3.0 2007 RAMP MONITORING ACTIVITIES

This section contains a description of RAMP monitoring conducted in 2007 and includes the following for each RAMP component:

- Summary of 2007 monitoring activities and field methods;
- Description of any other information obtained (i.e., information from regulatory agencies, owners and operators of the 2007 focal projects, knowledge obtained from local communities, and other sources);
- Description of changes in the monitoring network from the 2006 field program;
- Description of the challenges and issues encountered during 2007 and the means by which these challenges and issues were addressed;
- Summary of the component data that are now available; and
- A description of the detailed approach used for analyzing the RAMP data, including:
    - A description and explanation of the measurement endpoints that were selected;
    - A description and explanation of the criteria that were used in assessing whether or not changes in the selected measurement endpoints have occurred; and
    - A description of the statistical, graphical, or other analyses that were performed on the monitoring data to assess whether or not changes in the selected measurement endpoints have occurred.

Monitoring activities for all RAMP components in 2007 were implemented according to the monitoring protocols, field methods, and SOPs for the RAMP components as outlined in the RAMP Technical Design and Rationale document (RAMP 2005b). Any changes in monitoring protocols, field methods, and SOPs from those contained in RAMP (2005b) are noted below.

Quality Assurance and Quality Control (QA/QC) procedures were employed throughout and for all aspects of the monitoring conducted under RAMP in 2007. Appendix B contains a detailed description of the QA/QC procedures used for RAMP monitoring in 2007.

All 2007 monitoring data collected under RAMP have been added to the RAMP database, which is located in the members' area of the RAMP website at www.ramp-alberta.org. The 2007 data tables are included on the CD-ROM accompanying the final 2007 technical report.

3.1 CLIMATE AND HYDROLOGY

3.1.1 Overview of 2007 Activities

The climate and hydrology monitoring program for 2007 included the following:

- Monitoring an extensive set of climate variables at the Aurora Climate Station;
- Monitoring a number of climate variables at five other stations, with temperature and precipitation being monitored at most of these other stations;
- Conducting regional snow course surveys in February, March and April;

- Monitoring water levels and stream flows and collecting water samples for total suspended solids (TSS) analysis[1] at:
  - 11 hydrometric stations in the Muskeg River basin;
  - 12 hydrometric stations on other Athabasca River tributaries north of Fort McMurray;
  - 3 hydrometric stations on other Athabasca River tributaries south of Fort McMurray; and
  - 1 hydrometric station on the Athabasca River;
- Monitoring winter discharges at fifteen of the streamflow stations;
- Monitoring water levels at three lake / wetland stations; and
- Integrating regional climatic and hydrometric monitoring data collected by government agencies, the Wood Buffalo Environmental Association (WBEA) and oil sands operators into the RAMP database.

Locations of RAMP and federal and provincial government active and discontinued climate and hydrology stations, and 2007 snowcourse survey sites, are shown in Figure 3.1-1. Stations are identified by station number only in Figure 3.1-1; the corresponding station names are provided in Table 3.1-1.

3.1.2 Field Methods

3.1.2.1 General

Field staff visited the climate and hydrometric stations routinely (i.e., ten times per year for year-round stations and five times during the period of operation of seasonal stations) to check and maintain automated sensing equipment and to make manual streamflow measurements. Manual streamflow measurements are necessary for the development and refinement or adjustment of a stage-discharge relationship, which is used to convert continuously recorded water levels to discharge.

3.1.2.2 Streamflow Measurement

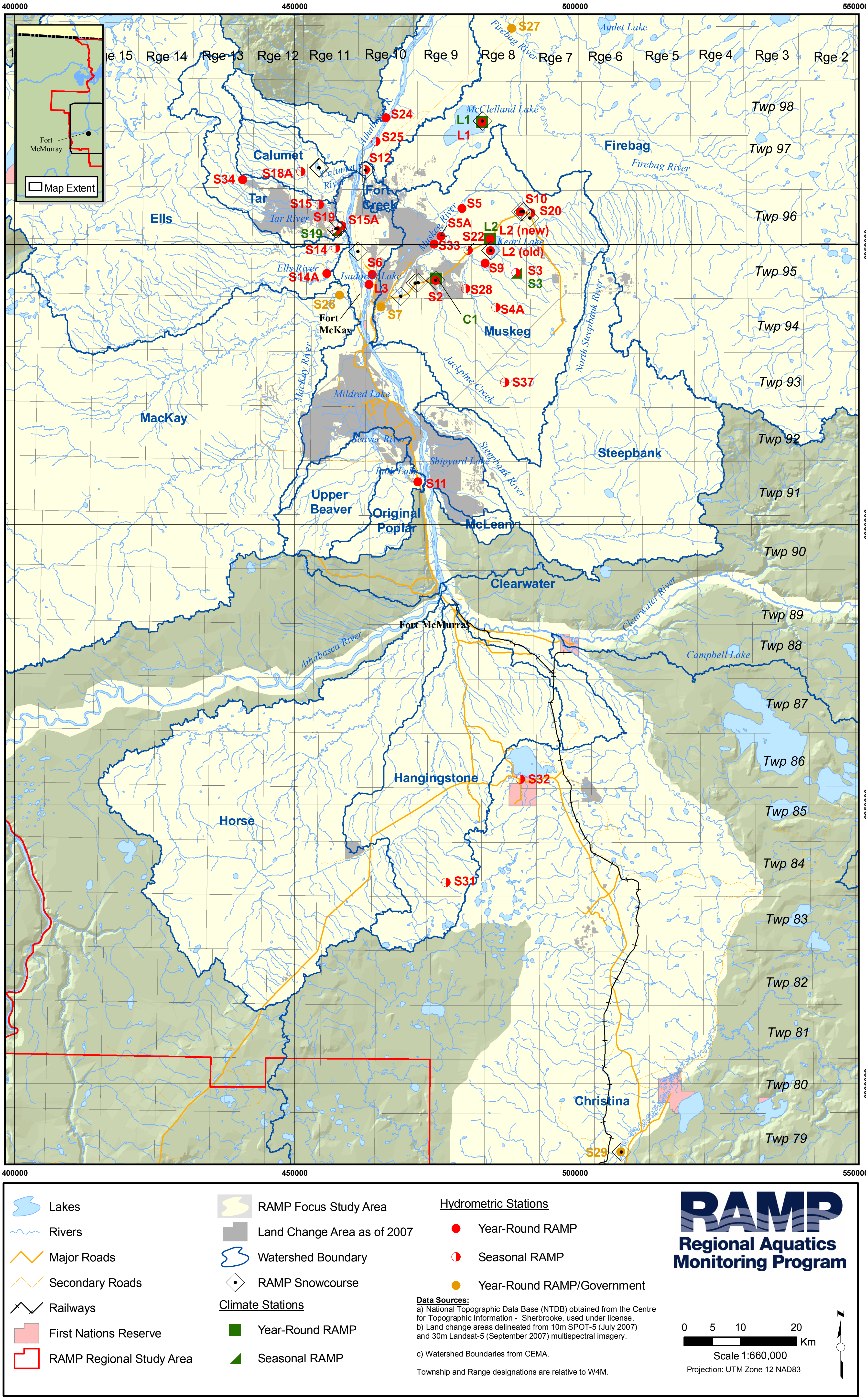
Streamflow measurement procedures and standards are based on recommendations by the Water Survey of Canada (WSC 2001), the United States Geological Survey (USGS 1982), the BC Ministry of Environment, Lands and Parks (BC MOELP 1998).

Measurements were made by wading or from a bridge or a boat. Measurement standards are summarized briefly below:

- Number of verticals: 20, or at a spacing of 0.1 m in small streams;
- Number of readings in the vertical for an open-water measurement: one at 60% of the depth below the surface for depths of 1.1 m or less; otherwise one at 20% and one at 80% of the depth;
- Number of readings in the vertical for a measurement under ice: one at 60% of the depth below the surface for depths of 1.0 m or less; otherwise one at 20% and one at 80% of the depth; and
- Velocity averaging: At least 20 seconds for electromagnetic meters; 45 seconds for mechanical meters.

[1] TSS is sampled five times during the open-water (summer) season. Water levels are monitored at 15-minute intervals and converted to streamflow. An exception to this is in some of the small streams in winter, where it is expected that the stream will freeze to depth. In those cases monthly flow measurements are taken during the winter season.

Figure 3.1-1 Locations of RAMP climate and hydrology stations, and snowcourse survey sites, 2007.



Data Sources:
a) National Topographic Data Base (NTDB) obtained from the Centre for Topographic Information - Sherbrooke, used under license.
b) Land change areas delineated from 10m SPOT-5 (July 2007) and 30m Landsat-5 (September 2007) multispectral imagery.

c) Watershed Boundaries from CEMA.

Township and Range designations are relative to W4M.

K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_D_CH_20080303.mxd

Table 3.1-1 RAMP climate and hydrology stations operating in 2007.

No.	Name	UTM Coordinates[1] Easting	Northing	Operating Season	Parameters Measured
C1	Aurora Climate Station	475230	6344049	All year	Air temperature, total precipitation, humidity, solar radiation, snow on the ground, wind speed and direction
L1	McClelland Lake	483430	6371950	All year	Water level, air temperature, humidity, total precipitation, snowfall
L2	Kearl Lake	484935[2] 485250[3]	6349023[2] 6351050[3]	All year	Water level, total precipitation, humidity, air temperature, water temperature
L3	Isadore's Lake	463297	6342987	All year	Water level
S2	Jackpine Creek at Canterra Road	475132	6343680	All year	Level, discharge, water temperature
S3	Iyinimin Creek above Kearl Lake	489491	6345029	Open-water	Level, discharge, rainfall
S5	Muskeg River above Stanley Creek	479820	6356551	All year	Level, discharge
S5A	Muskeg River above Muskeg Creek	476100	6351600	All year	Level, discharge, barometric pressure, water temperature
S6	Mills Creek at Highway 63	463829	6344743	All year	Level, discharge
S7	Muskeg River near Fort McKay (07DA008)	465408	6338944	Winter[4]	Level, discharge
S9	Kearl Lake Outlet	483980	6346750	All year	Level, discharge
S10	Wapasu Creek at Canterra Road	490272	6355942	All year	Level, discharge
S11	Poplar Creek at Highway 63 (07DA007)	471998	6307667	All year	Level, discharge
S12	Fort Creek at Highway 63	462600	6363400	Open-water	Level, discharge
S14	Ells River above Joslyn Creek	457310	6349466	Open-water	Level, discharge
S14A	Ells River at the CNRL Bridge	455748	6344947	All year	Level, discharge, water temperature
S15A	Tar River near the Mouth	458395	6353391	Open-water	Level, discharge, water temperature
S18A	Calumet River Upland Tributary	452702	6367295	Open-water	Level, discharge
S19	Tar River Lowland Tributary near the Mouth	457502	6352663	Open-water Winter	Level, discharge, rainfall Snowfall
S20	Muskeg River Upland	492106	6355709	Open-water	Level, discharge
S22	Muskeg Creek near the Mouth	480970	6349071	Open-water	Level, discharge
S24	Athabasca River below Eymundson Creek	466313	6372760	All year	Level, discharge
S25	Susan Lake Outlet			Open-water	Level, discharge
S26	MacKay River near Fort McKay (07DB001)	458120	6341037	Winter[4]	Level, discharge
S27	Firebag River near the mouth (07DC001)	489553	6388830	Winter[4]	Level, discharge
S28	Khahago Creek below Black Fly Creek	480489	6342185	Open-water	Level, discharge
S29	Christina River near Chard (07CE002)	508195	6187926	Winter[4]	Level, discharge
S31	Hangingstone Creek near the mouth	476713	6235953	Open-water	Level, discharge
S32	Surmont Creek at Highway 31	490310	6254473	Open-water	Level, discharge
S33	Muskeg River at the Aurora/Albian Boundary	474876	6350204	All year	Level, discharge
S34	Tar River above CNRL Lake	440729	6361689	All year	Level, discharge, water temperature
S37	East Jackpine Creek near 1300 m contour	485905	6338825	Open-water	Level, discharge

[1] UTM coordinate datum is NAD83.

[2] Until August 9, 2007.

[3] After August 9, 2007.

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

Details of the measurement procedures used for the Climate and Hydrology component are provided in the RAMP Design and Rationale Document. Quality assurance and quality control procedures are provided in Appendix B.

For snow course surveys, a sampling site was established at each snow course survey site and snow depths were measured at 40 locations at a 10 m spacing. At least four samples were taken for density measurements using an Adirondack snow density gauge. Snow depth and the sample mass were recorded for each density sample to allow calculation of the snow water equivalent and snow density.

3.1.3 Changes in Monitoring Program from 2006

3.1.3.1 New Monitoring Stations

A new streamflow station was established in the Muskeg River watershed to monitor runoff upstream of development. Station S37, East Jackpine Creek near the 1300 m Contour, replaces Station S4, Blackfly Creek near the Mouth, which was discontinued in 1998. The S4 station location is now within a planned development area, and therefore its replacement was established further upstream. East Jackpine Creek is a tributary of Jackpine Creek and was formerly known as Hartley Creek.

Imperial Oil initiated the establishment of a new climate station on the shore of Kearl Lake to support water balance analyses for the lake. The year-round station monitors precipitation, humidity, and air and water temperature.

3.1.3.2 Modified Stations

The following stations were modified in 2007:

- The Kearl Lake water level station (Station L2) was relocated to the site of the Kearl Lake climate station on August 9, 2007. The new site is the same as the location used for the lake level station during the period 1999 to 2002;
- At CNRL's request, Station S34, Tar River above CNRL Lake, was changed from open-water to year-round operation;
- Station S12, Fort Creek at Highway 63, was moved upstream at the beginning of the open-water season to avoid potential backwater effects from the Athabasca River; and
- Station S15, designated as Tar River near the Mouth, was moved even nearer to the mouth of the Tar River at the beginning of the open-water season to capture flow diverted out of the original channel as part of CNRL Horizon development. The station was renamed to Station S15A.

3.1.3.3 Discontinued Stations

Station S14, Ells River above Joslyn Creek, was decommissioned at the end of the 2007 open-water season. That station has been replaced by Station S14A, Ells River at the CNRL Bridge, which operates year-round. The two stations were operated concurrently for three years to provide a period of record for correlation of the measurements at the two stations.

3.1.4 Challenges Encountered and Solutions Applied

Historical monitoring at McClelland Lake has included lake level measurements and spot measurements of flow at the lake outlet, but attempts to develop a stage-discharge curve for the outlet have been hampered by poor hydraulic conditions there. Flow is not confined to a defined channel, but is diffused through a wide vegetated area. Annual wetland vegetation changes introduce unacceptable levels of variability in the stage-discharge relationship. Therefore, lake levels have historically been reported but outflows have not.

Petro-Canada wishes to monitor the water balance of McClelland Lake and requested the installation of streamflow stations to monitor lake inflow and outflow. Climate and Hydrology field crews spent considerable effort and helicopter time in attempts to find appropriate streamflow station locations upstream and downstream of the lake. However, they did not find any locations where either the inflow or the outflow were confined to measurable channels close enough to the lake to be useful for analysis. The proposed solution for outflow information is to install a combined depth and velocity sensor at the lake outlet and use the velocity data to support a more detailed analysis of the stage-outflow relationship, which accounts for dynamic vegetation effects, and produces reasonable flow estimates. A second sensor is proposed to be installed near the mouth of the outlet channel, upstream of the Firebag River. The difference between the two stations represents runoff from a relatively undisturbed catchment similar to the McClelland Lake catchment, so that the data from the two stations may be used to estimate McClelland Lake inflows.

3.1.5 Other Information Obtained

Climate and hydrometric information collected by other organizations was obtained and has been incorporated into the RAMP database. These agencies include the Meteorological Service of Canada (MSC) and the WSC (both agencies of Environment Canada), Alberta Environment (AENV), Alberta Sustainable Resource Development (ASRD), and the WBEA. Some of the data obtained were provisional because the collecting organization had not completed its quality control procedures at the time the data were provided to RAMP, and are flagged as such in the RAMP database.

3.1.6 Summary of Component Data Now Available

The climate and hydrology data collected to date for RAMP are summarized in Table 3.1-2. The table includes data collected by government agencies at combined government/RAMP stations.

3.1.7 Analytical Approach

3.1.7.1 Overall Approach

The analysis of the hydrologic data consisted of treating each watershed containing focal projects as both *reference* and *potentially influenced*. The observed hydrograph at a station was used as the operational case, and a baseline hydrograph for the station was generated using both land change information and water withdrawal and discharge information for the watershed. This approach isolates any influence of focal projects on the 2007 hydrograph from the effects of spatial and temporal variability. Additional details regarding this analytical approach are found in RAMP (2005b).

Table 3.1-2 Summary of RAMP data available for Climate and Hydrology component.

see symbol key at bottom

WATERBODY AND LOCATION	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Mainstem																																													
Athabasca River below Eymundson Creek	S24																		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Athabasca River Tributaries																																													
Mills Creek at Highway 63	S6		2	2	2		2	2	2		2	2	2		2e	2e	2e		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Poplar Creek at Highway 63 (07DA007)	S11		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fort Creek at Highway 63	S12														2	2	2		2	2	2		2g	2g	2g														2	2	2		2	2	2
Ells River above Joslyn Creek	S14																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Ells River at the CNRL Bridge	S14A																																	2g	2g	2g	2g	2g	2g	2g	2g	2	2	2	2
Tar River near the Mouth	S15																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Tar River near the Mouth	S15A																																										2g	2g	2g
Calumet River near the Mouth	S16																		2	2	2		2h	2h	2h		2h	2h	2h	h	2h	2h	2h	h	i	i									
Tar River Upland Tributary	S17																		2	2	2		2	2	2		2	2	2		2	2	2												
Upland Calumet River	S18																		2	2	2																								
Calumet River Upland Tributary	S18A																						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Tar River Lowland Tributary near the Mouth	S19																		2	2	2		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a	b	2a	2a	2a
Susan Lake Outlet	S25																						2	2	2														2	2	2		2	2	2
MacKay River near Fort McKay (07DB001)	S26		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2			
Firebag River near the Mouth (07DC001)	S27		4	4	4		4	4	4		4	4	4		4	4	4		4	4	4	2	4	4	4		4	4	4	2	4	4	4	2				2	4	4	4	2			
Tar River above CNRL Lake	S34																																		2	2	2		2	2	2	2g	2g	2g	2g
Fort Creek Basin Snowcourse Survey															d																														
CNRL Area Snowcourse Survey																			d				d				d																		
Clearwater River Tributaries																																													
Christina River near Chard (07CE002)	S29																					2	4a	4a	4a	2	4a	4a	4a	2	4	4	4	2	4	4	4	2	4	4	4	2			
Hangingstone River at Highway 63	S30																						2	2	2																				
Hangingstone Creek near the Mouth	S31																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2
Surmont Creek at Highway 31	S32																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2

Legend

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

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

potentially influenced (blue)
reference (green)

Table 3.1-2 (Cont'd.)

see symbol key at bottom

WATERBODY AND LOCATION	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Muskeg River Basin																																													
Aurora Climate Station	C1	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
Alsands Drain	S1		2	2			2	2	2		2	2	2	2					2	2	2	2	2	2	2																				
Jackpine Creek at Canterra Road	S2		2	2	2		2	2			2	2			2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2g	2g	2g	2g
Iyinimin Creek above Kearl Lake	S3		2	2	2		2a	2a	2a		2a	2a	2a						2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a
Blackfly Creek near the Mouth	S4		2	2	2		2	2	2																																				
Muskeg River above Stanley Creek	S5																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Muskeg River above Muskeg Creek	S5A		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i	2i
Muskeg River near Fort McKay (07DA008)	S7		4	4	4		4	4	4	4	4	4	4		4	4	4		4	4	4	2	4	4	4	2	2	2	2	2	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2
Stanley Creek near the Mouth	S8											1	1		1	1	1		1	1	1		1	1	1		1	1	1																
Kearl Lake Outlet	S9						2	2	2		2e	2e	2e						2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Wapasu Creek at Canterra Road	S10										2	2	2						2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Albian Pond 3 Outlet	S13														2	2	2		2	2	2		2	2	2																				
Muskeg River Upland	S20																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Shelley Creek near the Mouth	S21																		2	2	2		2	2	2		2	2	2																
Muskeg Creek near the Mouth	S22																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Aurora Boundary Weir	S23																	2	2	2	2	2	2	2	2																				
Khahago Creek below Black Fly Creek	S28																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2
Muskeg River at the Aurora/Albian Boundary	S33																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
East Jackpine Creek near 1300 m Contour	S37																																										2	2	2
Muskeg River Basin Snowcourse Survey			d				d				d				d				d																										
Muskeg River High Water Gauging				3				3				3				3				3																									
Jackpine Creek High Water Gauging				3				3												3																									
Wetlands and Lakes																																													
Isadore's Lake	L3													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kearl Lake	L2										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1j	1j	1j	1j
McClelland Lake	L1			2	2		2	2	2		2	2	2		2	2	2		2	2	2	1	2a	2a	2a	1	2a	2a	2a	1	2a	2a	2a	1	2a	2a	2a	2a	2a	2a	2c	1j	1j	1j	1j
Regional Data																																													
Wide-Area Snowcourse Survey																														d				d				d				d			
Compilation of Environment Canada data		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Legend

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

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

potentially influenced
reference

3.1.7.2 Analytical Approach for 2007

The RAMP 2007 hydrology analysis consisted of the following steps:

- Estimation of the 2007 baseline hydrographs;
- Review and selection hydrologic measurement endpoints, and generation of measurement endpoint values from the baseline and operational hydrographs; and
- Application of criteria to be used in assessing change in the hydrologic measurement endpoints.

3.1.7.3 Estimation of 2007 Baseline Hydrographs

Baseline hydrographs are defined for this analysis as the hydrograph that would have be observed if no focal project activities had ever occurred upstream in the watershed. The baseline hydrograph may include the effects of activities from other development projects in the watershed, and so is not necessarily a naturalized hydrograph. The baseline hydrograph is derived for the purpose of assessing any incremental effects of focal projects.

Baseline hydrographs were estimated for the outlet of each major watershed by adding water withdrawals and subtracting water releases from the observed hydrographs as follows:

Baseline Hydrograph = Observed (Operational) Hydrograph

+ Natural runoff that would have occurred from land change areas that are closed-circuited

- Incremental runoff that would have occurred from land change areas that are not closed-circuited or are being dewatered. Incremental runoff depth from these areas is assumed to 20% greater than runoff from areas of the catchment without land change

+ Water withdrawals from the watercourse in question by focal projects

- Water releases to the watercourse in question by focal projects

± Runoff from areas that have been diverted into (-) or out of (+) the watershed in question

- The difference between baseline and operational hydrographs on tributaries upstream of the station in question

The approach does not account for indirect effects of focal projects on streamflow, such as groundwater influences on surface water. It also does not account for the fact that an increase or decrease in catchment area affects the catchment responsiveness. In addition, the assumption of a 20% increase in runoff from land change areas that are not closed-circuited, while based on the professional judgment of members of the Climate and Hydrology subgroup under the RAMP Technical Program Committee, ignores the changes in runoff timing and catchment responsiveness that can be associated with activities that give rise to this type of land change designation, such as land clearing. Predicted effects during low flow periods are less robust than predicted effects during high flow periods. Monitoring reference catchments in RAMP provides a secondary basis for comparison. Considering these simplifications, however, the values estimated for the hydrologic measurement endpoints are appropriate for the objectives of this monitoring report in that the calculated measurement endpoints indicate the approximate magnitude of changes in the catchments.

3.1.7.4 Review, Selection, and Generation of Hydrologic Measurement Endpoints

The RAMP Technical Design and Rationale document (RAMP 2005b) outlines the following measurement endpoints to be used in the analysis of the hydrologic data:

- Mean open-water (1 May to approximately 31 October) season discharge;
- Mean winter (1 November to 31 March) discharge;
- Annual maximum daily discharge; and
- Open-water season minimum daily discharge.

These measurement endpoints are hydrologic measurement endpoints used in various oil sands project EIAs (RAMP 2005b), that can be computed from one year of data, and were selected for the analysis of the 2007 data. Preliminary estimates of additional endpoints, such as the 1:10 year flood flow or the $7Q_{10}$ low flow, can be added to the analysis with two to three years of additional information, when multiple years of both baseline and operational data are available for watersheds with areas designated as *potentially influenced*. Values for each of these four measurement endpoints were calculated for the operational and baseline hydrographs and a percent change in the measurement endpoints between the operational and baseline values was calculated.

3.1.7.5 Application of Criteria for Determining Effects

The percent change in the measurement endpoints calculated between the operational and baseline hydrographs were used for the assessment of hydrologic effects as follows: ± 2% - Negligible; ± 5% - Low; ± 15% - Moderate; > 15% - High. These ranges were derived from criteria for determining effects on hydrologic measurement endpoints in a number of EIAs prepared for oil sands projects (RAMP 2005b) and were reviewed by the RAMP Technical Subcommittee in March 2008.

3.2 WATER QUALITY COMPONENT

3.2.1 Summary of 2007 Monitoring Activities

Monitoring activities in 2007 for the Water Quality component were conducted in four sampling campaigns (Table 3.2-1). Rivers and lakes in the RAMP FSA were sampled to document water quality and assess any changes in water quality that may be occurring due to focal projects or other factors affecting the natural environment.

