5.0 ASSESSMENT OF 2006 RESULTS

This is the main results section of the RAMP 2006 Technical report. Sections 5.1 to 5.2 present 2006 results for the Athabasca River and the Athabasca River Delta; Sections 5.3 to 5.11 present 2006 results for the major tributaries of the Athabasca River in the RAMP Focus Study Area (FSA); Section 5.12 contains the 2006 results for miscellaneous aquatic systems throughout the RAMP FSA that were monitored in 2006; and Section 5.13 presents the 2006 results for the Acid-Sensitive Lakes component.

Table 5-1 Page number guide to watersheds and RAMP component reports.

	Athabasca River	Athabasca River Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Firebag	Ells	Christina-Clearwater	Hangingstone	Miscellaneous Aquatic Systems
Climate and Hydrology	5-4	5-54	5-58	5-122	5-160	5-182	5-206	5-224	5-242	5-260	5-304	5-320
Water Quality	5-6	5-54	5-59	5-123	5-161	5-182	5-206	5-225	5-243	5-261	5-305	5-322
Benthic Invertebrate Communities	5-8	5-54	5-63	5-125	5-163	5-184	5-208	5-226	5-244	5-262	5-306	5-330
Sediment Quality	5-8	5-54	5-65	5-126	5-164	5-185	5-209	5-226	5-244	5-263	5-306	5-332
Fish Populations	5-8	5-54	5-67	5-126	5-165	5-185	5-209	5-227	5-245	5-264	5-306	5-333

Definitions for Monitoring Status

- ***Potentially influenced*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) that may be influenced by focal developments. The use of this term does not imply or presume that effects of these developments are occurring or have occurred, but simply that data collected from these locations are to be designated as ***operational*** for the purposes of data analysis (see below);

- ***Reference*** is the term used in this report to describe aquatic resources and physical locations that are not yet influenced by focal developments, and that data on aquatic resources collected from these locations are to be designated as ***baseline*** for the purposes of data analysis (see below);

- ***Baseline*** is the term used to characterize data and information gathered from stations that are designated as ***reference***; and

- ***Operational*** is the term used to characterize data and information gathered from stations that are designated as ***potentially influenced.***

5.1 ATHABASCA RIVER

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge	√				Flows in the Athabasca River were below normal in 2006. Based on available hydrologic and oils sands development information, changes in hydrologic conditions in the Athabasca River basin up to and including 2006 due to focal projects have been negligible to low.
Mean winter discharge		√			
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006[1]**		
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Stations (n=7)**	**2006 *Reference* Stations (n=3)**	
Physical variables (max=7 for exp, 3 for ref)	0	0	No discernible or detectable effects of focal project activities on water quality in the Athabasca River were apparent in 2006, based on available water quality and focal project development information.
Nutrients (max=21 for exp, 9 for ref)	1	1	
Ions (max=14 for exp, 6 for ref)	0	0	
Selected metals (max=35 for exp, 15 for ref)	7	3	
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* Stations (n=7 stations X 15 endpoints)[1]**	**2006 *Reference* Stations (n=3 stations X 15 endpoints)**	
Greater than 95th percentile	0	0	
At or between 5th and 95th percentiles	91	36	
Less than 5th percentile	0	3	

Benthic Invertebrate Communities and Sediment Quality						
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**					
Values in Relation to Regional Baseline Mean	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=0)**		
	>2 SD below	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**
Abundance	No benthic invertebrate community sampling was conducted in the Athabasca River mainstem in 2006.					
Richness						
Diversity						
Evenness						
% EPT						

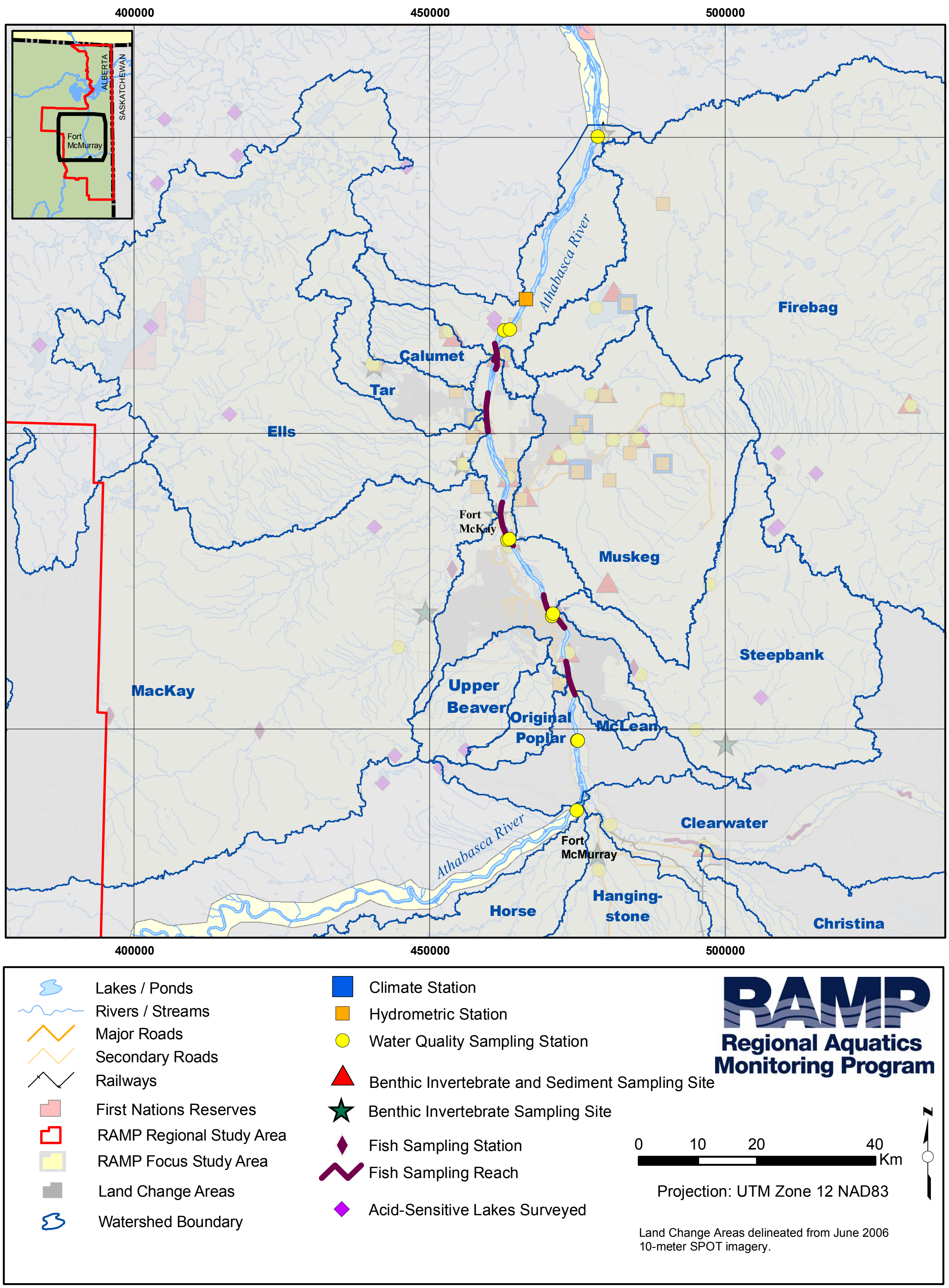
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**	
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Sites (n=0)**	**2006 *Reference* Sites (n=0)**
Total Hydrocarbons	No sediment quality sampling was conducted in the Athabasca River mainstem in 2006.	
PAHs		

Fish Populations		
Fish Inventory	Little evidence that characteristics of key indicator fish populations have changed during increasing development in the oil sands region.	Based on the results to date for the Athabasca River, there is little evidence to suggest that characteristics of key indicator fish populations have changed during increasing oil sands development in the Athabasca oil sands area.
Sentinel Studies	No sentinel fish studies conducted in 2005.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue studies were not conducted in the Athabasca River in 2006.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.1-1 Athabasca River.



K:\Data\Project\RAMP1245\GIS_MXD\Report\RAMP1245_J_Mainstem_2007MAR20c.mxd

5.1.1 Development Status

For 2006, all the tributaries of the Athabasca River considered in this report which are upstream of the McLean Creek confluence are designated as *reference*, while many of the significant tributaries of the Athabasca River considered in this report which are downstream of the McLean Creek confluence (including McLean Creek) have areas designated as *potentially influenced*. Therefore, for 2006, the confluence of McLean Creek with the Athabasca River is designated as the division between *reference* areas (upstream) and *potentially influenced* (downstream). All data gathered from 2006 RAMP stations located on the Athabasca River downstream of the McLean Creek confluence are designated as operational, while all data gathered from 2006 RAMP stations located upstream of the McLean Creek confluence are designated as baseline.

5.1.2 Hydrologic Conditions

5.1.2.1 2006 Hydrologic Conditions

Flows in the Athabasca River measured at WSC station 07DA001 (Athabasca River below McMurray) were significantly below normal in 2006, with a May 1- October 31 volume of 66% of the long-term average. Discharges were near or below the lower quartile for most of the open-water season (Figure 5.1-2). The maximum daily discharge of 1,590 m^3/s on May 30 was much less than the mean annual flood (the mean of the series of annual maximum daily discharges) of 2,500 m^3/s. The minimum open-water season daily discharge of 339 m^3/s was also significantly lower than the historical average minimum discharge of 436 m^3/s. As expected, discharges measured at RAMP station S24, Athabasca River below Eymundson Creek, downstream of all focal projects, were slightly higher than at WSC station 07DA001 (Figure 5.1-2) because of the incremental catchment area between the two stations.

5.1.2.2 Estimation of Hydrologic Effects

Hydrologic effects in 2006 on the Athabasca River were estimated for two cases. The first case considered only 2006 focal projects; that is, those projects owned by 2006 RAMP funders that were under construction or operational in 2006 in the RAMP FSA. The second case considered all 2006 focal projects plus oil sands projects in the RAMP FSA that were under construction or operational in 2006, but were not owned by 2006 RAMP funders. This latter case can be considered a type of cumulative assessment of hydrologic effects of all significant oil sands activities in the RAMP FSA as of 2006.

Estimation of Hydrologic Effects of Focal Projects A summary of the inputs to the water balance model for the Athabasca River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints from focal project activities is summarized below (details are provided in Table 5.1-1):

- Withdrawals from the Athabasca River by focal projects in 2006 are estimated at 93.7 million m^3;
- Discharges to the Athabasca River by focal projects in 2006 are estimated at 0.314 million m^3;
- A calculated 2.38 million m^3 additional discharge into the Athabasca River in 2006 from major Athabasca River tributaries (Calumet, Christina, Ells, Firebag, Fort Creek, Hangingstone, MacKay, Muskeg, Steepbank, and Tar rivers) that

would have occurred in the absence of focal project activities on these watersheds[1];

- As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 261 km^2 and 83.9 km^2, respectively, in the drainages of the minor Athabasca River tributaries entering the Athabasca River between Fort McMurray and RAMP station S24 (i.e., all Athabasca River tributaries except those listed above) as a result of cumulative development of focal projects in those drainages (Table 2.6.-1). The effect of these land change areas is estimated to be a loss of 16.8 million m^3 of discharge to the Athabasca River in 2006 from areas of closed-circuited land change and a gain of 1.28 million m^3 from other land change (not closed-circuited) in the minor Athabasca River tributaries.

The baseline hydrograph that would have occurred at RAMP station S24 in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the operational hydrograph recorded at RAMP station S24. The estimated net effect of focal project activities was to reduce inflows to the Athabasca River mainstem by an estimated 111 million m^3 in 2006. Withdrawals from the Athabasca River by focal projects in 2006 are the biggest contributor to the difference between the operational and estimated baseline flows. The estimated cumulative effect in 2006 is that mean open-water season discharge was reduced by 0.52%, mean winter discharge was reduced by 1.5%, annual maximum daily discharge was decreased by 0.27%, and open-water season minimum daily discharge was decreased by 1.1% (Figure 5.1-2, Table 5.1-2). Based on criteria used in previous oil sands project EIAs (RAMP 2005b), these differences would have been assessed as negligible, with the exception of the incremental mean winter discharge which would have been assessed as a low effect in some EIAs.

Estimation of Hydrological Effects of Focal Projects Plus Other Active Oil Sands Projects A summary of the inputs to the water balance model for the second case, effects of all focal projects plus oil sands projects in the RAMP FSA that were under construction or operation in 2006, but were not owned by 2006 RAMP funders is presented in Table 5.1-1. The only difference in the inputs to the water balance model between the two cases is that 3.26 million m^3 additional discharge into the Athabasca River in 2006 is assumed from major Athabasca River tributaries (Calumet, Christina, Ells, Firebag, Fort Creek, Hangingstone, MacKay, Muskeg, Steepbank, and Tar rivers); this is the discharge that would have occurred in the absence of focal projects and other oil sands projects on these watersheds. This is 0.84 million m^3 greater than in the first case and comes from non RAMP-funder oil sands projects in the Hangingstone and Christina River watersheds. The values of the hydrologic measurement endpoints for this second case are essentially identical to their values in the first case (focal projects only) (Table 5.1-3).

Summary Based on the available hydrologic information as well as information available regarding focal project activities and other oil sands projects in the RAMP FSA, cumulative, watershed-level changes in hydrologic conditions in the Athabasca River mainstem caused by focal project activities and other oil sands projects in the RAMP FSA as of 2006 have been negligible to low, depending on the specific measurement endpoint.

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[1] It is assumed that the 14.03 million m^3 entering the Athabasca River mainstem in 2006 from the upper Beaver drainage via the Poplar Creek spillway would have entered the Athabasca River mainstem in the baseline case via the original Beaver River drainage, and so the incremental effects of the Beaver Creek diversion on Athabasca River mainstem flows between the observed, operational case and the estimated, baseline case are assumed to be zero.

5.1.3 Water Quality

In 2006, water quality samples were collected from the following locations in the Athabasca River:

- Upstream of Donald Creek in the fall season (stations ATR-DC-E, ATR-DC-W, and ATR-DC-CC, *reference*, baseline data available most years from 1997 to 2006);
- Upstream of the Steepbank River in the fall season (stations ATR-SR-E and ATR-SR-W, *potentially influenced*, operational data available from 2000 to 2006);
- Upstream of the Muskeg River in the fall season (stations ATR-MR-E and ATR-MR-W, *potentially influenced*, operational data available most years from 1998 to 2006);
- Downstream of all development in all four seasons (stations ATR-DD-E and ATR-DD-W, *potentially influenced*, operational data available from 2002 to 2006); and
- Upstream of the Firebag River in the fall season (station ATR-FR-CC, *potentially influenced*, operational data available from 2002 to 2006).

Winter water quality was measured in 2006 from the Athabasca River upstream of Donald Creek (station ATR-DC-CC); the results of the winter water quality analyses are presented in Appendix D.

Concentrations of water quality measurement endpoints for fall 2006 are presented in Table 5.1-4. Concentrations of selected measurement endpoints (1997 to 2006) relative to regional baseline conditions at stations in the Athabasca River are shown in Figure 5.1-3 to Figure 5.1-6, and Table 5.1-5 contains all seasonal water quality guideline exceedances observed in 2006 at station ATR-DD-W and station ATR-DD-E, the only stations in the Athabasca River that were sampled in all seasons in 2006.

Overview of 2006 Results Water quality in fall 2006 was generally similar to that observed in fall 2005 (Table 5.1-4). Total suspended solids (TSS) were low (<20 mg/L) at all stations except station ATR-DD-W (Table 5.1-4), and water quality variables typically associated with TSS, including total aluminum and total phosphorus, were also highest at this station and substantially higher than the concentrations of these variables in the east bank sample. While concentrations of most variables were similar in the east and west bank samples at other locations, concentrations of phosphorus (total and dissolved) and ions (sodium, calcium, chloride, and sulphate) differed between station ATR-DC-E and station ATR-DC-W. Previous studies have shown that water quality along the east bank at this station may be highly influenced by inflows from the Clearwater River (RAMP 2004).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Overall, there were 10 (10%) out of 100[2] possible exceedances in water quality guidelines for the water quality measurement endpoints at all the Athabasca River stations in fall 2006 (Table 5.1-4). All these guideline exceedances were total aluminum, which exceeded its CCME/AENV guideline at every RAMP station, *reference* and *potentially influenced*, sampled in fall 2006.

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[2] Ten of the selected water quality measurement endpoints have guidelines and water quality was sampled at a total of ten locations on the Athabasca River downstream of Fort McMurray in fall 2006, making for a total of 100 possible guideline exceedances

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines for the following water quality variables not designated as water quality measurement endpoints were exceeded in the Athabasca River mainstem in fall 2006 (Table 5.1-4):

- The concentration of total phenols exceeded CCME guidelines in all three samples collected upstream of Donald Creek (station ATR-DC-CC, station ATR-DC-E, and station ATR-DC-W) and in both samples collected upstream of the Steepbank River (station ATR-SR-E, station ATR-SR-W);
- The British Columbia guideline for sulphide and the CCME guideline for total iron were exceeded at several stations; and
- The concentration of dissolved iron exceeded the guideline for total iron at station ATR-DC-E.

In addition, there were a number of water quality guidelines for water quality variables not designated as water quality measurement endpoints in all four seasons that were exceeded at stations ATR-DD-E and ATR-DD-W (Table 5.1-5).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Fall 2006 concentrations of 127 (98%) out of a possible 130 water quality measurement endpoint-sampling station combinations (i.e., thirteen selected water quality measurement endpoints sampled at ten locations (*reference* plus *potentially influenced*) on the Athabasca River downstream of Fort McMurray in fall 2006, making for a total of 130 water quality measurement endpoint-sampling station combinations) were between the 5th and 95th percentile of regional baseline concentrations (Figure 5.1-3 to Figure 5.1-6). No fall 2006 water quality measurement endpoints were above the 95th percentile of regional baseline concentrations and only fall concentrations of strontium, calcium, and sulphate, all at station ATR-DC-E, were below their 5th percentile of regional baseline concentrations. Because of the very high frequency of water quality endpoint station combinations that were between the 5th and 95th percentile of regional baseline concentrations, there was no difference in this frequency between *reference* and *potentially influenced* stations on the Athabasca River below Fort McMurray.

Ion Balance Ion balance characteristics of water sampled from the Athabasca River mainstem have varied within a narrow range for all stations between 1997 and 2006 with the exception of station ATR-DC-E in 2000, 2003, 2005, and 2006, and downstream of Fort Creek (east bank, station ATR-FC-E-D) in 1998 (Figure 5.1-14). Multivariate analysis of water quality in 2003 indicated that water quality at station ATR-DC-E was nearly identical to water quality at the lower Clearwater River in that year (RAMP 2004), with much higher chloride and lower dissolved calcium concentrations than the Athabasca River upstream of Fort McMurray. The ion balance at ATR-DC-E in 2000, 2005, and 2006 likely also resulted from the influence of the Clearwater River.

Long-term Trends Results of trend analysis for selected water quality measurement endpoints are presented in Table 5.1-6 and Figure 5.1-7 to Figure 5.1-13, which show values of the measurement endpoints from 1997 to 2006 at two stations: upstream of Fort McMurray (station ATR-UFM, reference), and downstream at Old Fort, at the head of the Athabasca River Delta (ARD, station ATR-OF, exposed-oil sands). With the addition of 2006 data, some minor changes in observed trends in metals and ions were observed relative to previous assessments (RAMP 2005), while trends in physical variables remained the same (Table 5.1-6). Trends included: upward trends in pH at both stations; a downward trend in specific conductance at ATR-UFM; an upward trend in total Kjeldahl nitrogen at station ATR-UFM; an upward trend in total aluminum at ATR-OF; and a downward trend in total molybdenum at ATR-OF (using the Mann-Kendall test for trend, rather than the seasonal Kendall test, as dictated by samples sizes). Differences in trends among stations located upstream of Fort McMurray and at Old Fort may be related to contributing influences of Athabasca River tributaries on water quality in the Athabasca River, or due to other anthropogenic point sources, such as the town of Fort McMurray sewage treatment plant outfall. Trend analyses do not suggest that oil sands development has led to changes in concentrations of water quality measurement endpoints in the Athabasca River since 1997.

Summary No discernible or detectable effects of focal project activities on water quality in the Athabasca River were apparent in 2006, based on available water quality and focal project development information.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

Benthic invertebrate communities have not been sampled in the Athabasca River since 1997. The shifting sands of the river present a naturally harsh environment for benthic macroinvertebrates. The benthic animals that can tolerate the naturally harsh shifting-sand environment of the Athabasca River include tolerant chironomids and ceratopogonids. It is expected that water and sediment quality would have to be severely degraded before their effects would be detectable in benthic invertebrates. Athabasca River tributaries, on the other hand, have more diverse benthic assemblages, and would likely demonstrate effects long before the mainstem river.

Because benthic invertebrate communities were not sampled in the Athabasca River in 2006, sediment quality was also not sampled in the Athabasca River in 2006.

5.1.5 Fish Populations

Fish population monitoring in 2006 on the Athabasca River included a spring and fall fish inventory and a tag return assessment.

5.1.5.1 Fish Inventory Results

Species Composition

A total of 1,855 fish were captured within the 10 standardized reaches (Figure 3.5-1) during the spring and fall fish inventory on the Athabasca River, of which:

- 707 fish comprised of 13 species were captured in the spring sampling plus three observed species (burbot, brook stickleback, and yellow perch) (Table 5.1-7); and
- 1,148 fish comprised of 17 species were recorded in the fall sampling (Table 5.1-8).

A total of 19 fish species were captured and observed in the 2006 Athabasca fish inventory, including a single lake cisco captured in the fall. This total species richness is in the upper range of previous inventories (highest: 22 species in 1997; lowest: 13 species in 1999 (Golder 2003b).

Walleye, followed by white sucker, were the most abundant large-bodied species captured in spring 2006 (Table 5.1-7), while walleye followed by longnose sucker were the most abundant large-bodied species captured in fall (Table 5.1-8). Key comparisons of spring 2006 species composition to historical spring species composition years are summarized as follows (detailed historical information is provided in Figure 5.1-15):

- The percentage of the total spring 2006 catch represented by walleye decreased relative to 2005, approached that recorded in 2004, and was lower than most years in the data record;
- The percentage of the total spring 2006 catch represented by goldeye decreased relative to 2005 and was the lowest for the species over the nine–year data set (1997 to 2006);
- The percentage of the total spring 2006 catch represented by longnose sucker was similar to those of recent years (2004 and 2005) and was lower than most years in the data record;
- The percentage of the total spring 2006 catch represented by white sucker decreased relative to 2004 and 2005, but was at about the historical average for this species; and
- The percentage of the total spring 2006 catch represented by northern pike declined slightly relative to 2004 and was the lowest for the species over the nine–year data set (1997 to 2006).

Key comparisons of fall 2006 species composition to historical fall species composition years are summarized as follows (detailed historical information is provided in Figure 5.1-15):

- The percentage of the total fall 2006 catch represented by walleye decreased relative to 2005, and approached that recorded in 2004, 1999 and 1998;
- The percentage of the total fall 2006 catch represented by goldeye decreased relative to 2005, was the lowest capture proportion for the species in four years and the second-lowest in the data record;
- The percentage of the total fall 2006 catch represented by longnose sucker increased slightly relative to 2005, was the third consecutive increase in proportion, and was similar to most years in the data record with the exception of 1998, 2000, and 2003 which were higher;
- The percentage of the total fall 2006 catch represented by white sucker was similar to most years in the data record, including 2004 and 2005, and with the exception of 1998 and 1999 which were higher; and
- The percentage of the total fall 2006 catch represented by northern pike was similar 2004 and 2005 and similar to all years in the data record with the exception of 1999 and 2003 which were higher.

Catch Per Unit Effort

The total standardized catch per unit effort (CPUE) for fish captured during the 2006 spring inventory was similar to 2005, which is the highest recorded CPUE over the 1997 to 2006 data record (Figure 5.1-16). Spring CPUE in 2006 was approximately 50% higher than in 2003, which is the lowest measured spring CPUE in the data record. The total standardized CPUE for fish captured during the 2006 fall inventory was the highest recorded and represents approximately a four-fold increase in fall CPUE over the 2003 fall CPUE, which is the lowest measured fall CPUE in the data record. Key comparisons of species-specific 2006 CPUE to historical CPUE are summarized as follows:

- Spring 2006 walleye CPUE was less than 2005 and was near the historical average spring CPUE for this species (Figure 5.1-17). Fall 2006 walleye CPUE was slightly higher than 2005 and represented a continued increase in CPUE since 1999 (Figure 5.1-17);

- Spring 2006 goldeye CPUE was lower than 2005 and was near CPUE measured in the spring of 2003 and 2004 (Figure 5.1-18). Fall 2006 goldeye CPUE was substantially lower than 2004 and 2005, and was near the lowest-measured fall CPUE of 2002 (Figure 5.1-18);

- Spring and fall 2006 white sucker CPUE were very similar to historical CPUE for this species. Seasonal CPUE for white sucker has remained relatively constant for this species throughout the data record (Figure 5.1-20);

- Spring 2006 longnose sucker CPUE was very similar to historical CPUE for this species. Spring CPUE for longnose sucker has remained relatively constant for this species throughout the data record (Figure 5.1-19). Fall 2006 longnose sucker CPUE was the second-highest measured since 1997 and represented a continued increase in CPUE since 2004; and

- Spring 2006 northern pike CPUE was the second-lowest measured and represented a continued decrease in CPUE since 1999. In contrast, fall 2006 northern pike CPUE was the highest recorded since 1999 and represented a continued increase in CPUE since 2002 (Figure 5.1-21).

Length-Frequency Analysis

Length-frequency histograms (1997-2006) for five Key Indicator Resource (KIR) species based on standardized capture data (i.e. 10 RAMP reaches only) are presented in Figure 5.1-22 to Figure 5.1-26. Key features with respect to each KIR are as follows:

- The dominant length class of walleye captured in the 2006 inventory was 100-150 mm, smaller than the 2005 dominant size class of 401-450 mm (Figure 5.1-22). The 401-450 mm dominant size class of 2005 was also dominant in 1998 and 2004, while the 351-400 mm length class dominated the walleye population size distribution in all other years. The presence of a dominant smaller size class in 2006 suggests the presence of a strong year class survival/recruitment from recent spawning;

- The dominant length class of goldeye captured in the 2006 inventory was 301-325 mm, smaller than the 2005 dominant size class of 376-400 (Figure 5.1-23). There has been little year-to-year consistency in the dominant length class of goldeye, and the data record is generally characterized by relatively few captures in the smaller size classes with the exception of 1998;

- No single clear dominant length class was present for longnose sucker in the 2006 inventory, although more individuals fell in the 101-150 mm length class than any other class (Figure 5.1-24). There is high variability in longnose sucker length-frequency distribution across the nine-year data record;

- The co-dominant length-classes of white sucker captured in the 2006 inventory were 351-400 mm and 401-450 mm, the same as in 1999, 2002, 2004, and 2005 (Figure 5.1-25). The length ranges of the dominant length classes of white sucker have been relatively consistent, from 301 to 450 mm. The data record is also characterized by typically few individuals in the smaller size classes captured by boat electrofishing; and

- No single dominant length class of northern pike was represented in the 2006 inventory (Figure 5.1-26). Variability in the northern pike length-frequency distribution is high and is partly a function of low sample sizes. However, in most years the co-dominant length-classes are from 400 to 600 mm, with some shifting of the dominant length class among years.

Recruitment to the Sport Fishery

The ratio of under-size to legal-size walleye, an index of recruitment to the sport fishery, was 3.3 in 2006, which is the highest measured value of this index in the data record (Figure 5.1-27). The high ratio in 2006 indicates that a greater proportion of the captured walleye in 2006 were smaller individuals (i.e. < 400 mm), which may suggest strong year class recruitment over recent years (Figure 5.1-22). This ratio suggests that there has been no degradation of recruitment to the sport fishery for walleye in recent years.

The ratio of under-size to legal-size northern pike was 1.7 in 2006, equaling the lowest-measured value of this index in the data record in 2004 (Figure 5.1-28). This ratio has been much higher in all other years, however and, to date represent anomalies in the long-term ratio.

Condition Factor

Values of mean spring condition factor (body weight vs. fork length) from 1997 to 2006 standardized captured data for the five KIR species are presented in Table 5.1-9 and Figure 5.1-29:

- There were significant differences in spring condition index among years for walleye (ANCOVA $p < 0.05$), which has ranged from 0.93 (2001) to 1.03 (2005) (Figure 5.1-29). The 2006 spring condition index for walleye was not significantly different from other years (Table 5.1-9; Figure 5.1-29);

- There were significant differences in spring condition index among years for goldeye ($p < 0.05$), which has ranged from 1.07 (2002) to 1.17 (1998) (Figure 5.1-29). The 2006 spring condition index for goldeye was not significantly different from other years (Table 5.1-9);

- There were significant differences in spring condition index among years for longnose sucker ($p < 0.05$), but no multiple pair-wise comparisons were significant after Bonferroni adjustment (Table 5.1-9, Figure 5.1-29);

- There were significant differences in spring condition index among years for white sucker ($p < 0.05$), which has ranged from 1.447 (1998) to 1.61 (2004) (Figure 5.1-29). The 2006 spring condition index for white sucker was not significantly different from other years (Table 5.1-9; Figure 5.1-29); and

- There were significant differences in spring condition index among years for northern pike, which has ranged from 0.65 (1998) to 0.79 (2004) (Figure 5.1-29). The 2006 spring condition index for northern pike was not significantly different from other years.

External Abnormality Assessment

3.2% of the fish examined in the 2006 Athabasca River fish inventory had some type of external abnormality; abnormalities observed were primarily associated with minor skin or body surface aberrations and fin erosion. The incidence of external abnormalities in 2006 for KIR species were within the range of incidences measured in previous years (Table 5.1-10).

Inventory Results for Reaches 19A and 19B

The species richness of captured plus observed fish in spring 2006 for Reach 19A was 9, the same as for 2005 (Table 5.1-11). The 2006 list of species was the same as the 2005 list of species. The species richness of captured plus observed fish in fall 2006 for reach 19A was 10, which was 2 greater than for 2005 (Table 5.1-11). The combined species richness across years and seasons is 11 for Reach 19A.

The species richness of captured plus observed fish in spring 2006 for Reach 19B was 10, 2 greater than for 2005 and the same as for 2003 (Table 5.1-11). The species richness of captured plus observed fish in fall 2006 for reach 19B was 13, which was 5 more than for 2005 (Table 5.1-11). The combined species richness across years and seasons is 16 for Reach 19B.

Total spring CPUE has been relatively similar for both reaches across years (Table 5.1-12), In contrast, total fall CPUE has been higher in Reach 19B in both 2005 and 2006 relative to Reach 19A.

5.1.5.2 Summary Assessment for Fish Inventory

As outlined in RAMP (2005b), the Athabasca River fish inventory is generally considered to be a community-driven activity, which is primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than detailed fish community structure. Standardized current and historical fish inventory data from the Athabasca River indicate some level of species-specific variability in relative abundance, length-frequency distribution, and condition factor. However, statistical analysis of the inventory data collected to date has demonstrated limited significant differences among years with no clear trends.

Currently, only condition factor can be applied as a measurement endpoint for the large-bodied Athabasca River inventory. The impact criterion for condition factor defined by Environment Canada (2002) is a ± 10% difference between *potentially influenced* and *reference* sites. A difference in condition that is greater than 10% indicates a population may be affected by some factor or factors. When this criteria is applied to the temporal analysis of condition for walleye, goldeye and white sucker, none of the between-year significant differences exceeded this threshold.

Based on the results to date for the Athabasca River inventory, there is little evidence to suggest that characteristics of FIR fish populations in the Athabasca River have changed during increasing activities from focal projects and other oils sands developments.

5.1.5.3 Fish Tag Return Assessment

A total of 13 RAMP Floy Tags (indicating capture of 13 tagged fish) were submitted to the Alberta Sustainable Resources Development (ASRD) Fort McMurray Office by anglers in 2006. Information provided with each tag return typically included tag number, species, capture location, and date of capture.

Table 5.1-11 shows the start and finish points, as well as the most direct travel route, for eleven of the fish for which tags were returned in 2006 (2 records were incomplete).

The 2006 tag returns were dominated by walleye, comprising 8 of the 11 tag returns (10 if incomplete records included, Table 5.1-13; a cumulative summary of RAMP tags returned to date (1999 to 2006) is presented in Table 5.1-14 for a comparison by species). This species has been tagged in large numbers during RAMP fish inventory programs on the Athabasca and Clearwater rivers as well as at the Muskeg River fish fences and is actively sought by sport fishers. As in previous years, recaptured walleye in 2006 exhibited the longest overall distance traveled between captures (403 km) (Table 5.1-13). In 2006, all walleye were tagged and re-captured in either the Athabasca River, Clearwater River or in Lake Athabasca, with the exception of walleye with Fish ID No. 1409 that was originally tagged and released in the Athabasca River and was recaptured in the Slave River at the Rapides of the Drowned in the Northwest Territories (Table 5.1-11). Although, the species continues to exhibit an ability to travel long distances, results to date suggest that the majority of recaptured walleye have remained and/or return to the lower section of the Athabasca River between Fort McMurray and Lake Athabasca.

The other three 2006 tag returns were for northern pike. One northern pike was found virtually at the same point in the Clearwater River on both capture occasions, despite a seven-year period between captures (Table 5.1-11). The remaining two northern pike both exhibited upstream movement from their originally tagged and release location, one in the Athabasca River and one in the Clearwater River.

In addition to the angler returns, eight fish (3 northern pike, 2 walleye) previously tagged by RAMP were recaptured in the 2006 Clearwater River fish inventory, and ten more previously tagged walleye were recaptured in the 2006 Athabasca River inventory.

5.1.6 Summary of Conditions

The large size and flow of the lower Athabasca River means that there is high year-to-year variation in aquatic resources represented by the RAMP components, much of which is due to natural factors; the much lower than average flow year for the lower Athabasca River in 2006 was no exception in this regard. The differences between hydrologic measurement endpoints for estimated baseline hydrologic conditions and measured operational hydrologic conditions were greater in 2006 than in 2005. This was due almost completely to the lower overall flows in the lower Athabasca River in 2006. It is estimated that focal project activities as of 2006 decreased 2006 mean open-water season discharge by 0.45%, lowered 2006 mean winter discharge by 1.5%, decreased annual maximum daily discharge by 0.21%, and lowered open-water season minimum daily discharge in 2006 by 0.76%. The cumulative effects of focal project activities plus all other active oil sands projects in the RAMP FS are estimated to be only marginally greater. Based on criteria used in previous oil sands project EIAs, these differences would have been assessed as negligible, with the exception of the incremental mean winter discharge, which would have been assessed as a low effect. There were no discernable changes in water quality conditions due to focal project activities in 2006 and there is no evidence to suggest that characteristics of key indicator fish populations have changed during the period of increasing focal project activity in the RAMP FSA.

Figure 5.1-2 Athabasca River: 2006 hydrograph and historical context.

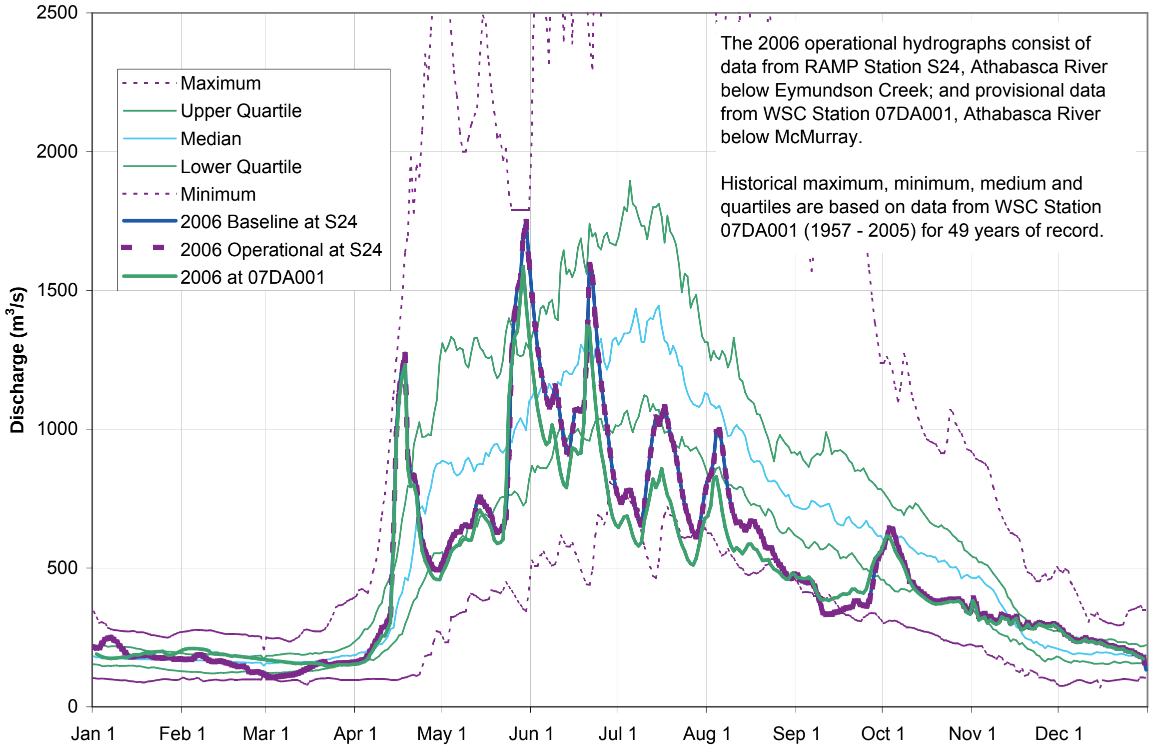


Table 5.1-1 Inputs for calculation of baseline hydrograph at RAMP Station S24, Athabasca River below Eymundson Creek.

