39	4300	< 2	< 1	35	-	-	1
C2 subst'd benzo(a)anthracene / chrysene	ng/g	14	1800	< 2	< 1	85	-	-	1
benzo(a)pyrene	ng/g	< 3	< 62	16	< 10	6	6	9	3
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 4	< 83	< 3	< 8	35	-	-	1

Table II-6

Sediment Quality in the Athabasca River Upstream of Fort Creek

Parameter	Units	2000		1998[(a)]		Historical (1975 - 1997)[(b)]			
		West	East	West	East	Median	Min	Max	n
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 3	< 53	< 4	< 3	35	-	-	1
benzofluoranthenes	ng/g	5	130	31	14	17	17	18	3
benzo(g,h,i)perylene	ng/g	< 2	< 67	14	9	12	7	12	3
biphenyl	ng/g	< 1	< 10	< 2	< 1	< 20	-	-	1
C1 subst'd biphenyl	ng/g	< 3	< 9	< 1	< 1	< 20	-	-	1
C2 subst'd biphenyl	ng/g	< 1	< 8	< 1	< 1	< 20	-	-	1
dibenzothiophene	ng/g	< 2	< 13	5	4	3	2	97	3
C1 subst'd dibenzothiophene	ng/g	< 2	210	50	53	8	7	25	3
C2 subst'd dibenzothiophene	ng/g	< 3	2000	250	320	24	22	95	3
C3 subst'd dibenzothiophene	ng/g	< 4	5300	< 3	< 2	200	-	-	1
C4 subst'd dibenzothiophene	ng/g	< 2	< 31	-	-	< 20	-	-	1
fluoranthene	ng/g	< 2	11	11	5	6	6	8	3
C1 subst'd fluoranthene / pyrene	ng/g	10	570	50	33	45	-	-	1
C2 subst'd fluoranthene / pyrene	ng/g	8	890	-	-	-	-	-	-
C3 subst'd fluoranthene / pyrene	ng/g	14	1100	-	-	-	-	-	-
fluorene	ng/g	< 2	< 19	7	< 3	4	3	4	3
C1 subst'd fluorene	ng/g	< 2	< 9	< 3	< 2	< 20	-	-	1
C2 subst'd fluorene	ng/g	< 2	< 25	< 3	< 2	45	-	-	1
C3 subst'd fluorene	ng/g	< 3	< 49	-	-	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	< 3	< 35	< 11	< 12	8	6	11	3
phenanthrene	ng/g	2	< 23	32	21	15	12	20	3
C1 subst'd phenanthrene / anthracene	ng/g	< 2	190	110	98	46	25	56	3
C2 subst'd phenanthrene / anthracene	ng/g	8	1200	140	150	100	92	120	3
C3 subst'd phenanthrene / anthracene	ng/g	6	2800	230	210	160	135	160	3
C4 subst'd phenanthrene / anthracene	ng/g	9	2300	720	57	230	70	300	3
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	13	280	-	-	-	-	-	-
pyrene	ng/g	3	130	22	12	12	10	12	3

[(a)] Based on information from Golder (1999b).
[(b)] Based on information from Golder (1998) and Crosley (1996).

Table II-7

Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca River Delta

Parameter	Units	Upstream of Embarras River		Delta					
				2000		Historical (1976 - 1999)[b]			
		2000	1995[a]	Composite	Flour Bay	Median	Min	Max	n
Particle Size									
partice size - % sand	%	36	99.4	10	16	14	-	-	1
partice size - % silt	%	42	0.01	58	52	64	-	-	1
partice size - % clay	%	22	0.54	32	32	22	-	-	1
moisture content	%	30	-	-	-	-	-	-	-
Carbon Content									
total inorganic carbon	% by wt	0.8	-	1.1	0.9	0.9	0.1	1.3	9
total organic carbon	% by wt	1.1	0.3	1.7	1.9	1.6	0.03	2.0	9
total carbon	% by wt	1.9	-	2.8	2.7	2.6	-	-	1
Toxicity									
Chironomus tentans - 10d mortality	% of control	84.1	-	86.4	88.6	42	-	-	1
Chironomus tentans - 10d growth	% of control	95.5	-	77.3	86.4	nt	-	-	1
Hyalella azteca - 10d mortality	% of control	nt	-	nt	nt	72	-	-	1
Hyalella azteca - 10d growth	% of control	83.3	-	nt	nt	nt	-	-	1
Lumbriculus variegatus - 10d mortality	% of control	nt	-	nt	nt	nt	-	-	1
Lumbriculus variegatus - 10d growth	% of control	68.4	-	52.6	57.9	62	-	-	1
Organics									
total recoverable hydrocarbons	mg/kg	500	-	700	700	800	-	-	1
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	< 0.5	< 0.5	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	59	-	81	82	-	-	-	-
Metals (Total)									
aluminum (Al)	ug/g	11800	-	18700	14700	48100	8850	67700	9
arsenic (As)	ug/g	4.6	< 5	6.2	5.8	4.3	1.9	5.7	10
barium (Ba)	ug/g	157	-	215	187	710	166	1130	9
beryllium (Be)	ug/g	0.7	-	0.9	0.9	1.9	0.5	3	9
boron (B)	ug/g	20	-	27	21	13	-	-	1
cadmium (Cd)	ug/g	0.2	< 1	0.3	0.3	-	0.15	< 0.5	2
calcium (Ca)	ug/g	20300	-	26800	20400	24500	3300	38800	9
chromium (Cr)	ug/g	61.3	3	92	50.8	89	24	120	10
cobalt (Co)	ug/g	7.1	-	9.1	8.4	17	6	29	9
copper (Cu)	ug/g	12.7	4	20	18.6	14.4	0.3	33.6	10
iron (Fe)	ug/g	17400	-	22600	21200	20350	5800	32700	10
lead (Pb)	ug/g	7.2	4	10.2	10.2	7.5	< 1	10	10
magnesium (Mg)	ug/g	7550	-	9330	7970	9400	1800	14500	9
manganese (Mn)	ug/g	336	-	523	403	381.5	71	722	10
mercury (Hg)	ug/g	0.05	-	0.08	0.09	0.0455	0.005	0.09	10
molybdenum (Mo)	ug/g	1.9	-	1.8	0.8	< 1	-	-	1
nickel (Ni)	ug/g	34.8	6	49.7	31.8	19.35	4.2	48.3	10
potassium (K)	ug/g	2250	-	3630	2770	1400	-	-	1
selenium (Se)	ug/g	0.6	-	0.8	0.8	-	0.25	0.6	2
silver (Ag)	ug/g	0.2	-	0.1	0.2	< 1	-	-	1
sodium (Na)	ug/g	257	-	297	258	7400	100	8900	9
strontium (Sr)	ug/g	59	-	80	64	179	69	197	9
thallium (Tl)	ug/g	0.18	-	0.27	0.26	-	-	-	-
uranium (U)	ug/g	1	-	1.3	1.2	< 40	-	-	1
vanadium (V)	ug/g	33.9	-	49.8	39.4	96.75	18	156	10
zinc (Zn)	ug/g	60.8	11	63.7	61.1	51.75	9.6	71	10
Target PAHs and Alkylated PAHs									
naphthalene	ug/g	27	-	24	22	19	-	-	1
C1 subst'd naphthalenes	ug/g	28	-	40	47	35	-	-	1
C2 subst'd naphthalenes	ug/g	38	-	49	54	43	-	-	1
C3 subst'd naphthalenes	ug/g	25	-	48	50	54	-	-	1
C4 subst'd naphthalenes	ug/g	6	-	< 4	< 10	32	-	-	1
acenaphthene	ug/g	< 6	-	< 10	< 5	< 1	-	-	1
C1 subst'd acenaphthene	ug/g	3	-	4	3	3	-	-	1
acenaphthylene	ug/g	< 6	-	< 8	< 4	< 4	-	-	1
anthracene	ug/g	< 5	-	< 3	< 2	< 4	-	-	1
dibenzo(a,h)anthracene	ug/g	< 5	-	< 5	< 7	< 6	-	-	1

Table II-7

Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca River Delta

Parameter	Units	Upstream of Embarras River		Delta					
				2000		Historical (1976 - 1999)[b]			
		2000	1995[a]	Composite	Flour Bay	Median	Min	Max	n
benzo(a)anthracene / chrysene	ug/g	15	-	26	31	31	-	-	1
C1 subst'd benzo(a)anthracene / chrysene	ug/g	120	-	250	230	36	-	-	1
C2 subst'd benzo(a)anthracene / chrysene	ug/g	42	-	63	< 140	15	-	-	1
benzo(a)pyrene	ug/g	6	-	6	9	13	-	-	1
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyre	ug/g	< 8	-	< 11	< 7	< 15	-	-	1
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyre	ug/g	< 4	-	< 4	< 3	< 13	-	-	1
benzofluoranthenes	ug/g	23	-	26	27	30	-	-	1
benzo(g,h,i)perylene	ug/g	18	-	20	18	17	-	-	1
biphenyl	ug/g	3	-	5	6	8	-	-	1
C1 subst'd biphenyl	ug/g	< 3	-	< 5	< 3	< 2	-	-	1
C2 subst'd biphenyl	ug/g	< 4	-	< 2	< 2	< 2	-	-	1
dibenzothiophene	ug/g	< 6	-	3	< 5	< 3	-	-	1
C1 subst'd dibenzothiophene	ug/g	7	-	18	14	17	-	-	1
C2 subst'd dibenzothiophene	ug/g	22	-	70	< 8	75	-	-	1
C3 subst'd dibenzothiophene	ug/g	70	-	140	180	110	-	-	1
C4 subst'd dibenzothiophene	ug/g	< 4	-	< 5	< 4	-	-	-	-
fluoranthene	ug/g	4	-	8	6	7	-	-	1
C1 subst'd fluoranthene / pyrene	ug/g	33	-	59	63	43	-	-	1
C2 subst'd fluoranthene / pyrene	ug/g	68	-	110	110	-	-	-	-
C3 subst'd fluoranthene / pyrene	ug/g	59	-	100	89	-	-	-	-
fluorene	ug/g	< 3	-	4	5	3	-	-	1
C1 subst'd fluorene	ug/g	< 4	-	< 3	< 4	< 4	-	-	1
C2 subst'd fluorene	ug/g	< 5	-	< 8	< 6	< 3	-	-	1
C3 subst'd fluorene	ug/g	< 6	-	< 8	< 4	-	-	-	-
indeno(1,2,3,cd)pyrene	ug/g	12	-	15	13	11	-	-	1
phenanthrene	ug/g	14	-	25	24	26	-	-	1
C1 subst'd phenanthrene / anthracene	ug/g	42	-	78	77	69	-	-	1
C2 subst'd phenanthrene / anthracene	ug/g	36	-	89	75	64	-	-	1
C3 subst'd phenanthrene / anthracene	ug/g	36	-	74	75	71	-	-	1
C4 subst'd phenanthrene / anthracene	ug/g	15	-	85	25	350	-	-	1
1-methyl-7-isopropyl-phenanthrene (retene)	ug/g	37	-	65	67	-	-	-	-
pyrene	ug/g	10	-	19	19	15	-	-	1

[a] Based on information from Dobson et al. (1996).
[b] Based on information from Golder (2000c), Allan and Jackson (1978) and Lutz and Hendzel (1977).

Table II-8
Water Quality in McLean and Poplar Creeks

Parameter	Units	McLean Creek (Fall)					Poplar Creek (Fall)				
			Historical (1995-1999)[a]					Historical (1976-1996)[b]			
		2000	median	min	max	n	2000	median	min	max	n
Field Measured											
pH		8.2	-	7.1	8.3	2	8.0	8.1	-	-	1
specific conductance	µS/cm	287	-	650	658	2	408	258	-	-	1
temperature	^oC	3.6	-	4.0	10.8	2	3.3	9.9	6.0	15.0	10
dissolved oxygen	mg/L	13.6	-	8.5	13.4	2	12.0	10.5	8.2	12.9	9
Conventional Parameters											
colour	T.C.U.	70	80	50	80	3	100	80	25	140	11
conductance	µS/cm	326	664	307	1000	4	442	375	237	1290	17
dissolved organic carbon	mg/L	21	14	12	21	4	24	26	24	30	12
hardness	mg/L	154	199	142	219	4	140	116	104	123	6
pH		8.0	8.1	8.0	8.3	4	7.9	7.9	7.3	8.3	17
total alkalinity	mg/L	146	195	133	251	4	166	156	117	259	17
total dissolved solids	mg/L	220	440	167	620	4	280	244	156	709	16
total organic carbon	mg/L	27	15	15	16	3	30	27	22	31	14
total suspended solids	mg/L	49	9	1	13	4	17	8	2	117	17
Major Ions											
bicarbonate (HCO3)	mg/L	178	238	162	305	4	202	-	160	190	2
calcium	mg/L	42	56	39	60	4	34	31	24	48	17
carbonate (CO3)	mg/L	< 5	< 5	< 1	< 5	4	< 5	0.25	0	< 1	4
chloride	mg/L	8	73	11	165	4	26	22	4	232	17
magnesium	mg/L	12	15	11	17	4	13	10	9	20	17
potassium	mg/L	0.7	1.5	1.4	2.1	4	1.5	1.4	0.0	2.9	17
sodium	mg/L	13	68	14	140	4	46	40	23	190	17
sulphate	mg/L	11	38	11	56	4	19	13	4	24	17
sulphide	µg/L	15	< 2	< 2	4	3	9	< 5	-	-	1
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.1	0.05	0.004	< 1	4	0.07	-	0.02	0.05	2
nitrogen - ammonia	mg/L	< 0.1	< 0.05	< 0.01	0.27	4	< 0.1	-	0.02	0.18	2
nitrogen - kjeldahl	mg/L	1	0.6	0.4	0.7	3	0.9	0.86	0.001	2	9
phosphorus, total	µg/L	53	14	12	42	4	31	48	0.04	129	17
phosphorus, total dissolved	µg/L	29	6	5	6	3	22	39	21	43	3
chlorophyll *a*	µg/L	5	-	1	3	2	4	3	< 1	7	6
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	< 2	< 2	4	3	< 2	0.3	-	-	1
Organics											
naphthenic acids	mg/L	2	1.5	< 1	2	4	2	< 1	-	-	1
total phenolics	µg/L	2	2	< 1	2	4	2	9	< 1	15	4
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 1	4	< 0.5	< 1	-	-	1
Toxicity											
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 100	4	> 91	> 100	-	-	1
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 100	4	> 91	> 100	-	-	1
algal growth inhibition test (72 h) - IC25	%	> 100	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - IC50	%	> 100	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - LOEC	%	> 100	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - NOEC	%	100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC25	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test - LC50	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test - LOEC	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test - NOEC	%	100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction Test - IC25	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction Test - IC50	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction Test - LOEC	%	> 100	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction Test - NOEC	%	100	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - IC25	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - IC50	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - LOEC	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - NOEC	%	100	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC25	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC50	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LOEC	%	> 100	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - NOEC	%	100	-	-	-	-	-	-	-	-	-

Table II-8
Water Quality in McLean and Poplar Creeks

Parameter	Units	McLean Creek (Fall)					Poplar Creek (Fall)				
			Historical (1995-1999)[a]					Historical (1976-1996)[b]			
		2000	median	min	max	n	2000	median	min	max	n
Metals (Total)											
aluminum (Al)	µg/L	1160	420	60	610	4	480	140	0.4	310	11
antimony (Sb)	µg/L	< 5.0	< 0.8	< 0.2	< 0.8	4	< 5	< 0.2	-	-	1
arsenic (As)	µg/L	< 1	< 1	0.8	< 1	4	< 1	0.6	0.5	7	5
barium (Ba)	µg/L	33	39	20	55	4	35	-	10	40	2
beryllium (Be)	µg/L	< 1	< 1	< 1	< 1	4	< 1	-	< 1	1	2
boron (B)	µg/L	24	77	73	201	4	116	-	100	140	2
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	3	4	< 0.2	< 1	< 0.2	3	4
calcium (Ca)	µg/L	39500	55200	54600	60700	3	31800	-	-	-	-
chromium (Cr)	µg/L	0.9	1.4	1	< 2	4	< 0.8	2.5	< 2	3	4
cobalt (Co)	µg/L	0.7	0.5	0.4	< 3	4	0.4	< 1	0.9	< 3	4
copper (Cu)	µg/L	2	2	1	4	3	2	2.7	< 1	4	3
iron (Fe)	µg/L	1410	785	410	930	4	1210	-	1100	1120	2
lead (Pb)	µg/L	0.7	1	0.2	< 20	4	0.4	-	0.4	< 20	2
lithium (Li)	µg/L	9	20	7	32	4	21	-	8	20	2
magnesium (Mg)	µg/L	11300	14400	14000	19900	3	12200	-	-	-	-
manganese (Mn)	µg/L	96	65	20	71	4	46	-	101	176	2
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.05	< 0.2	4	< 0.2	< 0.1	< 0.1	1.3	16
molybdenum (Mo)	µg/L	0.2	0.35	0.2	4	4	0.3	-	< 3	< 3	2
nickel (Ni)	µg/L	1.4	4.5	2.5	< 5	4	0.4	-	< 0.5	14	2
potassium (K)	µg/L	1270	1860	1820	2430	3	1740	-	-	-	-
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.2	< 0.8	4	< 0.8	< 0.2	< 0.2	< 0.2	4
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 2	4	< 0.4	-	< 0.1	< 2	2
sodium (Na)	µg/L	12500	66400	66300	188000	3	45300	-	-	-	-
strontium (Sr)	µg/L	111	193	96	266	4	194	-	149	167	2
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	0.1	0.2	0.2	0.4	3	0.1	-	-	-	-
vanadium (V)	µg/L	3.1	1.4	0.9	< 2	4	1.6	-	< 2	4	2
zinc (Zn)	µg/L	26	14	< 4	24	4	46	38	< 0	43	3
Metals (Dissolved)											
aluminum (Al)	µg/L	10	30	10	60	3	< 10	-	-	-	-
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	0.8	3	< 0.8	-	-	-	-
arsenic (As)	µg/L	0.4	0.4	< 0.4	1	3	0.7	0.7	0.0012	1.2	12
barium (Ba)	µg/L	23	37	35	44	3	29	-	-	-	-
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	3	< 0.5	-	-	-	-
boron (B)	µg/L	26	76	76	150	3	118	160	0.2	230	8
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	3	< 0.1	-	-	-	-
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	1.2	3	< 0.4	3	< 3	65	8
cobalt (Co)	µg/L	0.1	0.3	0.3	0.4	3	0.1	-	-	-	-
copper (Cu)	µg/L	< 0.6	1.1	1	3	3	0.8	-	-	-	-
iron (Fe)	µg/L	40	300	250	620	3	410	-	-	-	-
lead (Pb)	µg/L	0.2	0.2	< 0.1	0.3	3	0.1	-	-	-	-
lithium (Li)	µg/L	8.8	34	-	-	1	21.5	-	-	-	-
manganese (Mn)	µg/L	38.7	63.5	21.5	64.1	3	28.8	-	-	-	-
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	3	< 0.1	-	-	-	-
molybdenum (Mo)	µg/L	0.2	0.2	0.2	0.4	3	0.3	-	-	-	-
nickel (Ni)	µg/L	0.4	3.5	2.7	3.6	3	< 0.1	-	-	-	-
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	3	< 0.4	< 0.2	0.2	< 0.2	7
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	3	< 0.2	-	-	-	-
strontium (Sr)	µg/L	111	186	182	263	3	197	-	-	-	-
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	0.2	0.2	0.3	3	< 0.1	-	-	-	-
vanadium (V)	µg/L	0.3	< 0.1	< 0.1	0.9	3	0.4	-	-	-	-
zinc (Zn)	µg/L	6	3	2	4	3	5	-	-	-	-

[a] Based on information from Golder (1996, 2000c) and unpublished data from Suncor Energy Inc.
[b] Based on information from Golder (1996) and NAQUADAT station AB07DA0110.

Table II-9
Water Quality in the Steepbank and MacKay Rivers

Parameter	Units	Steepbank River (Fall)					MacKay River (Fall)				
			Historical (1972-1998)[(a)]					Historical (1976-1998)[(b)]			
		2000	median	min	max	n	2000	median	min	max	n
Field Measured											
pH		-	7.9	6.9	8.4	3	-	-	8.0	8.6	2
specific conductance	µS/cm	-	97	80	510	3	203	135	-	-	1
temperature	^oC	-	3.0	0.8	6.0	3	0.4	9.3	2.2	14.0	8
dissolved oxygen	mg/L	-	10.4	4.6	13.6	3	-	9.7	5.6	14.0	8
Conventional Parameters											
colour	T.C.U.	125	70	50	120	3	150	125	70	240	6
conductance	µS/cm	186	180	113	516	4	233	270	151	576	9
dissolved organic carbon	mg/L	19	20	11	27	4	24	30	20	34	9
hardness	mg/L	82	102	59	192	5	96	114	69	177	5
pH		7.7	7.8	7.4	8.4	5	7.6	7.9	7.6	8.4	9
total alkalinity	mg/L	86	109	54	263	5	100	121	71	202	9
total dissolved solids	mg/L	120	123	80	320	4	170	172	102	342	9
total organic carbon	mg/L	28	25	14	28	3	34	32	24	35	9
total suspended solids	mg/L	60	21	1	42	4	7	11	< 2	91	9
Major Ions											
bicarbonate (HCO3)	mg/L	105	105	65	306	4	122	-	87	245	2
calcium	mg/L	22	27	16	50	5	25	29	18	45	9
carbonate (CO3)	mg/L	< 5	< 3	< 1	< 5	4	< 5	-	< 1	< 5	2
chloride	mg/L	1	1	1	8	5	3	3	1	41	9
magnesium	mg/L	7	6	5	16	5	8	10	6	16	9
potassium	mg/L	0.6	0.4	0.3	1.6	5	1.0	1.0	0.5	1.7	9
sodium	mg/L	8	6	4	38	5	17	16	11	60	9
sulphate	mg/L	6	5	4	12	5	18	15	1	36	9
sulphide	µg/L	< 3	6	< 5	41	3	9	-	3	< 5	2
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.1	< 0.05	0.01	< 0.1	5	< 0.1	-	0.04	< 0.1	2
nitrogen - ammonia	mg/L	< 0.1	0.05	0.01	< 0.1	4	< 0.1	-	0	0.05	2
nitrogen - kjeldahl	mg/L	1.2	0.2	< 0.2	0.6	3	1	1.1	0.7	4.2	9
phosphorus, total	µg/L	54	47	8	300	5	52	54	11	70	9
phosphorus, total dissolved	µg/L	32	16	6	179	3	47	-	4	29	2
chlorophyll *a*	µg/L	2	-	1	2	2	< 1	2	-	-	1
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	2	0.3	7	3	< 2	-	0	< 2	2
Organics											
naphthenic acids	mg/L	1	< 1	< 1	< 1	3	1	< 1	-	-	1
total phenolics	µg/L	< 1	1	< 1	2	5	4	-	< 1	4	2
total recoverable hydrocarbons	mg/L	26.7	< 0.6	< 0.5	< 1	3	2.7	0.8	-	-	1
Toxicity											
Microtox IC_{50} @ 15 min	%	> 91	> 100	> 91	> 100	3	> 91	-	-	-	-
Microtox IC_{25} @ 15 min	%	> 91	> 100	> 91	> 100	3	> 91	-	-	-	-
algal growth inhibition test (72 h) - IC25	%	-	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - IC50	%	-	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - LOEC	%	-	-	-	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - NOEC	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC25	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC50	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LOEC	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - NOEC	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC25	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC50	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - LOEC	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - NOEC	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - IC25	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - IC50	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - LOEC	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - NOEC	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC25	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC50	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LOEC	%	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - NOEC	%	-	-	-	-	-	-	-	-	-	-

Table II-9
Water Quality in the Steepbank and MacKay Rivers

Parameter	Units	Steepbank River (Fall)					MacKay River (Fall)				
			Historical (1972-1998)[(a)]					Historical (1976-1998)[(b)]			
		2000	median	min	max	n	2000	median	min	max	n
Metals (Total)											
aluminum (Al)	µg/L	2730	275	53	902	4	200	150	50	620	9
antimony (Sb)	µg/L	< 5	< 0.8	< 0.2	< 0.8	3	< 5	< 0.8	-	-	1
arsenic (As)	µg/L	< 1	0.8	0.2	12.0	5	< 1	1	0.4	4	3
barium (Ba)	µg/L	41	27	20	52	4	21	-	20	49	2
beryllium (Be)	µg/L	< 1	< 1	< 1	2	4	< 1	-	< 1	5	2
boron (B)	µg/L	40	63	24	200	4	106	-	50	140	2
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	4	5	< 0.2	-	0	< 0.2	2
calcium (Ca)	µg/L	24100	-	18367	51300	2	25400	44600	-	-	1
chromium (Cr)	µg/L	8.3	3	0.5	11.3	5	1.8	-	< 1	11	2
cobalt (Co)	µg/L	0.5	0.9	< 0.2	4	5	2.6	-	0	0.3	2
copper (Cu)	µg/L	2	2.8	1.1	4	4	12	-	1	2.5	2
iron (Fe)	µg/L	2280	713	470	1350	5	23300	-	310	1350	2
lead (Pb)	µg/L	0.8	1.1	0.8	< 20	4	0.5	-	0.2	0.6	2
lithium (Li)	µg/L	< 6	8	3	26	4	15	-	9	32	2
magnesium (Mg)	µg/L	7130	-	5813	17100	2	8080	16300	-	-	1
manganese (Mn)	µg/L	48	36	15	61	4	442	-	24	57	2
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.1	< 50	5	< 0.2	< 0.1	0	0.9	9
molybdenum (Mo)	µg/L	0.2	1.8	0.2	< 3	4	0.6	-	0.6	< 3	2
nickel (Ni)	µg/L	2.2	3.4	< 0.5	7.3	4	20.7	-	< 1	2.7	2
potassium (K)	µg/L	1330	-	753	1840	2	1080	1710	-	-	1
selenium (Se)	µg/L	0.8	< 0.4	< 0.2	< 0.8	4	< 0.8	-	0	< 0.8	2
silver (Ag)	µg/L	< 0.4	< 0.3	< 0.1	< 2	4	< 0.4	-	0	< 0.4	2
sodium (Na)	µg/L	8100	-	6067	39200	2	15700	61000	-	-	1
strontium (Sr)	µg/L	91	79	55	252	4	133	-	91	287	2
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	-	< 0.1	0.2	2	0.1	0.4	-	-	1
vanadium (V)	µg/L	6.8	2	0.4	2.3	4	0.6	-	0	8	2
zinc (Zn)	µg/L	29	15	10	20	4	67	4	-	-	1
Metals (Dissolved)											
aluminum (Al)	µg/L	30	-	66	70	2	20	10	-	-	1
antimony (Sb)	µg/L	< 0.8	-	0.6	0.8	2	< 0.8	< 0.8	-	-	1
arsenic (As)	µg/L	0.5	-	< 0.4	0.4	2	< 0.4	0.6	0.3	13	5
barium (Ba)	µg/L	20	-	16	52	2	15	47	-	-	1
beryllium (Be)	µg/L	< 0.5	-	< 0.5	< 0.5	2	< 0.5	< 0.5	-	-	1
boron (B)	µg/L	47	-	23	243	2	65	170	30	230	7
cadmium (Cd)	µg/L	< 0.1	-	< 0.1	0.1	2	< 0.1	-	0	< 300	2
chromium (Cr)	µg/L	< 0.4	-	< 0.4	< 0.4	2	0.5	< 3	0	15	6
cobalt (Co)	µg/L	0.1	-	0.2	0.2	2	0.1	0.1	-	-	1
copper (Cu)	µg/L	1.7	-	1.0	2.8	2	0.9	1.9	-	-	1
iron (Fe)	µg/L	270	-	220	287	2	600	230	-	-	1
lead (Pb)	µg/L	0.2	-	1.1	1.1	2	0.2	0.1	-	-	1
lithium (Li)	µg/L	7.3	-	5	22	2	15.6	32	-	-	1
manganese (Mn)	µg/L	1.6	-	13.8	17.2	2	12.9	10.6	-	-	1
mercury (Hg)	µg/L	< 0.1	-	< 0.1	< 0.2	2	< 0.1	< 0.1	-	-	1
molybdenum (Mo)	µg/L	0.2	-	0.2	0.5	2	0.3	0.5	-	-	1
nickel (Ni)	µg/L	0.5	-	1	3.8	2	1.2	2.3	-	-	1
selenium (Se)	µg/L	< 0.4	-	< 0.4	< 0.4	2	< 0.4	< 0.2	0	0.5	6
silver (Ag)	µg/L	< 0.2	-	< 0.2	< 0.2	2	< 0.2	< 0.2	-	-	1
strontium (Sr)	µg/L	83	-	59	227	2	131	275	-	-	1
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	-	< 0.1	0.2	2	0.1	0.3	-	-	1
vanadium (V)	µg/L	0.3	-	< 0.1	< 0.1	2	0.4	0.2	-	-	1
zinc (Zn)	µg/L	5	-	11	15	2	< 2	5	-	-	1

[(a)] Based on information from Golder (1996, 1998, 1999b) and NAQUADAT station AB07DA0260.
[(b)] Based on information from Golder (1999b) and NAQUADAT stations AB07DB0060/0070.