Table 3.2-1 RAMP water quality sampling field campaigns, 2007.

Season	Duration
Winter	March 20 to 21
Spring	May 16 to 17
Summer	July 16 to 20
Fall	September 5 to 16

Water quality sampling in 2007 focused on the Athabasca River and its major tributaries in the Athabasca oil sands region, as well as regionally-important lakes and wetlands. Additional data were contributed by AENV and operators of individual focal projects for some locations. Water quality was examined at a total of 46 RAMP stations in 2007. Table 3.2-2 summarizes the location of the 2007 water quality sampling stations, seasonal distribution of the sampling effort, and water quality variables measured at each station, Figure 3.2-1 indicates the locations of the water quality stations sampled in 2007. Sampling intensity was greatest during the fall campaign, with samples collected from all 2007 RAMP monitoring stations in that season (Table 3.2-2).

Table 3.2-2 Summary of sampling for the RAMP 2007 Water Quality component.

Station Identifier and Location		UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	W	S	S	F	
Athabasca River								
ATR-DC-CC	Athabasca River upstream of Donald Creek (cross-channel)	475000	6298313	-[1]	-	-	1	Cross channel composite
ATR-DC-E	Athabasca River upstream of Donald Creek (east bank)	475080	6298313	-	-	-	1	East bank grab
ATR-DC-W	Athabasca River upstream of Donald Creek (west bank)	474783	6298332	-	-	-	1	West bank grab
ATR-DD-E	Athabasca River downstream of all development (east bank)	463766	6367816	1	1	1	1	East bank grab
ATR-DD-W	Athabasca River downstream of all development (west bank)	462791	6367681	1	1	1	1	West bank grab
ATR-FR	Athabasca River upstream of the Firebag River	478323	6400319	-	-	-	1	Cross channel composite
ATR-MR-E	Athabasca River upstream of the Muskeg River (east bank)	463504	6332230	-	-	-	1	East bank grab
ATR-MR-W	Athabasca River upstream of the Muskeg River (west bank)	463012	6332276	-	-	-	1	West bank grab
ATR-OF	Athabasca River at Old Fort (sampled monthly)	470205	6474330	12	12	12	12	AENV Sampling
ATR-SR-E	Athabasca River upstream of the Steepbank River (east bank)	471068	6319578	-	-	-	1	East bank grab
ATR-SR-W	Athabasca River upstream of the Steepbank River (west bank)	470738	6319216	-	-	-	1	West bank grab
ATR-UFM	Athabasca River upstream of Fort McMurray (monthly)	474901	6286327	13	11	13	11	AENV sampling
Tributaries to the Athabasca River (Eastern)								
FOC-1	Fort Creek	461539	6363105	-	-	-	7	Mid-channel grab
MCC-1	McLean Creek (mouth)	474636	6306054	-	-	-	9	Mid-channel grab
Steepbank River								
NSR-1	North Steepbank River	497438	6324318	-	-	-	1	Mid-channel grab
STR-1	Steepbank River (mouth)	471314	6320162	-	-	-	1	Mid-channel grab
STR-2	Steepbank River upstream of Suncor Millennium	485904	6309107	-	-	-	1	Mid-channel grab
STR-3	Steepbank River upstream of North Steepbank River	495074	6300008	-	1	1	1	Mid-channel grab
Muskeg River and Muskeg River Tributaries								
MUR-1	Muskeg River (mouth)	463622	6332482	-	-	-	1	Mid-channel grab
MUR-2	Muskeg River upstream of Canterra Road crossing	466576	6340478	4	4	4	4	Industry sampling
MUR-2	Muskeg River downstream of Canterra Road crossing	465545	6338322	15	15	15	14	AENV sampling
MUR-4	Muskeg River upstream of Jackpine Creek	474379	6349075	4	10	10	10	Industry sampling
MUR-5	Muskeg River upstream of Muskeg Creek	476043	6351800	10	10	10	10	Industry sampling
MUR-6	Muskeg River upstream of Wapasu Creek	492174	6355472	-	-	-	7	Mid-channel grab
IYC-1	Iyinimin Creek (mouth)	489482	6344768	-	-	1	1	Mid-channel grab
JAC-1	Jackpine Creek (mouth)	475012	6343973	-	-	-	1	Mid-channel grab
MUC-1	Muskeg Creek (mouth)	481026	6348765	-	-	-	1	Mid-channel grab
SHC-1	Shelley Creek (mouth)	475025	6349048	-	-	-	1	Mid-channel grab
STC-1	Stanley Creek (mouth)	477453	6356422	-	-	-	1	Mid-channel grab
WAC-1	Wapasu Creek at Canterra Road crossing	490339	6355704	-	-	-	1	Mid-channel grab
Firebag River								
FIR-1	Firebag River (mouth)	479363	6400434	-	-	-	1	Mid-channel grab
FIR-2	Firebag River upstream of Suncor Firebag	531543	6354925	-	-	-	1	Mid-channel grab

Table 3.2-2 (Cont'd.)

Station Identifier	and Location	UTM Coordinates (NAD83, Zone 12)		Analytical Package by Season				Sample Type
		Easting	Northing	W	S	S	F	
Tributaries to the Athabasca River (Western)								
BER-1	Beaver River (mouth)	463636	6330911	-	-	-	1	Mid-channel grab
CAR-1	Calumet River (mouth)	460713	6363190	-	-	-	1	Mid-channel grab
CAR-2	Calumet River (upper river)	454096	6366532	1	1	1	2	Mid-channel grab
ELR-1	Ells River (mouth)	459280	6351303	-	-	-	1	Mid-channel grab
ELR-2	Ells River (upstream)	455828	6344721	-	1	1	1	Mid-channel grab
MAR-1	MacKay River (mouth)	461321	6336060	-	-	-	1	Mid-channel grab
MAR-2	MacKay River upstream of Petro-Canada MacKay	444682	6314024	-	-	-	1	Mid-channel grab
POC-1	Poplar Creek (mouth)	472957	6308769	-	-	-	1	Mid-channel grab
TAR-1	Tar River (mouth)	458869	6353532	-	-	-	1	Mid-channel grab
TAR-2	Tar River upstream of CNRL Horizon	440330	6361565	-	1	1	2	Mid-channel grab
Tributaries to the Athabasca River (Southern)								
HAR-1	Hangingstone River upstream of Fort McMurray	478654	6276269	-	1	1	1	Mid-channel grab
Clearwater River								
CLR-1	Clearwater River upstream of Fort McMurray	480766	6284005	-	7	7	7	Mid-channel grab
CLR-2	Clearwater River upstream of Christina River	496120	6280513	-	7	-	7	Mid-channel grab
Christina River								
CHR-1	Christina River upstream of Fort McMurray	496646	6280035	1	-	-	1	Mid-channel grab
CHR-2	Christina River upstream of Janvier	511834	6192351	1	-	-	1	Mid-channel grab
CHR-2A	Christina River (mid)	532257	6236334	1	-	-	1	Mid-channel grab
Lakes and Wetlands								
ISL-1	Isadore's Lake	463481	6343377	-	-	16	16	Mid-lake grab
KEL-1	Kearl Lake	485011	6350205	-	-	16	16	Multi-location composite
MCL-1	McClelland Lake	478120	6370910	-	-	-	16	Mid-lake grab
SHL-1	Shipyard Lake	473430	6313408	-	-	16	16	Mid-lake grab
QA/QC[2]								
-				1	1	1	1	Trip and field blanks, split, duplicate

[1] Winter sampling at ATR-DC-CC planned but not possible, due to open leads that prevented safe site access and sampling.

[2] Results of the QA/QC analysis for the Water Quality component are presented in Appendix B.

Legend to Analytical Packages:

1. *RAMP standard (conventionals, major ions, nutrients, tot./dissolved metals, recoverable hydrocarbons, naphthenic acids, phenols)*
2. *RAMP standard + toxicity*
3. *RAMP standard + PAHs*
4. *RAMP standard + PAHs + toxicity*
5. *OPTI Lakes analytical package*
6. *Continuously-monitoring thermograph*
7. *RAMP standard + thermograph*
8. *RAMP standard + PAHs + thermograph*
9. *RAMP standard + toxicity + thermograph*
10. *RAMP standard + PAHs + toxicity + thermograph*
11. *AENV routine*
12. *AENV routine + RAMP standard*
13. *AENV routine + PAHs*
14. *AENV routine + DataSonde*
15. *AENV routine + PAHs + DataSonde*
16. *RAMP standard + chlorophyll-a*

3.2.2 Summary of Field Methods and Sample Analysis

Station locations were identified using GPS coordinates, Alberta Forestry, Lands and Wildlife Resource Access Maps, and where applicable, written descriptions from past RAMP reports. Stations were accessed by boat, helicopter, snowmobile, and/or four-wheel drive vehicle.

At all water quality stations, *in situ* measurements of dissolved oxygen (DO), temperature and conductivity were collected using an YSI Model 650 multi-probe water meter or a handheld thermometer (temperature), a handheld conductivity meter (conductivity) and a LaMott portable Winkler titration kit (dissolved oxygen).

Field sampling involved collecting either single grab samples of water from smaller creeks or rivers, collection of cross-channel composite samples or bank-adjacent grab samples in large rivers, and collection of multi-location composites in lakes and wetlands.

Grab samples were collected by submerging each sample bottle to a depth of approximately 30 cm, uncapping and filling the bottle, and recapping at depth. Each bottle was triple-rinsed using this procedure prior to the final sample collection.

Composite samples were collected at stations where average concentrations of monitored variables were desired, including lentic waterbodies (i.e., lakes or wetlands) and selected stations along the Athabasca River. Composites were collected through combining a series of 2 L grabs collected at regularly-spaced intervals (Table 3.2-3) into a triple-rinsed polymer bucket. Samples were removed from the composite bucket with a clean glass vessel and transferred to laboratory-supplied sample bottles. Caution was taken to ensure that the composite sample remained covered when not in use and that no contaminants were introduced during the course of sub-sampling. As with single grabs, all sample bottles were triple-rinsed prior to sample collection.

Samples taken at mouths of tributaries were collected approximately 100 m upstream of the confluence where possible to avoid influences of mainstem water on sampled water quality at each station. Similarly, stations located on river mainstems near tributaries were sampled approximately 100 m upstream of the tributary confluence.

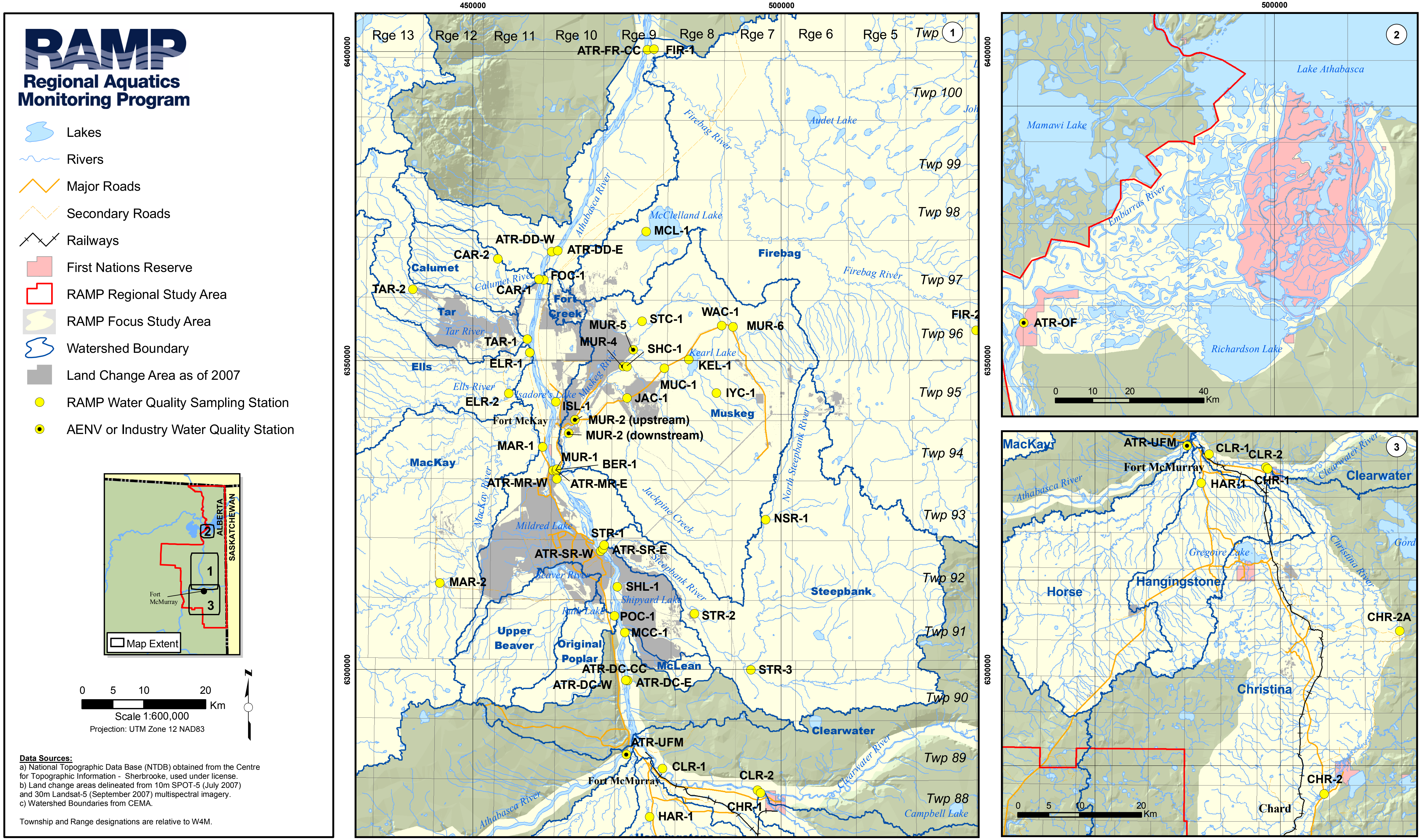
Sampling methods were modified during winter in response to environmental conditions, and to account for and preclude any sampling error or contamination associated with the requisite use of secondary sample transfer vessels and ice augers (all waterbodies sampled during other seasons were free of ice). Water was collected through holes in the river/lake ice drilled using a gas-powered auger. For single grab samples, one hole was drilled at the estimated stream thalweg; multiple holes were drilled for cross-channel composites following guidelines outlined in Table 3.2-3.

Samples were collected from approximately 0.2 m below the bottom of the ice layer using a 2 L Van Dorn sampler, to minimize the possibility of contaminant introduction associated with augering. Each grab was composited into a triple-rinsed polymer bucket. Composite water was transferred to individual sample bottles using a clean, triple-rinsed glass vessel, and then preserved as required. All intermediate sampling equipment and final sample collection bottles were triple rinsed prior to final sample collection.

Table 3.2-3 RAMP water quality composite sample sub-groups.

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

Figure 3.2-1 RAMP water quality sampling locations, 2007.



K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_E_Water_20080303.mxd

Four HOBO® Water Temp Pro automatic temperature sensor/data-loggers for collection of open-water temperature data were deployed during the spring sampling campaign (Table 3.2-4). Each sensor was attached to a steel rod anchored in the stream substrate in a pool or other deep area that was expected to contain water for the entire monitoring period. All sensors were programmed to collect temperature data at 15-minute intervals for the duration of their installation.

Table 3.2-4 Locations of 2007 continuous water temperature monitoring stations.

Location	Installation Date	Removal Date	Comments
Clearwater River (station CLR-1)	May 16, 2007	Sept 6, 2007	dry when removed
Clearwater River (station CLR-2)	May 16, 2007	Sept 6, 2007	dry when removed
Fort Creek (station FOC-1)	May 17, 2007	Sept 6, 2007	in the water when removed
Muskeg River (station MUR-6)	May 17, 2007	Sept 12, 2007	in the water when removed
McLean Creek (station MCC-1)	June 26, 2007	Sept 10, 2007	in the water when removed

All water samples were collected, filtered where appropriate (dissolved organic carbon only), preserved and shipped according to protocols specified by consulting laboratories. All water quality samples taken in 2007 were analyzed for the RAMP standard variables (Table 3.2-5) in all sampling seasons (ALS in Fort McMurray for conventional water quality variables, organics/hydrocarbons, and Alberta Research Council (ARC) in Vegreville for total and dissolved metals, including ultra-trace total mercury). In addition:

- Samples collected from regional lakes were analyzed for chlorophyll *a* (ALS); and
- Water sampled from three stations during the fall sampling campaign (McLean Creek, station MCC-1; Tar River upstream, station TAR-2; and Calumet River upstream, station CAR-2) was analyzed by Hydroqual Laboratories in Calgary for sublethal toxicity to aquatic organisms using the following three tests: algal growth inhibition, using the freshwater alga, *Pseudokirchneriella subcapitata*[2]; Invertebrate survival and reproduction, using the cladoceran, *Ceriodaphnia dubia*; and Fish early life-stage survival and growth, using fathead minnows *(Pimephales promelas)*.

3.2.3 Changes in Monitoring Network from 2006

The 2007 monitoring network for the Water Quality component was the same as the 2006 monitoring network with the following exceptions:

- Station CHR-2A (mid Christina River, between CHR-1 and CHR-2) was added as a new station in order to identify a site more comparable to the lower Christina station (station CHR-1), as previous water quality conditions measured at station CHR-1 suggest the presence of a saline seep upstream of the station; and
- Station IYC-1 (Iyinimin Creek, a tributary to the Muskeg River) was added as a reference station.

[2] This species was formerly known as *Selanastrum capricornutum*

Table 3.2-5 RAMP standard water quality variables.

Group	Water Quality Variable	
Conventional variables	Colour	Total dissolved solids (TDS)
	Dissolved organic carbon (DOC)	Total hardness
	pH	Total organic carbon
	Conductivity	Total suspended solids
	Total alkalinity	
Major ions	Bicarbonate	Potassium
	Calcium	Sodium
	Carbonate	Sulphate
	Chloride	Sulphide
	Magnesium	
Nutrients	Nitrate + nitrite	Phosphorus – total
	Ammonia nitrogen	Phosphorus – dissolved
	Total Kjeldahl nitrogen	Chlorophyll *a*
Biological oxygen demand	Biochemical oxygen demand	
Organics	Naphthenic acids	Total recoverable hydrocarbons
	Total phenolics	
Total and dissolved metals	Aluminum (Al)	Lithium (Li)
	Antimony (Sb)	Manganese (Mn)
	Arsenic (As)	Mercury, ultra-trace[1] (Hg)
	Barium (Ba)	Molybdenum (Mo)
	Beryllium (Be)	Nickel (Ni)
	Bismuth (Bi)	Selenium (Se)
	Boron (B)	Silver (Ag)
	Cadmium (Cd)	Strontium (Sr)
	Calcium (Ca)	Thallium (Tl)
	Chlorine (Cl)	Thorium (Th)
	Chromium (Cr)	Tin (Sn)
	Cobalt (Co)	Titanium (Ti)
	Copper (Cu)	Uranium (U)
	Iron (Fe)	Vanadium (V)
	Lead (Pb)	Zinc (Zn)

[1] Total mercury (Hg) measured with a detection limit of 1.2 ng/L (0.0000012 mg/L).

3.2.4 Challenges Encountered and Solutions Applied

Due to unexpectedly large drops in water levels between spring and fall sampling periods in 2007, thermographs installed on the Clearwater River at stations CLR-1 and CLR-2 were above water when removed. In future years, thermographs installed on the Clearwater River (any other large rivers) will be moved farther in the water away from the riverbank in order to reduce the risk of ending up above water, and use a combined float-and-anchor system to reduce the potential for thermographs to be either buried by shifting sediments or left dry by dropping water levels.

Collection of a cross-channel composite sample in winter 2007 was planned at ATR-DC, upstream of Donald Creek (ATR-DC). However, this sample could not be collected due to open leads and broken ice along this reach during the winter 2007 sampling event, which made site access and sampling unsafe for field crews.

3.2.5 Other Information Obtained

All sampling for the Water Quality component in 2007 was conducted by the RAMP implementation team, with the exception of:

- Three stations on the mainstem Muskeg River (stations MUR-2, MUR-4 and MUR-5) that were sampled by Syncrude and Albian Sands (Table 3.2-2); and
- Two stations on the mainstem Athabasca River (stations ATR-UFM, ATR-OF) and one station on the mainstem Muskeg River (station MUR-2) that were sampled by AENV (Table 3.2-2).

In addition, AENV collects continuous year-round dissolved oxygen monitoring data on the Muskeg River upstream of Stanley Creek (station D2) with a DataSonde continuous water quality monitoring probe purchased by RAMP, as well as at station MUR-2. These supplemental data are provided to RAMP on an annual basis.

3.2.6 Summary of Component Data Now Available

The water quality data collected to date by RAMP are summarized in Table 3.2-6. Table 3.2-6 does not include data collected by AENV and industry partners.

3.2.7 Analytical Approach

The analytical approach used in 2007 for the Water Quality component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2005b) and consisted of:

- Review and selection of particular water quality variables as water quality measurement endpoints;
- Review and selection of criteria to be used in detecting changes in water quality measurement endpoints;
- Updating of regional baseline data ranges for each water quality measurement endpoint; and
- Tabular and graphical presentation of results comparing 2007 concentrations of water quality measurement endpoints, historical concentrations of each endpoint at each station, water quality regional baseline conditions, and selected criteria for determining change in water quality.

3.2.7.1 Review and Selection of Water Quality Measurement Endpoints

Depending on the analytical package (Table 3.2-2) over 100 water quality variables can be analyzed in a RAMP water quality sample. A number of these variables were selected as water quality measurement endpoints for this 2007 technical report; the selection of the measurement endpoints was guided by:

- Water quality measurement endpoints used in the EIAs of oil sands projects (see RAMP [2005b] for a review of these EIAs and specific predictions of relevance to the RAMP Water Quality component);

- A draft list of water quality variables of concern in the lower Athabasca region developed by CEMA (2004);
- Water quality variables of interest listed in the RAMP 5-year report (Golder 2003a);
- Results of correlation analysis of the RAMP 1997-2006 water quality dataset indicating significant inter-correlation of various water quality variables, particularly metals (RAMP 2006);
- Discussions among RAMP Component Managers about the importance of various water quality variables to assist in interpreting results of other RAMP components, particularly the Benthic Invertebrate Community component and the Fish Population component; and
- Discussions with RAMP Technical Program Committee regarding appropriate analytical strategies for the Water Quality component.

Table 3.2-7 presents the water quality variables listed in these various sources.