Component	Annual Volume (million m³)		Basis and Data Source
	Focal Projects	Focal Projects Plus All Other Active Oil Sands Projects in RAMP FSA	
Observed hydrograph	15,500	15,500	Observed daily discharges obtained from RAMP Station S24, Athabasca River below Eymundson Creek
Natural runoff that would have occurred land area that was closed-circuited as of 2006	+ 16.8	+ 16.8	261 km² within drainages of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have been closed-circuited as of 2006 (Table 2.6-1). This includes the McLean Creek and upper Beaver River[1] drainages.
Incremental runoff from areas of land change that are not closed-circuited	- 1.28	- 1.28	83.9 km² within drainages of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have undergone land change as of 2006, but are not closed-circuited (Table 2.6-1). This includes the McLean Creek and upper Beaver River drainages.
Withdrawals from the Athabasca River by focal project activities	+ 93.7 (total)	+ 93.7 (total)	
	+ 50.9	+ 50.9	Withdrawals by Suncor (monthly values[1], Section 2.2)
	+ 33.9	+ 33.9	Withdrawals by Syncrude (monthly values, Section 2.2)
	+ 8.37	+ 8.37	Withdrawals by Albian (daily values, Section 2.2)
	+ 0.270	+ 0.270	Withdrawals by CNRL (daily values, Section 2.2)
	+ 0.270	+ 0.270	Withdrawals by Fort Hills (daily values, Section 2.2)
Releases to the Athabasca River by focal project activities	- 0.314	- 0.314	Releases by Syncrude (daily values, Section 2.2)
The difference between operational and baseline hydrographs on tributary streams	+ 2.38	+ 3.26	Net sum of results of hydrologic analyses from major Athabasca River tributaries (Calumet, Christina, Ells, Firebag, Fort, Hangingstone, MacKay, Muskeg, Steepbank, and Tar)
Baseline hydrograph (total annual discharge)	15,600	15,600	Estimated baseline flow for 2006
Incremental flow (change in total annual discharge)	- 111	- 110	Difference in total flow between operational and baseline hydrograph
Incremental flow (% of observed total annual discharge)	-0.7%	-0.7%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

[1] Annual totals were prorated to daily estimates using 2004 or 2005 daily data. Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.1-2 Calculated changes in hydrologic measurement endpoints for the Athabasca River, focal projects case.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	723	720	-0.52%
Mean winter discharge	210	207	-1.5%
Annual maximum daily discharge	1750	1,750	-0.27%
Open-water season minimum daily discharge	336	333	-1.1%

Note: As measured at RAMP Station S24, Athabasca River below Eymundson Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.1-3 Calculated changes in hydrologic measurement endpoints for the Athabasca River, cumulative effects case.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	723	720	-0.52%
Mean winter discharge	210	207	-1.5%
Annual maximum daily discharge	1750	1750	-0.27%
Open-water season minimum daily discharge	335	333	-1.1%

Note: As measured at RAMP Station S24, Athabasca River below Eymundson Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.1-4 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2006.

Variable	Units	Guideline	Upstream of Fort McMurray (ATR-UFM) Fall AENV data, 1976-2005				Upstream of Donald Creek (ATR-DC-E, ATR-DC-CC, ATR-DC-W)			Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)		Downstream of Development (ATR-DD-E, ATR-DD-W)		Upstream of Firebag River (ATR-FR-CC)
			n	min	median	max	East[1]	Cross-channel	West	East	West	East	West	East	West	Cross-channel
Physical variables																
pH	pH units	6.5-9.0	50	7.3	8.0	8.5	8.1	8.2	8.3	8.3	8.3	8.2	8.2	8.3	8.3	8.2
Total suspended solids	mg/L	-	52	0.4	7.2	344	18	9	<3	9	8	5	5	19	127	11
Conductivity	µS/cm	-	47	150	292	467	226	253	290	266	268	266	266	249	252	295
Nutrients																
Total dissolved phosphorus	mg/L	0.05[2]	29	0.003	0.007	0.03	0.024	0.009	0.008	0.008	0.009	0.008	0.008	0.009	0.010	0.007
Total nitrogen*	mg/L	1.0	44	0.133	0.425	**1.903**	0.6	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Nitrate+nitrite	mg/L	-	51	0.001	0.005	0.843	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	45	2.5	8	25	8	6	3	5	5	5	5	6	6	9
Ions																
Sodium	mg/L	-	47	4	10	20	21	15	11	13	12	14	14	13	13	18
Calcium	mg/L	-	42	19	35	57	18.9	27	35.9	31	30.6	33.3	33.3	30.1	30.4	33.3
Magnesium	mg/L	-	42	5	9	16	6.4	8.5	11	9.7	8.6	9.4	9.4	8.7	8.8	9.5
Chloride	mg/L	230, 860[3]	51	1	3	10.3	25	14	4	9	9	10	10	10	10	17
Sulphate	mg/L	100[4]	50	13	28.8	63.9	6.5	18.7	33.3	25.3	27.7	25.3	25.3	21.8	22.2	30.6
Total dissolved solids	mg/L	-	123	182	288	330	140	150	160	160	150	150	150	150	160	187
Total alkalinity	mg/L		51	64	122	195	69	89	110	97	96	99	99	92	92	98
Organic compounds																
Naphthenic acids	mg/L	-	-	-	-	-	1	<1	<1	<1	1	<1	<1	<1	<1	<1
Selected metals																
Total aluminum	mg/L	0.1	8	0.07	**0.18**	**1.18**	**0.720**	**0.436**	**0.220**	**0.366**	**0.325**	**0.245**	**0.245**	**0.958**	**1.30**	**0.303**
Dissolved aluminum	mg/L	0.1[2]	5	0.004	0.00812	0.02	0.00793	0.00663	0.0113	0.0066	-	0.00542	0.00542	0.00764	0.00774	0.00428
Total boron	mg/L	1.2[5]	7	0.01	0.0281	0.04	0.0338	0.0318	0.0228	0.0231	0.0242	0.023	0.023	0.0303	0.0253	0.024
Total molybdenum	mg/L	0.073	16	0.00066	0.001	0.018	0.00030	0.00050	0.00074	0.00073	0.00128	0.00094	0.00094	0.00059	0.00061	0.000582
Total mercury (ultra-trace)	ng/L	5, 13[6]	3	0.6	0.6	2.4	<0.6	<0.6	<0.6	<0.6	-	0.6	0.6	<0.6	<0.6	<0.6
Total strontium	mg/L	-	11	0.168	0.22	0.491	0.112	0.188	0.255	0.218	0.224	0.205	0.217	0.202	0.196	0.165
Other variables that exceeded CCME/AENV guidelines in 2006																
Total phenols	mg/L	0.004	32	<0.001	0.002	**0.011**	**0.008**	**0.007**	**0.005**	**0.005**	**0.006**	-	-	-	-	-
Sulphide	mg/L	0.002[7]	6[8]	<0.005	<0.01	<0.01	**0.005**	**0.004**	-	**0.003**	**0.004**	**0.005**	-	**0.005**	**0.005**	-
Total iron	mg/L	0.3	6	0.17	**0.32**	**2.42**	**1.33**	**0.717**	-	**0.599**	**0.485**	**0.553**	**0.402**	**1.09**	**1.43**	**0.508**
Dissolved iron	mg/L	0.3[2]	9	<0.01	0.06	0.17	**0.342**	-	-	-	-	-	-	-	-	-

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

* Total nitrogen calculated as the sum of nitrate+nitrite and total Kjeldahl nitrogen (TKN).

[1] Denotes sampling location. East=east bank; West=west bank; Cross-channel = cross-channel composite.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA guideline for continuous and maximum concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

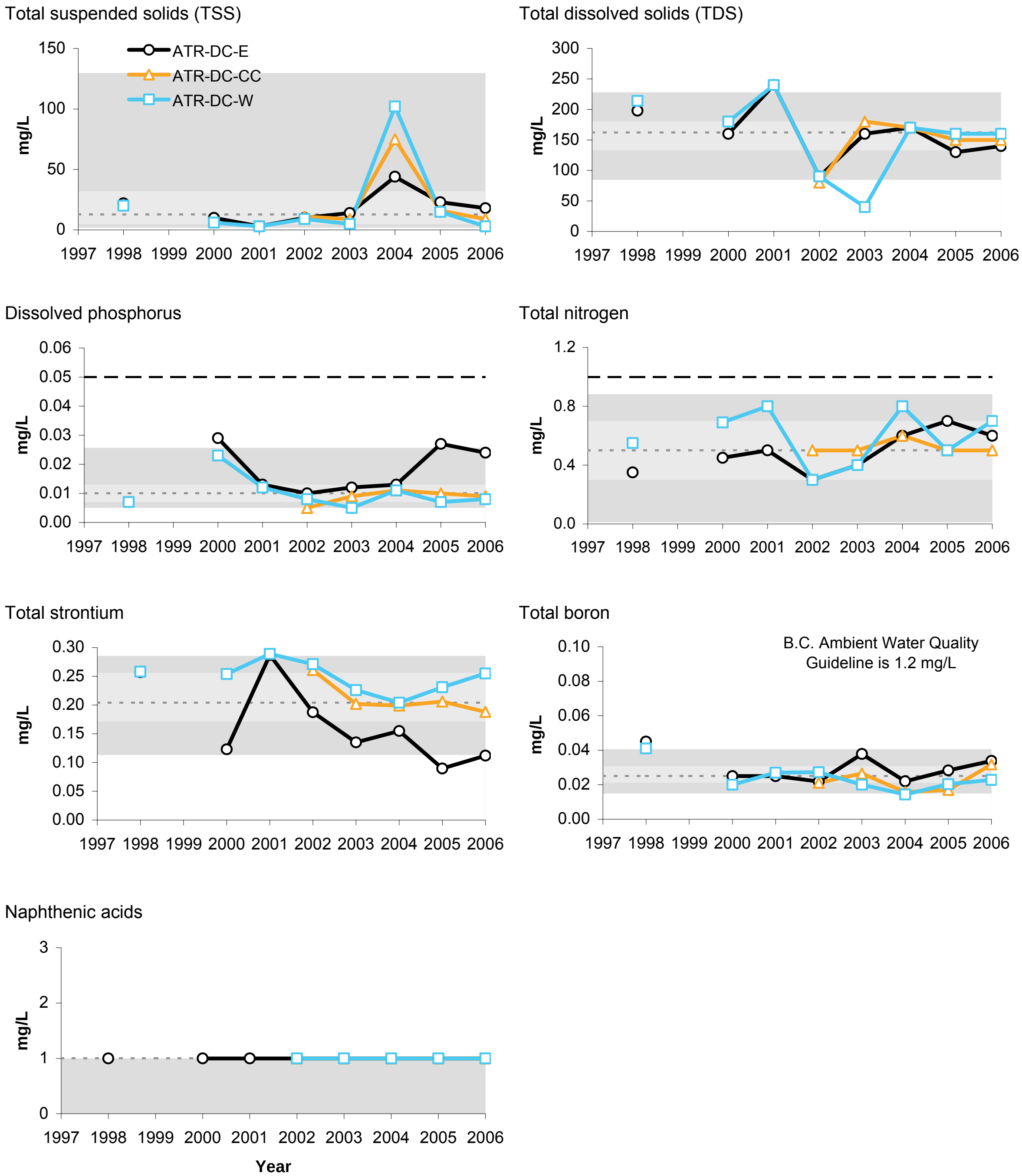
[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Data from 2003-2005 only.

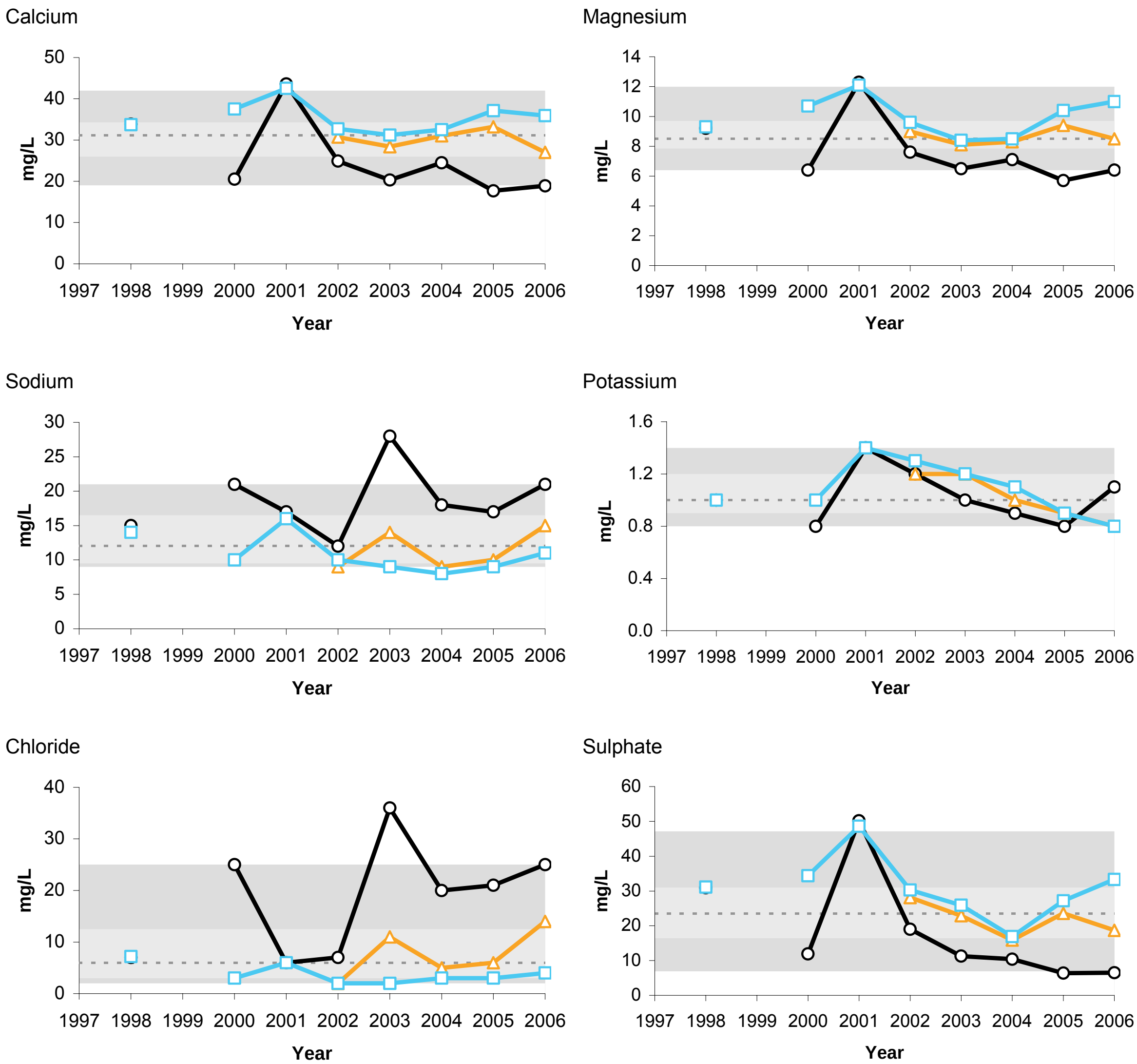
Figure 5.1-3 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of Donald Creek (ATR-DC).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

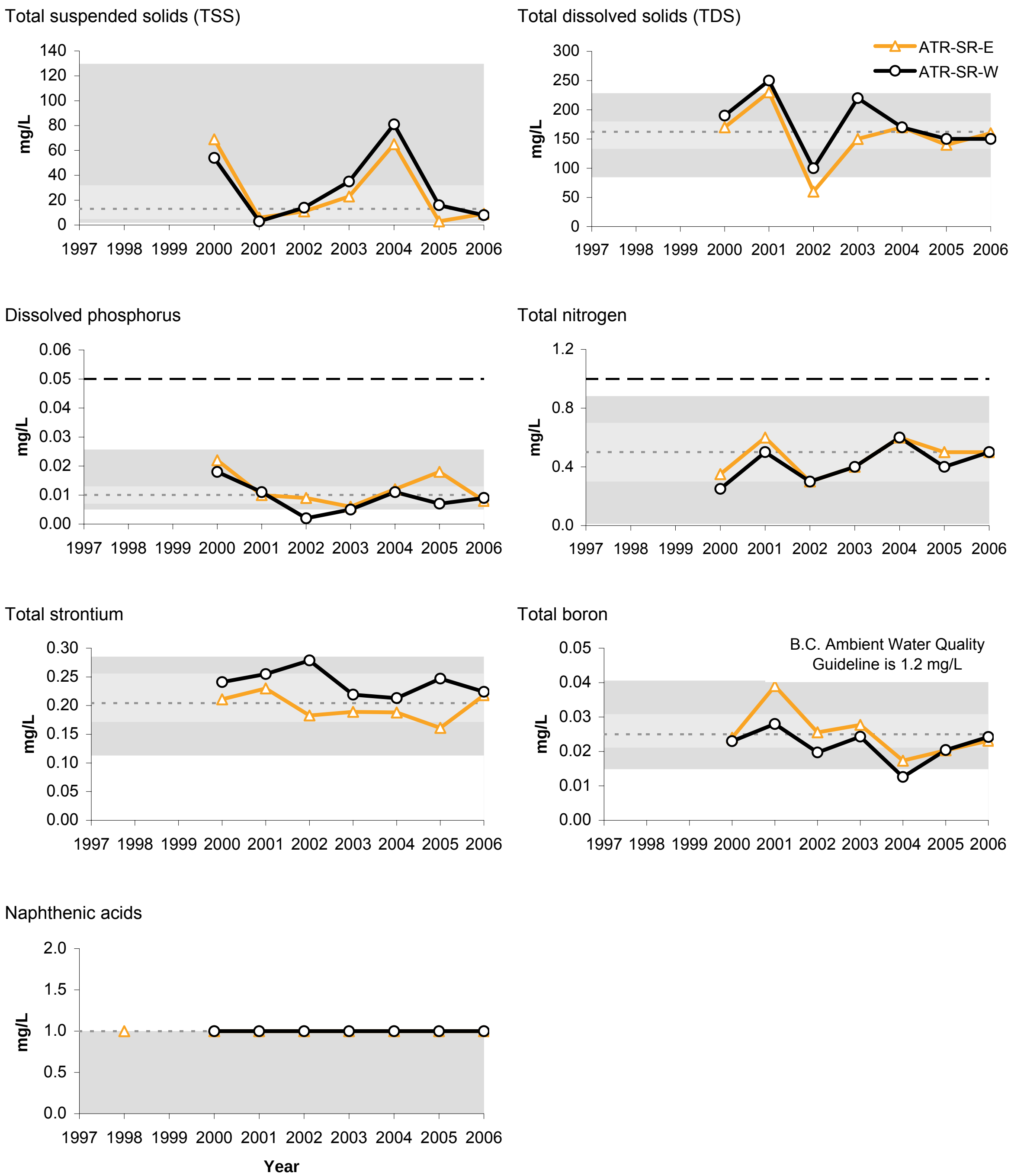
Figure 5.1-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

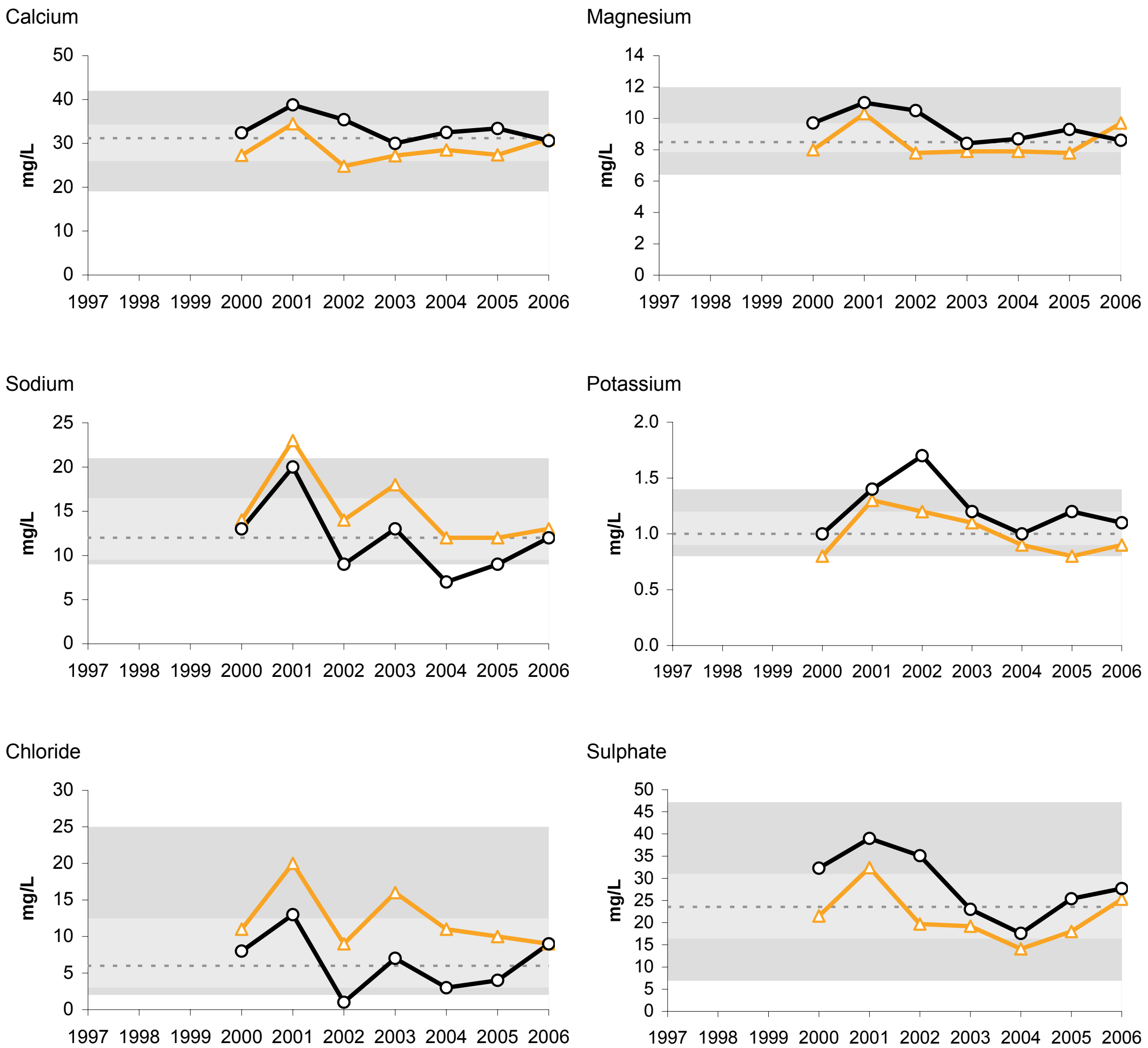
Figure 5.1-4 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Steepbank River (ATR-SR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

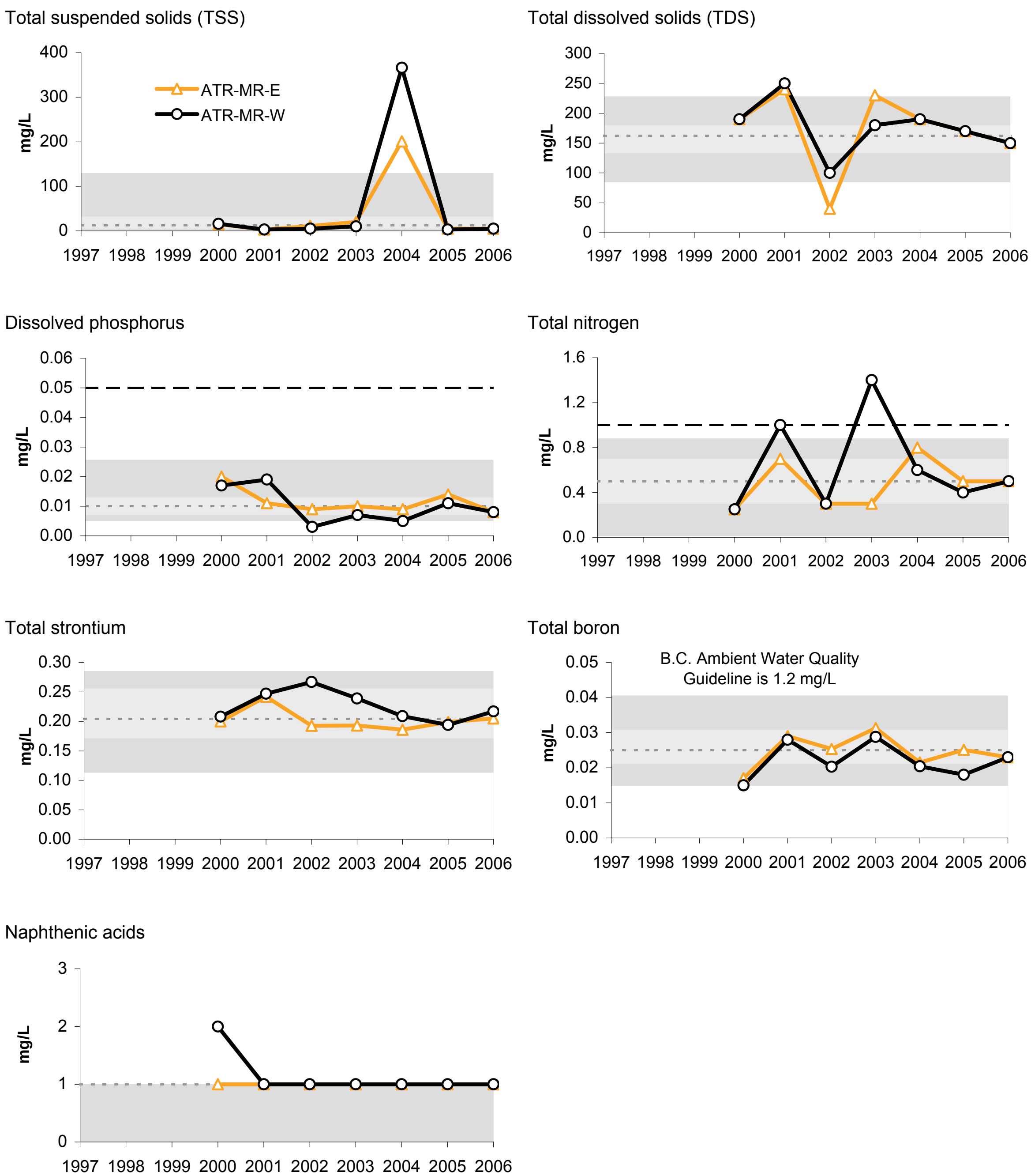
Figure 5.1-4 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

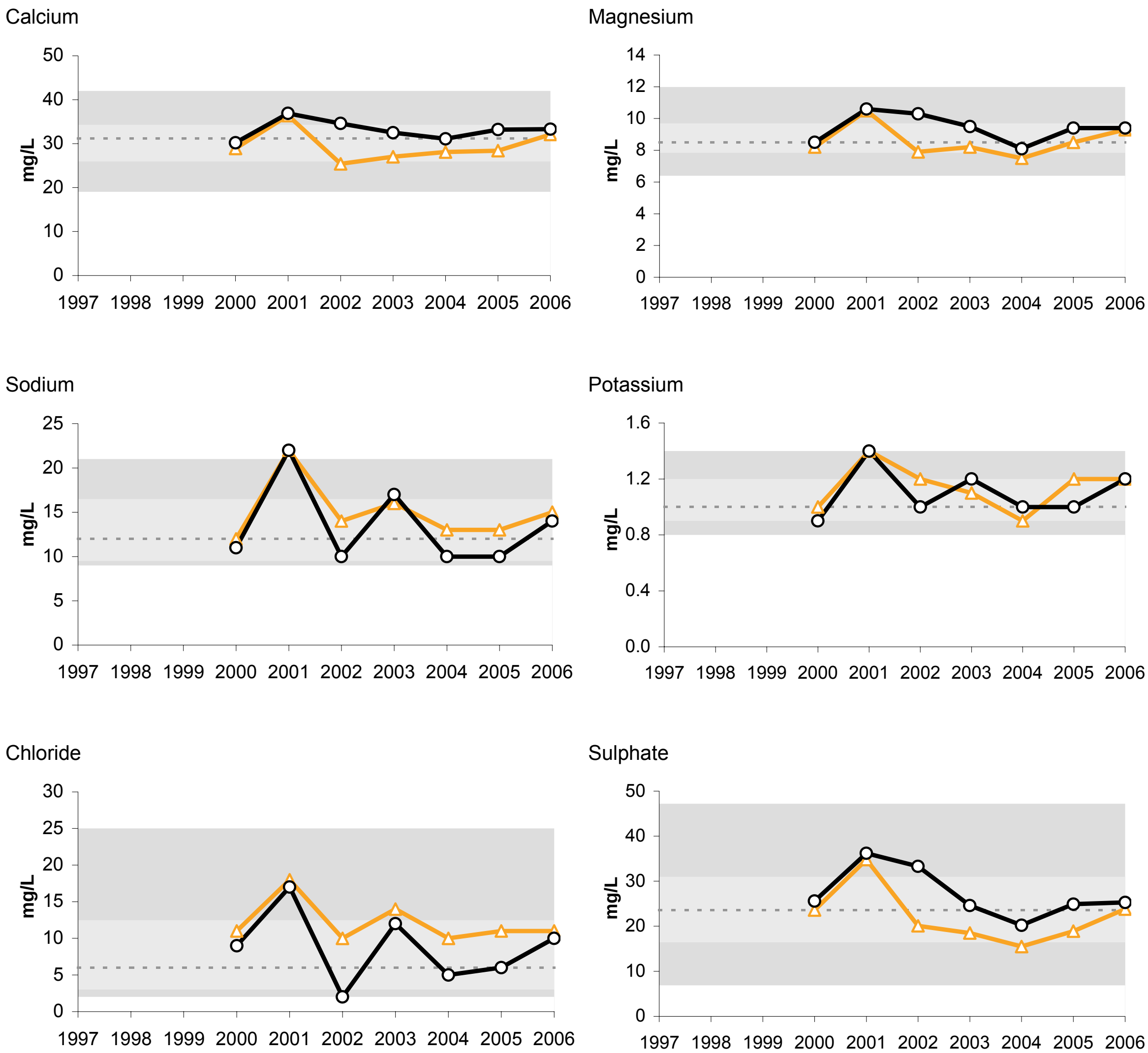
Figure 5.1-5 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Muskeg River (ATR-MR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

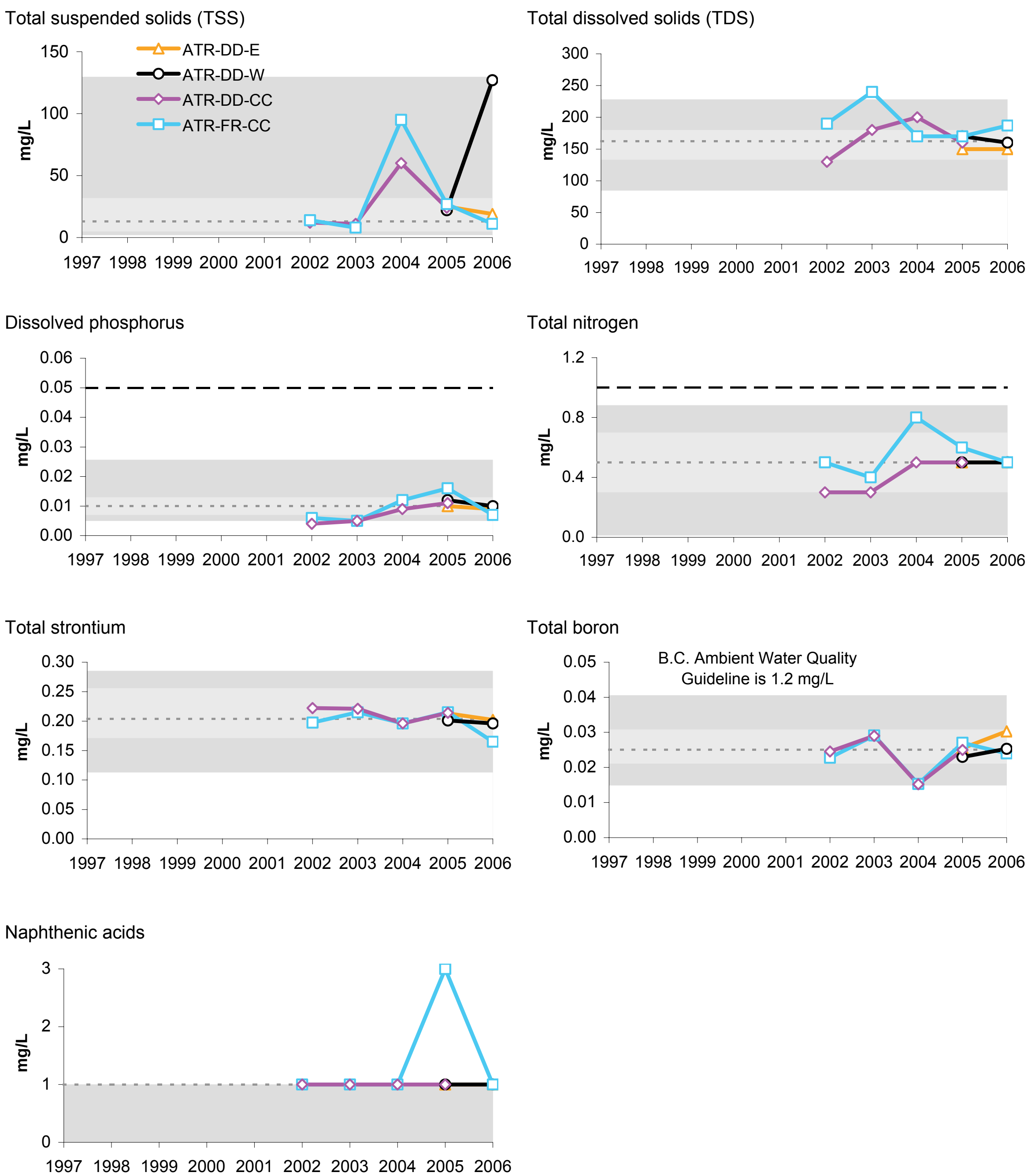
Figure 5.1-5 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

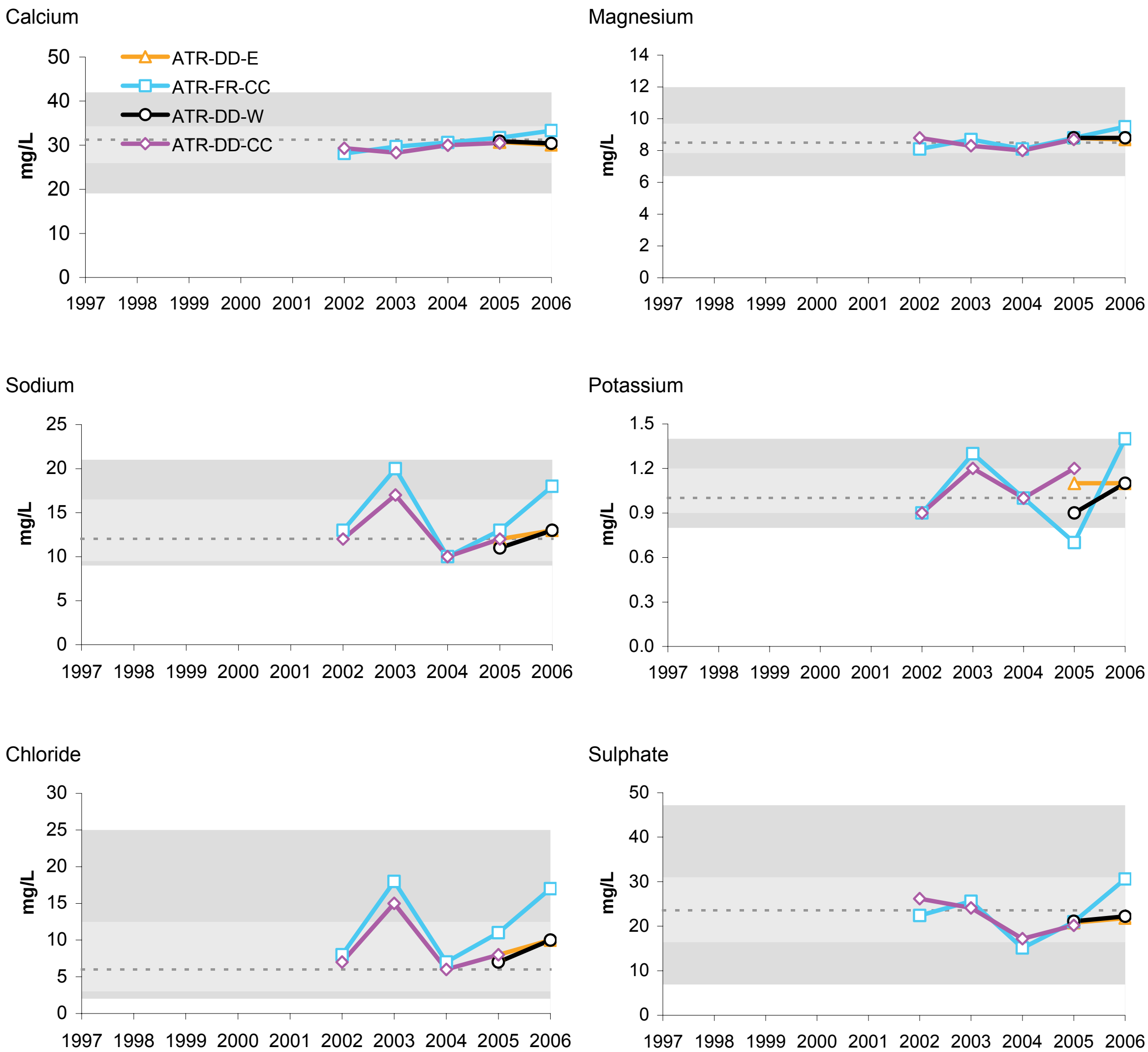
Figure 5.1-6 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD) and upstream of the Firebag River (ATR-FR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.1-6 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Table 5.1-5 Seasonal exceedances of water quality guidelines in the Athabasca River mainstem, downstream of development (ATR-DD), 2006.