Table II-10
Water Quality in Fort and Un-named Creeks

		Fort Creek							Un-named Creek (2000)		
			Fall								
		Spring	2000		Historical (1996-1999)[(a)]					Fall	
Parameter	**Units**	**(2000)**	**Trip 1**	**Trip 2**	**median**	**min**	**max**	**n**	**Spring**	**Trip 1**	**Trip 2**
Field Measured											
pH		-	8.2	8.1	8.2	-	-	1	-	8.1	7.9
specific conductance	µS/cm	-	458	417	368	-	-	1	-	289	289
temperature	°C	-	11.9	3.0	1.5	-	-	1	-	7.2	8.1
dissolved oxygen	mg/L	-	11.6	13.0	13.4	-	-	1	-	11.1	12.9
Conventional Parameters											
colour	T.C.U.	30	35	30	-	20	40	2	15	18	10
conductance	µS/cm	375	482	456	-	386	533	2	290	313	320
dissolved organic carbon	mg/L	11	13	13	-	10	15	2	4	3	3
hardness	mg/L	190	250	233	-	215	267	2	143	162	164
pH		8.1	8	8.1	-	8.1	8.3	2	8.1	8.1	8.1
total alkalinity	mg/L	190	260	235	-	221	284	2	143	161	160
total dissolved solids	mg/L	200	320	270	-	264	380	2	130	200	180
total organic carbon	mg/L	14	17	15	-	12	17	2	6	4	5
total suspended solids	mg/L	18	10	61	-	< 0	21	2	14	< 3	6
Major Ions											
bicarbonate (HCO3)	mg/L	232	315	287	-	269	347	2	175	197	195
calcium	mg/L	56	74	70	-	64	78	2	45	51	51
carbonate (CO3)	mg/L	< 5.0	< 5.0	< 5.0	-	< 0.5	< 5.0	2	< 5.0	< 5.0	< 5.0
chloride	mg/L	2	2	2	-	1	3	2	1	< 1	< 1
magnesium	mg/L	12	16	14	-	13	18	2	8	9	9
potassium	mg/L	1.2	0.9	1.0	-	1.1	1.5	2	0.8	0.8	0.9
sodium	mg/L	6	10	8	-	8	11	2	2	4	4
sulphate	mg/L	10	8	8	-	2	9	2	9	9	9
sulphide	µg/L	3	< 3	4	-	3	< 5	2	3	< 3	7
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	-	0.02	< 0.10	2	< 0.05	< 0.05	< 0.05
nitrogen - ammonia	mg/L	< 0.10	< 0.10	< 0.10	-	0.02	< 0.05	2	< 0.10	< 0.10	< 0.10
nitrogen - kjeldahl	mg/L	0.5	0.6	0.4	-	0.4	0.4	2	< 0.2	0.2	< 0.2
phosphorus, total	µg/L	33	29	19	-	18	33	2	24	14	16
phosphorus, total dissolved	µg/L	30	20	16	-	4	18	2	21	13	11
chlorophyll *a*	µg/L	1	1	< 1	-	1	5	2	2	< 1	1
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	< 2	< 2	-	< 0.1	2	2	< 2	< 2	< 2
Organics											
naphthenic acids	mg/L	< 1	< 1	2	1	-	-	1	< 1	< 1	2
total phenolics	µg/L	5	2	< 1	-	< 1	4	2	5	2	2
total recoverable hydrocarbons	mg/L	0.7	< 0.5	< 0.5	< 0.5	-	-	1	0.7	< 0.5	< 0.5
Toxicity											
Microtox IC_{50} @ 15 min	%	-	-	> 91	> 91	-	-	1	-	-	> 91
Microtox IC_{25} @ 15 min	%	-	-	> 91	> 91	-	-	1	-	-	> 91
algal growth inhibition test (72 h) - IC25	%	-	-	> 100	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - IC50	%	-	-	> 100	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - LOEC	%	-	-	> 100	-	-	-	-	-	-	-
algal growth inhibition test (72 h) - NOEC	%	-	-	100	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC25	%	-	-	< 6.25	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC50	%	-	-	< 6.25	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LOEC	%	-	-	6.25	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - NOEC	%	-	-	< 6.25	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC25	%	-	-	no results	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC50	%	-	-	no results	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - LOEC	%	-	-	no results	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - NOEC	%	-	-	no results	-	-	-	-	-	-	-
fathead minnow 7d growth - IC25	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d growth - IC50	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d growth - LOEC	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d growth - NOEC	%	-	-	100	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC25	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC50	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LOEC	%	-	-	> 100	-	-	-	-	-	-	-
fathead minnow 7d mortality test - NOEC	%	-	-	100	-	-	-	-	-	-	-

Table II-10
Water Quality in Fort and Un-named Creeks

Parameter	Units	Fort Creek							Un-named Creek (2000)		
			Fall								
		Spring	2000		Historical (1996-1999)[(a)]					Fall	
		(2000)	Trip 1	Trip 2	median	min	max	n	Spring	Trip 1	Trip 2
Metals (Total)											
aluminum (Al)	µg/L	320	50	50	-	50	430	2	280	110	130
antimony (Sb)	µg/L	< 5.0	< 5.0	< 5.0	< 0.8	-	-	1	< 5.0	< 5.0	< 5.0
arsenic (As)	µg/L	< 1.0	< 1.0	< 1.0	-	< 0.2	< 1.0	2	< 1.0	< 1.0	< 1.0
barium (Ba)	µg/L	88	105	72	-	60	95	2	82	82	76
beryllium (Be)	µg/L	< 1	< 1	< 1	-	< 1	3	2	< 1	< 1	< 1
boron (B)	µg/L	45	50	26	-	19	30	2	23	24	14
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	-	< 0.2	< 0.2	2	< 0.2	< 0.2	< 0.2
calcium (Ca)	µg/L	56100	73200	63800	80700	-	-	1	45400	48600	49200
chromium (Cr)	µg/L	2	< 1	< 1	-	< 1	10	2	2	< 1	1
cobalt (Co)	µg/L	< 0.2	< 0.2	< 0.2	-	0.3	1.1	2	< 0.2	< 0.2	< 0.2
copper (Cu)	µg/L	1	< 1	< 1	-	< 1	1	2	< 1	< 1	< 1
iron (Fe)	µg/L	690	710	560	-	610	1200	2	380	70	280
lead (Pb)	µg/L	0.3	0.6	< 0.1	-	< 0.3	0.5	2	0.2	1.0	0.4
lithium (Li)	µg/L	13	14	11	-	9	84	2	< 6	< 6	< 6
magnesium (Mg)	µg/L	11500	15600	13500	19000	-	-	1	7490	9410	8670
manganese (Mn)	µg/L	78	98	62	-	98	106	2	43	18	21
mercury (Hg)	µg/L	-	< 0.2	< 0.2	-	< 0.2	< 50.0	2	-	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.2	0.1	< 0.1	-	< 0.1	< 3.0	2	0.3	0.2	0.3
nickel (Ni)	µg/L	1.7	1.1	1.2	-	< 0.5	2.3	2	1.5	0.6	2.1
potassium (K)	µg/L	1220	1150	1120	1720	-	-	1	850	1020	1020
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	-	< 0.2	< 0.8	2	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	0.6	< 0.4	< 0.4	-	< 0.1	< 0.4	2	0.8	< 0.4	< 0.4
sodium (Na)	µg/L	6900	9700	9100	11300	-	-	1	2600	3600	3500
strontium (Sr)	µg/L	132	172	142	-	116	191	2	68	77	79
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0.1	-	-	-	-	< 0.1	< 0.1	< 0.1
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	-	-	1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	1.2	0.3	< 0.2	-	1.2	< 2.0	2	0.9	0.3	0.5
zinc (Zn)	µg/L	13	14	19	5	-	-	1	5	< 4	29
Metals (Dissolved)											
aluminum (Al)	µg/L	40	90	< 10	< 10	-	-	1	40	100	< 10
antimony (Sb)	µg/L	< 0.8	1.0	< 0.8	< 0.8	-	-	1	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	-	-	1	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	72	94	74	95	-	-	1	68	76	74
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	-	-	1	< 0.5	< 0.5	< 0.5
boron (B)	µg/L	44	50	24	24	-	-	1	226	24	12
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	-	-	1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	2.5	0.8	< 0.4	< 0.4	-	-	1	3.0	0.5	< 0.4
cobalt (Co)	µg/L	< 0.1	0.1	< 0.1	0.1	-	-	1	< 0.1	< 0.1	< 0.1
copper (Cu)	µg/L	< 0.6	1.0	1.2	< 0.6	-	-	1	0.7	0.7	2.4
iron (Fe)	µg/L	130	170	130	240	-	-	1	< 10	60	30
lead (Pb)	µg/L	0.5	0.3	0.5	< 0.1	-	-	1	0.6	0.5	0.8
lithium (Li)	µg/L	12	13	11	26	-	-	1	4	4	2
manganese (Mn)	µg/L	32.8	80.0	49.5	71.4	-	-	1	4.9	13.3	10.4
mercury (Hg)	µg/L	< 0.0	< 0.0	< 0.1	< 0.1	-	-	1	< 0.02	< 0.02	< 0.1
molybdenum (Mo)	µg/L	0.1	< 0.1	1.2	< 0.1	-	-	1	0.3	0.2	1.4
nickel (Ni)	µg/L	1.0	1.0	0.9	1.4	-	-	1	0.7	0.1	0.8
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	-	-	1	0.9	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	-	-	1	< 0.2	< 0.2	< 0.2
strontium (Sr)	µg/L	124	170	137	199	-	-	1	64	78	74
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0	-	-	-	-	< 0.1	< 0.1	< 0.1
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	-	-	1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.4	< 0.1	< 0.1	0.2	-	-	1	0.4	< 0.1	< 0.1
zinc (Zn)	µg/L	2.0	< 2	8	3.0	-	-	1	< 2.0	< 2.0	9.0

[(a)] Based on information from True North Baseline Monitoring and NAQUADAT station AB07DA2760.

Table II-11
Water Quality in the Muskeg River

Parameter	Units	Muskeg River (Fall) - Mouth 2000	Mouth Historical (1972-1999)[a] median	min	max	n	Upstream of Wapasu Creek (MUR-6) 2000	Upstream Historical (1976-1999)[b] median	min	max	n
Field Measured											
pH		8.1	8.2	7.8	9.2	4	7.5	7.8	7.6	7.9	3
specific conductance	µS/cm	250	610	177	655	7	211	352	303	400	3
temperature	^{o}C	5.1	4.3	1.5	12.0	7	3.8	4.0	0.4	10.5	6
dissolved oxygen	mg/L	11.4	12.3	9.5	12.6	7	9.5	7.6	3.4	10.2	5
Conventional Parameters											
colour	T.C.U.	80	35	29	120	10	60	100	60	140	5
conductance	µS/cm	269	310	193	666	10	233	345	248	441	6
dissolved organic carbon	mg/L	21	17	11	27	14	17	24	18	25	5
hardness	mg/L	132	252	96	353	16	128	201	146	240	7
pH		8.0	8.0	7.6	8.3	16	7.7	7.5	7.2	8.0	6
total alkalinity	mg/L	129	240	101	282	16	120	182	127	235	8
total dissolved solids	mg/L	220	288	120	482	13	210	189	158	320	8
total organic carbon	mg/L	26	22	12	29	6	22	23	21	30	8
total suspended solids	mg/L	3	3	1	70	15	3	4	0.4	25	8
Major Ions											
bicarbonate (HCO3)	mg/L	158	321	123	341	13	147	251	204	287	4
calcium	mg/L	37	77	26	111	16	32	49	31	67	8
carbonate (CO3)	mg/L	< 5.0	< 1.8	0	7.0	8	< 5.0	< 5.0	< 0.5	< 5.0	3
chloride	mg/L	2	5	1	18	16	< 1	1	1	2	8
magnesium	mg/L	10	14	7	19	16	12	15	12	17	8
potassium	mg/L	0.8	1.5	0.5	1.9	16	0.5	1.1	0.3	1.7	8
sodium	mg/L	10	13	8	27	16	3	6	5	7	8
sulphate	mg/L	13	16	1	95	16	5	2	0.1	6	8
sulphide	µg/L	< 3	1.5	< 1	< 5	8	11	-	< 2	14	2
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.05	< 0.01	0	0.1	14	< 0.05	0.039	0.009	< 0.1	4
nitrogen - ammonia	mg/L	< 0.1	0.05	0.04	0.09	5	< 0.1	0.065	< 0.05	0.27	4
nitrogen - kjeldahl	mg/L	0.9	0.6	0.4	0.8	9	0.7	1.3	0.6	5.5	8
phosphorus, total	µg/L	21	22	7	600	12	14	38	25	269	8
phosphorus, total dissolved	µg/L	17	8	2	16	7	12	-	23	29	2
chlorophyll *a*	µg/L	< 1	< 1	0	< 1	6	< 1	< 1	< 1	14	3
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2.0	0.9	< 0.1	4.0	11	< 2.0	2.0	1.6	6.0	4
Organics											
naphthenic acids	mg/L	< 1	< 1	< 1	1	5	< 1	-	< 1	12	2
total phenolics	µg/L	< 1	1	< 1	2	6	< 1	-	3	5	2
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 1.0	5	< 0.5	0.5	< 0.1	0.6	4
Toxicity											
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 100	5	> 91	> 91	> 91	> 91	3
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 100	5	> 91	> 91	> 91	> 91	3
algal growth inhibition test (72 h) - IC25	%	-	-	-	-	-	> 100	> 100	-	-	1
algal growth inhibition test (72 h) - IC50	%	-	-	-	-	-	> 100	> 100	-	-	1
algal growth inhibition test (72 h) - LOEC	%	-	-	-	-	-	> 100	> 100	-	-	1
algal growth inhibition test (72 h) - NOEC	%	-	-	-	-	-	100	100	-	-	1
Ceriodaphnia 7 d mortality test - LC25	%	-	-	-	-	-	> 100	-	> 100	> 100	2
Ceriodaphnia 7 d mortality test - LC50	%	-	-	-	-	-	> 100	-	> 100	> 100	2
Ceriodaphnia 7 d mortality test - LOEC	%	-	-	-	-	-	> 100	-	> 100	> 100	2
Ceriodaphnia 7 d mortality test - NOEC	%	-	-	-	-	-	100	-	100	100	2
Ceriodaphnia 7 d reproduction test - IC25	%	-	-	-	-	-	> 100	-	35	> 100	2
Ceriodaphnia 7 d reproduction test - IC50	%	-	-	-	-	-	> 100	-	> 100	> 100	2
Ceriodaphnia 7 d reproduction test - LOEC	%	-	-	-	-	-	> 100	-	25	> 100	2
Ceriodaphnia 7 d reproduction test - NOEC	%	-	-	-	-	-	100	-	12.5	100	2
fathead minnow 7d growth - IC25	%	-	-	-	-	-	> 100	-	12	> 100	2
fathead minnow 7d growth - IC50	%	-	-	-	-	-	> 100	-	39	> 100	2
fathead minnow 7d growth - LOEC	%	-	-	-	-	-	> 100	-	50	> 100	2
fathead minnow 7d growth - NOEC	%	-	-	-	-	-	100	-	25	100	2
fathead minnow 7d mortality test - LC25	%	-	-	-	-	-	28	-	6.4	49	2
fathead minnow 7d mortality test - LC50	%	-	-	-	-	-	81	-	13	> 100	2
fathead minnow 7d mortality test - LOEC	%	-	-	-	-	-	100	-	12.5	> 100	2
fathead minnow 7d mortality test - NOEC	%	-	-	-	-	-	50	-	6.25	100	2

Table II-11
Water Quality in the Muskeg River

		Muskeg River (Fall)									
		Mouth					Upstream of Wapasu Creek (MUR-6)				
			Historical (1972-1999)[a]					Historical (1976-1999)[b]			
Parameter	**Units**	**2000**	**median**	**min**	**max**	**n**	**2000**	**median**	**min**	**max**	**n**
Metals (Total)											
aluminum (Al)	µg/L	90	95	30	1200	8	90	50	< 10	120	8
antimony (Sb)	µg/L	< 5.0	< 0.7	< 0.2	< 0.8	4	< 5.0	-	< 0.8	< 0.8	2
arsenic (As)	µg/L	< 1.0	1.0	< 0.2	14.0	7	< 1.0	1.0	0.4	9.0	6
barium (Ba)	µg/L	42	34	20	92	6	34	-	42	88	2
beryllium (Be)	µg/L	< 1	< 1	< 1	3	6	< 1	-	< 1	< 1	2
boron (B)	µg/L	32	37	28	160	6	6	16	8	< 50	4
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	4.0	7	< 0.2	< 0.6	< 0.2	< 1.0	4
calcium (Ca)	µg/L	39300	104000	36300	114000	3	31800	-	59900	70500	2
chromium (Cr)	µg/L	1	4	1	8	7	4	< 1	< 1	6	4
cobalt (Co)	µg/L	< 0.2	1.2	< 0.2	6.0	7	< 0.2	-	< 0.2	0.4	2
copper (Cu)	µg/L	< 1	2	< 1	4	7	< 1	< 1	< 1	1	4
iron (Fe)	µg/L	540	800	420	1810	7	190	1780	1050	13900	4
lead (Pb)	µg/L	0.4	1.0	< 0.1	< 20.0	6	0.7	1.2	< 0.1	2.0	4
lithium (Li)	µg/L	8	8	6	12	6	< 6	-	9	9	2
magnesium (Mg)	µg/L	10500	18200	7880	19000	3	11200	-	16500	17400	2
manganese (Mn)	µg/L	19	43	16	115	6	14	210	58	786	4
mercury (Hg)	µg/L	< 0.2	< 0.2	< 0.1	< 50.0	8	< 0.2	< 0.2	< 0.1	4.3	8
molybdenum (Mo)	µg/L	0.3	< 1.7	< 0.1	5.0	6	0.3	-	< 0.1	0.1	2
nickel (Ni)	µg/L	1.4	4.0	< 0.5	15.0	6	4.3	1.3	< 1.0	4.0	4
potassium (K)	µg/L	1090	1710	1380	1820	3	630	-	1570	2110	2
selenium (Se)	µg/L	< 0.8	< 0.4	< 0.2	< 0.8	5	< 0.8	< 0.8	< 0.2	0.9	4
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.1	3.0	6	< 0.4	-	< 0.4	< 0.4	2
sodium (Na)	µg/L	23300	8600	8000	20800	3	2900	-	5600	5800	2
strontium (Sr)	µg/L	113	97	72	225	6	63	-	120	164	2
thallium (TI)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	< 0.5	< 0.1	< 500	5	< 0.1	-	< 0.1	< 0.1	2
vanadium (V)	µg/L	< 0.2	2.0	< 0.2	2.9	6	0.9	< 0.7	< 0.2	< 1.0	4
zinc (Zn)	µg/L	21	16	4	33	6	75	14	6	51	4
Metals (Dissolved)											
aluminum (Al)	µg/L	< 10	27	10	90	3	< 10	-	< 10	10	2
antimony (Sb)	µg/L	< 0.8	-	< 0.8	< 0.8	2	< 0.8	-	< 0.8	< 0.8	2
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 1.0	4	< 0.4	< 0.4	< 0.2	< 0.4	4
barium (Ba)	µg/L	25.7	79.3	24.3	92.9	3	16.8	-	31.6	42.2	2
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	3	< 0.5	-	< 0.5	< 0.5	2
boron (B)	µg/L	34	33	10	160	5	6	40	3	110	6
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	3	< 0.0	-	< 0.1	< 0.1	2
chromium (Cr)	µg/L	< 0.4	< 0.4	< 0.4	4.0	5	< 0.4	< 3.0	< 0.4	< 3.0	6
cobalt (Co)	µg/L	< 0.1	0.2	0.2	0.2	3	< 0.1	-	0.2	0.2	2
copper (Cu)	µg/L	< 0.6	1.3	1.1	1.6	3	< 0.6	-	< 0.6	1.0	2
iron (Fe)	µg/L	220	250	72	440	5	40	-	820	890	2
lead (Pb)	µg/L	0.8	0.3	< 0.1	0.9	3	< 0.1	-	< 0.1	0.2	2
lithium (Li)	µg/L	9	9	7	10	3	4	-	7	8	2
manganese (Mn)	µg/L	15.3	22.6	13.0	35.4	5	8.1	-	332	626	2
mercury (Hg)	µg/L	< 0.1	< 0.1	< 0.0	0.2	3	< 0.1	-	< 0.0	< 0.1	2
molybdenum (Mo)	µg/L	0.2	0.1	0.1	0.2	3	0.1	-	< 0.1	0.1	2
nickel (Ni)	µg/L	0.5	2.8	0.4	4.4	3	0.4	-	0.9	3.3	2
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.5	4	< 0.4	< 0.3	< 0.2	< 0.4	4
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	3	< 0.2	-	< 0.2	< 0.2	2
strontium (Sr)	µg/L	98	193	74	234	3	60	-	121	147	2
thallium (TI)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	-	0.2	0.5	2	< 0.1	-	< 0.1	< 0.1	2
vanadium (V)	µg/L	< 0.1	-	< 0.1	0.3	2	< 0.1	-	< 0.1	< 0.1	2
zinc (Zn)	µg/L	13.0	-	< 2.0	4.0	2	10.0	-	2.0	10.0	2

(a) Based on information from Golder (1996, 1998, 1999b, 2000c), R.L.&L. (1982) and NAQUADAT stations AB07DA0620/0630.
(b) Based on information from Golder (1999b, 2000c), R.L.&L. (1989) and NAQUADAT station AB07DA0440.

Table II-12
Water Quality in Jackpine and Muskeg Creeks

		Jackpine Creek (Fall)					Muskeg Creek (Fall)				
			Historical (1976-1999)[(a)]					Historical (1976-1999)[(b)]			
Parameter	**Units**	**2000**	**median**	**min**	**max**	**n**	**2000**	**median**	**min**	**max**	**n**
Field Measured											
pH		-	-	7.8	7.8	2	-	-	7.6	7.8	2
specific conductance	µS/cm	-	413	220	451	5	-	-	80	585	2
temperature	°C	-	6.5	0.0	11.4	16	-	9.5	2.8	13.0	3
dissolved oxygen	mg/L	-	9.8	6.3	12.6	16	-	7.2	4.4	8.6	3
Conventional Parameters											
colour	T.C.U.	70	100	35	150	14	60	-	68	120	2
conductance	µS/cm	197	197	120	436	15	251	291	192	671	5
dissolved organic carbon	mg/L	22	24	18	36	15	20	24	21	28	5
hardness	mg/L	83	110	77	222	11	111	162	83	244	5
pH		7.8	7.6	7.1	7.9	18	7.7	7.8	7.4	8.1	5
total alkalinity	mg/L	93	113	80	243	19	123	155	107	313	5
total dissolved solids	mg/L	110	127	94	271	18	150	166	123	378	5
total organic carbon	mg/L	29	26	18	40	15	26	27	21	30	4
total suspended solids	mg/L	< 3	8	< 0.4	52	19	3	3	1	9	5
Major Ions											
bicarbonate (HCO3)	mg/L	114	242	102	297	7	150	362	189	382	3
calcium	mg/L	22	28	19	62	19	30	44	22	71	5
carbonate (CO3)	mg/L	< 5.0	< 0.5	< 0.5	< 5.0	3	< 5.0	-	< 0.5	< 5.0	2
chloride	mg/L	2	2	1	13	19	2	1	0.3	36	5
magnesium	mg/L	7	8	6	16	19	9	13	7	17	5
potassium	mg/L	0.7	0.8	0.2	1.4	19	0.7	1.1	0.5	2.1	5
sodium	mg/L	10	13	9	21	19	7	15	6	64	5
sulphate	mg/L	4	4	0	10	19	5	5	1	8	5
sulphide	µg/L	103	4	1	6	4	5	-	< 2	4	2
Nutrients and Chlorophyll *a*											
nitrate + nitrite	mg/L	< 0.05	< 0.005	< 0.003	< 0.1	7	< 0.05	< 0.05	0.014	< 0.1	3
nitrogen - ammonia	mg/L	< 0.1	0.04	0.01	0.05	4	< 0.1	-	0.07	0.28	2
nitrogen - kjeldahl	mg/L	0.8	0.8	0.5	3.4	15	0.7	1.1	0.5	1.3	4
phosphorus, total	µg/L	1	35	10	60	18	1	42	32	66	5
phosphorus, total dissolved	µg/L	14	14	6	17	4	18	-	14	30	2
chlorophyll *a*	µg/L	1	< 1	< 1	3	6	7	-	0	< 1	2
Biochemical Oxygen Demand											
biochemical oxygen demand	mg/L	< 2.0	1.5	0.6	3.0	7	< 2.0	-	< 2.0	8.0	2
Organics											
naphthenic acids	mg/L	1	-	< 1	< 1	2	1	< 1	< 1	2	3
total phenolics	µg/L	2	1	< 1	4	3	2	-	5	5	2
total recoverable hydrocarbons	mg/L	2.9	0.5	0.4	< 1.0	4	3.5	< 0.8	< 0.5	< 1.0	3
Toxicity											
Microtox IC_{50} @ 15 min	%	> 91	> 91	> 91	> 100	3	> 91	> 91	> 91	> 100	4
Microtox IC_{25} @ 15 min	%	> 91	> 91	> 91	> 100	3	> 91	> 91	> 91	> 100	4
Algal Growth Inhibition Test (72 h	%	-	-	-	-	-	-	-	-	-	-
Algal Growth Inhibition Test (72 h	%	-	-	-	-	-	-	-	-	-	-
Algal Growth Inhibition Test (72 h	%	-	-	-	-	-	-	-	-	-	-
Algal Growth Inhibition Test (72 h	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test -	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test -	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test -	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Mortality Test -	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction T	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction T	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction T	%	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d Reproduction T	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Growth - IC2	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Growth - IC5	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Growth - LOE	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Growth - NOI	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Mortality Tes	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Mortality Tes	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Mortality Tes	%	-	-	-	-	-	-	-	-	-	-
Fathead Minnow 7d Mortality Tes	%	-	-	-	-	-	-	-	-	-	-

Table II-12
Water Quality in Jackpine and Muskeg Creeks

Parameter	Units	Jackpine Creek (Fall)					Muskeg Creek (Fall)				
			Historical (1976-1999)[a]					Historical (1976-1999)[b]			
		2000	median	min	max	n	2000	median	min	max	n
Metals (Total)											
aluminum (Al)	µg/L	100	115	30	564	10	50	40	30	70	5
antimony (Sb)	µg/L	< 5.0	< 0.6	< 0.2	< 1.0	4	< 5.0	-	< 0.8	< 0.8	2
arsenic (As)	µg/L	< 1.0	1.0	0.2	2.0	5	< 1.0	< 1.0	< 1.0	2.0	3
barium (Ba)	µg/L	13	22	20	49	3	22	51	40	67	3
beryllium (Be)	µg/L	< 1	1	< 1	1	3	< 1	< 1	< 1	< 1	3
boron (B)	µg/L	33	40	30	66	3	24	86	20	150	3
cadmium (Cd)	µg/L	< 0.2	0.2	< 0.2	4.0	4	< 0.2	< 0.2	< 0.2	< 3.0	3
calcium (Ca)	µg/L	22600	-	20500	55800	2	31200	-	67200	72500	2
chromium (Cr)	µg/L	< 1	1	< 1	12	3	76	< 1	< 1	11	3
cobalt (Co)	µg/L	< 0.2	9.0	0.3	480.0	5	1.0	0.4	0.4	6.0	3
copper (Cu)	µg/L	< 1	< 1	< 1	10	3	11	< 1	< 1	< 1	3
iron (Fe)	µg/L	380	580	< 3	1570	5	1160	1750	1740	1810	3
lead (Pb)	µg/L	0.2	< 2.6	< 0.1	< 20.0	3	0.3	0.2	< 0.1	20.0	3
lithium (Li)	µg/L	11	9	8	79	3	8	28	7	95	3
magnesium (Mg)	µg/L	6120	-	6380	14900	2	8490	-	16000	19000	2
manganese (Mn)	µg/L	17	50	21	58	3	92	350	92	534	3
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.1	0.3	11	< 0.2	< 0.2	< 0.1	< 0.2	4
molybdenum (Mo)	µg/L	0.2	0.3	0.1	3.0	3	6.4	< 0.1	< 0.1	< 3.0	3
nickel (Ni)	µg/L	3.9	3.3	1.6	< 5.0	3	36.3	4.2	1.6	10.0	3
potassium (K)	µg/L	690	-	1097	1550	2	790	-	2160	2360	2
selenium (Se)	µg/L	< 0.8	< 0.4	< 0.2	< 0.8	3	< 0.8	-	< 0.8	< 0.8	2
silver (Ag)	µg/L	< 0.4	0.4	0.1	5.0	3	< 0.4	< 0.4	< 0.4	3.0	3
sodium (Na)	µg/L	10900	-	9533	17100	2	8700	-	46900	63000	2
strontium (Sr)	µg/L	85	94	77	171	3	81	243	89	296	3
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	0.1	0.1	< 500	3	< 0.1	0.2	0.1	< 500	3
vanadium (V)	µg/L	0.5	1.4	0.8	< 2.0	3	< 0.2	0.8	0.4	< 2.0	3
zinc (Zn)	µg/L	27	25	7	186	3	32	7	4	7	3
Metals (Dissolved)											
aluminum (Al)	µg/L	20	-	< 10	79	2	< 10	-	< 10	30	2
antimony (Sb)	µg/L	< 0.8	-	0.4	< 0.8	2	< 0.8	-	< 0.8	< 0.8	2
arsenic (As)	µg/L	< 0.4	0.4	< 0.2	1.1	10	< 0.4	< 0.4	< 0.2	0.5	3
barium (Ba)	µg/L	12.1	-	19.2	44.2	2	19.1	-	48.4	62.7	2
beryllium (Be)	µg/L	< 0.5	-	< 0.5	0.5	2	< 0.5	-	< 0.5	< 0.5	2
boron (B)	µg/L	34	80	40	150	10	25	124	80	170	4
cadmium (Cd)	µg/L	< 0.1	-	< 0.1	< 0.1	2	< 0.1	-	< 0.1	< 0.1	2
chromium (Cr)	µg/L	0.9	3.0	< 0.4	8.0	10	0.5	< 1.9	< 0.4	< 3.0	4
cobalt (Co)	µg/L	< 0.1	-	0.2	0.2	2	< 0.1	-	0.3	0.7	2
copper (Cu)	µg/L	< 0.6	-	< 0.6	2.0	2	< 0.6	-	< 0.6	0.7	2
iron (Fe)	µg/L	190	280	168	450	3	210	-	350	1020	2
lead (Pb)	µg/L	0.1	-	< 0.1	1.0	2	0.1	-	< 0.1	0.1	2
lithium (Li)	µg/L	10	-	8	23	2	8	-	26	33	2
manganese (Mn)	µg/L	12.1	48.9	46.3	51.8	3	9.6	-	319	522	2
mercury (Hg)	µg/L	< 0.1	-	< 0.0	0.2	2	< 0.1	-	< 0.0	< 0.1	2
molybdenum (Mo)	µg/L	0.1	-	< 0.1	0.1	2	< 0.1	-	< 0.1	< 0.1	2
nickel (Ni)	µg/L	0.9	-	0.6	1.2	2	0.6	-	1.1	3.5	2
selenium (Se)	µg/L	< 0.4	< 0.2	< 0.1	0.4	8	< 0.4	< 0.4	< 0.2	< 0.4	3
silver (Ag)	µg/L	< 0.2	-	< 0.2	0.2	2	< 0.2	-	< 0.2	< 0.2	2
strontium (Sr)	µg/L	79	-	72	180	2	74	-	250	274	2
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	-	-	-
uranium (U)	µg/L	< 0.1	-	0.05	< 0.1	2	< 0.1	-	0.2	0.2	2
vanadium (V)	µg/L	0.4	-	0.3	0.3	2	< 0.1	-	< 0.1	0.4	2
zinc (Zn)	µg/L	8.0	-	2.0	16.0	2	7.0	-	2.0	4.0	2

[a] Based on information from Golder (1996, 1998, 2000c), R.L.&L. (1982, 1989) and NAQUADAT station AB07DA0600.
[b] Based on information from Golder (1996, 1999b, 2000c) and NAQUADAT station AB07DA0500.