The final list of water quality measurement endpoints used in this report, and reasons for their inclusion, are:

- *pH:* an indicator of acidity;
- *Conductivity*: basic indicator of overall ion concentration;
- *Total suspended solids (TSS):* a variable strongly associated with several other measured water quality variables, including total phosphorus, total aluminum and numerous other metals;
- *Dissolved phosphorus, total nitrogen and nitrate+nitrite:* indicators of nutrient status. Dissolved phosphorus rather than total phosphorus is included because it is the primary biologically available species of phosphorus and because total phosphorus levels are strongly associated with TSS (RAMP 2006);
- *Various ions (sodium, chloride, calcium, magnesium, sulphate):* indicators of ion balance, which could be affected by discharges or seepages from focal projects or by changes in the water table and changes in the relative influence of groundwater;
- *Total alkalinity:* an indicator of the buffering capacity and acid-sensitivity of waters;
- *Total dissolved solids (TDS) and dissolved organic carbon (DOC):* indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively;
- *Total and dissolved aluminum:* aluminum is mentioned as a variable of interest in some oil sands EIAs, by CEMA, and in the RAMP 5-year report (Table 3.2-7). Total aluminum, for which water quality guidelines exist, has been demonstrated to be strongly associated with suspended solids (Golder 2003a). Dissolved aluminum more accurately represents biologically available forms of aluminum that may cause toxicity to aquatic organisms (Butcher 2001);

Table 3.2-6 Summary of RAMP data available for Water Quality component. (page 1 of 2)

see symbol key at bottom

WATERBODY AND LOCATION	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																													
Athabasca River upstream of Donald Creek (cross-channel)	ATR-DC-CC		1	1	1																				1				3				1	1	1	1	1	1			1				1
Athabasca River upstream of Donald Creek (east bank) [a]	ATR-DC-E								1								1				3				1				1				1	1	1	1	1				1				1
Athabasca River upstream of Donald Creek (middle)	ATR-DC-M																1																												
Athabasca River upstream of Donald Creek (west bank)[a]	ATR-DC-W								1								1				3				1				1				1	1	1	1	1				1				1
Athabasca River downstream of all development	ATR-DD																					1,1	1	1	3	1,1	1	1	3	1,1	1	1	3	1,1	1	1	1	1	1	1	1	1	1	1	1
Athabasca River upstream of the Embarras River (cross channel)	ATR-ER																1				3																								
Athabasca River upstream Fort Creek (cross channel)	ATR-1		1	1	1																																								
Athabasca River upstream Fort Creek (east bank) [a b]	ATR-FC-E								1								1				3				1				1								1								
Athabasca River upstream Fort Creek (middle)	ATR-FC-M																1																												
Athabasca River upstream Fort Creek (west bank) [a b]	ATR-FC-W								1								1				3				1				1								1								
Athabasca River upstream of the Firebag River	ATR-FR																								1				1				1				1				1				1
Athabasca River upstream of the Muskeg River (east bank) [a b]	ATR-MR-E								1								1				1				1				1				1				1				1				1
Athabasca River upstream of the Muskeg River (middle)	ATR-MR-M																1																												
Athabasca River upstream of the Muskeg River (west bank) [a b]	ATR-MR-W								1								1				1				1				1				1				1				1				1
Athabasca River at Old Fort (sampled monthly)[c]	ATR-OF													11	11	11	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12					12	12	12	12	12	12	12	12
Athabasca River upstream of the Steepbank River (east bank)	ATR-SR-E																1				1				1				1				1				1				1				1
Athabasca River upstream of the Steepbank River (middle)	ATR-SR-M																1																												
Athabasca River upstream of the Steepbank River (west bank)	ATR-SR-W																1				1				1				1				1				1				1				1
Athabasca River upstream of Fort McMurray (monthly)[d]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11					13	11	13	11	13	11	13	11
Embarras River	EMR-1																												1																
Athabasca River Delta																																													
Big Point Channel [e]	ARD-1											1					1				1								1				1				1								
Athabasca River Tributaries (Eastern)																																													
McLean Creek (mouth)	MCC-1											6	7		6	6	9		6	6	9	1	6	6	7		6	6	7		6	6	9		6	6	9		6	6	9				9
McLean Creek (100 m upstream)	MCC-2											6	6																																
North Steepbank River	NSR-1																					1	1	1	1	1	1	1	1	1	1	1	1		1	1	1				1				1
Steepbank River (mouth)	STR-1		1	1	1		1	1	1	1							1				1	1			1				1				1				1				1				1
Steepbank River upstream of Suncor Millennium	STR-2																					1			1				1				1				1				1				1
Steepbank River upstream of North Steepbank River	STR-3																													1	1	1	1	1	1	1	1		1	1	1		1	1	1
Athabasca River Tributaries (Southern)																																													
Christina River upstream of Fort McMurray	CHR-1																					1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3				1	1			1
Christina River upstream of Janvier	CHR-2																					1	1	1	3	1	1	1	3	1	1	1	1	1	1	1	3				1	1			1
Christina River (mid)	CHR-2A																																									1			1
Clearwater River upstream of Fort McMurray	CLR-1																	3	8	8	8	1	7	7	8	1	7	7	8	1	7	7	7	1	7	7	7	1	7	7	7		7	7	7
Clearwater River upstream of Christina River	CLR-2																	3	8	8	8	1	7	7	8	1	7	7	8		6	6	7	1	7	7	7		6	6	7		7		7
Hangingstone River upstream of Fort McMurray	HAR-1																														1	1	1		1	1	3		1	1	1		1	1	1
Athabasca River Tributaries (Western)																																													
Beaver River (mouth)	BER-1																																1			1	1				1				1
Calumet River (mouth)	CAR-1																					1	1	1	2	1	1	1	2	1	1	1	2		1	1	2				1				1
Calumet River (upper river)	CAR-2																																		1	1	2		1	1	2	1	1	1	2
Ells River (mouth)	ELR-1						1	1	1						11	11	11	11				1	1	1	2	1	1	1	2	1	1	1	2	1	1	1	2				1				1
Ells River (upstream	ELR-2														11	11	11	14												1	1	1	2		1	1	2		1	1	1		1	1	1
Firebag River (mouth)	FIR-1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1
Firebag River upstream of Suncor Firebag	FIR-2																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1				1
Fort Creek	FOC-1														7	7	9		6	6	7	1	6	6	7		6	6	7										6	6	7				7
MacKay River (mouth)	MAR-1								1								1				1	1			1								1				1				1				1
MacKay River upstream of Petro-Canada MacKay	MAR-2																					1			1	1	1	1	1				1				1				1				1
Poplar Creek (mouth)	POC-1																1				1	1			1				1				1				1				1				1
Tar River (mouth)	TAR-1						1	1	1													1	1	1	2	1	1	1	2	1	1	1	1		1	1	1				1				1
Tar River upstream of CNRL Horizon	TAR-2																													1	1	1	1		1	1	1		1	1	2		1	1	2

Legend

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

(blue) *potentially influenced*
(green) *reference*

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

Table 3.2-6 Cont'd. (page 2 of 2)

see symbol key at bottom

WATERBODY AND LOCATION	STATION	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Muskeg River																																													
Muskeg River (mouth)[f]	MUR-1		1	1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1				1				1				1				1				1
Muskeg River upstream of Canterra Road crossing [f]	MUR-2									2	9	9	9	10	10	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Muskeg River downstream of Canterra Road crossing [g]	MUR-2					13	13	13	11	13	13	13	11	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14	15	15	15	14
Downstream of Alsands Drain	MUR-3																																												
Muskeg River upstream of Jackpine Creek [f g h]	MUR-4					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10
Muskeg River upstream of Muskeg Creek [f g]	MUR-5					13	13	13	11	13,2	13,9	13,9	11,9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Muskeg River upstream of Wapasu Creek	MUR-6					2			2	2	9	9	9		6	6	9		6	6	9		6	6	9		6	6	7		6	6	9		6	6	9		6	6	7				7
Muskeg River Tributaries																																													
Alsands Drain (mouth) [f g h]	ALD-1					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10	4	10	10	10												
Iyinimin Creek (mouth)	IYC-1																																											1	1
Jackpine Creek (mouth) [f]	JAC-1					13	13	13	11	13	13	13	11,1				1				1				1				1				1				1				1				1
Muskeg Creek (mouth)	MUC-1								11,2				11,1				1				1				1				1				1		1	1	1				1				1
Shelley Creek (mouth)	SHC-1								11				11,1																												1				1
Stanley Creek (mouth)	STC-1								11				11,1								1	1	1	1	1	1	1	1	1				1		1	1	1				1				1
Wapasu Creek at Canterra Road crossing	WAC-1					2			11	2			11,1																				1				1				1				1
Wetlands and Lakes																																													
Isadore's Lake	ISL-1							1									1			1	1												1			1	1				16			16	16
Kearl Lake	KEL-1							1									1			1	1				1	1			1			1	1			1	1			16	16			16	16
McClelland Lake	MCL-1																1			1	1				1															16	16				16
Shipyard Lake	SHL-1							1			1	1	1			1	1			1	1			1	1			1	1			1	1			1	1				16			16	16
Additional Sampling (Non-Core Programs)																																													
Unnammed Creek north of Ft. Creek (mouth)	UNC-1															1	1																												
OPTI Lakes	-																		5		5		5		5														5		5				
Potential TIE	-																								√				√				√												
QA/QC																																													
Field and trip blanks, plus one split sample	-														1	1	1			1	1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Legend

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

Blue: *potentially influenced*
Green: *reference*

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

Table 3.2-7 Potential key water quality measurement endpoints.

Group	RAMP (2005b) Variables Listed in EIAs (No. of projects)	CEMA Variables of Concern (CEMA 2004)	RAMP 5-year report (Golder 2003a)	Variables to Support other RAMP Components[1]	Additional Suggested Variables[2]
Physical Variables	Temperature (3) Total suspended solids (9) Dissolved oxygen (3) Conductivity (1) pH (1)	(None)	pH Total suspended solids	Temperature Dissolved oxygen pH Total suspended solids Conductivity	
Nutrients	Ammonia-N (1) Total nitrogen (2) Total phosphorus (2)	Ammonia-N Total nitrogen Total phosphorus	Dissolved organic carbon Total Kjeldahl nitrogen Total phosphorus	Dissolved phosphorus Nitrate+nitrite	
Ions and Ion Balance	Chloride (2) Sulphide (2) Total dissolved solids (2)	Sodium Chloride Potassium **Fluoride** Sulphate	Total dissolved solids Sulphate Total alkalinity	Total alkalinity Hardness	Carbonate Bicarbonate Magnesium Calcium
Dissolved and Total Metals	Aluminum (3) Arsenic (2) Barium (2) Boron (1) Cadmium (3) Chromium (3) Copper (3) Iron (2) Manganese (2) Mercury (2) Molybdenum (1) Selenium (1) Silver (1) Zinc (1)	Aluminum Antimony Boron Cadmium Chromium Lithium Molybdenum Nickel Strontium Vanadium	Total chromium Total boron Total aluminum	Total & dissolved copper Total & dissolved lead Total & dissolved nickel Total & dissolved zinc Ultra trace mercury	Total strontium Total arsenic
Organics/ Hydrocarbons	Oil & grease (1) Naphthenic acids (1) Total phenolics (2)	Oil & grease Total hydrocarbons Naphthenic acids **Toluene** **Xylene**	(None)	(None)	(None)
PAHs	Benzo(a)anthracene (3) Benzo(a)pyrene (2) Misc. PAHs (3)	**Naphthalene** **Biphenyl** **Acenapthene** **Acenaphthylene** **Fluorene** **Fluoranthene** **Alkyl-naphthalenes** **Alkyl-biphenyls** **Alkyl-acenaphthene** **Alkyl-benzo(a)anthracene** **Alkyl-fluorenes** **Alkyl-phenanthrenes** **Dibenzothiophene** **Alkyl-dibenzothiophenes**	(None)	(None)	(None)
Effects-based Endpoints	Acute toxicity (1) Chronic toxicity (2)	Acute toxicity Chronic toxicity **Fish tainting**			

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

[1] Primarily Benthic Invertebrate Community and Fish Population Components (inferred).

[2] Suggested by the RAMP Technical Program Committee, February 2006 and February 2008, and from ongoing review of stakeholder concerns.

- *Total boron, total molybdenum, total strontium*: three metals found in predominantly dissolved form in waters of the RAMP FSA (RAMP 2004) and may therefore be indicators of groundwater influence in surface waters;
- *Total arsenic and total mercury (ultra-trace)*: metals of potential importance to the health of aquatic life and human health, which may originate from natural and anthropogenic sources; and
- *Naphthenic acids*: relatively labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern.

In addition to the above water quality measurement endpoints, overall ionic composition at each station was assessed graphically using Piper diagrams, as discussed in Section 3.2.7.4.

3.2.7.2 Criteria for Determining Effects

Two criteria for determining water quality effects were used:

- **Comparison to Water Quality Guidelines**: All water quality data collected by RAMP in 2007 were screened against Alberta acute and sublethal water quality guidelines for the protection of aquatic life (AENV 1999b) and Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) (CCME 2007). Variables for which there are no AENV or CCME guidelines were screened against applicable guidelines from other jurisdictions (e.g., British Columbia) where appropriate. Water-quality guidelines used for screening of RAMP data appear in Table 3.2-8. All values that exceeded these guidelines are reported explicitly in the body of the RAMP report.
- **Comparison to Natural Variation in Baseline Conditions**: 2007 water quality data for each of the selected water quality measurement endpoints were assessed against a rigorously defined range of natural variability in concentration of each of these measurement endpoints.

Table 3.2-8 Water quality guidelines used to screen data collected by the RAMP Water Quality Component, 2007

Water Quality Variable	Units	CCME[1]	AENV[2]		Other jurisdictions[3]
			Acute	Chronic	-
Metals					
Aluminum (Al)	mg/L	0.005, 0.1[a]	-	-	0.05 (dissolved)[i]
Antimony (Sb)	mg/L	-	-	-	0.020
Arsenic (As)	mg/L	0.0050	-	-	-
Barium (Ba)	mg/L	-	-	-	*5*
Beryllium (Be)	mg/L	-	-	-	-
Bismuth (Bi)	mg/L	-	-	-	-
Boron (B)	mg/L	-	-	-	1.2
Cadmium (Cd)	mg/L	0.000017[b]	-	-	-
Calcium (Ca)	mg/L	-	-	-	-
Chromium III (Cr^{3+})	mg/L	0.0089	-	-	-
Chromium VI (Cr^{6+})	mg/L	0.0010	-	-	-
Cobalt (Co)	mg/L	-	-	-	0.11
Copper (Cu)	mg/L	0.002 to 0.004[c]	-	-	-
Gallium (Ga)	mg/L	-	-	-	-
Iron (Fe)	mg/L	0.300	-	-	-
Lead (Pb)	mg/L	0.001 to 0.007[d]	-	-	-
Lithium (Li)	mg/L	-	-	-	*5*
Magnesium (Mg)	mg/L	-	-	-	-
Manganese (Mn)	mg/L	-	-	-	0.8 to 3.8[j]
Mercury (Hg)[e]	mg/L	-	0.000013	0.000005	-
Molybdenum (Mo)	mg/L	0.073	-	-	-
Nickel (Ni)	mg/L	0.025 to 0.150[f]	-	-	-
Phosphorus (P)	mg/L	-	-	-	-
Potassium (K)	mg/L	-	-	-	-
Rubidium (Rb)	mg/L	-	-	-	-
Selenium (Se)	mg/L	0.0010	-	-	-
Silicon (Si)	mg/L	-	-	-	-
Silver (Ag)	mg/L	0.0001	-	-	-
Sodium (Na)	mg/L	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-
Sulphur (S)	mg/L	-	-	-	-
Thallium (Tl)	mg/L	0.0008	-	-	-
Tin (Sn)	mg/L	-	-	-	-
Titanium (Ti)	mg/L	-	-	-	0.100
Uranium (U)	mg/L	-	-	-	0.300
Vanadium (V)	mg/L	-	-	-	-
Zinc (Zn)	mg/L	0.030	-	-	-
Nutrients		-	-	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-
Total Organic Nitrogen	mg/L	-	-	-	-
Ammonia	mg/L	0.043 to 153[g]	-	-	-
Nitrate-N	mg/L	13	-	-	-
Nitrite-N	mg/L	0.060	-	-	-
Nitrite+Nitrate-N	mg/L	-	-	-	-
Total Nitrogen	mg/L	-	-	1.0	-
Ortho-phosphorus	mg/L	-	-	-	-
Total Dissolved Phosphorus	mg/L	-	-	-	-
Total Phosphorus	mg/L	-	-	0.05	-
Conventionals		-	-	-	-
pH	pH units	6.5 to 9.0	-	-	-
Dissolved oxygen	mg/L	5.5 to 9.5[h]	5.0 (min)	6.5 (7-day mean)[j]	-
Temperature	^oC	-	-	-	-
Suspended Solids	mg/L	-	-	-	-
Turbidity	NTU	-	-	-	-
Ions		-	-	-	-
Fluoride	mg/L	-	-	-	0.2 to 0.3[k]
Sulphate	mg/L	-	-	-	100
Sulphide (as H_2S)	mg/L	-	-	-	0.014
Chloride (Cl)	mg/L	-	-	-	230 (BC), 860 (EPA)
Organics		-	-	-	-
Total phenols	mg/L	-	-	0.005	0.05[l]
Naphthenic acids	mg/L	-	-	-	-

[1] CCME 2007.
[2] AENV 1999.
[3] All from British Columbia (2006), except chloride (230 mg/L = BC; 860 mg/L = EPA), and sulphide (EPA)
a: 0.005 at pH<6.5; [Ca2+]<4 mg/L; DOC<2 mg/L; 0.100 at pH>=6.5; [Ca2+]>=4 mg/L; DOC>=2 mg/L
b: Hardness-dependant. Guideline = =10^(0.86[log(hardness)]-3.2)/1000
c: 0.002 at [CaCO3]=0 to 120 mg/L; 0.003 at [CaCO3]=120 to 180 mg/L; 0.004 at [CaCO3]>180 mg/L
d: 0.001 at [CaCO3]=0 to 60 mg/L; 0.002 at [CaCO3]=60 to 120 mg/L; 0.004 at [CaCO3]=120 to 180 mg/L; 0.007 at [CaCO3]>180 mg/L
e: for inorganic mercury
f: 0.025 at [CaCO3]=0 to 60 mg/L; 0.065 at [CaCO3]=60 to 120 mg/L; 0.110 at [CaCO3]=120 to 180 mg/L; 0.150 at [CaCO3]>180 mg/L
g: Guidelines for total ammonia are temperature and pH dependent; see reference for additional information.
h: For cold-water biota, 9.5 mg/L for early life stages, 6.5 mg/L for other life stages. For warm-water biota, 6.0 mg/L for early life stages, 5.5 mg/L for other life stages.
i: For dissolved Al at pH>=6.5. At pH<6.5, guidelines are e^(1.209-2.426*pH+0.286*pH^2) (maximum concentration) and e^(1.6-3.327*median pH+0.402*pH^2)
j: Hardness-dependant. Guideline = 0.01102*hardness+0.54.
k: 0.2 at hardness <=50 mg/L CaCO3, 0.3 at hardness >=50 mg/L
l: For all pnenolic compounds minus 3- and 4-hydroxyphenol, which have separate guidelines.

3.2.7.3 Development of Regional Water Quality Baselines

RAMP uses a regional baseline approach, in which individual observations are compared against regional baseline data. In this approach, water quality data from all RAMP reference water quality stations for 1997 to 2007 were pooled using Objective Classification Analysis (OCA), which involved multivariate data reduction of the RAMP total metals, dissolved metals and major ions dataset using Principal Component Analysis (PCA), followed by application of hierarchical and k-means clustering algorithms to define groups of stations exhibiting similar and consistent water quality characteristics. Similar approaches to consolidation and analysis of large water quality datasets are presented and discussed by Jones and Boyer (2002) and Güler *et al.* (2004). The analytical methodology is more fully described in the RAMP Technical Design and Rationale document (RAMP 2005b).

Detailed methods and results of the OCA of the RAMP water quality data are provided in Appendix D. Results of this analysis of the RAMP 1997 to 2007 dataset indicated three major groups of stations with similar water quality types (Table 3.2-9):

- Stations in tributary watersheds to the northeast and south of Fort McMurray, including the Muskeg, Steepbank, Firebag, and Clearwater-Christina rivers, as well as Kearl and McClelland lakes;
- Stations in tributary watersheds to the northwest of Fort McMurray, including the MacKay, Ells, Tar, Calumet, Poplar Creek, and Beaver rivers, as well as Fort Creek, McLean Creek, the Hangingstone River, and lakes in the floodplain of the Athabasca River (Isadore's and Shipyard); and
- All stations in the Athabasca River, Athabasca River Delta and Unnamed Creek.

For many stations included in the cluster analysis, samples from different years clustered closely together, indicating that water quality at these stations was consistent at specific locations across years of sampling (i.e., spatial variation was more important than temporal variation in defining cluster membership).

These groupings are generally consistent with groupings of water quality in the oil sands area by AOSERP (1985), and may be associated with patterns of underlying and surficial geology (AOSERP 1985). In addition, the groupings of stations into clusters in 2007 was generally consistent with the clusters defined in the 2006 analysis, with the exception of Unnamed Creek, which was grouped with the eastern and southern tributaries in 2006. These results indicate that water quality data collected in 2007 were consistent with the water quality characteristics of each group.

Within each cluster, data from stations designated as *reference* (i.e., those stations located in areas of watersheds that are not being influenced by focal project activities) were pooled to develop descriptions of regional baseline water quality, against which RAMP data from stations designated as *potentially influenced* and *reference* were assessed. Table 3.2-10 lists the stations from which baseline data from 1997 to 2007 were pooled to develop these baseline descriptions. The numbers of observations in regional baseline datasets varied by cluster and by water quality measurement endpoint.

Table 3.2-9 Classification of groups of RAMP water quality monitoring stations with similar water quality, from 1997 to 2007 data.

Waterbody	Total No. of Station/Year Combinations	Cluster		
		1	2	3
Athabasca River	**94**	**3**	**0**	**91**
Athabasca River Delta	**4**	**0**	**0**	**4**
Eastern tributaries	**28**	**13**	**13**	**2**
Firebag River	12	12	0	0
Fort Creek	6	1	5	0
McLean Creek	9	0	8	1
Unnamed Creek	1	0	0	1
Regional Lakes	**30**	**19**	**9**	**2**
Isadore’s Lake	6	3	3	0
Kearl Lake	9	8	0	1
McClelland Lake	6	6	0	0
Shipyard Lake	9	2	6	1
Muskeg River	**77**	**44**	**31**	**1**
Alsands Drain	1	0	1	0
Jackpine Creek	9	8	1	0
Muskeg Creek	10	6	4	0
Muskeg River	39	19	19	1
Shelley Creek	3	0	3	0
Stanley Creek	8	6	2	0
Iyinimin Creek	1	1	0	0
Wapasu Creek	6	5	1	0
Southern tributaries	**31**	**19**	**7**	**5**
Christina River	13	7	4	2
Clearwater River	14	12	0	2
Hangingstone River	4	0	3	1
Steepbank River	**26**	**19**	**5**	**2**
North Steepbank River	6	6	0	0
Steepbank River	20	13	5	2
Western tributaries	**59**	**8**	**44**	**8**
Beaver River	5	0	5	0
Calumet River	9	0	9	0
Ells River	11	6	3	2
MacKay River	15	1	12	2
Poplar Creek	8	0	8	0
Tar River	11	0	7	4
Total	**349**	**125**	**109**	**115**

Bold entries refer to sum of station-year combinations in each group of waterbodies.

Shaded entries denote the cluster designated for each waterbody.

Table 3.2-10 Regional baseline water quality data groups and station comparisons.

Regional Baseline Grouping (Cluster)	Baseline Stations Used in creating Regional Comparison[1]	Stations (2007) Compared against this Regional Baseline
1. Eastern and southern tributaries to the Athabasca River; Kearl Lake; McClelland Lake	FIR-1, FIR-2, FIR-2X, KEL-1, MCL-1, JAC-1, MUC-1, SHC-1, STC-1, WAC-1, MUR-5, MUR-6, CHR-1, CHR-2, CLR-1, CLR-2, STR-2, STR-3, NSR-1, IYC-1, CHR-2A	FIR-1, FIR-2, KEL-1, MCL-1, JAC-1, MUC-1, SHC-1, STC-1, WAC-1, MUR-1, MUR-6, CHR-1, CHR-2, CLR-1, CLR-2, STR-1, STR-2, STR-3, NSR-1, IYC-1, CHR-2A
2. Western tributaries to the Athabasca River; Fort Creek; McLean Creek; Hangingstone River; Isadore's Lake; Shipyard Lake	FOC-1, HAR-1, CAR-1, CAR-2, ELR-1, ELR-2, MAR-1, MAR-2, TAR-1, TAR-2	FOC-1, MCC-1, ISL-1, SHL-1, HAR-1, BER-1, CAR-1, CAR-2, ELR-1, ELR-2, MAR-1, MAR-2, POC-1, TAR-1, TAR-2
3. Athabasca River and Athabasca River delta	ATR-DC-CC, ATR-DC-CC-D, ATR-DC-E, ATR-DC-W, ATR-DC-M, ATR-UFM[2]	ATR-DC-E, ATR-DC-W, ATR-DC-CC, ATR-SR-E, ATR-SR-W, ATR-MR-E, ATR-MR-W, ATR-FR-CC, ATR-DD-E, ATR-DD-W

[1] See Table 3.2-6 for classification of station status by year. Where station status changed from *reference* to *potentially influenced* during 1997-2007, only baseline data were used in the determination of regional water quality characteristics.

[2] ATR-UFM data are from the AENV dataset (1976-2004).

3.2.7.4 Tabular and Graphical Presentation of Results

Comparison to Water Quality Guidelines and Historical Data

Water quality data from fall 2007 for each water quality measurement endpoint were tabulated for each station sampled. Historical variability was presented for each water quality measurement endpoint, represented by minimum, maximum and median values observed, as well as number of observations, at that station from 1997 to 2007 (fall observations only). All cases in which concentrations of water quality variables that exceeded relevant guidelines were also reported.

Comparison to Natural Variation in Baseline Conditions

To allow a regional comparison, untransformed data from all baseline stations sampled by RAMP from 1997 to 2007 (fall only), for thirteen selected water quality measurement endpoints, were pooled from each cluster of similar stations (Table 3.2-9). Descriptive statistics describing natural water quality characteristics for each group were calculated; for each water quality cluster (Table 3.2-9), the 5th, 25th, 50th (median), 75th, and 95th percentiles were determined for comparison against 2007 data. The number of observations for each of the thirteen selected water quality measurement endpoints varied by cluster (Table 3.2-11). The median rather than the mean was used as an indicator of typical conditions, given water quality data are characteristically positively skewed.

Data for a subset of the water quality measurement endpoints were presented graphically in the context of relevant regional variability by presenting data for each station for all years of sampling by RAMP to allow assessment of any temporal trends. Where possible, stations located upstream and downstream on specific watersheds were presented together, to allow assessment of any differences in values or trends between upstream/downstream locations.

Piper diagrams also were used to assess temporal and spatial differences in ion balance at each station or at multiple stations within a watershed.

Table 3.2-11 Number of observations for determination of baseline regional water quality.

Water Quality Measurement Endpoint	Number of observations (station-year combinations) for baseline regional water quality		
	Cluster 1	Cluster 2	Cluster 3
Total Suspended Solids (TSS)	105	42	74
Total Dissolved Solids (TDS)	105	42	49
Dissolved phosphorus	103	42	48
Total nitrogen	101	42	46
Total strontium	101	42	5
Total boron	102	42	37
Naphthenic acids	105	42	28
Calcium	102	42	37
Magnesium	102	42	25
Sodium	102	42	25
Potassium	102	42	5
Chloride	105	42	25
Sulphate	105	42	25

Trend Analysis of Water Quality

Statistical trend analysis was undertaken on water quality data for the Athabasca River, which has been monitored continuously by Alberta Environment since 1976. Trend analysis was undertaken on data from: Athabasca River upstream of Fort McMurray (station ATR-UFM, approximately 100 m upstream of the Horse River); and Athabasca River at Old Fort (station ATR-OF), located near the head of the Athabasca River Delta, downstream of the Embarras River distributary. Trend analysis was conducted on the water quality measurement endpoints (Section 3.2.7.1) from the period of RAMP sampling (1997 to 2007), to assess trends potentially related to development between the two stations during this time period.