Parameter	Units	Guideline*	ATR-DD-E	ATR-DD-W
Winter				
Total iron	mg/L	0.3	**0.454**	**0.47**
Spring				
Sulphide	mg/L	0.002[2]	**0.004**	**0.005**
Total phosphorus	mg/L	0.05	**0.096**	**0.102**
Total cadmium	mg/L	-[3]	**0.0000362**	**0.000043**
Total copper	mg/L	-[3]	**0.00292**	**0.00349**
Total iron	mg/L	0.3	**2.93**	**3.3**
Summer				
Sulphide	mg/L	0.002 [2]	**0.004**	**0.006**
Total phosphorus	mg/L	0.05	**0.056**	**0.053**
Total iron	mg/L	0.3	**1.65**	**1.58**
Fall				
Sulphide	mg/L	0.002 [2]	**0.005**	**0.005**
Total phosphorus	mg/L	0.05	-	**0.105**
Total iron	mg/L	0.3	**1.09**	**1.43**

ns = not sampled

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[2] B.C. Working Water Quality Guideline (2001).

[3] Guidelines are hardness-dependent.

Table 5.1-6 Trend analysis of water quality measurement endpoints for Athabasca River mainstem stations.

AENV Analyte	Upstream of Fort McMurray 1997 - 2006 (station ATR-UFM)			At Old Fort 1997 - 2006 (station ATR-OF)		
	n	Trend Direction	Slope Estimate[1] (units per year)	n	Trend Direction	Slope Estimate[1] (units per year)
Physical variables						
pH	80	up	0.0205	77	up	0.0556
Specific conductance	72	down	-6.811	77	-	-
Nutrients						
Total phosphorus	83	-	-	74	-	-
Total dissolved phosphorus	83	-	-	71	-	-
Total nitrogen	83	-	-	75	-	-
Nitrate+nitrite	83	-	-	76	-	-
Total Kjeldahl nitrogen	83	up	0.019	74	-	-
Dissolved organic carbon	88	-	-	75	-	-
Ions						
Sodium	80	-	-	77	-	-
Calcium	80	-	-	77	-	-
Magnesium	80	-	-	77	-	-
Chloride	79	-	-	77	-	-
Sulphate	79	-	-	77	-	-
Total dissolved solids (calculated)	80	-	-	77	-	-
Alkalinity (as $CaCO_3$)	80	-	-	77	-	-
Selected metals						
Total aluminum	43	-	-	44	up	0.074
Dissolved aluminum[1]	19	-	-	26[2]	-	-
Total boron	36	-	-	32[2]	-	-
Total molybdenum	32*	-	-	33[2]	down	0.000
Total mercury (ultra-trace)	11[2]	-	-	14[2]	-	-

* Trend analyzed from 1999 to 2006 due to high detection limits in 1997 and 1998.

[1] Reported slope is the median of slopes estimated for individual season (Seasonal Kendall test) or individual time periods (Sen's slope estimate).

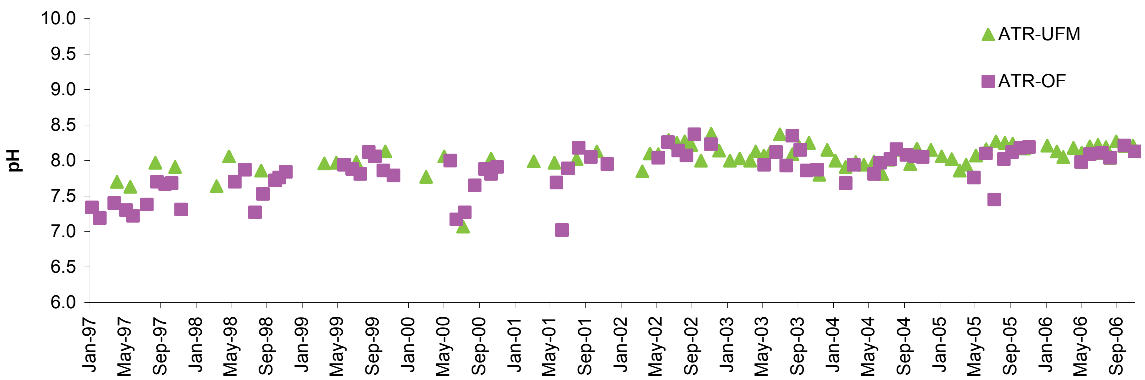
[2] Insufficient data in each season for Seasonal Kendall analysis. Trends were assessed using the Mann-Kendall test for trend and Sen's slope estimator.

Figure 5.1-7 Water quality measurement endpoints (physical variables), 1997 to 2006 AENV data, Athabasca River mainstem stations.

pH

Trend at ATR-UFM: up

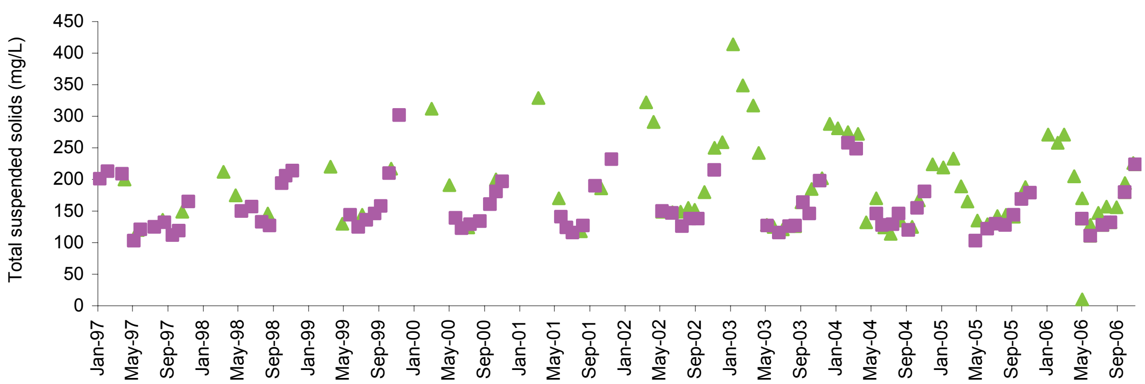
Trend at ATR-OF: up



Total dissolved solids

Trend at ATR-UFM: none

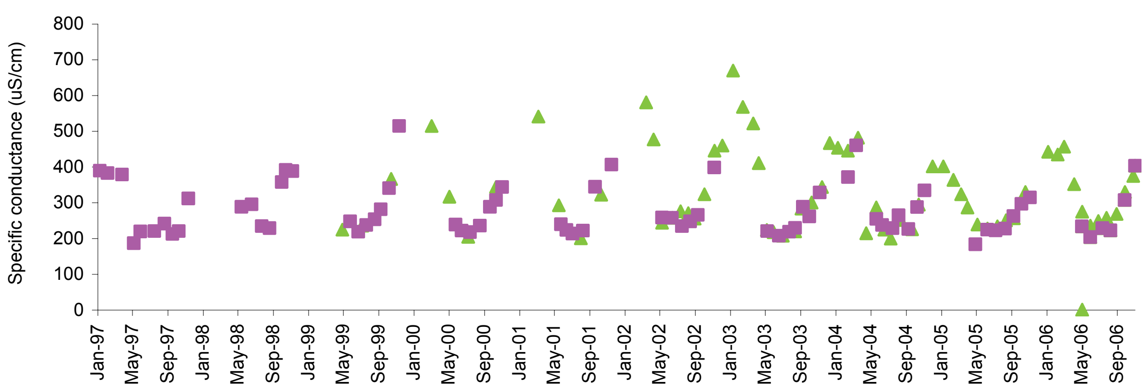
Trend at ATR-OF: none



Specific conductance

Trend at ATR-UFM: down

Trend at ATR-OF: none

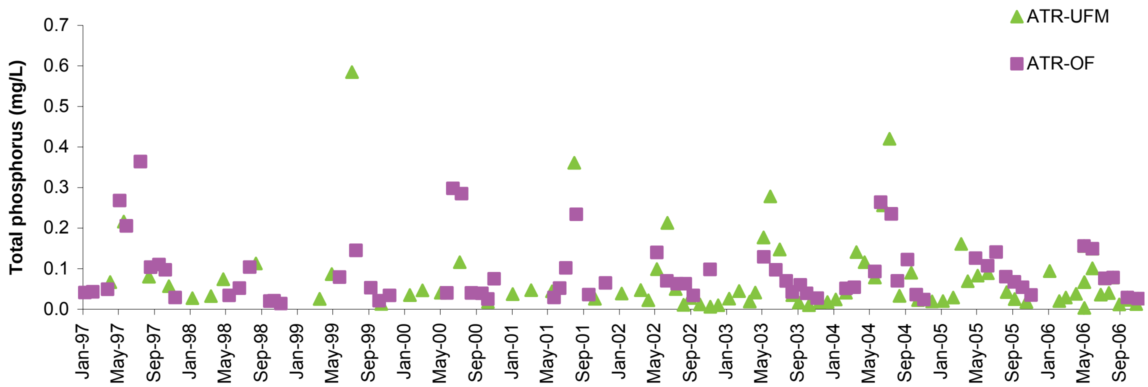


Non-detectable results are shown at the detection limit.

Figure 5.1-8 Water quality measurement endpoints (nutrients, set No. 1), 1997-2006 AENV data, Athabasca River mainstem stations.

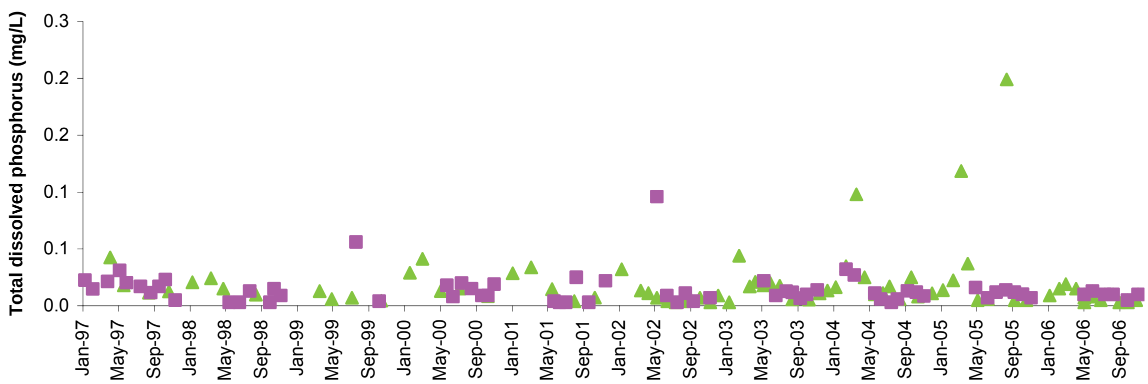
Total phosphorus

Trend at ATR-UFM: none Trend at ATR-OF: none



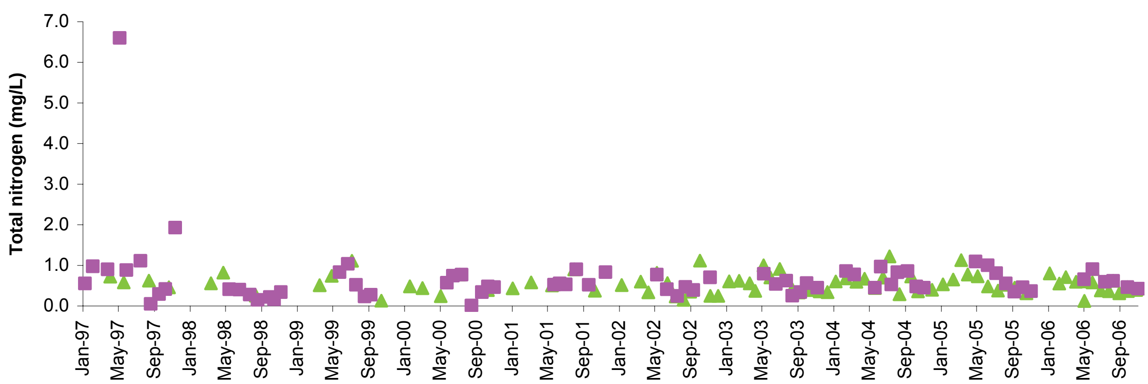
Total dissolved phosphorus

Trend at ATR-UFM: none Trend at ATR-OF: none



Total nitrogen

Trend at ATR-UFM: none Trend at ATR-OF: none



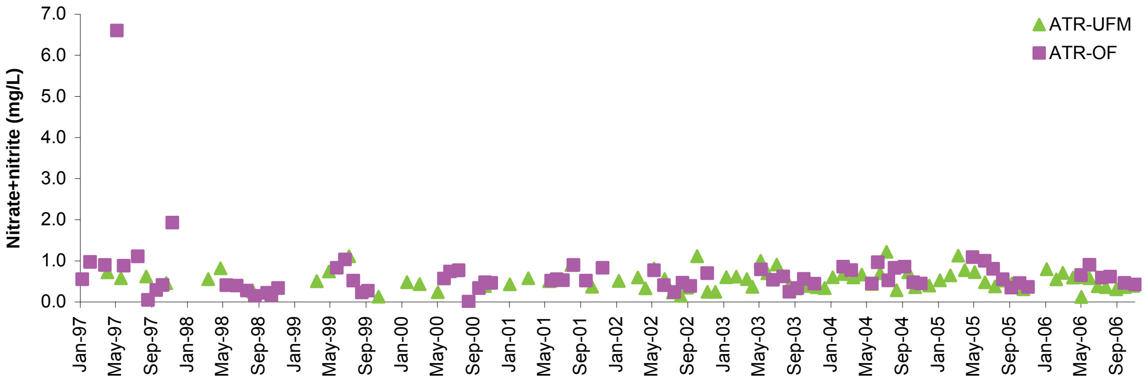
Non-detectable values are shown at the detection limit.

Figure 5.1-9 Water quality measurement endpoints (nutrients, set No. 2), 1997-2006 AENV data, Athabasca River mainstem stations.

Nitrate + Nitrite

Trend at ATR-UFM: none

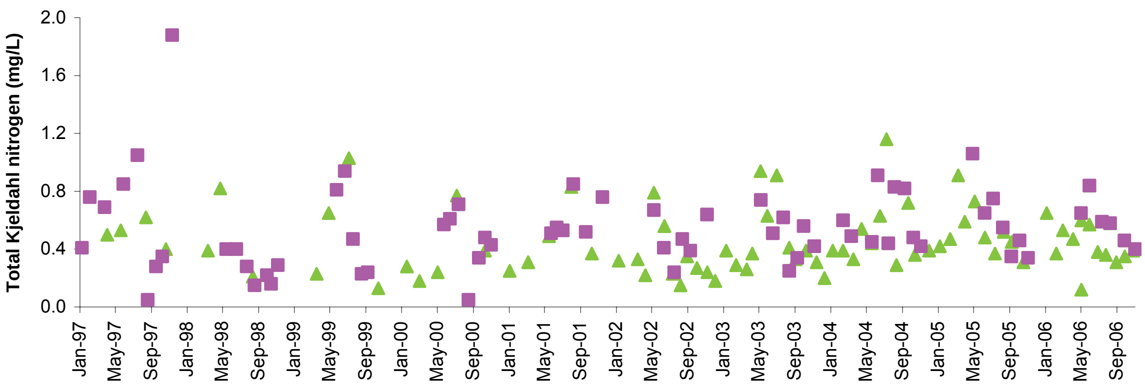
Trend at ATR-OF: none



Total Kjeldahl nitrogen

Trend at ATR-UFM: up

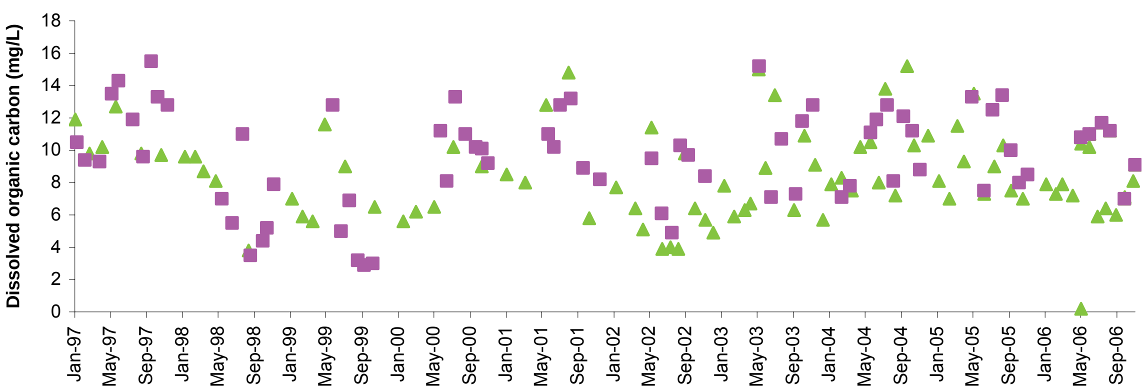
Trend at ATR-OF: none



Dissolved organic carbon

Trend at ATR-UFM: none

Trend at ATR-OF: none

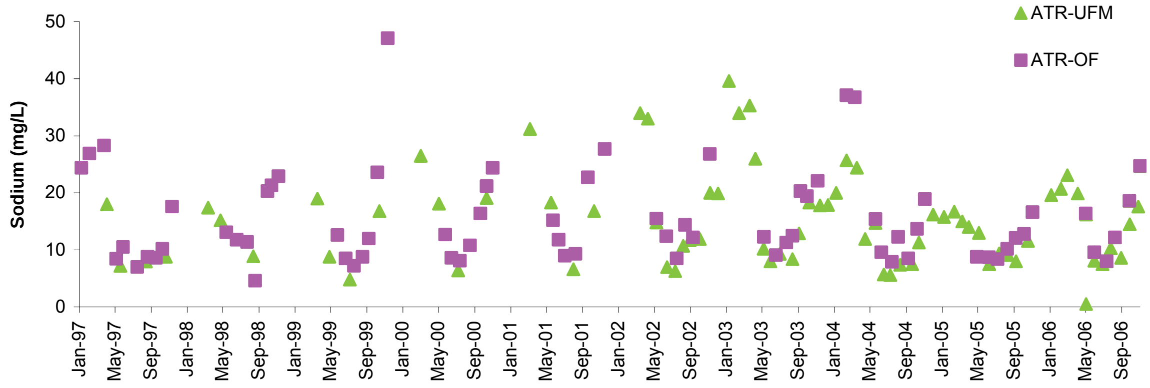


Non-detectable values are shown at the detection limit.

Figure 5.1-10 Water quality measurement endpoints (ions, set No. 1), 1997-2006 AENV data, Athabasca River mainstem stations.

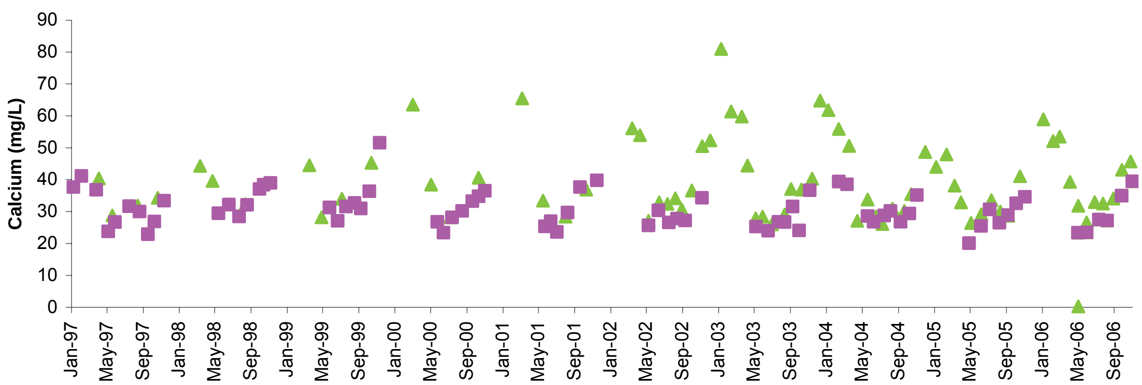
Sodium

Trend at ATR-UFM: none　　　　Trend at ATR-OF: none



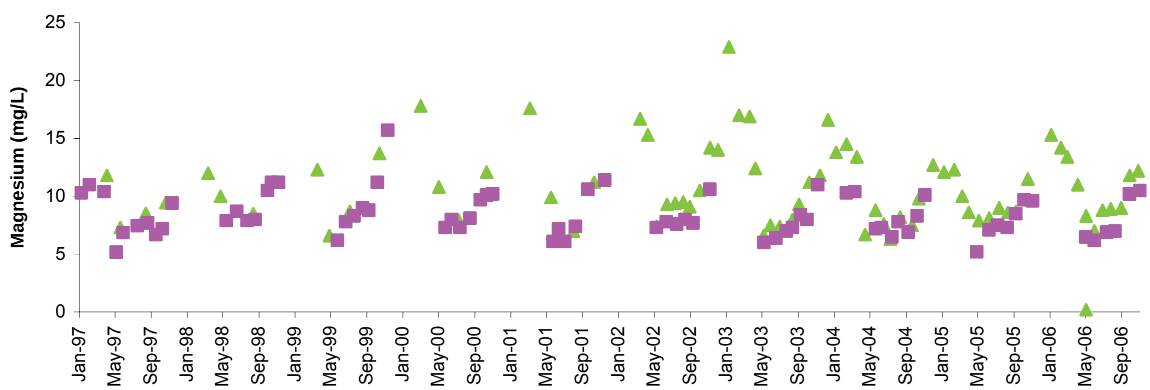
Calcium

Trend at ATR-UFM: none　　　　Trend at ATR-OF: down



Magnesium

Trend at ATR-UFM: none　　　　Trend at ATR-OF: down

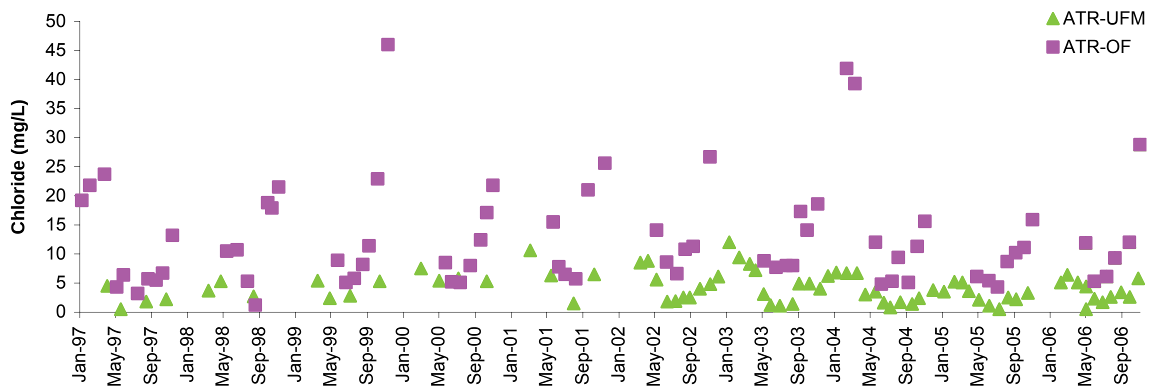


Non-detectable values are shown at the detection limit.

Figure 5.1-10 Cont'd.

Chloride

Trend at ATR-UFM: down Trend at ATR-OF: none

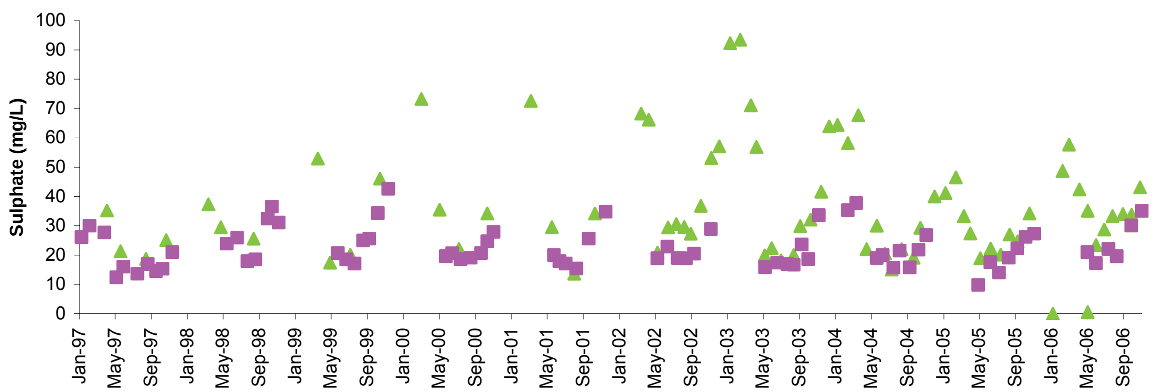


Non-detectable values are shown at the detection limit.

Figure 5.1-11 Water quality measurement endpoints (ions, set No. 2), 1997-2006 AENV data, Athabasca River mainstem stations.

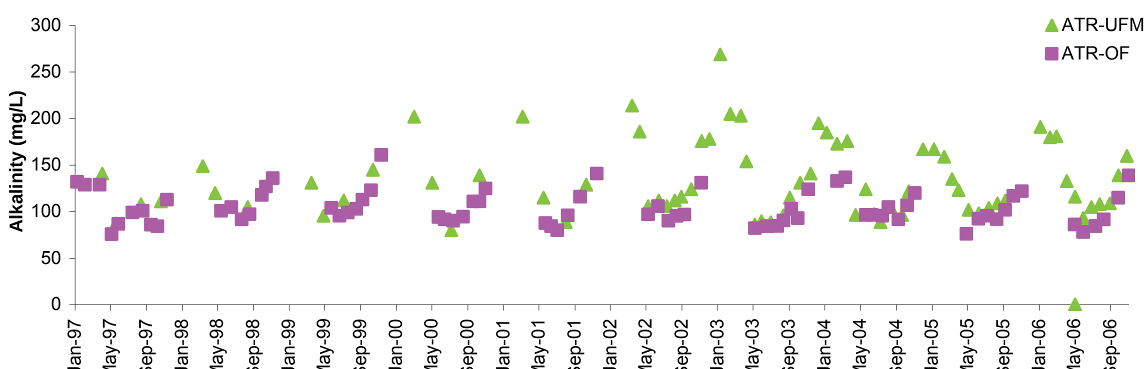
Sulphate

Trend at ATR-UFM: none Trend at ATR-OF: none



Alkalinity (as $CaCO_3$)

Trend at ATR-UFM: none Trend at ATR-OF: none

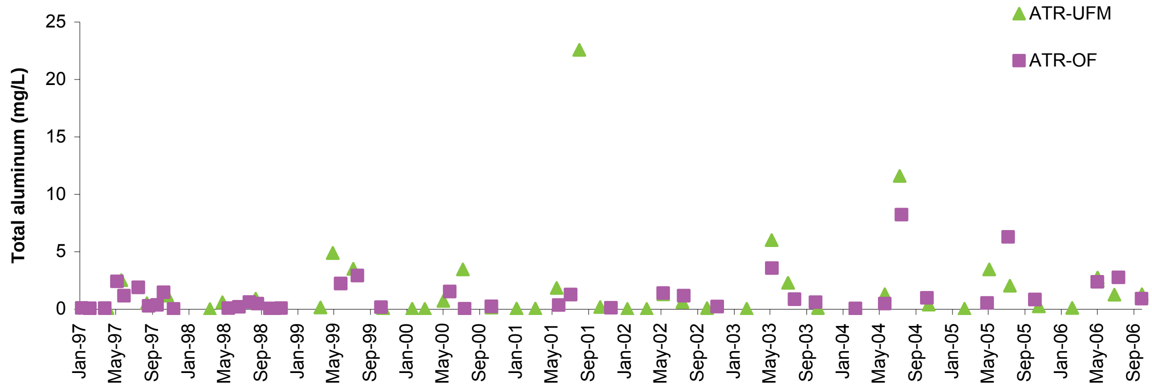


Non-detectable values are shown at the detection limit.

Figure 5.1-12 Water quality measurement endpoints (metals, set No. 1), 1997-2006 AENV data, Athabasca River mainstem stations.

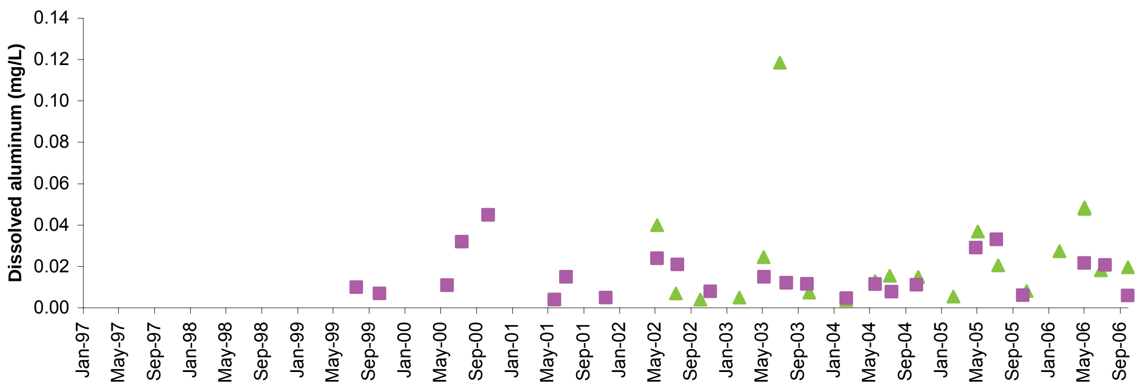
Total aluminum

Trend at ATR-UFM: none Trend at ATR-OF: up



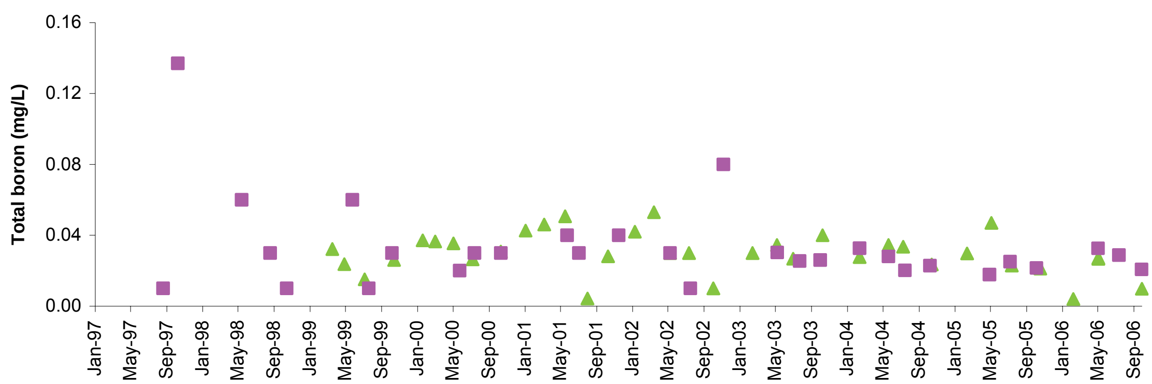
Dissolved aluminum

Trend at ATR-UFM: none Trend at ATR-OF: none



Total boron

Trend at ATR-UFM: none Trend at ATR-OF: none

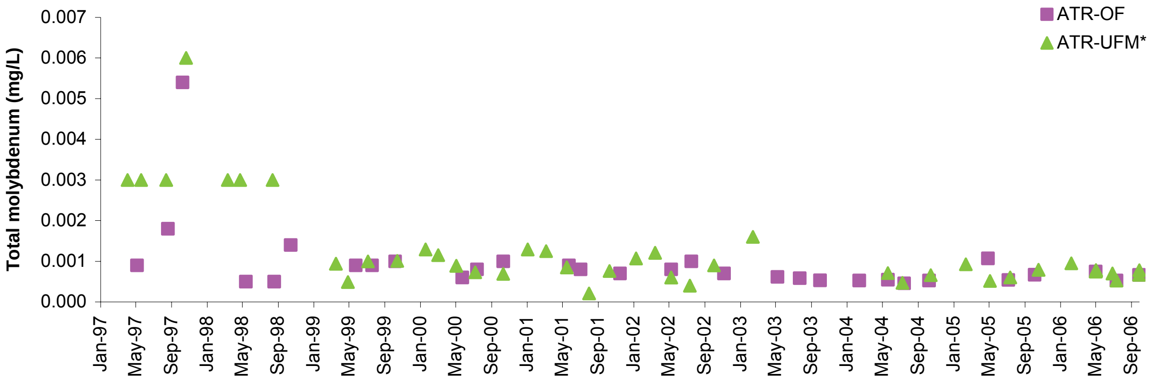


Non-detectable values are shown at the detection limit.

Figure 5.1-13 Water quality measurement endpoints (metals, set No. 2), 1997-2006 AENV data, Athabasca River mainstem stations.

Total molybdenum

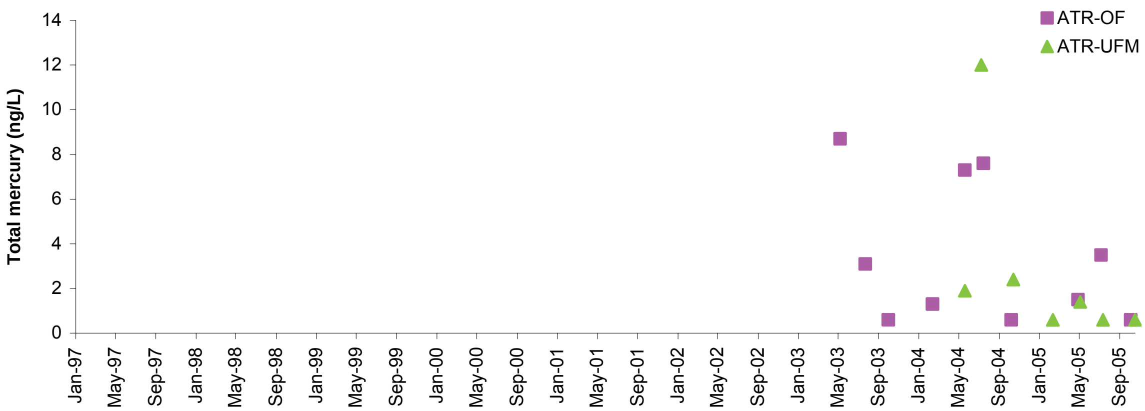
Trend at ATR-UFM: none Trend at ATR-OF: down



* ATR-UFM data analyzed from 1999-2005 due to a higher detection limit in 1997 and 1998.

Total mercury (ultra-trace)

Trend at ATR-UFM: none Trend at ATR-OF: none



Non-detectable values are shown at the detection limit.

Figure 5.1-14 Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2006.

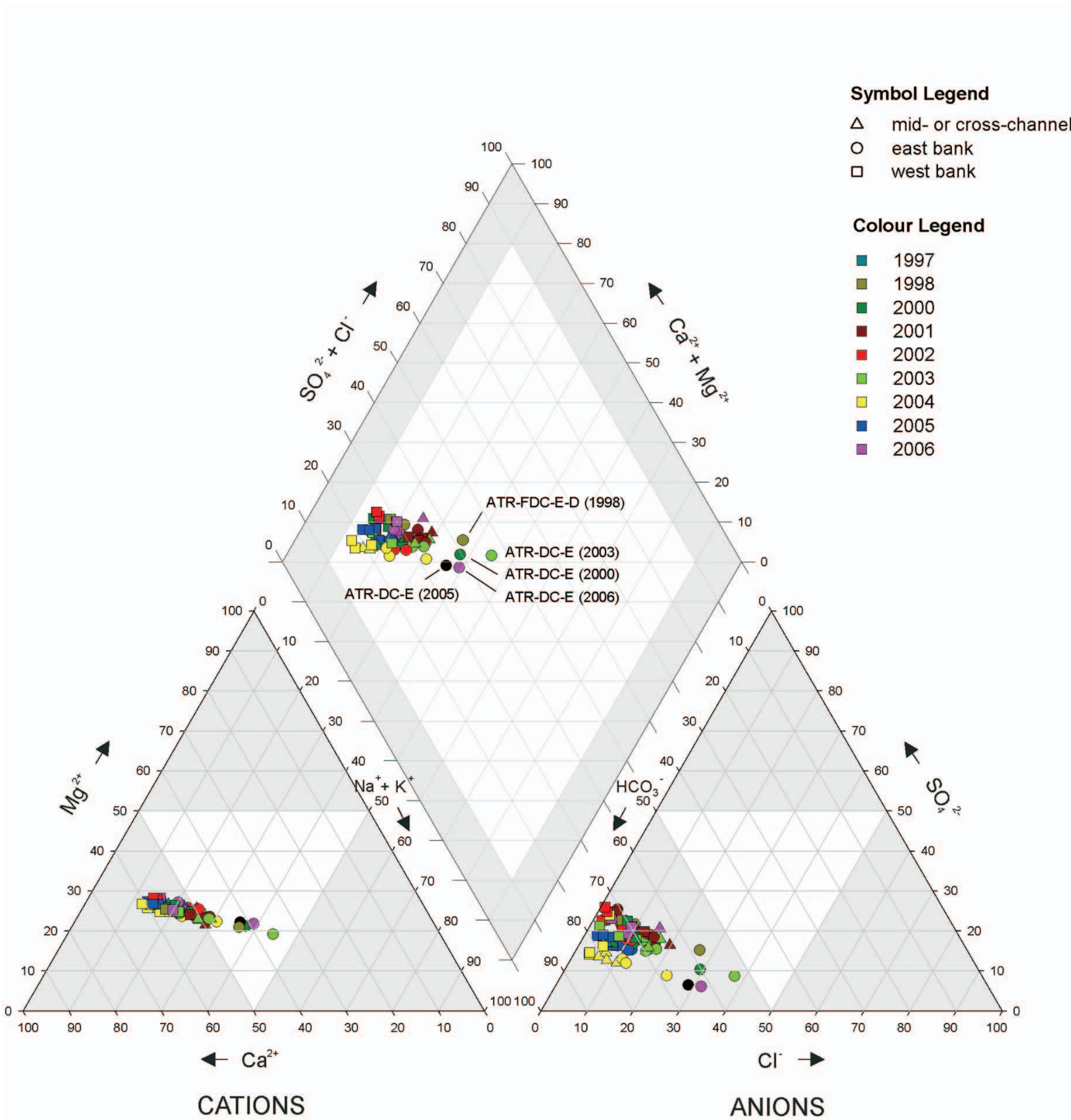


Table 5.1-7 Athabasca River fish inventory results, spring 2006.