Table II-13
Sediment Quality in McLean and Fort Creeks

Parameter	Units	McLean Creek 2000	McLean Creek 1999[(a)]	Fort Creek (2000)
Particle Size				
partice size - % sand	%	84	10	85
partice size - % silt	%	12	60	12
partice size - % clay	%	4	30	4
moisture content	%	19	-	21
Carbon Content				
total inorganic carbon	% by wt	< 0.1	1.1	0.6
total organic carbon	% by wt	5.6	2.3	3.2
total carbon	% by wt	5.7	3.4	3.8
Organics				
total recoverable hydrocarbons	mg/kg	43900	900	9450
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	0.6
total extractable hydrocarbons (C11-C30)	mg/kg	5800	-	985
Metals (Total)				
aluminum (Al)	ug/g	3500	15500	5305
arsenic (As)	ug/g	3.4	6.4	3.7
barium (Ba)	ug/g	49.7	205	116.5
beryllium (Be)	ug/g	0.2	< 1	0.35
boron (B)	ug/g	< 5	15	6
cadmium (Cd)	ug/g	< 0.1	< 0.5	0.15
calcium (Ca)	ug/g	3200	39600	7130
chromium (Cr)	ug/g	31.8	29.4	11.6
cobalt (Co)	ug/g	4.4	12.0	3.8
copper (Cu)	ug/g	10.5	24.0	9.2
iron (Fe)	ug/g	10100	24600	10925
lead (Pb)	ug/g	4.4	12.0	6.95
magnesium (Mg)	ug/g	1580	9440	2160
manganese (Mn)	ug/g	188	682	312.5
mercury (Hg)	ug/g	< 0.04	0.04	< 0.04
molybdenum (Mo)	ug/g	1.5	< 1	0.3
nickel (Ni)	ug/g	23.2	33.0	12.1
potassium (K)	ug/g	1120	3050	1207.5
selenium (Se)	ug/g	< 0.2	0.4	0.45
silver (Ag)	ug/g	< 0.1	< 1	< 0.1
sodium (Na)	ug/g	< 100	500	86
strontium (Sr)	ug/g	16	95	27
thallium (Tl)	ug/g	0.06	-	0.105
uranium (U)	ug/g	0.5	< 40	0.55
vanadium (V)	ug/g	19.4	38.0	18.5
zinc (Zn)	ug/g	24.7	81.1	54.1
Target PAHs and Alkylated PAHs				
naphthalene	ng/g	16	27	21
C1 subst'd naphthalenes	ng/g	24	64	66
C2 subst'd naphthalenes	ng/g	100	81	44
C3 subst'd naphthalenes	ng/g	310	92	< 32
C4 subst'd naphthalenes	ng/g	< 30	51	< 25
acenaphthene	ng/g	< 17	< 3	< 24
C1 subst'd acenaphthene	ng/g	< 4	8	< 13
acenaphthylene	ng/g	< 7	< 4	< 15
anthracene	ng/g	< 58	< 3	< 25
dibenzo(a,h)anthracene	ng/g	< 100	< 10	< 100
benzo(a)anthracene / chrysene	ng/g	1200	61	190
C1 subst'd benzo(a)anthracene / chrysene	ng/g	14000	56	2100
C2 subst'd benzo(a)anthracene / chrysene	ng/g	6200	10	850

Table II-13
Sediment Quality in McLean and Fort Creeks

Parameter	Units	McLean Creek 2000	McLean Creek 1999[(a)]	Fort Creek (2000)
benzo(a)pyrene	ng/g	< 45	< 14	< 100
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyren	ng/g	< 5	< 31	< 120
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyre	ng/g	< 18	< 14	< 73
benzofluoranthenes	ng/g	410	38	60
benzo(g,h,i)perylene	ng/g	210	24	< 81
biphenyl	ng/g	7	11	< 17
C1 subst'd biphenyl	ng/g	< 4	< 3	< 14
C2 subst'd biphenyl	ng/g	< 5	< 3	< 9
Dibenzothiophene	ng/g	< 26	4	< 19
C1 subst'd dibenzothiophene	ng/g	740	23	55
C2 subst'd dibenzothiophene	ng/g	4000	76	390
C3 subst'd dibenzothiophene	ng/g	20000	130	1580
C4 subst'd dibenzothiophene	ng/g	< 47	-	< 35
fluoranthene	ng/g	60	10	< 34
C1 subst'd fluoranthene / pyrene	ng/g	2400	65	340
C2 subst'd fluoranthene / pyrene	ng/g	5300	-	805
C3 subst'd fluoranthene / pyrene	ng/g	7400	-	1185
fluorene	ng/g	14	6	< 18
C1 subst'd fluorene	ng/g	< 11	< 4	< 20
C2 subst'd fluorene	ng/g	< 8	< 3	< 27
C3 subst'd fluorene	ng/g	< 17	-	< 50
indeno(1,2,3,cd)pyrene	ng/g	160	14	< 60
phenanthrene	ng/g	87	45	28
C1 subst'd phenanthrene / anthracene	ng/g	< 28	120	< 40
C2 subst'd phenanthrene / anthracene	ng/g	2100	96	151
C3 subst'd phenanthrene / anthracene	ng/g	7800	120	710
C4 subst'd phenanthrene / anthracene	ng/g	4500	420	585
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	1100	-	210
pyrene	ng/g	490	26	41

(a) Based on information from Golder (2000c).

Table II-14
Sediment Quality in the Muskeg River

Parameter	Units	MUR-1					1 km upstream of mouth	MUR-2	MUR-4		MUR-5	MUR-6	
		2000	Historical (1975 - 1999)[a]										
			median	min	max	n	(2000)	(2000)	2000	1997[b]	(2000)	2000	1998[c]
Particle Size													
partice size - % sand	%	90	70	68	89	3	88	72	75	64	43	28	-
partice size - % silt	%	4	20	6.3	20	3	8	16	11	18.3	21	46	-
partice size - % clay	%	6	10	4.7	12	3	4	12	15	17.7	36	26	-
moisture content	%	24	-	-	-	-	22	41	54	-	74	82	-
Carbon Content													
total inorganic carbon	% by wt	0.9	1.3	1.2	1.4	2	1.7	0.1	0.1	-	0.1	0.1	-
total organic carbon	% by wt	0.5	1.5	1.2	3.0	3	1.1	2.8	4.5	4.5	13.6	21.2	-
total carbon	% by wt	1.4	2.6	2.6	2.7	2	2.9	2.8	4.6	-	13.7	21.3	-
Organics													
total recoverable hydrocarbons	mg/kg	1900	2040	800	3440	3	1800	11300	9800	3690	3400	2200	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	-	-	-	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5	-
total extractable hydrocarbons (C11-C30)	mg/kg	72	-	-	-	-	47	370	140	-	270	130	-
Metals (Total)													
aluminum (Al)	ug/g	4180	7480	2970	9030	3	9440	2000	9040	5820	6230	15600	-
arsenic (As)	ug/g	1.9	2.9	1.0	3.5	4	2.1	0.6	1.2	2.4	1.4	2	-
barium (Ba)	ug/g	116	113	40.1	120	3	78.5	50.4	89	118	106	151	-
beryllium (Be)	ug/g	0.3	< 1	< 1	< 1	3	0.3	< 0.2	0.2	< 1	0.2	0.4	-
boron (B)	ug/g	20	14	-	-	1	26	< 2	14	-	13	27	-
cadmium (Cd)	ug/g	< 0.1	< 0.5	0.1	< 0.5	4	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	0.3	-
calcium (Ca)	ug/g	64800	47400	39400	50600	3	58000	2020	3290	5650	6470	19800	-
chromium (Cr)	ug/g	36.8	19.6	6.9	59	4	17.1	4.5	12.2	12.3	8.8	98.1	-
cobalt (Co)	ug/g	4.4	5.0	3.0	6.0	3	3.4	1.5	2.9	4	2.3	5.1	-
copper (Cu)	ug/g	7.8	9.5	7.0	26.2	4	6.5	3.8	7	10	8.8	14.6	-
iron (Fe)	ug/g	16000	18650	11200	22400	4	15400	5370	12400	23000	20400	12500	-
lead (Pb)	ug/g	6.1	7.5	< 5	9.9	4	5.3	2.5	5.1	< 5	3.5	5.7	-
magnesium (Mg)	ug/g	4070	5800	3240	6140	3	3720	670	1420	1390	1560	3580	-
manganese (Mn)	ug/g	756	475	327	583	4	346	225	314	620	288	116	-
mercury (Hg)	ug/g	0	0.04	0.03	0.05	4	0.04	< 0.04	0	0.04	< 0.04	0.08	-
molybdenum (Mo)	ug/g	1.3	< 1	< 1	< 1	3	0.6	0.1	0.3	< 1	0.1	5.5	-
nickel (Ni)	ug/g	26.9	16.0	6.0	20.5	4	12.7	4.6	10.3	9	6.1	59.4	-
potassium (K)	ug/g	1180	1280	741	1840	3	1870	270	1260	744	900	1920	-
selenium (Se)	ug/g	< 0.2	0.3	< 0.1	0.7	4	< 0.2	< 0.2	0.4	0.6	0.6	< 0.2	-
silver (Ag)	ug/g	< 0.1	< 1	< 1	< 1	3	< 0.1	< 0.1	< 0.1	< 1	< 0.1	< 0.1	-
sodium (Na)	ug/g	171	114	< 100	200	3	136	56	112	121	83	188	-
strontium (Sr)	ug/g	99	67	62	75	3	89	10	26	27	29	43	-
thallium (Tl)	ug/g	0.07	-	-	-	-	0.07	< 0.05	0.08	-	0.05	0.18	-
uranium (U)	ug/g	0.4	< 40	-	-	1	0.4	0.2	0.4	-	0.3	1.1	-
vanadium (V)	ug/g	4.8	21.0	9.0	86.0	4	19.3	6.6	19.5	16	14.4	< 0.1	-
zinc (Zn)	ug/g	28.0	42.0	26.4	57.2	4	23.7	19.1	39.9	37.9	28.7	38.7	-
Target PAHs and Alkylated PAHs													
naphthalene	ng/g	8.5	14	< 3	18	3	7.3	20	10	3	7.1	10	6.29
C1 subst'd naphthalenes	ng/g	< 10	15	< 3	20	3	8.1	< 19	15	< 3	12	10	20.82
C2 subst'd naphthalenes	ng/g	< 4.4	20	18	22	3	14	< 6	21	30	16	21	97
C3 subst'd naphthalenes	ng/g	< 9.8	23	16	40	3	8.7	< 12	6.8	30	14	8.7	27.4
C4 subst'd naphthalenes	ng/g	< 6.7	4.5	< 2.2	60	3	< 2.8	1200	< 3.2	160	34	< 2.3	17.6
acenaphthene	ng/g	< 6.1	< 3	< 2.6	< 4	3	< 2.2	< 8.4	< 3.1	< 3	2	< 3	0.41
C1 subst'd acenaphthene	ng/g	< 1.8	< 2.8	< 1.1	< 20	3	< 0.87	< 6.8	< 0.5	< 20	1.5	3	-
acenaphthylene	ng/g	< 5.6	< 3	< 1	< 3.5	3	< 1.3	< 4.9	< 1.2	4	< 1.4	< 2.7	0.42
anthracene	ng/g	< 2.4	< 3	< 2	< 3.1	3	< 2.3	< 14	< 1.7	< 3	< 3.5	< 1	0.4
dibenzo(a,h)anthracene	ng/g	< 21	< 3.7	< 3	< 21	3	< 2.5	< 20	< 11	< 3	< 9.2	< 3.6	-
benzo(a)anthracene / chrysene	ng/g	17	16.500	16	35	3	16.5	259	64	57	40.8	12	12.39
C1 subst'd benzo(a)anthracene / chrysene	ng/g	120	17	< 2.5	70	3	< 17	3600	630	120	440	230	5
C2 subst'd benzo(a)anthracene / chrysene	ng/g	52	9.200	< 1.7	130	3	58	1600	320	200	130	16	5.2
benzo(a)pyrene	ng/g	< 3.9	< 10	< 5.1	13	3	3	< 34	< 6.9	16	< 6.8	15	-
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	ng/g	< 5.2	< 12	< 8.6	90	3	< 4.9	< 27	< 18	120	< 6.1	< 2	-
C2 subst'd benzo(b& k) fluoranthene / benzo(a)pyrene	ng/g	< 5.7	< 9.2	< 5.7	100	3	< 5	< 29	< 16	190	< 8.5	< 2.5	-
benzo(b&k)fluoranthene	ng/g	7.8	12	11	14	3	9.7	62	18	34	13	13	5.64
benzo(g,h,i)perylene	ng/g	12	12	11	14	3	6.9	34	30	10	16	< 16	13.94
biphenyl	ng/g	< 4.3	< 4.4	< 1.1	< 20	3	< 1.5	< 4.3	< 1.9	< 20	2.3	2.6	-
C1 subst'd biphenyl	ng/g	< 2.4	< 2.3	< 1	< 20	3	< 1.7	< 2.1	< 2.8	< 20	0.27	< 3	-
C2 subst'd biphenyl	ng/g	< 2.4	< 1.6	< 0.6	< 20	3	< 0.97	< 6.9	< 0.7	< 20	< 1.1	< 1	-
dibenzothiophene	ng/g	< 2.4	< 1.9	< 1.2	< 3	3	0.92	< 14	2.7	5	< 1.7	< 1.8	2.59
C1 subst'd dibenzothiophene	ng/g	16	< 11	< 10	< 20	3	< 2.7	200	< 4.7	30	14	< 1.5	52.8
C2 subst'd dibenzothiophene	ng/g	44	42	< 4.2	110	3	4	2800	81	300	100	< 2.2	97.6
C3 subst'd dibenzothiophene	ng/g	72	82	< 3.6	210	3	79	7600	180	580	310	< 1.5	26.6

Table II-14
Sediment Quality in the Muskeg River

Parameter	Units	MUR-1 2000	MUR-1 Historical (1975 - 1999)[a] median	min	max	n	1 km upstream of mouth (2000)	MUR-2 (2000)	MUR-4 2000	MUR-4 1997[b]	MUR-5 (2000)	MUR-6 2000	MUR-6 1998[c]
C4 subst'd dibenzothiophene	ng/g	44	240	-	-	1	< 2.3	< 14	< 7.3	560	< 4.6	< 1.4	-
fluoranthene	ng/g	< 2.5	2.8	2.7	3	3	1.9	< 22	< 1.9	6	2.7	5.9	1.86
C1 subst'd fluoranthene / pyrene	ng/g	21	17	16	70	3	13	510	100	70	50	7.1	163.8
C2 subst'd fluoranthene / pyrene	ng/g	64	-	-	-	-	51	1400	250	-	120	16	-
C3 subst'd fluoranthene / pyrene	ng/g	78	-	-	-	-	47	1900	340	-	130	< 3.6	-
fluorene	ng/g	< 3	2.700	2	< 3	3	< 0.8	< 2.5	< 1	< 3	< 2.8	3.1	2.82
C1 subst'd fluorene	ng/g	< 2.9	< 2.2	< 1.9	< 20	3	< 1.4	< 10	< 2.3	20	< 1.8	< 1.3	29.4
C2 subst'd fluorene	ng/g	< 4.1	< 3	< 2	60	3	< 2.8	< 43	< 1.9	150	< 2.3	< 1.8	69.6
C3 subst'd fluorene	ng/g	< 6.8	-	-	-	-	< 2.9	2300	< 6.9	-	< 4	< 3	-
indeno(c,d-123)pyrene	ng/g	11	6.400	6	< 13	3	6.8	23	17	9	7.2	4.5	-
phenanthrene	ng/g	5.700	9.800	7	14	3	4.7	58	5.9	9	9.5	10	10.94
C1 subst'd phenanthrene / anthracene	ng/g	22	40	24	41	3	14	464	23	90	46	5.2	42.4
C2 subst'd phenanthrene / anthracene	ng/g	42	40	40	100	3	34	2000	51	260	83	20	59.6
C3 subst'd phenanthrene / anthracene	ng/g	44	51.000	36	180	3	36	2900	84	600	130	6	-
C4 subst'd phenanthrene / anthracene	ng/g	46	110	36	150	3	10	1100	130	210	63	140	-
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	13	-	-	-	-	16	< 210	17	-	170	280	362
pyrene	ng/g	7.6	6	5.1	12	3	3.5	110	13	15	11	4.5	3.7

[a] Based on information from Golder (1998, 1999b, 2000c) and Lutz and Hendzel (1977).
[b] Based on information from Golder (1998)
[c] Based on information from Golder (1999b).

Table II-15
Wetland Water Quality

Parameter	Units	Kearl Lake (Fall)					Isadore's Lake		Shipyard Lake								McClelland Lake		
									Summer										
			Historical (1985-1998)[a]				(Fall)			Historical (1995-1999)[c]					Fall		Spring	Fall 2000	
		2000	median	min	max	n	2000	1997[b]	2000	median	min	max	n		2000	1999[c]	2000	Trip 1	Trip 2
Field Measured																			
pH		8.1	7.4	-	-	1	-	-	-	8.9	-	-	1		7.7	8.7	-	9.0	8.6
specific conductance	µS/cm	159	170	-	-	1	-	-	-	264	-	-	1		346	333	-	234	220
temperature	^oC	6.3	2.0	-	-	1	-	-	-	22.8	-	-	1		7.3	2.2	-	13.0	7.2
dissolved oxygen	mg/L	11.0	13.7	-	-	1	-	-	-	14.0	-	-	1		9.0	8.2	-	10.7	11.5
Conventional Parameters																			
colour	T.C.U.	30	100	50	100	3	20	20	60	-	40	80	2		10	30	13	10	5
conductance	µS/cm	179	-	169	182	2	462	349	318	275	269	329	5		378	358	263	241	253
dissolved organic carbon	mg/L	17	-	15	23	2	9	9	17	-	16	16	2		18	17	10	12	17
hardness	mg/L	80	74	68	83	4	227	164	128	135	120	149	5		150	152	127	119	115
pH		8.0	-	7.6	8.1	2	7.7	8.0	7.9	7.5	7.3	8.9	5		7.8	8.1	8.3	8.4	8.1
total alkalinity	mg/L	92	85	82	88	4	173	136	142	135	134	161	5		159	165	137	128	129
total dissolved solids	mg/L	220	94	90	98	4	250	220	220	149	146	386	5		200	240	105	165	140
total organic carbon	mg/L	22	25	18	27	3	11	12	19	24	18	24	5		21	19	11	14	20
total suspended solids	mg/L	4	2	1	4	4	5	6	6	175	4	190	5		15	5	< 3	< 3	5
Major Ions																			
bicarbonate (HCO3)	mg/L	112	103	100	107	4	211	166	173	165	131	196	5		194	201	165	152	158
calcium	mg/L	20	19	17	22	4	49	38	35	41	32	44	5		42	42	26	22	22
carbonate (CO3)	mg/L	< 5.0	< 0.5	< 0.5	< 5.0	3	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	16.0	5		< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
chloride	mg/L	< 1	1	< 1	1	3	4	2	13	5	4	8	5		18	11	1	< 1	< 1
magnesium	mg/L	7	7	6	7	4	26	17	10	9	8	10	5		11	11	15	15	15
potassium	mg/L	0.9	1.0	0.6	1.1	3	2.2	1.8	0.8	0.8	0.5	0.9	5		1.5	1.0	2.8	2.6	2.7
sodium	mg/L	10	10	8	11	4	6	6	14	10	9	13	5		18	16	4	5	4
sulphate	mg/L	6	4	3	6	4	64	38	5	2	2	4	5		11	6	3	2	2
sulphide	µg/L	7	< 2	-	-	1	11	2	< 3	< 5	< 2	< 5	5		8	5	< 3	< 3	< 3
Nutrients and Chlorophyll *a*																			
nitrate + nitrite	mg/L	< 0.05	0.02	< 0.003	< 0.05	4	< 0.05	0.07	< 0.05	0.03	0.02	0.10	5		< 0.05	< 0.10	< 0.05	< 0.05	< 0.05
nitrogen - ammonia	mg/L	< 0.10	0.08	0.04	0.20	3	< 0.10	0.11	< 0.10	0.07	< 0.05	0.11	5		< 0.10	< 0.05	< 0.10	< 0.10	< 0.10
nitrogen - kjeldahl	mg/L	0.4	1.0	0.9	1.5	3	1.2	0.4	1.1	0.8	0.5	0.9	5		1.2	0.8	0.7	0.8	0.5
phosphorus, total	µg/L	11	27	12	37	4	75	12	20	31	12	37	5		16	17	14	14	15
phosphorus, total dissolved	µg/L	9	12	-	-	1	67	12	14	15	4	24	5		13	7	8	15	13
chlorophyll *a*	µg/L	2	3	-	-	1	10	< 1	2	-	3	6	2		-	-	2	3	1
Biochemical Oxygen Demand																			
biochemical oxygen demand	mg/L	< 2	2	2	3	3	6	2	< 2	-	2	3	2		-	< 2	< 2	2	< 2
Organics																			
naphthenic acids	mg/L	< 1	-	< 1	< 1	2	< 1	1	< 1	< 1	< 1	< 1	5		2	< 1	< 1	-	2
total phenolics	µg/L	< 1	5	-	-	1	< 1	< 1	< 1	-	2	3	2		< 1	6	< 1	2	3
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.1	< 1.0	4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.0	3		< 0.5	< 0.5	1.0	-	< 0.5
Toxicity																			
Microtox IC_{50} @ 15 min	%	> 91	-	> 91	> 91	2	> 91	> 91	> 91	> 91	> 91	> 91	5		> 91	> 91	-	-	> 91
Microtox IC_{25} @ 15 min	%	> 91	-	> 91	> 91	2	> 91	> 91	68	> 91	> 91	> 91	5		> 91	> 91	-	-	> 91
Metals (Total)																			
aluminum (Al)	µg/L	20	< 10	< 10	130	4	< 20	62	160	50	30	70	5		140	30	70	60	< 20
antimony (Sb)	µg/L	< 5.0	2.3	-	-	1	< 5.0	0.7	< 5.0	0.2	0.2	< 0.8	5		< 5.0	< 0.8	< 5.0	< 5.0	< 5.0
arsenic (As)	µg/L	< 1.0	< 0.3	< 0.2	< 1.0	3	< 1.0	1.8	< 1.0	< 1.0	< 1.0	< 1.0	5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
barium (Ba)	µg/L	20	-	20	115	2	82	55	42	30	22	35	5		32	27	37	32	31
beryllium (Be)	µg/L	< 1	-	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1	< 1	5		< 1	< 1	< 1	< 1	< 1
boron (B)	µg/L	47	60	12	70	4	35	42	45	34	20	60	5		33	27	57	69	61
cadmium (Cd)	µg/L	< 0.2	< 1.0	< 0.2	< 3.0	4	< 0.2	0.3	< 0.2	< 3.0	< 0.2	< 3.0	5		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
calcium (Ca)	µg/L	20000	48900	-	-	1	49500	38500	35700	-	32200	49600	2		44700	43200	25850	21550	23000
chromium (Cr)	µg/L	< 1	< 2	< 1	348	4	3	< 0.4	< 1	4	< 1	17	5		4	2	2	1	< 1
cobalt (Co)	µg/L	< 0.2	-	< 3.0	16.0	2	< 0.2	< 0.5	< 0.2	< 3.0	< 0.2	< 3.0	5		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
copper (Cu)	µg/L	2	< 1	< 1	1	4	< 1	7	< 1	-	< 1	1	2		4	< 1	20	1	< 1
iron (Fe)	µg/L	50	90	70	190	4	130	< 10	4660	2220	220	2740	5		420	270	40	< 20	< 20
lead (Pb)	µg/L	0.8	< 2.0	0.3	< 20.0	4	< 0.1	0.9	1.3	< 20.0	0.1	< 20.0	5		< 0.1	< 0.1	2.6	1.1	0.3
lithium (Li)	µg/L	< 6	-	< 6	6	2	< 6	9	11	8	7	10	5		< 6	11	19	20	23
magnesium (Mg)	µg/L	6620	12400	-	-	1	21400	17800	9810	-	9550	9830	2		10700	11300	14450	15250	15100
manganese (Mn)	µg/L	7	16	8	50	4	13	43	79	179	98	215	5		6	15	20	8	7
mercury (Hg)	µg/L	< 0.2	< 0.1	< 0.1	0.3	3	< 0.2	< 0.1	< 0.2	< 50.0	< 0.2	< 50.0	5		< 0.2	< 0.2	-	< 0.2	< 0.2
molybdenum (Mo)	µg/L	0.2	-	0.9	3.0	2	< 0.1	0.8	< 0.1	< 3.0	< 0.1	< 3.0	5		< 0.1	0.2	0.2	0.1	< 0.1
nickel (Ni)	µg/L	0.8	3.0	< 1.0	5.7	4	< 0.2	1.2	1.5	8.0	0.6	14.0	5		< 0.2	1.6	2.7	2.0	1.0
potassium (K)	µg/L	1000	610	-	-	1	2190	2030	670	-	1	1	2		1660	1140	2720	3035	2730
selenium (Se)	µg/L	< 0.8	< 0.7	< 0.2	< 0.8	3	1.1	< 0.4	< 0.8	< 1.0	< 0.8	< 1.0	5		< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	-	< 0.4	3.0	2	< 0.4	< 0.1	< 0.4	< 2.0	< 0.4	< 2.0	5		< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
sodium (Na)	µg/L	10300	7800	-	-	1	5300	7100	15100	-	11500	14500	2		19100	14200	4100	4450	4300

Table II-15
Wetland Water Quality

Parameter	Units	Kearl Lake (Fall)					Isadore's Lake		Shipyard Lake							McClelland Lake		
									Summer									
			Historical (1985-1998)(a)				(Fall)			Historical (1995-1999)(c)				Fall		Spring	Fall 2000	
		2000	median	min	max	n	2000	1997(b)	2000	median	min	max	n	2000	1999(c)	2000	Trip 1	Trip 2
strontium (Sr)	µg/L	68	-	62	215	2	206	220	126	116	113	132	5	129	133	151	132	142
thallium (Tl)	µg/L	< 0.1	-	-	-	-	< 0.1	-	< 0.1	-	-	-	-	< 0.1	-	< 0.1	< 0.1	< 0.1
uranium (U)	µg/L	< 0.1	-	0.3	< 0.5	2	< 0.1	0.2	< 0.1	-	< 0.1	< 0.1	2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	< 0.2	< 1.5	< 0.2	2.0	4	< 0.2	< 0.2	< 0.2	< 2.0	< 0.2	< 2.0	5	< 0.2	0.2	0.5	0.3	< 0.2
zinc (Zn)	µg/L	15	9	3	24	4	32	12	12	12	< 4	16	5	31	< 4	28	46	5
Metals (Dissolved)																		
aluminum (Al)	µg/L	< 10	30	-	-	1	< 10	35	110	-	10	60	2	< 10	< 10	30	60	< 10
antimony (Sb)	µg/L	< 0.8	< 0.8	-	-	1	< 0.8	0.5	1.0	-	< 0.8	< 0.8	2	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	< 0.4	< 0.4	-	-	1	< 0.4	1.6	0.6	-	0.5	1.3	2	0.4	< 0.4	< 0.4	< 0.4	< 0.4
barium (Ba)	µg/L	17	18	-	-	1	80	54	28	-	17	33	2	27	28	32	30	31
beryllium (Be)	µg/L	< 0.5	< 0.5	-	-	1	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5	2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
boron (B)	µg/L	47	50	-	-	1	32	44	44	-	33	35	2	69	26	90	60	62
cadmium (Cd)	µg/L	< 0.1	< 0.1	-	-	1	< 0.1	0.3	< 0.1	-	< 0.1	0.1	2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	< 0.4	< 0.4	-	-	1	< 0.4	< 0.4	< 0.4	-	< 0.4	< 0.4	2	0.5	0.8	2.0	0.9	< 0.4
cobalt (Co)	µg/L	0.1	1.2	-	-	1	< 0.1	0.2	< 0.1	-	< 0.1	0.1	2	< 0.1	0.1	< 0.1	< 0.1	< 0.1
copper (Cu)	µg/L	< 0.6	1.4	-	-	1	< 0.6	1.5	< 0.6	-	0.6	1.6	2	1.5	0.9	< 0.6	0.9	3.0
iron (Fe)	µg/L	< 10	90	-	-	1	< 10	20	280	-	130	1480	2	< 10	220	< 10	10	< 10
lead (Pb)	µg/L	< 0.1	0.3	-	-	1	0.1	0.3	0.9	-	0.1	0.2	2	0.1	< 0.1	0.5	1.1	0.2
lithium (Li)	µg/L	7	6	-	-	1	10	9	12	-	7	10	2	14	11	23	22	23
manganese (Mn)	µg/L	4.4	3.8	-	-	1	14.5	33.5	32.9	-	0.8	102	2	3.1	3.0	1.8	2.2	0.9
mercury (Hg)	µg/L	< 0.1	< 0.1	-	-	1	< 0.1	< 0.2	< 0.1	-	< 0.1	0.2	2	< 0.1	0.03	< 0.02	< 0.02	< 0.1
molybdenum (Mo)	µg/L	0.2	< 0.1	-	-	1	< 0.1	0.7	< 0.1	-	< 0.1	< 0.9	2	0.2	0.2	0.1	0.2	0.2
nickel (Ni)	µg/L	0.2	1.6	-	-	1	0.2	0.8	1.6	-	0.3	0.5	2	0.4	1.8	0.5	1.6	< 0.1
selenium (Se)	µg/L	< 0.4	< 0.4	-	-	1	< 0.4	< 0.4	< 0.4	-	< 0.4	< 0.4	2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
silver (Ag)	µg/L	< 0.2	< 0.2	-	-	1	< 0.2	< 0.2	< 0.2	-	< 0.2	< 0.2	2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
strontium (Sr)	µg/L	66	67	-	-	1	207	202	118	-	112	131	2	129	135	147	133	142
thallium (Tl)	µg/L	< 0.05	-	-	-	-	< 0.05	-	< 0.05	-	-	-	-	< 0.05	-	< 0.05	< 0.05	< 0.05
uranium (U)	µg/L	< 0.1	< 0.1	-	-	1	< 0.1	0.1	< 0.1	-	< 0.1	< 0.1	2	< 0.1	0.3	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	< 0.1	0.1	-	-	1	< 0.1	0.1	< 0.1	-	< 0.1	0.2	2	0.3	0.1	0.2	< 0.1	< 0.1
zinc (Zn)	µg/L	11.0	5.0	-	-	1	11.0	17.0	15.0	-	< 2.0	< 2.0	2	6.0	3.0	3.5	42.5	13.0

(a) Based on information from Golder (1996, 1999b) and R.L.&L. (1989).
(b) Based on information from Golder (1997a).
(c) Based on information from Golder (1996, 1999b, 2000c).
(d) Based on information from Golder (2000c).