Trend analysis was also conducted on the water quality measurement endpoints at those sampling stations in which there was at least seven consecutive years of fall water quality data.

Regional Analysis of Water Quality

In addition to watershed-level analyses, this report includes regional-level analyses of water quality, based on comparisons of water quality in different regional groups (clusters) of water quality stations described above. Specific comparisons include those between historical regional reference data and regional reference data collected in 2007, and between data from potentially influenced stations and regional reference data from 2007 and historically. Details of these comparisons are included in Section 6.

3.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

3.3.1 Benthic Invertebrate Community Component

3.3.1.1 Summary of 2007 Monitoring Activities

A total of 23 locations were sampled in 2007 for the Benthic Invertebrate Community component, comprising 19 river reaches, and four lakes (Figure 3.3-1, Table 3.3-1). As in previous years, samples were collected in the dominant habitat type found in each reach (Table 3.3-1). Habitats were defined as being either depositional (dominated by fine sediment deposits and low to no current) or erosional (dominated by rocky substrates and frequent riffle areas). A series of physical measurements were recorded as supporting information from each replicate station. These measurements are identical to those recorded in previous RAMP sampling years (RAMP 2005b).

3.3.1.2 Summary of Field Methods

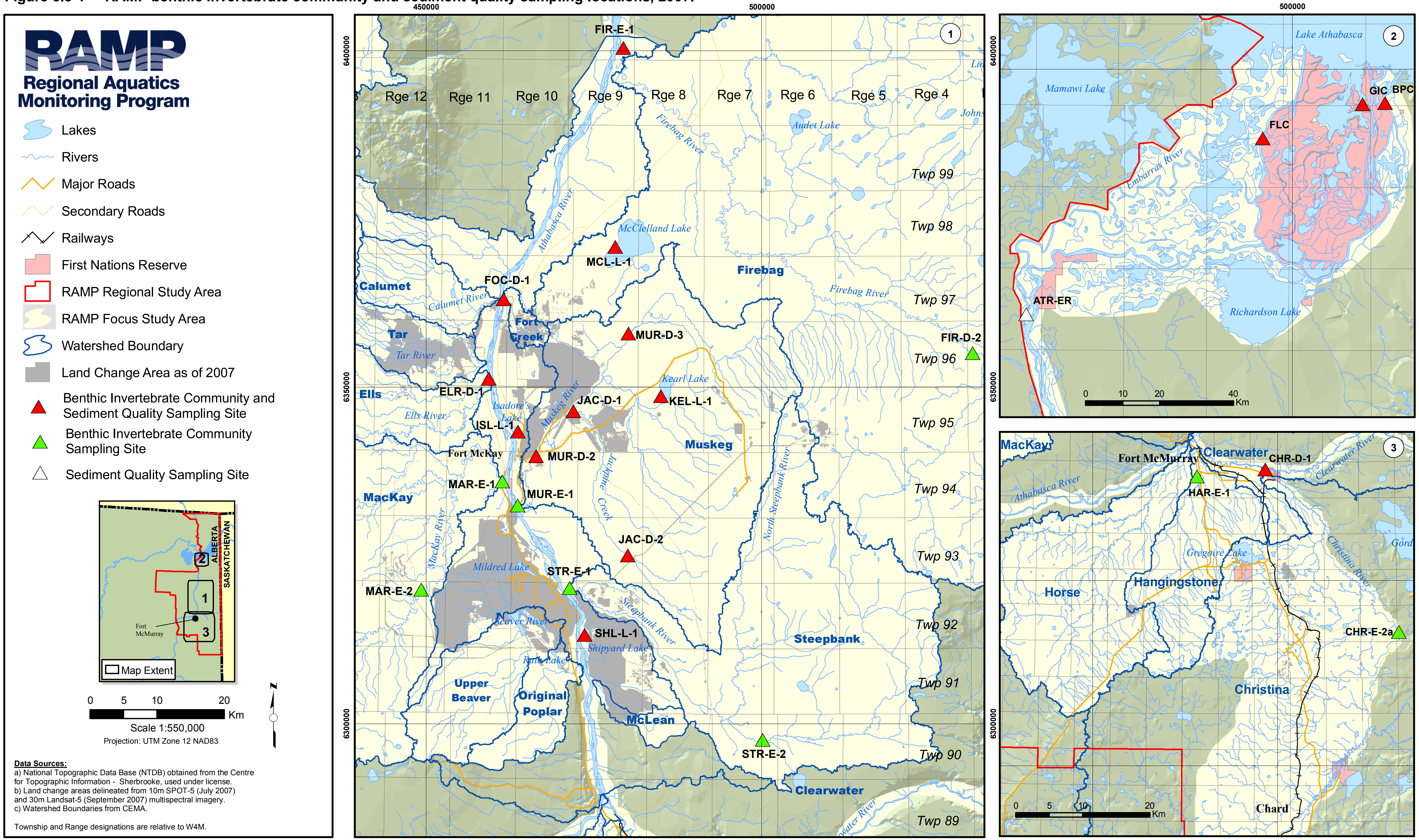
Benthic invertebrates were collected according to standard methods used in previous years (Golder 2003a, RAMP 2005b, which were developed from Alberta Environment [1990], Environment Canada [1993], Klemm et al. [1990] and Rosenberg and Resh [1993]). A Neill-Hess cylinder (0.093-m^2 opening and 210-μm mesh) was used for collection of invertebrates in erosional areas. In depositional habitats, a pole-mounted Ekman grab (0.023 m^2, 6″ x 6″) was used for invertebrate collection. In lakes greater than 1 m deep, the 6″ x 6″ Ekman grab was used, but the device was deployed using a rope and messenger from the surface.

In rivers, a total of 10 replicate samples were collected from within pre-established reaches. Reaches were typically 2 to 4 km long. Samples were selected randomly from within the reach, based on habitat availability and approximately equal spacing. In lakes (i.e., Shipyard Lake, Kearl Lake, McClelland Lake, Isadore's Lake), a total of 10 replicate samples were randomly selected from littoral areas based on a controlled depth range (0.5 to 3 m). Samples collected at depositional stations were sieved in the field using a 250-μm screen, preserved in 10% buffered formalin, and bottled for transport.

As in previous years, a series of measurements were recorded as supporting information:

- Wetted and bankfull channel widths – visual estimate (for rivers/streams only); field water quality measurements – dissolved oxygen, conductivity, temperature, and pH. All instruments calibrated according to manufacturers instructions;
- Current velocity – determined by measuring the time for a semi-submerged object to travel a known distance (2 m);
- Water depth at the benthic sample location – measured with a graduated device (pole or Hess cylinder);
- Amount of benthic algae at erosional stations (for chlorophyll *a* measurement) – obtained by scraping of a 1 cm x 1 cm square from three randomly-selected cobbles and combined these into one composite sample per station;
- Substrate particle size distribution (erosional stations only) – visual estimates of areal coverage by particles in standard size categories using the modified Wentworth classification system (Cummins 1962) and expressed as percentages;
- An additional Ekman grab sample was collected at depositional stations for analysis of total organic carbon (TOC as a dry weight percentage) and particle size (% sand, silt and clay, as dry weight);
- Geographical position – using a hand-held Magellan Global Positioning System (GPS) unit; and
- General station appearance.

Figure 3.3-1 RAMP benthic invertebrate community and sediment quality sampling locations, 2007.



K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_FG_BenthosSed_20080303.mxd

Table 3.3-1 Summary of sampling for the RAMP 2007 Benthic Invertebrate Community component.

Waterbody and Location	Habitat	Reach or Station	UTM Coordinates			
			Downstream Limit of Reach		Upstream Limit of Reach	
			Easting	Northing	Easting	Northing
Athabasca River Delta						
Goose Island Channel	depositional	GIC	508361	6495891	508838	6495860
Big Point Channel	depositional	BPC	511050	6496033	511258	6494673
Fletcher Channel	depositional	FLC	496467	6491822	496101	6491089
Christina River						
Lower Reach	depositional	CHR-D-1	496646	6280035	497747	6278491
Middle Reach	erosional	CHR-E-2a	532759	6236195	532281	6236327
Ells River						
Lower Reach	depositional	ELR-D-1	459318	6351291	459277	6351314
Firebag River						
Lower Reach	depositional	FIR-D-1	479363	6400434	479683	6397769
Upper Reach	erosional	FIR-E-2	531283	6355080	531933	6355118
Fort Creek						
Lower Reach	depositional	FOC-1	461527	6363105	461561	6363105
Hangingstone River						
Lower Reach	erosional	HAR-E-1	478160	6278143	428169	6277607
Jackpine Creek						
Lower Reach	depositional	JAC-D-1	417911	6346469	473076	6346324
Upper Reach	depositional	JAC-D-2	480018	6325009	480818	6324437
MacKay River						
Lower Reach	erosional	MAR-E-1	461321	6336060	460404	6336934
Upper Reach	erosional	MAR-E-2	449277	6319931	448863	6318821
Muskeg River						
Lower Reach	erosional	MUR-E-1	463622	6332482	464931	6332690
Middle Reach	depositional	MUR-D-2	466361	6339763	466554	6340421
Upper Reach	depositional	MUR-D-3	480100	6357995	482143	6359808
Steepbank River						
Lower Reach	erosional	STR-E-1	471314	6320162	472399	6319896
Upper Reach	erosional	STR-E-2	500055	6297639	501002	6297523
Lakes[2]						
			Easting	**Northing**		
Kearl Lake	lake	KEL-1	484917	6348686		
McClelland Lake	lake	MCL-1	478122	6370897		
Shipyard Lake	lake	SHL-1	473589	6313227		
Isadores Lake	lake	ISL-1	463646	6343448		

[1] Sediment quality sampling was conducted at these sites.

[2] UTM coordinates of first station

Laboratory Methods

ASL Laboratories conducted the chlorophyll *a* laboratory analyses for erosional stations as well as analysis of TOC and particle size distribution for depositional stations.

Dr. Jack Zloty in Summerland, BC, performed sorting and taxonomic identifications, as in previous years. Benthic samples were sieved in the laboratory using a 250-μm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by the sieve was elutriated using a flotation technique to separate organic material from sand and gravel, and invertebrates from organic material. Samples containing bitumen were treated with paint thinner to remove hydrocarbons prior to sorting. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. 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 sub-sampled using a modification of the method described by Wrona *et al*. (1982) in which fine materials were scanned for invertebrates with the aid of a dissecting microscope at a magnification of 6X to 10X. All sorted material was preserved for random checks of removal efficiency. Quality assurance and quality control (QA/QC) procedures related to sample processing for benthic invertebrate communities are discussed in Appendix B.

Organisms were identified to lowest practical taxonomic levels using up-to-date taxonomic literature, and as per the guidelines in Appendix E.

3.3.1.3 Changes in Monitoring Program from 2006

Water levels in the Athabasca River Delta were high enough in September 2007 to successfully complete the benthic invertebrate community sampling program in the delta.

The middle Christina River reach (reach CHR-E-2a) was sampled for the first time in 2007 and is designated as erosional because of the presence of large riffles interspersed with long shallow, gravel-bottomed runs.

Stream slope was not recorded in 2007, as the use of a clinometer in 2006 was found to produce highly variable estimates of stream slope, and was considered inappropriate for the purposes of this component.

3.3.1.4 Challenges Encountered and Solutions Applied

All stations scheduled for monitoring in 2007 were accessed and successfully sampled.

3.3.1.5 Other Information Obtained

No additional or supplementary information was obtained as part of the 2007 Benthic Invertebrate Community component.

3.3.1.6 Summary of Component Data Now Available

As of 2007, 1,835 benthic invertebrate community samples have been collected under RAMP. The distribution of stations and reaches, and the time-series of data available for individual locations are presented in Table 3.3-2.

3.3.1.7 Analytical Approach and Methods

The analytical approach used in 2007 for the Benthic Invertebrate Community component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2005b) and consisted of:

- Selection of benthic invertebrate community measurement endpoints;
- Development of criteria to be used in detecting changes in benthic invertebrate community measurement endpoints; and

Table 3.3-2 Summary of RAMP data available for the Benthic Invertebrate Community component.

see symbol key at bottom

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

Type Legend:

1 = RAMP site

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

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

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

potentially influenced

reference

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

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

Table 3.3-2 (Cont'd.)

see symbol key at bottom

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

Type Legend:
1 = RAMP site
2 = Sampled outside of RAMP (data available to RAMP)

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

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

potentially influenced (blue)
reference (green)

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

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

- Detailed data analysis, consisting of:
  - Analysis of variance testing for differences between upstream reference and downstream exposure reaches, and/or differences in time trends; and
  - Calculation of normal ranges of variability for the benthic invertebrate community measurement endpoints, and comparison of data from reaches designated as *potentially-influenced* to reaches designated as *reference* to determine how the communities compare to natural variability.

Selection of Benthic Invertebrate Community Measurement Endpoints

For each sample, the following benthic invertebrate community measurement endpoints were calculated:

- Abundance (total number of individuals/m^2);
- Taxon richness (number of distinct taxa);
- Simpson's Diversity Index (D), where

$$D = 1 - \sum (p_i)^2 \qquad [1]$$

  and p_i is the proportion that taxon i contributes to the total number of invertebrates in a sample;

- Evenness, where

$$\text{Evenness} = \frac{D}{D_{max}} \qquad [2]$$

$$D_{max} = 1 - \left(\frac{1}{S}\right) \qquad [3]$$

  and S is the total number of taxa in the sample. In situations where S = 1 (i.e., only one taxon was identified in a sample), evenness was set to 1; and

- Percent EPT (Ephemeroptera, Plecoptera, Trichoptera).

All benthic invertebrate community measurement endpoints were determined for each sample and then averaged for each reach or lake. The measurement endpoints were computed for all RAMP data dating from 1998 onward to evaluate trends in these measures over time.

Criteria for Determining Effects

The criterion used for determining effects of focal projects on benthic invertebrate communities was whether or not the benthic invertebrate community measurement endpoints in a given site (i.e., river reach or lake) that is designated as *potentially influenced* exceed regional baseline conditions. The determination of regional baseline conditions is described below.

3.3.1.8 Detailed Data Analysis

Determination of Regional Baseline Conditions

An ordination of the data was conducted using Correspondence Analysis (CA) to identify natural groupings of reaches among all the reaches that were designated as *reference* (Table 3.3-2). The technical aspects of the CA are documented in Appendix E.

Depositional and erosional habitats each grouped well in the analysis and justified the calculation of "normal ranges" for each of the benthic community indices for erosional and depositional reaches. On the basis of these results, habitat type (i.e., erosional versus depositional) was used as the natural grouping on which regional baseline conditions were calculated.

Regional baseline conditions were defined as the normal range of variability for measurement endpoints across all reference sites. The normal range of variability for measurements endpoints was calculated as the mean value of the measurement endpoint (for a given habitat type) ± 2 standard deviations of measurement endpoint values. These calculations were made separately for each measurement endpoint and for each habitat type.

Effects of Focal Projects on Benthic Invertebrate Communities

Possible effects of focal projects were evaluated by comparing benthic invertebrate community measurement endpoints in reaches designated as *potentially influenced* to upstream *reference* reaches and/or to pre-development conditions with analysis of variance (ANOVA). When necessary, the measurement endpoints were $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances. One-way ANOVAs were conducted for each benthic invertebrate community measurement endpoint with each reach-year combination as the factorial variable. Planned linear orthogonal contrasts (Hoke *et al*., 1990) were then used to identify differences between *reference* and *potentially influenced* reaches, between baseline and operational periods, and differences in time trends between lower *potentially influenced* reaches and upper *reference* reaches. Differences between *reference* reaches and reaches designated as *potentially influenced* were also evaluated for data collected in 2007 only. In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

Reaches designated as *potentially influenced* and reaches designated as *reference* within a watercourse were not always the same habitat type (e.g., Muskeg River, reach MUR-E-1 and reach MUR-D-3). In these cases it was expected that trends over time should be the same in both reaches unless focal projects were influencing the lower reach differently than the upstream reach.

3.3.1.9 Environmental Variables

A number of environmental variables, including physical substrate condition and water temperature, chemistry, and flow velocities, were measured at each site. These environmental variables were measured because they fundamentally influence the kinds of benthic invertebrate fauna found at a site. Where benthic invertebrate communities are shown to vary over time in a manner consistent with the development of focal projects, the variation may be attributed to changes in one or more of these environmental variables. An examination of these potential associations was made if the criteria for determination of effect in benthic invertebrate communities were met.

In addition, some general conclusions about the condition of a reach can be made using a number of the environmental variables:

- Dissolved oxygen is typically above concentrations considered critical for the protection of aquatic life (5.5 mg/L for warm-water biota; CCME 2006). Concentrations below this guideline are indicative of potential risks to aquatic life, especially if those concentrations are observed during the day, which is the typical time of sampling for RAMP; and
- Chlorophyll *a*, one of the environmental variables measured in erosional reaches was identified early in the AOSERP studies as a potential indicator of oil sands activity (Barton and Lock 1979). Chlorophyll *a* can also be used to classify the

nutrient status of a stream; for this report, concentrations of chlorophyll *a* below 70 mg/m^2, between 70 and 200 mg/m^2, and greater than 200 mg/m^2 are used to define oligotrophic, mesotrophic, and eutrophic conditions, respectively (from Dodds *et al.* 1998). In addition, the limits of the normal range of chlorophyll *a* values from reaches designated as *reference* was determined (Appendix E) and is provided in figures that illustrate trends over time in chlorophyll *a* values.

3.3.2 Sediment Quality

3.3.2.1 Overview of 2007 Program

Sediment samples were collected from 5 to 17 September 2007 at the most downstream replicate sampling location in each depositional reach sampled for benthic invertebrate communities (total of 12 depositional reaches), as well as four regionally-important lakes and wetlands (Table 3.3-3, Figure 3.3-1).

3.3.2.2 Summary of Field Methods and Sample Shipping and Analysis

Sediment sampling locations were identified from historical GPS coordinates recorded for benthic invertebrate community sampling locations or written descriptions from previous reports. Stations were accessed by helicopter, jet boat, or four-wheel drive vehicle.

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

Homogenized samples were transferred into labeled, sterilized glass jars for chemical analyses, and to a sealable plastic bucket for chronic toxicity testing. All samples were stored on ice or refrigerated prior to and during shipment to analytical laboratories.

All chemical and physical (e.g., particle size, TOC) analyses were conducted by ALS (Edmonton, Alberta) except polycyclic aromatic hydrocarbons (PAHs), which were analyzed by AXYS Analytical Services Ltd. (Sidney, British Columbia). Evaluation of sediment toxicity was undertaken by HydroQual Laboratories Ltd. (Calgary, Alberta).

Sediments were analyzed for the RAMP standard sediment quality variables (Table 3.3-4), as well as sediment toxicity to aquatic organisms at all locations sampled.

3.3.3 Changes in Monitoring Network from 2006 Field Program

Water levels in the Athabasca River Delta were high enough in September 2007 to successfully complete sediment quality sampling in the Delta. One additional station on the Athabasca River downstream of the Embarras River (station ATR-ER), was added in 2007 to intensify sampling for a more complete data set for the Athabasca River Delta because it was not sampled in 2006. Sediment toxicity sampling was not conducted at station JAC-D-1, and station JAC-D-2, or at station CHR-D-1 (lower Christina station), and toxicity samples were not taken at any of the Athabasca River Delta stations.

3.3.4 Challenges Encountered and Solutions Applied

The RAMP sediment-quality component includes collection of a single sample, at the site furthest downstream in each depositional benthic reach. However, due to a miscommunication between field crews, five replicate sediment samples were collected instead of a single sample at several sites in September 2007, including: FOC-D-1, BPC-1,

Table 3.3-3 Summary of sampling for the RAMP Sediment Quality component, September 2007.

Station Identifier and Location		UTM Coordinates		Analytical Package
		Easting	Northing	
Athabasca River				
ATR-ER	Athabasca River at Embarras River	465945	6470800	1
Athabasca Delta				
FLC-1	Fletcher Channel	496467	6491822	1
GIC-1	Goose Island Channel	508361	6495891	1
BPC-1	Big Point Channel	511050	6496033	1
Tributaries to the Athabasca River (Eastern)				
FIR-D-1	Firebag River (lower reach)	479363	6400434	3
FOC-1	Fort Creek	461527	6363105	3
Tributaries to the Athabasca River (Western)				
ELR-D-1	Ells River (lower reach)	459318	6351291	3
Tributaries to the Athabasca River (Southern)				
CHR-D-1	Christina River (lower reach)	496646	6280035	1
Muskeg River				
MUR-D-2	Muskeg River (middle reach)	466361	6339763	3
MUR-D-3	Muskeg River (upper reach)	480100	6357995	3
JAC-D-1	Jackpine Creek (lower reach)	471911	6346469	1
JAC-D-2	Jackpine Creek (upper reach)	480018	6325009	1
Regional Lakes				
KEL-1	Kearl Lake	484917	6348686	3
MCL-1	McClelland Lake	478122	6370897	3
SHL-1	Shipyard Lake	473589	6313227	3
ISL-1	Isadore's Lake	463646	6343448	3
QA/QC				
-	Two sets of split and duplicate samples			1
-	One rinsate blank			Metals, PAHs

Legend to Analytical Packages:

1. *RAMP standard variables (carbon, particle size, total hydrocarbons, metals, PAHs, alkylated PAHs)*
3. *RAMP standard + toxicity (Chironomus tentans, Hyalella azteca)*

FLC-1, GIC-1, SHL-1, ISL-1, MUR-D-3, and ELR-D-1. In tables and figures of this report, 2007 replicated sediment-quality data for these stations are reported as a single value, which represents an average of all replicates. Although collected unintentionally, these replicate data provide useful information regarding within-reach spatial variability of sediment quality in the RAMP FSA. Results of these replicate samples are presented and discussed in Appendix E.

High organic carbon content in Kearl Lake (KEL-1), McClelland Lake (MCL-1) and upper Jackpine Creek (JAC-D-2) precluded particle size analysis at several replicate locations. A single sample from upper Jackpine Creek (JAC-D2), intended for analysis of PAHs, was lost in transit to the analytical laboratory, and therefore not analyzed. Additionally, the lid of a jar loosened in transit to the analytical laboratory on a sediment sample from Fort Creek (FOC-D1) intended for analysis of total hydrocarbons; this compromised the integrity of the sample and precluded analysis. In future sampling programs, additional attention will be paid to ensuring that grit is not trapped in the seal of the sediment jar to prevent lids from loosening in transit.

3.3.5 Other Information Obtained

No additional sediment quality data for 2007 were obtained.

Table 3.3-4 RAMP standard sediment quality variables.

Group	Sediment Quality Variable	
Physical variables	Percent sand Percent silt	Percent clay Moisture content
Carbon content	Total inorganic carbon Total organic carbon Total carbon	
Total metals	Aluminum Arsenic Barium Beryllium Boron Cadmium Calcium Chromium Cobalt Copper Iron Lead Magnesium	Manganese Mercury Molybdenum Nickel Potassium Selenium Silver Sodium Strontium Thallium Uranium Vanadium Zinc
Organics	CCME 4-fraction total hydrocarbons: - BTEX (Benzene, Toluene, Ethylene, Xylene) - F1 (C6-C10) - F2 (C10-C16) - F3 (C16-C34) - F4 (C34-C50) - Total hydrocarbons (C6-C50)	
Target PAHs	Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene/chrysene Benzo(a)pyrene Benzofluoranthenes Benzo(g,h,i)perylene Biphenyl	Dibenzo(a,h)anthracene Dibenzothiophene Fluoranthene Fluorene Indeno(c,d-123)pyrene Naphthalene Phenanthrene Pyrene
Alkylated PAHs	C1-substituted acenaphthene C1-substituted benzo(a)anthracene/chrysene C2-substituted benzo(a)anthracene/chrysene C1-substituted biphenyl C2-substituted biphenyl C1-substituted benzofluoranthene/ benzo(a)pyrene C2-substituted benzofluoranthene/benzo(a)pyrene C1-substituted dibenzothiophene C2-substituted dibenzothiophene C3-substituted dibenzothiophene C4-substituted dibenzothiophene C1-substituted fluoranthene/pyrene C2-substituted fluoranthene/pyrene C3-substituted fluoranthene/pyrene C1-substituted fluorene C2-substituted fluorene C3-substituted fluorene C1-substituted naphthalenes C2-substituted naphthalenes C3-substituted naphthalenes C4-substituted naphthalenes C1-substituted phenanthrene/anthracene C2-substituted phenanthrene/anthracene C3-substituted phenanthrene/anthracene C4-substituted phenanthrene/anthracene 1-methyl-7-isopropyl-phenanthrene (retene)[1]	
Sublethal toxicity testing	Survival and growth of the amphipod *Hyalella azteca* Survival and growth of *Chironomus tentans* midge larvae	

[1] Any summations of total PAHs did not include retene, as it is also accounted for in total C4-substituted phenanthrene/anthracene.

3.3.6 Summary of Component Data Now Available

Table 3.3-5 summarizes historical sediment quality sampling undertaken by RAMP since 1997.