Species	Total Captured	Species Composition (% of seasonal total)	CPUE (No./100 s) (mean ± SE)
Emerald shiner	13	1.8	0.078 ± 0.029
Fathead minnow	4	0.7	0.017 ± 0.012
Flathead chub	150	21.2	0.705 ± 0.107
Goldeye	49	6.9	0.212 ± 0.054
Lake chub	13	1.8	0.062 ± 0.018
Lake whitefish	9	1.3	0.046 ± 0.016
Longnose sucker	32	4.5	0.152 ± 0.029
Northern pike	10	1.4	0.054 ± 0.019
Spoonhead sculpin	1	0.1	0.004 ± 0.004
Spottail shiner	1	0.1	0.006 ± 0.006
Trout-perch	168	23.8	0.722 ± 0.159
Walleye	196	27.7	0.872 ± 0.202
White sucker	61	8.6	0.272 ± 0.072
TOTAL	**707**	**100**	**3.20 ± 0.407**

Total spring electrofishing effort = 20,890 s

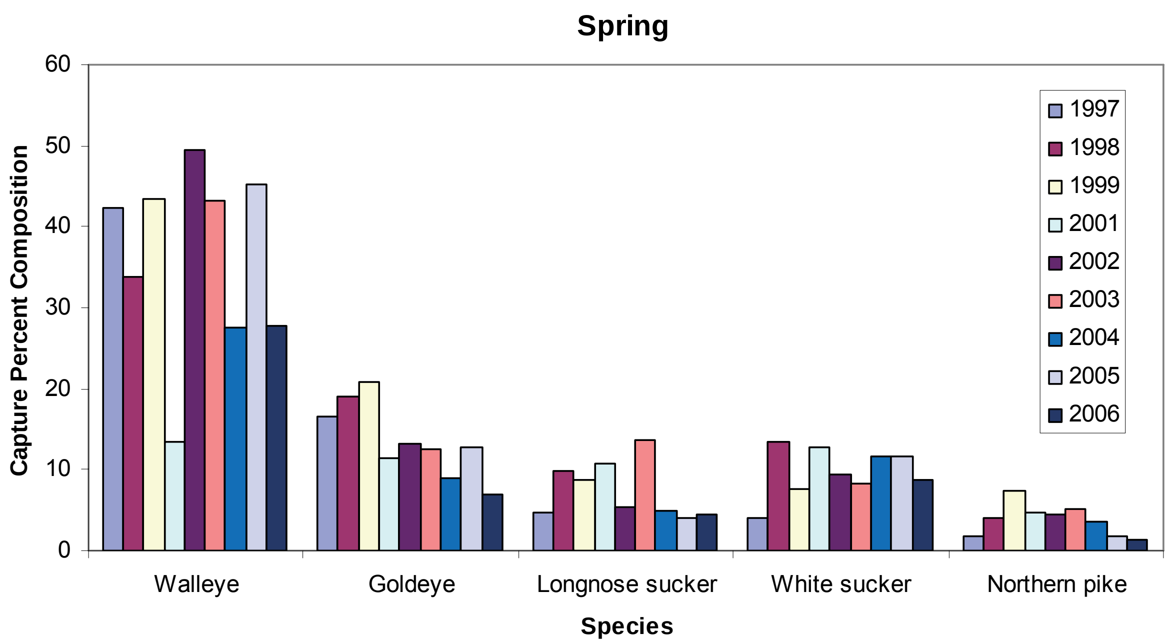
Table 5.1-8 Athabasca River fish inventory results, fall 2006.

Species	Total Captured	Species Composition (% of seasonal total)	CPUE (No./100 s) (mean ± SE)
Arctic grayling	2	0.2	0.010 ± 0.007
Burbot	2	0.2	0.010 ± 0.007
Emerald shiner	33	3.1	0.109 ± 0.078
Flathead chub	32	3.0	0.135 ± 0.052
Goldeye	25	2.3	0.115 ± 0.037
Lake chub	58	5.4	0.257 ± 0.072
Lake cisco	1	0.1	0.005 ± 0.005
Lake whitefish	69	--	0.337 ± 0.089
Longnose sucker	67	6.2	0.321 ± 0.065
Mountain whitefish	9	0.8	0.048 ± 0.020
Northern pike	39	3.6	0.193 ± 0.031
Spoonhead sculpin	2	0.2	0.011 ± 0.011
Spottail shiner	11	1.0	0.038 ± 0.018
Trout-perch	574	53.2	2.722 ± 0.496
Walleye	145	13.4	0.657 ± 0.187
White sucker	48	4.4	0.232 ± 0.102
Yellow perch	31	2.9	0.144 ± 0.037
TOTAL	**1148**	**100**	**5.34 ± 0.811**

Total fall electrofishing effort = 21,260 s

Lake whitefish were excluded from the CPUE calculation due to biased sampling associated with the fall spawning run of this species.

Figure 5.1-15 Percent composition of captured large-bodied species, Athabasca River spring and fall inventories, 1997 to 2006.



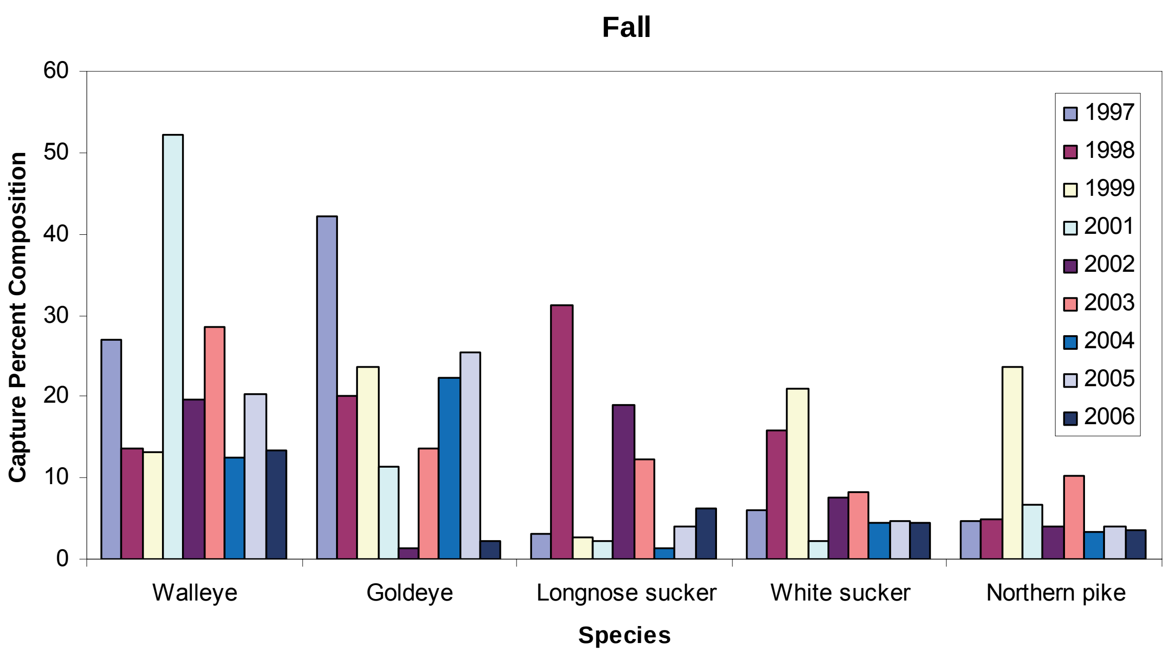


Figure 5.1-16 Seasonal CPUE for all species combined (captured fish only), Athabasca River spring inventory, 1997 to 2006.

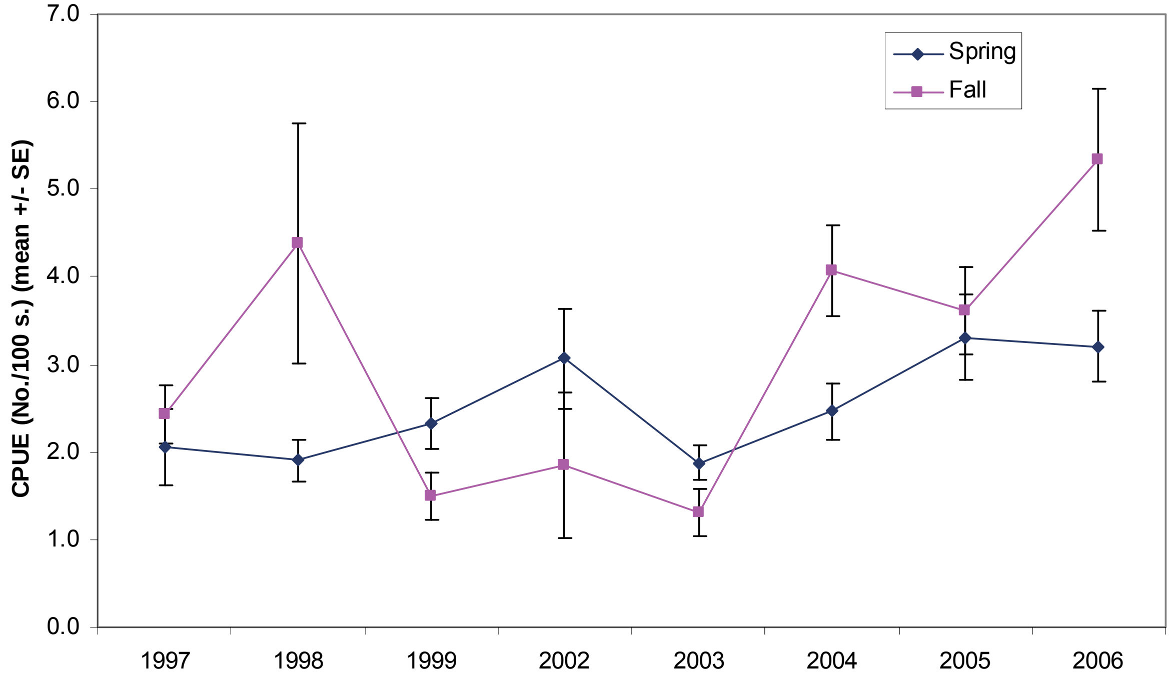


Figure 5.1-17 Seasonal walleye CPUE (captured fish only), Athabasca River inventory, 1997 to 2006.

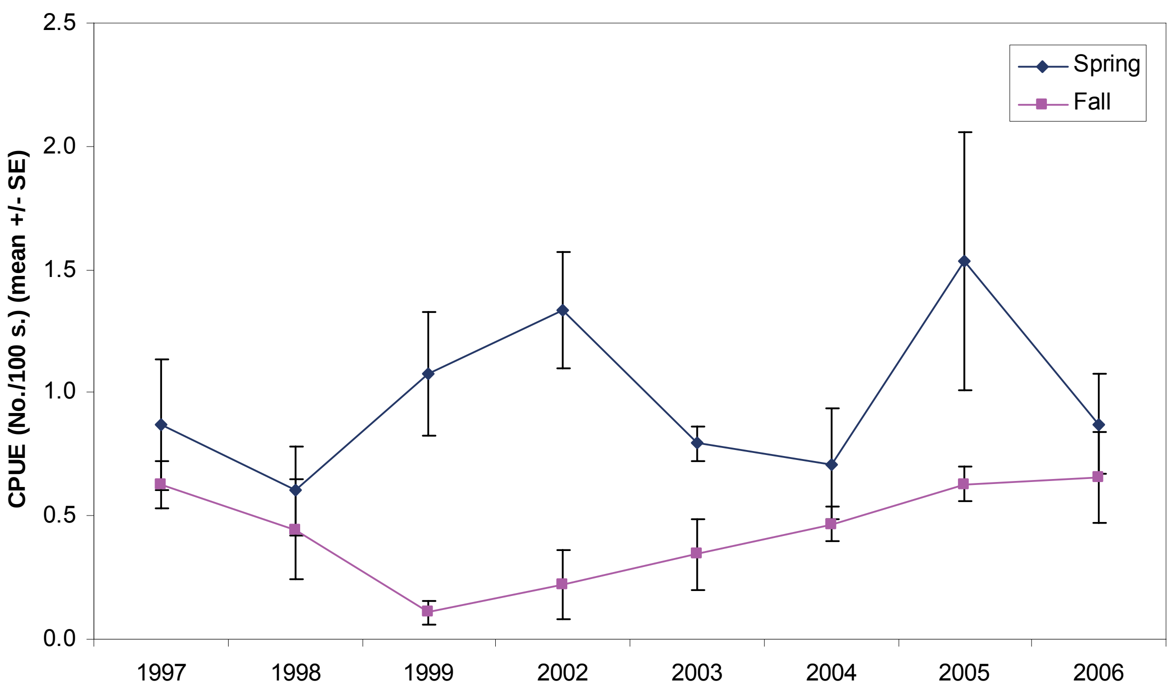


Figure 5.1-18 Seasonal goldeye CPUE (captured fish only), Athabasca River inventory, 1997 to 2006.

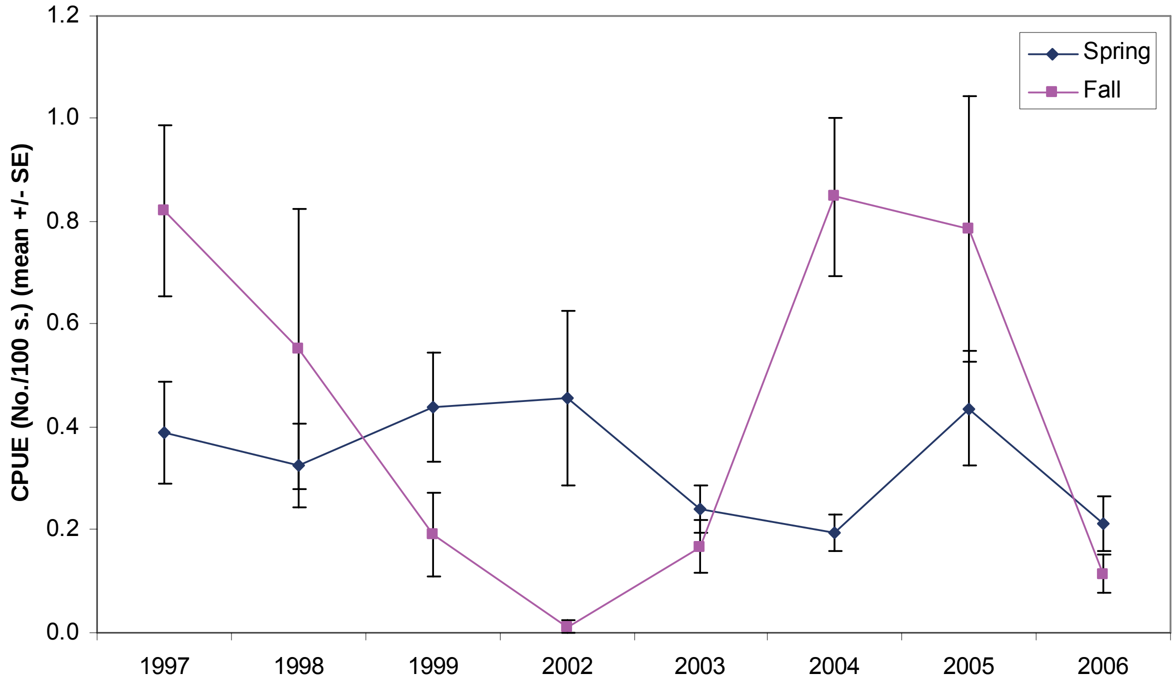


Figure 5.1-19 Seasonal longnose sucker CPUE (captured fish only), Athabasca River, 1997 to 2006.

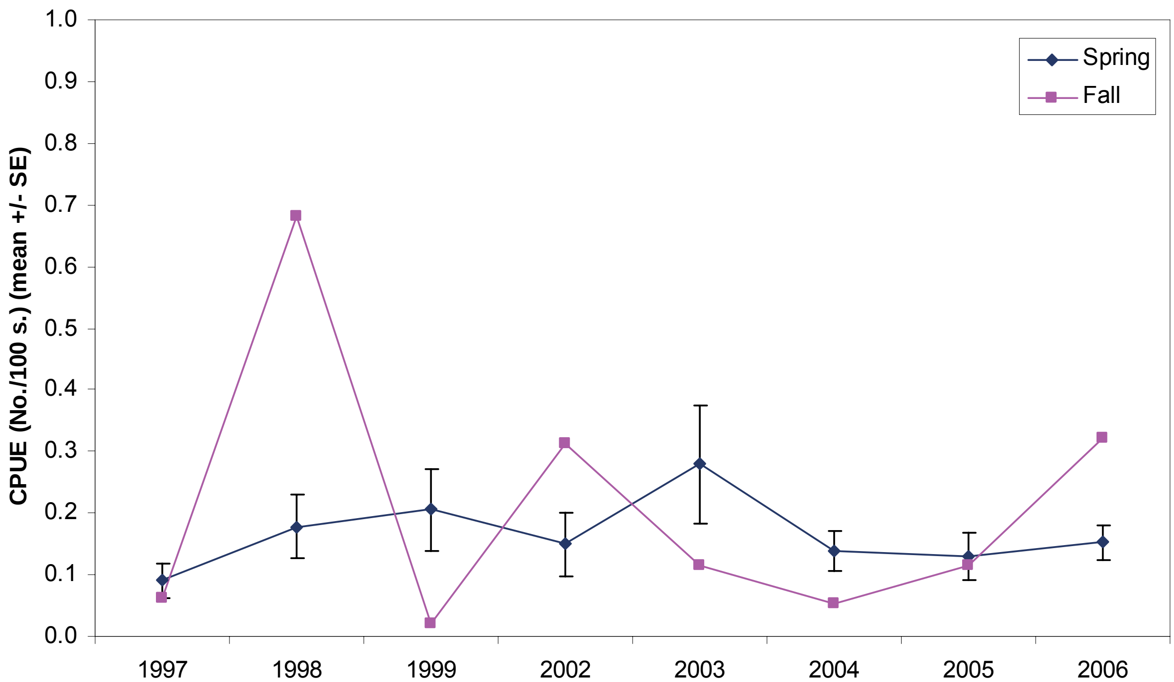


Figure 5.1-20 Seasonal white sucker CPUE (captured fish only), Athabasca River, 1997 to 2006.

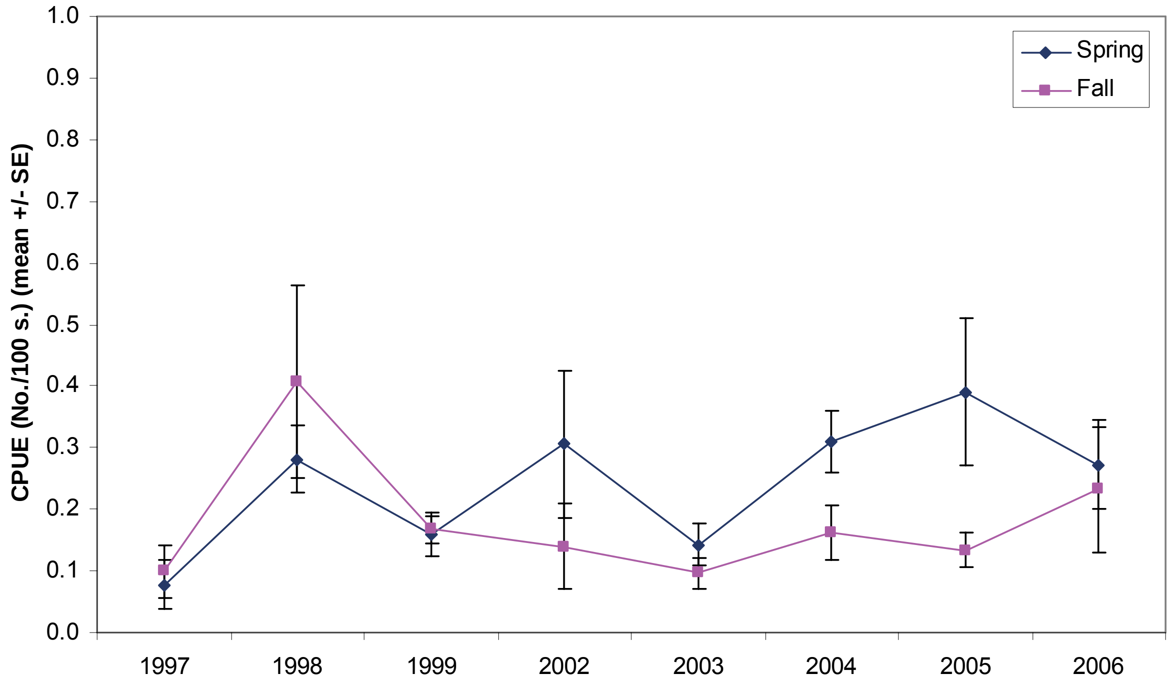


Figure 5.1-21 Seasonal northern pike CPUE (captured fish only), Athabasca River, 1997 to 2006.

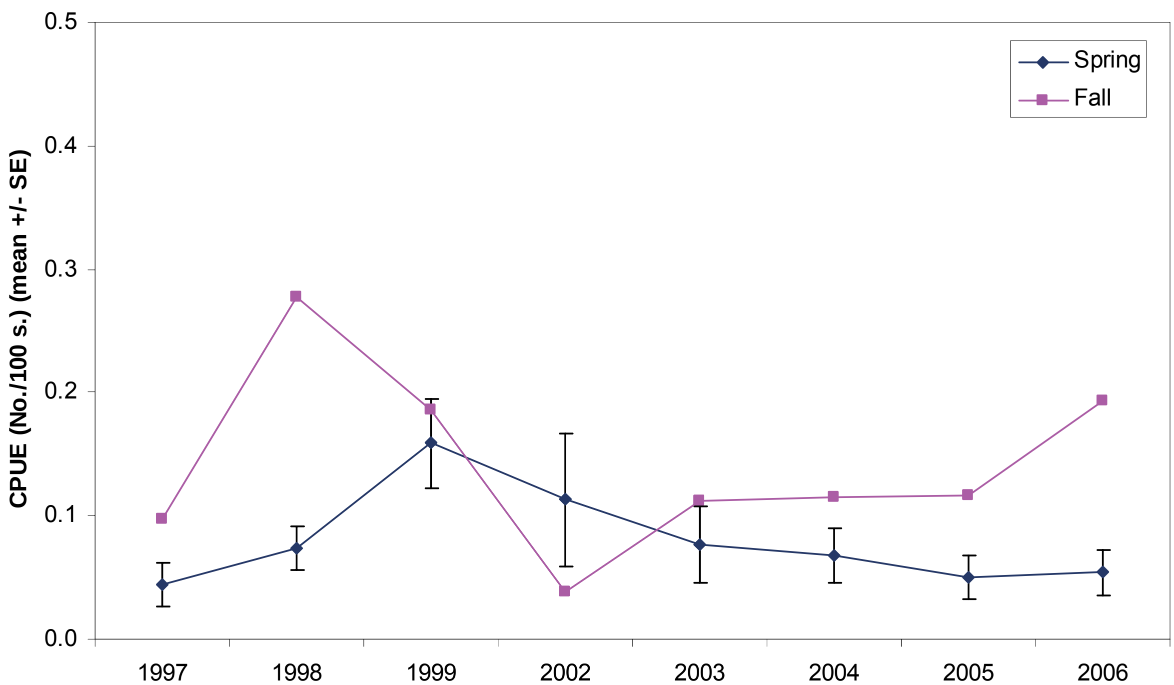


Figure 5.1-22 Relative length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997 to 2006.

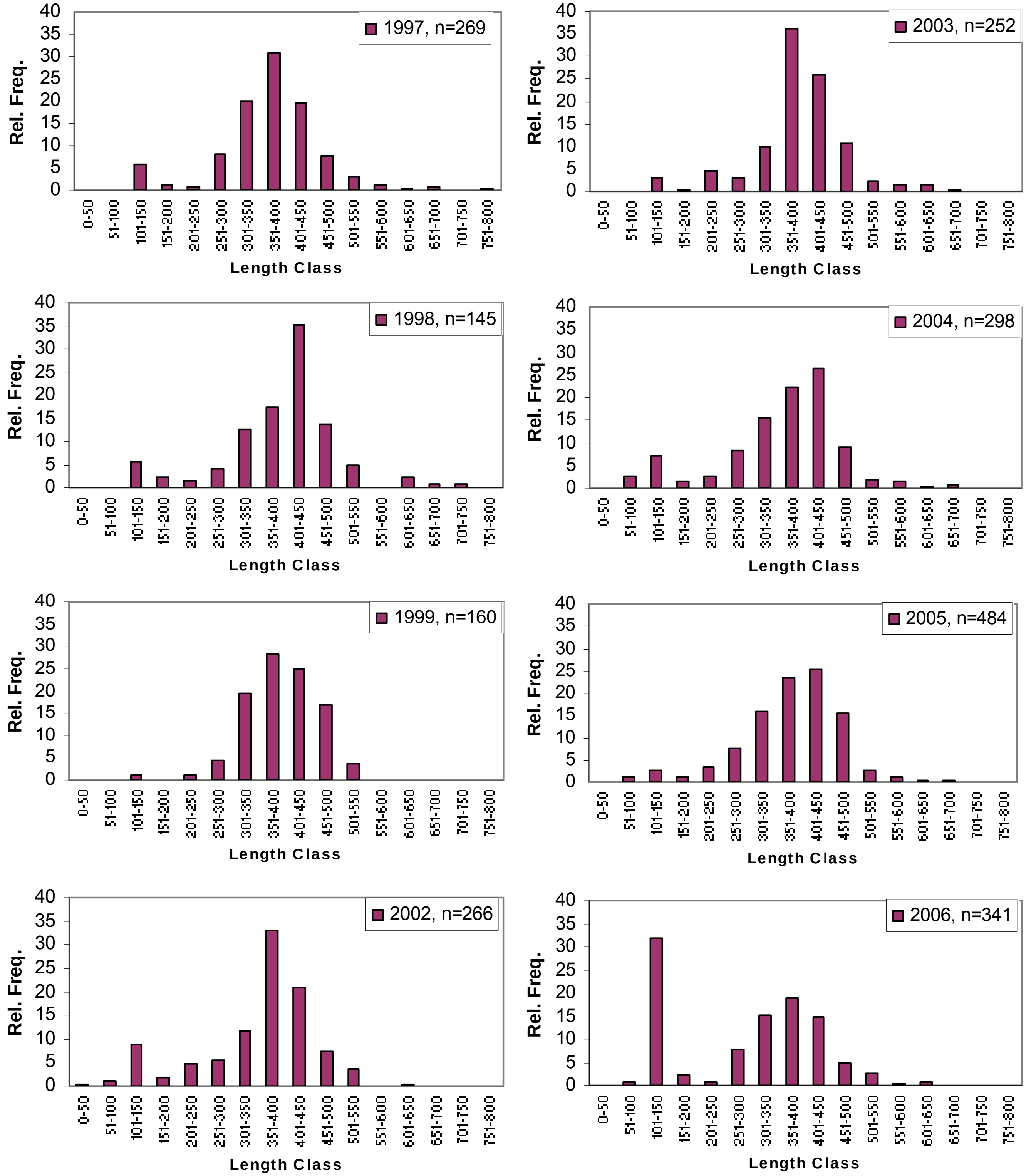


Figure 5.1-23 Relative length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997 to 2006.

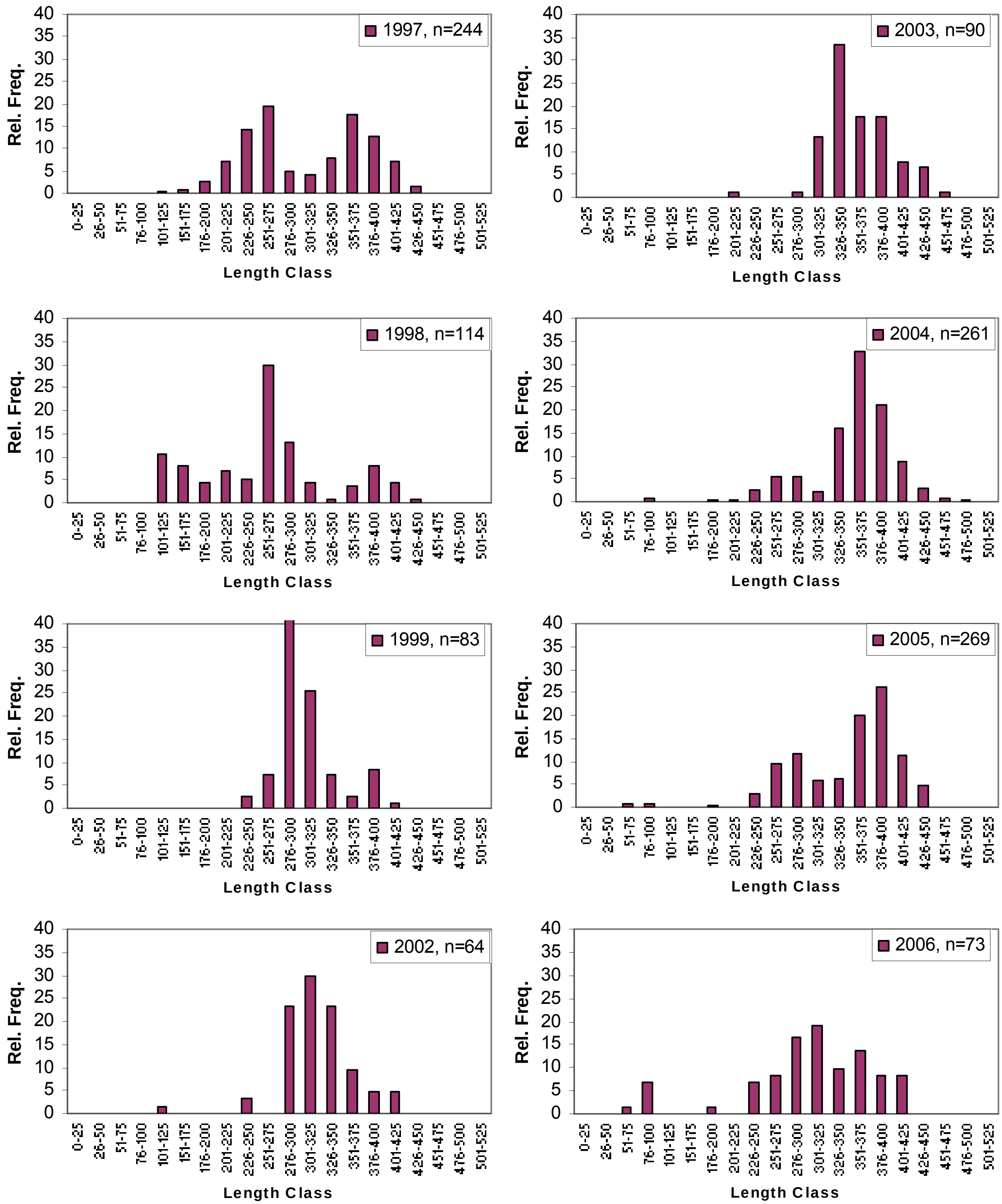


Figure 5.1-24 Relative length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall, 1997 to 2006.

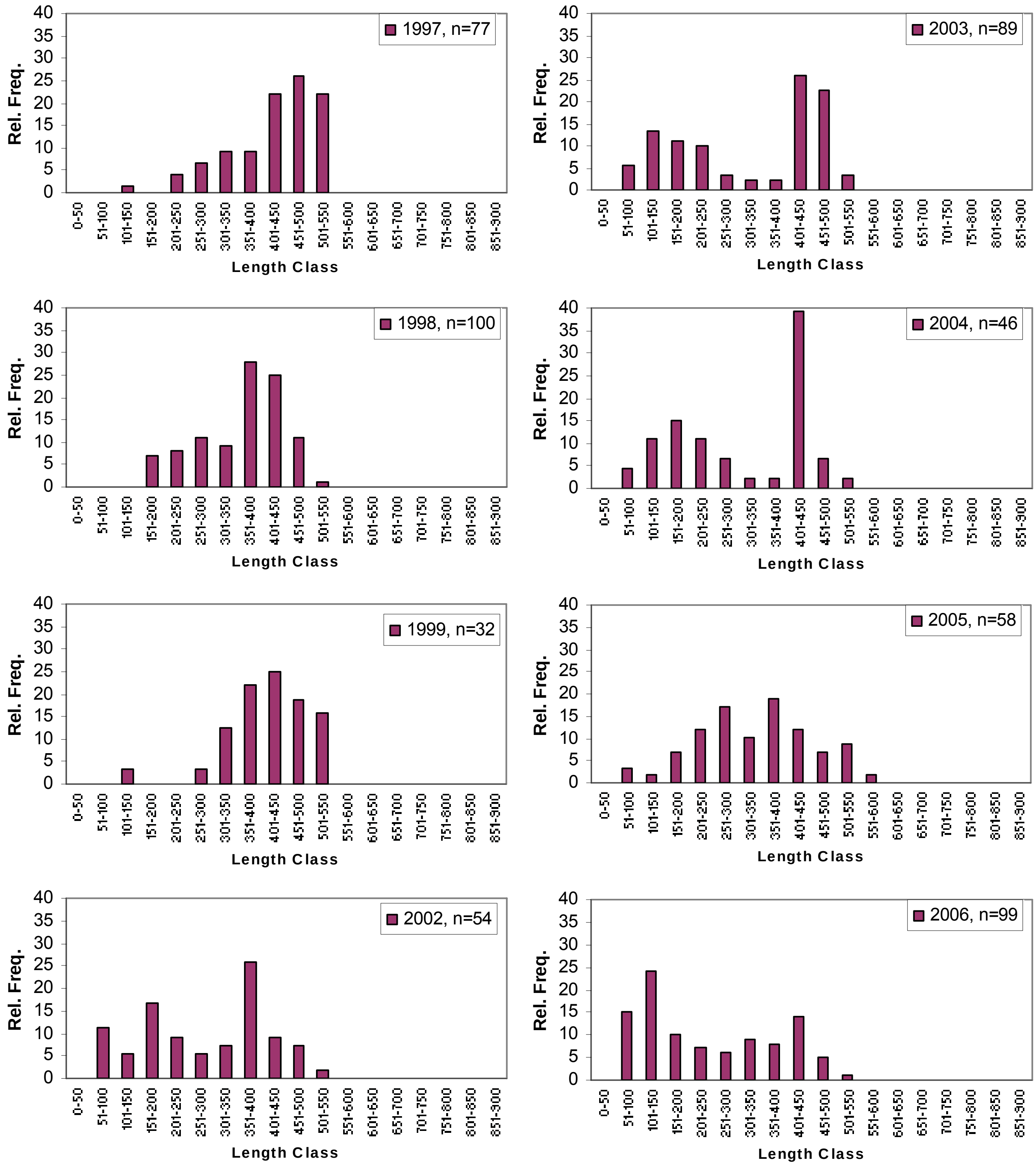


Figure 5.1-25 Relative length-frequency distributions for white sucker captured in the Athabasca River, spring and fall, 1997 to 2006.