APPENDIX III

QUALITY ASSURANCE / QUALITY CONTROL DATA

Table III-1
Water Quality of Field Blanks, Trip Blanks and Lab Blanks, RAMP 2000 QA/QC Program

Parameter	Units	Field Blanks			Trip Blanks			Lab Blanks		
		Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip #1	Fall Trip #2
Conventional Parameters										
colour	T.C.U.	10	< 3	8	5	< 3	< 3	< 3	< 3	< 3
conductance	μS/cm	2.2	1.8	3.9	2.6	1.7	2.2	-	-	-
dissolved organic carbon	mg/L	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	-
hardness	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	-	-	-
pH	-	5.9	5.4	6.3	6	5.5	5.2	-	-	-
total alkalinity	mg/L	< 5	< 5	7	< 5	< 5	< 5	-	-	-
total dissolved solids	mg/L	< 10	< 10	30	< 10	20	< 10	< 10	< 10	< 10
total organic carbon	mg/L	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1
total suspended solids	mg/L	< 3	< 3	3	4	< 3	< 3	< 3	< 3	< 3
Major Ions										
bicarbonate	mg/L	< 5	< 5	9	< 5	< 5	6	-	-	-
calcium	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5
carbonate	mg/L	< 5	< 5	< 5	< 5	< 5	< 5	-	-	-
chloride	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
magnesium	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1
potassium	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1
sodium	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	-	< 1	< 1
sulphate	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.5
sulphide	mg/L	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Nutrients and Chlorophyll *a*										
nitrate + nitrite	μg/L	< 50	< 50	< 50	< 50	< 50	< 50	< 100	< 100	< 100
nitrogen - ammonia	μg/L	< 100	< 100	< 100	< 100	< 100	< 100	< 50	< 50	< 50
nitrogen - Kjeldahl	μg/L	< 200	< 200	< 200	< 200	< 200	< 200	< 200	-	< 200
phosphorus, total	μg/L	4	8	< 1	4	4	19	< 1	< 1	< 1
phosphorus, dissolved	μg/L	1	2	< 1	1	5	3	-	< 1	< 1
chlorophyll *a*	μg/L	< 1	< 1	< 1	< 1	< 1	-	-	-	-
Biological Oxygen Demand										
biochemical oxygen demand	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
General Organics										
naphthenic acids	mg/L	< 1	< 1	< 1	< 1	< 1	-	< 1	< 1	< 1
total phenolics	mg/L	0.003	0.002	< 0.001	< 0.001	0.002	0.002	-	0.002	< 0.001
total recoverable hydrocarbons	mg/L	0.7	< 0.5	< 0.5	0.6	< 0.5	1	0.6	0.5	< 0.5
Toxicity										
Microtox IC_{50} @ 15 min	%	-	-	> 91	-	-	-	-	-	-
Microtox IC_{25} @ 15 min	%	-	-	> 91	-	-	-	-	-	-

Table III-1
Water Quality of Field Blanks, Trip Blanks and Lab Blanks, RAMP 2000 QA/QC Program

Parameter	Units	Field Blanks			Trip Blanks			Lab Blanks		
		Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip #1	Fall Trip #2
Total Metals										
aluminum (Al)	µg/L	50	60	< 20	40	30	< 20	1600	40	20
antimony (Sb)	µg/L	< 5	< 5	< 5	< 5	< 5	< 5	-	< 5	< 5
arsenic (As)	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
barium (Ba)	µg/L	0.9	0.4	2	0.9	0.5	1	22.7	1.6	2.5
beryllium (Be)	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
boron (B)	µg/L	3	3	4	3	5	14	5	3	8
cadmium (Cd)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
calcium (Ca)	µg/L	< 100	< 100	200	< 100	800	< 100	2300	200	200
chromium (Cr)	µg/L	1.8	< 0.8	< 0.8	1.3	< 0.8	< 0.8	5.1	0.9	< 0.8
cobalt (Co)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	1	< 0.2	< 0.2
copper (Cu)	µg/L	< 1	4	< 1	1	< 1	< 1	2	< 1	< 1
iron (Fe)	µg/L	20	< 20	30	< 20	< 20	< 20	2230	20	110
lead (Pb)	µg/L	0.3	1.1	0.3	< 0.1	0.1	0.2	3.4	0.3	< 0.1
lithium (Li)	µg/L	< 6	< 6	< 6	< 6	< 6	< 6	-	< 6	< 6
magnesium (Mg)	µg/L	40	< 20	50	50	50	< 20	750	< 20	50
manganese (Mn)	µg/L	2.9	0.9	0.5	2.1	0.8	< 0.2	41.6	0.3	14.8
mercury (Hg)	µg/L	-	< 0.2	< 0.2	-	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
molybdenum (Mo)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.3	0.2	0.2
nickel (Ni)	µg/L	1.2	2.7	0.4	0.6	0.5	< 0.2	4.1	0.3	0.4
potassium (K)	µg/L	50	140	< 20	70	< 20	30	110	200	1340
selenium (Se)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	1.5	< 0.4	0.6
sodium (Na)	µg/L	< 200	< 200	< 200	< 200	300	< 200	< 200	200	500
strontium (Sr)	µg/L	0.5	< 0.2	0.6	0.6	0.8	0.5	5.6	0.3	1.7
thallium (Tl)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
titanium (Ti)	µg/L	0.8	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	28.2	< 0.6	0.7
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	3.9	0.3	3
zinc (Zn)	µg/L	11	73	8	< 4	36	< 4	10	18	7
Dissolved Metals										
aluminum (Al)	µg/L	30	90	< 10	130	< 10	< 10	80	< 10	-
antimony (Sb)	µg/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	-
arsenic (As)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	-
barium (Ba)	µg/L	0.2	0.2	0.6	0.1	0.2	0.9	< 0.1	< 0.1	-
beryllium (Be)	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-
boron (B)	µg/L	10	< 2	< 2	-	2	11	17	3	-
cadmium (Cd)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-
chromium (Cr)	µg/L	1.1	< 0.4	< 0.4	1	< 0.4	1	0.5	0.5	-
cobalt (Co)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-

Table III-1
Water Quality of Field Blanks, Trip Blanks and Lab Blanks, RAMP 2000 QA/QC Program

Parameter	Units	Field Blanks			Trip Blanks			Lab Blanks		
		Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip # 1	Fall Trip # 2	Spring	Fall Trip #1	Fall Trip #2
copper (Cu)	µg/L	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	-
iron (Fe)	µg/L	< 10	< 10	< 10	< 10	< 10	< 10	20	20	-
lead (Pb)	µg/L	0.1	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-
lithium (Li)	µg/L	< 3	0.3	< 0.1	< 3	0.2	0.4	< 0.1	< 0.1	-
manganese (Mn)	µg/L	1.6	0.7	0.2	2.2	0.6	0.3	0.8	2.4	-
mercury (Hg)	µg/L	< 0.02	< 0.02	< 0.1	< 0.02	< 0.1	< 0.1	< 0.1	< 0.1	-
molybdenum (Mo)	µg/L	0.1	0.2	0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	-
nickel (Ni)	µg/L	0.5	< 0.1	0.2	0.5	< 0.1	< 0.1	0.2	0.1	-
selenium (Se)	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.5	< 0.4	< 0.4	-
silver (Ag)	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	-
strontium (Sr)	µg/L	0.3	< 0.1	0.6	0.4	0.4	0.3	< 0.1	< 0.1	-
thallium (Tl)	µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.3	-
titanium (Ti)	µg/L	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	-
uranium (U)	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-
vanadium (V)	µg/L	0.1	< 0.1	< 0.1	0.1	< 0.1	0.2	< 0.1	< 0.1	-
zinc (Zn)	µg/L	< 2	< 2	9	< 2	< 2	< 2	< 2	< 2	-

- = No data.

Table III-2
Sediment Quality of Lab Blanks, RAMP 2000 QA/QC Program

Parameter	Units	Fall Trip #1	Fall Trip #2		
Organics					
total recoverable hydrocarbons	mg/kg	< 100	-	-	-
total volatile hydrocarbons	mg/kg	< 0.5	-	-	-
total extractable hydrocarbons	mg/kg	9	-	-	-
Total Metals					
aluminum (Al)	µg/g	47	-	-	-
antimony (Sb)	µg/g	-	-	-	-
arsenic (As)	µg/g	< 0.5	-	-	-
barium (Ba)	µg/g	0.4	-	-	-
beryllium (Be)	µg/g	< 0.2	-	-	-
boron (B)	µg/g	< 2	-	-	-
cadmium (Cd)	µg/g	< 0.1	-	-	-
calcium (Ca)	µg/g	70	-	-	-
chromium (Cr)	µg/g	< 0.2	-	-	-
cobalt (Co)	µg/g	< 0.1	-	-	-
copper (Cu)	µg/g	2	-	-	-
iron (Fe)	µg/g	20	-	-	-
lead (Pb)	µg/g	0.7	-	-	-
lithium (Li)	µg/g	-	-	-	-
magnesium (Mg)	µg/g	< 10	-	-	-
manganese (Mn)	µg/g	0.5	-	-	-
mercury (Hg)	µg/g	-	-	-	-
molybdenum (Mo)	µg/g	< 0.1	-	-	-
nickel (Ni)	µg/g	0.3	-	-	-
phosphorus (P)	µg/g	-	-	-	-
potassium (K)	µg/g	< 2	-	-	-
selenium (Se)	µg/g	< 0.2	-	-	-
silicon (Si)	µg/g	-	-	-	-
silver (Ag)	µg/g	< 0.1	-	-	-
sodium (Na)	µg/g	< 2	-	-	-
strontium (Sr)	µg/g	< 1	-	-	-
sulphur (S)	µg/g	-	-	-	-
thallium (Tl)	µg/g	< 0.05	-	-	-
titanium (Ti)	µg/g	0.98	-	-	-
uranium (U)	µg/g	< 0.1	-	-	-
vanadium (V)	µg/g	< 0.1	-	-	-
zinc (Zn)	µg/g	8.2	-	-	-
Target PAHs and Alkylated PAHs					
naphthalene	µg/g	-	14	8.2	10[(b)]
C1 subst'd naphthalenes	µg/g	-	9.4	10	11
C2 subst'd naphthalenes	µg/g	-	< 5.1	14	< 1.3
C3 subst'd naphthalenes	µg/g	-	< 5.1	< 3	< 2.3
C4 subst'd naphthalenes	µg/g	-	< 3.6	< 2.4	< 1.4
acenaphthene	µg/g	-	< 5.4	< 1.8	< 2.7
C1 subst'd acenaphthene	µg/g	-	< 2.4	< 1.9	< 1.1
acenaphthylene	µg/g	-	< 6.2	< 1.3	< 1.4
anthracene	µg/g	-	< 2.6	< 0.92	< 2.5
dibenzo(a,h)anthracene	µg/g	-	4.2	< 1.5	< 7
benzo(a)anthracene / chrysene	µg/g	-	< 1.9	< 0.82	< 2.5
C1 subst'd benzo(a)anthracene / chrysene	µg/g	-	< 11	< 3.2	< 9.6

Table III-2
Sediment Quality of Lab Blanks, RAMP 2000 QA/QC Program

Parameter	Units	Fall Trip #1	Fall Trip #2		
C2 subst'd benzo(a)anthracene / chrysene	µg/g	-	< 1.8	< 1.4	< 2.4
benzo(a)pyrene	µg/g	-	< 1.5	< 2.4	< 4.2
C1 subst'd benzo(b&k) f/ b(a)pyrene[(a)]	µg/g	-	< 1.8	< 2.2	< 5.2
C2 subst'd benzo(b& k) f/b(a)pyrene[(a)]	µg/g	-	< 2.7	< 2.2	< 7.1
benzofluoranthenes	µg/g	-	< 1.4	< 1.2	< 2.6
benzo(g,h,i)perylene	µg/g	-	4.6	< 1.4	< 2.6
biphenyl	µg/g	-	< 2.3	< 3.1	< 1.6
C1 subst'd biphenyl	µg/g	-	< 2.3	< 3.2	< 0.78
C2 subst'd biphenyl	µg/g	-	< 2.2	< 2.1	< 2.1
dibenzothiophene	µg/g	-	< 3.6	< 0.99	< 0.89
C1 subst'd dibenzothiophene	µg/g	-	< 3.8	< 1.6	< 2.3
C2 subst'd dibenzothiophene	µg/g	-	< 1.8	< 2.7	< 2.9
C3 subst'd dibenzothiophene	µg/g	-	< 1.4	< 1.4	< 3
C4 subst'd dibenzothiophene	µg/g	-	< 2.6	< 1.6	< 2.4
fluoranthene	µg/g	-	< 1.2	0.72[(b)]	< 1.5
C1 subst'd fluoranthene / pyrene	µg/g	-	< 1.2	< 1.2	< 2.3
C2 subst'd fluoranthene / pyrene	µg/g	-	< 2.3	< 1.3	< 1.6
C3 subst'd fluoranthene / pyrene	µg/g	-	< 1.2	< 0.94	< 2.8
fluorene	µg/g	-	< 3	< 1.1	< 2
C1 subst'd fluorene	µg/g	-	< 1.8	< 2.7	< 2.5
C2 subst'd fluorene	µg/g	-	< 2.6	< 2.3	< 2.2
C3 subst'd fluorene	µg/g	-	< 4.6	< 4.1	< 4.4
indeno(1,2,3,cd)pyrene	µg/g	-	< 3.6	< 1.2	< 1.8
phenanthrene	µg/g	-	< 2.6	2.5	2.3[(b)]
C1 subst'd phenanthrene / anthracene	µg/g	-	< 3.8	< 1.7	< 3.6
C2 subst'd phenanthrene / anthracene	µg/g	-	< 1.7	< 1.5	< 1.5
C3 subst'd phenanthrene / anthracene	µg/g	-	< 1.7	< 1.6	< 1.5
C4 subst'd phenanthrene / anthracene	µg/g	-	< 2.7	< 1.7	< 1.3
1-methyl-7-isopropyl-phenanthrene (Retene)	µg/g	-	< 7.1	< 2.7	< 2.8
pyrene	µg/g	-	< 1.4	2.5[(b)]	< 1.6

[(a)]fluoranthene/benzo(a)pyrene
[(b)]PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
- = No data.

APPENDIX IV

OVERVIEW OF PREVIOUS SEDIMENT STUDIES COMPLETED IN THE LOWER ATHABASCA RIVER

PREVIOUS STUDIES

Organization: Environment Canada and the Department of Fisheries and Oceans (on going)

Findings: In 1998, 14 grab samples were collected from Lake Athabasca. Half of these samples were analyzed for PAHs, alkylated PAHs and alkanes. The other 7 samples were archived for future analyses. PAH concentrations were low (i.e., near analytical detection limits), and no clear spatial patterns were observed (Marlene Evans pers. com.).

In 1999, sediment samples were collected from the Athabasca River Delta and Lake Athabasca. Data is currently being analyzed.

Future work: In March 2000, Environment Canada and DFO plan to collected three sediment cores from Lake Athabasca at the same sample sites as those used by Bourbonniere et al. (1996). Samples will be dated and analyzed for hydrocarbons. Although research is currently focused on the Athabasca River Delta and Peace River Delta, the study area will likely expand to include Mamawi, Claire and Richardson lakes. Smaller lakes, such as Frezie, Limon, Mudd and Egg lakes, may also be added at some later date (Marlene Evans, pers. com.).

Organization: RAMP (1997, 1998 and 1999)

Findings: Sediment quality at the mouth of the Muskeg River in 1999 was generally consistent with data from 1997 and 1998. In 1999, polycyclic aromatic hydrocarbon (PAH) concentrations in the upper Muskeg River were similar to concentrations at the river mouth, with the exception of C2-substituted naphthalene, methyl benzo(a)pyrene, methyl dibenzothiophene and methyl fluorene; these substances were present at higher concentrations in the upper Muskeg River. Sediments from the mouth of McLean Creek were found to be chronically toxic to several species of invertebrates. They generally contained higher total metal and PAH concentrations than sediments from the Muskeg River. Sediment PAH concentrations in McLean Creek were also higher than PAH concentrations observed in sediments from the Athabasca River Delta.

In 1998, bottom sediment samples were collected from the MacKay, Muskeg, Tar, Ells and Steepbank rivers. Sediment samples were also collected from the Athabasca River upstream of Donald Creek, downstream of the Muskeg River and downstream of Fort Creek. In the Athabasca River, organic and metal concentrations were directly related to silt and clay content in river sediments. In the tributaries, parameters concentrations in 1998 were generally consistent with historical data. All samples were non-toxic to the three invertebrate test species.

In 1997, bottom sediment samples were collected from Jackpine Creek, the MacKay River, the Muskeg River (2 sites), the Steepbank River and Poplar

Creek. Sediment samples were also collected from the Athabasca River upstream of Donald Creek, downstream of the Muskeg River and downstream of Fort Creek. Sample results were generally consistent with historical data. All samples were non-toxic in laboratory tests with three species of invertebrates.

Organization: Alberta Environment (1989 to 1999)

Findings: Sediment samples have been periodically collected from the Athabasca River, the Athabasca Delta and Lake Athabasca by Alberta Environment. These samples are archived with the Northern River Basins Study (NRBS) and have been referenced in NRBS technical reports.

Organization: NRBS - Brownlee et al. (1997)

Findings: Samples were collected in October, 1989, at three sites in the lower Athabasca River (i.e., upstream of the Horse and Firebag rivers and at mouth of the Athabasca River). The study focused on PAHs levels in bottom sediments. No spatial trends were observed, with the exception of a slight increase in chrysene at the mouth of the Athabasca River.

Organization: NRBS - Dobson et al. (1996)

Findings: Bottom sediments were collected from the Athabasca, Peace and Smoky Rivers in June 1995. Toxicity testing was completed with *Chironomus riparius*, *Hyalella azteca*, *Hexagenia spp.* and *Tubifex tubifex*. Sediments collected near existing oil sands operations had no significant effect on test species survival or growth.

Organization: NRBS - Crosley (1996)

Findings: Samples were collected in October 1994 and May 1995 from the Peace, Wapiti and Athabasca rivers. PAH concentrations were higher in the Peace and Wapiti rivers than in the Athabasca River. A slight decrease in total PAH concentrations between the two Athabasca River sample sites suggested that oil sands development in the area was not affecting PAH levels in Athabasca River sediments.

Composite sampling was found to be as representative as discrete sampling for a given study area. However, Crosley (1996) recommends that:

- composite samples should contain material from 10 or more depositional areas within a study reach ranging from 1 to 5 km,
- sediment sampling should be done at low flow periods in late fall or early spring, and

- unpartitioned, wet sediment should be analyzed to minimize handling and loss of sediment components (e.g., contaminant-coated sand).

Organization: NRBS - Bourbonniere et al. (1996)

Findings: Surficial sediments and sediment cores were collected from Lake Athabasca in May 1992 and May 1993. PAH and metal concentrations were generally consistent across the lake, and they were lower than levels observed in the Great Lakes. PAH and metal concentrations in the sediment cores were generally consistent through time and lower than levels observed in other Canadian lakes. However, benzo(a)pyrene and phenanthracene levels increased in response to large forest fires and arsenic levels decreased with depth in the western section of the lake.

Organization: Golder Associates Ltd. (1996)

Findings: Bottom sediment samples were collected in the fall of 1995 from the Athabasca River and in the spring and fall of 1995 from the Steepbank River. Porewater samples were collected from the Athabasca, Steepbank and Muskeg rivers and Jackpine Creek. Low PAH concentrations detected at all sites in the Athabasca River. Samples collected adjacent to and downstream of Tar Island Dyke (TID) contained slightly higher PAH levels than the other samples collected from the Athabasca River. One sample collected from the mouth of the Steepbank River in the fall of 1995 contained relatively high PAH levels; PAH concentrations were below analytical detection limits further upstream.

Organization: PERD - Brownlee et al. (1993)

Findings: Samples were collected in August, 1990, from four sites in the lower Athabasca River to characterize PAH concentrations in suspended sediments. No upstream - downstream comparisons were made.

Organization: National Water Research Institute - Brownlee (1990)

Findings: Sediment samples were collected in August 1989 and March 1990, at two sites in the Athabasca River (i.e., above and below the oil sands area). The study examined PAH levels in suspended sediments. Concentrations of PAHs were slightly higher downstream of the oil sands area.

Organization: Alberta Oil Sands Environmental Research Program (AOSERP) - Allan and Jackson (1978)

Findings: A total of 129 sediment samples were collected from the Athabasca River, the Athabasca River Delta and Lake Athabasca in August and September, 1976.

Twenty one (21) samples were characterized by particle size and analyzed for organic and heavy metal content. Results indicate that:

- metals levels in the lower Athabasca River Watershed were not affected by oil sands development in the area;
- variations in metal concentrations result primarily from differences in sediment characteristics (e.g., organic content, texture and carbonate content);
- fine textured sediments predominate from river to delta to lake, and metal levels tend to increase as one moves downstream and into Lake Athabasca; and,
- metal levels in the Athabasca River Watershed are generally lower than observed in other comparable environments across Canada.

Organization: AOSERP - Lutz and Hendzel (1977)

Findings: Sediment, fish, water and several benthos samples were collected from the lower Athabasca River Watershed in October, 1975. Metal and organic concentrations in water and fish tissues were near detection limits or at levels characteristic of the area. Metal concentrations in bottom sediments were consistent with historical data; no evidence of sediment contamination was observed.

REFERENCES

Allan, R. and T. Jackson. 1978. Heavy metals in bottom sediments of the mainstem Athabasca River system in the AOSERP study area. Prepared for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 34.

Bourbonniere, R.A., S.L. Telford and J.B. Kemper. 1996. Depositional history of sediments in Lake Athabasca: geochronology, bulk parameters, contaminants and biogeochemical markers. Northern River Basins Study, Project Report No. 72. NRBS, Edmonton.

Brownlee, B.G., S.L. Telford, R.W. Crosley and L.R. Noton. 1997. Distribution of organic contaminants in bottom sediments: Peace and Athabasca River basins, 1988 to 1992. NRBS Project Report No. 134. NRBS, Edmonton.

Brownlee, B.G., G.A. MacInnis, B.J. Dutka, W. Xu, W.L. Lockhart and D.A. Metner. 1993. Polycyclic aromatic hydrocarbon analysis and ecotoxicological testing of Athabasca River water and sediment. PERD Project 57205.

Brownlee, B.G. (editor). 1990. Athabasca River Project 1989/90, progress report. Rivers Research Branch, National Water Research Institute, Canada Centre for Inland Waters, Burlington Ontario. NWRI Contribution No. 90-76.

Crosley, R.W. 1996. Environmental contaminants in bottom sediments: Peace and Athabasca River Basins, October 1994 and May 1995. NRBS Project Report No. 106. NRBS, Edmonton.

Dobson, E., K. Day and T.B. Reynoldson. 1996. Ecotoxicology of suspended and bottom sediments: Athabasca, Smoky and Peace Rivers, June 1995. NRBS Project Report No. 135. NRBS, Edmonton.

Golder (Golder Associates Ltd). 1996. Aquatic baseline report for the Athabasca, Steepbank and Muskeg rivers in the vicinity of the Steepbank and Aurora Mines. Prepared for Suncor Inc. and Syncrude Canada.

Golder. 1998. Oil Sands Regional Aquatics Monitoring Program (RAMP) 1997. Prepared for Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd. and Shell Canada Limited.

Golder. 1999. Oil Sands Regional Aquatics Monitoring Program (RAMP), 1998. Prepared for Suncor Energy Inc., Shell Canada Ltd., Mobil Oil and Syncrude Canada Ltd., Fort McMurray. May 1999.

Golder. 2000. Oil Sands Regional Aquatics Monitoring Program (RAMP), 1999 - Draft Report. Prepared for Suncor Energy Inc., Shell Canada Ltd., Mobil Oil and Syncrude Canada Ltd., Fort McMurray. January 2000.

Lutz, A. and M. Hendzel. 1977. A survey of baseline levels of contaminates in aquatic biota of the AOSERP study area. Prepared for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 17.

APPENDIX V

BENTHIC INVERTEBRATE DATA
AND SUMMARY DATA

Table V-1
Benthic Invertebrate Abundance Data (numbers/sample) for the MacKay River, Steepbank River and Muskeg River in Fall 2000

Samples were collected between 1 and 7 October, 2000.[(a)]

Major Taxon	Family	Genus/Species	MAR-E-1	MAR-E-2	MAR-E-3	MAR-E-4	MAR-E-5	MAR-E-6	MAR-E-7	MAR-E-8	MAR-E-9	MAR-E-10	MAR-E-11	MAR-E-12	MAR-E-13	MAR-E-14	MAR-E-15	STR-E-1	STR-E-2	STR-E-3	STR-E-4	STR-E-5	STR-E-6	STR-E-7	STR-E-8	STR-E-9	STR-E-10	STR-E-11	STR-E-12	STR-E-13	STR-E-14	STR-E-15	MUR-E-1	MUR-E-2
Hydrozoa	Hydridae	*Hydra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	-- [(b)]	--	0	0	12	64	4	6	16	16	40	2	8	12	0	12	13	3	3	3	2	6	0	4	0	9	8	4	6	8	3	1	0	0
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Helobdella stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Erpobdellidae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Enchytraeidae	--	101	81	140	182	49	50	32	60	68	48	50	67	26	72	120	5	38	35	18	20	33	22	37	16	6	16	30	26	34	32	4	28
	Lumbriculidae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Naididae	--	94	116	68	36	64	40	273	252	108	80	48	56	42	165	176	6	15	69	45	35	62	27	117	79	41	17	29	33	31	85	42	20
	Tubificidae	--	10	1	0	0	1	0	1	0	1	0	0	2	2	5	19	1	9	3	1	0	2	5	2	3	0	3	1	6	4	2	1	1
Hydracarina	--	--	24	12	32	24	32	6	32	20	6	14	2	10	24	52	44	0	8	5	13	2	8	4	5	14	8	2	8	2	4	9	64	64
Ostracoda	Candonidae	*Candona*	4	0	4	0	32	2	0	0	2	2	2	6	14	0	8	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	12	12
Copepoda - Cyclopoida	--	--	0	0	0	4	4	0	0	0	0	2	0	0	2	4	0	1	0	1	2	0	0	0	1	0	0	0	1	2	0	0	0	4
Copepoda - Harpacticoida	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	2	0	0	0	0	0	0	0
Cladocera	Chydoridae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0
	Macrothricidae	--	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Talitridae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Collembola	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	0	0	0
Gastropoda	Ancylidae	*Ferrissia rivularis*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
	Hydrobiidae	(d)[(c)]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	Lymnaeidae	*Stagnicola*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Physidae	*Physa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Planorbidae	*Gyraulus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	5
	Valvatidae	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelecypoda	Unionidae	*Lampsilis radiata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sphaeriidae	*Pisidium / Sphaerium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pisidium	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3
Ephemeroptera	Ameletidae	*Ameletus subnotatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
	Baetidae	*Acentrella*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Baetis	25	83	130	134	167	25	33	96	10	32	63	94	53	284	190	6	9	15	27	40	28	23	23	284	63	20	21	24	120	87	608	370
	Baetiscidae	*Baetisca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
	Ephemerellidae	(d) [(d)]	12	12	8	0	4	2	8	4	6	8	4	6	10	20	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
		Drunella grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0
		Ephemerella	0	4	0	0	4	3	3	6	2	0	1	1	3	17	11	1	23	36	24	32	26	6	14	111	54	23	30	27	22	15	0	4
	Heptageniidae	(d)	0	0	8	8	0	4	0	4	2	2	4	0	0	0	0	1	1	0	2	3	2	0	2	8	2	0	2	2	0	0	0	0
		Heptagenia	3	2	1	0	7	0	3	0	2	2	2	1	3	2	0	2	0	0	1	1	0	0	0	7	1	1	1	0	0	0	16	12
		Rhithrogena	0	0	0	2	7	3	2	0	4	2	4	5	4	2	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		Stenonema	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	7
	Tricorythidae	*Tricorythodes*	35	22	10	0	20	7	4	9	2	0	0	15	22	56	42	0	5	3	1	0	3	1	2	10	11	10	6	8	2	6	0	1
	Caenidae	*Caenis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Leptophlebiidae	*Leptophlebia*	4	0	0	0	2	0	0	4	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	26	3
Plecoptera	--	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	44	20
	Capniidae	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chloroperlidae	(d)	8	4	37	21	39	12	7	0	20	12	26	14	4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	8	4
	Nemouridae	*Zapada*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Claassenia sabulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Perlodidae	*Isoperla*	7	8	11	7	5	0	3	1	1	1	1	3	6	20	25	0	1	0	0	0	0	1	0	0	5	0	0	1	0	0	0	0
		Skwala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
	Pteronarcyidae	*Pteronarcys*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Taeniopterygidae	*Taeniopteryx*	6	8	11	2	10	3	20	9	3	1	0	2	5	27	18	0	0	2	0	0	0	0	0	2	1	1	0	7	0	0	3	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	*Hydroptila*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
		Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydropsychidae	(d)	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0
		Cheumatopsyche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropsyche	2	2	0	0	11	0	1	2	0	2	1	1	7	4	0	1	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0
	Leptoceridae	*Oecetis*	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Lepidostomatidae	*Lepidostoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gomphidae	*Ophiogomphus*	11	7	0	0	8	0	9	8	0	6	0	0	5	14	9	0	0	1	0	0	3	0	0	0	0	2	0	0	0	0	22	7
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	Elmidae	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dubiraphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Optioservus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
	Haliplidae	*Brychius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Haliplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	Corixidae	*Sigara*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Callicorixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lepidoptera	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Table V-1
Benthic Invertebrate Abundance Data (numbers/sample) for the MacKay River, Steepbank River and Muskeg River in Fall 2000

Major Taxon	Family	Genus/Species	MAR-E-1	MAR-E-2	MAR-E-3	MAR-E-4	MAR-E-5	MAR-E-6	MAR-E-7	MAR-E-8	MAR-E-9	MAR-E-10	MAR-E-11	MAR-E-12	MAR-E-13	MAR-E-14	MAR-E-15	STR-E-1	STR-E-2	STR-E-3	STR-E-4	STR-E-5	STR-E-6	STR-E-7	STR-E-8	STR-E-9	STR-E-10	STR-E-11	STR-E-12	STR-E-13	STR-E-14	STR-E-15	MUR-E-1	MUR-E-2
Diptera	(Brachycera)	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	0	0	0	3	0	2	0	0	2	2	0	0	0	0	0	0	1	0	0	0	2	2	0	0	4	1	0	0	0
	Tipulidae	*Dicranota*	0	4	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4
		Hexatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Athericidae	*Atherix*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	3	0	0
	Dolichopodidae	*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae	*Tabanus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
	Empididae	*Chelifera*	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Hemerodromia	16	12	4	5	17	0	5	5	4	0	9	0	2	0	0	0	0	5	2	2	13	0	2	2	1	1	0	0	0	6	5	0
		Rhamphomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ceratopogonidae	--	4	6	4	16	8	1	0	8	4	2	0	1	2	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chironomidae	(p)[e]	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	2	0	0	1	0	0	0
	Tanypodinae	*Ablabesmyia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Larsia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6	5
		Nilotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemannimyia complex	12	5	4	8	30	8	13	21	8	4	6	12	22	36	62	0	0	0	4	0	2	0	1	10	8	12	6	3	5	4	128	142
	Chironomini	(d)	0	4	8	0	0	0	0	0	8	0	24	4	1	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cryptochironomus	0	0	0	5	0	0	0	0	2	2	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	4	3	5	1	1	0	0
		Demicryptochironomus	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Microtendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pagastiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracladopelma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paralauterborniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paratendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phaenopsectra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
		Polypedilum	12	4	60	40	12	5	5	24	84	89	172	116	11	12	47	4	11	0	2	2	4	11	4	2	2	8	8	7	2	3	0	4
		Robackia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stictochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Saetheria	0	0	0	80	8	4	0	0	28	26	24	10	8	0	0	0	0	0	0	0	0	1	3	2	0	0	0	0	0	0	0	0
		Nilothauma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tanytarsini	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
		Cladotanytarsus	0	0	4	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Micropsectra	16	20	8	28	80	26	16	28	40	34	14	13	18	72	180	0	0	0	3	0	0	1	1	18	18	27	25	26	3	9	16	28
		Paratanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheotanytarsus	88	52	20	9	113	12	29	61	44	16	20	25	10	116	77	0	1	0	0	1	2	0	0	0	8	3	5	1	1	1	33	28
		Stempellina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stempellinella	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	8
		Tanytarsus	4	28	5	0	48	14	12	20	20	20	8	6	10	24	33	0	0	0	0	0	0	0	0	2	0	2	1	1	0	0	48	24
	Orthocladiinae	(d)	0	0	0	9	0	0	0	0	4	2	16	4	0	13	8	0	0	0	2	2	2	0	0	8	6	2	3	0	2	0	0	0
		Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Corynoneura	0	4	0	0	0	0	0	8	4	8	12	4	4	4	0	0	0	0	0	0	0	0	0	6	2	0	1	0	0	0	4	0
		Cricotopus/Orthocladius	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	1	4	0	0	0	13	4	0	7	2	1	2	0	0
		Eukiefferiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
		Euryhapsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heterotrissocladius	0	4	0	0	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lopescladius	4	0	28	16	6	12	4	20	42	10	32	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4
		Nanocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
		Parakiefferiella	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	0	9	7	0	0	0	0
		Parametriocnemus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	2	0	0
		Psectrocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheocricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
		Synorthocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0
		Thienemanniella	0	4	0	0	0	8	0	4	8	2	4	2	0	0	0	0	0	0	0	0	0	0	0	6	0	3	0	5	1	1	4	0
		Tvetenia	4	0	0	0	8	2	12	20	2	4	8	4	2	16	0	0	0	0	1	1	0	1	0	9	4	0	1	1	4	5	4	0
	Diamesinae	*Potthastia* (*gaedii* type)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	8	8
		Potthastia (*longimanus* type)	0	1	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0
Terrestrial	--	--	0	5	1	1	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	2	3	3	2	1	4	3	1	1	1	1	1	0
Total			511	523	627	705	813	259	546	723	587	436	565	514	329	1066	1123	38	129	182	157	159	201	114	225	644	284	173	211	218	250	277	1184	846

[a] MacKay River (MAR-E, Neill cylinder samples); Steepbank River (STR-E, Neill cylinder samples) and Muskeg River (MUR-E, Neill cylinder samples; MUR-D, Ekman grab samples).
[b] -- = not identified to this level.
[c] (d) = small or damaged.
[d] Early instars but probably all *Ephemerella*.
[e] (p) = pupa.