3.3.7 Analytical Approach

The analytical approach undertaken for the sediment quality component in 2007 was similar to 2006. The RAMP 2007 sediment quality analysis included the following steps:

- Review and selection of particular sediment quality variables as sediment quality measurement endpoints, including predicted toxicity of sediments due to PAHs (calculated using an equilibrium-partitioning model);
- Tabular presentation of 2007 results comparing 2007 concentrations of the sediment quality measurement endpoints to concentrations previously observed within the reach, where data were available, and sediment quality guidelines; and
- Analysis of the relationship between various sediment quality measurement endpoints and benthic invertebrate community measurement endpoints, using correlation analysis.

These steps are described in detail below.

3.3.7.1 Selection of Sediment Quality Measurement Endpoints

A number of sediment quality variables were selected as sediment quality measurement endpoints for this 2007 technical report; the selection of the measurement endpoints was guided by information obtained from a number of sources (Table 3.3-6):

- Sediment quality measurement endpoints listed in the environmental impact assessments of oil sands projects as being potentially affected by oil sands development activities (RAMP 2005b);
- Sediment quality variables of interest listed in the RAMP 5-year report (Golder 2003a);
- Results of correlation analysis of the RAMP 1997-2004 sediment quality dataset indicating significant inter-correlation of various variables;
- Discussions among RAMP Component Managers about the importance of various sediment quality variables to interpretation of other RAMP components (e.g., benthos, fish); and
- Discussions with RAMP Technical Program Committee members, during and in relation to meetings held to discuss approaches and strategies for the sediment quality component of RAMP.

Table 3.3-5 Summary of available RAMP sediment quality data, 1997 to 2007.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																													
Upstream of Fort McMurray (cross channel)	ATR-UFM																								1				3				1												
Upstream of Donald Creek (west bank)[a]	ATR-DC-W				3				3								1				3				1				3				1												
(east bank)[a]	ATR-DC-E				3				3								1				3				1				3				1												
Upstream of Steepbank River (west bank)	ATR-SR-W																1				3				1				3				1												
(east bank)	ATR-SR-E																1				3				1				3				1												
Upstream of the Muskeg River (west bank)[a,b]	ATR-MR-W								3								1				3				1				3				1												
(east bank)[a,b]	ATR-MR-E								3								1				3				1				3				1												
Upstream of Fort Creek (west bank)[a,b]	ATR-FC-W				3				3								1				3				1				3																
(east bank)[a,b]	ATR-FC-E				3				3								1				3				1				3																
Testing inter-site variability (3 comp. samples)	-																1								1																				
Downstream of all development (west bank)	ATR-DD-W																								1				3				1												
(east bank)	ATR-DD-E																								1				3				1												
Upstream of mouth of Firebag River (west bank)	ATR-FR-W																								1				3				1												
(east bank)	ATR-FR-E																								1				3				1												
Upstream of the Embarras River	ATR-ER																3				1				1				3				1												
Athabasca Delta / Lake Athabasca																																													
Delta composite[c]	ARD-1											3					3																												
Embarras River	ATR-ER																																												1
Big Point Channel	BPC																				3				3				3								1								1
Goose Island Channel	GIC																				3				3				3								1								1
Fletcher Channel	FLC																				3				3				3								1								1
Flour Bay	FLB-1																3																												
Athabasca River Tributaries (South of Fort McMurray)																																													
Clearwater River (upstream of Fort McMurray)	CLR-1																				1				3				3																
(upstream of Christina River)	CLR-2																				1				3				3																
Christina River (upstream of Fort McMurray)	CHR-1																								1				3				3												
(upstream of Janvier)	CHR-2																								1				3				3												
(benthic reach at mouth)	CHR-D1																																								3				1
benthic react at upper Christina River)	CHR-D2																																								3				
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																3				3								
Athabasca River Tributaries (North of Fort McMurray)																																													
McLean Creek (mouth)	MCC-1												3				3				1				3												3								
Poplar Creek (mouth)	POC-1				1																				3								3												
Steepbank River (mouth)	STR-1				1				1																3												3								
(upstream of Project Millennium)	STR-2				1																				3												3								
(upstream of Nt. Steepbank)	STR-3																																				3								
North Steepbank River (upstream of P.C. Lewis)	NSR-1																								3				3				1				1								
MacKay River (mouth)	MAR-1				1				1												3				3								3												
(upstream of P.C. MacKay)	MAR-2																				1				3								3												

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)

2 = sediment toxicity testing (*Chironomus tentans, Lumbriculus variegatus,* Hyalella azteca)

3 = standard s.q. + toxicity testing

√ = allowance made for potential TIE

* Sediment program integrated with benthos component in 2006.

Footnotes

[a] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the Delta)

[b] Samples were collected downstream of tributary in 1998

[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

potentially influenced

reference

Table 3.3-5 (Cont'd.)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006*				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Tributaries (North of Fort McMurray) (cont'd)																																													
Ells River (mouth)	ELR-1								1																3				3				3				1								
(benthic reach at mouth)	ELR-D1																																								3				3
(upstream of CNRL Lease 7)	ELR-2																																3				1								
Tar River (mouth)	TAR-1								1																3				3				1				1								
(benthic reach at mouth)	TAR-D1																																								3				
(upstream of CNRL Horizon)	TAR-2																																1				1								
Calumet River (mouth)	CAR-1																								3								3				3								
(upstream of CNRL)	CAR-2																																				3								
(benthic reach at upper Calumet)	CAL-D2																																								3				
Fort Creek (mouth)	FOC-1																1								3																				
(benthic reach at mouth)	FOC-D1																																								3				3
Firebag River (mouth)	FIR-1																								3				3				1				1								
(benthic reach at mouth)	F1R-D1																																								3				1
(upstream of Suncor Firebag)	FIR-2																								3				3				1				1								
Muskeg River																																													
Mouth	MUR-1				1				1				3				1				1				3				3				3												
1 km upstream of mouth	MUR-1b																1												1																
Upstream of Canterra Road Crossing	MUR-2																1								3				3				3												
Upstream of Jackpine Creek	MUR-4				1												1												1																
Upstream of Muskeg Creek	MUR-5																1												1																
Upstream of Stanley Creek	MUR-D2																								3				3				3												
Upstream of Wapasu Creek	MUR-6																1												1																
(benthic reach - downstream of Jackpine Creek)	MUR-D2																																								3				3
(benthic reach - upstream of Stanley Creek)	MUR-D3																																								3				3
Muskeg River Tributaries																																													
Jackpine Creek (mouth)	JAC-1				1																												3												
(benthic reach at mouth)	JAC-D1																																								3				1
(benthic reach at upper Jackpine Creek)	JAC-D2																																								3				1
Stanley Creek (mouth)	STC-1																												1																
Wetlands																																													
Kearl Lake (composite)	KEL-1																				1												1								3				3
Isadore's Lake (composite)	ISL-1																				1																				3				3
Shipyard Lake (composite)	SHL-1																				1				3				1				3								3				3
McClelland Lake (composite)	MCL-1																								1																3				3
Additional Sampling (Non-Core Programs)																																													
Un-nammed Creek - north of Ft. Creek (mouth)	UNC-1																																												
Potential TIE	-																				√																								
QA/QC																																													
One split and one duplicate sample	-																1				1				1				1				1				1				1				1

Legend

1 = standard sediment quality parameters (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)

2 = sediment toxicity testing (*Chironomus tentans, Lumbriculus variegatus,* Hyalella azteca)

3 = standard s.q. + toxicity testing

√ = allowance made for potential TIE

* Sediment program integrated with benthos component in 2006.

Footnotes

[a] Sample sites were previously labeled ATR-1, 2 and 3 (moving upstream from the Delta)

[b] Samples were collected downstream of tributary in 1998

[c] In 1999, one composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel

potentially influenced

reference

Table 3.3-6 Potential sediment quality measurement endpoints.

Analyte Group	EIA Review: Variables Listed in EIAs (No. of projects)	RAMP 5-year Report (Golder 2003a)	Variables to Support other RAMP Components[1]	Additional Suggested Variables[2]
Physical variables	(None)	(None)	Particle size distribution	-
Carbon content	(None)	(None)	Total organic carbon	Total inorganic carbon Total organic carbon
Total Hydrocarbons	(None)	Total recoverable hydrocarbons	CCME F1, F2	CCME F1 to F4 +BTEX
Metals	(None)	Total metals	Total metals	Total arsenic and metals that exceed sediment quality guidelines
PAHs	General PAHs (4)	Naphthalene C1-Naphthalene	Total PAHs LMW PAHs (parent+alkylated)	LMW PAHs HMW PAHs Naphthalene Dibenzothiophenes Retene
Effects-based endpoints	Sublethal toxicity (1)	-	Sublethal toxicity	-

[1] Primarily Benthic Invertebrate Community component (inferred).

[2] Suggested by the RAMP Technical Program Committee and from ongoing review of stakeholder concerns

Final sediment quality measurement endpoints selected for use in this report, and reasons for their inclusion, are as follows:

- *Particle size distribution (clay, silt and sand)*: sediment particle size is an indicator of depositional regime at a given station, and an important factor affecting organic chemical sorption;
- *Total organic carbon*: an indicator of organic matter in sediment, including hydrocarbons;
- *Total hydrocarbons (CCME fractions)*: Indicators of the total hydrocarbon content of sediments, with each indicator (fraction) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), based on methods presented by CCME (2001a) ;
- *Various PAH measurement endpoints,* including*:*
    - o *Total PAHs:* a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
    - o *Total low-molecular-weight (LMW) PAHs:* a sum of concentrations of all PAHs with 1 to 3 benzene rings (including parent and alkylated forms) measured in a given sample;
    - o *Total high-molecular-weight (HMW) PAHs:* a sum of concentrations of all PAHs with 4 to 6 benzene rings (including parent and alkylated forms) measured in a given sample;
    - o *Naphthalene:* a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;

- *Total dibenzothiophenes:* a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic);
- *Retene:* an alkylated phenanthrene generated through decomposition of plant materials (i.e., biogenic/diagenic, rather than petrogenic); and
- *Predicted PAH toxicity:* an estimate of the cumulative toxicity of all PAHs in a sediment sample (the methodology for calculating predicted PAH toxicity is presented in Appendix F);

- *Metals:* With the exception of total arsenic (see below), only metals in sediment that exceeded CCME Interim Sediment Quality Guideline (ISQG) values (CCME 1999b) were presented, as metals in sediments are not listed in oil sands EIAs as being potentially affected by development (RAMP 2005b);
- *Total arsenic:* In analyses of sediment quality in the ARD (Section 5.1) and in regional analyses of sediment quality in tributaries (Section 6), data for total arsenic in sediments are presented, given recent stakeholder concerns regarding arsenic in regional sediments; and
- *Sublethal toxicity:* sublethal toxic effects of sediment on the survival and growth of the amphiphod (seed-shrimp) *Hyalella azteca* or the midge *Chironomus tentans.*

3.3.7.2 Tabular Presentation of 2007 Sediment Quality Results

2007 sediment quality data for each sediment quality measurement endpoint were tabulated for each station sampled. Historical variability also was presented for each measurement endpoint, represented by minimum, maximum and median values observed (as well as number of observations) from 1997 to 2006 at the historically-sampled station within the reach. Concentrations of any sediment quality measurement endpoint and any metal that exceeded relevant guidelines were reported in the tables.

3.3.7.3 Correlation with Benthic Invertebrate Metrics

Spearman's rank correlations were used to evaluate the relationship between benthic community metrics (i.e., abundance, diversity, evenness, taxa richness, and EPT values) and selected sediment quality measurement endpoints. Correlations were calculated for all depositional stations, sampled at the lowest (most downstream) end of the reach. Correlations greater than r_s of $|0.306|$ were indicative of statistically significant relationships for n=30 (number of depositional stations) (α=0.10, two-tailed test). Moderate correlations were defined as those ranging from $|0.50|$ to $|0.75|$, while strong correlations were defined as those ranging from $|0.75|$ to $|1.00|$.

3.4 FISH POPULATION COMPONENT

3.4.1 Overview of 2007 Monitoring Activities

The following monitoring activities were performed in 2007 for the Fish Population component:

- Fish inventories on the Athabasca and Clearwater rivers (spring and fall sampling);
- Tissue analyses and health evaluations on target fish species in the Clearwater River (fall sampling);
- Tissue analyses on target fish species in the following two regional lakes: Namur Lake (summer sampling) and Gregoire Lake (fall sampling);
- Sentinel fish species program using non-lethal sampling methods on the Athabasca River (summer and fall sampling); and
- Sentinel fish species program using non-lethal sampling methods on the Ells River, a tributary to the Athabasca (summer and fall sampling).

Table 3.4-1 summarizes the watercourses sampled and the target fish species for each monitoring activity; sampling locations are presented in Figure 3.4-1. Common and scientific names for each fish species noted in this report are listed in Appendix G.

A fish fence program was originally planned for spring 2007 on the lower Muskeg River; however, this program could not be implemented due to prohibitively high water levels during the scheduled installation period (April/May). Discharge on the river in the third week of April was recorded at levels greater than 12 m^3/s, which exceeded the safe installation discharge criterion of 9 m^3/s. The fish fence program, which was intended to be a repeat of the one carried out in 2006, is scheduled to be implemented in spring 2008, pending assessment of seasonal water levels at that time.

3.4.2 Summary of Field Methods

3.4.2.1 Fish Inventories

Athabasca River and Clearwater River Fish Inventories

In 2007, spring and fall inventories of the following RAMP key indicator fish species (analogous to Key Indicator Resources, KIRs) were carried out on the Athabasca and Clearwater rivers:

- Walleye (*Stizostedion vitreum*);
- Northern pike (*Esox lucius*);
- Longnose sucker (*Catostomus catostomus*);
- White sucker (*Catostomus commersoni*);
- Lake whitefish (*Coregonus clupeaformis*);
- Goldeye (*Hiodon alosoides*); and
- Trout-perch (*Percopis omiscomaycus*).

Table 3.4-1 Summary of 2007 Fish Population component monitoring activities.

Watercourse	Fish Population Component Monitoring Activity		
	Fish Inventory	Fish Tissue	Sentinel Species
Athabasca River	Spring and Fall: fish community		Summer and Fall: trout-perch
Clearwater River	Spring and Fall: fish community	Fall: northern pike	
Ells River			Summer and Fall: longnose dace
Namur Lake (Regional Lake)		Summer: lake trout	
Gregoire Lake (Regional Lake)		Fall: walleye, pike, lake whitefish	

Spring sampling was conducted between May 7 and May 30, 2007. The focus of the survey was primarily on the Athabasca River (6 days of effort), with a secondary effort on the Clearwater River (2 days of effort).

Fall sampling was conducted between September 13 and September 25, 2007. The fall survey repeated the focus on the Athabasca River (6 days of effort), and included one day of effort on the Clearwater River.

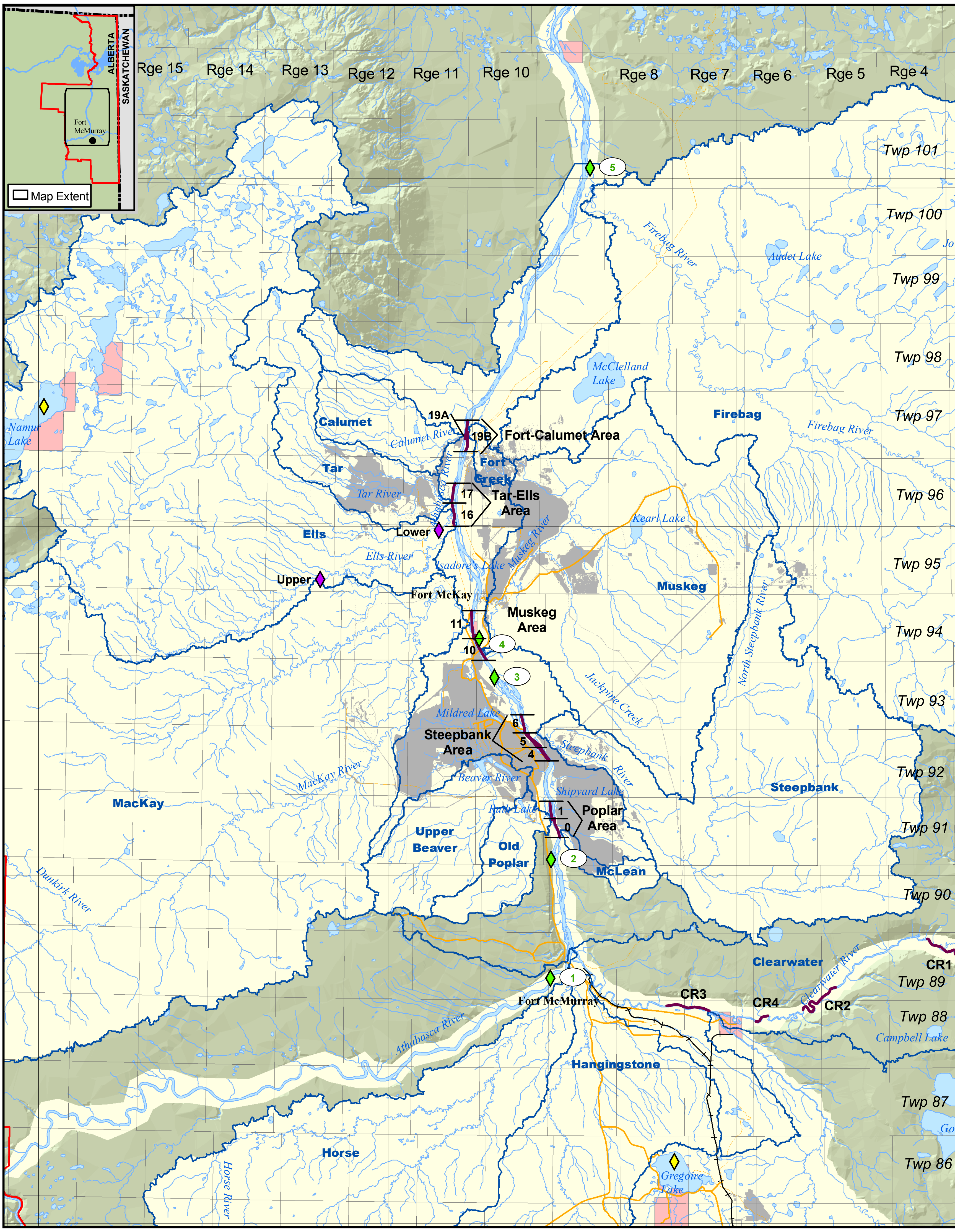
Sampling on the Athabasca River was implemented within ten reaches specifically established by RAMP for the inventory program, all of which have been sampled annually since 1997, and a number of which have been sampled continuously since 1989 by Syncrude Canada Ltd. (i.e., pre-RAMP) (Figure 3.4-1, Table 3.4-2). These ten reaches fall within key areas of the river, as follows:

- Poplar Area (Reaches 0 and 1);
- Steepbank Area (Reaches 4, 5, and 6);
- Muskeg Area (Reaches 10 and 11);
- Tar-Ells Area (Reaches 16 and 17); and
- Fort-Calumet Area (Reach 19).

Sampling in the Clearwater River was conducted at three locations (i.e., CR1, CR2, CR3) during the spring program (Figure 3.4-1, Table 3.4-2). The intention was to resample these three locations during the fall program. The majority of area CR1 was sampled, including all of CR1A (upstream section) and a portion of CR1B (downstream section). However, a boat motor malfunction prevented completion of sampling at CR1, and prevented sampling in any sections of CR2 or CR3. The boat was not able to be fixed in time to complete the program within the acceptable seasonal timeframe. Northern pike captured during the partially completed fall Clearwater River inventory were also used to support fish tissue monitoring studies (Section 3.4.2.2).

On both rivers, sampling was primarily conducted in areas conducive to electrofishing, primarily shallow river margins deep enough to be accessible by boat.

Figure 3.4-1 Location of areas used to sample fish for the inventory, tissue, and sentinel species monitoring activities for the 2007 RAMP Fish Population component.



Lakes	Land Change Area as of 2007
Rivers	Athabasca/Clearwater Fish Inventory Reaches (with Reach Number)
Major Roads	Non-lethal Athabasca River Sentinel Species Sampling
Secondary Roads	Non-lethal Ells River Sentinel Species Sampling
Railways	Regional Lakes Fish Tissue Sampling
First Nations Reserve	
RAMP Regional Study Area	
RAMP Focus Study Area	
Watershed Boundary	

RAMP
Regional Aquatics Monitoring Program

Data Sources:
a) National Topographic Data Base (NTDB) obtained from the Centre for Topographic Information - Sherbrooke, used under license.
b) Land change areas delineated from 10m SPOT-5 (July 2007) and 30m Landsat-5 (September 2007) multispectral imagery.
c) Watershed Boundaries from CEMA.

Township and Range designations are relative to W4M.

0 10 20 40 km
Scale 1:600,000
Projection: UTM Zone 12 NAD83

K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_H_Fish_20080314.mxd

Table 3.4-2 Fish inventory sampling locations on the Athabasca and Clearwater rivers, 2007.

Area	Reach Numbers	UTM Coordinates (NAD 83, Zone 12)	
		Upstream Boundary	Downstream Boundary
Athabasca River			
Poplar Area	00B	474646 E / 6305438 N	473932 E / 6308141 N
	01A	473480 E / 6307893 N	473103 E / 6310531 N
Steepbank Area	04A	472890 E / 6316361 N	471314 E / 6318285 N
	05A	471314 E / 6318285 N	469636 E / 6320525 N
	06A	469636 E / 6320525 N	468911 E / 6323011 N
	04B	473156 E / 6316650 N	471877 E / 6318562 N
	05B	471877 E / 6318562 N	470153 E / 6320420 N
Muskeg Area	10B	464172 E / 6330904 N	462582 E / 6334464 N
	11A	462220 E / 6333918 N	462025 E / 6337965 N
Tar-Ells Area	16A	459425 E / 6350065 N	458958 E / 6353380 N
	17A	458958 E / 6353380 N	459360 E / 6356213 N
Fort-Calumet Area	19A	461057 E / 6362604 N	460943 E / 6365216 N
	19B	461181 E / 6360892 N	461417 E / 6363621 N
Clearwater River			
CR1	CR1A	531982 E / 6288505 N	529592 E / 6289549 N
	CR1B	529592 E / 6289549 N	527714 E / 6291560 N
CR2	CR2A	514112 E / 6283950 N	512193 E / 6282517 N
	CR2B	512193 E / 6282517 N	510345 E / 6281510 N
	CR2C	510345 E / 6281510 N	509500 E / 6280700 N
CR3	CR3A	496071 E / 6280509 N	493022 E / 6280960 N
	CR3B	493022 E / 6280960 N	489943 E / 6281368 N

Fish were sampled using a Smith-Root model SR-18 electrofishing boat equipped with a 5.0 GPP electrofishing unit, configured with two anode boom arrays and multiple dropper cables. The boat's hull acted as the cathode. Stunned fish were captured with dip nets and held in an on-board flow-through live well. Fish observed, but not captured, were enumerated by species.

Captured fish were measured for fork length (±1 mm) and weight (±1 g), and sex and state of maturity were recorded when discernible by external examination. An external assessment was conducted to evaluate the general health (e.g., presence of disease, incidence of parasites, physical anomalies, etc.) of each fish. The examination was conducted using an inventory-specific coding system (Appendix G) that focused on the following structures: body (form and surface); lips and jaws; snout; barbels; anus; opercles; isthmous; fins; gills; pseudobranchs; thymus; eyes; and urogenital area.

In order to ensure consistency with external health assessments performed for the other monitoring activities (e.g. fish tissue studies), the results were re-coded using the external pathology index (EPI) scoring system (Golder 2003b, also Appendix G). Accordingly, the condition of each external structure was evaluated according to type and was assigned an associated index code and value representing degree of severity ranging from 0 to 30, where 0 indicated no signs of pathology. An external pathology index (EPI) score was then calculated for each fish by summing the index values for all structures. A mean EPI score was then calculated for each species.

Adults and larger juvenile walleye, northern pike, longnose sucker, and white sucker were sampled for aging structures and fixed with RAMP floy tags prior to their live release. Floy tags were inscribed with a discrete ID number and a contact phone number to facilitate tracking in the event of a recapture during future inventories, and to encourage anglers to report them. Aging structures were collected non-lethally according to procedures outlined in MacKay *et al*. (1990), as follows:

- Walleye, longnose sucker, and white sucker – two leading rays from left pectoral fin;
- Northern pike (inventory program) – two leading rays from left pelvic fin; and
- Northern pike (tissue program) – cleithra and two leading rays from right pelvic fin.

Aging structures were dried and stored in labeled coin envelopes pending future analyses, and all fish were released in the same area of the watercourse where they were captured.

3.4.2.2 Fish Tissue Studies

Clearwater River Tissue Study

In 2007, the fish tissue study on the Clearwater River targeted northern pike. Tissue samples were acquired from northern pike captured in area CR4 of the Clearwater River in fall 2007 (Figure 3.4-1). Muscle tissue was collected non-lethally for mercury analysis, and lethal dissections were performed for internal health assessments and the collection of tissue for analyses of tainting compounds (organics) and metals. The boat motor malfunction that prevented completion of the fall inventory sampling on the river also compromised achieving the planned lethal tissue program, but did not affect completion of the non-lethal mercury tissue program.