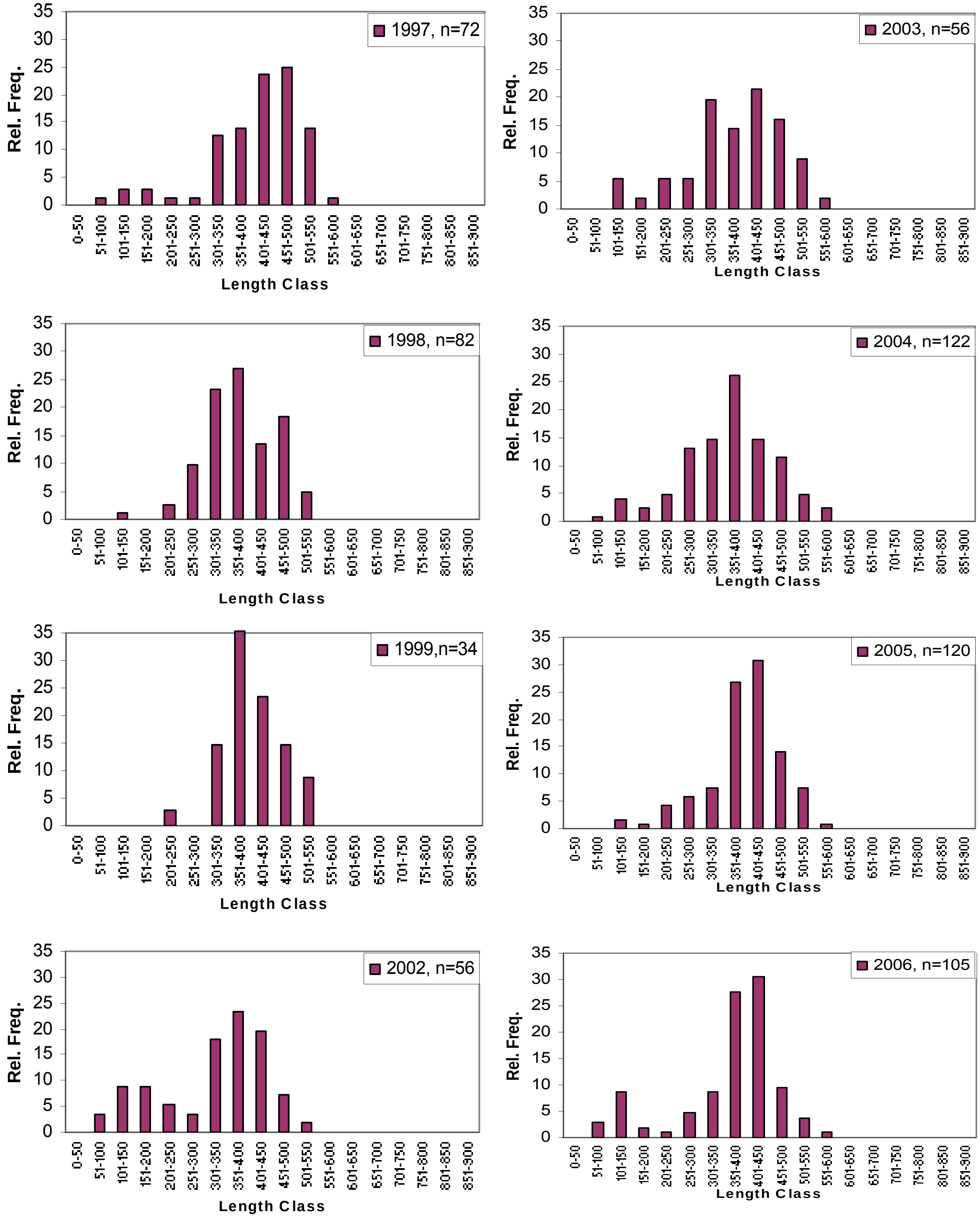


Figure 5.1-26 Relative length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997 to 2006.

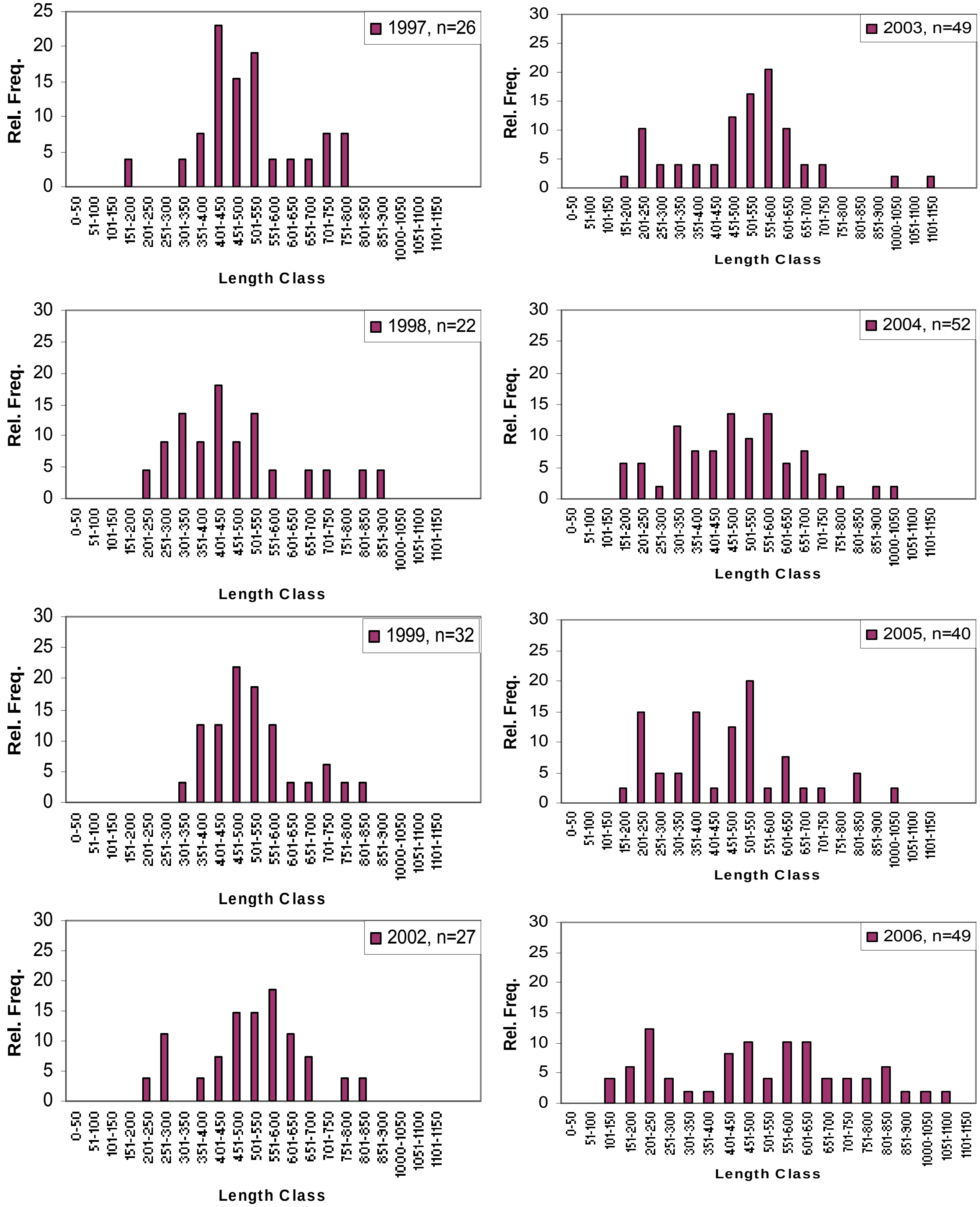


Figure 5.1-27 **Ratio of undersize to legal size walleye captured from the Athabasca River, spring 2006.**

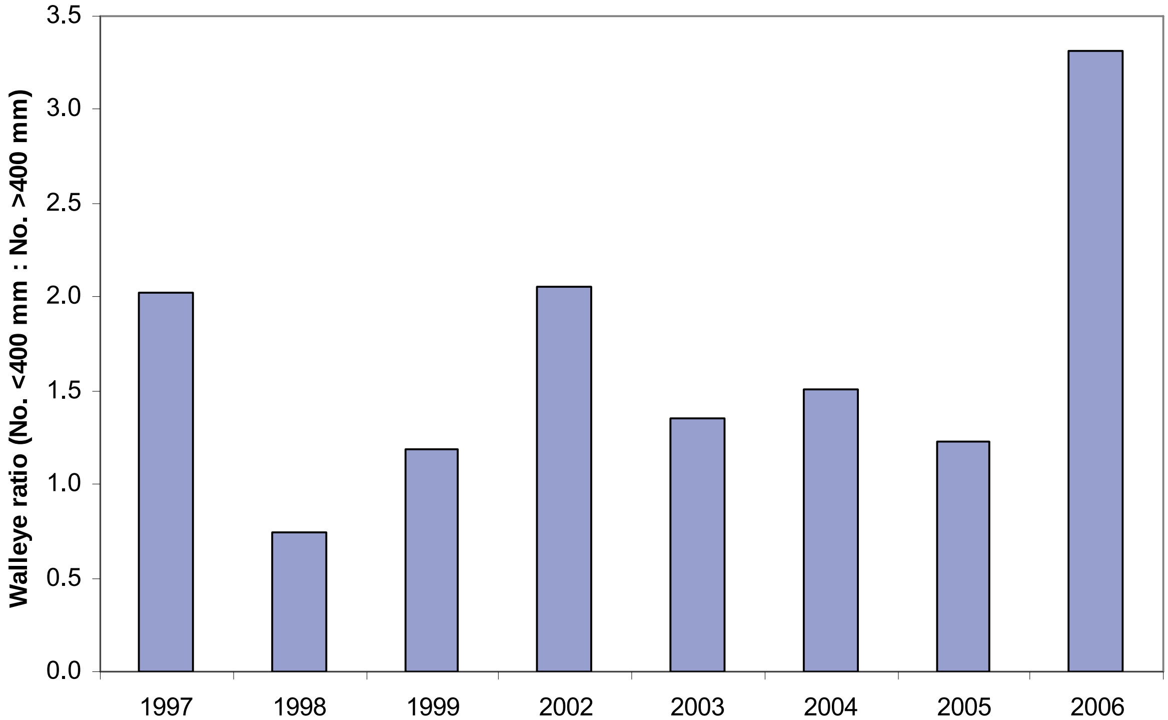


Figure 5.1-28 **Ratio of undersize to legal size northern pike captured from the Athabasca River, spring 2006.**

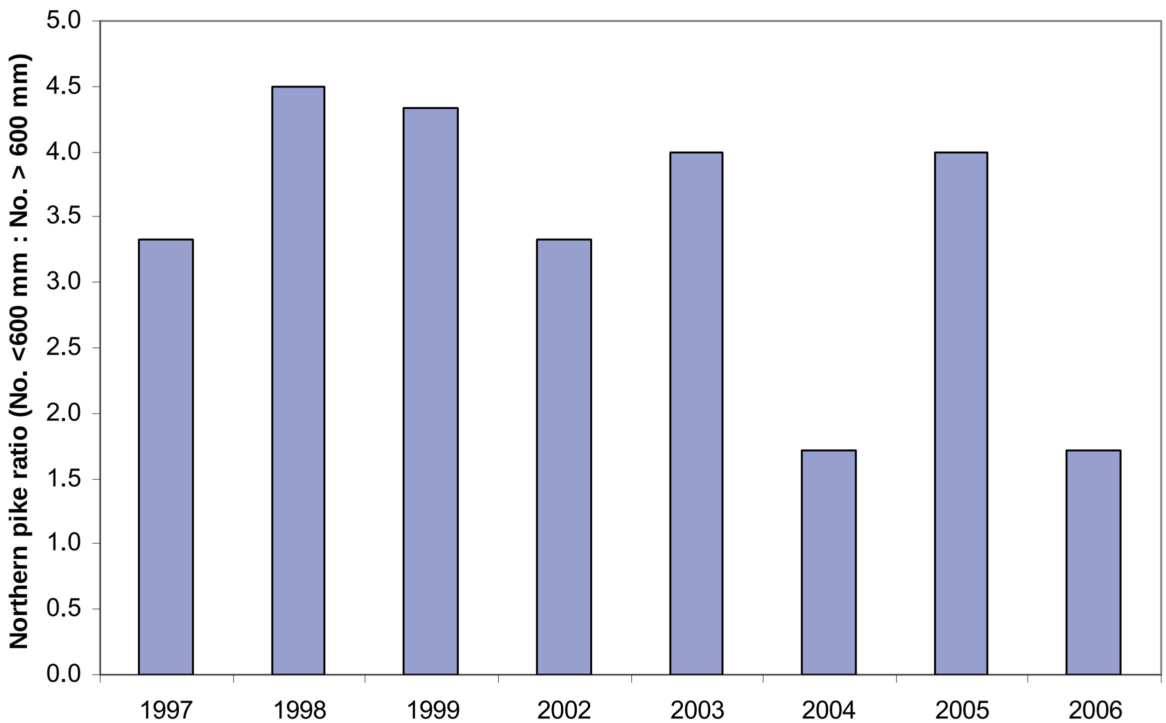


Table 5.1-9 Results of multi-year (1997-2006) comparisons of weight-length relationship (condition) for four key indicator fish species, Athabasca River.

Species		1997	1998	1999	2002	2003	2004	2005	2006
Walleye	n =	66	67	72	84	52	90	171	67
(≥ 400 mm)	Mean	0.952	0.983	0.996	0.987	0.931	0.986	1.033	0.987
	SE	0.013	0.014	0.010	0.016	0.020	0.016	0.015	0.008
Goldeye	n =	59	9	10	27	37	47	47	13
(≥ 300 mm)	Mean	1.099	1.171	1.164	1.07	1.146	1.165	1.094	1.089
	SE	0.023	0.021	0.034	0.011	0.057	0.019	0.018	0.062
Longnose sucker	n =	53	9	25	12	23	17	16	15
(≥ 350 mm)	Mean	1.276	1.154	1.290	1.279	1.203	13.09	1.375	1.224
	SE	0.023	0.028	0.024	0.038	0.024	0.025	0.115	0.016
White sucker	n =	45	25	19	26	18	41	65	42
(≥ 350 mm)	Mean	1.587	1.447	1.576	1.477	1.543	1.609	1.546	1.538
	SE	0.032	0.041	0.058	0.029	0.027	0.021	0.022	0.025
Northern pike	n =	9	5	20	16	12	13	6	6
(≥ 400 mm)	Mean	0.678	0.646	0.696	0.660	0.651	0.793	0.713	0.688
	SE	0.028	0.031	0.019	0.023	0.079	0.061	0.037	0.035

Figure 5.1-29 Mean condition factor for key indicator fish species in the Athabasca River, 1997-2006.

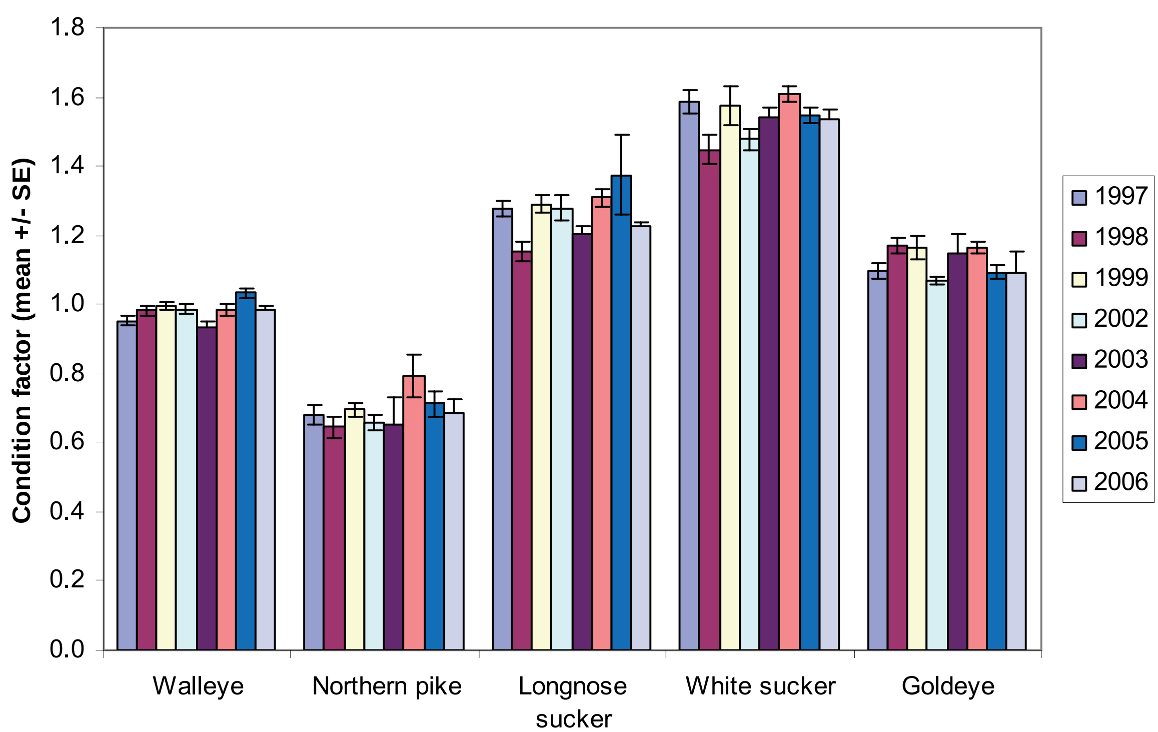


Table 5.1-10 Summary of external pathology indices, Athabasca River, 1995-2006.

Species	Mean Pathology Index								
	1995	1997	1998	1999	2002	2003	2004	2005	2006
Walleye	2.8	1.5	2.1	18.3	1.4	1.1	0.3	1.5	1.2
Goldeye	9.6	4.3	0.5	3.7	0.4	1.9	0.4	0.7	0.8
Longnose sucker	11	5.8	3.5	4.1	0.9	0.5	1.4	1.1	0.7
White sucker	18.6	3.2	9.6	5.7	0.6	7.1	0.4	2.5	1.6

Table 5.1-11 Fish species presence-absence summary for reaches 19A and 19B resulting from the Athabasca River Inventory, 2003 to 2006.

Species	Reach 19A					Reach 19B					
	Spring		Fall		Total	Spring			Fall		Total
	2005	2006	2005	2006		2003	2005	2006	2005	2006	
Brook stickleback									√		√
Burbot							√	√			√
Emerald shiner	√	√			√	√		√	√	√	√
Flathead chub	√	√		√	√	√	√	√	√	√	√
Fathead minnow								√			√
Goldeye	√	√	√	√	√	√	√	√		√	√
Lake chub	√	√	√	√	√					√	√
Lake whitefish			√	√	√	√			√	√	√
Longnose sucker	√	√	√	√	√	√	√	√	√	√	√
Mountain whitefish						√				√	√
Northern pike	√	√	√	√	√	√	√	√		√	√
Spottail shiner										√	√
Trout-perch	√	√	√	√	√	√		√	√	√	√
Walleye	√	√	√	√	√	√	√	√	√	√	√
White sucker	√	√		√	√	√	√	√	√	√	√
Yellow perch			√	√	√					√	√
Total	**9**	**9**	**8**	**10**	**11**	**10**	**7**	**10**	**8**	**13**	**16**

Table 5.1-12 Seasonal total CPUE for reaches 19A and 19B.

Year	Spring		Fall	
	Reach 19A	Reach 19B	Reach 19A	Reach 19B
2003	NS	2.34	NS	NS
2005	2.93	3.87	1.70	4.29
2006	3.49	2.95	2.58	9.93

NS – Indicates reach was not sampled.

Figure 5.1-23 Fish tag recovery locations, 2006.

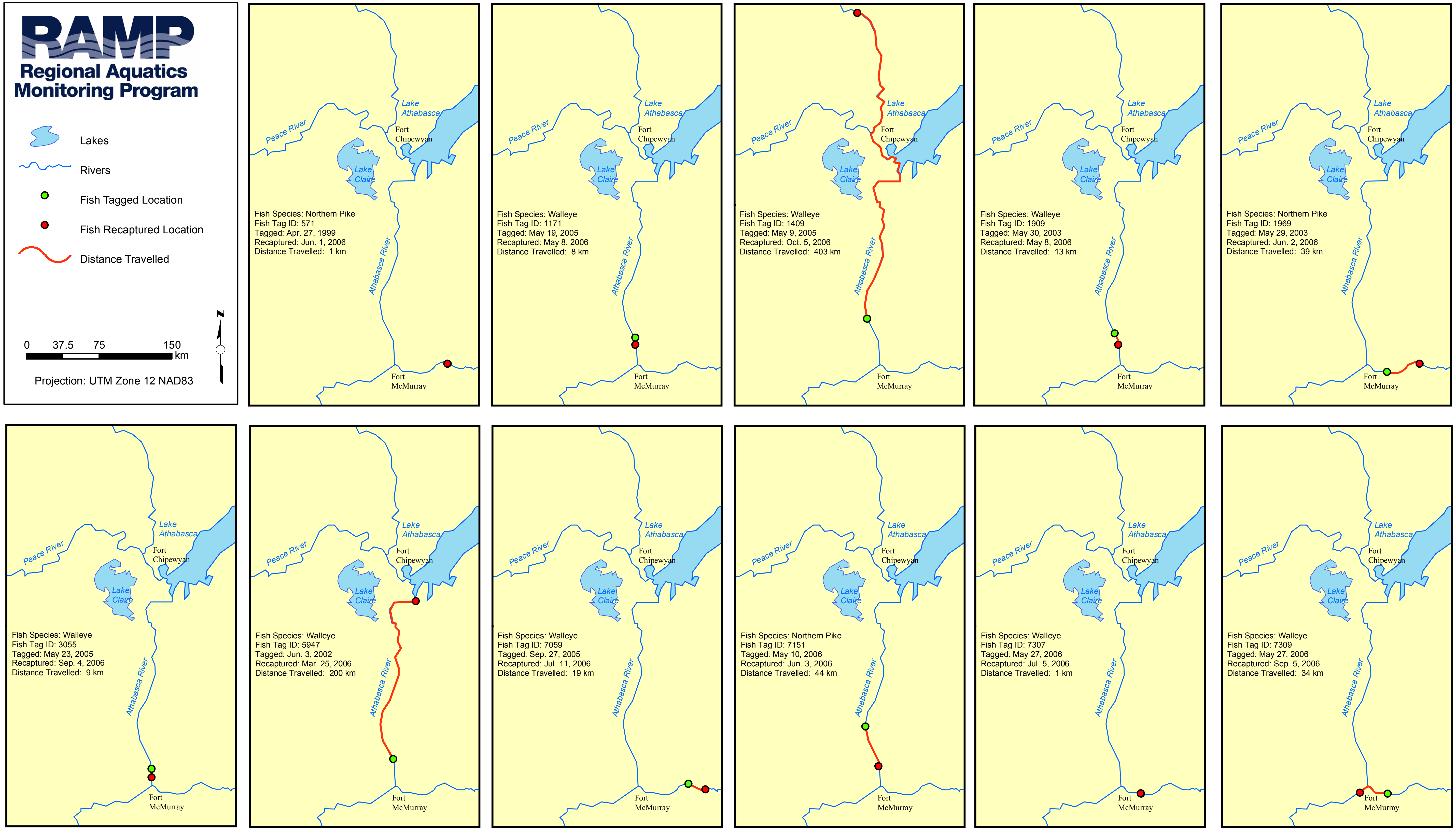


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Table 5.1-13 Results of RAMP fish tag return analysis, 2006.

Parameter	Fish Species	
	Walleye	Northern Pike
No. of Fish Recaptured	3	8
Min. Distance Traveled (km)	1	1
Max. Distance Traveled (km)	44	403

Table 5.1-14 Results of RAMP fish tag return analysis, 1999 to 2006.

Parameter	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Recaptured	1	2	11	55	3
Min. Distance Traveled (km)	271	5.3	0	1	1
Max. Distance Traveled (km)	271	236	57	715	241

5.2 ATHABASCA RIVER DELTA

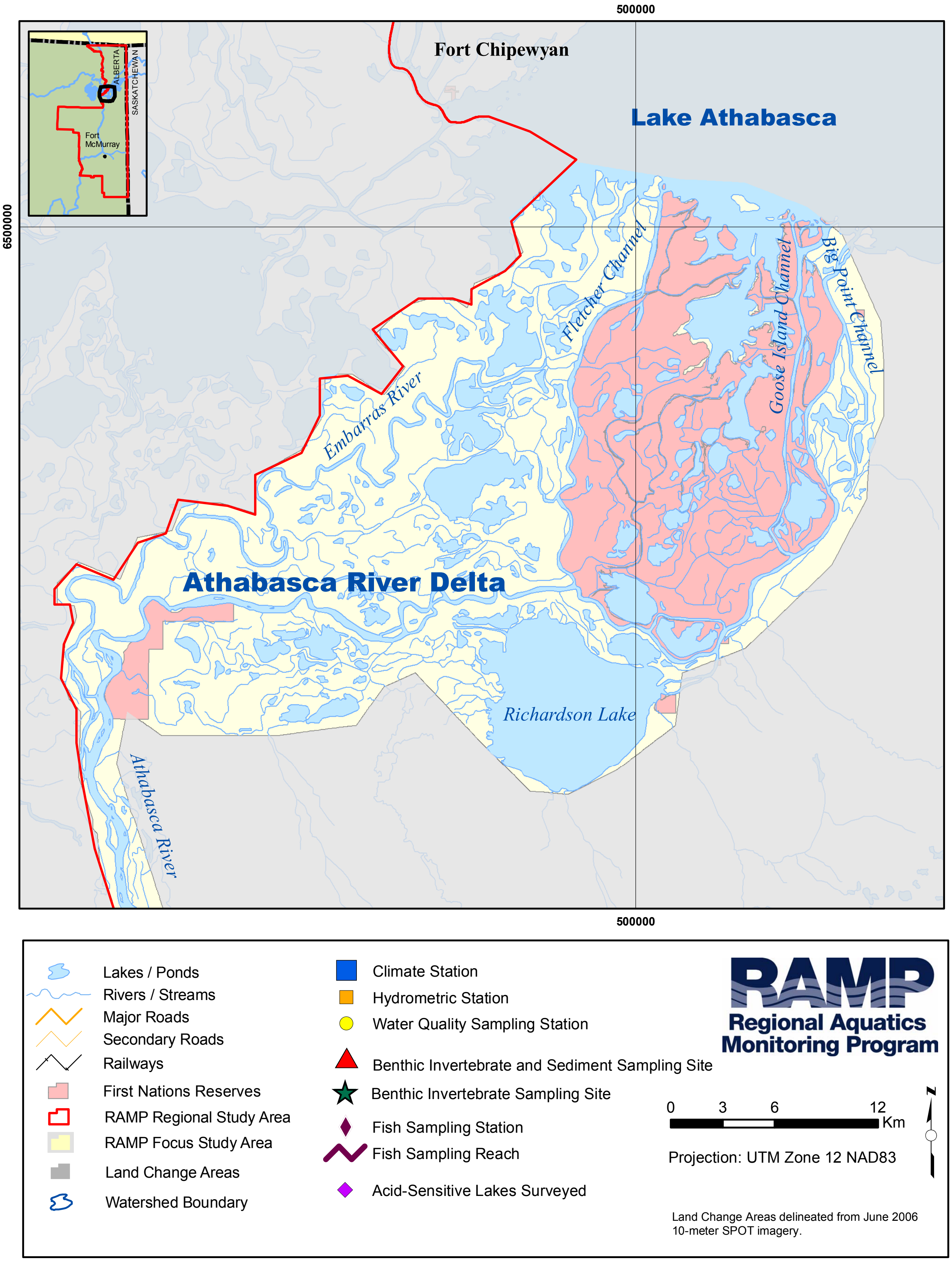
Summary of Results

Measurement Endpoint	Summary of 2006 Conditions						
Climate and Hydrology							
	Assessment of Change						
	Negligible	**Low**	**Moderate**	**High**			The general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those at RAMP Station S24, as discussed in Section 5.1.2.
Mean open-water season discharge	Because of the absence of hydrometric stations in the ARD, this was no estimate made of the hydroligic changes in relation to focal developments.						
Mean winter discharge							
Annual maximum daily discharge							
Minimum open-water season discharge							
Water Quality							
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**[1]						
Measurement endpoints with guidelines	**2006 *Potentially Influenced* (n=0)**			**2006 Reference Stations (n=0)**			
Physical variables	The 2006 RAMP Water Quality component did not include any activities in the ARD.						
Nutrients							
Ions							
Selected metals							
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**[2]						
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* Stations (n=0 stations X 13 endpoints)**			**2006 *Reference* Stations (n=0 stations X 13 endpoints)**			
Greater than 95th percentile	The 2006 RAMP Water Quality component did not include any activities in the ARD.						
Between 5th and 95th percentiles							
Less than 5th percentile							
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**						
Values in Relation to Regional Baseline Mean	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=0)**			
	>2 SD below	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling was conducted in the ARD in 2006 due to low water levels that prevented access to the sampling sites.						
Richness							
Diversity							
Evenness							
% EPT							
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**						
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=0)**			
Total Hydrocarbons (max=44)	No sediment quality sampling was conducted in the ARD in 2006 due to low water levels that prevented access to the sampling sites.						
PAHs (max=11)							
Fish Populations							
Fish Inventory	No fish inventory studies conducted in 2006 in the ARD.						
Sentinel Studies	No sentinel fish studies conducted in 2006 in the ARD.						
Fish Tissue	**Level of Risk**						
Human Health: Subsistence	Fish tissue program was not conducted in 2006 in the ARD.						
Human Health: Recreational Fishers							
Human Health: General Consumers							
Human Health: Tainting							

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.2-1 Athabasca River Delta.



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5.2.1 Development Status

The Athabasca River Delta (ARD) is designated as a *potentially influenced* portion of the RAMP FSA because it is downstream of all focal projects within the RAMP FSA (Figure 5.2-1).

5.2.2 Hydrologic Conditions

Athabasca River discharges are not monitored downstream of RAMP station S24. However, the incremental catchment area between RAMP station S24 and the ARD is relatively small, so that the general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those at RAMP station S24, as discussed in Section 5.1.2.

5.2.3 Water Quality

No water quality sampling was conducted in the ARD in 2006.

5.2.4 Benthic Invertebrate Communities and Sediment Quality

Benthic invertebrate community monitoring for 2006 included plans for sampling the ARD, as in previous years. However, benthic invertebrate community sampling was not conducted in the ARD in 2006 due to very low water levels during the fall sampling period that prevented access to the sampling sites.

5.2.5 Fish Populations

The 2006 RAMP fish population component did not include any activities in the ARD.

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5.3 MUSKEG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge	√				Total runoff in 2006 was about 50% of long-term average. Focal projects are predicted to have increased mean open-water season, mean winter, and open-season minimum daily discharge by 1.1%, 33%, and 25%, respectively, and decreased annual maximum daily discharge by 1.4%.
Mean winter discharge				√	
Annual maximum daily discharge	√				
Minimum open-water season discharge				√	

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006[1]**		
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Stations (n=4)**	**2006 *Reference Stations* (n=3)**	Influences of focal development and other oil sands activities in 2006 had no discernible effect on water quality in the Muskeg River mainstem, based on the analyses described in this section with the possible exception of the greater frequency of measurement endpoints being below 5th or above 95th percentile of regional baselines in potentially influenced stations than at reference stations. Elevated levels of dissolved solids and various ions in Stanley Creek were likely due to the operation of the Aurora North Clean Water Discharge.
Physical variables (max = 4 for exp, 3 for ref)	0	0	
Nutrients (max = 12 for exp, 9 for ref)	2	1	
Ions (max = 8 for exp, 6 for ref)	0	0	
Selected metals (max=20 for exp, 15 for ref)	0	1	
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* Stations (n=4 stations X 13 endpoints)**	**2006 *Reference* Stations (n=3 stations X 13 endpoints)**	
Greater than 95th percentile	6	1	
Between 5th and 95th percentiles	44	38	
Less than 5th percentile	2	0	

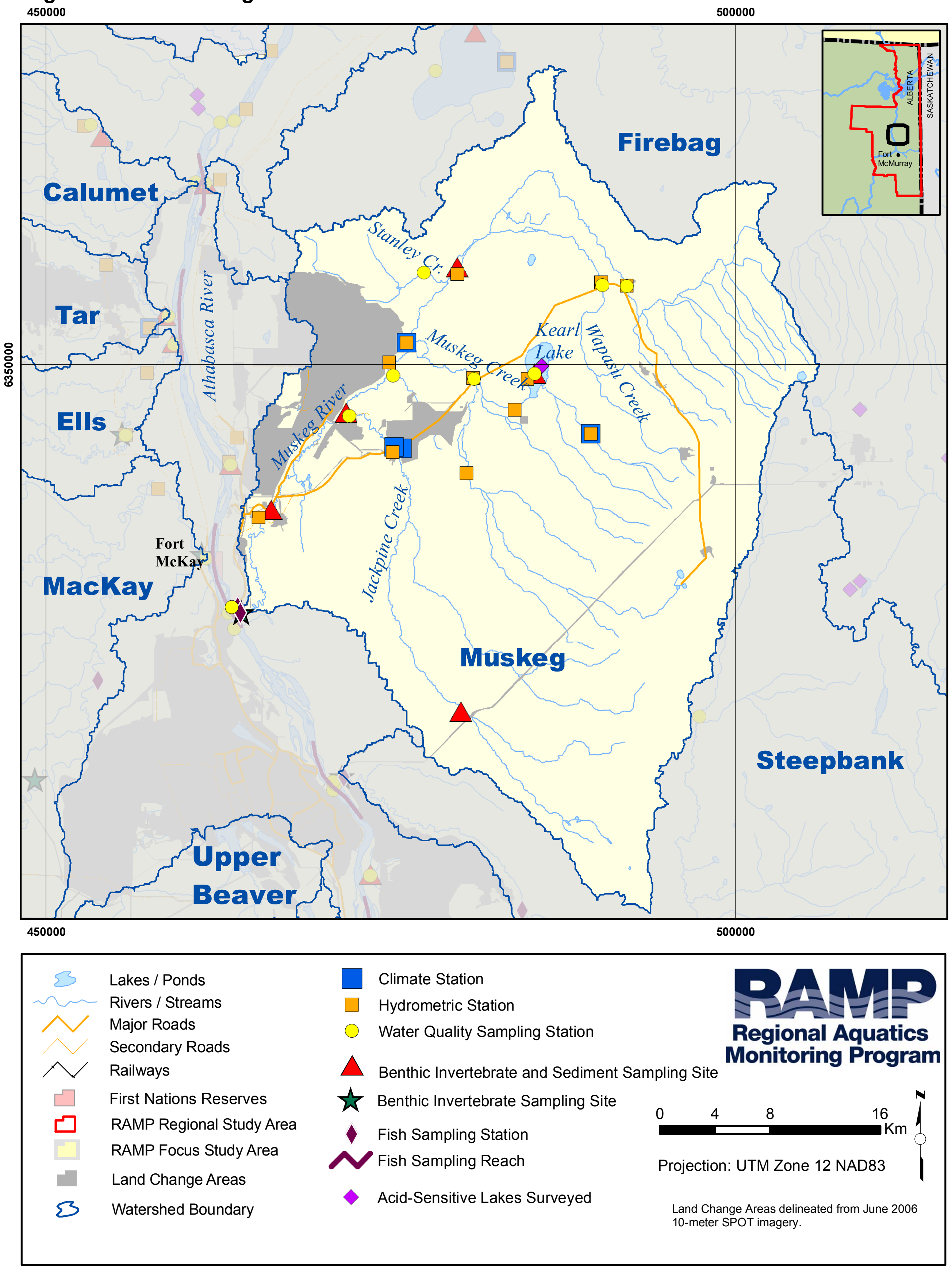
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**						
	2006 *Potentially Influenced* Stations (n= 2)			**2006 *Reference* Stations (n= 3)**			There is little evidence of effects of focal projects on benthic invertebrate communities in 2006. There were some differences in benthic measurement endpoints between potentially-influenced and reference reaches. However, all benthic invertebrate community measurement endpoints in 2006 at all sampled reaches were within the normal range of values of regional baseline reaches. There was little correlation between differences in sediment quality measurement endpoints and changes in benthic invertebrate community measurement endpoints
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance		2			3		
Richness		2			3		
Diversity		2			3		
Evenness		2			3		
% EPT		2			3		
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006[1]**						
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Stations (n= 1)**			**2006 *Reference* Stations (n= 3)**			
Total Hydrocarbons(max=3 for exp,9 for ref)	1			0			
PAHs (max=1 for exp, 3 for ref)	0			0			

0		
Fish Inventory	No fish inventory studies conducted in 2006.	2006 fish fence results are largely consistent with results of the 2003 fish fence: Muskeg River in the spring continues to be utilized by a number of fish species, dominated by longnose sucker, white sucker, and northern pike; migration timing for all three dominant species was similar in 2006 to 2003; and a number of sex-specific differences in size and condition indicated in 2006 were also indicated for 2003.
Sentinel Studies	Sentinel fish studies conducted in 2006 and presented in Section 5.4.5	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue program was not conducted in 2006.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.3-1 Muskeg River watershed.



K:\Data\Project\RAMP1245\GIS_MXD\Report\RAMP1245_M_Muskeg_2007MAR20.mxd

5.3.1 Development Status

As of 2006, approximately 7% of the Muskeg River watershed had undergone land change as a result of focal project activities (Table 2.6-2). The designations of specific areas of the Muskeg River watershed are therefore as follows:

- The Muskeg River downstream of its confluence with Shelley Creek, as well as the lower part of the Stanley Creek, Jackpine Creek and Shelley Creek drainages and all lands within the Muskeg River and Aurora North mine leases (Figure 5.3-1) are designated as *potentially influenced*. All data gathered from 2006 RAMP stations located in this area of the watershed are designated as operational data; and

- The remainder of the watershed (Figure 5.3-1) is designated as *reference*, and all data gathered from the 2006 RAMP stations located in these parts of the watershed are designated as baseline data.