Table V-1
Benthic Invertebrate Abundance Data (numbers/sample) for the MacKay River, Steepbank River and Muskeg River in Fall 2000

Samples were collected between 1 and 7 October, 2000.[a]

Major Taxon	Family	Genus/Species	MUR-E-3	MUR-E-4	MUR-E-5	MUR-E-6	MUR-E-7	MUR-E-8	MUR-E-9	MUR-E-10	MUR-E-11	MUR-E-12	MUR-E-13	MUR-E-14	MUR-E-15	MUR-D-1	MUR-D-2	MUR-D-3	MUR-D-4	MUR-D-5	MUR-D-6	MUR-D-7	MUR-D-8	MUR-D-9	MUR-D-10	MUR-D-11	MUR-D-12	MUR-D-13	MUR-D-14	MUR-D-15
Hydrozoa	Hydridae	*Hydra*	4	4	0	0	2	8	4	0	0	0	0	0	4	0	10	0	0	0	0	0	0	0	40	0	0	0	0	0
Nematoda	-- [b]	--	16	12	1	4	0	4	0	0	4	6	4	0	0	10	20	0	21	52	121	1	50	0	20	10	1	8	0	0
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	2	1
		Helobdella stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	2	5	0	5	8	1	0	0	2	1
	Erpobdellidae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Oligochaeta	Enchytraeidae	--	8	0	1	0	4	0	0	2	0	0	0	8	2	0	0	0	0	0	0	0	30	0	12	0	0	1	0	0
	Lumbriculidae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	1	17	1	3	22	10	12	42	8	3	19	28	10
	Naididae	--	8	16	13	24	9	4	0	4	0	0	32	5	2	10	0	51	10	0	0	100	121	40	20	0	0	0	0	0
	Tubificidae	--	0	0	0	0	0	0	0	0	1	4	0	0	0	55	47	66	76	22	0	80	1103	250	62	16	5	78	146	42
Hydracarina	--	--	48	64	88	88	55	52	25	15	69	23	53	56	32	0	10	0	0	20	0	10	10	40	0	20	2	0	10	20
Ostracoda	Candonidae	*Candona*	16	4	0	0	2	16	0	2	4	0	0	8	4	40	0	6	50	0	20	40	10	40	0	0	0	0	0	0
Copepoda - Cyclopoida	--	--	0	0	0	0	0	0	0	0	4	4	8	8	2	10	0	10	20	0	0	0	10	40	0	0	0	0	0	0
Copepoda - Harpacticoida	--	--	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera	Chydoridae	--	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Macrothricidae	--	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	30	0	30	30	0	100	0	0	0	0	0	10
Amphipoda	Talitridae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	--	--	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia rivularis*	0	0	0	0	0	0	0	0	0	0	12	0	0	0	3	0	0	1	0	0	0	0	0	1	1	0	0	0
	Hydrobiidae	(d)[c]	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	10	0	0	0	0	1	0	0	0	0	0	0
	Lymnaeidae	*Stagnicola*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Physidae	*Physa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Planorbidae	*Gyraulus*	9	0	0	1	0	0	0	1	0	0	2	1	0	10	0	0	0	10	0	1	1	3	0	1	0	8	0	0
	Valvatidae	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
		Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0
Pelecypoda	Unionidae	*Lampsilis radiata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sphaeriidae	*Pisidium / Sphaerium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	36	59	179	56	5	83	125	98	17	12	70	43	28
		Pisidium	7	0	6	9	3	2	2	6	32	15	4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae	*Ameletus subnotatus*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetidae	*Acentrella*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Baetis	315	391	987	651	272	496	360	277	479	221	252	428	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetiscidae	*Baetisca*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ephemerellidae	(d) [d]	8	12	36	28	18	36	4	39	92	28	89	128	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Drunella grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ephemerella	1	4	14	9	2	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heptageniidae	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heptagenia	11	7	17	7	3	1	1	2	7	6	8	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rhithrogena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stenonema	6	0	1	0	0	0	0	1	0	1	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	0	0	0	0	0	0	0	0	2	1	0	2	1	0	0	0	0	0	0	0	2	0	0	0	0	0
	Caenidae	*Caenis*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	25	1	0	0	1	1	0
	Leptophlebiidae	*Leptophlebia*	9	0	0	0	1	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	4	11	0	0	0	1	0
Plecoptera	--	(d)	36	24	16	0	0	8	4	7	17	4	103	53	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Capniidae	(d)	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chloroperlidae	(d)	3	32	68	33	24	29	33	16	40	18	48	26	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nemouridae	*Zapada*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Claassenia sabulosa	3	3	3	0	2	2	6	3	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlodidae	*Isoperla*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Skwala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcys*	0	1	0	0	1	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Taeniopterygidae	*Taeniopteryx*	3	2	1	0	0	0	0	0	0	0	8	0	1	0	6	0	0	2	0	0	0	1	1	0	0	0	1	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	*Hydroptila*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	10	0	0	0	0	0	0
	Hydropsychidae	(d)	4	0	0	8	0	0	0	0	0	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheumatopsyche	0	0	0	0	0	0	0	1	5	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropsyche	2	1	0	0	0	0	5	5	22	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepidostomatidae	*Lepidostoma*	0	1	4	1	2	2	0	0	1	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0
	Gomphidae	*Ophiogomphus*	5	4	3	0	3	0	0	0	16	0	5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	1	0	0	2	0
Coleoptera	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elmidae	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dubiraphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Optioservus	17	0	13	22	10	12	7	4	20	14	2	29	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haliplidae	*Brychius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Haliplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Hemiptera	Corixidae	*Sigara*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Callicorixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table V-1
Benthic Invertebrate Abundance Data (numbers/sample) for the MacKay River, Steepbank River and Muskeg River in Fall 2000

Major Taxon	Family	Genus/Species	MUR-E-3	MUR-E-4	MUR-E-5	MUR-E-6	MUR-E-7	MUR-E-8	MUR-E-9	MUR-E-10	MUR-E-11	MUR-E-12	MUR-E-13	MUR-E-14	MUR-E-15	MUR-D-1	MUR-D-2	MUR-D-3	MUR-D-4	MUR-D-5	MUR-D-6	MUR-D-7	MUR-D-8	MUR-D-9	MUR-D-10	MUR-D-11	MUR-D-12	MUR-D-13	MUR-D-14	MUR-D-15
Diptera	(Brachycera)	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	*Dicranota*	8	0	1	0	0	0	0	0	0	0	4	8	0	0	0	7	18	0	4	5	2	63	0	12	0	11	5	0
		Hexatoma	0	0	1	0	2	5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Athericidae	*Atherix*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dolichopodidae	*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Tabanidae	*Tabanus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	2	1	0	0	1	0	2
	Empididae	*Chelifera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Hemerodromia	2	9	3	1	2	5	10	0	8	4	13	0	3	0	1	0	0	50	1	0	10	1	10	0	0	8	0	0
		Rhamphomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Ceratopogonidae	--	4	0	0	0	0	13	0	2	8	2	13	0	6	0	45	2	5	2	21	33	6	5	3	5	3	8	6	9
	Chironomidae	(p)[e]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tanypodinae	*Ablabesmyia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	0	0	20	0	102	23	0	0	0	0	0
		Larsia	12	0	0	0	0	0	0	0	0	0	0	1	0	52	79	51	32	31	237	112	171	276	29	33	1	11	57	183
		Nilotanypus	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	59	23	2	20	20	15	44	20	30	2	10	89	73
		Thienemannimyia complex	87	4	9	4	0	0	21	4	5	12	35	7	6	6	1	0	0	1	0	1	1	0	0	0	0	0	1	0
	Chironomini	(d)	4	1	12	0	0	5	0	0	0	0	24	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Cryptochironomus	4	4	0	0	0	0	0	0	4	0	4	4	2	20	20	3	0	0	0	0	0	0	0	0	0	0	0	0
		Demicryptochironomus	0	4	12	12	2	12	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Microtendipes	4	4	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pagastiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	10	0	0	0	20	0	16	0	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Paracladopelma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
		Paralauterborniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	30	0	0	0	0	0	0	0	0
		Paratendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	70	50	10	10	20	30	40	10	20	0	0	0	0	21	20
		Phaenopsectra	4	4	0	4	2	4	0	0	4	0	4	2	0	0	10	0	0	0	0	0	0	0	0	10	0	0	20	0
		Polypedilum	0	12	4	4	8	8	20	0	32	22	8	0	4	21	87	10	20	45	48	20	11	40	22	25	2	2	10	10
		Robackia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stictochironomus	8	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Saetheria	12	16	8	0	0	16	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nilothauma	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tanytarsini	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cladotanytarsus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Micropsectra	36	0	0	8	4	16	0	2	25	10	89	101	92	1723	674	645	540	182	587	914	1642	1324	379	201	9	103	563	240
		Paratanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	20	60	50	20	60	21	12	0	16	1	0
		Rheotanytarsus	8	0	4	0	0	4	4	2	21	0	28	20	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stempellina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0
		Stempellinella	12	0	0	0	0	0	4	0	4	0	4	0	0	80	40	0	0	0	30	30	60	0	0	0	0	0	0	20
		Tanytarsus	24	12	0	16	4	1	16	4	16	5	57	48	32	100	70	0	0	10	110	330	360	360	50	0	1	8	60	40
	Orthocladiinae	(d)	1	0	0	8	0	4	0	0	4	0	0	0	0	10	0	10	10	0	10	10	0	0	0	0	0	0	0	0
		Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	0	10	10	0	0	0	0	0	0	0	0
		Corynoneura	0	0	0	0	0	0	0	2	0	0	4	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cricotopus/Orthocladius	0	0	0	0	4	0	0	0	0	1	4	0	2	0	10	0	0	0	0	10	0	60	0	0	10	24	10	0
		Eukiefferiella	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Euryhapsis	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heterotrissocladius	0	0	0	0	0	0	0	0	0	0	4	0	0	61	30	30	30	10	30	31	20	80	0	0	0	0	10	10
		Lopescladius	108	556	244	124	11	386	468	24	53	107	112	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nanocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0	0	0	0
		Parakiefferiella	0	0	0	0	0	0	0	0	0	0	0	4	0	20	30	20	10	20	10	31	20	20	0	0	10	0	20	0
		Parametriocnemus	4	4	4	12	8	12	13	1	4	5	12	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Psectrocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
		Rheocricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Synorthocladius	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemanniella	9	0	0	0	0	0	4	0	0	0	0	5	0	0	10	0	0	10	0	0	0	0	0	0	0	0	10	0
		Tvetenia	0	0	8	0	2	4	4	4	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Diamesinae	*Potthastia* (*gaedii* type)	0	0	0	8	2	1	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Potthastia (*longimanus* type)	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1
Terrestrial	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total			906	1213	1588	1088	466	1169	1021	432	1017	536	1084	1041	336	2340	1417	1034	1020	693	1561	2020	3783	3158	879	433	62	404	1121	721

[a] MacKay River (MAR-E, Neill cylinder samples); Steepbank River (STR-E, Ne

[b] -- = not identified to this level.

[c] (d) = small or damaged.

[d] Early instars but probably all *Ephemerella.*

[e] (p) = pupa.

Table V-2
Benthic Invertebrate Abundance Data (numbers/sample) for Shipyard Lake (Ekman grab samples)

Major Taxon	Family	Genus/Species	SHL-1	SHL-2	SHL-3	SHL-4	SHL-5	SHL-6	SHL-7	SHL-8	SHL-9	SHL-10
Oligochaeta	Naididae	-- [a]	0	0	0	1	0	8	5	4	12	32
	Tubificidae	--	0	0	0	8	0	0	0	0	0	0
Cladocera	Chydoridae	--	8	0	0	0	0	8	0	0	8	0
Ostracoda	--	--	16	24	8	1	0	8	0	0	4	8
Copepoda - Cyclopoid	--	--	0	0	8	0	0	0	0	0	4	0
Amphipoda	Talitridae	*Hyalella azteca*	9	24	30	3	0	4	1	1	9	9
Pelecypoda	Sphaeriidae	(d)[b]	8	8	24	8	5	0	0	0	8	24
Gastropoda	Valvatidae	*Valvata*	0	0	8	2	5	0	10	0	4	0
	Planorbidae	*Armiger crista*	0	8	8	8	0	0	0	8	20	8
		Gyraulus	0	8	40	8	1	0	0	4	4	0
Ephemeroptera	Caenidae	*Caenis*	16	72	8	0	16	0	5	0	64	36
Odonata - Zygoptera	Coenagrionidae	*Enallagma*	8	32	1	0	0	0	0	0	0	4
Odonata - Anisoptera	Libellulidae	*Libellula*	0	0	0	0	0	0	0	0	0	4
Coleoptera	Haliplidae	*Peltodytes*	0	0	0	0	0	0	0	0	0	1
Hemiptera	Corixidae	*Trichocorixa*	0	0	0	0	0	1	0	0	0	0
Trichoptera	Hydroptilidae	*Oxyethira*	8	0	0	0	0	0	0	0	0	0
	Polycentropodidae	*Polycentropus*	1	3	1	0	0	0	0	0	0	0
	Phryganeidae	*Agrypnia*	0	0	1	0	0	0	1	0	0	0
		Phryganea	0	0	1	0	0	0	0	0	0	0
	Leptoceridae	*Triaenodes*	0	6	0	0	0	0	0	1	0	0
Diptera	Chaoboridae	*Chaoborus*	0	17	5	1	8	0	1	0	0	0
	Chironomidae	--	0	0	0	0	0	0	0	0	0	0
	Tanypodinae	*Ablabesmyia*	0	2	9	1	0	0	0	0	1	0
		Procladius	1	1	9	1	0	0	0	0	2	2
		Thienemannimyia compl	0	1	0	0	1	0	0	0	1	0
	Chironomini	*Chironomus*	0	1	8	2	0	0	0	0	3	1
		Dicrotendipes	0	11	0	0	0	0	0	0	6	5
		Endochironomus	0	2	10	0	1	8	1	0	0	0
		Glyptotendipes	0	3	0	15	21	8	0	0	2	0
		Microtendipes	0	0	0	0	0	0	0	0	0	1
		Parachironomus	0	1	0	0	0	0	0	0	0	0
	Tanytarsini	*Paratanytarsus*	8	19	0	0	8	8	2	4	0	0
		Tanytarsus	0	0	0	0	0	0	0	0	3	5
	Orthocladiinae	*Psectrocladius*	0	1	10	0	0	8	0	4	3	0
		Zalutschia	0	0	0	0	0	0	0	0	4	0
Total			83	244	189	59	66	61	26	26	162	140

[a] -- = not identified to this level.

[b] (d) = small or damaged.

Table V-3
Supporting Data Collected During the Fall 2000 Benthic Surveys of the MacKay, Steepbank and Muskeg Rivers

River	Site	General Habitat Type	Sample Date	Sample Time	Location: UTM E	Location: UTM N	Field Water Quality: Dissolved Oxygen (mg/L)	Field Water Quality: Conductivity (µS/cm)	Field Water Quality: pH	Field Water Quality: Water Temp (°C)
Mackay	MAR-E-1	Erosional	07-Oct-00	16:20	460825	6336438	-[(a)]	202	-	0.3
Mackay	MAR-E-2	Erosional	07-Oct-00	16:20	460825	6336438	-	202	-	0.3
Mackay	MAR-E-3	Erosional	07-Oct-00	15:40	460391	6336739	-	203	-	0.4
Mackay	MAR-E-4	Erosional	07-Oct-00	15:40	460391	6336739	-	203	-	0.4
Mackay	MAR-E-5	Erosional	07-Oct-00	13:40	460442	6337051	-	-	-	-
Mackay	MAR-E-6	Erosional	07-Oct-00	13:40	460442	6337051	-	-	-	-
Mackay	MAR-E-7	Erosional	07-Oct-00	13:40	460442	6337051	-	-	-	-
Mackay	MAR-E-8	Erosional	07-Oct-00	13:40	460442	6337051	-	-	-	-
Mackay	MAR-E-9	Erosional	07-Oct-00	13:25	460423	6337763	-	210	-	1.0
Mackay	MAR-E-10	Erosional	07-Oct-00	13:25	460423	6337763	-	210	-	1.0
Mackay	MAR-E-11	Erosional	07-Oct-00	12:30	459533	6338639	-	204	-	0.5
Mackay	MAR-E-12	Erosional	07-Oct-00	12:30	459533	6338639	-	204	-	0.5
Mackay	MAR-E-13	Erosional	07-Oct-00	11:50	459652	6338795	-	207	-	-0.1
Mackay	MAR-E-14	Erosional	07-Oct-00	11:50	459652	6338795	-	207	-	-0.1
Mackay	MAR-E-15	Erosional	07-Oct-00	11:50	459652	6338795	-	207	-	-0.1
Steepbank	STR-E-1	Erosional	01-Oct-00	10:50	471071	6319616	12.6	151	7.7	4.1
Steepbank	STR-E-2	Erosional	01-Oct-00	11:00	471834	6320100	-	-	-	-
Steepbank	STR-E-3	Erosional	01-Oct-00	12:15	471896	6320035	13.0	149	8.1	4.4
Steepbank	STR-E-4	Erosional	01-Oct-00	12:25	471747	6320472	12.8	151	8.1	4.4
Steepbank	STR-E-5	Erosional	01-Oct-00	12:45	471455	6319960	12.7	150	8.1	4.5
Steepbank	STR-E-6	Erosional	01-Oct-00	14:10	473022	6319731	12.6	149	8.1	4.9
Steepbank	STR-E-7	Erosional	01-Oct-00	14:25	473091	6319755	12.1	149	8.1	4.9
Steepbank	STR-E-8	Erosional	01-Oct-00	14:40	473066	6319652	13.1	149	8.1	4.8
Steepbank	STR-E-9	Erosional	01-Oct-00	14:40	473106	6319671	12.1	149	8.1	4.8
Steepbank	STR-E-10	Erosional	01-Oct-00	15:15	473132	6319704	12.5	149	8.1	4.8
Steepbank	STR-E-11	Erosional	01-Oct-00	16:05	473308	6319163	12.4	144	8.1	4.8
Steepbank	STR-E-12	Erosional	01-Oct-00	16:25	473342	6319169	12.2	144	8.1	4.8
Steepbank	STR-E-13	Erosional	01-Oct-00	16:45	473404	6319167	12.7	144	8.1	4.7
Steepbank	STR-E-14	Erosional	01-Oct-00	16:55	473442	6319156	12.2	144	8.1	4.8
Steepbank	STR-E-15	Erosional	01-Oct-00	17:15	473491	6319186	12.2	143	8.1	4.7
Muskeg	MUR-E-1	Erosional	06-Oct-00	18:35	463675	6332260	-	210	-	1.2
Muskeg	MUR-E-2	Erosional	06-Oct-00	18:35	463675	6332260	-	210	-	1.2
Muskeg	MUR-E-3	Erosional	06-Oct-00	18:35	463675	6332260	-	210	-	1.2
Muskeg	MUR-E-4	Erosional	06-Oct-00	17:25	464203	6331838	-	211	-	1.2
Muskeg	MUR-E-5	Erosional	06-Oct-00	17:25	464203	6331838	-	211	-	1.2
Muskeg	MUR-E-6	Erosional	06-Oct-00	17:25	464203	6331838	-	211	-	1.2
Muskeg	MUR-E-7	Erosional	06-Oct-00	16:25	465325	6332659	-	211	-	1.3
Muskeg	MUR-E-8	Erosional	06-Oct-00	16:25	465325	6332659	-	211	-	1.3
Muskeg	MUR-E-9	Erosional	06-Oct-00	16:25	465325	6332659	-	211	-	1.3
Muskeg	MUR-E-10	Erosional	06-Oct-00	16:05	465849	6333433	-	210	-	1.1
Muskeg	MUR-E-11	Erosional	06-Oct-00	16:05	465849	6333433	-	210	-	1.1
Muskeg	MUR-E-12	Erosional	06-Oct-00	16:05	465849	6333433	-	210	-	1.1
Muskeg	MUR-E-13	Erosional	06-Oct-00	15:15	465230	6334393	-	208	-	0.9
Muskeg	MUR-E-14	Erosional	06-Oct-00	15:15	465230	6334393	-	208	-	0.9
Muskeg	MUR-E-15	Erosional	06-Oct-00	15:15	465230	6334393	-	208	-	0.9
Muskeg	MUR-D-1	Depositional	06-Oct-00	11:45	465427	6338742	-	208	-	0.4
Muskeg	MUR-D-2	Depositional	06-Oct-00	11:30	465983	6339249	-	207	-	0.3
Muskeg	MUR-D-3	Depositional	06-Oct-00	11:05	466394	6339624	-	208	-	0.3
Muskeg	MUR-D-4	Depositional	06-Oct-00	11:05	466588	6339572	-	208	-	0.2
Muskeg	MUR-D-5	Depositional	06-Oct-00	10:55	466575	6339613	-	207	-	0.2
Muskeg	MUR-D-6	Depositional	06-Oct-00	10:45	466603	6339794	-	207	-	0.3
Muskeg	MUR-D-7	Depositional	06-Oct-00	10:35	466470	6339790	-	207	-	0.2
Muskeg	MUR-D-8	Depositional	06-Oct-00	10:25	466551	6339893	-	207	-	0.3
Muskeg	MUR-D-9	Depositional	06-Oct-00	10:05	466698	6339918	-	200	-	0.2
Muskeg	MUR-D-10	Depositional	06-Oct-00	10:05	466675	6340049	-	207	-	0.2
Muskeg	MUR-D-11	Depositional	06-Oct-00	9:55	466639	6340204	-	207	-	0.2
Muskeg	MUR-D-12	Depositional	06-Oct-00	9:40	466688	6340295	-	207	-	0.2
Muskeg	MUR-D-13	Depositional	06-Oct-00	9:20	466779	6340490	-	208	-	0.2
Muskeg	MUR-D-14	Depositional	06-Oct-00	8:45	466949	6340650	-	209	-	0.3
Muskeg	MUR-D-15	Depositional	06-Oct-00	8:40	466809	6340680	-	206	-	0.3

[(a)] - = No data.

Table V-3
Supporting Data Collected During the Fall 2000 Benthic Surveys of the MacKay, Steepbank and Muskeg Rivers

River	Site	General Habitat Type	Sample Date	Water Depth (cm)	Current Velocity (m/s)	Bankfull Channel Width (m)	Wetted Channel Width (m)	Specific Habitat Type	Amount of Macrophytes (visual est. as % cover)	Amount of Benthic Algae (visual est.)
Mackay	MAR-E-1	Erosional	07-Oct-00	30	0.61	52	42	riffle	0	M
Mackay	MAR-E-2	Erosional	07-Oct-00	29	0.67	52	42	riffle	0	M
Mackay	MAR-E-3	Erosional	07-Oct-00	37	0.76	42	34	riffle	0	L-M
Mackay	MAR-E-4	Erosional	07-Oct-00	32	0.71	42	34	riffle	0	L-M
Mackay	MAR-E-5	Erosional	07-Oct-00	25	0.64	-	-	riffle	0	-
Mackay	MAR-E-6	Erosional	07-Oct-00	28	0.99	-	-	riffle	0	-
Mackay	MAR-E-7	Erosional	07-Oct-00	34	0.77	-	-	riffle	0	-
Mackay	MAR-E-8	Erosional	07-Oct-00	30	0.63	-	-	riffle	0	-
Mackay	MAR-E-9	Erosional	07-Oct-00	27	0.51	44	37	riffle	0	-
Mackay	MAR-E-10	Erosional	07-Oct-00	36	0.63	44	37	riffle	0	-
Mackay	MAR-E-11	Erosional	07-Oct-00	34	0.81	38	30	riffle	0	L-M
Mackay	MAR-E-12	Erosional	07-Oct-00	25	0.89	38	30	riffle	0	L-M
Mackay	MAR-E-13	Erosional	07-Oct-00	29	0.83	41	36	riffle	0	L-M
Mackay	MAR-E-14	Erosional	07-Oct-00	34	0.83	41	36	riffle	0	L-M
Mackay	MAR-E-15	Erosional	07-Oct-00	27	0.81	41	36	riffle	0	L-M
Steepbank	STR-E-1	Erosional	01-Oct-00	32	0.98	26	17	riffle	0	N
Steepbank	STR-E-2	Erosional	01-Oct-00	30	0.60	26	22	riffle	0	N
Steepbank	STR-E-3	Erosional	01-Oct-00	37	0.70	23	19	riffle	0	N
Steepbank	STR-E-4	Erosional	01-Oct-00	34	0.82	-	-	riffle	0	N
Steepbank	STR-E-5	Erosional	01-Oct-00	23	0.71	39	21	riffle	0	L
Steepbank	STR-E-6	Erosional	01-Oct-00	46	0.66	35	23	riffle	0	L
Steepbank	STR-E-7	Erosional	01-Oct-00	34	0.60	35	25	riffle	0	L
Steepbank	STR-E-8	Erosional	01-Oct-00	36	0.80	38	25	riffle	0	L
Steepbank	STR-E-9	Erosional	01-Oct-00	29	0.65	33	24	riffle	0	M
Steepbank	STR-E-10	Erosional	01-Oct-00	38	0.65	35	25	riffle	0	M
Steepbank	STR-E-11	Erosional	01-Oct-00	40	0.67	40	31	riffle	0	M
Steepbank	STR-E-12	Erosional	01-Oct-00	42	0.66	33	25	riffle	0	M-H
Steepbank	STR-E-13	Erosional	01-Oct-00	29	0.79	34	26	riffle	0	L
Steepbank	STR-E-14	Erosional	01-Oct-00	38	0.98	30	21	riffle	0	L
Steepbank	STR-E-15	Erosional	01-Oct-00	30	0.71	29	22	riffle	0	L
Muskeg	MUR-E-1	Erosional	06-Oct-00	37	0.65	26	25	riffle	0	H
Muskeg	MUR-E-2	Erosional	06-Oct-00	35	0.79	26	25	riffle	0	H
Muskeg	MUR-E-3	Erosional	06-Oct-00	32	0.59	26	25	riffle	0	H
Muskeg	MUR-E-4	Erosional	06-Oct-00	26	0.74	24	24	riffle	0	H
Muskeg	MUR-E-5	Erosional	06-Oct-00	30	0.81	24	24	riffle	0	H
Muskeg	MUR-E-6	Erosional	06-Oct-00	29	0.84	24	24	riffle	0	H
Muskeg	MUR-E-7	Erosional	06-Oct-00	28	0.84	22	18	riffle	0	H
Muskeg	MUR-E-8	Erosional	06-Oct-00	30	0.81	22	18	riffle	0	H
Muskeg	MUR-E-9	Erosional	06-Oct-00	32	0.76	22	18	riffle	0	H
Muskeg	MUR-E-10	Erosional	06-Oct-00	35	0.90	24	17	riffle	0	H
Muskeg	MUR-E-11	Erosional	06-Oct-00	32	0.85	24	17	riffle	0	H
Muskeg	MUR-E-12	Erosional	06-Oct-00	26	0.97	24	17	riffle	0	H
Muskeg	MUR-E-13	Erosional	06-Oct-00	38	0.51	27	21	riffle	0	H
Muskeg	MUR-E-14	Erosional	06-Oct-00	26	0.68	27	21	riffle	0	H
Muskeg	MUR-E-15	Erosional	06-Oct-00	34	0.67	27	21	riffle	0	H
Muskeg	MUR-D-1	Depositional	06-Oct-00	110	0.40	19	19	run	75	-
Muskeg	MUR-D-2	Depositional	06-Oct-00	100	0.35	24	24	run	90	-
Muskeg	MUR-D-3	Depositional	06-Oct-00	115	0.15	28	28	backwater	90	-
Muskeg	MUR-D-4	Depositional	06-Oct-00	115	0.10	29	23	run	70	-
Muskeg	MUR-D-5	Depositional	06-Oct-00	200	0.45	17	14	run	70	-
Muskeg	MUR-D-6	Depositional	06-Oct-00	195	0.10	31	27	backwater/pool	50	-
Muskeg	MUR-D-7	Depositional	06-Oct-00	25	0.20	25	18	run	60	-
Muskeg	MUR-D-8	Depositional	06-Oct-00	110	0.10	31	24	backwater	70	-
Muskeg	MUR-D-9	Depositional	06-Oct-00	150	0.15	21	15	run	40	-
Muskeg	MUR-D-10	Depositional	06-Oct-00	130	0.25	19	16	run	20	-
Muskeg	MUR-D-11	Depositional	06-Oct-00	160	0.15	24	21	run	0	-
Muskeg	MUR-D-12	Depositional	06-Oct-00	150	0.30	20	16	run	0	-
Muskeg	MUR-D-13	Depositional	06-Oct-00	130	0.10	22	17	run	0	-
Muskeg	MUR-D-14	Depositional	06-Oct-00	100	0.15	21	17	backwater	10	-
Muskeg	MUR-D-15	Depositional	06-Oct-00	110	0.10	17	15	run	0	-

[(a)] - = No data.