During the inventory, captured pike selected for tissue sampling were transferred to a stable, onshore sampling station where they were sampled for the two types of tissue analyses, as per methods described below.

Non-Lethal Tissue Analysis for Mercury A target of 25 northern pike was set for non-lethal mercury tissue analysis, with specific targets of five fish (irrespective of sex) in each of five size classes of 100 mm increments in fork length from 200 mm to 700 mm. These size classes were selected in order to:

- Ensure adequate representation of typical size ranges for northern pike observed in the fall during past inventories on the river (RAMP 2004, 2005, 2006);
- Ensure an even distribution of tissue samples across a wide range of fish sizes and ages;
- Ensure consistency with those size classes targeted in the fall during past tissue programs on the river (RAMP 2004, 2006), in order to allow comparisons with historical data; and
- Facilitate a better understanding of tissue concentrations within the populations.

In addition, the 2007 program included analyses of 5 pike from the >700mm size category for mercury, given the catch success within this larger size class during the inventory.

Prior to tissue sampling, each fish was measured for fork length (± 1 mm) and total weight (± 1 g), and an external assessment was conducted to evaluate general health (e.g., presence of disease, incidence of parasites, physical anomalies, etc.) based on the following structures: fins; skin; eyes; opercles; pseudobranchs; gills; and thymus.

The condition of each external structure was evaluated according to type and was assigned an associated index code and value representing degree of severity ranging from 0 to 30, where 0 indicated no signs of pathology (Golder 2003b, also Appendix G). An external pathology index (EPI) score was then calculated for each fish by summing the index values for all structures. A mean EPI score was then calculated for each species.

Muscle tissue was then sampled non-lethally from each pike for mercury analysis using a clean, unused 4 mm dermal biopsy punch (Acuderm Inc.), a method that was first adopted by RAMP in 2005 (RAMP 2005). Prior to sampling, a few scales were removed from the fish and the dermal punch was then positioned on the surface of the skin overtop the dorsal musculature. The punch was then pushed into the dorsal musculature, using pressure and a twisting motion moderate enough to penetrate the muscle, but not to penetrate through the fish cavity. Upon extraction, the punch was rotated in a twisting motion using slight angular pressure in order to assist in obtaining the muscle plug sample. The tissue plug was then blown through the hollow punch into a sterile, pre-labelled, pre-weighed (±0.001 g) 4 mL externally-threaded cryovial. The wet weight of the plug was then recorded (±0.001 g) for the calculation of total mercury concentration, and was placed immediately on dry ice in a cooler. After extraction of the punch, the void left in the fish was filled with a waterproof "bandage" sealant (Nexaband S/C, Topical Tissue Adhesive, Formulated Cyanoacrylate) following methods described by Baker *et al*. (2004), in order to decrease the chance of infection by closing the wound.

Following mercury tissue sampling, all pike not designated for lethal dissections were released immediately into the calm margins of the river to limit additional handling/confinement stress. All sampling equipment was rinsed using metals-free soap and distilled water, hexane, then acetone, and re-rinsed with deionized water after each fish to avoid cross contamination. Samples were transported in a cooler on dry ice and held in the Hatfield deep-freeze (Fort McMurray) before being shipped on dry ice to Flett Research (Winnipeg, Manitoba) for mercury analysis.

Lethal Dissections and Tissue Analysis for Tainting Compounds and Metals A 2007 target of five male pike (fork length: 450 mm - 500 mm) and five female pike (fork length: 500 mm - 550 mm) was originally set for dissection and comprehensive tissue sampling for tainting compounds (organics) and metals analysis. These sex/length combinations were set as targets in an attempt to minimize potential variability associated with size and age, and to allow for direct comparisons with data from previous tissue surveys on the river (RAMP 2004, 2006).

The boat motor malfunction that prevented completion of the fall inventory sampling on the river also compromised achieving target catch numbers for the lethal tissue program. Only two target-sized male pike and one target-sized female pike were captured for lethal sampling; additional pike outside of, but approaching, the target size ranges (450 mm – 600 mm) were used to provide supplementary tissues for both sexes. The following sex/length combinations of pike were used in the analysis:

- 6 males (450 mm – 600 mm):
    - 2 x 450 mm – 500 mm (target size)
    - 3 x 500 mm – 550 mm
    - 1 x 550 mm – 600 mm

- 3 females (450 mm – 600 mm):
  - 1 x 450 mm – 500 mm
  - 1 x 500 mm – 550 mm (target size)
  - 1 x 550 mm – 600 mm

Each of these fish was measured for fork length and weight, given an external health assessment, and sampled for mercury analysis as described above. The fish were then sacrificed for dissections and comprehensive tissue sampling, as per methods described below.

Each sacrificed fish was dissected and an internal assessment was conducted to evaluate general health (e.g., presence of disease, incidence of parasites, physical anomalies, etc.) based on the following structures and characteristics: liver; kidney; spleen; hindgut; gall bladder; fat content; and parasite presence.

For each fish, the sex, stage of maturity, liver weight (± 0.01 g), gonad weight (± 0.01 g), and carcass weight (total weight minus the internal organs, ± 1 g) were recorded. The fecundity (# eggs/g body wt.) was also determined for mature female pike. Aging structures (cleithra and two leading rays from the right pelvic fin) were then collected, dried, and stored in labeled coin envelopes to be sent to North/South Consultants Inc. (Winnipeg, Manitoba) for analysis.

Tissues were then removed from the musculature above the lateral line and posterior to the dorsal fin on the left side of each fish for analysis of tainting compounds, and from the right side of each fish for assessing metals (RAMP 2005b). Minimum muscle tissue requirements per fish were 20 g (50 to 100 g preferred) for tainting compounds analyses and 2 g (5 g preferred) for metals analyses. Skin and bone were removed from the muscle tissue. Samples collected for organics analysis were individually wrapped in solvent-rinsed aluminum foil, and samples collected for metals analysis were individually placed in clean, sealable plastic bags. All samples were labeled, and placed immediately on dry ice in a cooler for transportation to the Hatfield deep-freeze (Fort McMurray) where they were held prior to being shipped on dry ice to ALS Laboratory Group Edmonton (via the Fort McMurray ALS office) for chemical analysis.

Organics and metals analyses were performed on the composite samples of female and male target-sized fish in order to facilitate comparison of results with data from previous surveys. An additional set of composite samples was analyzed for female and male fish between 450 mm and 600 mm in an attempt to provide supplementary results based on larger sample sizes. Six males and three females were analyzed within this size range (including tissue from the target-sized fish).

The composites were prepared at ALS by combining an equal weight of muscle tissue from each fish. Two sets of each composite were prepared for the following analyses:

- Metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, vanadium, and zinc; and
- Tainting Compounds (PAHs): thiophene, toluene, M+P-xylenes, 1,3,5-trimethylbenzene, and naphthalene.

Methods and detection limits used for all chemical analyses, including tainting compounds, metals, and mercury are presented in Table 3.4-3. All remaining tissue samples were archived at the testing laboratory for additional analyses, if required.

Regional Lakes Tissue Studies

In 2007, tissue studies were performed on a sacrificed subsample of fish captured during Alberta Sustainable Resource Development's (ASRD's) fish population surveys on the following two regional lakes:

- Namur Lake (target species: lake trout); and
- Gregoire Lake (target species: walleye, northern pike, lake whitefish).

At Namur Lake, fish sacrificed for tissue subsampling during the 2007 Summer Profundal Index Netting (SPIN) program were collected on August 2, 2007. A target of 25 lake trout was set for mercury tissue analysis, with specific targets of five fish (irrespective of sex) in each of five size classes of 100 mm increments in fork length from 300 mm to 800 mm. These five classes were selected based on size ranges observed during a 1996 Namur lake trout inventory survey, and were considered to be representative of a wide range of fish sizes and ages within the population.

At Gregoire Lake, fish sacrificed for tissue subsampling during the 2007 Fall Walleye Index Netting (FWIN) program were collected on September 12, 2007. A target of 30 walleye, 30 northern pike, and 30 lake whitefish was set for mercury tissue analysis, with specific targets of five fish (irrespective of sex) in each of six size classes of 100 mm increments in fork length from 200 mm to 800 mm. These six length classes were selected in order to ensure consistency with those size classes targeted in the fall during past tissue programs on Gregoire Lake (Golder 2002a), in order to allow comparisons with historical data. These classes were originally selected based on typical size ranges observed for each species during past fall lake inventories, and were therefore considered to be representative of a wide range of fish sizes and ages within each species' population.

Fish tissues from both regional lakes were analyzed for mercury, but were collected and sampled lethally using a modified protocol. Fish were collected by ASRD using experimental multi-mesh gill nets, sacrificed, measured on-site for fork length (± 1 mm) and total weight (± 1 g), and evaluated for sex and stage of maturity. The tail sections (between the last rib and end of the caudal peduncle) were then removed, placed on ice, and transported to Hatfield (Fort McMurray) where they were stored in a deep-freeze and eventually sampled for mercury analysis.

Skinless, boneless, interior muscle tissues were sampled from each fish peduncle for mercury analysis using clean, stainless steel dissection equipment. Tissues from each fish were collected individually in sterile, pre-labelled, pre-weighed (± 0.001 g) 4 mL externally-threaded cryovials. Tissue sample wet weights were recorded (± 0.001 g) for the calculation of total mercury concentration, and samples were held in the Hatfield deep-freeze (Fort McMurray) before being shipped on dry ice to Flett Research (Winnipeg, Manitoba) for mercury analysis. All sampling equipment was rinsed using metals-free soap and distilled water, hexane, then acetone, and re-rinsed with deionized water in between each fish to avoid cross contamination.

Methods and detection limits used by Flett for mercury analysis are presented in Table 3.4-3.

Table 3.4-3 Methods of analyses and detection limits for mercury, metals, and tainting compounds in Clearwater River fish tissues, 2007.

Variable	Detection Limit (mg/kg)	Method of Analysis
Metals		
Aluminum (Al)	2	EPA 200.3/200.8-ICPMS
Antimony (Sb)	0.05	EPA 200.3/200.8-ICPMS
Arsenic (As)	0.01	APHA 3114 C-AAS – Hydride
Barium (Ba)	0.1	EPA 200.3/200.8-ICPMS
Beryllium (Be)	0.2	EPA 200.3/200.8-ICPMS
Boron (B)	2	EPA 200.3/200.8-ICPMS
Cadmium (Cd)	0.01	EPA 200.3/200.8-ICPMS
Chromium (Cr)	0.1	EPA 200.3/200.8-ICPMS
Cobalt (Co)	0.1	EPA 200.3/200.8-ICPMS
Copper (Cu)	0.05	EPA 200.3/200.8-ICPMS
Iron (Fe)	5	EPA 200.3/200.7-ICPOES
Lead (Pb)	0.02	EPA 200.3/200.8-ICPMS
Lithium (Li)	0.5	EPA 200.3/200.8-ICPMS
Manganese (Mn)	0.5	EPA 200.3/200.7-ICPOES
Mercury (Hg)[1]	0.002	Cold Vapor Atomic Fluorescence Spectraphotometry (CVAFS)
Molybdenum (Mo)	0.05	EPA 200.3/200.8-ICPMS
Nickel (Ni)	0.02	EPA 200.3/200.8-ICPMS
Selenium (Se)	0.002	APHA 3114 C-Auto Continuous Hydride
Silver (Ag)	0.02	EPA 200.3/200.8-ICPMS
Strontium (Sr)	0.05	EPA 200.3/200.8-ICPMS
Thallium (Tl)	0.05	EPA 200.3/200.8-ICPMS
Tin (Sn)	0.1	EPA 200.3/200.8-ICPMS
Titanium (Ti)	0.05	EPA 200.3/200.7-ICP-OES
Vanadium (V)	0.006	EPA 200.3/200.8-ICPMS
Zinc (Zn)	0.5	EPA 200.3/200.8-ICPMS
Tainting Compounds (PAHs)		
1,3,5-Trimethylbenzene	0.01	EPA 5021/8260-Headspace GC/MS
M+P-Xylenes	0.01	EPA 5021/8260-Headspace GC/MS
Naphthalene[2]	0.05	EPA 3540/8270-GC/MS
Thiophene	0.01	EPA 5021/8260-Headspace GC/MS
Toluene	0.01	EPA 5021/8260-Headspace GC/MS

[1] Analyzed by Flett Research (all other variables analyzed by ALS).

[2] Naphthalene was analyzed for three target compounds, 1-Methylnaphthalene, 2,6-Dimethylnaphthalene, 2,3,5-Trimethylnaphthalene, all with same detection limit and using the same method of analysis.

3.4.2.3 Non-Lethal Sentinel Species Monitoring

Athabasca River Sentinel Species Monitoring

Fish Sampling and Handling In 2007, non-lethal sentinel species monitoring was carried out at five sites on the Athabasca River during the summer and fall (Figure 3.4-1 and Table 3.4-4). As in the past (Golder 2002a) trout-perch (*Percopis omiscomaycus*) was the sentinel species, and a target of 100 individuals was set for each site, per season. The summer program was carried out from August 14 to 18, 2007, and the fall program took place from October 11 to 15, 2007. An emphasis was made on capturing young-of-year fish in order to evaluate growth between seasons.

All sampling was carried out by a four-person field crew using a Coffelt VVP-15 boat electrofisher; beach seines and a backpack electrofisher were used as supporting methods. Sampling efforts focused on river margins deep enough to be accessible by boat, but shallow enough to provide suitable habitat for younger trout-perch. During both sampling seasons, young-of-year trout-perch were found to prefer shallow, muddy substrate with overlying larger substrate (i.e. cobble, boulders, or woody debris). During the summer program, trout-perch were captured in greater numbers within shadier areas during the cool, early morning hours.

The boat electrofisher was configured with two anode boom arrays and multiple dropper cables. The boat's hull acted as the cathode. Electrofishing was performed in a downstream direction, and current was applied in 4 to 5 second bursts at a higher frequency (i.e., to catch small-bodied fish) within the designated site. Stunned trout-perch were captured downstream of the current using dip nets with a fine mesh net (6.35 mm mesh size) to ensure collection of sufficient young-of-year individuals (typically < 50 mm fork length).

At sites where shallow water limited access and did not permit sampling by boat electrofisher (e.g., Site 1), crews fished on foot using a Smith-Root 12B-POW battery-powered backpack electrofishing unit and a dip net (6.35 mm mesh size), which was placed downstream of the anode prior to and during the application of electrical current. At sites where electrofishing did not result in adequate catch success, beach seines (6.35 mm mesh size) were pulled manually along the shoreline to supplement collections.

Captured fish were held in large buckets filled with fresh site water prior to their analysis and subsequent release. Sampling was conducted at each site until the target 100 trout-perch were captured or until conditions did not permit continued fishing (e.g., poor site access). Non-target species were noted and released at the point of capture.

Trout-perch were measured for fork length (±1 mm) and weight (±0.01 g), and an external health assessment was conducted and used to calculate an external pathology index (EPI) score according to methods described in Section 3.4.2.2.

Immediately following assessment, each fish was revived in fresh water and then released back into the river near the original capture location.

Water Quality Measurements and Habitat Assessments The sentinel fish monitoring program on the Athabasca River also included habitat and water quality assessments at each site, using methods similar to those outlined in Golder (2002a) and RIC (1999) (examples of habitat and water quality assessment site cards produced are presented in Appendix G). Habitat assessments, performed only during the summer program, involved measuring and recording a range of variables relating to channel morphology, substrate, and stream cover. Water quality assessments, performed in both seasons, included *in situ* measurements for temperature (°C), dissolved oxygen (mg/L), pH, and specific conductance (μS/cm). Measurements were taken using either a YSI multi-meter or a combination of hand-held probes (temperature, conductivity, pH) and titration kits (DO). Temperature data loggers (HOBO Water Temp Pro v2) set to record temperature data at 15 minute intervals were deployed at each site during the August 2007 program, and retrieved during the October 2007 program to provide information on daily and seasonal temperature fluctuations that may influence growth.

Ells River Sentinel Species Monitoring

Fish Sampling and Handling In 2007, Athabasca tributary sentinel species monitoring was carried out during the summer and fall on the Ells River at two sites, UPPER and LOWER (Figure 3.4-1 and Table 3.4-5). Since all parts of the Ells River watershed continue to be designated as *reference*, neither of the sentinel monitoring sites were designated as *potentially influenced* by oil sands activity during the 2007 monitoring program. As in 2005, longnose dace (*Rhinichthys cataractae*) was selected as the sentinel species, and a target of 100 individuals was set for each site, per season. The summer program was carried out on August 19, 2007, and the fall program took place from October 1 to 2, 2007. An emphasis was made on capturing young-of-year fish in order to evaluate growth between seasons.

Sites were accessed by helicopter, and sampling was carried out on foot by two-person field crews using Smith-Root 12B-POW battery-powered backpack electrofishing units. Current was applied in 4 to 5 second bursts at a higher frequency (i.e., to catch small-bodied fish) within the designated site. Stunned longnose dace were captured downstream of the current using a portable pole seine or dip net equipped with a fine mesh net (6.35 mm mesh size) to ensure collection of sufficient young-of-year individuals (as small as 10–20 mm fork length).

Sampling efforts were focused in areas shallow enough to be accessible on foot, but deep enough to provide suitable habitat for longnose dace. Habitat preference was somewhat unpredictable, but during both sampling seasons, young-of-year longnose dace were found to prefer depths over 0.25 to 0.5 m, moderate flows, and sand/gravel substrate with some overlying larger substrate (i.e. boulders, some vegetation or woody debris).

Captured fish were held in large buckets filled with fresh site water prior to their analysis and subsequent release. Sampling was conducted at each site until the target 100 longnose dace were captured. Non-target species were noted and released at the point of capture.

Longnose dace were measured for fork length (±1 mm) and weight (±0.01 g), and an external health assessment was conducted and used to calculate an external pathology index (EPI) score according to methods described in Section 3.4.2.2.

Immediately following assessment, each fish was revived in fresh water and then released back into the river near the original capture location.

Water Quality Measurements and Habitat Assessments The sentinel fish monitoring program on the Ells River also included habitat and water quality assessments at each site, using the same methods described for the Athabasca River sentinel species program (above).

Table 3.4-4 Monitoring sites on the Athabasca River used for the sentinel fish survey, 2007.

Site Code	Location Description		UTM Coordinates (NAD83, Zone 12)		
			Target 2007 (2002*)	Summer 2007	Fall 2007
1	*Reference* site upstream of Ft. McMurray STP and oil sands development area	Start (U/S):	470302 E / 6283093 N	472168 E / 6283780 N	473237 E / 6285291 N
		Finish (D/S):	475650 E / 6286679 N	473714 E / 6286168 N	473435 E / 6285811 N
2	*Reference* site between STP discharge and oil sands development area	Start (U/S):	474101 E / 6301565 N	473401 E / 6302206 N	473326 E / 6302326 N
		Finish (D/S):	474476 E / 6306201 N	473482 E / 6303586 N	474525 E / 6305058 N
3	*Potentially influenced* site below Beaver R. confluence	Start (U/S):	463707 E / 6330992 N	464187 E / 6330151 N	465215 E / 6328425 N
		Finish (D/S):	463407 E / 6331547 N	463529 E / 6332195 N	463743 E / 6330862 N
4	*Potentially influenced* site below Muskeg R. confluence	Start (U/S):	463263 E / 6332929 N	462951 E / 6333370 N	463061 E / 6334014 N
		Finish (D/S):	462534 E / 6334554 N	462204 E / 6335522 N	462524 E / 6334538 N
5	*Potentially influenced* site below Firebag R. confluence	Start (U/S):	478852 E / 6401786 N	478801 E / 6410313 N	478935 E / 6401596 N
		Finish (D/S):	478761 E / 6410216 N	477364 E / 6414134 N	478671 E / 6402361 N

* Previous program

Table 3.4-5 Monitoring sites on the Ells River used for the sentinel fish survey, 2007.

Site Code	Location Description		UTM Coordinates (NAD83, Zone 12)		
			Target 2007 (2005*)	Summer 2007	Fall 2007
UPPER	Upstream of the CNRL road bridge (~10km)	D/S:	440611 E / 6342439 N	440621 E / 6342443 N	440630 E / 6342432 N
		U/S:	440286 E / 6342418 N	440416 E / 6342384 N	440285 E / 6342517 N
LOWER	In the area of the CNRL access road bridge	D/S:	457556 E / 6349891 N	457356 E / 6349944 N	457450 E / 6349776 N
		U/S:	457363 E / 6349969 N	457320 E / 6349930 N	457270 E / 6349582 N

* Previous program

3.4.2.4 Fish Tag Return Assessment

Tagging of key indicator fish species has been regularly undertaken as part of the Fish Population component of RAMP since 1999. RAMP fish tags are uniquely identified by a colour and ID number (for tracking the fish in the event of recapture), as well as a contact phone number that anglers can use to report catch information to the Alberta Ministry of Sustainable Resource Development (ASRD). Data recorded at the time of tagging include tag number, tag colour, species, basic morphology (fish length and weight), maturity, sex (if possible), external health condition, date, and geographical location.

RAMP and ASRD maintain records of tagged fish recaptured by anglers or during RAMP monitoring (e.g. inventory). In general, information reported and recorded from angler recaptures has been limited to the recapture date, tag number, species, and a description of the geographical recapture location. This information is compared to data compiled at the time of tagging and used to analyze patterns of fish movements over time. Information reported and recorded from RAMP program recaptures can include re-evaluations of fish length and weight, and external health. These data can be used to analyze changes over time in basic morphology and health.

3.4.3 Changes in Monitoring Network from 2006

2007 Fish Population component monitoring activities differed from those carried out during the 2006 program in the following ways:

- The Muskeg River fish fence program was planned for spring 2007, but not implemented due to prohibitively high water levels;
- Sentinel species monitoring in 2007 was carried out on the Athabasca and Ells Rivers;
- No sentinel species reconnaissance activities were required in 2007;
- Regional Lakes fish tissue programs were implemented on Namur Lake and Gregoire Lake in 2007; and
- The fall 2007 Clearwater River fish inventory and tissue programs were only partially completed (due to a boat motor malfunction).

3.4.4 Challenges Encountered and Solutions Applied

In general, most monitoring activities implemented under the 2007 Fish Population component were completed successfully without significant difficulties. However, the following three programs faced logistical challenges:

- High water flows on the Muskeg River in spring 2007 prohibited implementation of the Muskeg River fish fence program;
- A boat motor malfunction in September and October 2007 prohibited completion of the fall Clearwater River fish inventory and tissue programs; and
- Site access issues on the Athabasca River in August 2007 prohibited completion of fish sampling at Site 1 during the Athabasca River sentinel species summer program.

The Muskeg River fish fence program originally planned for spring 2007 could not be implemented due to prohibitively high water levels during the scheduled installation period (April/May). Discharge on the river in the third week of April was recorded at levels

>12 m^3/s, which exceeded the safe installation discharge criterion of 9 m^3/s. The fish fence program, which was intended to be a repeat of the one carried out in 2006, is scheduled to be implemented in spring 2008, pending assessment of seasonal water levels at that time.

Fish inventory sampling in the Clearwater River was completed at all three planned locations (i.e., CR1, CR2, CR3) during the spring 2007 program. However, due to a boat motor malfunction, sampling during the fall program (September, 2007) was only partially completed at CR1, and no sampling was carried out at CR2 or CR3. The boat was not able to be fixed in time to complete the inventory program within the acceptable seasonal timeframe.

A boat motor malfunction that prevented completion of the fall inventory sampling program in September 2007 on the Clearwater River also compromised achieving target catch numbers of northern pike for the planned lethal tissue program, but did not affect completion of the non-lethal mercury tissue program. A second attempt was made to complete the lethal tissue program in October 2007, one month after the September inventory, but the onset of winter conditions limited catch success and further boat motor malfunctions prohibited completion of the program. Sampling in October was conducted in a new reach on the Clearwater (CR4) in an effort to catch adequate numbers of fish for the lethal tissue analysis.

Sentinel species sampling in the Athabasca River could not be completed during the summer program at Site 1, a reference site upstream of the Fort McMurray sewage treatment plant and focal project activities, given site access limitations. The water level in the river was too low and sand/cobble bars were too prevalent to allow for the electrofishing boat to navigate safely into trout-perch habitat within the shallower river margins. Attempts to seine the area on foot also resulted in poor catch success. The target number of trout-perch therefore could not be achieved at Site 1 during the summer program. During the fall program, crews accessed the general site area by boat and sampled the shallower river margins on foot using backpack electrofishers, and were able to achieve target catch numbers.

3.4.5 Other Information Obtained

No additional information or data was obtained for the Fish Population component in 2007.

3.4.6 Summary of Component Data Now Available

Fish Population data collected to date by RAMP are summarized in Table 3.4-7.

3.4.7 Analytical Approach

The analytical approach used in 2007 for the Fish Population component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2005b) and consisted of:

- Selecting fish population measurement endpoints;
- Conducting detailed analysis on fish population measurement endpoints, including statistical analyses and tabular/graphical presentations; and
- Selecting and using criteria to determine effects according to fish population measurement endpoints.

Table 3.4-6 Measurement endpoints for non-lethal sentinel species monitoring.

Indicator	Measurement Endpoint
Growth	▪ Length / weight of young-of-year at end of growth period[1] ▪ Size of 1+ fish ▪ Size at age
Reproduction	▪ Abundance of young-of-year ▪ Young-of-year survival
Condition	▪ *Body weight vs. length (k)
Survival	▪ Age frequency distribution (if possible) ▪ Length frequency distribution[1]

[1] Key measurement endpoints used for determining effects. Other endpoints used for supporting analyses.