5.3.2 Hydrologic Conditions

2006 Hydrologic Conditions Total runoff in the Muskeg River basin in 2006, as measured at RAMP Station S7, Muskeg River near Fort McKay (07DA008), was well below normal at approximately 50% of the long-term average (Figure 5.3-2). Discharges were close to normal in spring but fell below normal early in June and were close to lower quartile values during the early summer. Several rainfall events early in July raised the streamflow to the upper-quartile range, but by mid-August the flow subsided to median values and early in September returned to the lower quartile level (Figure 5.3-2). The annual maximum daily discharge of 10.3 m^3/s was less than half of the mean annual flood of 24.8 m^3/s, and the minimum open-water season discharge of 0.66 m^3/s was about 40% lower than the historical average minimum flow.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the Muskeg River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is as follows (details are provided in Table 5.3-1):

- Discharges to the Muskeg River by focal projects in 2006 are estimated at 2.53 million m^3. This discharge was via Syncrude's Aurora Clean Water Diversion (CWD). It was assumed for this analysis that none of the water released from the CWD would have reached the Muskeg River naturally. In fact, given that some of the CWD flows are diverted surface waters, some proportion of the CWD flow likely would have contributed to the Muskeg River naturally. The assumption that none of the water released from the CWD would have reached the Muskeg River naturally is therefore a worst-case assumption; and

- As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 74.1 km^2 and 25.5 km^2, respectively, in the Muskeg River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6.-1), the estimated effects of which were to reduce inflows to the Muskeg River by 2.598 million m^3.

The baseline hydrograph that would have occurred at the Muskeg River near Fort McKay hydrometric station (WSC station 07DA008, RAMP station S7) in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have decreased mean open-water season discharge by 1.1%, increased mean winter discharge by 11%, decreased annual maximum daily discharge by 2.1%, and increased open-season minimum daily discharge by 9.7% (Table 5.3-2, Figure 5.3-2). These estimated changes in hydrologic measurement endpoints for 2006 would have been assessed as Negligible to High in oil sands EIAs (RAMP 2005b), depending on the specific measurement endpoint and EIA. For the purposes of this assessment, effects on mean open water season discharge and annual maximum daily discharge are assessed as low and effects on mean winter discharge and open-season minimum daily discharge are assessed as high. Water discharge via the CWD and runoff that was estimated to have been captured from land change areas that are closed-circuited were the two most significant contributors to the differences between the baseline and operational hydrographs at WSC station 07DA008/RAMP station S7 in 2006 (Table 5.3-1). The increased runoff from land change areas that were not closed-circuited was a minor contributor in 2006 to differences between the operational and calculated baseline hydrographs (Figure 5.3-2).

Summary Based on the available hydrologic and information regarding focal project activities in the Muskeg River watershed, changes in hydrologic conditions in the Muskeg River up to and including 2006 have ranged from low to high.

5.3.3 Water Quality

In fall 2006, water quality samples were collected from the following stations:

- Mouth of the Muskeg River (station MUR-1, *potentially influenced*, operational data available from 1997 to 2006);
- Mouth of Jackpine Creek (station JAC-1, *reference* prior to 2006, baseline data available from 1998 to 2006, designated as *potentially influenced* beginning in 2006, operational data in 2006);
- Stanley Creek (station STC-1, *potentially influenced*, operational data, first sampled in 1998 and sampled every year since 2001);
- Shelley Creek near the mouth (SHC-1 sampled in 1998 and 1999 as a *reference* station, designated as *potentially influenced* in 2006, operational data in 2006);
- Muskeg River upstream of Wapasu Creek (station MUR-6, *reference*; baseline data available from 1998 to 2006);
- Muskeg Creek at Canterra Road (station MUC-1, *reference*, baseline data available from 1998 to 2006); and
- Wapasu Creek (station WAC-1, *reference*, baseline data available intermittently from 1998 to 2006).

Winter water quality has been measured at Muskeg River upstream of Wapasu Creek (MUR-6) in 1998, Stanley Creek (station STC-1) in 2002, and Wapasu Creek (station WAC-1) in 1998 and 1999; the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration At stations designated as *potentially influenced* in fall 2006 there were 9 (14%) of a possible 66[1] cases of water quality

[1] There are 22 water quality measurement endpoints (Section 3.2.6.1) and water quality was sampled at four stations designated as *potentially influenced* in 2006, but Shelley Creek near the mouth (station SHC-1) had only been sampled once previous to 2006 and so minimum and maximum values could not be established for that station. Therefore, there are a total of 66 water quality measurement endpoint cases to be considered in this analysis from stations designated as *potentially influenced*.

measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values. This statistic is similar to stations designated as *reference* in fall 2006, at which there were 11 (17%) of a possible 66[2] cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values. Station-specific details are provided below.

Fall 2006 water quality was similar to historical water quality at the mouth of the Muskeg River (station MUR-1). Fall 2006 concentrations of all water quality measurement endpoints, with the exception of sulphate, dissolved aluminum, and total molybdenum, were within historically observed ranges; concentrations of these water quality measurement endpoints were below previously-measured minimum concentrations (Table 5.3-3).

Concentrations of water quality measurement endpoints at the mouth of Jackpine Creek (station JAC-1) in fall 2006 were consistent with historical results; pH was slightly higher in fall 2006 than previously-measured maximum concentrations, while total and dissolved aluminum were slightly lower than previously-measured minimum concentrations (Table 5.3-4).

In 2006, muskeg dewatering water and clean surficial water were discharged to Stanley Creek via the Aurora North Clean Water Diversion (CWD). CWD operation in May 2003 was thought to have contributed to elevated levels of total dissolved solids and various ions at station STC-1 in that year (RAMP 2006); elevated concentrations of ions and various dissolved constituents in 2005 at station STC-1 were also attributed to the operation of the CWD that year. With the exception of total aluminum and dissolved aluminum, all water quality measurement endpoints were within historically established ranges of concentration at station STC-1 in fall 2006 (Table 5.3-5).

Comparison of 2006 water quality results at Shelly Creek (station SHC-1) with historical results is limited due to the lack of data. However, concentrations of ions, nutrients, and measures of ionic abundance (e.g., conductivity, total dissolved solids) were, in general, lower than in 1999 (Table 5.3-6).

Water quality in fall 2006 was also similar to historical fall water quality at Muskeg River upstream of Wapasu Creek (station MUR-6); concentrations of all water quality measurement endpoints in fall 2006 were within the range of historically-measured concentrations with the exception of pH which was slightly higher than the previously recorded maximum concentration, and total aluminum and total molybdenum with fall 2006 concentrations lower than the previously-measured minimum concentration (Table 5.3-7).

Water quality in fall 2006 was similar to historical water quality at Muskeg Creek (station MUC-1). Fall 2006 concentrations of total dissolved phosphorus and total aluminum concentrations were higher than previously-measured maximum concentrations, while the fall 2006 concentration of dissolved aluminum was slightly lower than previously measured minimum concentrations (Table 5.3-8).

While most concentrations of water quality measurement endpoints were within the range of previously measured concentrations at Wapasu Creek (station WAC-1), concentrations of the following water quality measurement endpoints were either above

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[2] Water quality was sampled at three stations designated as *reference* in fall 2006.

previously-recorded minimum or below previously-recorded minimum concentrations in fall 2006: total dissolved phosphorus (above); sodium (above); chloride (above); total aluminum (below); and dissolved aluminum (Table 5.3-9).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were no exceedances of water quality guidelines for any of the water quality measurement endpoints at mouth of the Muskeg River (station MUR-1, (Table 5.3-3), mouth of Jackpine Creek (station JAC-1, Table 5.3-4), Stanley Creek (station STC-1, Table 5.3-5), Muskeg River upstream of Wapasu Creek (station MUR-6, Table 5.3-7), or Wapasu Creek (station WAC-1, Table 5.3-9) in fall 2006. Overall, there were 4 (6%) out of 70[3] possible exceedances in water quality guidelines for the water quality measurement endpoints at all the Muskeg River stations in fall 2006 (Table 5.3-3 to Table 5.3-9). Two of these guidelines exceedances, total phosphorus and total nitrogen, were measured at Shelley Creek near the mouth (station SHC-1, designated as *potentially influenced* in 2006), while two of these guidelines exceedances, total nitrogen and total aluminum, were measured at Muskeg Creek at Canterra Road (MUC-1, designated as *reference* in 2006).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the Muskeg River watershed in fall 2006 (Table 5.3-10):

- Sulphide, total iron, and total phenols at the mouth of the Muskeg River (station MUR-1);
- Sulphide, dissolved and total iron, and total phenols at the mouth of Jackpine Creek (station JAC-1);
- Sulphide, total phenols, and dissolved oxygen in Stanley Creek (station STC-1);
- Sulphide, total Kjeldahl nitrogen, dissolved and total iron, dissolved oxygen, and total phenols at Shelley Creek near the mouth (station SHC-1);
- Sulphide and total phenols in Muskeg River upstream of Wapasu Creek (station MUR-6);
- Sulphide, dissolved and total iron, and total phenols at Muskeg Creek at Canterra Road (station MUC-1); and
- Sulphide, total iron, and total phenols in Wapasu Creek (station WAC-1).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At stations designated as *potentially influenced* in fall 2006, the concentrations of 8 (15%) out of a possible 52[4] water quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations (Figure 5.3-3, Figure 5.3-4). This is higher than at stations designated as *reference* in fall 2006, at which the concentration of 1 (3%) out of a possible 39[5] water

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[3] Ten of the selected water quality measurement endpoints have water quality guidelines and water quality was sampled at a total of seven locations in the Muskeg River watershed in fall 2006, making for a total of 70 possible guideline exceedances.

[4] Thirteen selected water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4) were sampled at four stations designated as *potentially influenced* in the Muskeg River watershed in fall 2006, making for a total of 52 water quality measurement endpoint- station combinations.

[5] Three water quality stations were designated as *potentially influenced* in the Muskeg River watershed in fall 2006, making for a total of 39 water quality measurement endpoint-station combinations.

quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations (Figure 5.3-3, Figure 5.3-4). This difference in fall 2006 between *potentially influenced* and *reference* areas is similar to differences measured in fall 2003 (RAMP 2004) and fall 2004 (RAMP 2005a). Station-specific details are provided below:

- Concentrations of most of the selected water quality measurement endpoints were at or between the 5th and 95th percentile of regional baseline concentrations (Figure 5.3-3, Figure 5.3-4) for both mouth of the Muskeg River (station MUR-1) and Muskeg River upstream of Wapasu Creek (station MUR-6); the exceptions were total magnesium at station MUR-6 (higher than the 95th percentile) and sulphate at station MUR-1 (lower than the 5th percentile) (Figure 5.3-3, Figure 5.3-4);

- At the mouth of Jackpine Creek (station JAC-1), concentrations of all selected water quality measurement endpoints were at or within the range of regional baseline concentrations with the exception of sulphate whose concentration was below the 5th percentile of regional baseline concentrations (Figure 5.3-4);

- All water quality measurement endpoint concentrations were between the 5th and 95th percentile of regional baseline concentrations at Muskeg Creek at Canterra Road (station MUC-1) (Figure 5.3-4);

- At Shelley Creek mouth (station SHC-1), in contrast to fall 1999, concentrations of selected water quality measurement endpoints were generally between the 5th and 95th percentile of regional baseline concentrations in fall 2006. The exceptions were total dissolved solids, total strontium, and sodium, which were higher than the 95th percentile regional baseline concentration (Figure 5.3-4);

- While the concentrations of total dissolved solids, calcium, and sulphate were lower at Stanley Creek (station STC-1) in fall 2006 than in fall 2005, they were above the 95th percentile of regional baseline concentrations for these measurement endpoints in fall 2006 (Figure 5.3-4); and

- All selected water quality measurement endpoints were between the 5th and 95th percentile values in fall 2006 for Wapasu Creek (station WAC-1).

Ion Balance Ion balance throughout the Muskeg River watershed continued to remain relatively stable in fall 2006 and similar to ion balance of previous years (Figure 5.3-5). The exception to this in fall 2006 was Stanley Creek mouth (station STC-1) at which sulphate was a more dominant anion and bicarbonate a less dominant anion than at other stations in the Muskeg River watershed. This is likely due to the operation of the CWD in 2006; ion balance of water sampled at Stanley Creek mouth (station STC-1) has demonstrated more temporal variability throughout sampling under RAMP than water sampled at other stations in the Muskeg River watershed, likely because of the operation of the CWD (Figure 5.3-5).

Summary The results described above suggest that focal projects in the Muskeg River watershed had generally no discernible impact on water quality at the lower Muskeg River in 2006. There were few exceedances of water quality guidelines throughout the watershed and concentrations of most water quality measurement endpoints throughout the watershed were within historical regional baseline ranges. Ion balance in fall 2006 was generally consistent with ion balance in previous years. The influence of the CWD on water quality in Stanley Creek continues to be apparent in the greater variability in ionic balance at the mouth of Stanley Creek (STC-1) as compared to other stations. However, with respect to water quality guideline exceedance and relation to historical ranges, water quality at the mouth of Stanley Creek (station STC-1) was similar to other stations in the Muskeg River watershed in fall 2006. The only exception to these overall results is the larger proportion of selected water quality measurement endpoints measured at stations designated as *potentially influenced* that was either below the 5th or greater than the 95th percentile of their regional baseline concentrations than at stations designated as *reference*, similar to 2004 and 2005 conditions. This suggests that focal projects may be having some influence on the variability of water quality in the Muskeg River watershed.

5.3.4 Benthic Invertebrate Communities and Sediment Quality

5.3.4.1 Benthic Invertebrate Communities

In 2006, benthic invertebrate community samples were collected from the following locations in the Muskeg River watershed:

- An erosional lower reach near the Muskeg River mouth (reach MUR-E-1, *potentially influenced*, operational data available from 2000 to 2006);
- A depositional reach in the middle sections of the Muskeg River near the Canterra Road crossing (reach MUR-D-2, *potentially influenced*, operational data available from 2000 to 2006);
- A depositional upper reach in the Muskeg River watershed located upstream of the Muskeg River Mine and Aurora North oil sands developments (reach MUR-D-3, *reference*, baseline data available from 2002 to 2006);
- A depositional lower reach near the mouth of Jackpine Creek (reach JAC-D-1, *reference*, baseline data available from 2002 to 2006); and
- A depositional upper reach of Jackpine Creek (reach JAC-D-2, *reference*, baseline data available from 2003 to 2006).

Muskeg River Reaches

2006 Habitat Conditions The lower reach near the Muskeg River mouth (reach MUR-E-1) was shallow (0.2 m), had high current velocity (0.8 m/s) and generally low macrophyte cover at the time of sampling (Table 5.3-11). Benthic algal biomass (measured as chlorophyll *a*) was low (30 mg/m^2), similar to what had been observed in the reach since 2000, and indicated oligotrophic conditions (Figure 5.3-6). Substrate was comprised of a mixture of coarse materials including boulder, cobble and gravel (Table 5.3-11). By comparison, reach MUR-D-2 and reach MUR-D-3 had deeper water with slower current velocities, and higher macrophyte cover (Table 5.3-11). The sediments in the two upper reaches were dominated by sand, silt and clay.

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Table 5.3-12 contains the historical major percent taxon abundances and values of the benthic invertebrate community endpoints, respectively, for the reaches sampled in the Muskeg River. The lower reach near the Muskeg River mouth (reach MUR-E-1) was dominated in 2006 by chironomids, mayflies, caddisflies, and mites. Stoneflies were also prevalent, while a number of worms (tubificids, naidids), bivalves (Sphaeriidae fingernail clams), and beetles (Coleoptera) were present in lower abundances. Abundance averaged about 11,000 individuals/m^2 in 2006, and has historically varied between 5,000 and 70,000 individuals/m^2. The number of taxa (richness) has been close to 30 for the past seven years, while diversity has been very high (>0.8) for the past five years. Percent EPT was high (44%) in 2006, compared to historical ranges of this benthic invertebrate community measurement endpoint. Some of the more sensitive taxa found in reach MAR-E-1 in 2006 included the caddisfly *Brachycentrus*, and the stoneflies *Claasenia sabulosa, Isoperla* and *Skwala*. *C. sabulosa* was collected from the lower Muskeg River in the late 1970s by Barton (1980). That species has interesting potential as an indicator of habitat quality because it has at least a three-year life cycle with eggs hatching throughout the year (Barton, 1980). Other important taxa (numerically) were the mayfly *Baetis*, the caddisflies *Protoptila* and *Hydropsyche*, the beetle *Optioservus* and the chironomids *Rheotanytarsus* and *Tvetenia*.

The middle reach of the Muskeg River near the Canterra Road crossing (reach MUR-D-2) in 2006 was numerically dominated by chironomids and tubificid worms (Table 5.3-12). Other taxa present included amphipods (*Hyalella azteca*), biting midges (Ceratopogonidae), mayflies, gastropods, mites, stoneflies, and caddisflies. Of the chironomids, the generalists *Polypedilum* and *Micropsectra* were the most common. Total abundance in the middle reach was lower in 2006 (27,000 individuals/m^2) compared to previous years (up to 60,000 individuals/m^2 in previous years), but the number of taxa (average of 24), and diversity (mean of 0.69) in 2006 were similar to the long-term average for this reach (Figure 5.3-9). Percent EPT (1%) was typical for the reach. The stoneflies *Isoperla* and *Taeniopteryx* were the most sensitive taxa found in this reach in 2006.

The upper reach in the Muskeg River watershed (reach MUR-D-3) in 2006 was dominated by chironomids including *Polypedilum* and *Procladius* (Table 5.3-12). Other relatively dominant groups included Nematoda, worms (Naididae, Tubificidae), fingernail clams (Bivalvia) and mayflies (Ephemeroptera). Total abundances in the upper reach were lower in 2006 than in previous years (6,000 individuals/m^2), while the number of taxa (average of 15), diversity (0.89), and %EPT (3%) were all within historical ranges (Table 5.3-12).

Effects of Focal Project Activities An ANOVA was conducted to compare the benthic invertebrate community measurement endpoints for reaches MUR-E-1 and MUR-D-3. For reach MUR-E-1, the *time x reach* interaction in an analysis of variance (ANOVA) was the most relevant contrast for testing potential effects related to focal projects (other contrasts between these two reaches would only confirm that the benthic communities in these two reaches are different, which they should be naturally given their different benthic habitat types). The *time x reach* interaction was significant for every benthic invertebrate community measurement endpoint (Table 5.3-13), implying potential effects of focal project activities on benthic invertebrate communities in the lower Muskeg River, reach MUR-E-1, which is designated as *potentially influenced*. All of the benthic invertebrate community measurement endpoints in reach MUR-E-1, however, have been within the normal range of values expected for a reference condition, and there have been no trends over time at reach MUR-E-1 that would indicate a degrading condition (Figure 5.3-7). In addition, benthic invertebrate communities have been sampled regularly in the lower reach near the Muskeg River mouth (reach MUR-E-1) since 1998 and benthic invertebrate community composition over time has consistently reflected the expected community composition based on regional baseline data for erosional habitats (Figure 5.3-8. There are, therefore, no substantive indications of an impaired benthic community in the lower reach of the Muskeg River (reach MUR-E-1).

The most relevant ANOVA contrasts of the middle and upper reaches of the Muskeg River (reach MUR-D-2 and reach MUR-D-3) were the *time x reach* interaction, as well as those relating to differences between reaches (i.e., *reach* contrast). The *time x reach* interaction was significant for benthic invertebrate community abundance and richness (Table 5.3-14), indicating a potential effect of focal projects on benthic invertebrate communities in reach MUR-D-2. Variations in both benthic invertebrate community measurement endpoints between 2002 and 2006, however, have been within the range of values observed from regional reference reaches (Figure 5.3-9). Total numbers of animals, numbers of taxa, diversity and evenness have generally been higher reach MUR-E-2 than reach MUR-D-3, although total abundance and richness have decreased marginally in both reaches since 2002 (Figure 5.3-9). Diversity and evenness, though generally higher in the reach MUR-D-2 since about 2002, were both lower in reach MUR- D-2 in 2006, causing a significant *time x reach* interaction (Table 5.3-14). All of the observed variations in benthic invertebrate community measurement endpoints in reach MUR-E-2 were within the normal range of variability observed in reference depositional reaches (Figure 5.3-9). Finally, the ordination of the benthic invertebrate community for reach MUR-E-2 indicates considerable similarity across years with the anticipated reference condition since monitoring began in 2002 (Figure 5.3-10). These results indicate no significant impacts of focal project activities in the middle reach of the Muskeg River (reach MUR-E-2).

Jackpine Creek

2006 Habitat Conditions Both reach JAC-D-1 and JAC-D-2 in 2006 were shallow, with no measurable current and minimal macrophyte cover (Table 5.3-15). Water quality at the two reaches in 2006 was similar with respect to dissolved oxygen (~8.5 mg/L), conductivity (~300 µS/cm), and pH (~7.7), and sediments at both reaches were dominated by sand.

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The benthic invertebrate communities of reach JAC-D-1 and JAC-D-2 were heavily dominated by chironomids (Table 5.3-16). Ephemeroptera (mayflies) were present in both reaches, but in low numbers in reach JAC-D-1 (1%), while in higher numbers in the reach JAC-D-2 (6%) (Table 5.3-16). *Caenis* and *Leptophlebia*, neither of which is considered overly sensitive, dominated the mayfly fauna in Jackpine Creek.

Effects of Focal Project Activities An ANOVA was conducted to compare the benthic invertebrate community measurement endpoints for reaches JAC-D-1 and JAC-D-2. The most relevant ANOVA contrasts were the *reach x before to after* contrast, as well as those relating to differences between reaches in 2006 (i.e., *reach 2006* contrast). All *reach x before to after* contrasts were insignificant with the exception of diversity (Table 5.3-17). The levels of significance for this diversity comparison are considered low in this situation because of available samples sizes and resulting statistical power available for these tests (RAMP 2005b). Though the *reach 2006* contrast terms were significant for Simpson's Diversity, Evenness and percent EPT, similarities in values of these measurement endpoints between 2006 and 2005 implies that those differences may be representative of natural fluctuations. Temporal trends in benthic invertebrate community measurement endpoints over time (Figure 5.3-11), and the ordination results (Figure 5.3-12) indicate that the benthic invertebrate community of the lower reach of Jackpine Creek (reach JAC-D-1) has been representative of normal baseline conditions for reference depositional reaches throughout the sampling period; there is no indication of undue effects of focal project activities in lower Jackpine Creek.

5.3.4.2 Sediment Quality

Sediment quality was sampled in fall 2006 in the depositional reaches where benthic invertebrate communities were sampled: MUR-D-2; MUR-D-3; JAC-D-1; and JAC-D-2.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is therefore no historical record of sediment quality at these reaches. Therefore, data from the closest sediment quality sampling location prior to 2006 was used as the basis of comparison for 2006 results: station MUR-2 with reach MUR-D-2; station MUR-D2 with reach MUR-D-3, and station JAC-1 with reach JAC-D-1. There is no historical sediment quality sampling station against which 2006 sediment quality information from reach JAC-D-2 can be compared.

At depositional reaches designated as *potentially influenced* in fall 2006 (reach MUR-D-2 and reach JAC-D-1) there were 16 (67%) of a possible 24[6] cases of sediment quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values measured their paired stations (station MUR-2 and JAC-1). This statistic is higher than at reach MUR-D-3 which was designated as *reference* in fall 2006, at which there were 9 (53%) of a possible 17 cases of sediment quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values at its paired station (station MUR-D2). It is noted that this analysis is characterized by very small sample sizes (n=2 to n=4). Reach-specific details are as follows:

- At reach MUR-D-2, all sediment quality measurement endpoints in fall 2006 were either below historical minima or above historical maxima with the exception of %silt, total organic carbon, naphthalene, *Chironomus* growth, and *Hyalella* survival and growth (Table 5.3-18);
- At reach MUR-D-3, fraction 4 hydrocarbons, naphthalene, retene, total HMW PAHs, and all indicators of chronic toxicity were within historical ranges of concentrations for these sediment quality measurement endpoints (Table 5.3-19); and
- At reach JAC-D-1, %silt and predicted PAH toxicity were within historical ranges of concentrations for these sediment quality measurement endpoints (Table 5.3-20). There were relatively few sediment quality measurement endpoints in this reach that had been measured prior to 2006 (Table 5.3-20).

As indicated above, there is no historical sediment quality sampling station against which 2006 sediment quality information from reach JAC-D-2 can be compared and so 2006 results for reach JAC-D-2 are presented in Table 5.3-21.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines Fraction 3 hydrocarbons at reach MUR-D-2 was the only sediment quality measurement endpoint to exceed sediment quality guidelines in fall 2006 (Table 5.3-18).

Qualitative Among-Reach Comparisons The following comparisons in 2006 concentrations of sediment quality measurement endpoints among reaches are noted (Table 5.3-18 to Table 5.3-21):

- Total organic carbon was higher at reach MUR-D-3 (24.9%) than at reach MUR-D-2 (3.6%);

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[6] There are 20 non-metal sediment quality measurement endpoints (Section 3.3.2.6) and sediment quality was measured at three reaches in the Muskeg River that already had been sampled previous to 2006 and for which a historical record therefore exists against which to compare 2006 values (sediment quality at reach JAC-D-2 was sampled for the first time in 2006 and so there was no historical record against which to compare 2006 values at this reach. In addition, a number of sediment quality measurement endpoints in other reaches were measured for the first time in 2006). Sediment quality variables with concentrations that were below detection limits, either in 2006 or as either a minimum or maximum observed in the historical record were excluded. This resulted in a total of 24 sediment quality measurement endpoints at reaches designated as *potentially influenced* in 2006 (reach MUR-D-2 and reach JAC-D-1) and a total of 17 sediment quality measurement endpoints at reaches designated as *reference* in 2006 (reach JAC-D-2).

- At both reach MUR-D-2 and reach MUR-D-3, concentrations of fraction 1 hydrocarbons (C6-C10, including BTEX) were non-detectable. At reach MUR-D-2, concentrations of fraction 3 hydrocarbons (C16-C34) were the most abundant hydrocarbon fraction, while concentrations of fraction 4 hydrocarbons (C34-C50) were the most abundant hydrocarbon fraction at reach MUR-D-3. Concentrations of total hydrocarbons were higher at MUR-D-2 than at MUR-D-3;
- Concentrations of low molecular weight, high molecular weight, and total PAHs were higher at reach MUR-D-2 than at reach MUR-D-3. However, concentrations of naphthalene and retene were higher at reach MUR-D-3 than at reach MUR-D2;
- Survival and growth of *Chironomus tentans* were lower at reach MUR-D-3 than at MUR-D-2, while results of chronic toxicity testing using *Hyalella azteca* were similar at both reaches;
- Fraction 1 hydrocarbons (C6-C10, including BTEX) were non-detectable at both reach JAC-D-1 and reach JAC-D-2, and concentrations of other hydrocarbon fractions (i.e., C10-C50) were relatively low at both reaches; and
- PAH concentrations at both reach JAC-D-1 and reach JAC-D-2 were low relative to PAH concentrations observed at reach MUR-D-2 and MUR-D-3. Results of chronic toxicity testing were similar for both reaches.

Correlations among Sediment Quality Variables and Benthic Invertebrate Community Measurement Endpoints The analysis of benthic invertebrate community measurement endpoints above for reach MUR-D-2 and MUR-D-3 indicate statistically significant *time x reach* interactions for benthic invertebrate community diversity and evenness. The results of the correlation analysis among sediment quality measurement endpoints and benthic invertebrate community measurement endpoints in depositional reaches (Appendix E) revealed no sediment quality measurement endpoints that are significantly correlated with either benthic invertebrate community diversity or evenness.

5.3.4.3 Summary

There is little evidence of effects of focal project activities on benthic invertebrate communities in the Muskeg River watershed in 2006. There were some statistically significant differences in benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference*. However, values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled in the Muskeg River watershed were within the normal range of values observed from regional reference reaches, and there continues to be consistency across years in values of all benthic invertebrate community measurement endpoints with respect to regional reference reaches. There may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in the Muskeg River watershed.

5.3.5 Fish Populations

Fish Population component activities undertaken in the Muskeg River watershed in 2006 included a spring fish fence study and a non-lethal sentinel species monitoring study. Activities related to sentinel monitoring was part of a larger sentinel species monitoring study undertaken in 2006 in a number of RAMP FSA watersheds including the Steepbank River watershed; the results of the Muskeg River watershed portion of this study are presented in the Fish Population component results for the Steepbank River watershed (Section 5.4.5).

The use of a fish counting fence as a core monitoring tool for RAMP is relatively recent and is in part due to the success achieved with the Muskeg River fish fence in 2003. While data from fish fences are best suited for assessing time trends in abundance and population variables for each spawning species, the high level of natural annual variability common in spawning run strength necessitates the need to collect a large number of sampling years before observed trends and possible effects of focal project activities can be described with confidence. Therefore, the material below focuses on a presentation of the results of the spring 2006 Muskeg River fish fence study and a comparison with results from the 2003 Muskeg River fish fence (RAMP 2004), rather than an assessment of possible impact-related effects related to focal project activities in the Muskeg River watershed.

Size, age and health data for fish captured at the fish fence are provided in the RAMP database. The majority of fish captured during the fence program were adults; with the exception of a limited number of juvenile fish (<1%), the majority of which were white sucker.

5.3.5.1 Fish Species and Percent Species Composition

A total of 1,256 fish were counted at the fish fence site during the operation of the Muskeg River fish fence (Table 5.3-22) ,which is approximately 200 more fish than were captured in 2003, although the fence was operated four days longer in 2006 relative to 2003. Seven fish species representing five families were captured at the Muskeg River fish fence 2006. Table 5.3-22 lists the most common fish species observed in spring migration movements upstream and/or downstream of the fish fence. Longnose sucker (674 fish), white sucker (431 fish) and northern pike (135 fish) accounted for 98.7% of all the fish captured at the Muskeg River fish fence; almost identical to 2003 when these three species accounted for 99.2% of the total catch. As in 2003, only a small number of Arctic grayling (n=2, one upstream, one downstream) were captured during the entire fence operation. In addition, low numbers of mountain whitefish (n=3), lake whitefish (n=8) and walleye (n=3, two upstream, one downstream) were captured at the fence in 2006.

The proportion of upstream migrants relative to the total catch (1,230 of 1256 fish, or 98%) far exceeded downstream migrants in 2006 (26 fish, 2%). The proportion of upstream migrants is greater than that what was recorded in 2003, when 74% of captured fish were upstream migrants. Based on the daily counts of dominant fish caught, the timing of the fence operation in 2006 appears to have been effective in catching the dominant upstream spawning runs. In 2006, 93% of all upstream migrants were caught between day 5 and day 25 of the month-long operation of the fish fence. This is similar to 2003, when 97.4% of the upstream migrants were captured between day 9 and day 25 of the fence operation.

The tagging protocol (i.e., only the first 50 individuals of each species were tagged on any given day), resulted in 93% of captured northern pike and 90% of white sucker were tagged during the fence operation. In contrast, about 69% of all captured longnore sucker were tagged because more than 50 longnose sucker were caught on several days of the fish fence operation (Table 5.3-22).

Individual fish that were caught more than once in the 2006 season (recaptured) were enumerated only once, while fish caught with tags from previous years were included in the 2006 data.

5.3.5.2 Recapture Rates

Mark-recapture data obtained at the 2006 fence provides information on yearly movement patterns, site fidelity, and the amount of time each fish species spend in the upper reaches of the Muskeg River (Table 5.3-23).

The total percentage of migrant sucker returns (i.e. fish previously tagged or recaptured at the fence in 2001 and 2003) moving upstream in the Muskeg River in 2006 was 7.3%, which exceeds the expected return of 3-5% for mark-recapture studies involving fish. The recapture rate for longnose sucker females was highest at 29.5%, followed by female white sucker (13.1%) Male returns were considerably lower at approximately 1.5 - 3%.

5.3.5.3 Timing of Migration

Longnose Sucker

Longnose sucker made up the largest portion of the migrant fish enumerated at the Muskeg River fence. The upstream migration of longnose sucker exhibited two distinct waves corresponding roughly to a 10°C water temperature threshold (Figure 5.3-13). This temperature threshold occurred first around April 25, 2006 coinciding with an early spike in migration. However, migrant numbers fell off rapidly after April 28 even though maximum water temperatures continued to exceed 10°C for several more days. This pattern was also observed in 2003 when the first major upstream pulse of longnose sucker started to peak on May 10, 2003 when water temperatures reached 10°C and lasted for six days (RAMP 2004), followed by a 5-day period of reduced upstream movement. A second peak followed beginning May 23, 2003, even though the water temperature had been 10°C or above throughout the entire period.

In 2006, at the time upstream migration of longnose sucker dropped, field technicians at the fish fence observed initial signs of beaver activity and otter predation of fish, which may partially explain the decline in longnose sucker migration. Further evidence of predation persisted to a minor extend throughout the operation of the fish fence.

Only 3% (6 fish) of 674 longnose sucker caught at the fish fence were migrating downstream (Table 5.3-22). Ninety five percent of the upstream migration of longnose sucker were caught between day 7 (April 25 2006) and day 25 (May 14 2006) of the thirty-day operation of the fish fence. In 2006, the ratio of female to male longnose sucker captured at the fish fence was 1.1:1 (Table 5.3-23) and lower than ratio of 2.4:1 observed in 2003 (RAMP 2004).

White Sucker

As with longnose sucker, upstream white sucker migrants were captured in large numbers at the fence when daily maximum water temperatures reached approximately 10°C (Figure 5.3-14). A second pulse began around May 6 and was sustained over a period of five to eight consecutive days, during which daily counts of white sucker often peaked above 30 fish per day. In total, 431 white sucker (not including recaptures) were enumerated at the fence; 387 of these fish were tagged. The ratio of female to male white sucker captured at the fish fence was 1.5:1 (Table 5.3-23), in contrast to 2.5:1 observed in 2003 (RAMP 2004).

Northern Pike

Northern pike were captured at the Muskeg fish fence throughout the study period in smaller numbers than either sucker species (Figure 5.3-15). In both 2003 and 2006, daily counts averaged 3 to 5 fish with daily figures ranging from 0 to 10 fish. Two periods of elevated northern pike captures occurred in advance of the major sucker migrations. A total of 135 northern pike were counted at the fence in 2006, which is 21.5% more than in 2003 (total=106). Only eight pike (6% of all northern pike captured) were caught moving in the downstream direction. The ratio of female to male northern pike captured at the fish fence was 0.7:1 (Table 5.3-23), less than the 1.8:1 ratio reported for 2003 (RAMP 2004).

5.3.5.4 Residency Time

The estimated residency time for longnose sucker, white sucker and northern pike in the Muskeg River in 2006 is summarized in Table 5.3-24. Residency time was estimated as: 1) the actual known residence time of recaptured individuals; and 2) a range based on minimum estimates for captured and tagged upstream migrant fish that did not return downstream during the operation of the fish fence. Average residency time for 2006 recaptures across species ranged from 0.6 to 4 days in 2006 (Table 5.3-24). Many of the recaptures occurred only a short time after initial capture, processing, and release upstream of the fence suggesting that it may be a reflection of fish fatigue/stress related to handling at the fence.

Given the limited number of fish that were recaptured, confidence in the estimates of residency time is low. Currently, the Muskeg River fish fence is operated for 30-days after initial installation, but this duration is not sufficient to accurately characterize the out-migration of these dominant fish species, which have been observed to leave the Muskeg River in late May and into June (Bond and Machniak 1979).

5.3.5.5 Size and Age Composition of Migrants

Longnose Sucker

Length-frequency distributions of migrant longnose sucker captured in 2006 are shown in Figure 5.3-16. The overall frequency distributions for male and female longnose sucker were significantly different ($p < 0.10$), with the average length of migrating female sucker significantly longer than males ($p < 0.05$). Both male and female length-frequency distributions in 2006 were significantly different from what was observed in 2003 (male, $p<0.001$; female, $p<0.10$), with female sucker form 2006 being longer than was observed in 2003 ($p< 0.05$).

The weight-length (i.e., fish condition) relationship for 2006 migrant longnose sucker is shown in Figure 5.3-17. There were no significant differences in slopes (ANCOVA $p > 0.001$) of the sex-specific weight-length regressions presented in Figure 5.3-17. However, female longnose sucker were heavier for a given length relative to both male longnose sucker and longnose sucker of unknown sex (ANCOVA $p< 0.05$; multiple comparison $p< 0.05$). A similar result was observed during the 2003 Muskeg fish fence operation.

Migrant longnose sucker ranged in age from 4 to 14 y in 2006 (Figure 5.3-18); this is a narrower age range than reported in 2003 (7 to 19). The median age for longnose sucker in 2006 was 8 y for males and 9 y for females. In 2006, just over 86% of all females aged were between 7 to 11 y old (inclusive), while 75% of the males that were aged fell within the 6 to 9 y age range.

In 2006, upstream migrant female longnose sucker were significantly older than upstream migrant male longnose sucker, by approximately 1 year ($p < 0.05$). This finding is also consistent with 2003 Muskeg River fish fence results.

Length-at-age relationships for upstream migrant longnose sucker are presented in Figure 5.3-19. There were no significant differences in the slopes of the sex-specific length-at-age regressions, but females were longer than males at a given age ($p < 0.05$). This finding is also consistent with 2003 Muskeg River fish fence results.

White Sucker

Length-frequency distributions of upstream migrant white sucker are shown in Figure 5.3-20. 2006 length-frequency distributions for male and female white sucker were significantly different ($p < 0.01$), with females significantly longer than males ($p < 0.05$). Both male and female distributions in 2006 were significantly different than 2003 distributions (males and females, $p < 0.10$). 2006 female white sucker (upstream and downstream migrants) were significantly longer than those in 2003 (two sample *t* test, $p < 0.05$).

The weight-length relationships of white sucker are shown in Figure 5.3-21. As in 2003, there was no significant difference in the condition of male and female migrating white sucker in 2006 ($p > 0.05$).

Migrant white sucker ranged in age from 4 to 14 y (Figure 5.3-22); the median age was 8 y for males and 10 y for females. Almost 57% of all females aged were 8 to 10 y old, while only about 35% of the males fell within the same age range. Upstream migrant females were significantly older than males, by approximately 1 year ($p < 0.05$); this is in contrast to 2003 results for which there was no significant difference in ages of male and female white sucker.