Table V-3
Supporting Data Collected During the Fall 2000 Benthic Surveys of the MacKay, Steepbank and Muskeg Rivers

River	Site	General Habitat Type	Sample Date	Benthic Algal Chlorophyll *a* (µg/sample [12 cm^2])	Bottom Sediments (lab analysis) Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)
Mackay	MAR-E-1	Erosional	07-Oct-00	40	-	-	-	-
Mackay	MAR-E-2	Erosional	07-Oct-00	40	-	-	-	-
Mackay	MAR-E-3	Erosional	07-Oct-00	8	-	-	-	-
Mackay	MAR-E-4	Erosional	07-Oct-00	15	-	-	-	-
Mackay	MAR-E-5	Erosional	07-Oct-00	60	-	-	-	-
Mackay	MAR-E-6	Erosional	07-Oct-00	43	-	-	-	-
Mackay	MAR-E-7	Erosional	07-Oct-00	51	-	-	-	-
Mackay	MAR-E-8	Erosional	07-Oct-00	5	-	-	-	-
Mackay	MAR-E-9	Erosional	07-Oct-00	25	-	-	-	-
Mackay	MAR-E-10	Erosional	07-Oct-00	71	-	-	-	-
Mackay	MAR-E-11	Erosional	07-Oct-00	4	-	-	-	-
Mackay	MAR-E-12	Erosional	07-Oct-00	6	-	-	-	-
Mackay	MAR-E-13	Erosional	07-Oct-00	6	-	-	-	-
Mackay	MAR-E-14	Erosional	07-Oct-00	9	-	-	-	-
Mackay	MAR-E-15	Erosional	07-Oct-00	24	-	-	-	-
Steepbank	STR-E-1	Erosional	01-Oct-00	3	-	-	-	-
Steepbank	STR-E-2	Erosional	01-Oct-00	8	-	-	-	-
Steepbank	STR-E-3	Erosional	01-Oct-00	6	-	-	-	-
Steepbank	STR-E-4	Erosional	01-Oct-00	<1	-	-	-	-
Steepbank	STR-E-5	Erosional	01-Oct-00	10	-	-	-	-
Steepbank	STR-E-6	Erosional	01-Oct-00	39	-	-	-	-
Steepbank	STR-E-7	Erosional	01-Oct-00	19	-	-	-	-
Steepbank	STR-E-8	Erosional	01-Oct-00	2	-	-	-	-
Steepbank	STR-E-9	Erosional	01-Oct-00	190	-	-	-	-
Steepbank	STR-E-10	Erosional	01-Oct-00	220	-	-	-	-
Steepbank	STR-E-11	Erosional	01-Oct-00	62	-	-	-	-
Steepbank	STR-E-12	Erosional	01-Oct-00	89	-	-	-	-
Steepbank	STR-E-13	Erosional	01-Oct-00	13	-	-	-	-
Steepbank	STR-E-14	Erosional	01-Oct-00	59	-	-	-	-
Steepbank	STR-E-15	Erosional	01-Oct-00	17	-	-	-	-
Muskeg	MUR-E-1	Erosional	06-Oct-00	67	-	-	-	-
Muskeg	MUR-E-2	Erosional	06-Oct-00	63	-	-	-	-
Muskeg	MUR-E-3	Erosional	06-Oct-00	58	-	-	-	-
Muskeg	MUR-E-4	Erosional	06-Oct-00	27	-	-	-	-
Muskeg	MUR-E-5	Erosional	06-Oct-00	23	-	-	-	-
Muskeg	MUR-E-6	Erosional	06-Oct-00	31	-	-	-	-
Muskeg	MUR-E-7	Erosional	06-Oct-00	42	-	-	-	-
Muskeg	MUR-E-8	Erosional	06-Oct-00	52	-	-	-	-
Muskeg	MUR-E-9	Erosional	06-Oct-00	39	-	-	-	-
Muskeg	MUR-E-10	Erosional	06-Oct-00	74	-	-	-	-
Muskeg	MUR-E-11	Erosional	06-Oct-00	49	-	-	-	-
Muskeg	MUR-E-12	Erosional	06-Oct-00	57	-	-	-	-
Muskeg	MUR-E-13	Erosional	06-Oct-00	96	-	-	-	-
Muskeg	MUR-E-14	Erosional	06-Oct-00	55	-	-	-	-
Muskeg	MUR-E-15	Erosional	06-Oct-00	51	-	-	-	-
Muskeg	MUR-D-1	Depositional	06-Oct-00	-	95	2	3	0.3
Muskeg	MUR-D-2	Depositional	06-Oct-00	-	92	4	4	0.7
Muskeg	MUR-D-3	Depositional	06-Oct-00	-	76	12	12	4.4
Muskeg	MUR-D-4	Depositional	06-Oct-00	-	71	9	20	2.9
Muskeg	MUR-D-5	Depositional	06-Oct-00	-	72	9	19	2.9
Muskeg	MUR-D-6	Depositional	06-Oct-00	-	77	6	17	1.9
Muskeg	MUR-D-7	Depositional	06-Oct-00	-	82	9	9	3.8
Muskeg	MUR-D-8	Depositional	06-Oct-00	-	72	14	14	6.1
Muskeg	MUR-D-9	Depositional	06-Oct-00	-	85	7	8	2.5
Muskeg	MUR-D-10	Depositional	06-Oct-00	-	78	11	11	4.0
Muskeg	MUR-D-11	Depositional	06-Oct-00	-	77	6	17	1.5
Muskeg	MUR-D-12	Depositional	06-Oct-00	-	95	2	3	0.3
Muskeg	MUR-D-13	Depositional	06-Oct-00	-	83	8	9	3.2
Muskeg	MUR-D-14	Depositional	06-Oct-00	-	80	10	10	2.9
Muskeg	MUR-D-15	Depositional	06-Oct-00	-	75	12	13	4.2

[(a)] - = No data.

Table V-3
Supporting Data Collected During the Fall 2000 Benthic Surveys of the MacKay, Steepbank and Muskeg Rivers

				Substratum as Areal Cover (visual est.) and Weighted Average Inde								
River	Site	General Habitat Type	Sample Date	Sand / Silt/ Clay (%)	Small Grav el (%)	Large Grav el (%)	Small Cobbl e (%)	Large Cobbl e (%)	Bould er (%)	Bedro ck (%)	Weight ed Average Index	Embedd ed-ness (%)
Mackay	MAR-E-1	Erosional	07-Oct-00	10	40	35	15	0	0	0	4.00	10
Mackay	MAR-E-2	Erosional	07-Oct-00	10	40	35	15	0	0	0	4.00	10
Mackay	MAR-E-3	Erosional	07-Oct-00	5	45	45	5	0	0	0	3.98	20
Mackay	MAR-E-4	Erosional	07-Oct-00	5	45	45	5	0	0	0	3.98	20
Mackay	MAR-E-5	Erosional	07-Oct-00	10	40	30	20	0	0	0	4.05	15
Mackay	MAR-E-6	Erosional	07-Oct-00	5	30	30	30	5	0	0	4.63	10
Mackay	MAR-E-7	Erosional	07-Oct-00	5	30	30	30	5	0	0	4.63	10
Mackay	MAR-E-8	Erosional	07-Oct-00	5	30	30	30	5	0	0	4.63	10
Mackay	MAR-E-9	Erosional	07-Oct-00	10	50	30	10	0	0	0	3.75	20
Mackay	MAR-E-10	Erosional	07-Oct-00	10	50	30	10	0	0	0	3.75	30
Mackay	MAR-E-11	Erosional	07-Oct-00	0	25	40	30	5	0	0	4.90	5
Mackay	MAR-E-12	Erosional	07-Oct-00	0	35	40	20	5	0	0	4.60	5
Mackay	MAR-E-13	Erosional	07-Oct-00	10	40	30	20	0	0	0	4.05	10
Mackay	MAR-E-14	Erosional	07-Oct-00	10	40	30	20	0	0	0	4.05	10
Mackay	MAR-E-15	Erosional	07-Oct-00	20	40	20	20	0	0	0	3.70	15
Steepbank	STR-E-1	Erosional	01-Oct-00	0	0	10	30	60	0	0	6.50	5
Steepbank	STR-E-2	Erosional	01-Oct-00	20	40	30	10	0	0	0	3.60	25
Steepbank	STR-E-3	Erosional	01-Oct-00	10	20	50	20	0	0	0	4.45	15
Steepbank	STR-E-4	Erosional	01-Oct-00	10	20	30	30	10	0	0	4.75	10
Steepbank	STR-E-5	Erosional	01-Oct-00	0	20	40	30	10	0	0	5.10	5
Steepbank	STR-E-6	Erosional	01-Oct-00	5	20	50	20	5	0	0	4.73	10
Steepbank	STR-E-7	Erosional	01-Oct-00	0	5	25	40	30	0	0	5.90	5
Steepbank	STR-E-8	Erosional	01-Oct-00	10	20	20	40	10	0	0	4.85	10
Steepbank	STR-E-9	Erosional	01-Oct-00	0	0	5	25	70	0	0	6.65	5
Steepbank	STR-E-10	Erosional	01-Oct-00	0	0	5	25	70	0	0	6.65	5
Steepbank	STR-E-11	Erosional	01-Oct-00	10	15	0	20	50	5	0	5.73	25
Steepbank	STR-E-12	Erosional	01-Oct-00	0	0	20	20	40	20	0	6.70	10
Steepbank	STR-E-13	Erosional	01-Oct-00	0	0	10	20	40	30	0	7.05	10
Steepbank	STR-E-14	Erosional	01-Oct-00	20	35	25	20	0	0	0	3.80	5
Steepbank	STR-E-15	Erosional	01-Oct-00	0	5	30	30	0	0	35	6.95	0
Muskeg	MUR-E-1	Erosional	06-Oct-00	10	25	40	25	0	0	0	4.40	25
Muskeg	MUR-E-2	Erosional	06-Oct-00	10	25	40	25	0	0	0	4.40	20
Muskeg	MUR-E-3	Erosional	06-Oct-00	10	20	40	30	0	0	0	4.55	15
Muskeg	MUR-E-4	Erosional	06-Oct-00	0	25	45	30	0	0	0	4.80	20
Muskeg	MUR-E-5	Erosional	06-Oct-00	0	25	45	30	0	0	0	4.80	10
Muskeg	MUR-E-6	Erosional	06-Oct-00	0	25	45	30	0	0	0	4.80	10
Muskeg	MUR-E-7	Erosional	06-Oct-00	5	5	25	65	0	0	0	5.38	20
Muskeg	MUR-E-8	Erosional	06-Oct-00	5	5	25	65	0	0	0	5.38	20
Muskeg	MUR-E-9	Erosional	06-Oct-00	5	5	25	65	0	0	0	5.38	20
Muskeg	MUR-E-10	Erosional	06-Oct-00	0	0	60	40	0	0	0	5.40	5
Muskeg	MUR-E-11	Erosional	06-Oct-00	0	0	60	40	0	0	0	5.40	5
Muskeg	MUR-E-12	Erosional	06-Oct-00	0	0	60	40	0	0	0	5.40	5
Muskeg	MUR-E-13	Erosional	06-Oct-00	0	5	30	65	0	0	0	5.55	20
Muskeg	MUR-E-14	Erosional	06-Oct-00	0	5	20	70	5	0	0	5.70	10
Muskeg	MUR-E-15	Erosional	06-Oct-00	0	5	15	80	0	0	0	5.70	5
Muskeg	MUR-D-1	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-2	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-3	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-4	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-5	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-6	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-7	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-8	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-9	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-10	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-11	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-12	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-13	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-14	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-
Muskeg	MUR-D-15	Depositional	06-Oct-00	-	-	-	-	-	-	-	-	-

[a] - = No data.

Table V-4
Supporting Data Collected During the Fall 2000 Benthic Survey of Shipyard Lake

			Location				Field Water Quality				Bottom Sediments			
Site	Sample Date	Sample Time	UTM E	UTM N	Water Depth (m)	Secchi Depth (m)	Dissolved Oxygen (mg/L)	Conduc-tivity (μS/cm)	pH	Water Temp (°C)	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)
SHL-1	28-Sep-00	13:30	473567	6313129	1.5	(bottom)	7.9	350	7.5	7.2	1	43	56	9.5
SHL-2	28-Sep-00	13:30	473594	6313129	1.5	(bottom)	8.3	365	7.6	7.4	1	40	59	11.0
SHL-3	28-Sep-00	13:30	473504	6312973	1.9	(bottom)	7.7	378	7.5	7.3	6	41	53	7.0
SHL-4	28-Sep-00	13:30	473628	6312818	1.9	(bottom)	7.4	363	7.5	7.2	1	46	53	7.2
SHL-5	28-Sep-00	13:30	473337	6312821	1.4	(bottom)	10.2	327	7.0	7.3	1	41	58	12.0
SHL-6	28-Sep-00	13:30	473316	6312877	1.6	(bottom)	10.3	325	7.8	7.3	1	48	51	8.5
SHL-7	28-Sep-00	13:30	473345	6312975	1.8	(bottom)	10.1	321	7.9	7.3	1	47	52	8.0
SHL-8	28-Sep-00	13:30	473399	6312965	1.8	(bottom)	10.1	335	7.9	7.3	1	45	54	8.2
SHL-9	28-Sep-00	13:30	473449	6312984	1.8	(bottom)	9.4	353	7.7	7.3	1	40	59	9.3
SHL-10	28-Sep-00	13:30	473490	6313106	1.2	(bottom)	8.9	344	7.6	7.3	1	42	57	9.1

APPENDIX VI

RADIOTELEMETRY DATA

Table VI-1
Specific Information for Radio Tagged Fish, 2000 RAMP Radiotelemetry Study

Watercourse	Species	Fork Ln. (mm)	Weight (g)	Life Stage	Sex	Maturity	Floy Tag No.	Radio Transmitter *Frequency*	Radio Transmitter *Code*	Release Information *Date*	Release Information *Location*
Athabasca River	longnose sucker	494	1690	A	F	SP	0058	149.620	09	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	440	1040	A	M	SP	0012	149.620	10	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	505	1460	A	F	SP	0002	149.620	13	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	473	1300	A	F	SP	0008	149.620	16	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	470	1210	A	M	SP	0051	149.620	20	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	512	1620	A	F	SP	0033	149.660	08	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	523	1750	A	F	SP	0063	149.660	11	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	448	1070	A	M	SP	0056	149.660	13	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	518	1660	A	F	SP	0010	149.660	18	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	474	1390	A	F	SP	0006	149.660	19	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	497	1360	A	F	SP	0059	149.680	04	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	463	1140	A	F	SP	0016	149.680	05	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	480	1370	A	M	SP	0043	149.680	08	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	473	1300	A	M	SP	0035	149.680	14	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	475	1270	A	F	SP	0003	149.680	16	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	536	1820	A	F	SP	0017	149.700	11	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	468	1240	A	M	SP	0007	149.700	12	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	464	1210	A	M	SP	0066	149.700	15	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	451	1070	A	M	SP	0042	149.700	16	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	419	1020	A	M	SP	0075	149.700	18	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	523	1800	A	F	SP	0005	149.720	03	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	520	1680	A	F	SP	0062	149.720	04	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	451	1110	A	M	SP	0038	149.720	06	16-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	421	960	A	M	SP	0025	149.720	16	15-May	3 Km d/s of Mountain Rapids
Athabasca River	longnose sucker	455	1050	A	M	SP	0055	149.720	19	16-May	3 Km d/s of Mountain Rapids
Muskeg River	longnose sucker	431	904	A	F	SP	0377	149.620	01	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	384	645	A	M	PR	0362	149.620	02	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	463	1425	A	F	PR	0356	149.620	06	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	372	675	A	M	RP	0353	149.620	12	26-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	406	832	A	M	SP	0373	149.620	17	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	390	820	A	F	PR	0365	149.620	18	28-May	Muskeg River Mouth
Muskeg River	longnose sucker	370	590	A	M	SP	0374	149.660	01	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	389	720	A	F	RP	0352	149.660	05	26-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	415	965	A	F	PR	0359	149.660	12	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	412	792	A	F	SP	0375	149.660	17	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	414	821	A	M	RP	0369	149.660	20	29-May	Reach 4 - Jackpine Creek Confluence
Muskeg River	longnose sucker	415	970	A	F	PR	0351	149.680	02	26-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	414	780	A	F	SP	0394	149.680	03	31-May	Lower Reach 2
Muskeg River	longnose sucker	351	569	A	M	SP	0397	149.680	12	31-May	Muskeg River Mouth
Muskeg River	longnose sucker	395	779	A	M	RP	0376	149.680	13	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	381	710	A	M	SP	0366	149.680	20	28-May	Muskeg River Mouth
Muskeg River	longnose sucker	455	1320	A	F	RP	0370	149.700	01	29-May	Reach 4 - Jackpine Creek Confluence

Table VI-1
Specific Information for Radio Tagged Fish, 2000 RAMP Radiotelemetry Study

Watercourse	Species	Fork Ln. (mm)	Weight (g)	Life Stage	Sex	Maturity	Floy Tag No.	Radio Transmitter *Frequency*	Radio Transmitter *Code*	Release Information *Date*	Release Information *Location*
Muskeg River	longnose sucker	471	1495	A	F	PR	0379	149.700	03	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	462	1245	A	F	PR	0355	149.700	04	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	450	1105	A	F	PR	0371	149.700	06	29-May	Reach 4 - Jackpine Creek Confluence
Muskeg River	longnose sucker	434	961	A	F	SP	0358	149.700	08	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	428	1105	A	F	PR	0380	149.720	07	30-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	396	779	A	M	RP	0354	149.720	10	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	385	752	A	F	PR	0360	149.720	18	27-May	Reach 3/4 Boundary
Muskeg River	longnose sucker	398	750	A	M	SP	0372	179.720	05	29-May	Reach 4 - Jackpine Creek Confluence
Muskeg River	northern pike	733	2450	A	F	PR	0396	149.620	03	31-May	Muskeg River Mouth
Muskeg River	northern pike	580	1295	A	F	SP	0401	149.620	05	01-Jun	Mid Reach 2
Muskeg River	northern pike	613	1039	A	F	SP	0395	149.620	07	31-May	Muskeg River Mouth
Muskeg River	northern pike	493	748	A	M	SP	0393	149.620	08	31-May	Lower Reach 2
Muskeg River	northern pike	548	1020	A	F	PR	0390	149.620	11	31-May	Lower Reach 2
Muskeg River	northern pike	438	540	J	F	IM	0384	149.680	01	31-May	Mid Reach 2
Muskeg River	northern pike	482	670	J	F	IM	0382	149.680	10	31-May	Mid Reach 2
Muskeg River	northern pike	531	830	A	M	SP	0392	149.680	15	31-May	Lower Reach 2
Muskeg River	northern pike	543	1245	A	M	SP	0363	149.680	17	28-May	Muskeg River Mouth
Muskeg River	northern pike	533	958	A	F	PR	0357	149.680	18	27-May	Reach 3/4 Boundary
Muskeg River	northern pike	485	725	J	M	IM	0403	149.700	02	01-Jun	Mid Reach 2
Muskeg River	northern pike	550	1010	A	M	SP	0412	149.700	05	01-Jun	Mid Reach 2
Muskeg River	northern pike	580	1110	A	M	PR	0367	149.700	07	28-May	Muskeg River Mouth
Muskeg River	northern pike	483	705	A	M	MA	0404	149.700	09	01-Jun	Mid Reach 2
Muskeg River	northern pike	566	1040	A	M	SP	0381	149.700	10	31-May	Mid Reach 2
Muskeg River	northern pike	558	1145	A	F	PR	0402	149.700	13	01-Jun	Mid Reach 2
Muskeg River	northern pike	590	1260	A	M	SP	0400	149.700	14	01-Jun	Mid Reach 2
Muskeg River	northern pike	527	880	A	M	SP	0385	149.700	19	31-May	Mid Reach 2
Muskeg River	northern pike	562	1105	A	F	PR	0383	149.720	02	31-May	Mid Reach 2
Muskeg River	northern pike	570	1000	A	M	SP	0413	149.720	08	01-Jun	Mid Reach 2
Muskeg River	northern pike	576	1130	A	F	PR	0364	149.720	12	28-May	Muskeg River Mouth
Muskeg River	northern pike	551	980	A	F	PR	0407	149.720	14	01-Jun	Mid Reach 2
Muskeg River	northern pike	570	1083	A	F	SP	0361	149.720	15	28-May	Muskeg River Mouth
Muskeg River	northern pike	566	885	A	M	SP	0391	149.720	20	31-May	Lower Reach 2
Muskeg River	northern pike	595	1245	A	M	SP	0398	149.720	21	01-Jun	Mid Reach 2

Life Stage: J = juvenile
A = adult
U = unknown

Sex: M = male
F = female
U = unknown

Maturity: PR = pre-spawning
RP = ripe (spawning)
SP = spent (post-spawning)
IM = immature
MA = maturing

TableVI-2
Radio Tracking Results, 2000 RAMP Telemetry Study (continued)

Radio Transmitter			Release		Telemetry Survey (Flight Number and Date)																				
					1	2	3	4	5	6	7	7a*	8	9	10	11	12	13	14	15	16	17	18	19	20
Frequency	*Code*	Species	*Date*	*Site*	04-Jun	09-Jun	19-Jun	27-Jun	24-Jul	09-Aug	18-Aug	23-Aug	08-Sep	22-Sep	10-Oct	19-Oct	27-Oct	03-Nov	09-Nov	17-Nov	23-Nov	01-Dec	11-Dec	12-Jan	24-Jan
149.620	09	longnose sucker	16-May	KP -8.0	KP111																				
149.620	10	longnose sucker	15-May	KP -8.0						KP213			KP215							KP213		KP213		KP213	KP213
149.620	13	longnose sucker	15-May	KP -8.0																					
149.620	16	longnose sucker	15-May	KP -8.0																					
149.620	20	longnose sucker	16-May	KP -8.0		KP40.5		MR-R4						KP43	KP40	KP40	KP40	KP41	KP41	KP40	KP39	KP40	KP40	KP40	KP40
149.660	08	longnose sucker	15-May	KP -8.0			MR-R3																		
149.660	11	longnose sucker	16-May	KP -8.0														KP23			KP15				KP5
149.660	13	longnose sucker	16-May	KP -8.0																					
149.660	18	longnose sucker	15-May	KP -8.0																					
149.660	19	longnose sucker	15-May	KP -8.0																					
149.680	04	longnose sucker	16-May	KP -8.0																					
149.680	05	longnose sucker	15-May	KP -8.0						KP16	KP15		KP15	KP15	KP15	KP15	KP17	KP17	KP17	KP16	KP16	KP18	KP15	KP16	KP16
149.680	08	longnose sucker	15-May	KP -8.0															KP142	KP137		KP112			
149.680	14	longnose sucker	16-May	KP -8.0	KP1.5	MR-R2																			
149.680	16	longnose sucker	15-May	KP -8.0																					
149.700	11	longnose sucker	15-May	KP -8.0																					
149.700	12	longnose sucker	15-May	KP -8.0																					
149.700	15	longnose sucker	16-May	KP -8.0	KP17.5	KP17								KP18	KP18	KP18		KP21	KP18	KP18	KP18	KP20	KP20	KP17	KP17
149.700	16	longnose sucker	16-May	KP -8.0	KP17																				
149.700	18	longnose sucker	16-May	KP -8.0																					
149.720	03	longnose sucker	15-May	KP -8.0	KP13																				
149.720	04	longnose sucker	16-May	KP -8.0																					
149.720	06	longnose sucker	16-May	KP -8.0																		KP115			KP97
149.720	16	longnose sucker	15-May	KP -8.0																					
149.720	19	longnose sucker	16-May	KP -8.0																					
149.620	01	longnose sucker	30-May	M. R. - R 3/4 boundary		KP133.5													KP165	KP165		KP166		KP166	KP166
149.620	02	longnose sucker	27-May	M. R. - R 3/4 boundary						KP232			KP225	KP243	KP235		KP235			KP232		KP236		KP233	KP233
149.620	06	longnose sucker	27-May	M. R. - R 3/4 boundary	MR - R3	MR-R4	MR-R4	MR-R4	MR-R4	MR-R3		MR-R3	MR-R3	MR-R3	MR-R3	MR-R3		MR-R3	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2
149.620	12	longnose sucker	26-May	M. R. - R 3/4 boundary	KP55																				
149.620	17	longnose sucker	30-May	M. R. - R 3/4 boundary	MR - R3			MR-R4		MR-R3		MR-R2			MR-R3		MR-R3		MR-R2		MR-R2		MR-R2	MR-R2	MR-R2
149.620	18	longnose sucker	28-May	M. R. Mouth																					
149.660	01	longnose sucker	30-May	M. R. - R 3/4 boundary																					KP88
149.660	05	longnose sucker	26-May	M. R. - R 3/4 boundary	KP51								55KP						KP19		KP14	KP16			KP16.5
149.660	12	longnose sucker	27-May	M. R. - R 3/4 boundary															MR-R3	MR-R4					
149.660	17	longnose sucker	30-May	M. R. - R 3/4 boundary																					
149.660	20	longnose sucker	29-May	M. R. @ Jackpine Ck.																					
149.680	02	longnose sucker	26-May	M. R. - R 3/4 boundary						MR-R4		MR-R2	MR-R3		MR-R2			MR-R3		MR-R2		MR-R2	MR-R2		MR-R2
149.680	03	longnose sucker	31-May	M. R. - R2																					KP164
149.680	12	longnose sucker	31-May	M. R. Mouth																					
149.680	13	longnose sucker	30-May	M. R. - R 3/4 boundary	MR-R3			MR-R4		MR-R3		MR-R3	MR-R3	MR-R2	MR-R3		MR-R3	MR-R3	MR-R2	MR-R2	MR-R3	MR-R2	MR-R2	MR-R3	MR-R3
149.680	20	longnose sucker	28-May	M. R. Mouth															KP58		KP58				
149.700	01	longnose sucker	29-May	M. R. @ Jackpine Ck.	KP16.5																				MR-R2
149.700	03	longnose sucker	30-May	M. R. - R 3/4 boundary																					
149.700	04	longnose sucker	27-May	M. R. - R 3/4 boundary	KP75													KP66		KP71	KP71	KP73			KP51
149.700	06	longnose sucker	29-May	M. R. @ Jackpine Ck.											KP230										KP231
149.700	08	longnose sucker	27-May	M. R. - R 3/4 boundary																		KP173		KP175	KP175
149.720	05	longnose sucker	29-May	M. R. @ Jackpine Ck.			MR-R4		MR-R4	MR-R4			MR-R4		MR-R3	MR-R3	MR-R3	MR-R3	MR-R3	MR-R3	MR-R3	MR-R3		MR-R4	MR-R4
149.720	07	longnose sucker	30-May	M. R. - R 3/4 boundary																				MR-R4	MR-R4
149.720	10	longnose sucker	27-May	M. R. - R 3/4 boundary		MR-R2																			
149.720	18	longnose sucker	27-May	M. R. - R 3/4 boundary															MR-R4						
149.620	03	northern pike	31-May	M. R. Mouth	Removed By Angler		– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
149.620	05	northern pike	01-Jun	M. R. - R2														KP5	KP9	KP1	KP3	KP3			
149.620	07	northern pike	31-May	M. R. Mouth																					
149.620	08	northern pike	31-May	M. R. - R2	MR-R2	MR-R2	MR-R2	MR-R3		MR-R2		MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2		MR-R2	MR-R2	MR-R2	MR-R2	MR-R2
149.620	11	northern pike	31-May	M. R. - R2															KP29						
149.680	01	northern pike	31-May	M. R. - R2	MR-R2			MR-R3				MR-R2	MR-R3	MR-R3				MR-R3	MR-R2	MR-R2	MR-R1		MR-R2	MR-R2	MR-R2
149.680	10	northern pike	31-May	M. R. - R2						MR-R4															KP37
149.680	15	northern pike	31-May	M. R. - R2	KP51			MR-R2																	
149.680	17	northern pike	28-May	M. R. Mouth								MR-R3							KP5		KP8	KP10	KP10		KP13
149.680	18	northern pike	27-May	M. R. - R 3/4 boundary	KP7					MR-R3		MR-R3	MR-R3		KP23			KP22	KP22	KP22		KP22	KP21	KP12	KP12