3.4.7.1 Selection of Fish Population Measurement Endpoints

The measurement endpoints selected to evaluate Fish Population component data were specific to each study undertaken.

Fish Inventories

The following measurement endpoints were used to analyze fish inventory results from the Athabasca and Clearwater Rivers:

- Percent species composition (relative to all fish captured);
- Relative abundance (catch per unit effort – CPUE);
- Length-frequency distributions;
- Condition factor;
- Incidence of external health anomalies; and
- Recruitment to the sport fishery (Athabasca River only).

Fish Tissue Studies

Measurement endpoints used to analyze fish tissue results from the Clearwater River included whole-organism metrics (fork length, body weight, and age), incidence of external/internal health anomalies, and all metals (including mercury) and tainting compounds measured (Table 3.4-3).

Whole-organism metrics (fork length and body weight) and mercury burden (both concentration and concentration normalized to fork length) were the only endpoints used to analyze fish tissues results from Namur and Gregoire regional lakes.

Non-Lethal Sentinel Species Monitoring

Measurement endpoints used to analyze non-lethal sentinel species monitoring results on the Athabasca and Ells rivers are summarized in Table 3.4-6. The selected endpoints are based on Environment Canada's Environmental Effects Monitoring (EEM) guidelines developed for the metal mining and pulp and paper sectors (Environment Canada 2002, 2005).

Table 3.4-7 Summary of RAMP data available for the Fish Population component.

see symbol key at bottom

WATERBODY AND LOCATION	REACH	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																													
Poplar Area	0/1[a]		1	1,5	1,5		1,6	1,5	1,3,6														1				1		1		1		1		1		1		1		1		1		1
Steepbank Area	4/5/6		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6		1		1,6		1		1		1		1,6		1		1		1		1
Muskeg Area	10/11/12		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6		1		1,6		1		1		1		1,6		1		1		1		1
Tar-Ells Area	16/17		1	1,5	1,5		1,6	1	1,3,6									7					1				1		1		1		1		1		1		1		1		1		1
Fort-Calumet Area	19A																																		1		1		1		1		1		1
	19B																										1												1		1		1		1
Reference Area - about 200 km upstream[b]	5/6							1,5	1,3,6																																				
Reference Area - upstream of Fort McMurray[c]			1																																										
Radiotelemetry study region[d]					2		2		2						2	2	2	2	2																										
Downstream of Suncor's Discharge	AR-SD/3												1,3												10,3				10															3	3
Below Muskeg River	AR-MR/4												1,3												10,3				10															3	3
Reference site upstream of Ft. McMurray STP	1																								3				10															3	3
Reference site between STP and Suncor	AR-R/2												1,3												3				10															3	3
Downstream of Developments (near Firebag R.)	5																								3				10,6															3	3
Athabasca River Delta																																													
Athabasca River Tributaries																																													
Fort Creek (mouth)															1,8,5,9	1																													
Historical Review of Tributary Fish Data																																													
Clearwater River	CR1																										1		1		1		1		1		1		1		1,6		1		1,6
Clearwater River	CR2																										1		1		1				1				1		1,6		1		1,6
Clearwater River	CR3																										1	10	1		1				1				1		1,6		1		1,6
Christina River[i]																																	1				1								
Ells River																																													
Upper and lower Ells River[h]													1,3																		4a		3a			1,3	3							3	3
Isadore's Lake																																													
Kearl Lake																																													
Mackay River																																													
Lower reach (85 km section from bridge to mouth)[j]	MAR-1		1																				1					10			4a				4a						3a				
Marguerite River Sentinel																																													
McLean Creek																																													
Mouth																																													
Upstream of mouth (100 m)																																													
Muskeg River																																													
Lower 35 km below Jackpine Creek confluence				1			4						1,3		2,8	2	2	2	2	1	6			1	6							1	6												
Mouth (within 1 km of confl. with Athabasca R.)	MR-E												1,3						4		3		4		4		4						3						4	3	3				
Reference sites (Steepbank, Horse and Dunkirk R.)	SR-R																3				3												3												
	HR-R,																3				3												3							3	3				
	DR-R																3				3												3							3	3				
Upper Muskeg River (near Wapasu Ck. Confluence)																							1,4		1,4																				
Muskeg River Tributaries																																													
Alsands Drain																																													
Jackpine Creek (accessable areas of lower creek)															8					1				1								1													
Shelley Creek																																													
Muskeg Creek (Canterra road crossing)[e]																							1,4		1,4																				
Stanley Creek																																													
Wapasu Creek (mouth or Canterra road)[e]																							1,4		1,4																				
Regionally Important Lakes																																													
Various lakes in water/air emissions pathway																													6				6												6
Poplar Creek																																													
Shipyard Lake																																													
Steepbank River																																													
Steepbank Mine baseline fisheries reach (1995)[f]	AF014			1																																									
Vicinity of Steepbank Mine	SR-E												1,3								3												3							3	3				
Original Sentinel reference site on Steepbank River[g]	SR-EC												1,3				3				3												3												
Reference site in vicinity of Bitumin Heights	SR-R												1,3																																
New Sentinel Reference site on Steepbank River	SR-R2																																							3	3				
Sentinel reference sites (Horse and Dunkirk R.)	HR-R, DR-R																3				3												3							3	3				

Legend

1 = fish inventory
2 = radiotelemetry; 1997-1998 walleye, lake whitefish (Athabasca River)
2000-2001: longnose sucker, northern pike, Arctic grayling (Athabasca River and Muskeg River)
3 = sentinel fish monitoring
3a = sentinel fish reconnaisance
4 = fish fence
4a = fish fence reconnaisance
5 = fish habitat association
6 = fish tissue
7 = winter fish habitat sampling
8 = spawning survey
9 = benthic drift survey
10 = IBI Assessment - Test program
N/A = site unnamed

Blue = *potentially influenced*
Green = *reference*

Footnotes

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

3.4.7.2 Detailed Data Analysis

Detailed analyses were performed on measurement endpoints calculated from the Fish Population component data; all analyses were conducted using Microsoft Excel (Excel 2003) and SYSTAT 10 (SPSS 2000).

Fish Inventories

Measurement endpoints calculated from data collected during the spring and fall inventory programs on the Athabasca and Clearwater rivers were used to evaluate general trends in fish abundance and population, with a focus on large-bodied KIR species (i.e., walleye, northern pike, white sucker, longnose sucker, lake whitefish).

Measurement endpoints subjected to data analysis were calculated using capture data only (i.e. fish collected and measured); observed data were reported separately for each watercourse, but not analyzed.

Species Composition and Relative Abundance (CPUE) All fish captured during the Athabasca River and Clearwater River fish inventories were summarized by percent species composition (relative to total abundance for all species), and relative abundance for each species (catch per unit effort - CPUE). In the past, these measurement endpoints were calculated for all combined reaches on a river, for each season. In 2007, species composition and CPUE were also calculated per area (i.e. all combined reaches within a distinct area of the river; see Table 3.4-2), for each season. Temporal comparisons were graphically presented in order to compare species composition between 1997 and 2007 for each of the large-bodied KIR species, per season (with the exception of lake whitefish, given insufficient data). Observed individuals (i.e., those not collected and measured) were simply reported.

Length-Frequency Distributions Length-frequency distributions (i.e. number of fish per fork length class) were calculated for each large-bodied KIR species captured during the Athabasca River and Clearwater River fish inventories (spring and fall combined). Length classes were divided into 25 mm increments for goldeye and 50 mm increments for walleye, longnose sucker, white sucker, and northern pike. Length-frequency distributions were displayed graphically for each year in order to evaluate trends in dominant length classes over time.

Condition Factor Fish condition was evaluated over time as a measure of change in energy storage for all large-bodied KIR species captured during the Athabasca River and Clearwater River fish inventories. In order to be consistent with past analyses, 2007 analyses were restricted to fish of the following species-specific minimum lengths: walleye >400 mm; lake whitefish >350 mm; northern pike >400 mm; goldeye >300 mm; longnose sucker >350 mm; and white sucker >350 mm.

In the past, analyses of fish condition have traditionally been limited to fish collected in the spring only, with the exception of lake whitefish for which only fall condition was evaluated given insufficient spring sample sizes (Golder 2002a). In 2007, spring condition for whitefish and fall condition for the other large-bodied KIR species were also included in order to evaluate seasonal comparisons over time.

The following analyses were performed in order to evaluate condition for fish captured on both rivers:

- Fish condition (or "fatness") was compared between years (1997 to 2007) for each season using analysis of covariance (ANCOVA; $\alpha = 0.05$), where body weight ($\log_{10}$ transformed) represented the dependent variable, site the independent variable, and fork length ($\log_{10}$ transformed) the covariate. The first step in the analysis was to compare slopes of length-weight regressions from different populations, and the second step was to compare the intercepts of the regressions; and

- Fulton's Condition Factor was calculated, as K= (body weight/fork length^3 x 10^5), and used in tabular and graphical presentations showing condition for each species, per season, over time.

Incidence of External Health Anomalies Incidence of external fish health anomalies were evaluated for all large-bodied KIR species captured during the Athabasca River and Clearwater River fish inventories using the following analyses:

- Percentage of anomalies was calculated relative to total number of fish captured during each season;
- Key types of anomalies were identified; and
- Mean annual EPI scores were calculated for each large-bodied KIR species and compared graphically over time.

Recruitment to the Sport Fishery Fish captured during the Athabasca River inventory were used to estimate recruitment of walleye and northern pike to the sport fishery. The ratios of under-size to legal-size fish were calculated and compared over time (1997 to 2007) for each species. Although fork length is the standard length measure used in RAMP fish population studies, ASRD legal catch size limits for the Athabasca River in the Northern Boreal Zone 3 are given in total length (walleye ≥ 430 mm; northern pike ≥ 630 mm). Using regression equations for each species, the associated fork length limits were estimated to be ≥ 370 mm for walleye and ≥ 600 mm for northern pike.

Fish Tissue Studies

Measurement endpoints calculated from data collected during the fish tissue programs on the Clearwater River and regional lakes (i.e., Namur and Gregoire Lakes) were used to evaluate trends in fish health and chemical concentrations.

Whole-organism metrics Whole-organism metrics (i.e., fork length, body weight, age) were reported along with fish sex and stage for northern pike collected during the tissue program on the Clearwater River. These metrics, with the exception of age, were also reported for fish collected during tissue programs on Namur and Gregoire lakes.

Incidences of Health Anomalies Incidences of anomalies observed during external and internal health assessments were reported for northern pike collected and dissected during the tissue program on the Clearwater River.

Mercury Mercury results were reported for fish collected during tissue programs on the Clearwater River and Namur and Gregoire lakes. Scatterplots were then used to initially assess relationships between mercury concentrations and whole-organism metrics for each species and sex combination. Spearman's rank correlations (two-tailed, $\alpha = 0.05$) were then used to statistically evaluate the significance of these relationships. Correlations with correlation coefficients (r_s) greater than the critical r_s were indicative of statistically significant relationships. A correlation was described as moderate if $|0.50| > r_s < |0.75|$ and strong if $r_s > |0.75|$. Linear regression was used to further evaluate significant rank correlations. Assumptions of regression models were tested and, if necessary, analyses were performed using $\log_{10}$-transformed or ranked data. Mercury concentrations between years (2004, 2006, 2007) were compared graphically and statistically using analysis of covariance (ANCOVA; $\alpha = 0.05$), where mercury concentration ($\log_{10}$ transformed) represented the dependent variable, year the independent variable, and fork length ($\log_{10}$ transformed) the covariate. The first step in the analysis was to compare slopes of length-weight regressions from different populations, and the second step was to compare the intercepts of the regressions.

Mercury concentrations in fish tissue samples from all three waterbodies sampled in the RAMP 2007 program (i.e., Clearwater River, Gregoire Lake and Namur Lake) were standardized to fish weight and compared to weight standardized fish tissue mercury concentrations from lakes in the region (Grey et al. 1995, Golder 2004, RAMP 2003, RAMP 2004) to assess temporal and spatial comparisons.

Total Metals and Organic Compounds Results for total metals and tainting compounds were reported for northern pike collected during the Clearwater River fish tissue program.

Non-Lethal Sentinel Species Monitoring

Trout-perch data generated from the summer and fall sampling programs on the Athabasca River were used to evaluate for differences in growth, condition, and survival measurement endpoints between the *reference* sites (Sites 1 and 2) and *potentially influenced* sites (Sites 3, 4, and 5). Longnose dace data from both seasons on the Ells River were used to evaluate for differences in the same three indicators between the UPPER and LOWER sites (both considered *reference* in 2007).

Growth In order to evaluate growth, an important measure of energy use, the following analyses were performed:

- Growth between seasons: Lengths and weights for young-of-year fish were $\log_{10}$-transformed and statistically compared between seasons for each site using ANOVA ($\alpha = 0.05$);
- Size between sites: Lengths and weights for all fish were $\log_{10}$-transformed and statistically compared between sites for each season using ANOVA ($\alpha = 0.05$);
- Growth rates: Lengths for young-of-year fish were used to calculate growth rate (mm/day) between seasons for each site; and
- Proportion of young-of-year: The proportion of young-of-year fish as a percentage of the total population was calculated for each site and each season.

Condition In order to evaluate condition, an important measure of energy storage, the following analyses were performed:

- Fish condition (or "fatness") was compared between sites for each season using analysis of covariance (ANCOVA; $\alpha = 0.05$), where body weight ($\log_{10}$ transformed) represented the dependent variable, site the independent variable, and fork length ($\log_{10}$ transformed) the covariate. The first step in the analysis was to compare slopes of length-weight regressions from different populations, and the second step was to compare the intercepts of the regressions; and
- Fulton's Condition Factor was calculated, as K= (body weight/fork length^3 x 10), and used in graphical analyses, tabular presentations, and effects analyses.

Survival In order to evaluate survival, the following analyses were performed:

- Length-frequency distributions for fish populations were generated using 2-mm length classes and between sites for each season, and between seasons for each site using a Kolmogorov-Smirnov (K-S) pairwise comparison test (two-sided, $\alpha = 0.05$). The K-S test evaluates whether or not two cumulative distributions are from the same population, and is sensitive to differences in both the shape (abundance or frequency of individuals within each length class) and position (range of lengths) of distributions; and

- In order to further examine differences identified by K-S testing in range of lengths and abundance of individuals in each length class, cumulative length-frequency distribution graphs and seasonal relative frequency distribution graphs were observed.

Fish Tag Return Assessment

A spatial presentation of tag return information (location tagged and location recaptured) was prepared for the tag returns received in 2007.

3.4.7.3 Criteria for Determining Effects

Criteria were selected and used for determining effects according to measurement endpoints calculated from the Fish Population component data.

Fish Inventories

As indicated in Section 1.4.4.4, the RAMP fish inventories are considered to be stakeholder-driven activities best suited for assessing general trends in abundance and population variables for large-bodied species. They are not specifically designed for assessing environmental effects of focal project activities, and therefore no effects criteria were used to evaluate measurement endpoints calculated from the results of the Athabasca River and Clearwater River fish inventories.

Fish Tissue Studies

Metals (including mercury) and tainting compounds measured in fish collected from the Clearwater River were used to evaluate potential effects on human health, fish, and palatability (tainting).

Mercury in fish collected from Namur Lake and Gregoire Lake was used to evaluate potential effects on human health and fish.

Potential Effects on Human Health To assess potential effects on human health due to ingestion of fish tissues, fish tissue data were screened against the following criteria (Table 3.4-8):

- Health Canada Guidelines for general fish consumption (Health Canada 2007a and 2007b, last updated July 2007) and subsistence level fish consumption (Health and Welfare Canada 1979, INAC 2003, updated June 2006);
- Region III USEPA risk-based criteria for consumption of fish tissue for recreational and subsistence fishers (USEPA 2003, updated October 2007); and
- National USEPA risk-based screening values for consumption of fish tissue (USEPA 2000, updated November 2000).

Mercury is the only RAMP fish tissue study endpoint that currently has a Health Canada consumption guideline, both for general as well as subsistence level consumers. USEPA criteria exist for a larger number of RAMP fish tissue study endpoints, and are risk-based values that take into account the toxicity (including carcinogenicity) of the contaminant, body weight of the consumer, and exposure rate. National USEPA criteria have been developed for both recreational and subsistence users, and are available for arsenic, selenium, and mercury. Regional USEPA criteria apply to general adult exposure, and are in place for several total metals, mercury, and toluene (tainting compound).

Health Canada's mercury guidelines are for total mercury, while the USEPA's mercury guidelines are for methylmercury. Evidence suggests that over 85 to 95% of mercury in fish tissues is present as methylmercury and that past reports of substantially lower

CH_3Hg fractions may have been biased by analytical and homogeneity variability (Bloom 1992, Ullrich *et al.* 2001). As such, both sets of guidelines make the conservative assumption that, for the purposes of screening for human health risks, 100% of total mercury in edible fish tissues is present as methylmercury (USEPA 2000, Health Canada 2007b). Guidance accompanying both countries' criteria therefore assumes and recommends that most health risk assessments will employ the more cost-effective method of analyzing for total mercury, while screening against methylmercury and mercury guidelines interchangeably.

Health Canada's guideline for general consumption of total mercury in fish (Health Canada 2007a and 2007b) was designed for the average fish consumer, and is less conservative than their guideline for subsistence level consumption of total mercury (INAC 2003), which was originally derived from various studies on toxicity of methylmercury to aboriginal consumers (Health Canada 1979). Similarly, the USEPA methylmercury guideline for recreational fishers is less conservative than the one developed for subsistence level fishers. Overall, the National USEPA mercury guideline for subsistence fishers is the most stringent value used for evaluating RAMP fish tissue concentrations; the screening value is four times lower than Health Canada's value for subsistence fishers.

Potential Effects on Fish Health To assess potential effects on fish health, fish tissue data were screened against minimum effects and no-effects thresholds derived from laboratory-based studies summarized in Jarvinen and Ankley (1999). These criteria were only available for some of the RAMP fish tissue study endpoints, including several total metals and mercury, but not for any of the tainting compounds. The thresholds were developed based on ranges of fish tissue residue concentrations linked to both effects and a lack of effects on both sublethal (e.g. growth) and lethal (survival) endpoints; the lowest concentrations were used to evaluate effects. The thresholds are presented in Table 3.4-9, along with information regarding the studies from which they were derived, including the endpoints evaluated, tissue type, species, life stage and/or fish size, exposure route, and duration of exposure. Only thresholds derived from the most relevant studies were used to screen the RAMP fish tissue data; those derived from studies on small-bodied fish or tropical fish species, and those that simultaneously evaluated effects of conventional variables on toxicity or maternal transfer studies, were excluded. Effects concentrations associated with acute exposures were only included for contaminants where few other data existed.

Potential Effects on Palatability Elevated concentrations of tainting compounds may cause undesirable odors or flavours in fish that can decrease their palatability. Potential effects on palatability were assessed by evaluating tainting compound data based on a method developed by Jardine and Hrudey (1988), whereby compounds present at concentrations above 1 mg/kg have the potential to result in detectable undesirable odor or taste.

Non-Lethal Sentinel Species Monitoring

Of the suite of measurement endpoints used to analyze non-lethal sentinel species monitoring results on the Athabasca and Ells rivers, condition factor is the only endpoint that has been assigned effects criteria based on Environment Canada's Environmental Effects Monitoring (EEM) criteria (Environment Canada [2002, 2005]). The impact criterion for condition factor, as defined by Environment Canada, is:

- *Condition factor at exposed site ±10% difference from reference site*

In other words, if fish condition at an exposed site differs from fish condition at the reference site by at least 10%, this may be an indication that the exposed population has been somehow ecologically affected.

Table 3.4-8 Criteria used for evaluating potential effects of fish consumption on human health.

RAMP Fish Tissue Endpoint	Units	Health Canada		National USEPA[3]		Region III USEPA[4]
		General[1]	Subsistence[2]	Recreational	Subsistence	Risk-based Criteria
Total Metals						
Aluminum (Al)	mg/kg	nc	nc	nc	nc	nc
Antimony (Sb)	mg/kg	nc	nc	nc	nc	0.54
Arsenic (As)	mg/kg	nc	nc	0.026	0.00327	0.0021
Barium (Ba)	mg/kg	nc	nc	nc	nc	270
Beryllium (Be)	mg/kg	nc	nc	nc	nc	2.7
Boron (B)	mg/kg	nc	nc	nc	nc	120
Cadmium (Cd)	mg/kg	nc	nc	nc	nc	1.4
Calcium (Ca)	mg/kg	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	nc	nc	nc	nc	4.1
Cobalt (Co)	mg/kg	nc	nc	nc	nc	nc
Copper (Cu)	mg/kg	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	nc	nc	nc	nc	410
Lead (Pb)	mg/kg	nc	nc	nc	nc	nc
Lithium (Li)	mg/kg	nc	nc	nc	nc	27
Manganese (Mn)	mg/kg	nc	nc	nc	nc	190
Mercury (Hg)[5]	mg/kg	0.5	0.2	0.4	0.049	0.14
Molybdenum (Mo)	mg/kg	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	nc	nc	nc	nc	27
Selenium (Se)	mg/kg	nc	nc	20	2.457	6.8
Silver (Ag)	mg/kg	nc	nc	nc	nc	6.8
Strontium (Sr)	mg/kg	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	nc	nc	nc	nc	810
Titanium (Ti)	mg/kg	nc	nc	nc	nc	nc

[1] Last updated July 2007; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] Last updated June 2006; found at http://www.ainc-inac.gc.ca/ncp/pub/hig/hig15_e.html

[3] Last updated November 2000; found at http://www.epa.gov/waterscience/fishadvice/volume1/index.html (see Chapter 5).

[4] Last updated October 2007; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

[5] Criteria are for total mercury and methylmercury, assuming equivalence.

Table 3.4-8 (Cont'd.)

RAMP Fish Tissue Endpoint	Units	Health Canada		National USEPA[3]		Region III USEPA[4]
		General[1]	Subsistence[2]	Recreational	Subsistence	Risk-based Criteria
Total Metals cont'd						
Vanadium (V)	mg/kg	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	nc	nc	nc	nc	410
Tainting Compounds						
Thiophene	mg/kg	nc	nc	nc	nc	nc
Toluene	mg/kg	nc	nc	nc	nc	110
m+p-Xylenes	mg/kg	nc	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	nc	nc	nc	nc	nc
Naphthalene	mg/kg	nc	nc	nc	nc	nc

[1] Last updated July 2007; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] Last updated June 2006; found at http://www.ainc-inac.gc.ca/ncp/pub/hig/hig15_e.html

[3] Last updated November 2000; found at http://www.epa.gov/waterscience/fishadvice/volume1/index.html (see Chapter 5)

[4] Last updated October 2007; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

[5] Criteria are for total mercury and methylmercury, assuming equivalence.

Table 3.4-9 Criteria used for evaluating potential effects on fish health based on concentrations of metals that have lethal, sublethal, or no effects on freshwater fish.

Variable	Endpoint		Effects Concentrations (mg/kg)	Tissue	Species	Life Stage or Size	Route	(days)
Metals								
Aluminum	Survival	no effects	1.0 - 1.15	muscle	rainbow trout, Atlantic salmon	171 g, alevin	oral, water	30 - 42
		effects	20 - 36.8	whole body	Atlantic salmon	alevin	water	30
Antimony	Survival	no effects	5	whole body	rainbow trout	fingerling (1.2 g)	water	30
		effects	9	whole body	rainbow trout	fingerling (1.2 g)	water	30
Arsenic	Survival	no effects	2.6 - 11.4	carcass, whole body	rainbow trout	juvenile	oral, water	21 - 56
		effects	11.2 - 17.9	carcass	rainbow trout	juvenile	oral	56
	Growth	no effects	0.9 - 6.5	carcass, whole body	rainbow trout	juvenile	oral, water	21 - 56
		effects	3.1	carcass	rainbow trout	juvenile	oral	56
Barium	-	-	-	-	-	-	-	-
Cadmium	Survival	no effects	0.02 - 2.8	muscle	rainbow trout, brook trout	150 -200 g, adult	water, ip injection	210 - 455
		effects	0.14 - 0.7	whole body	rainbow trout, brook trout	5 - 15 g	water	29 - 30
	Growth	no effects	0.09 - 2.8	muscle, whole body	rainbow trout, brook trout	3.1 g, 5 g, adult	water	30 - 455
		effects	0.12 - 0.96	muscle, whole body	rainbow trout, Atlantic salmon	3.1 g, alevin	water	92 - 210
	Reproduction	no effects	0.4	muscle	rainbow trout	adult	water	455
		effects	0.6	muscle	rainbow trout	adult	water	455
Chromium	-	-	-	-	-	-	-	-
Copper	Survival	no effects	0.5 - 3.4	muscle	rainbow trout, brook trout	embryo-adult-juvenile	water	0.33 - 720
		effects	0.5	muscle	rainbow trout	138 g	water	0.33
	Growth	no effects	3.4	muscle	brook trout	embryo-adult-juvenile	water	720
	Reproduction	no effects	3.4	muscle	brook trout	embryo-adult-juvenile	water	720
Iron	-	-	-	-	-	-	-	-
Lead	Survival	no effects	4.0	carcass	rainbow trout	under-yearlings (6.5 g)	water	224
Manganese	-	-	-	-	-	-	-	-

- = no data; [1] methylated forms of mercury

Table 3.4-9 (Cont'd.)