Length-at-age relationships for upstream migrant white sucker are presented in Figure 5.3-23. There were no sex-specific differences in the slope of length-at-age regressions; however, females were significantly longer at any given age relative to males (ANCOVA and multiple comparison $p < 0.05$), which is consistent with results from 2003.

Northern Pike

The 2006 length-frequency distributions of northern pike captured in the Muskeg River fish fence are presented in Figure 5.3-24. The largest female captured was 901 mm and the largest known male captured was 764 mm.

Like white and longnose sucker, the length-frequency distributions of male and female pike were significantly different ($p < 0.001$); female pike were significantly longer and heavier than males (length $p < 0.05$, weight $p < 0.05$). These results are consistent with what was observed in 2003.

The 2006 weight-length relationships of northern pike are shown in Figure 5.3-25. There were no significant sex-specific differences in northern pike condition in 2006, contrary to what was found in 2003 when females were found to increase in weight relative to length at a higher rate than male pike.

Captured northern pike ranged in age from 2 to 11 y (Figure 5.3-26). Female northern pike were significantly older than males ($p < 0.05$) (differences between male and female northern pike age were not present in 2003).

The 2006 length-age relationships for northern pike are shown in Figure 5.3-27. As in 2003, there were no significant differences in length-at-age of northern pike in 2006.

5.3.5.6 External Pathology

The incidence of abnormalities in dominant fish species ranged from 15% to 53% in 2006, while in 2003 it ranged from 12% to 25% (Table 5.3-25). The total percent of captured fish affected by abnormalities in 2006 (30%) was somewhat higher than in 2003 (22%). White sucker had the highest incidence of abnormality/pathology and the highest mean EPI value in both years, while longnose sucker had the lowest incidence of abnormalities among the dominant fish species.

Species-specific comparisons indicate that the percent abnormalities in white sucker and northern pike in 2006 was double what was observed in 2003, while the percent abnormality in longnose sucker was similar in both years. Although, the percentage of white sucker and northern pike with abnormalities was greater in 2006 than in 2003, the mean EPI value for the species was within the historical range documented for the Athabasca River.

Most of the abnormalities reported in both 2003 and 2006 were associated with some level of fin erosion or skin aberration. The incidence of other abnormalities was low, considering the high number of fish examined during both Muskeg River fish fence operations.

5.3.5.7 Other Fish Species

The following additional fish species were captured in the Muskeg River fish fence (Table 5.3-26):

- Two Arctic grayling were captured during the operation of the Muskeg River fence. On May 5, 2006, a maturing four year old was captured in the upstream trap, tagged and released. Another Arctic grayling was caught on May 10, 2006, but the age of this individual could not be ascertained due to a deficient fin. In 2003, a single Arctic grayling moved upstream on May 25, 2003, followed by a individual moving downstream two days later;

- Nine lake whitefish were caught ranging in age from 6 to 18 y of age. Most of these fish were captured during the last week of the fence operation, and the sex of only one individual (female) was identified. In contrast, only two lake whitefish were captured in 2003;

- A single 8 y old mountain whitefish was counted twice moving upstream on May 9, 2006, and May 18, 2006. Another mountain white fish (2 y old) was caught moving in the downstream direction on May 13. In 2003, two mountain whitefish were captured on two occasions, all moving in the upstream direction; and

- Three adult walleye were caught during the final three days of the fence operation, two fish in the upstream trap and one in the downstream trap. The fish ranged in age from 8 to 10 y - only two walleye moving downstream on the same day were captured in 2003.

5.3.5.8 Summary

The 2006 Muskeg River fish fence represents only the second successful fence operation undertaken by RAMP. Although a fence was planned for the Muskeg River in 2005, spring discharge values >30 m^3/s did not permit the installation of the fence. As indicated above, high levels of natural annual variability common in spawning run strength necessitates the need to collect a larger number of sampling years before observed trends and possible effects of development activities can be identified with confidence.

The 2006 Muskeg River fish fence results were largely consistent with results of the 2003 Muskeg River fish fence:

- The Muskeg River in the spring continues to be utilized by populations of a number of fish species, dominated by longnose sucker, white sucker, and northern pike;
- The time of migration for all three dominant species was similar in 2006 and 2003 (dictated by an initial temperature threshold of about 10°C); and
- A number of the sex-specific differences in size and condition in the three dominant species observed in 2006 were consistent with observations in 2003.

The key differences between 2006 and 2003 results are as follows:

- The sex ratio of captured fish was more skewed towards males than females in 2006 than 2003 for all the dominant species;
- There were some differences in size and condition of the three dominant species in 2006 that were not found in 2003: sex-specific age differences in longnose sucker and northern pike;
- There were some differences in size and condition of the three dominant species in 2003 that were not observed in 2006: sex-specific condition of northern pike; female northern pike were significantly longer at a given age in 2003 relative to male northern pike;
- There are some differences in size and condition in the three dominant species between 2006 and 2003: length frequency distributions of male and female longnose sucker and white sucker; and length of female longnose sucker and white sucker; and
- Percentage of abnormality occurrence for white sucker and northern pike was higher in 2006 than in 2003.

With only two years of Muskeg River fish fence results, any influence of focal project activities on fish utilizing the Muskeg River during the spring spawning season remains largely undetectable and unknown.

5.3.6 Summary of Conditions

The cumulative effects of focal projects at the watershed level for the Muskeg River watershed for 2006 are assessed as follows:

- There appear to be some effects on watershed hydrology, with large differences in two of the four hydrologic measurement endpoints (mean winter discharge and open-water season minimum daily discharge) between observed, *potentially* *influenced* conditions and estimated *reference* conditions. It must be noted that these differences have been estimated under the assumption that all CWD discharge waters would not have reported to the Muskeg River under *reference* conditions;

- Water quality remains largely unaffected by focal project activities, with few exceedances of water quality guidelines throughout the watershed and concentrations of most water quality measurement endpoints throughout the watershed that remained within historical regional baseline ranges. The only exception to these overall results for water quality is an indication of greater variability of water quality in fall 2006 in *potentially influenced* areas of the Muskeg River watershed than in *reference* areas;

- There is little evidence of effects on benthic invertebrate communities. Values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled in the Muskeg river watershed were within the normal range of values observed from regional reference reaches, and there continues to be consistency across years in values of all benthic invertebrate community measurement endpoints with respect to regional reference reaches. In addition, there may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in the Muskeg River watershed; and

- Any influence of focal project activities on fish utilizing the Muskeg River during the spring spawning season remains largely undetectable and unknown, given the few years of information available from Muskeg River fish fence studies.

Figure 5.3-2 Muskeg River: 2006 hydrograph and historical context.

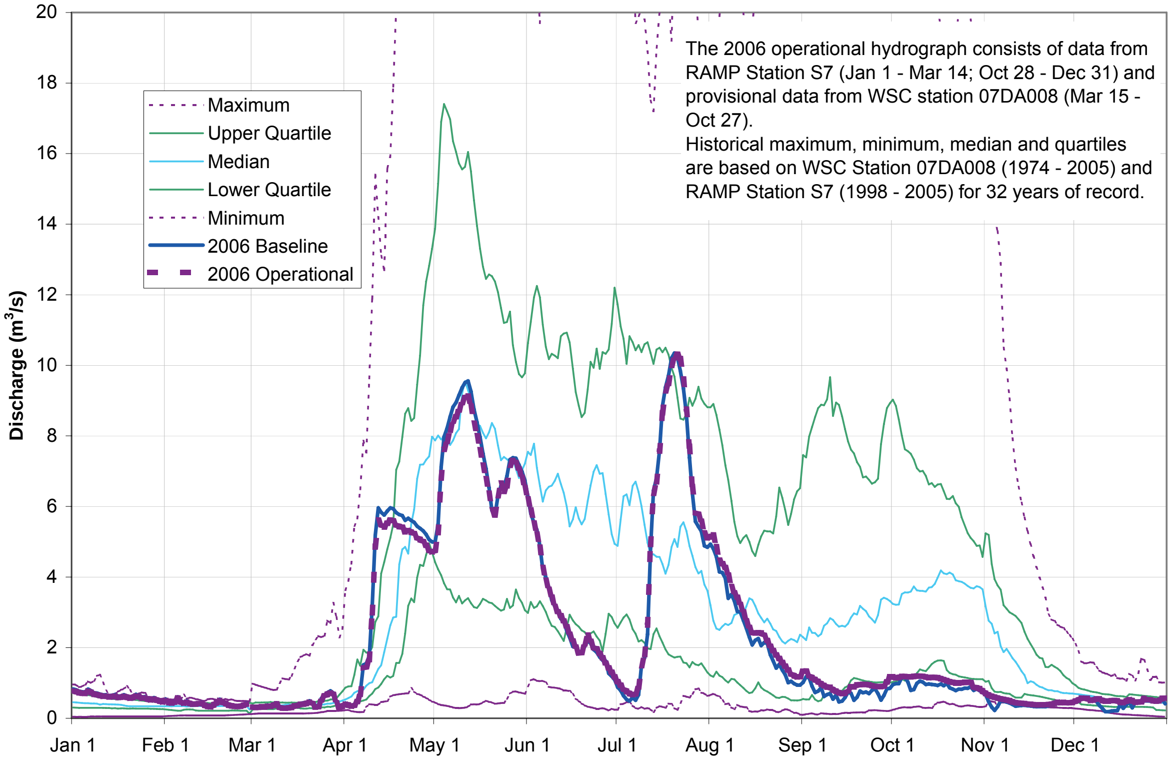


Table 5.3-1 Inputs for calculation of baseline hydrograph at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph	71.4	Observed daily discharges obtained from RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008)
Natural runoff that would have occurred from focal project areas that were closed-circuited as of 2006	+ 2.86	74.1 km^2 within Muskeg River drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change due to focal project development areas and are not closed-circuited	- 0.262	25.5 km^2 within Muskeg River drainage estimated to have undergone land change by focal projects as of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from the Muskeg River by focal project activities	0	Unknown, assumed to be negligible
Releases to the Muskeg River by focal project activities	- 2.53	Aurora Clean Water Diversion discharges to Stanley Creek – annual total (Section 2.2), data provided by Syncrude
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects on tributaries of Muskeg River not accounted for in figures contained in this table
Baseline hydrograph	71.4	Estimated baseline ("without focal project") flow for 2006
Incremental flow	0 .069	Difference in total flow between operational and baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.10%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.3-2 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed.

Measurement Endpoint[1]	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	3.45	3.41	- 1.1%
Mean winter discharge	0.495	0.552	11%
Annual maximum daily discharge	10.5	10.3	-2.1%
Open-water season minimum daily discharge	0.603	0.661	9.7%

[1] As measured at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).

Note: Baseline values shown in the table are likely underestimated, because they are based on the simplifying assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.3-3 Concentrations of selected water quality measurement endpoints, Muskeg River mouth (station MUR-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	9	7.4	8.2	8.4
Total suspended solids	mg/L	-[1]	3	9	<3	3	70
Conductivity	µS/cm	-	424	9	220	338	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.01	9	0.004	0.014	0.03
Total nitrogen*	mg/L	1.0	0.9	9	0.4	0.8	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	9	15	21	25
Ions							
Sodium	mg/L	-	15	9	8	12	64
Calcium	mg/L	-	62.9	9	28.8	50.6	108
Magnesium	mg/L	-	14.9	9	7.1	12.0	18.9
Chloride	mg/L	230, 860[3]	6	9	1	3	36
Sulphate	mg/L	100[4]	0.6	9	2.1	5.4	91
Total dissolved solids	mg/L	-	280	9	170	280	405
Total alkalinity	mg/L		218	9	105	177	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.038	9	0.027	0.078	**1.2**
Dissolved aluminum	mg/L	0.1[2]	0.0019	9	<0.01	0.00611	0.030
Total boron	mg/L	1.2[5]	0.0545	9	0.032	0.042	0.15
Total molybdenum	mg/L	0.073	0.00008	9	<0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	0.8
Total strontium	mg/L	-	0.158	9	0.086	0.127	0.296

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.3-4 Concentrations of selected water quality measurement endpoints, Jackpine Creek (station JAC-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	7	7.8	7.9	8.2
Total suspended solids	mg/L	-[1]	<3	7	<3	8	8
Conductivity	µS/cm	-	320	7	183	197	413
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.019	7	0.006	0.014	0.026
Total nitrogen*	mg/L	1.0	0.9	7	0.7	0.9	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	7	<0.1	<0.1	<0.05
Dissolved organic carbon	mg/L	-	22	7	18.6	22	28
Ions							
Sodium	mg/L	-	15	7	10	11	18
Calcium	mg/L	-	43.4	7	22.2	25.8	56.6
Magnesium	mg/L	-	11.7	7	6.6	7.3	14.2
Chloride	mg/L	230, 860[3]	4	7	1	2	6
Sulphate	mg/L	100[4]	<0.5	7	<3	2.9	4.3
Total dissolved solids	mg/L	-	220	7	110	210	234
Total alkalinity	mg/L		165	7	93	100	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0179	7	0.0381	0.074	0.12
Dissolved aluminum	mg/L	0.1[2]	0.0033	7	<0.01	0.0087	0.17
Total boron	mg/L	1.2[5]	0.0495	7	0.033	0.0421	0.066
Total molybdenum	mg/L	0.073	0.000119	7	0.00007	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.163	7	0.085	0.092	0.171

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.3-5 Concentrations of selected water quality measurement endpoints, Stanley Creek (station STC-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	5	7.6	8.0	8.2
Total suspended solids	mg/L	-[1]	<3	5	<3	<3	6
Conductivity	µS/cm	-	548	5	271	307	760
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.03	6	0.01	0.01	0.03
Total nitrogen*	mg/L	1.0	0.4	6	0.3	0.5	**2.1**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	8	5	6	7	9
Ions							
Sodium	mg/L	-	17	5	2	3	26
Calcium	mg/L	-	84.9	5	45.4	54.2	112
Magnesium	mg/L	-	17.2	5	11.1	11.3	20.5
Chloride	mg/L	230, 860[3]	13	5	<1	2	14
Sulphate	mg/L	100[4]	49	5	2.4	5.3	**126**
Total dissolved solids	mg/L	-	380	5	200	200	480
Total alkalinity	mg/L		231	5	157	170	260
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.015	6	<0.02	0.004	0.02
Dissolved aluminum	mg/L	0.1[2]	0.00029	6	<0.01	0.0008	0.02
Total boron	mg/L	1.2[5]	0.0502	6	0.018	0.023	0.087
Total molybdenum	mg/L	0.073	0.00011	6	<0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.191	6	0.075	0.095	0.248

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

8 AENV 1-day minimum dissolved oxygen level. Dissolved oxygen measured by titration in the field.

Table 5.3-6 Concentrations of selected water quality measurement endpoints, Shelley Creek (station SHC-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	1	-	-	7.2
Total suspended solids	mg/L	-[1]	5	1	-	-	39
Conductivity	µS/cm	-	495	1	-	-	1172
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.02	1	-	-	0.04
Total nitrogen*	mg/L	1.0	**1.2**	1	-	-	**3.9**
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	25	1	-	-	28.6
Ions							
Sodium	mg/L	-	32	1	-	-	96
Calcium	mg/L	-	59.1	1	-	-	83.5
Magnesium	mg/L	-	15.8	1	-	-	13.8
Chloride	mg/L	230, 860[3]	15	1	-	-	80
Sulphate	mg/L	100[4]	<0.5	1	-	-	10
Total dissolved solids	mg/L	-	340	1	-	-	500
Total alkalinity	mg/L		242	1	-	-	354
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.088	1	-	-	0.06
Dissolved aluminum	mg/L	0.1[2]	0.0032	1	-	-	<0.01
Total boron	mg/L	1.2[5]	0.0833	1	-	-	0.169
Total molybdenum	mg/L	0.073	0.00016	1	-	-	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	-	-	-	-
Total strontium	mg/L	-	0.207	1	-	-	0.435

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

[9] AENV 1-day minimum dissolved oxygen level. Dissolved oxygen measured by titration in the field.

Table 5.3-7 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (station MUR-6), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	8	7.2	8.0	8.3
Total suspended solids	mg/L	-[1]	<3.0	8	<3.0	4	176
Conductivity	µS/cm	-	384	8	233	307.5	556
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.018	8	0.011	0.014	0.039
Total nitrogen*	mg/L	1.0	0.9	8	0.3	0.80	**1.65**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	8	14	18.5	24
Ions							
Sodium	mg/L	-	4	8	3	4	9
Calcium	mg/L	-	56.6	8	31.3	46.9	85.3
Magnesium	mg/L	-	21.4	8	11.6	16.1	23.4
Chloride	mg/L	230, 860[3]	2	8	<1	1	3
Sulphate	mg/L	100[4]	2.2	8	1.6	4.9	6.6
Total dissolved solids	mg/L	-	260	8	180	250	340
Total alkalinity	mg/L		212	8	120	186	318
Organic compounds							
Naphthenic acids	mg/L	-	1	8	<1	<1	12
Selected metals							
Total aluminum	mg/L	0.1	0.0097	8	<0.02	0.036	**0.17**
Dissolved aluminum	mg/L	0.1[2]	0.0025	8	0.0017	0.0084	0.08
Total boron	mg/L	1.2[5]	0.0153	8	0.006	0.0118	0.081
Total molybdenum	mg/L	0.073	0.00007	8	<0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	8	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.103	8	0.058	0.085	0.164

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.3-8 Concentrations of selected water quality measurement endpoints, Muskeg Creek (station MUC-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	8	7.4	7.7	8.2
Total suspended solids	mg/L	-[1]	8	8	<3	3.5	9
Conductivity	µS/cm	-	350	8	184	274	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.034	8	0.013	0.016	0.03
Total nitrogen*	mg/L	1.0	**1.1**	8	0.4	1.0	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.1	<0.1	<0.05
Dissolved organic carbon	mg/L	-	24	8	20	22.5	28
Ions							
Sodium	mg/L	-	17	8	7	15.5	64
Calcium	mg/L	-	47.1	8	20.8	32.1	71.1
Magnesium	mg/L	-	14.8	8	7.2	9.7	17.3
Chloride	mg/L	230, 860[3]	3	8	<1	3	36
Sulphate	mg/L	100[4]	3	8	2	4.1	8
Total dissolved solids	mg/L	-	270	8	140	215	378
Total alkalinity	mg/L	-	185	8	93	138	313
Organic compounds							
Naphthenic acids	mg/L	-	1	8	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.142**	8	0.031	0.050	0.09
Dissolved aluminum	mg/L	0.1[2]	0.0052	8	<0.01	0.0066	0.03
Total boron	mg/L	1.2[5]	0.0583	8	0.024	0.0525	0.15
Total molybdenum	mg/L	0.073	0.00010	8	<0.0001	0.00005	0.0064
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.152	8	0.069	0.096	0.296

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.3-9 Concentrations of selected water quality measurement endpoints, Wapasu Creek (station WAC-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	7.4	7.8	8.2
Total suspended solids	mg/L	-[1]	<3	4	<3	3	23
Conductivity	µS/cm	-	319	4	220	312	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.022	4	0.012	0.014	0.016
Total nitrogen*	mg/L	1.0	1.0	3	0.8	1.0	1.0
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	17	4	11	17.5	26
Ions							
Sodium	mg/L	-	9	4	6	6.5	8
Calcium	mg/L	-	44	4	31.3	49.1	71.7
Magnesium	mg/L	-	15.4	4	9.6	16.0	25.1
Chloride	mg/L	230, 860[3]	3	4	1	2	2
Sulphate	mg/L	100[4]	3.3	4	1.9	4.2	7.6
Total dissolved solids	mg/L	-	230	4	160	245	300
Total alkalinity	mg/L		168	4	114	187	292
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.014	4	0.015	0.019	0.05
Dissolved aluminum	mg/L	0.1[2]	0.0064	4	<0.01	0.0050	0.05
Total boron	mg/L	1.2[5]	0.032	4	0.014	0.023	0.081
Total molybdenum	mg/L	0.073	0.00004	4	<0.0001	0.00004	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	2	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.102	4	0.071	0.099	0.130

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.3-10 List of all 2006 water quality guideline exceedances, Muskeg River.

Variable	Units	Guideline*	JAC-1	MUR-1	SHC-1	STC-1	MUC-1	MUR-6	WAC-1
Fall									
Sulphide	mg/L	0.002[1]	**0.009**	**0.009**	**0.013**	**0.008**	**0.016**	**0.009**	**0.011**
Total phosphorus	mg/L	0.05	**-**	**-**	**0.051**	-	-	-	-
Total nitrogen	mg/L	1.0	**-**	**-**	**1.2**	-	**1.1**	-	-
Total Kjeldahl nitrogen	mg/L	1.0[2]	**-**	**-**	**1.1**	-	-	-	-
Total aluminum	mg/L	0.10	**-**	**-**	-	-	**0.142**	-	-
Dissolved iron	mg/L	0.3[3]	**0.452**	**-**	**0.613**	-	**0.701**	-	-
Total iron	mg/L	0.3	**0.656**	**0.452**	**2.5**	-	**1.1**	-	**0.39**
Total phenols	mg/L	0.004	**0.012**	**0.011**	**0.013**	**0.005**	**0.017**	**0.01**	**0.016**

Sampling conducted in fall 2006 only in the Muskeg River watershed.

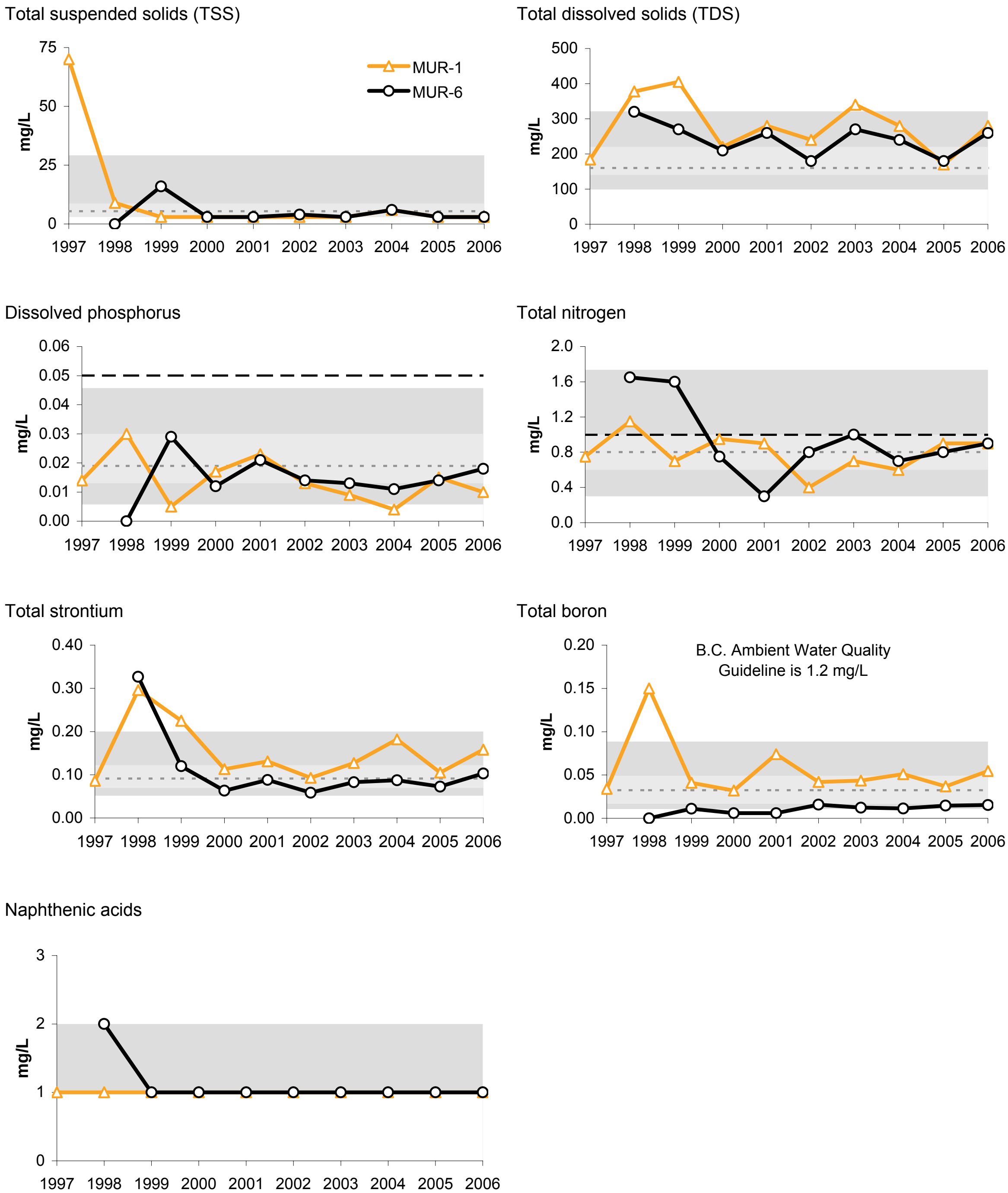
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S.

[2] Guideline is for total nitrogen (no guideline for TKN).

[3] Guideline is for total metal (no guideline for dissolved analyte).

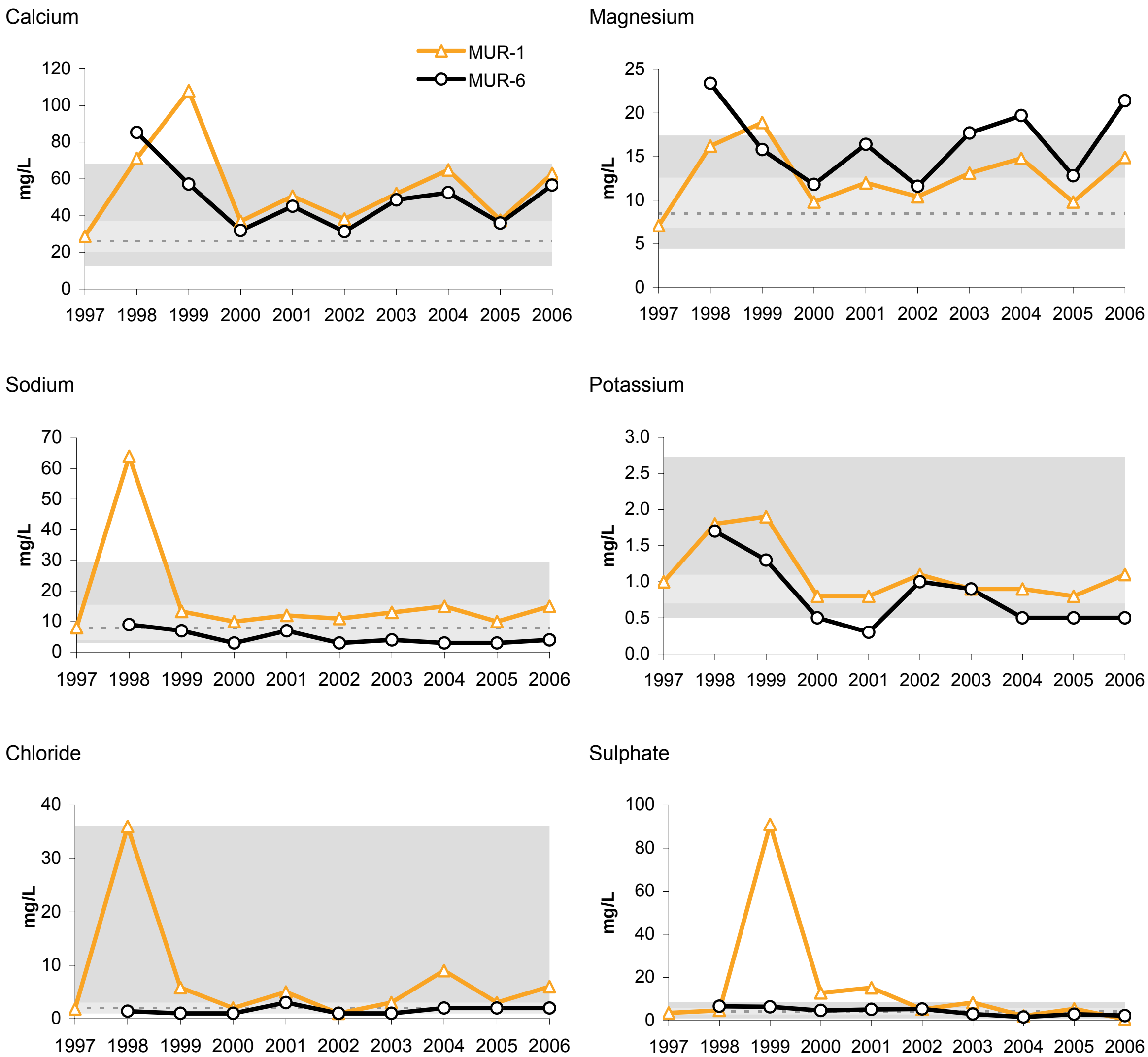
Figure 5.3-3 Selected water quality measurement endpoints in the Muskeg River at the mouth (station MUR-1) and upstream of Wapasu Creek (station MUR-6), fall data, relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

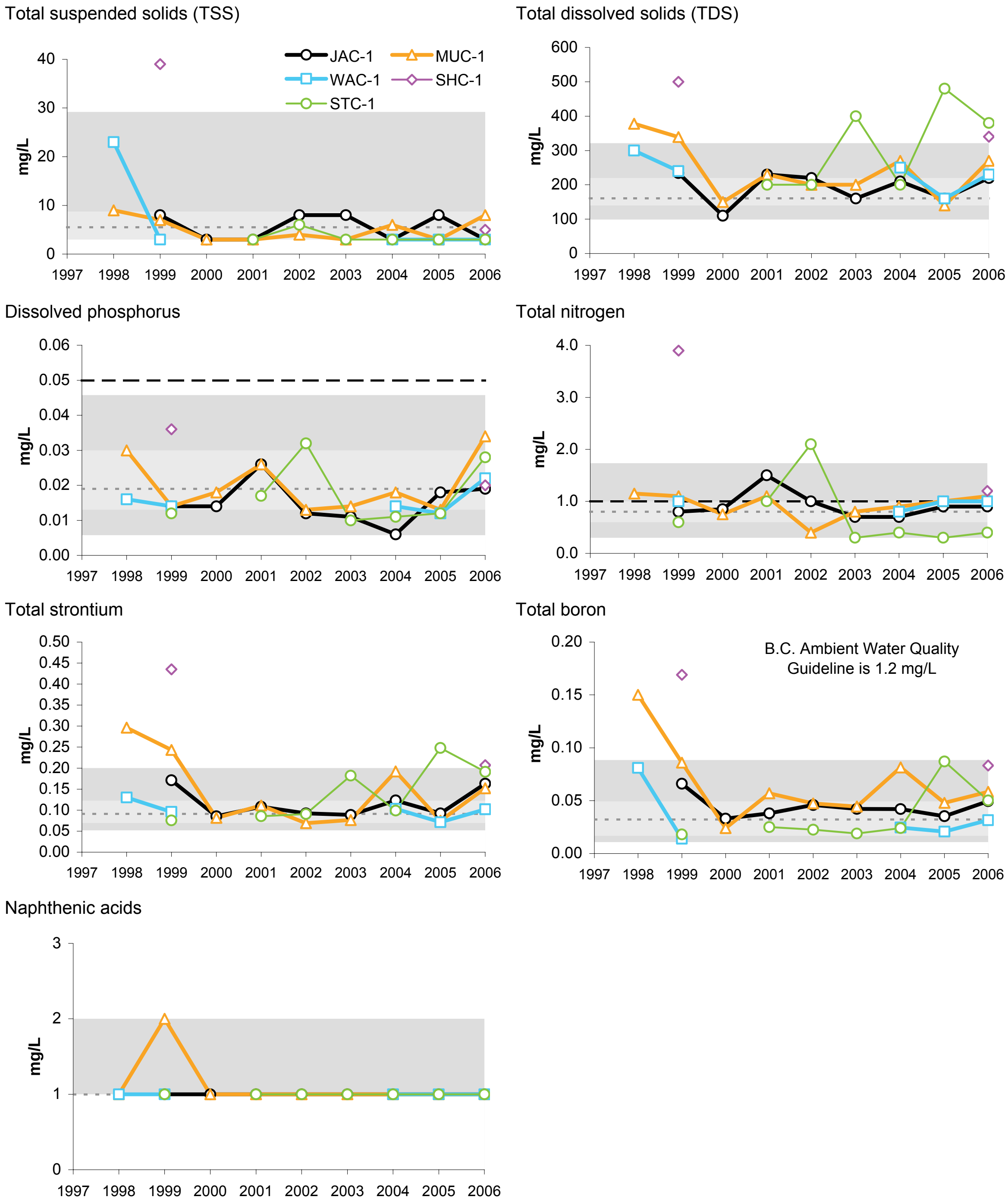
Figure 5.3-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

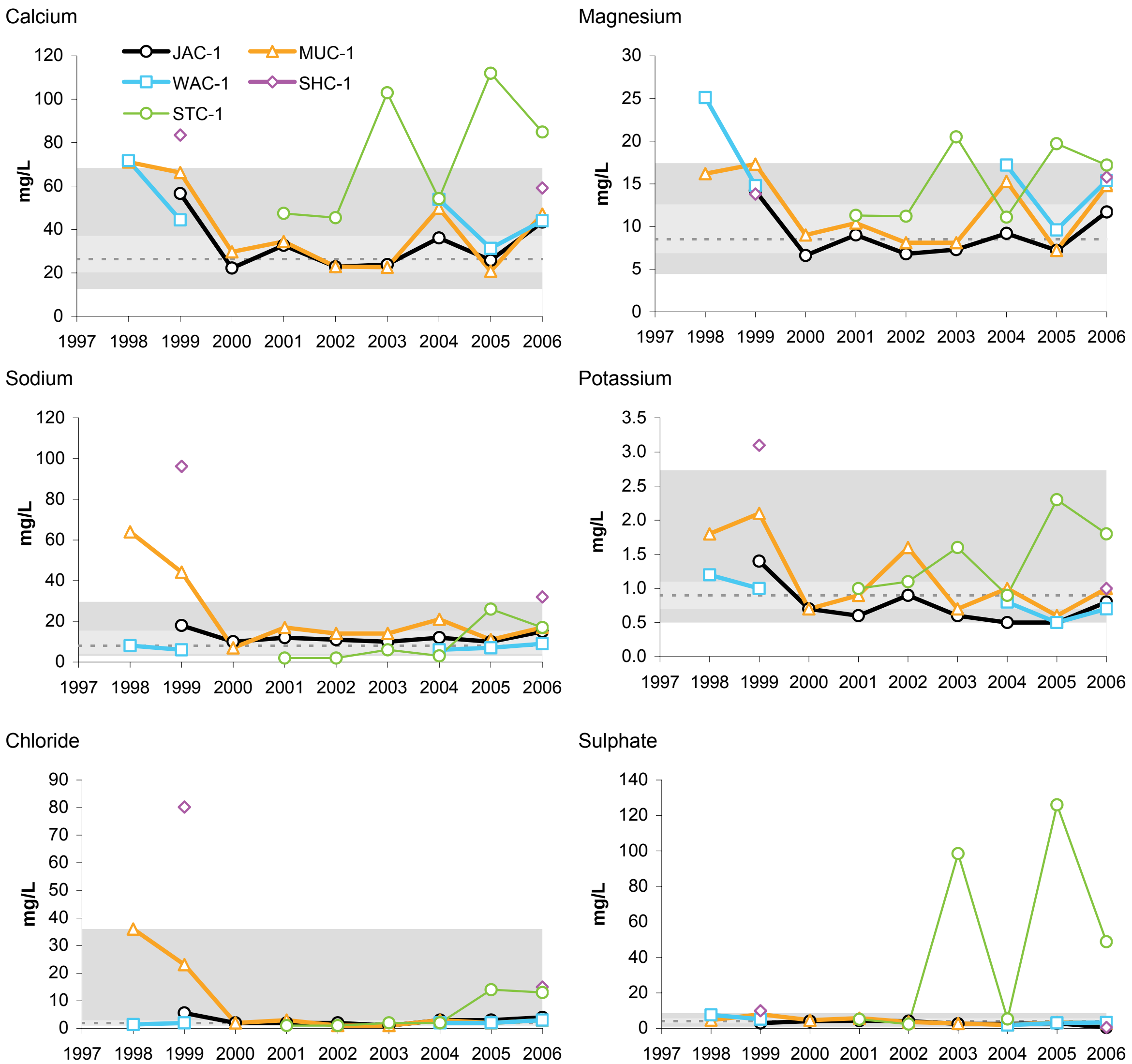
Figure 5.3-4 Selected water quality measurement endpoints in Muskeg River tributaries, fall data, relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.3-4 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

**Figure 5.3-5	Piper diagram of fall ion concentrations in the Muskeg River and its tributaries, 1997 to 2006.**

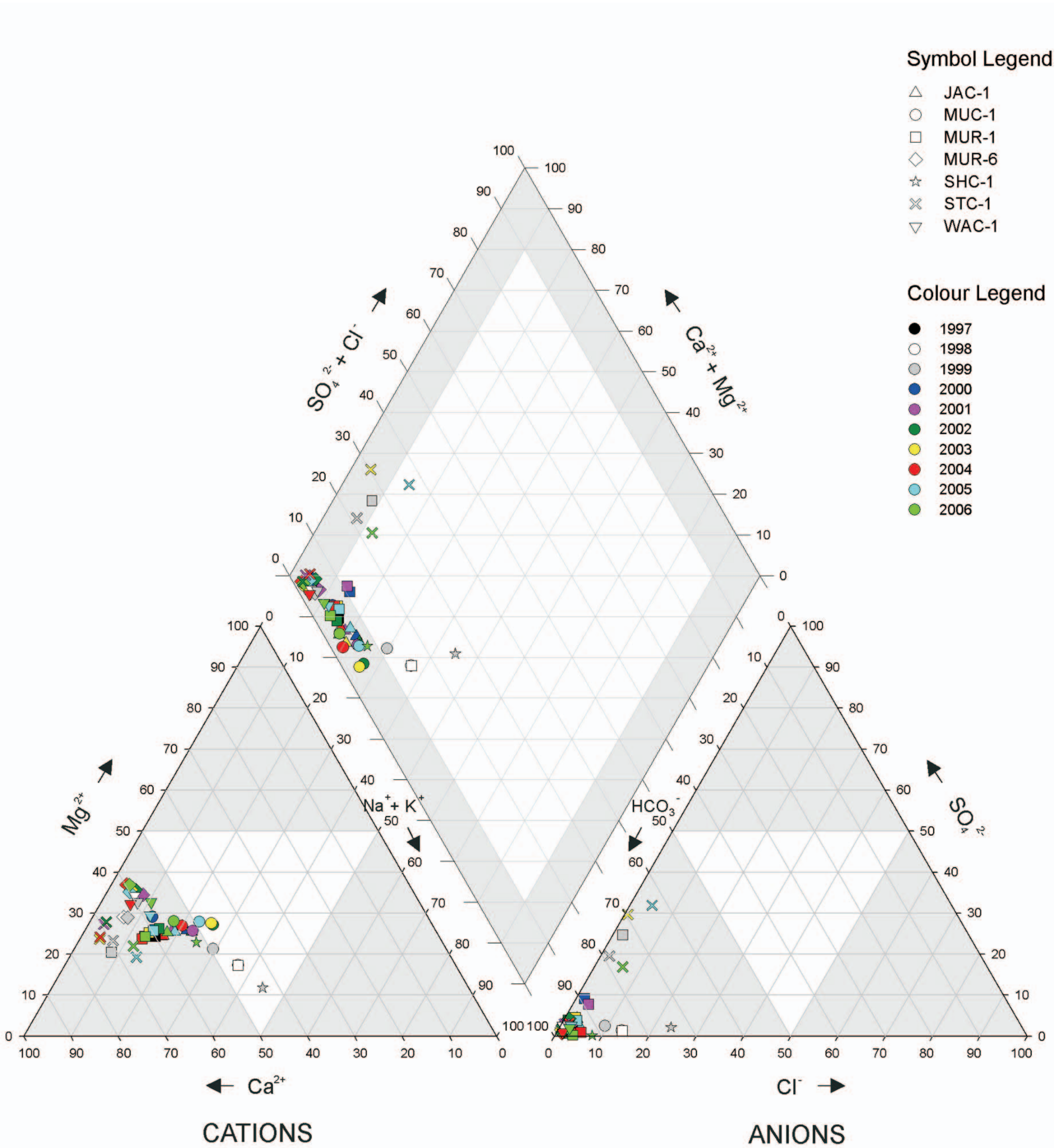


Table 5.3-11 Habitat characteristics of benthic invertebrate community sampling reaches in the Muskeg River, fall 2006.