TableVI-2
Radio Tracking Results, 2000 RAMP Telemetry Study (continued)

Radio Transmitter			Release		Telemetry Survey (Flight Number and Date)																				
					1	**2**	**3**	**4**	**5**	**6**	**7**	**7a***	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Frequency	***Code***	**Species**	***Date***	***Site***	**04-Jun**	**09-Jun**	**19-Jun**	**27-Jun**	**24-Jul**	**09-Aug**	**18-Aug**	**23-Aug**	**08-Sep**	**22-Sep**	**10-Oct**	**19-Oct**	**27-Oct**	**03-Nov**	**09-Nov**	**17-Nov**	**23-Nov**	**01-Dec**	**11-Dec**	**12-Jan**	**24-Jan**
149.700	02	northern pike	01-Jun	M. R. - R2					KP137	KP140	KP135								KP138	KP138		KP138		KP139	KP139
149.700	05	northern pike	01-Jun	M. R. - R2	KP50	MR-R1	MR-R1								KP44			KP43	KP43	KP45	KP43		KP45		KP45
149.700	07	northern pike	28-May	M. R. Mouth																					
149.700	09	northern pike	01-Jun	M. R. - R2																					
149.700	10	northern pike	31-May	M. R. - R2		MR-R2												CWR		CWR					
149.700	13	northern pike	01-Jun	M. R. - R2	MR-R2																	KP242		KP239	KP239
149.700	14	northern pike	01-Jun	M. R. - R2			MR-R3			MR-R3		MR-R2	MR-R3		KP25			KP13	KP15	KP3	KP4	KP10	KP9		KP15
149.700	19	northern pike	31-May	M. R. - R2		MR-R2			MR-R3	MR-R2	MR-R2	MR-R2	MR-R3	MR-R2	MR-R3	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2	MR-R2
149.720	02	northern pike	31-May	M. R. - R2		MR-R1						MR-R2						MR-R1	MR-R1	MR-R1	MR-R1	MR-R1			MR-R1
149.720	08	northern pike	01-Jun	M. R. - R2			MR-R2					MR-R2				MR-R2		MR-R2	MR-R2	MR-R2		MR-R2			MR-R2
149.720	12	northern pike	28-May	M. R. Mouth																					
149.720	14	northern pike	01-Jun	M. R. - R2	MR-R2					KP186			KP185	KP204	KP191		KP195		KP195	KP195		KP195		KP195	KP195
149.720	15	northern pike	28-May	M. R. Mouth																					
149.720	20	northern pike	31-May	M. R. - R2				MR-R1		MR-R2		MR-R2	MR-R2					MR-R2		MR-R2	MR-R2	MR-R2	MR-R1	MR-R2	MR-R2
149.720	21	northern pike	01-Jun	M. R. - R2	Removed By Angler	- -																			

Locations: KP = Athabasca River Kilometer Post
Distance upstream or downstream of Ft. McMurray (Highway 63 Bridge = KP 0.0)
M.R. = Muskeg River Reach R1=Reach 1 (Mouth)
R2=Reach 2 (Canyon)
R3=Reach 3 (Ford to the Canyon)
R4=Reach 4 (Jackpine Creek to Ford)
CWR = Clearwater River

* Ground Survey August 23 - floated Muskeg River survey area by canoe

APPENDIX VII

REFERENCE SURVEY DATA AND PHOTOGRAPHS

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Muskeg River	MR-FF	exposed	65	3.2	unknown
Muskeg River	MR-FF	exposed	68	3.6	unknown
Muskeg River	MR-FF	exposed	68	2.9	unknown
Muskeg River	MR-FF	exposed	70	3.7	unknown
Muskeg River	MR-FF	exposed	70	4.7	unknown
Muskeg River	MR-FF	exposed	72	4.1	unknown
Muskeg River	MR-FF	exposed	74	5.1	unknown
Muskeg River	MR-FF	exposed	75	5.3	unknown
Muskeg River	MR-FF	exposed	76	6.9	adult
Muskeg River	MR-FF	exposed	78	5.3	adult
Muskeg River	MR-FF	exposed	78	6	adult
Muskeg River	MR-FF	exposed	81	8.3	adult
Muskeg River	MR-FF	exposed	85	7.4	adult
Muskeg River	MR-MT	exposed	43	0.9	juvenile
Muskeg River	MR-MT	exposed	44	1.1	juvenile
Muskeg River	MR-MT	exposed	45	1.1	juvenile
Muskeg River	MR-MT	exposed	47	1.2	juvenile
Muskeg River	MR-MT	exposed	48	1	juvenile
Muskeg River	MR-MT	exposed	48	1.2	juvenile
Muskeg River	MR-MT	exposed	49	1.2	juvenile
Muskeg River	MR-MT	exposed	50	1.2	juvenile
Muskeg River	MR-MT	exposed	50	1.2	juvenile
Muskeg River	MR-MT	exposed	50	1.1	juvenile
Muskeg River	MR-MT	exposed	51	1.4	juvenile
Muskeg River	MR-MT	exposed	51	1.6	juvenile
Muskeg River	MR-MT	exposed	51	1.4	juvenile
Muskeg River	MR-MT	exposed	51	1.4	juvenile
Muskeg River	MR-MT	exposed	52	1.5	juvenile
Muskeg River	MR-MT	exposed	53	1.6	juvenile
Muskeg River	MR-MT	exposed	54	1.6	juvenile
Muskeg River	MR-MT	exposed	54	1.6	juvenile
Muskeg River	MR-MT	exposed	55	1.6	juvenile
Muskeg River	MR-MT	exposed	66	3.3	unknown
Muskeg River	MR-MT	exposed	68	3.9	adult
Muskeg River	MR-MT	exposed	70	2.6	adult
Muskeg River	MR-MT	exposed	71	4	adult
Muskeg River	MR-MT	exposed	78	5.7	adult
Muskeg River	MR-MT	exposed	79	5	adult
Muskeg River	MR-MT	exposed	80	5.7	adult
Muskeg River	MR-MT	exposed	80	5.4	adult
Muskeg River	MR-MT	exposed			juvenile
Muskeg River	MR-MT	exposed	42	0.9	juvenile
Muskeg River	MR-MT	exposed	42	0.7	juvenile
Muskeg River	MR-MT	exposed	47	0.9	juvenile
Muskeg River	MR-MT	exposed	47	1.3	juvenile
Muskeg River	MR-MT	exposed	47	1.3	juvenile
Muskeg River	MR-MT	exposed	49	0.9	juvenile
Muskeg River	MR-MT	exposed	49	1	juvenile
Muskeg River	MR-MT	exposed	49	1.2	juvenile

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Muskeg River	MR-MT	exposed	50	1.2	juvenile
Muskeg River	MR-MT	exposed	52	1.4	juvenile
Hangingstone Rive	HR-2	reference	39	0.6	juvenile
Hangingstone Rive	HR-2	reference	41	0.9	juvenile
Hangingstone Rive	HR-2	reference	42	0.8	juvenile
Hangingstone Rive	HR-2	reference	44	1.2	juvenile
Hangingstone Rive	HR-2	reference	44	0.8	juvenile
Hangingstone Rive	HR-2	reference	46	1.1	juvenile
Hangingstone Rive	HR-2	reference	48	1	juvenile
Hangingstone Rive	HR-2	reference	52	1.2	juvenile
Hangingstone Rive	HR-2	reference	58	2.1	unknown
Hangingstone Rive	HR-2	reference	63	2.8	unknown
Hangingstone Rive	HR-2	reference	64	3	unknown
Hangingstone Rive	HR-2	reference	64	2.8	unknown
Hangingstone Rive	HR-2	reference	65	2.9	unknown
Hangingstone Rive	HR-2	reference	67	3.2	adult
Hangingstone Rive	HR-2	reference	68	3.7	adult
Hangingstone Rive	HR-2	reference	68	3.4	adult
Hangingstone Rive	HR-2	reference	69	3.6	adult
Hangingstone Rive	HR-2	reference	69	3.2	adult
Hangingstone Rive	HR-2	reference	69	3.6	adult
Hangingstone Rive	HR-2	reference	71	4.2	adult
Hangingstone Rive	HR-2	reference	71	4.4	adult
Hangingstone Rive	HR-2	reference	71	3.9	adult
Hangingstone Rive	HR-2	reference	74	3.6	adult
Hangingstone Rive	HR-2	reference	77	4.6	adult
Hangingstone Rive	HR-2	reference	79	5	adult
Hangingstone Rive	HR-2	reference	81	5.8	adult
Hangingstone Rive	HR-2	reference	82	6	adult
Hangingstone Rive	HR-1	reference	52	1.5	juvenile
Hangingstone Rive	HR-1	reference	52	1.1	juvenile
Hangingstone Rive	HR-1	reference	52	1.5	juvenile
Hangingstone Rive	HR-1	reference	53	1.7	juvenile
Hangingstone Rive	HR-1	reference	53	1.6	juvenile
Hangingstone Rive	HR-1	reference	68	4.1	adult
Hangingstone Rive	HR-1	reference	68	3.6	adult
Hangingstone Rive	HR-1	reference	68	4.1	adult
Hangingstone Rive	HR-1	reference	69	3.6	adult
Hangingstone Rive	HR-1	reference	72	3.9	adult
Hangingstone Rive	HR-1	reference	74	4.8	adult
Hangingstone Rive	HR-1	reference	74	4.8	adult
Hangingstone Rive	HR-1	reference	75	5.5	adult
Hangingstone Rive	HR-1	reference	76	5.1	adult
Hangingstone Rive	HR-1	reference	81	5.4	adult
Hangingstone Rive	HR-1	reference	82	6.6	adult
Hangingstone Rive	HR-1	reference	82	6.1	adult
Hangingstone Rive	HR-1	reference	87	8.5	adult
Steepbank River	SR-R	reference	42	0.9	juvenile
Steepbank River	SR-R	reference	47	1.1	juvenile

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Steepbank River	SR-R	reference	48	1.2	juvenile
Steepbank River	SR-R	reference	48	1.2	juvenile
Steepbank River	SR-R	reference	50	1.4	juvenile
Steepbank River	SR-R	reference	50	1.1	juvenile
Steepbank River	SR-R	reference	50	1.4	juvenile
Steepbank River	SR-R	reference	51	1.6	juvenile
Steepbank River	SR-R	reference	51	1.5	juvenile
Steepbank River	SR-R	reference	52	1.5	juvenile
Steepbank River	SR-R	reference	52	1.6	juvenile
Steepbank River	SR-R	reference	52	1.6	juvenile
Steepbank River	SR-R	reference	52	1.5	juvenile
Steepbank River	SR-R	reference	52	1.6	juvenile
Steepbank River	SR-R	reference	52	1.8	juvenile
Steepbank River	SR-R	reference	52	2	juvenile
Steepbank River	SR-R	reference	52	1.8	juvenile
Steepbank River	SR-R	reference	53	1.5	juvenile
Steepbank River	SR-R	reference	53	1.5	juvenile
Steepbank River	SR-R	reference	53	1.5	juvenile
Steepbank River	SR-R	reference	54	1.8	unknown
Steepbank River	SR-R	reference	54	0.9	unknown
Steepbank River	SR-R	reference	54	2.3	unknown
Steepbank River	SR-R	reference	55	2	unknown
Steepbank River	SR-R	reference	56	1.7	juvenile
Steepbank River	SR-R	reference	56	2.1	unknown
Steepbank River	SR-R	reference	56	2.1	unknown
Steepbank River	SR-R	reference	56	2.1	unknown
Steepbank River	SR-R	reference	56	2.5	unknown
Steepbank River	SR-R	reference	56	2.1	unknown
Steepbank River	SR-R	reference	56	3	unknown
Steepbank River	SR-R	reference	57	2	unknown
Steepbank River	SR-R	reference	57	2.1	unknown
Steepbank River	SR-R	reference	58	2.3	unknown
Steepbank River	SR-R	reference	58	2.1	unknown
Steepbank River	SR-R	reference	58	2.1	unknown
Steepbank River	SR-R	reference	58	1.9	unknown
Steepbank River	SR-R	reference	58	1.9	unknown
Steepbank River	SR-R	reference	58	2.3	unknown
Steepbank River	SR-R	reference	58	1.9	unknown
Steepbank River	SR-R	reference	58	2.5	unknown
Steepbank River	SR-R	reference	59	2.7	unknown
Steepbank River	SR-R	reference	59	2.1	juvenile
Steepbank River	SR-R	reference	59	2.2	unknown
Steepbank River	SR-R	reference	59	2.3	unknown
Steepbank River	SR-R	reference	60	2.6	unknown
Steepbank River	SR-R	reference	60	2.3	unknown
Steepbank River	SR-R	reference	61	2.7	unknown
Steepbank River	SR-R	reference	64	2.6	unknown
Steepbank River	SR-R	reference	65	3.1	adult
Steepbank River	SR-R	reference	67	3.1	adult

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Steepbank River	SR-R	reference	68	3.6	adult
Steepbank River	SR-R	reference	71	4	adult
Steepbank River	SR-R	reference	72	3.9	adult
Steepbank River	SR-R	reference	73	4.2	adult
Steepbank River	SR-R	reference	75	4.5	adult
Steepbank River	SR-R	reference	84	6	adult
Steepbank River	SR-MN	exposed	41	1	juvenile
Steepbank River	SR-MN	exposed	54	1.5	juvenile
Steepbank River	SR-MN	exposed	55	1.8	juvenile
Steepbank River	SR-MN	exposed	59	1.9	juvenile
Steepbank River	SR-MN	exposed	60	2.6	unknown
Steepbank River	SR-MN	exposed	60	2	unknown
Steepbank River	SR-MN	exposed	61	2.5	unknown
Steepbank River	SR-MN	exposed	61	2.4	unknown
Steepbank River	SR-MN	exposed	62	1.7	unknown
Steepbank River	SR-MN	exposed	63	2.7	unknown
Steepbank River	SR-MN	exposed	63	2.4	unknown
Steepbank River	SR-MN	exposed	63	3.2	unknown
Steepbank River	SR-MN	exposed	64	2.5	unknown
Steepbank River	SR-MN	exposed	64	2.8	unknown
Steepbank River	SR-MN	exposed	64	2.6	unknown
Steepbank River	SR-MN	exposed	65	2.8	unknown
Steepbank River	SR-MN	exposed	78	4.8	adult
Steepbank River	SR-MN	exposed	39	0.6	juvenile
Steepbank River	SR-MN	exposed	42	0.7	juvenile
Steepbank River	SR-MN	exposed	46	1.1	juvenile
Steepbank River	SR-MN	exposed	58	2	juvenile
Steepbank River	SR-MN	exposed	61	2.2	unknown
Steepbank River	SR-MN	exposed	61	1.8	unknown
Steepbank River	SR-MN	exposed	63	2.4	unknown
Steepbank River	SR-MN	exposed	68	3.2	adult
Steepbank River	SR-MN	exposed	70	3.8	adult
Ells River	ER-1	reference	68	2.9	unknown
Ells River	ER-2	reference	69	4.4	adult
Ells River	ER-2	reference	72	5.2	adult
Ells River	ER-2	reference	72	3.7	adult
Ells River	ER-2	reference	80	6.4	adult
Ells River	ER-3	reference	40	1.1	juvenile
Ells River	ER-3	reference	42	0.8	juvenile
Ells River	ER-3	reference	62	3.1	unknown
Ells River	ER-3	reference	64	3.3	unknown
Ells River	ER-3	reference	71	4.3	adult
Ells River	ER-3	reference	72	4.5	adult
Ells River	ER-3	reference	74	4.1	adult
Ells River	ER-3	reference	75	4.5	adult
Dunkirk River	1	reference	39	0.7	juvenile
Dunkirk River	1	reference	44	1.3	juvenile
Dunkirk River	1	reference	46	1.4	juvenile
Dunkirk River	1	reference	62	2.7	unknown

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Dunkirk River	1	reference	65	3	unknown
Dunkirk River	1	reference	67	3.1	adult
Dunkirk River	1	reference	67	3.1	adult
Dunkirk River	1	reference	68	3.5	adult
Dunkirk River	1	reference	69	3.9	adult
Dunkirk River	1	reference	70	3.7	adult
Dunkirk River	1	reference	71	3.7	adult
Dunkirk River	1	reference	71	4.6	adult
Dunkirk River	1	reference	72	3.8	adult
Dunkirk River	1	reference	72	3.6	adult
Dunkirk River	1	reference	74	4.5	adult
Dunkirk River	1	reference	74	4.4	adult
Dunkirk River	1	reference	75	5	adult
Dunkirk River	1	reference	75	4.3	adult
Dunkirk River	1	reference	75	5.2	adult
Dunkirk River	1	reference	76	4.7	adult
Dunkirk River	1	reference	78	5	adult
Dunkirk River	1	reference	79	4.9	adult
Dunkirk River	1	reference	79	5.5	adult
Dunkirk River	1	reference	80	5.7	adult
Dunkirk River	1	reference	83	6.4	adult
Horse River	1	reference	42	0.6	juvenile
Horse River	1	reference	43	0.7	juvenile
Horse River	1	reference	44	0.7	juvenile
Horse River	1	reference	46	1.1	juvenile
Horse River	1	reference	46	1	juvenile
Horse River	1	reference	47	0.9	juvenile
Horse River	1	reference	47	1.2	juvenile
Horse River	1	reference	47	1	juvenile
Horse River	1	reference	47	0.9	juvenile
Horse River	1	reference	47	0.9	juvenile
Horse River	1	reference	48	1	juvenile
Horse River	1	reference	48	1	juvenile
Horse River	1	reference	48	1.2	juvenile
Horse River	1	reference	49	1.4	juvenile
Horse River	1	reference	49	1.2	juvenile
Horse River	1	reference	50	1.2	juvenile
Horse River	1	reference	50	1.4	juvenile
Horse River	1	reference	50	1.2	juvenile
Horse River	1	reference	50	1.2	juvenile
Horse River	1	reference	51	1.2	juvenile
Horse River	1	reference	51	1.1	juvenile
Horse River	1	reference	51	1.2	juvenile
Horse River	1	reference	51	1.3	juvenile
Horse River	1	reference	51	1.4	juvenile
Horse River	1	reference	51	1.3	juvenile
Horse River	1	reference	51	1.1	juvenile
Horse River	1	reference	51	1.4	juvenile
Horse River	1	reference	51	1.2	juvenile

Slimy Sculpin Captured During the Reference Site Survey

River	Site	Exposure	Total Length (mm)	Body Weight (g)	Maturity
Horse River	1	reference	51	1.4	juvenile
Horse River	1	reference	52	1.4	juvenile
Horse River	1	reference	52	1.6	juvenile
Horse River	1	reference	52	1.2	juvenile
Horse River	1	reference	52	1.6	juvenile
Horse River	1	reference	52	1.4	juvenile
Horse River	1	reference	52	1.5	juvenile
Horse River	1	reference	52	1.4	juvenile
Horse River	1	reference	52	1.3	juvenile
Horse River	1	reference	52	1.4	juvenile
Horse River	1	reference	52	1.4	juvenile
Horse River	1	reference	53	1.4	juvenile
Horse River	1	reference	53	1.5	juvenile
Horse River	1	reference	53	1.4	juvenile
Horse River	1	reference	53	1.2	juvenile
Horse River	1	reference	53	1.4	juvenile
Horse River	1	reference	54	1.6	juvenile
Horse River	1	reference	54	1.6	juvenile
Horse River	1	reference	54	1.6	juvenile
Horse River	1	reference	54	1.6	juvenile
Horse River	1	reference	54	1.5	juvenile
Horse River	1	reference	55	1.6	juvenile
Horse River	1	reference	56	1.7	juvenile
Horse River	1	reference	56	1.9	juvenile
Horse River	1	reference	56	1.5	juvenile
Horse River	1	reference	57	1.5	juvenile
Horse River	1	reference	57	1.8	juvenile
Horse River	1	reference	58	1.9	juvenile
Horse River	1	reference	58	1.8	juvenile
Horse River	1	reference	59	2.1	unknown
Horse River	1	reference	60	2.1	unknown
Horse River	1	reference	61	1.8	juvenile
Horse River	1	reference	61	2.5	unknown
Horse River	1	reference	61	2	unknown
Horse River	1	reference	61	2.2	unknown
Horse River	1	reference	62	2.2	unknown
Horse River	1	reference	63	2.3	unknown
Horse River	1	reference	63	2.3	unknown
Horse River	1	reference	64	2.8	unknown
Horse River	1	reference	65	2.8	unknown
Horse River	1	reference	66	3	unknown
Horse River	1	reference	66	3.1	juvenile
Horse River	1	reference	67	3	unknown
Horse River	1	reference	68	31	adult
Horse River	1	reference	68	3.3	adult
Horse River	1	reference	69	2.9	adult
Horse River	1	reference	70	3.3	adult
Horse River	1	reference	71	3.8	adult
Horse River	1	reference	72	3.5	adult

Photographs

Photo 1 Looking upstream at turbulent run and riffle habitat along RDB of MR-MT, September 19th, 2000.

Photo 2 Looking upstream at riffle habitat along LDB of MR-MT, September 19th, 2000.

Photographs

↑ Photo 3 Looking downstream at riffle and turbulent run habitat at MR-FF, September 18th, 2000.

↑ Photo 4 Riffle and run habitat at SR-MN (September 22nd, 2000). Note bitumen visible on exposed gravel bar along RDB.

Photographs

Photo 5 Riffle and turbulent run habitat along SR-MN, upstream of Photo 4.

Photo 6 Looking downstream at riffle habitat at SR-RF (September 20th, 2000).

Photographs

↑ Photo 7 Looking upstream at riffle and boulder garden habitats at SR-RF (September 20th, 2000).

↑ Photo 8 Riffle habitat along Dunkirk River sampled for slimy sculpin (September 21st, 2000).

Photographs

↑ Photo 9 Looking downstream at riffles along Horse River (September 22nd, 2000).

↑ Photo 10 Looking upstream at riffle habitats sampled for slimy sculpin, Horse River.

Photographs

Photo 11 Riffle habitat at Hangingstone River site, south of Highway 63, September 18th, 2000.

Photo 12 Riffles along side channel of Hangingstone River (south of Highway 63).

Photographs

Photo 13 — Run and riffle habitats sampled at Hangingstone River site between Highway 63 and Fort McMurray, September 22nd, 2000.

Photo 14 — Unstable banks and channel at Hangingstone River site between Highway 36 and Fort McMurray.

Photo 15 Turbulent run habitat sampled at the Dover River, September 20th, 2000.

Photo 16 Riffle area sampled at Ells River 1, September 20th, 2000.

Photo 17 Looking upstream at Ells River 2, September 20th, 2000.

Photo 18 Turbulent run and riffle habitat sampled for slimy sculpin at Ells River 3, September 20th, 2000.

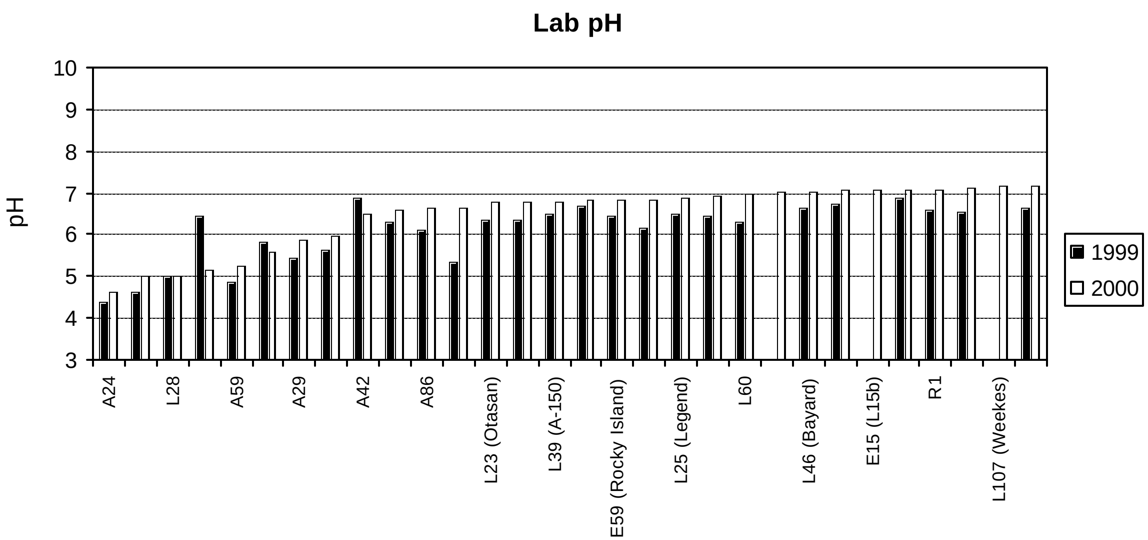
Photo 19 Riffle habitat at Ells River 4, September 21st, 2000.

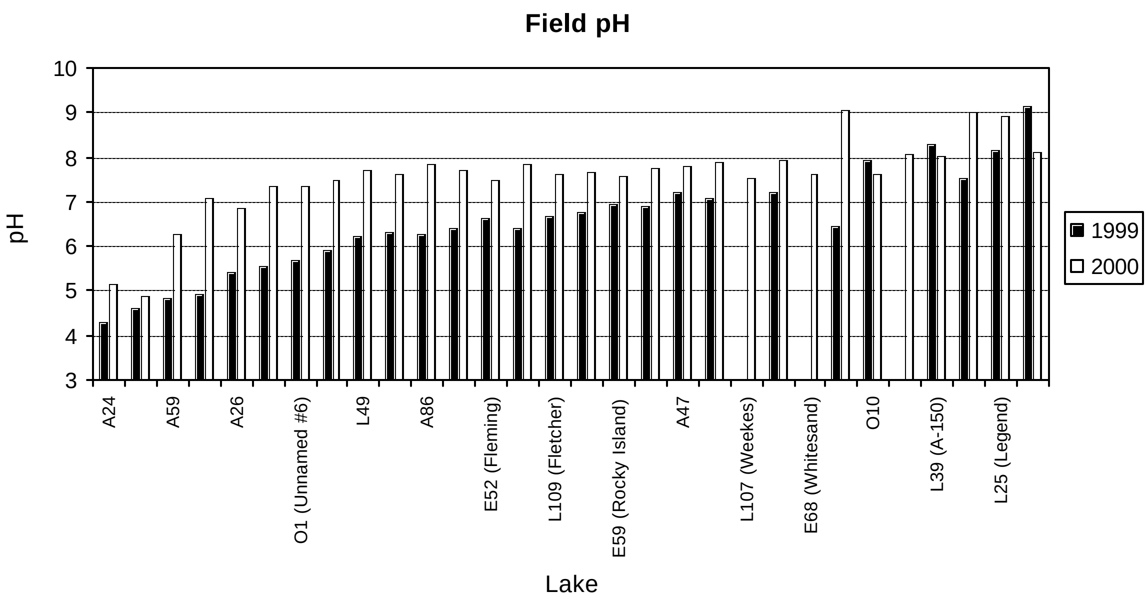
APPENDIX VIII

WATER CHEMISTRY DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

COMPARISON OF 1999 AND 2000 pH DATA

COMPARISON OF 1999 AND 2000 pH DATA





FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Table VIII-1
Field Parameter Data and Water Chemistry Data for Acid Sensitive Lakes Monitored in 2000

Lake	Secchi Depth (m)	Conductivity (field) (µS/cm)	Water Temp. (field) (°C)	Dissolved Oxygen (field) (mg/L)	pH (field)	pH (lab)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Total Alkalinity (mg/L as $CaCO_3$)	Gran Alkalinity (mg/L as $CaCO_3$)
Oil Sands Region											
A21	0.60	14	8.73	9.07	4.88	4.99	52.0	6.4	2.8	1.85	0.21
A24	0.40	14	9.74	9.29	5.15	4.63	42.8	2.7	4.6	0.55	-1.53
A26	0.50	12	8.37	9.77	6.85	5.14	36.2	15.6	7.9	1.74	-0.60
A29	0.95	13	10.05	9.61	7.34	5.9	37.0	5.0	1.5	3.19	1.14
A42	0.10	35	13.01	12.00	8.13	6.49	114.4	175.0	30.0	11.33	12.13
A47	1.70	31	10.50	11.00	7.78	6.66	56.7	2.1	1.4	7.89	6.64
A59	0.40	25[(a)]	11.28	7.99	6.29	5.24	95.9	8.4	2.5	3.49	3.56
A86	2.25	25	13.20	9.21	7.86	6.62	44.5	2.3	0.79	6.81	5.03
E15 (L15b)	0.25	49[(a)]	10.62	10.50	8.05	7.07	178.6	56.0	9.5	21.30	24.03
L4 (A-170)	0.48	24	10.22	10.09	7.47	5.61	67.5	1.6	0.46	4.69	4.73
L7	1.40	36	10.80	10.05	7.84	6.58	84.0	0.9	1.1	8.66	8.94
L8	1.00	46	9.80	9.28	7.92	7.06	72.5	4.8	2.5	20.30	20.11
L18 (Namur)	3.20	61	12.16	8.26	9.00	7.09	45.3	1.4	0.8	20.21	18.08
L23 (Otasan)	2.40	22	11.93	8.97	7.75	6.79	37.4	1.4	1.1	8.43	6.99
L25 (Legend)	1.80	26	11.82	8.23	8.92	6.87	38.1	2.6	2.5	9.95	8.30
L28	0.40	17	8.81	9.60	7.10	5.02	76.0	2.1	1.4	2.16	1.45
L39 (A-150)	0.25	32	10.76	10.42	8.03	6.8	50.7	22.0	7.0	11.98	10.26
L46 (Bayard)	0.30	58	9.90	9.81	7.72	7.04	95.0	10.7	11.0	15.10	14.95
L47	0.75	55[(a)]	8.66	10.22	7.89	6.82	84.5	10.3	7.3	13.34	12.88
L49	0.75	57[(a)]	9.42	10.28	7.73	6.84	84.5	10.0	7.0	10.10	9.71
L60	1.00	54	10.49	9.03	9.04	6.99	81.0	3.3	4.7	11.75	11.35
Caribou Mountains											
E52 (Fleming)	--[(b)]	46	9.64	10.16	7.49	7.13	71.0	0.5	1.3	17.63	17.55
E59 (Rocky Island)	2.20	24	8.44	9.84	7.57	6.83	37.5	1.6	1.4	9.01	7.41
E68 (mean of 2 samples)	0.70	40	8.38	10.76	7.60	7.03	71.5	5.9	3.7	14.81	14.50
O1 (Unnamed #6)	0.75	25	8.40	9.50	7.37	5.99	48.0	2.4	1.6	4.46	3.35
O2 (Unnamed #9)	1.10	31	9.12	10.75	7.62	6.79	62.0	1.2	0.87	10.26	9.83
Canadian Shield											
L107 (Weekes)	6.00	60	12.86	9.01	7.51	7.17	48.0	0.8	0.43	24.06	22.29
L109 (Fletcher)	1.85	59	13.92	9.59	7.64	7.18	67.0	0.9	1.3	21.44	20.60
O10	0.55	32	13.17	11.35	7.62	6.93	73.2	25.0	5.3	13.06	12.55
R1	2.10	37	13.45	10.10	7.66	7.09	55.5	1.3	0.91	15.80	14.68

[(a)] Conductivity at 0.5 m depth shown; surface conductivity was unusually low, possibly due to meter malfunction.
[(b)] -- = no data.