Variable	Endpoint		Effects Concentrations (mg/kg)	Tissue	Species	Life Stage or Size	Route	(days)
Mercury[1]	Survival	no effects	1.91 - 35.0	whole body, muscle	rainbow trout, brook trout	10 - 20 mm, juvenile, fingerling, yearling-adult, adult	ip injection, oral, water	15 -273
		effects	3.7 - 31	whole body, muscle	rainbow trout, brook trout	10 - 20 mm, subadult (100 - 150 g),	ip injection, oral,	186 - 273
					northern pike	yearling-adult, adult	water	
	Growth	no effects	2.28 - 29.0	whole body, muscle	rainbow trout	fingerling, juvenile	oral, water	24 - 105
		effects	8.6 - 35.0	whole body, muscle	rainbow trout	fingerling	oral	84 - 105
	Reproduction	no effects	9.2	muscle	brook trout	yearling-adult	water	273
		effects	23.5	muscle	brook trout	yearling-adult	water	273
Nickel	Survival	no effects	0.82 - 58.0	muscle	rainbow trout, carp	15 g, 150 - 200 g	water	5 - 180
		effects	118.1	muscle	carp	15 g	water	4
Selenium	Survival	no effects	0.28 - 3.1	whole body, carcass	rainbow trout, chinook salmon,	larvae-swim-up, egg-juvenile,	water, oral	28 - 308
					largemouth bass	fingerling-juvenile, juvenile		
		effects	0.92 - 2.5	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, .fingerling-juvenile	water, oral	28 - 168
	Growth	no effects	0.08 - 1.08	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, egg-juvenile,	oral	60 - 308
						fingerling-juvenile, juvenile		
		effects	0.32 - 2.08	whole body, carcass	rainbow trout, chinook salmon	larvae-swim-up, fingerling-juvenile, juvenile	oral	60 -168
Silver	Survival	no effects	0.003	carcass	largemouth bass	young-of-year	water	180
	Growth	no effects	0.003	carcass	largemouth bass	young-of-year	water	180
Strontium		-	-	-	-	-	-	-
Tin		-	-	-	-	-	-	-
Titanium		-	-	-	-	-	-	-
Vanadium	Survival	no effects	5.33	carcass	rainbow trout	juvenile	oral	84
	Growth	no effects	0.02	carcass	rainbow trout	juvenile	oral	84
		effects	0.41	carcass	rainbow trout	juvenile	oral	84
Zinc	Survival	no effects	60	whole body	Atlantic salmon	juvenile	water	80
	Growth	no effects	60	whole body	Atlantic salmon	juvenile	water	80

- = no data; [1] methylated forms of mercury

3.5 ACID-SENSITIVE LAKES

As in previous years, the 2007 Acid-Sensitive Lakes (ASL) component consisted of monitoring 50 lakes and ponds within and beyond the RAMP RSA for water quality variables during late August and early September 2007. The locations of each lake are presented in Figure 3.5-1, along with each lake's acid-sensitivity based on three separate classification systems using (i) Gran alkalinity, (ii) pH, and (iii) the critical load. Table 3.5-1 presents the three classification systems and the number of lakes that are classified as highly acid-sensitive, moderately acid-sensitive, of low acid-sensitivity and least acid-sensitive. Using the Gran alkalinity criteria, 25 of the 50 RAMP lakes are considered highly sensitive to acidification, 12 lakes are considered moderately sensitive and 13 of the lakes are considered low or least sensitive. Using the pH criteria 17 of the lakes are considered highly sensitive to acidification, 20 lakes are considered moderately sensitive and 13 of the lakes are considered low or least sensitive. Using the critical load criteria 31 of the lakes are considered highly sensitive to acidification, 11 lakes are considered moderately sensitive and 8 of the lakes are considered low or least sensitive.

Table 3.5-1 Acid sensitivity criteria for Alberta lakes.

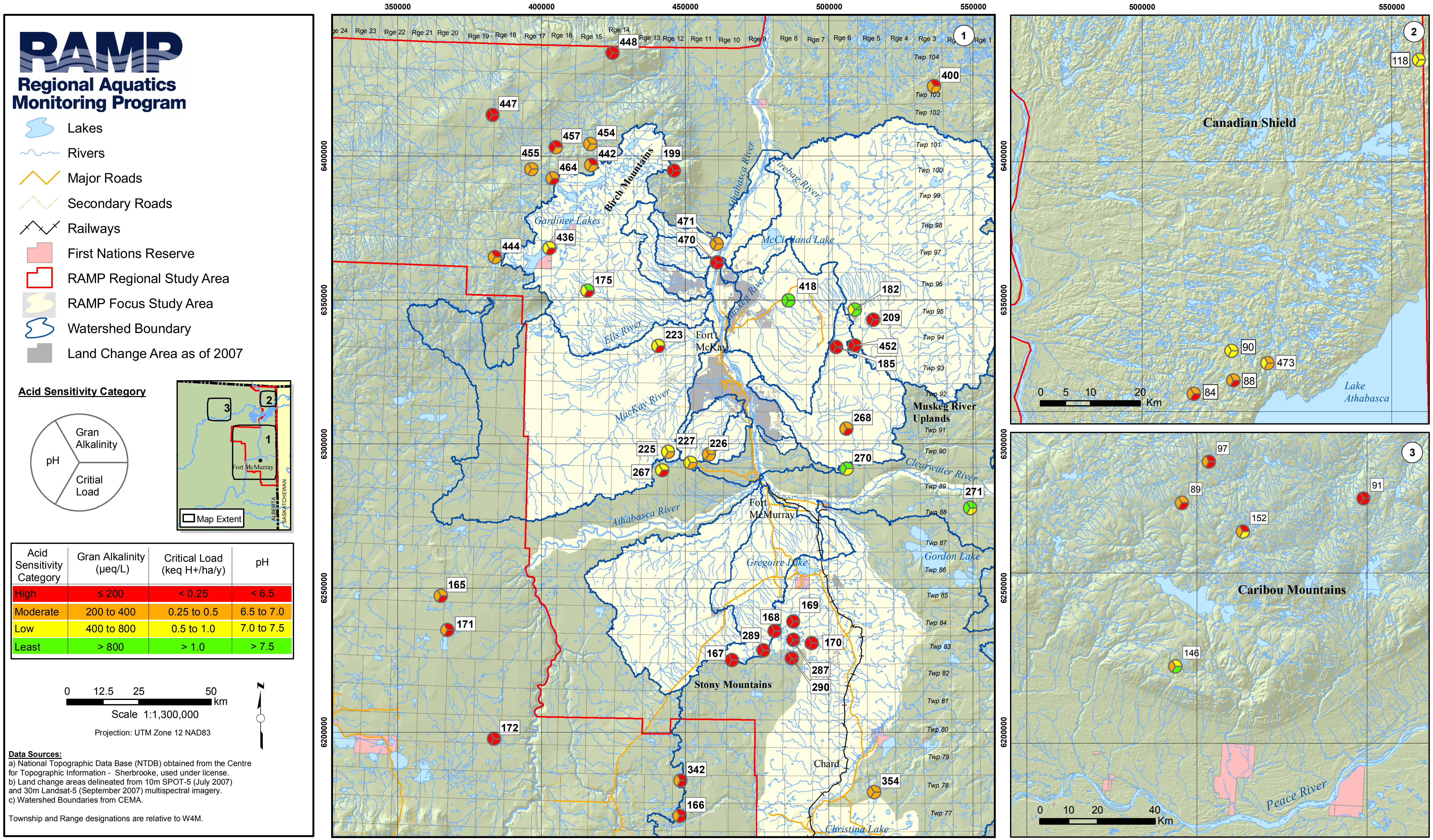
Acid Sensitivity Category	Alkalinity[1] (µeq/L)	No. of Lakes in Alkalinity Categories	pH[1] (Units)	No. of Lakes in each pH Category	Critical[3] Load (CL) Keq H^+/ha/y	No. of Lake in each CL Category
High Sensitivity	Negative to 200	25	4.0 to 6.5	17	<0.25	31
Moderate Sensitivity	200 to 400	12	6.5 to 7.0	20	0.25 to 0.50	11
Low Sensitivity	400 to 800	8	7.0 to 7.5	10	0.50 to 1.00	5
Least Sensitive	> 800	5	> 7.5	3	>1.00	3

[1] Sources: Erickson 1987; [2]Saffron and Trew 1996; [3]CASA 1999).

Figure 3.5-1 shows that the most acid-sensitive lakes are found in the upland areas, in particular the Smoky Mountains, the Muskeg River Uplands and the Caribou Mountains. The least sensitive lakes are found scattered throughout the region with a high concentration in the area west of Fort McMurray.

The date of lake sampling, the UTM coordinates of each lake and the tertiary watershed in which each lake is located are presented in Table 3.5-2. The unique ID number listed in Table 3.5-2 is that ascribed to each lake by the NO_xSO_x Monitoring Working Group (NSMWG) lake sensitivity mapping program (WRS 2004).

Figure 3.5-1 Location and acid sensitivity of RAMP ASL lakes surveyed in 2007.



K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_I_ASL_20080411.mxd

Table 3.5-2 Lakes sampled in 2007 for the Acid-Sensitive Lakes component.

Lake Identification			UTM Coordinates		Sampling Date
Unique ID[1]	Name	Tertiary Watershed	E	N	m/d
Stony Mountains Sub-Region					
168	A21	7CE	483819	6235130	08/25
169	A24	7CE	484387	6230872	08/25
170	A26	7CE	489502	6230877	08/25
167	A29	7CE	466180	6224950	08/25
166	A86	7CE	448014	6170896	08/25
287	25		487594	6229281	08/25
289	27		477248	6228400	08/25
290	28		487068	6225576	08/25
342	82		448271	6183205	08/25
354	94		515689	6179207	08/25
Birch Mountains Sub-Region					
436	L18/Namur		402704	6368016	08/23
442	L23/Otasan		417321	6396959	08/23
444	L25/Legend		383849	6364923	08/23
447	L28		382996	6414339	08/23
448	L29/Clayton	7KE/7KF	424694	6435790	08/23
454	L46/Bayard		416941	6404239	08/23
455	L47		396500	6395456	08/23
457	L49		404995	6403111	08/23
464	L60		403796	6392247	08/23
175	P13	7DA	416003	6353212	09/01
199	P49	7DA	446002	6394961	09/01
Northeast of Fort McMurray Sub-Region					
452	L4 (A-170)		508990	6334305	08/25
470	L7		461006	6368512	
471	L8		460931	6369481	08/25
400	L39/E9/A-150		536495	6424234	08/25
268	E15		506092	6305335	08/25
182	P23	7DA	509000	6346712	08/28
185	P27	7DA	508300	6333712	09/01
209	P7	7DC	515399	6343212	09/01
270	4		506113	6291421	08/25
271	6		549064	6277789	08/25
418	Kearl		485939	6349881	08/25
West of Fort McMurray Sub-Region					
165	A42	7CC	365015	6247322	08/30
171	A47	7CC	367321	6235430	08/30
172	A59	7PA	383467	6197733	08/30
223	P94	7BD	440557	6334112	08/30
225	P96	7BD	444002	6295513	08/30
226	P97	7DA	456002	6296463	08/30
227	P98	7CC	451762	6293513	08/30
267	1		441917	6290884	08/30
Caribou Mountains Sub-Region					
146	E52/ Fleming	7JF	243692	6522556	08/25
91	O-1/E55	7PC	298955	6571856	08/25
97	O-2/E67	7PA	253582	6582654	08/25
152	E59/Rocky Island	7JF	263546	6562225	08/25
89	E68 Whitesand	7PA	245596	6570610	08/25
Canadian Shield Sub-Region					
118	L107/Weekes	7MD	555469	6620456	08/28
84	L109/Fletcher	7NA	510321	6553552	08/28
90	R1	7NA	517889	6562197	08/28

[1] Unique identification number derived from the Lake Sensitivity Mapping Program conducted by NSMWG (WRS 2004).

3.5.1 Summary of Field Methods

AENV provided the sampling equipment and logistical support for the lake sampling. A float plane was used to access the majority of study lakes while a helicopter with floats was used to reach the smaller lakes.

Water samples were collected from the euphotic zone at a single deep-water site in each major basin of each lake using weighted Tygon tubing and were then combined to form a single composite sample for chemical analysis. When the euphotic zone extended to the lake bottom, sampling was restricted to depths greater than 1 m above the lake bottom. In shallow lakes (< 3 m deep), composite samples were created from five to ten 1-L grab samples collected at 0.5 m depth along a transect dictated by wind direction (upwind to downwind shore).

The euphotic zone was defined as twice the Secchi disk depth. 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 were taken from the composite samples for phytoplankton taxonomy and 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 (63 µm), conical plankton net. Zooplankton samples were preserved in approximately 5% formalin after anaesthetizing in soda water. Plankton samples are archived at AENV and the zooplankton samples were sent to Environment Canada for analysis.

The water samples were analyzed for the water quality variables listed in Table 3.5-3.

One blind field blank was collected using deionized water from the Limnology Laboratory, University of Alberta. Split samples were additionally assessed by the University of Alberta laboratory. Quality control samples were analyzed for all variables listed in Table 3.5-3 (Appendix B).

Table 3.5-3 Water quality variables analyzed in 2007 in lake water sampled under the ASL component.

pH	Gran alkalinity	total dissolved nitrogen
turbidity	bicarbonate	ammonia
colour	Gran bicarbonate	nitrite + nitrate
total suspended solids	chloride	total Kjeldahl nitrogen
total dissolved solids	sulphate	total nitrogen
dissolved organic carbon	calcium	total phosphorus
dissolved inorganic carbon	potassium	total dissolved phosphorus
conductivity	sodium	chlorophyll *a*
total alkalinity (fixed point titration to pH 4.5)	magnesium	
	iron	
	silicon	

3.5.2 Changes in Monitoring Network from 2006

Logistical difficulties prevented two lakes (lakes 88 and 473) from being sampled in 2007. Otherwise, there were no changes in the ASL monitoring network in 2007.

3.5.3 Challenges Encountered and Solutions Applied

There were no exceptional challenges encountered in implementing field activities under the ASL component in 2007.

3.5.4 Other Information Obtained

AENV collected additional samples from each lake surveyed in the ASL component (Table 3.5-2) during the 2007 field season. These water samples were sent to the Alberta Research Council, Vegreville, for analysis for both total and dissolved metals. In addition, AENV provided the results of seasonal sampling conducted for the Cumulative Environmental Management Association on ten of the lakes listed in Table 3.5-2. These data were used to assess the natural within-year variability in water quality in these lakes.

3.5.5 Summary of Component Data Now Available

The selection of lakes sampled during the nine years of the ASL component is summarized in Table 3.5-4.

3.5.6 Analytical Approach

The analytical approach used in 2007 for the ASL component was in accordance with the overall analytical approach outlined in the RAMP Technical Design and Rationale (RAMP 2005b) and consisted of:

- Selecting ASL measurement endpoints;
- Developing criteria to be used in detecting changes in ASL measurement endpoints; and
- Detailed data analysis of 2007 results.

3.5.6.1 Measurement Endpoints

The measurement endpoints for the ASL component in 2007 were:

- pH;
- Gran alkalinity;
- Base cation concentrations;
- Nitrate plus nitrite;
- Sulphate;
- Dissolved organic carbon; and
- Dissolved aluminum.

The Gran alkalinity and pH are considered the principal ASL measurement endpoints. Sulphate is included in the list of ASL measurement endpoints but, unlike most lakes in eastern North America, sulphate and acidity (H^+) in Alberta lakes are poorly correlated because of the abundance of neutral sulphate compounds in wet and dry deposition (AEP 1990, Lau 1982, Legge 1988). The poor correlation between sulphate and H^+ in the RAMP ASL lakes was demonstrated in RAMP (2004).

Table 3.5-4 Summary of lakes sampled during RAMP, 1999 to 2007.

NO_x-SO_x GIS No.	Original RAMP Designation	1999	2000	2001	2002	2003	2004	2005	2006	2007
168	A21	+	+	+	+	+	+	+	+	+
169	A24	+	+	+	+	+	+	+	+	+
170	A26	+	+	+	+	+	+	+	+	+
167	A29	+	+	+	+	+	+	+	+	+
166	A86	+	+		+	+	+	+	+	+
287	25 (287)				+	+	+	+	+	+
289	27 (289)				+	+	+	+	+	+
290	28 (290)				+	+	+	+	+	+
342	82 (342)				+	+	+	+	+	+
354	94 (354)				+	+	+	+	+	+
165	A42	+	+	+	+	+	+	+	+	+
171	A47	+	+	+	+	+	+	+	+	+
172	A59	+	+	+	+	+	+	+	+	+
223	P94 (223)				+	+	+	+	+	+
225	P96 (225)				+	+	+	+	+	+
226	P97 (226)				+	+	+	+	+	+
227	P98 (227)				+	+	+	+	+	+
267	1 (267)				+	+	+	+	+	+
452	L4	+	+	+	+	+	+	+	+	+
470	L7	+	+	+	+	+	+	+	+	+
471	L8	+	+	+	+	+	+	+	+	+
400	L39	+	+	+	+	+	+	+	+	+
268	E15 (268)		+	+	+	+	+	+	+	+
182	P23 (182)				+	+	+	+	+	+
185	P27 (185)				+	+	+	+	+	+
209	P7 (209)				+	+	+	+	+	+
270	4 (270)				+	+	+	+	+	+
271	6 (271)				+	+	+	+	+	+
418	Kearl L.					+	+	+	+	+
+436	L18 Namur	+	+	+	+	+	+	+	+	+
442	L23 Otasan	+	+	+	+	+	+	+	+	+
444	L25 Legend	+	+	+	+	+	+	+	+	+
447	L28	+	+	+	+	+	+	+	+	+
448	L29 Clayton	+		+	+	+	+	+	+	+
454	L46 Bayard	+	+	+	+	+	+	+	+	+
455	L47	+	+	+	+	+	+	+	+	+
457	L49	+	+	+	+	+	+	+	+	+
464	L60	+	+	+	+	+	+	+	+	+
175	P13 (175)				+	+	+	+	+	+
199	P49 (199)				+	+	+	+	+	+
473	A301			+	+	+	+	+	+	
118	L107 Weekes		+	+	+	+	+	+	+	+
84	L109 Fletcher	+	+	+	+	+	+	+	+	+
88	O-10	+	+	+	+	+	+	+	+	
90	R1	+	+	+	+	+	+	+	+	+
146	E52 Fleming	+	+	+	+	+	+	+	+	+
152	E59 Rocky Is.	+	+	+	+	+	+	+	+	+
89	E68 Whitesand		+	+	+	+	+	+	+	+
91	O-1	+	+	+	+	+	+	+	+	+
97	O-2	+	+	+	+	+	+	+	+	+
428	L1	+								
83	O3/E64	+								
85	R2	+								
86	R3	+								
310	A300			+						

3.5.6.2 Criteria for Determining Effects

Criteria for determining changes in the ASL measurement endpoints were stated in the RAMP Technical Design and Rationale document (RAMP 2005b) as follows:

- *A significant impact on a lake from acid* deposition is concluded if a significant change is noted in one or more measurement endpoints beyond natural variability.
- These endpoints include a reduction of lake pH, Gran alkalinity, critical load or base cation concentrations or an increase in nitrates or aluminum concentrations.
- A significant change is defined as a statistically significant change at $P<0.05$ that is directly attributable to increased deposition of acidifying substances. Natural variability is measured as the variance of the mea*surement endpoint.*

3.5.6.3 Details of Data Analysis

Primary Analyses

The emphasis in the data analysis was placed on the detection and evaluation of potential trends in the ASL measurement endpoints in the RAMP ASL lakes that would indicate incipient changes in the buffering capacity and acid sensitivity of the lakes according to the criteria for determining effects described above. In this regard, three specific data analyses were conducted.

Between-Year Comparison of Measurement Endpoints An Analysis of Variance (ANOVA) was conducted to determine whether there have been any significant changes in the concentrations of the ASL measurement endpoints in the 50 RAMP lakes, as a group, during the five years when all 50 lakes were sampled. Any observed changes were discussed in relation both to acidification and natural variability.

Calculation of Critical Loads of Acidity and Comparison to Modeled Potential Acid Input The critical loads (CL), in units of keq H+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology and represents a measure of a lake's sensitivity to acidification. CLs for the RAMP lakes in 2007 were calculated using the Henriksen steady state water chemistry model (Henriksen and Posch 2001; Henriksen *et al*. 1992; Forsius *et al*. 1992; Rhim 1995) modified for the effects of organic acids on buffering and acid sensitivity (RAMP 2005a; WRS 2006).

In 2007, the runoff to each lake, a term in the Henriksen model, was calculated both from traditional hydrometric methods and from analysis of heavy isotopes of oxygen (^{18}O) and (^{2}H) in each lake. In the latter technique, the natural evaporative enrichment of ^{18}O and ^{2}H in the lakes is used to partition water losses between evaporation and liquid outflow and hence derive an estimate of runoff (Gibson 2002; Gibson et al. 2002; Gibson and Edwards 2002). This technique utilizes a different set of assumptions from the hydrometric method which extrapolates water yields from one or more gauged catchments to the ungauged lake catchments. Potential inaccuracies in the hydrometric method, especially in low-relief catchments, have long been recognized (WRS 2004). The isotopically derived values of runoff were taken from a recent study by Bennett et al. (2006, submitted). Critical loads were calculated using both estimates of runoff and the values compared.

The critical loads for each lake were compared with levels of the Potential Acid Input (PAI) to each lake basin taken as the modeled rate of acid deposition (planned development case) for each lake published in the Joslyn North Mine Project EIA (DCEL 2006). As listed values of PAI for most EIAs are unavailable for lakes in the Caribou

Mountains and the Shield region, they were estimated from the air modeling study reported for the Joslyn North Mine Project EIA (Deer Creek 2006). In both regions the values of the PAI corresponded to background values (no industrial input) determined from RELAD modeling conducted by Alberta Environment in 2002.

Mann-Kendall Trend Analysis on Measurement Endpoints in Individual Lakes Potential trends in the ASL measurement endpoints were examined for the 31 lakes that have been monitored for at least eight consecutive years. The analysis involved trend analysis using the Mann-Kendall non-parametric test (Gilbert 1987). Estimates of analytical error (determined as the percent error of the analysis reported by the laboratory at each concentration) were incorporated in the analyses to evaluate the validity of any trends observed in ASL measurement endpoints.

Trends Analysis by Control Charting of ASL Measurement Endpoints in Individual Lakes In addition to the Mann Kendall analyses described above, key measurement endpoints (pH, Gran alkalinity, sulphate, sum of base cations and nitrates, dissolved organic carbon) were charted in Shewhart control plots for 10 lakes deemed most at risk to acidification. These control plots are extremely helpful in detecting trends before significant change has occurred. Ten lakes were selected for control charting on the basis of a high ratio of PAI to the value of the critical load; the greater this ratio in a lake, the greater is the risk for acidification. The control plots follow standard analytical control chart theory where control limits representing two and three standard deviations are plotted on the graphs with the points and the mean value (Gilbert 1987). The lines at two standard deviations represent warning limits while the lines at three standard deviations identify distinct outliers. A trend in an endpoint parameter is often assumed if three consecutive points fall on the same side outside of the two standard deviation warning limits or one point outside of the three standard deviation control limit.

Supporting Analyses

The following supporting data analyses were also conducted, the results of which are presented in Appendix H:

- Update of the ASL database, calculation of summary statistics, identification of lakes with unusual chemical characteristics and comparisons of the chemistry of the RAMP lakes in 2007 to the range of chemical characteristics of lakes within the Athabasca oil sands region;
- Analysis of metals in the individual RAMP lakes with emphasis on those (e.g., aluminum) that are known to increase with acidification. Extreme values of individual metals and exceedances of Alberta and CCME water quality guidelines for metals (CCME 2006, AENV 1999b) were identified in individual lakes and in regions within the study area; and
- Estimates of the seasonal variability in water quality variables in ten of the ASL lakes were updated with the 2007 data and summary statistics were calculated.

Update of the ASL Database, Summary Statistics and Comparisons of RAMP ASL Lake Chemistry to Regional Lake Chemistry The chemical data from all years of the ASL component were tabulated and summarized statistically. Box plots were drawn of selected variables in the 2007 data to show the range of each variable and existence of outliers. A Piper plot was prepared for the 2007 data to characterize the RAMP ASL lakes by their major ion chemistry. The chemical characteristics of the RAMP ASL lakes in 2007 were compared to those of 450 regional lakes reported in the NSMWG lake sensitivity mapping study (WRS 2004). Comparisons involved:

- Examination of the ranges, medians and mean values of key chemical variables for 2007 in the RAMP lakes relative to the regional dataset;
- Graphical presentation of both datasets in box plots; and
- Statistical comparison of chemical variables between the RAMP ASL lakes and the regional dataset including a multivariate principal components analysis

Analysis of Metal Concentrations in the RAMP ASL Lakes The total and dissolved metal fractions from six years of monitoring by AENV (2001, 2003-2007) were tabulated and summarized statistically to establish baseline concentrations for each metal. Lakes having extreme mean metal concentrations were identified as those exceeding the 95th percentile concentration for individual metals; exceedances of the Alberta and CCME surface water quality guidelines were also identified.