Table VIII-1
Field Parameter Data and Water Chemistry Data for Acid Sensitive Lakes Monitored in 2000

Lake	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Ammonia (μg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Nitrite + Nitrate (μg/L)
Oil Sands Region									
A21	1.62	0.50	0.79	0.41	19.28	2.26	0.10	1.67	2.71
A24	0.74	0.36	0.57	0.47	7.98	0.67	0.11	1.45	10.75
A26	1.18	0.35	0.67	0.38	8.95	2.12	0.10	1.83	6.00
A29	1.25	0.48	1.03	0.47	20.47	3.89	0.18	0.66	0.67
A42	5.44	1.31	3.11	0.47	94.10	13.81	0.22	1.38	160.96
A47	4.18	0.83	0.42	0.63	12.67	9.62	0.21	0.90	367.29
A59	3.36	0.78	0.76	0.36	85.08	4.25	0.12	0.48	7.59
A86	2.16	0.86	0.59	1.43	54.11	8.31	0.20	1.15	0.17
E15 (L15b)	8.96	1.93	3.85	0.55	32.88	25.97	0.20	0.35	6.00
L4 (A-170)	3.67	1.16	0.45	0.13	25.68	5.72	<0.03	0.71	3.90
L7	5.19	1.55	0.64	0.34	16.72	10.56	0.08	1.11	17.54
L8	5.84	2.61	2.07	0.11	36.86	24.75	0.06	1.37	9.24
L18 (Namur)	6.47	2.02	2.28	1.06	5.19	24.64	0.20	7.42	5.12
L23 (Otasan)	2.94	1.06	0.82	0.43	11.87	10.27	0.09	1.49	0.62
L25 (Legend)	3.51	0.99	0.81	0.71	17.25	12.13	0.11	2.84	6.30
L28	2.21	0.68	0.95	0.28	19.97	2.64	0.05	1.08	13.72
L39 (A-150)	3.25	1.42	1.76	0.55	18.41	14.60	0.26	1.25	6.71
L46 (Bayard)	6.74	2.37	3.31	0.82	22.30	18.41	0.08	10.08	19.47
L47	6.29	1.99	3.01	0.80	64.65	16.26	0.09	9.84	40.56
L49	6.31	2.07	3.45	0.72	20.04	12.31	0.07	14.06	17.84
L60	6.47	2.26	2.68	0.76	10.77	14.33	0.09	10.12	9.46
Caribou Mountains									
E52 (Fleming)	7.99	1.74	0.82	0.70	<0.001	21.49	0.13	2.71	35.48
E59 (Rocky Island)	3.84	1.00	0.40	0.27	3.87	10.99	0.09	2.32	4.29
E68 (mean of 2 samples)	6.59	2.06	1.04	0.28	8.99	18.06	0.11	3.58	20.60
O1 (Unnamed #6)	3.19	0.68	0.37	0.14	2.35	5.44	0.10	1.36	6.02
O2 (Unnamed #9)	5.70	1.42	0.44	0.16	3.13	12.51	0.07	1.21	22.41
Canadian Shield									
L107 (Weekes)	7.78	1.59	1.77	1.03	0.35	29.34	2.42	1.00	0.45
L109 (Fletcher)	6.50	2.29	1.90	0.57	<0.001	26.14	1.80	0.68	3.38
O10	3.95	1.58	3.00	0.53	<0.001	15.93	0.82	1.10	2.52
R1	4.82	1.65	1.49	0.43	0.17	19.26	1.05	0.58	0.37

[a] Conductivity at 0.5 m de
[b] -- = no data.

Table VIII-1
Field Parameter Data and Water Chemistry Data for Acid Sensitive Lakes Monitored in 2000

Lake	Ion balance (Cations/ Anions)	Colour (Pt units)	DOC (mg/L)	DIC (mg/L)	PC (µg/L)	TDN (µg/L)	PN (µg/L)	TP (µg/L)	TDP (µg/L)	Chloro-phyll *a* (µg/L)
Oil Sands Region										
A21	2.24	276.2	19.66	0.17	1991	586	176	55.4	33.3	9.66
A24	2.33	223.9	15.38	0.14	2043	617	223	63.3	34.1	15.01
A26	1.67	103.8	10.83	0.24	5729	595	409	56.1	20.6	18.43
A29	1.92	78.1	13.28	0.46	2996	635	281	27.5	5.9	14.70
A42	2.02	87.0	40.60	2.23	84466	1836	7054	299.1	16.5	368.77
A47	1.71	88.2	15.46	1.07	1547	1176	189	52.6	29.2	9.69
A59	3.30	316.0	37.12	0.30	4104	961	450	62.1	21.8	48.24
A86	1.45	47.7	13.89	1.08	1591	791	174	23.4	8.4	6.89
E15 (L15b)	1.80	132.1	16.66	3.50	54955	1465	3935	127.0	12.7	370.98
L4 (A-170)	2.76	337.4	27.40	0.25	994	592	126	21.4	11.2	9.03
L7	2.13	371.9	30.97	0.81	752	597	66	17.3	11.0	7.62
L8	1.37	152.2	20.66	4.00	2094	819	328	44.1	13.8	17.96
L18 (Namur)	1.09	14.1	7.08	4.56	714	340	92	20.8	9.6	6.81
L23 (Otasan)	1.39	50.2	11.31	1.49	1192	396	183	14.8	5.9	5.85
L25 (Legend)	1.19	40.4	7.79	1.87	1256	404	162	37.4	10.9	12.81
L28	3.20	426.6	27.46	0.17	777	537	61	57.1	47.5	2.65
L39 (A-150)	1.36	76.7	11.97	2.63	10681	419	967	41.9	5.7	38.51
L46 (Bayard)	1.36	251.5	23.40	1.40	2767	712	467	127.8	46.4	57.13
L47	1.33	162.6	20.46	2.10	1904	1040	195	74.1	46.9	4.25
L49	1.32	199.4	23.00	1.45	3155	690	544	75.0	34.4	40.04
L60	1.44	193.4	18.65	1.85	1391	659	209	128.4	84.8	19.87
Caribou Mountains										
E52 (Fleming)	1.44	283.5	21.22	2.86	335	557	50	48.4	42.7	4.37
E59 (Rocky Island)	1.29	82.3	10.47	1.42	762	357	103	21.9	11.7	4.18
E68 (mean of 2 samples)	1.47	311.2	22.59	2.27	1898	634	271	50.6	25.8	12.88
O1 (Unnamed #6)	1.95	286.1	18.96	0.35	1145	504	179	27.1	14.2	13.06
O2 (Unnamed #9)	1.83	307.0	22.01	1.27	419	602	48	33.7	28.2	2.87
Canadian Shield										
L107 (Weekes)	1.09	8.0	6.99	5.40	552	328	46.9	4.2	2.4	1.53
L109 (Fletcher)	1.24	111.4	14.34	4.51	497	496	43.3	13.5	9.3	3.63
O10	1.53	69.8	21.65	2.60	10673	839	794.0	38.8	4.9	29.87
R1	1.27	57.0	12.82	2.90	616	450	62.6	7.9	4.6	3.88

[a] Conductivity at 0.5 m de
[b] -- = no data.

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **A21** Date: 29-Aug-2000 Initials: ES

Latitude: 56.2590 Longitude: 111.2600 Altitude (m): 719

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	8:40	0.05	220	8.73	9.07	14	4.88	83.8
		0.10	450	8.52	9.30	14	5.89	85.9
		0.50	20	8.54	9.19	14	5.19	84.8
		0.90	2.5	8.54	9.12	14	4.81	84.2

Air Temp (°C): 4
Wind Speed (km/h): 4
Wind Direction: NW
Cloud Cover (%): 100
Wave Height (m): 0
Secchi Depth (m): 0.60
Euphotic Depth (m): 0.8
Bottom Depth (m): 1.2
Zooplankton Haul Depth (m): 0.8
Comments: - light at surface and 0.10 m low and variable (note by WFD after sampling)

Lake: **A24** Date: 29-Aug-2000 Initials: ES

Latitude: 56.2219 Longitude: 111.2540 Altitude (m): 710

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	11:30	0.05	2000	9.77	9.51	15	5.82	90.3
		0.50	120	9.74	9.38	14	5.38	88.6
		0.80	24					
		0.90	17	9.75	9.15	14	4.65	86.9
		1.00	7					
		1.30		9.67	9.39	14	4.51	88.8
2	12:05	0.05		9.70	9.07	13	4.48	86.0
		0.50		9.83	9.10	13	4.32	86.5
		1.00		9.77	9.05	13	4.33	86.0

Air Temp (°C): 8
Wind Speed (km/h): 10
Wind Direction: NW
Cloud Cover (%): 10
Wave Height (m): 0.02
Secchi Depth (m): 0.40
Euphotic Depth (m): 0.9
Bottom Depth (m): 1.6
Zooplankton Haul Depth (m): 0.9
Comments: None

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **A26** Date: 29-Aug-2000 Initials: ES

Latitude: 56.2125 Longitude: 111.2028 Altitude (m): 712

Site No.	Time	Depth (m)	Light (Lux)	Temp (^{o}C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	10:17	0.05	1100	8.49	9.73	12	7.10	89.2
		0.50	930	8.49	9.54	12	6.44	87.9
		0.90	12	8.45	9.46	11	8.89	86.7
		1.00	8	8.46	9.55	10	5.59	88.3
2	10:45	0.05		8.25	9.80		6.59	90.0
		0.50		8.70	9.57		6.15	87.5
		0.90		8.57	9.36		5.83	86.4
		1.40		8.49	9.33		5.41	86.0

Air Temp (^{o}C): 5
Wind Speed (km/h): 1
Wind Direction: NW
Cloud Cover (%): 50
Wave Height (m): 0.01
Comments: - depth at Site 2 = 1.65 m

Secchi Depth (m): 0.50
Euphotic Depth (m): 0.9
Bottom Depth (m): 1.3
Zooplankton Haul Depth (m): 0.9

Lake: **A29** Date: 29-Aug-2000 Initials: ES

Latitude: 56.1685 Longitude: 111.5459 Altitude (m): 714

Site No.	Time	Depth (m)	Light (Lux)	Temp (^{o}C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	12:48	0.05	4000	10.05	9.61	13	7.34	92.1
		0.50	1200	10.04	9.55	13	7.26	91.1
		1.00	510	10.05	9.45	13	7.02	90.5
		1.30	260					

Air Temp (^{o}C): 8
Wind Speed (km/h): 5
Wind Direction: NW
Cloud Cover (%): 10
Wave Height (m): 0.02
Comments: None

Secchi Depth (m): 0.95
Euphotic Depth (m): 1.1
Bottom Depth (m): 1.4
Zooplankton Haul Depth (m): 1.0

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **A42** Date: 30-Aug-2000 Initials: ES

Latitude: 56.3529 Longitude: 113.1753 Altitude (m): 643

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	12:55	0.05	4000	13.01	12.00	35	8.13	121.1
		0.30	40	11.40	11.37	31	8.48	118.9
		0.50	8	9.84	7.55	36	8.18	72.0

Air Temp (°C): 11
Wind Speed (km/h): 2
Wind Direction: S
Cloud Cover (%): 40
Wave Height (m): 0.01
Comments: - very muddy and shallow

Secchi Depth (m): 0.10
Euphotic Depth (m): 0.3
Bottom Depth (m): 1.3
Zooplankton Haul Depth (m): 0.8

Lake: **A47** Date: 30-Aug-2000 Initials: ES

Latitude: 56.2440 Longitude: 113.1410 Altitude (m): 643

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	10:52	0.05	3500	10.50	11.00	31	7.78	91.4
		0.50	1000	10.57	8.53	30	7.62	82.1
		1.00	342	10.50	8.33	30	7.57	80.1

Air Temp (°C): 8
Wind Speed (km/h): 5
Wind Direction: W
Cloud Cover (%): 0
Wave Height (m): 0.02
Comments: None

Secchi Depth (m): 1.70
Euphotic Depth (m): 1.7
Bottom Depth (m): 1.7
Zooplankton Haul Depth (m): 1.0

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **A59** Date: 30-Aug-2000 Initials: ES

Latitude: 55.9127 Longitude: 112.8622 Altitude (m): 555

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1		0.05	3100	11.28	7.99	11	6.29	78.6
		0.50	34	11.17	7.86	25	6.03	77.1
		1.00	1.4	11.12	7.69	21	5.87	77.3
		1.50		11.11	7.60	21	5.72	74.5

Air Temp (°C): 4
Wind Speed (km/h): 0
Wind Direction: N/A
Cloud Cover (%): 5
Wave Height (m): 0
Secchi Depth (m): 0.40
Euphotic Depth (m): 0.5
Bottom Depth (m): 2
Zooplankton Haul Depth (m): 1.0
Comments: - conductivity meter may have been faulty

Lake: **A86** Date: 29-Aug-2000 Initials: WFD/ES

Latitude: 55.6833 Longitude: 111.8250 Altitude (m): 712

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	14:18	0.05	1100	13.20	9.21	25	7.86	92.2
		0.50	550	13.24	8.60	23	7.77	88.4
		1.00	290	13.60	8.52	21	7.74	87.5
		1.50	170	13.27	8.44	21	7.64	86.5
		2.00	97	13.22	8.37	20	7.56	85.4
		2.50	64					

Air Temp (°C): 9
Wind Speed (km/h): 6
Wind Direction: NW
Cloud Cover (%): 85
Wave Height (m): 0.01
Secchi Depth (m): 2.25
Euphotic Depth (m): 2.6
Bottom Depth (m): 2.6
Zooplankton Haul Depth (m): N/A; see below
Comments: - zooplankton haul depth at Site 1 = 1.0 m
- zooplankton haul depth at Site 2 = 2.0 m (total depth = 3.0 m)

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **E15 (L15b)** Date: 1-Sep-2000 Initials: ES

Latitude: 56.8939 Longitude: 110.8980 Altitude (m): 457

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	13:23	0.05	410	10.62	10.50	8	8.05	101.0
		0.30	4	10.61	10.05	49	8.01	97.2
		1.00		10.61	10.05	49	7.99	96.6

Air Temp (^oC): 12
Wind Speed (km/h): 28
Wind Direction: E
Cloud Cover (%): 100
Wave Height (m): 0.15
Comments: - conductivity meter may have been faulty

Secchi Depth (m): 0.25
Euphotic Depth (m): 0.3
Bottom Depth (m): 1.65
Zooplankton Haul Depth (m): 0.3

Lake: **L4** Date: 1-Sep-2000 Initials: ES

Latitude: 57.1509 Longitude: 110.8469 Altitude (m): 549

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	11:55	0.05	170	10.22	10.09	24	7.47	95.4
		0.50	2	10.22	8.65	22	7.19	82.2
		1.00						

Air Temp (^oC): 14
Wind Speed (km/h): 17
Wind Direction: E
Cloud Cover (%): 95
Wave Height (m): 0.12
Comments: None

Secchi Depth (m): 0.48
Euphotic Depth (m): 0.5
Bottom Depth (m): 2.1
Zooplankton Haul Depth (m): 0.5

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **L7** Date: 30-Aug-2000 Initials: ES

Latitude: 57.0913 Longitude: 110.7512 Altitude (m): 594

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	15:28	0.05	500	10.80	10.05	36	7.84	94.5
		0.50	30	10.80	9.07	35	7.65	88.4
		1.00	4.5	10.80	8.99	36	7.50	87.4

Air Temp (^oC): 14
Wind Speed (km/h): 7
Wind Direction: W
Cloud Cover (%): 86
Wave Height (m): 0.02
Comments: None

Secchi Depth (m): 1.40
Euphotic Depth (m): 1.0
Bottom Depth (m): 1.7
Zooplankton Haul Depth (m): 1.0

Lake: **L8** Date: 1-Sep-2000 Initials: ES

Latitude: 57.0461 Longitude: 110.5895 Altitude (m): 610

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	12:38	0.05	250	9.80	9.28	46	7.92	87.4
		0.50	17	9.79	9.05	45	7.90	85.5
		0.70	2.5					
		1.00		8.98	8.98	45	7.83	85.4

Air Temp (^oC): 12
Wind Speed (km/h): 13
Wind Direction: E
Cloud Cover (%): 100
Wave Height (m): 0.08
Comments: None

Secchi Depth (m): 1.00
Euphotic Depth (m): 0.7
Bottom Depth (m): 1.95
Zooplankton Haul Depth (m): 0.7

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: L18 (Namur) Date: 31-Aug-2000 Initials: ES

Latitude: 57.4444 Longitude: 112.6211 Altitude (m): 722

Site No.	Time	Depth (m)	Light (Lux)	Temp (^{o}C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	9:20	0.05	700	12.16	8.26	61	9.00	82.8
		0.50	340					
		1.00	250	12.20	8.22	60	8.86	82.5
		2.00	160	12.20	8.15	59	8.77	82.2
		3.00	110	12.20	8.18	58	8.72	82.0
		4.00	67	12.20	8.04	59	8.68	80.9
		5.00	41	12.10	8.02	59	8.54	80.4
		6.00	26	12.20	8.01	59	8.47	80.2
		7.00	17	12.20	7.95	59	8.39	79.8
		8.00	11	12.20	7.91	58	8.33	79.2

Air Temp (^{o}C): 9
Wind Speed (km/h): 8
Wind Direction: S
Cloud Cover (%): 99
Wave Height (m): 0.08
Comments: None

Secchi Depth (m): 3.20
Euphotic Depth (m): 8.4
Bottom Depth (m): 24
Zooplankton Haul Depth (m): 8.4

Lake: L23 (Otasan) Date: 31-Aug-2000 Initials: ES

Latitude: 57.7020 Longitude: 112.3760 Altitude (m): 732

Site No.	Time	Depth (m)	Light (Lux)	Temp (^{o}C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	14:42	0.05	630	11.93	8.97	22	7.75	88.9
		1.00	130	11.92	8.76	22	7.77	87.5
		2.00	69	11.91	8.69	22	7.73	86.4
		3.00	42	11.89	8.68	22	7.74	86.7
		4.00	19	11.83	8.62	22	7.74	85.9
		5.00	6	11.84	8.64	22	7.43	85.7

Air Temp (^{o}C): 13
Wind Speed (km/h): 18
Wind Direction: S
Cloud Cover (%): 92
Wave Height (m): 0.12
Comments: None

Secchi Depth (m): 2.40
Euphotic Depth (m): 5.0
Bottom Depth (m): 7.6
Zooplankton Haul Depth (m): 5.0

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: L25 (Legend) Date: 31-Aug-2000 Initials: ES

Latitude: 57.4045 Longitude: 112.9294 Altitude (m): 789

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	10:30	0.05	500	11.82	8.23	26	8.92	82.0
		1.00	100	11.83	8.18	26	8.72	81.5
		2.00	45	11.83	8.15	26	8.67	81.4
		3.00	12	11.82	8.10	26	8.64	80.9
		4.00	9	11.80	8.09	26	8.60	80.5
		5.00	5	11.82	8.06	26	8.56	80.5
		6.00						

Air Temp (^oC): 8
Wind Speed (km/h): 13
Wind Direction: S
Cloud Cover (%): 98
Wave Height (m): 0.06
Comments: None

Secchi Depth (m): 1.80
Euphotic Depth (m): 5.0
Bottom Depth (m): 10.2
Zooplankton Haul Depth (m): 5.0

Lake: L28 Date: 31-Aug-2000 Initials: ES

Latitude: 57.8526 Longitude: 112.9727 Altitude (m): 716

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	12:28	0.05	270	8.81	9.60	17	7.10	87.8
		0.50	22	8.78	9.16	17	6.84	84.7
		1.00	2.3	8.77	9.01	17	6.59	83.2

Air Temp (^oC): 10
Wind Speed (km/h): 15
Wind Direction: S
Cloud Cover (%): 99
Wave Height (m): 0.09
Comments: None

Secchi Depth (m): 0.40
Euphotic Depth (m): 1.0
Bottom Depth (m): 1.9
Zooplankton Haul Depth (m): 1.0

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **L39** Date: 1-Sep-2000 Initials: ES

Latitude: 57.959 Longitude: 110.3995 Altitude (m): 427

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	10:42	0.05	600	10.76	10.42	32	8.03	100.9
		0.50	27	10.75	9.48	30	8.04	91.5
		1.00	9	10.75	9.46	29	7.95	92.0
		1.20	6					

Air Temp (^oC): 14
Wind Speed (km/h): 12
Wind Direction: E
Cloud Cover (%): 98
Wave Height (m): 0.12
Comments: None

Secchi Depth (m): 0.25
Euphotic Depth (m): 1.2
Bottom Depth (m): 1.45
Zooplankton Haul Depth (m): 1.2

Lake: **L46 (Bayard)** Date: 31-Aug-2000 Initials: ES

Latitude: 57.7700 Longitude: 112.3970 Altitude (m): 640

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	14:01	0.05	660	9.90	9.81	58	7.72	93.0
		0.50	24	9.83	9.72	58	7.68	92.8
		1.00	3.5	9.80	9.66	58	7.67	92.1

Air Temp (^oC): 12
Wind Speed (km/h): 12
Wind Direction: S
Cloud Cover (%): 88
Wave Height (m): 0.09
Comments: None

Secchi Depth (m): 0.30
Euphotic Depth (m): 0.9
Bottom Depth (m): 1.78
Zooplankton Haul Depth (m): 0.9

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **L47** Date: 1-Sep-2000 Initials: ES

Latitude: 56.243 Longitude: 113.14 Altitude (m): 643

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	8:50	0.05	160	8.66	10.22	24	7.89	92.7
		0.50	1.9	8.67	9.38	55	7.78	86.2
		1.00		8.68	9.05	55	7.74	83.5

Air Temp (^oC): 8
Wind Speed (km/h): 16
Wind Direction: E
Cloud Cover (%): 100
Wave Height (m): 0.12
Secchi Depth (m): 0.75
Euphotic Depth (m): 0.5
Bottom Depth (m): 1.3
Zooplankton Haul Depth (m): 0.5
Comments: - conductivity meter may have been faulty

Lake: **L49** Date: 31-Aug-2000 Initials: ES

Latitude: 57.7600 Longitude: 112.5960 Altitude (m): 671

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	13:23	0.05	1000	9.42	10.28	2	7.73	96.3
		0.50	46	9.33	10.23	57	7.66	95.8
		1.00	11	9.32	10.20	57	7.67	95.6

Air Temp (^oC): 10
Wind Speed (km/h): 10
Wind Direction: S
Cloud Cover (%): 99
Wave Height (m): 0.09
Secchi Depth (m): 0.75
Euphotic Depth (m): 1.0
Bottom Depth (m): 1.4
Zooplankton Haul Depth (m): 1.0
Comments: - conductivity meter may have been faulty

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **L60** Date: 31-Aug-2000 Initials: ES

Latitude: 57.6539 Longitude: 112.6167 Altitude (m): 671

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	13:23	0.05	450	10.49	9.03	54	9.04	87.0
		0.50	27	10.51	8.76	52	8.75	84.6
		1.00	13	10.52	8.65	52	8.57	83.4
		1.50	3.6	10.50	8.59	52	8.50	83.3

Air Temp (°C): 11
Wind Speed (km/h): 12
Wind Direction: S
Cloud Cover (%): 90
Wave Height (m): 0.08
Comments: None

Secchi Depth (m): 1.00
Euphotic Depth (m): 1.4
Bottom Depth (m): 2.65
Zooplankton Haul Depth (m): 1.4

Lake: **E52** Date: 6-Sep-2000 Initials: SF

Latitude: 58.7743 Longitude: 115.4432 Altitude (m): 853

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	10:59	0.05	940	9.64	10.16	46	7.49	94.6
		0.50	300	9.64	9.08	46	7.45	86.2
		1.00	105	9.62	9.00	46	7.41	85.0
		1.50	30					
		2.00	10	9.62	8.97	46	7.40	84.7

Air Temp (°C): 8
Wind Speed (km/h): 30
Wind Direction: N
Cloud Cover (%): 5
Wave Height (m): 0.25

Secchi Depth (m): N/A
Euphotic Depth (m): 2.0
Bottom Depth (m): N/A; see below
Zooplankton Haul Depth (m): 5.0

Comments:
- bottom depth wasn't measured because anchors wouldn't hold properly
- used Secchi disk to determine depth, except when drifting in high winds
- conductivity meter may have been faulty

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **E59** Date: 6-Sep-2000 Initials: SF

Latitude: 59.135 Longitude: 115.1535 Altitude (m): 914

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	11:47	0.05	980	8.44	10.23	24	7.65	93.1
		0.50	200	8.44	9.62	24	7.53	88.4
		1.00	80	8.43	9.55	24	7.50	87.4
		1.50						
		2.00	50	8.43	9.45	23	7.49	87.1
		3.00	30	8.44	9.11	23	7.47	84.8
		4.00	20	8.44	9.05	23	7.42	83.6
		5.00	10	8.44	8.78	25	7.46	87.0
		6.00						

Air Temp (^oC): 8
Wind Speed (km/h): 38
Wind Direction: N
Cloud Cover (%): 1
Wave Height (m):

Secchi Depth (m): 2.20
Euphotic Depth (m): 5.0
Bottom Depth (m): N/A; see below
Zooplankton Haul Depth (m): 5.0

Comments:
- bottom depth wasn't measured because anchors wouldn't hold properly
- used Secchi disk to determine depth, except when drifting in high winds
- conductivity meter may have been faulty

Lake: **E68** Date: 6-Sep-2000 Initials: SF

Latitude: 59.1905 Longitude: 115.4490 Altitude (m): 911

Site No.	Time	Depth (m)	Light (Lux)	Temp (^oC)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	12:40	0.05	120	8.38	10.76	40	7.60	93.9
		0.20	10	8.36	9.35	40	7.52	86.4
		0.30	1	8.36	9.22	39	7.48	84.7

Air Temp (^oC): 9
Wind Speed (km/h): 35
Wind Direction: N
Cloud Cover (%): 5
Wave Height (m): 0.18

Secchi Depth (m): 0.70
Euphotic Depth (m): 0.3
Bottom Depth (m): 1.5
Zooplankton Haul Depth (m): 0.3

Comments: None

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **L107** Date: 5-Sep-2000 Initials: SF

Latitude: 59.7093 Longitude: 110.0082 Altitude (m): 320

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	11:40	0.05	4000	12.86	9.01	60	7.51	91.4
		1.00	3000	12.86	8.93	60	7.53	90.7
		2.00	1300	12.85	8.95	59	7.54	91.0
		3.00	700	12.82	8.93	59	7.54	91.1
		4.00	480	12.80	8.87	59	7.55	90.2
		5.00	350	12.82	8.88	57	7.55	90.5
		6.00	240	12.82	8.84	58	7.55	90.2
		7.00	150	12.73	8.79	57	7.54	88.8

Air Temp (°C): 15
Wind Speed (km/h): 28
Wind Direction: S
Cloud Cover (%): 20
Wave Height (m): 0.2
Comments: None

Secchi Depth (m): 6.00
Euphotic Depth (m): 7.8
Bottom Depth (m): 7.8
Zooplankton Haul Depth (m): 7.5

Lake: **L109** Date: 5-Sep-2000 Initials: SF

Latitude: 59.1187 Longitude: 110.8252 Altitude (m): 268

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	15:35	0.05	860	13.92	9.59	59	7.64	98.6
		1.00	90	13.93	8.96	57	7.56	92.9
		2.00	50	13.88	8.60	55	7.52	89.4
		2.50	30					
		3.00	10	13.66	8.48	55	7.51	87.7

Air Temp (°C): 18
Wind Speed (km/h): 16
Wind Direction: W
Cloud Cover (%): 60
Wave Height (m): 0.08
Comments: None

Secchi Depth (m): 1.85
Euphotic Depth (m): 3.0
Bottom Depth (m): 13.7
Zooplankton Haul Depth (m): 3.0

FIELD DATA FOR ACID SENSITIVE LAKES SAMPLED IN 2000

Lake: **O10** Date: 5-Sep-2000 Initials: SF

Latitude: 59.1429 Longitude: 110.6821 Altitude (m): 308

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	14:40	0.05	620	13.17	11.35	32	7.62	94.6
		0.50	170	13.12	10.01	32	7.66	86.2
		1.00	40	13.12	9.83	32	7.65	85.0
		1.20	6	13.07	9.77	31	7.63	

Air Temp (°C): 18
Wind Speed (km/h): 16
Wind Direction: W
Cloud Cover (%): 92
Wave Height (m): 0.07
Comments: None

Secchi Depth (m): 0.55
Euphotic Depth (m): 1.2
Bottom Depth (m): 1.8
Zooplankton Haul Depth (m): 1.2

Lake: **R1** Date: 5-Sep-2000 Initials: SF

Latitude: 59.1927 Longitude: 110.6792 Altitude (m): 305

Site No.	Time	Depth (m)	Light (Lux)	Temp (°C)	D.O. (mg/L)	Cond (µS/cm)	pH	D.O.%
1	13:25	0.05	850	13.45	10.10	37	7.66	101.2
		1.00	180	13.45	9.29	37	7.60	95.6
		2.00	120	13.39	9.14	37	7.58	93.8
		3.00	70	13.38	9.10	37	7.56	93.8
		4.00	40	13.38	9.08	37	7.56	93.7
		5.00	10	13.37	9.05	37	7.56	93.3

Air Temp (°C): 18
Wind Speed (km/h): 18
Wind Direction: S
Cloud Cover (%): 98
Wave Height (m): 0.1
Comments: None

Secchi Depth (m): 2.10
Euphotic Depth (m): 5.0
Bottom Depth (m): 13.05
Zooplankton Haul Depth (m): 5.0