Variable	Units	Lower Reach of the Muskeg River (MUR-E-1)	Middle Reach of the Muskeg River (reach MUR-D-2)	Upper Reach of the Muskeg River (MUR-D-3)
Sample date	-	Sept. 9, 2006	Sept. 14, 2006	Sept. 7, 2006
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	0.65	0.97
Current velocity	m/s	0.8	0.1	n/a
Macrophyte cover	%	n/a	11	4.9
Benthic algae	μg/m²	30.1	n/a	n/a
Sand/Silt/Clay	%	5	100	100
Field Water Quality				
Dissolved oxygen	mg/L	8.4	8.5	6.1
Conductivity	μS/cm	423	402	450
pH	-	8	7.8	7.3
Water temperature	°C	13.8	13.6	14.2
Sediment Composition				
Sand	%		85	86
Silt	%		13	8
Clay	%		2	6
Sand/Silt/Clay	%	1		
Small gravel	%	13		
Large gravel	%	15		
Small cobble	%	24		
Large cobble	%	30		
Boulder	%	17		
Bedrock	%	0		
Total Organic Carbon	%	n/a	2.3	19.7

Figure 5.3-6 Annual variation in periphyton chlorophyll *a* in the lower Muskeg River (reach MUR-E-1).

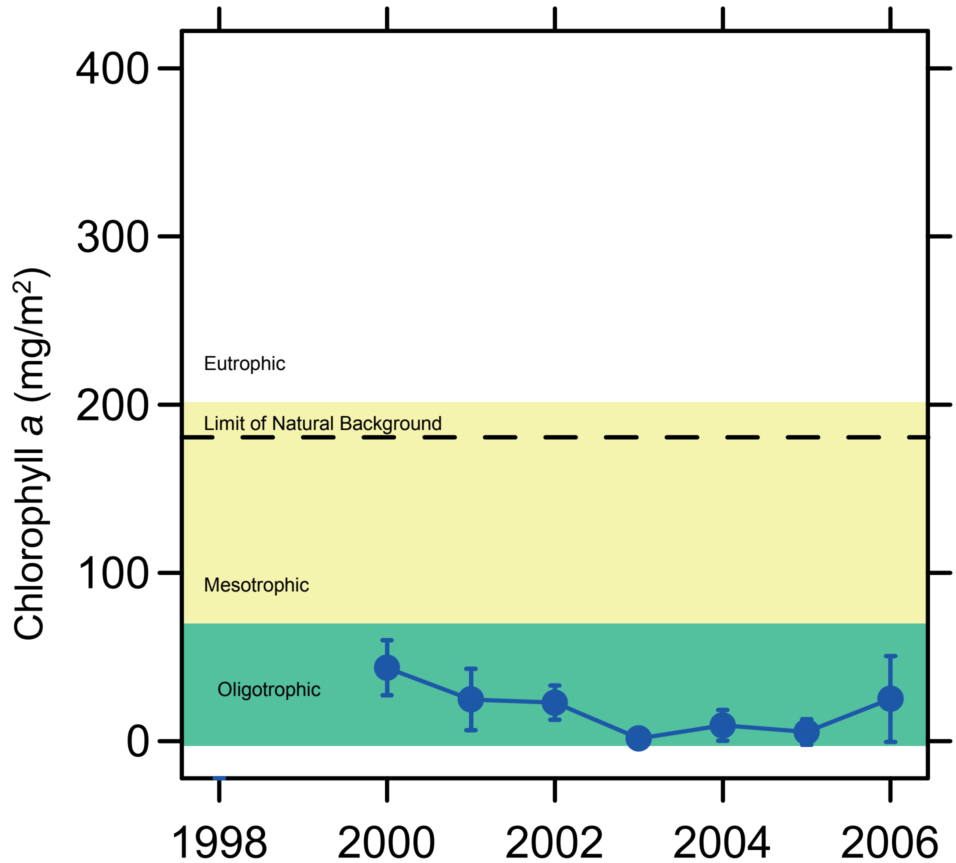


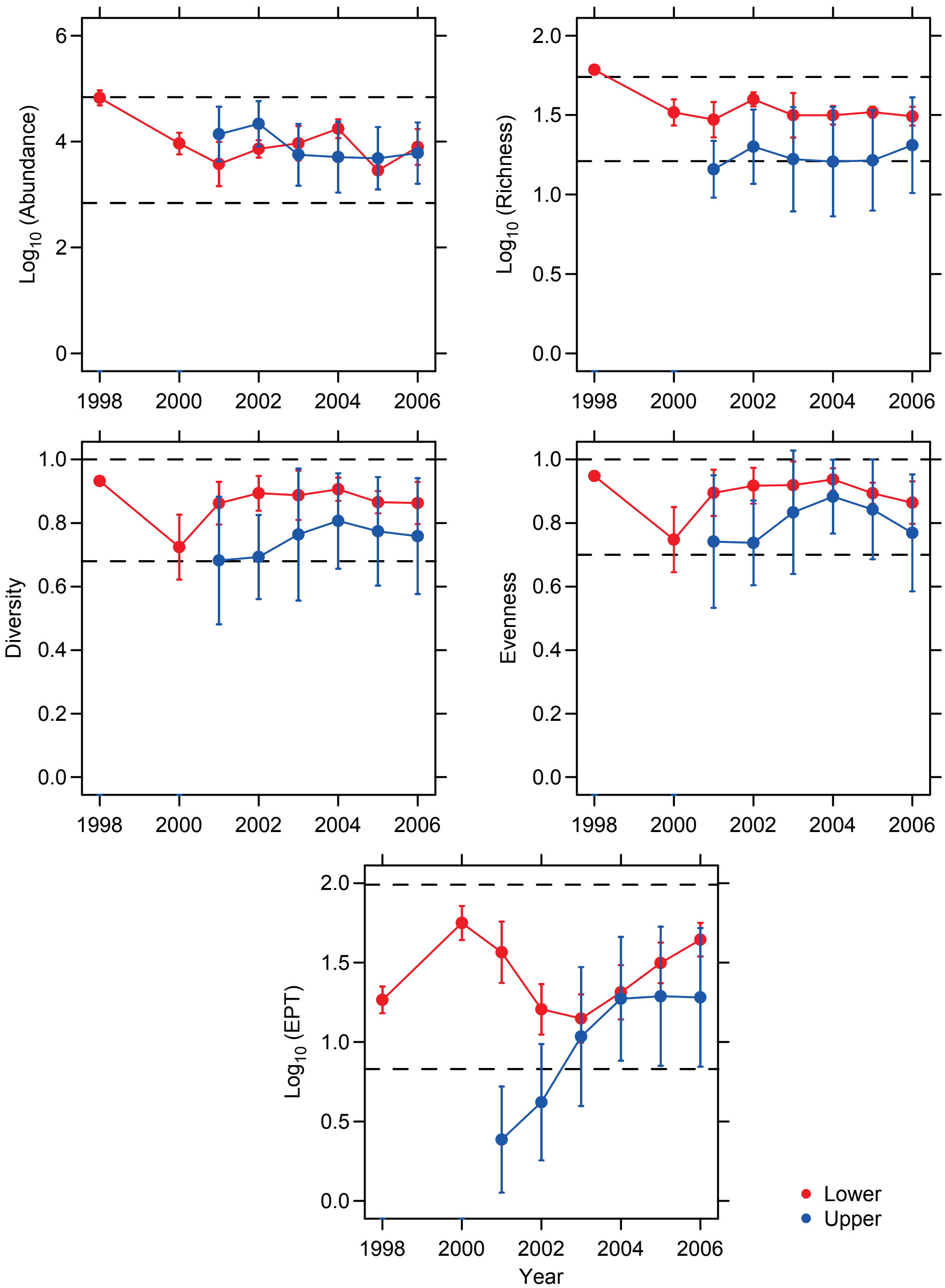
Table 5.3-12 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Muskeg River.

Taxon	Reach MUR-E-1								Reach MUR-D-2							Reach MUR-D-3				
	1998	2000	2001	2002	2003	2004	2005	2006	2000	2001	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
% Major Taxa Enumerated in Each Year																				
Amphipoda		<1		<1	<1					<1	<1	1	<1	<1	<1	<1	1	5	<1	1
Anisoptera	<1	<1	2	1	1	2	<1	<1	<1	<1	<1	<1		<1			<1	<1		
Bivalvia	6	1	3	5	1	3	2		4	1	3	1	1	<1		28	17	18	8	
Ceratopogonidae	1	<1	<1	1		<1	<1	1	1	1	2	3	7	4	2	<1	2	2	1	1
Chironomidae	32	31	23	37	58	37	20	31	75	84	69	81	74	44	55	66	65	27	79	54
Coleoptera	5	1	2	1	3	10	5	3	<1	<1	<1		<1	1	<1		<1	<1		
Copepoda	<1	<1	<1	2	<1	<1	1		<1	1	<1	<1	1	<1	<1		1	3	1	
Empididae	4	<1	2	2	3	6	22	1	<1	<1	<1	<1	1	1	1					
Enchytraeidae	<1	<1	1	<1	<1	1	1	<1	<1	1	2	2	3	3	<1		<1	1	<1	
Ephemeroptera	12	50	28	5	5	9	21	24	<1	1	2	1	<1	6	1		5	5	2	3
Gastropoda	3	<1	<1	<1	<1				<1	3	1	<1		<1	1	<1	1	2	<1	<1
Glossiphoniidae				<1					<1	<1	<1	<1			<1	<1	1	1	<1	3
Hydracarina	14	6	15	13	13		10	11	1	1	2	1	<1	<1	2	<1	1	<1	<1	
Lumbriculidae				<1	<1	<1			1	<1	<1	1		<1	<1		<1	1		1
Naididae	5	1	6	14	3	3	1	4	2	1	<1	2	1	11	1	<1	1	1	2	2
Nematoda	2	<1	4	2	3	5	2	1	2	1	6	3	3	6	1	1	2	6	3	4
Ostracoda	3	1	<1	3	<1			<1	1	2	5		<1	10	<1	4	1	7	1	
Plecoptera	4	6	5	5	3	8	8	5	<1	<1	<1	<1		<1	<1					
Trichoptera	2	1	8	5	4	4	2	16	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	1	
Tubificidae	5	<1	<1	1	1	13	5		10	<1	3	2	8	10	31	<1	2	15	2	15
Benthic Invertebrate Community Measurement Endpoints																				
Total Abundance (No./m^2)	68,374	9,983	4,953	7,754	11,343	18,757	2,849	11,131	59,328	64,032	34,672	12,635	10,440	11,948	26,888	9,905	13,566	7,190	15,887	6,039
Richness	60	32	29	39	32	31	32	30	26	30	21	14	10	17	24	12	17	9	11	15
Simpson's Diversity	0.93	0.72	0.86	0.89	0.89	0.91	0.87	0.86	0.75	0.84	0.86	0.7	0.68	0.78	0.69	0.64	0.78	0.71	0.75	0.84
Evenness	0.95	0.75	0.89	0.92	0.92	0.94	0.89	0.86	0.78	0.87	0.91	0.77	0.77	0.83	0.69	0.71	0.85	0.81	0.83	0.86
% EPT	18	57	39	16	14	21	31	44	<1	1	2	2	<1	5	1	<1	6	5	2	3

Table 5.3-13 Results of Analysis Of Variance (ANOVA) between the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.

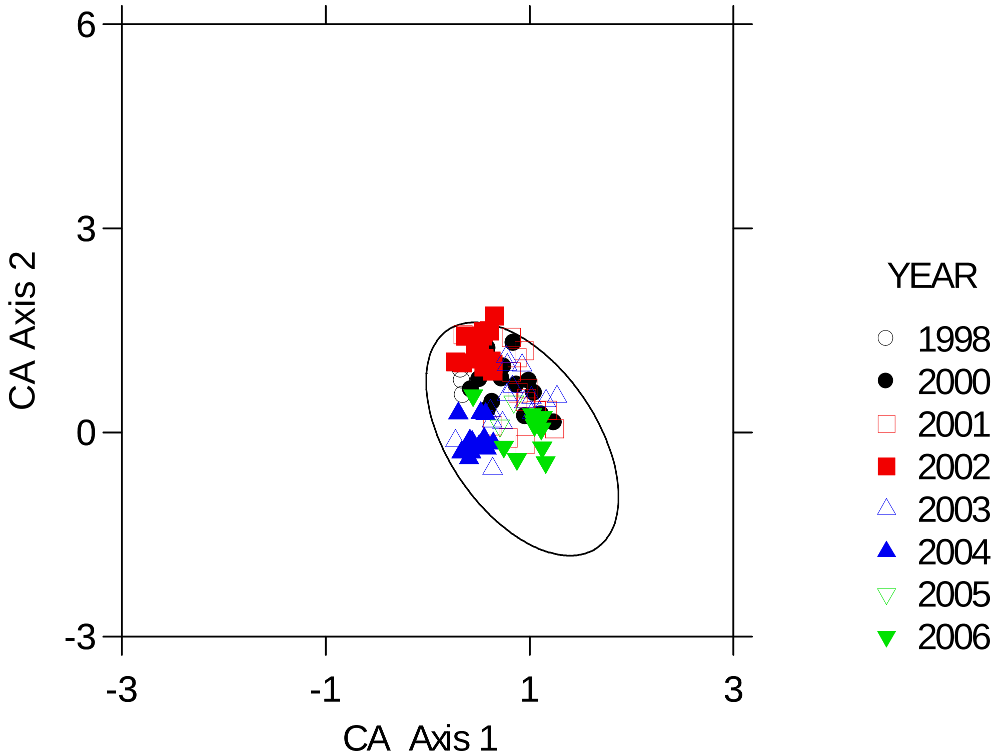
Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	8.55	12	6.87	<0.001
Reach (Upper vs Lower)	2.84	1	13.68	<0.001
Time (Linear Trend)	2.83	1	13.68	<0.001
Reach x Time (Linear)	3.33	1	16.06	<0.001
Reach (2006)	12.86	1	13.78	<0.001
Error	14.72	142		
Log_{10} Richness				
Reach-Year	7.65	12	37.790	<0.001
Reach (Upper vs Lower)	0.67	1	20.03	<0.001
Time (Linear Trend)	4.88	1	144.78	<0.001
Reach x Time (Linear)	0.69	1	20.48	<0.001
Reach (2006)	0.81	1	24.17	<0.001
Error	2.39	142		
Simpson's Diversity				
Reach	1.17	12	10.69	<0.001
Reach (Upper vs Lower)	0.12	1	6.42	0.002
Time (Linear Trend)	0.51	1	27.92	<0.001
Reach x Time (Linear)	0.14	1	7.45	<0.001
Reach (2006)	0.07	1	3.91	0.022
Error	2.39	142		
Evenness				
Reach	0.809	12	6.95	<0.001
Reach (Upper vs Lower)	0.050	1	2.65	0.073
Time (Linear Trend)	0.252	1	13.00	<0.001
Reach x Time (Linear)	0.096	1	4.96	0.008
Reach (2006)	0.027	1	1.43	0.243
Error	1.378	142		
Log_{10} EPT %				
Reach	51.39	12	47.75	<0.001
Reach (Upper vs Lower)	2.45	1	13.67	<0.001
Time (Linear Trend)	27.60	1	153.89	<0.001
Reach x Time (Linear)	0.68	1	3.83	<0.001
Reach (2006)	4.91	1	27.39	<0.001
Error	12.96	142		

Figure 5.3-7 Annual variation in benthic invertebrate community measurement endpoints in the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional sites.
Note: Lower: reach MUR-E-1; upper: reach MUR-D-3.

Figure 5.3-8 Ordination biplot for the lower reach of the Muskeg River (reach MUR-E-1).

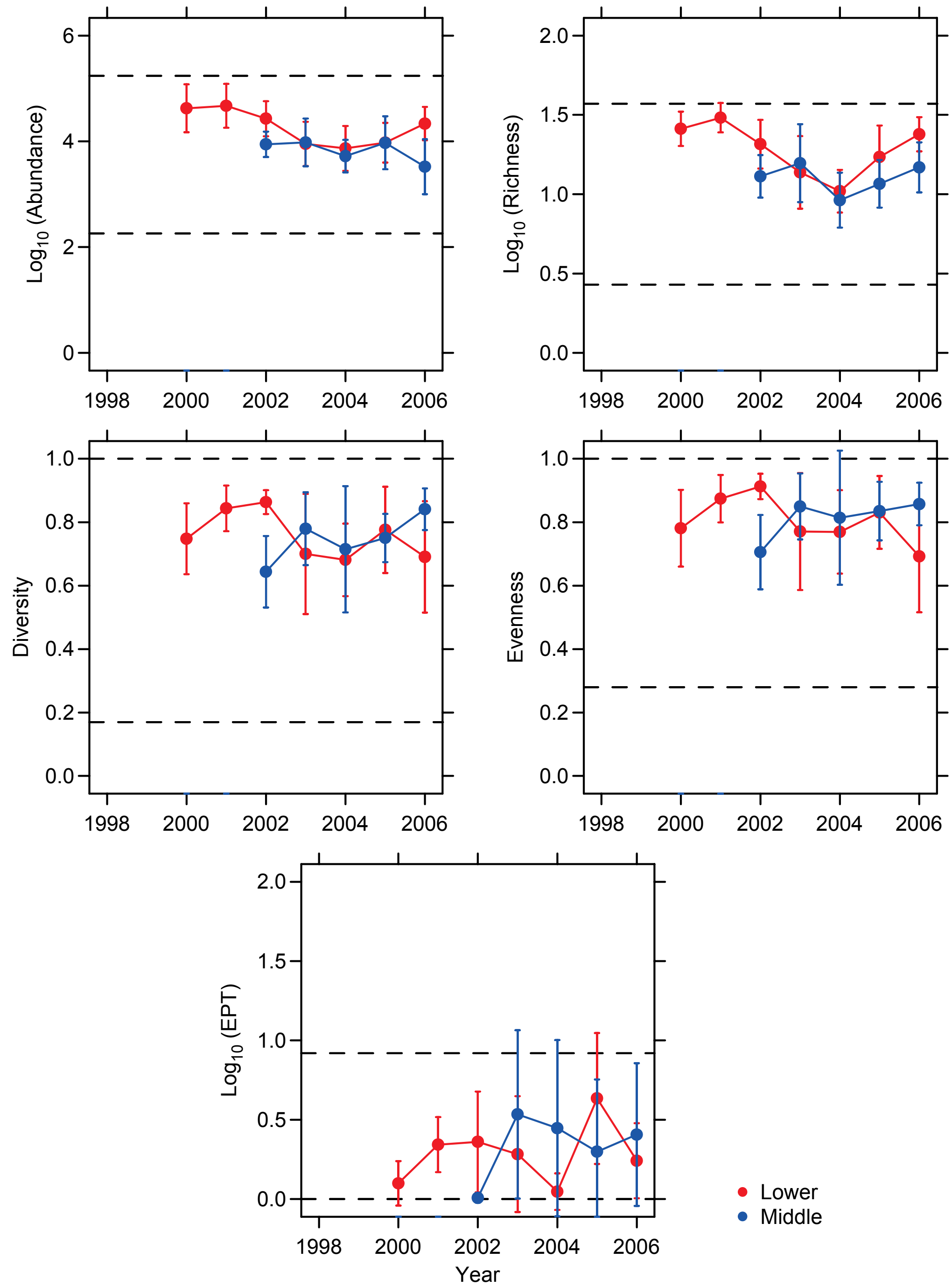


Note: ellipse is for the baseline erosional reaches.

Table 5.3-14 Analysis of variance (ANOVA) between middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.

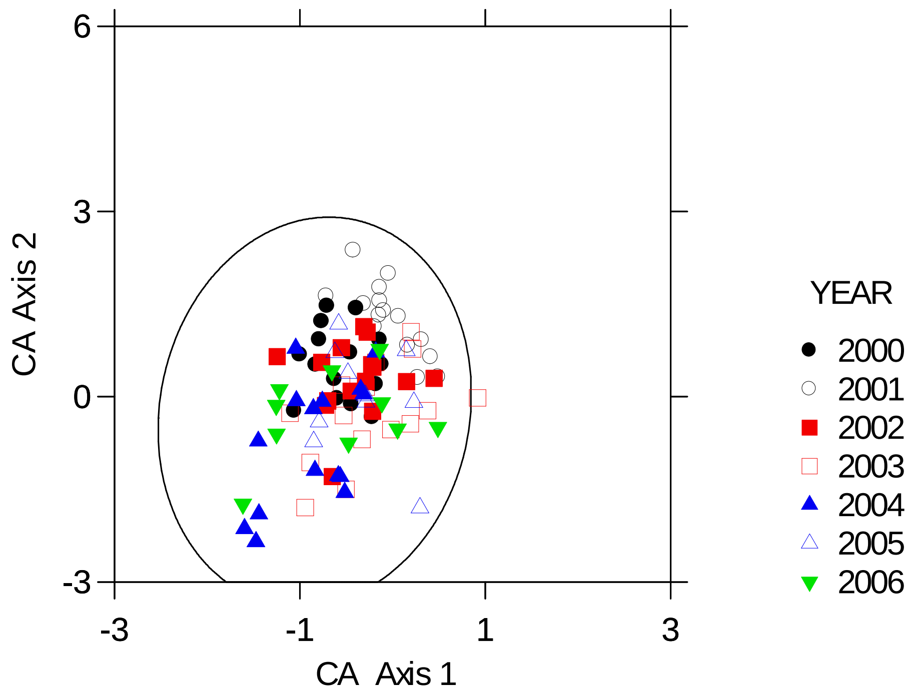
Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	18.76	11	11.61	<0.001
Reach	5.70	1	19.41	<0.001
Time (Linear Trend)	4.89	1	16.66	<0.001
Reach x Time (Linear)	4.99	1	16.97	<0.001
Reach (2006)	4.89	1	16.64	<0.001
Error	21.75	148		
Log_{10} Richness				
Reach-Year	4.10	11	14.95	<0.001
Reach	0.80	1	16.09	<0.001
Time (Linear Trend)	0.92	1	18.54	<0.001
Reach x Time (Linear)	0.69	1	13.88	<0.001
Reach (2006)	0.78	1	15.69	<0.001
Error	3.69	148		
Simpson's Diversity				
Reach	0.758	11	4.61	<0.001
Reach	0.165	1	5.53	0.005
Time (Linear Trend)	0.001	1	0.040	0.961
Reach x Time (Linear)	0.028	1	0.947	0.390
Reach (2006)	0.194	1	6.48	0.002
Error	2.213	148		
Evenness				
Reach	0.638	11	3.72	<0.001
Reach	0.227	1	7.28	0.001
Time (Linear Trend)	0.065	1	2.08	0.128
Reach x Time (Linear)	0.038	1	1.21	0.301
Reach (2006)	0.187	1	6.00	0.003
Error	2.311	148		
Log_{10} EPT %				
Reach	5.34	11	4.31	<0.001
Reach	0.27	1	2.44	0.120
Time (Linear Trend)	0.02	1	0.18	0.675
Reach x Time (Linear)	0.42	1	1.08	0.300
Reach (2006)	0.14	1	1.20	0.274
Error	16.67	148		

Figure 5.3-9 Annual variation in benthic invertebrate community measurement endpoints in the middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.
Note: Lower: reach MUR-D-2; upper: reach MUR-D-3.

Figure 5.3-10 Ordination biplot for the middle reach (MUR-D-2) of the Muskeg River.



Note: ellipse is for *reference* depositional reaches.

Table 5.3-15 Habitat characteristics of benthic invertebrate community sampling reaches in Jackpine Creek, fall 2006.

Variable	Units	Lower Reach of Jackpine Creek (JAC-D-1)	Upper Reach of Jackpine Creek (JAC-D-2)
Sample date	-	Sept 8 2006	Sept 16 2006
Habitat	-	Depositional	Depositional
Water depth	m	0.3	0.4
Current velocity	m/s	0.2	0.1
Macrophyte cover	%	4	10.4
Sand/Silt/Clay	%	99.5	97
Total Organic Carbon	%	n/a	1.8
Field Water Quality			
Dissolved oxygen	mg/L	8.4	8.5
Conductivity	µS/cm	315	294
pH	-	7.75	7.6
Water temperature	°C	12.9	12.32
Sediment Composition			
Sand	%	97	77
Silt	%	2	13
Clay	%	1	10
Total Organic Carbon	%	0.55	1.72

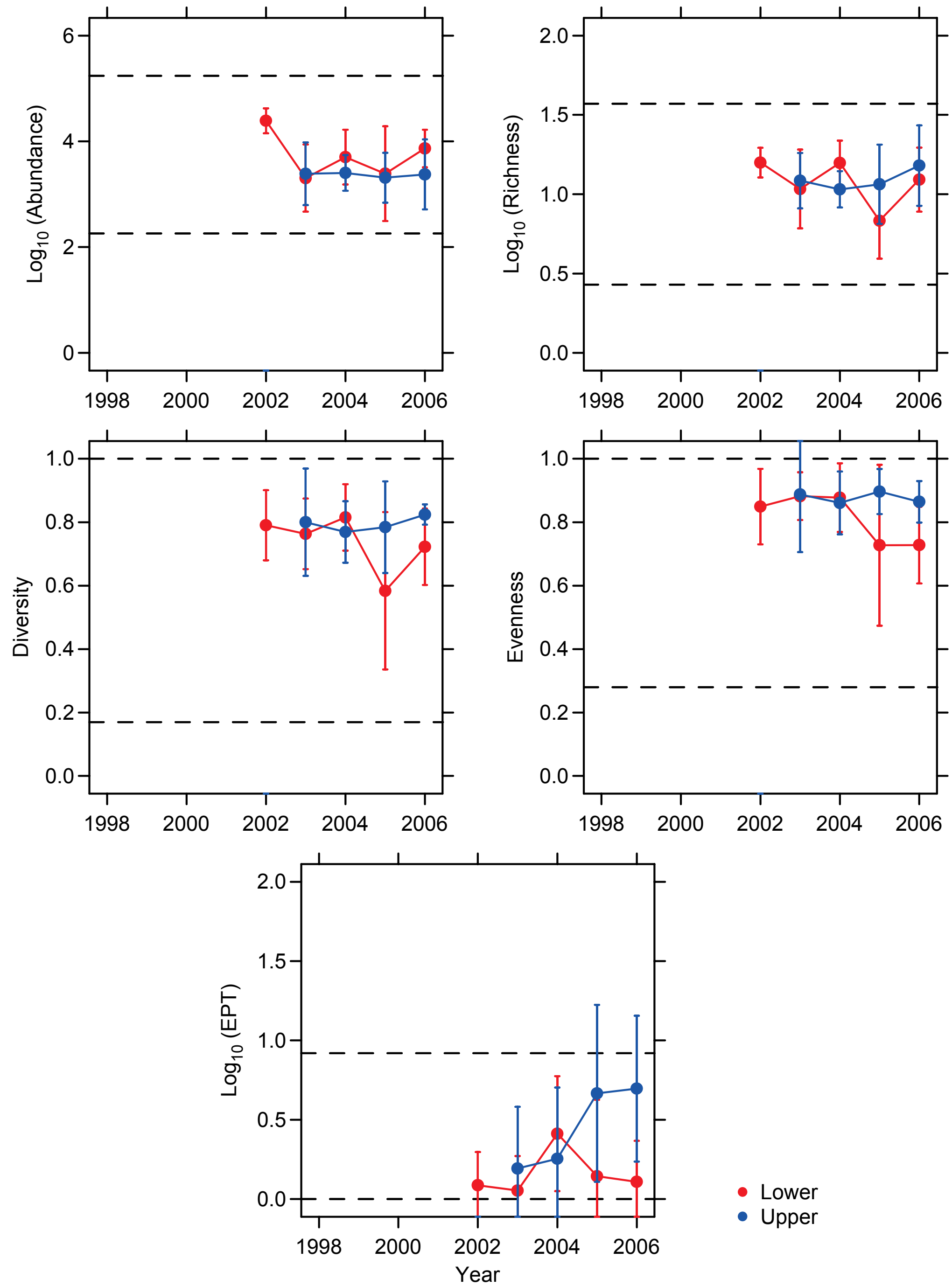
Table 5.3-16 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in Jackpine Creek.

Taxon	Reach JAC-D-1					Reach JAC-D-2			
	2002	2003	2004	2005	2006	2003	2004	2005	2006
% Major Taxa Enumerated in Each Year									
Amphipoda		<1	<1						
Anisoptera	<1	<1	<1		1			<1	
Bivalvia	1	3	<1	<1	<1	<1	<1	<1	<1
Ceratopogonidae	2	2	4		5	1	31	4	2
Chironomidae	88	66	69	69	86	67	3	44	63
Chydoridae			8		<1		<1		
Coleoptera		<1	<1			6	3	6	1
Copepoda	<1	1	6	1			2	3	
Empididae	<1	2	2	4	2	1	<1	3	3
Enchytraeidae	<1	4	<1			1	1	1	2
Ephemeroptera	<1		2	1	1	<1	2	1	6
Ephydridae		<1				<1	<1		
Gastropoda	<1		<1					<1	<1
Glossiphoniidae		<1							
Hydra			<1						
Hydracarina	1	1	1	8	1	<1	<1	18	1
Naididae	<1	2	2		1	3	1	1	2
Nematoda	5	6	1	4	2	6	4	2	4
Ostracoda	<1		2	4		<1	1	3	1
Plecoptera					1	<1			
Tabanidae	<1	<1	<1	<1	<1	1	2	<1	<1
Tipulidae	<1	2	1	1	1	1	13	4	2
Trichoptera	<1	<1	<1	3	<1	<1	1	7	1
Tubificidae	<1	<1	1	5	<1	2	5	1	2
Benthic Invertebrate Community Measurement Endpoints									
Total Abundance (No./m^2)	28,172	4,017	9,230	7,417	9,331	4,787	3,448	2,957	5,012
Richness	15	11	15	7	12	12	10	12	16
Simpson's Diversity	0.79	0.76	0.81	0.58	0.72	0.8	0.77	0.78	0.82
Evenness	0.85	0.88	0.88	0.73	0.73	0.89	0.86	0.9	0.86
% EPT	<1	<1	2	3	<1	2	2	7	6

Table 5.3-17 Analysis of variance between lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.

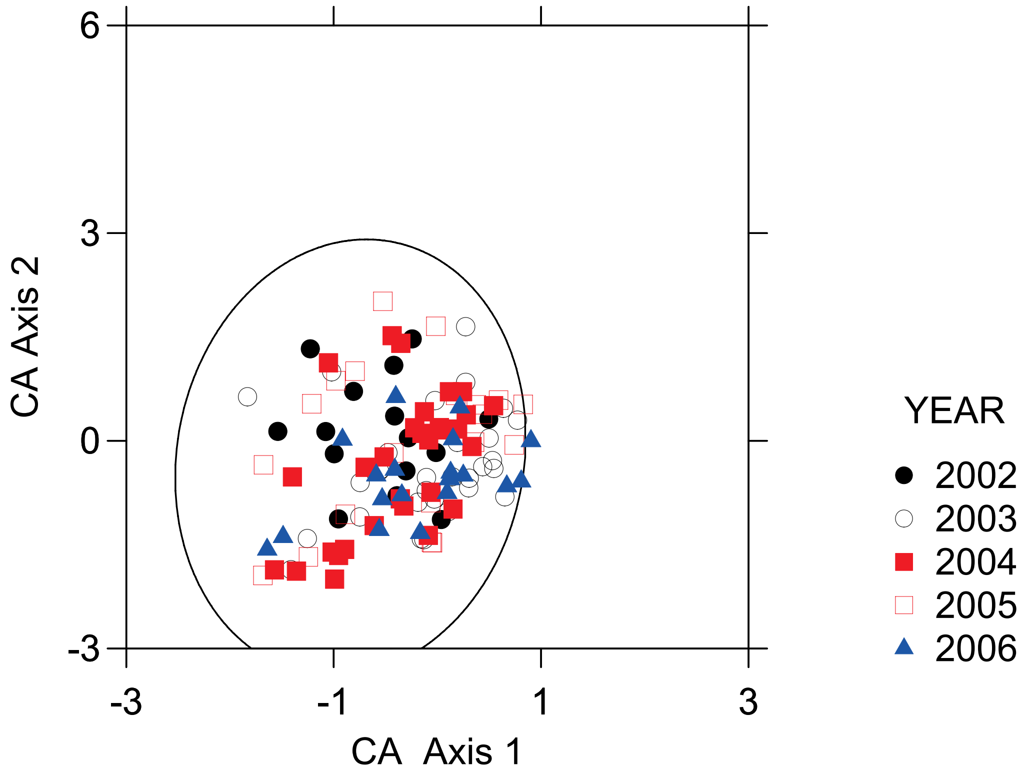
Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	14.47	8	6.76	<0.001
Reach	0.92	1	3.44	0.066
Before to After	0.66	1	2.45	0.120
Reach x Before to After	0.61	1	2.28	0.134
Reach (2006)	1.20	1	4.48	0.037
Error	28.35	106		
Log_{10} Richness				
Reach-Year	1.203	8	4.50	<0.001
Reach	0.062	1	1.85	0.176
Before to After	0.146	1	4.40	0.038
Reach x Before to After	0.010	1	0.29	0.589
Reach (2006)	0.039	1	1.16	0.284
Error	3.540	106		
Simpson's Diversity				
Reach	0.451	8	3.43	0.001
Reach	0.129	1	7.84	0.006
Before to After	0.007	1	0.41	0.521
Reach x Before to After	0.006	1	0.34	0.559
Reach (2006)	0.052	1	3.13	0.079
Error	1.742	106		
Evenness				
Reach	0.372	8	2.94	0.005
Reach	0.130	1	8.22	0.005
Before to After	0.056	1	3.52	0.063
Reach x Before to After	0.028	1	1.76	0.187
Reach (2006)	0.092	1	5.88	0.017
Error	1.675	106		
Log_{10} EPT %				
Reach	5.40	8	5.08	<0.001
Reach	1.78	1	13.41	<0.001
Before to After	0.21	1	1.60	0.209
Reach x Before to After	0.70	1	5.26	0.024
Reach (2006)	1.77	1	12.97	<0.001
Error	14.08	108		

Figure 5.3-11 Annual variation in benthic invertebrate community measurement endpoints in lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.



Notes: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches.
Lower: reach JAC-D-1; upper: reach JAC-D-2.

Figure 5.3-12 Ordination biplot for the lower reach (reach JAC-D-1) of Jackpine Creek.



Note: ellipse is for *reference* depositional reaches.

Table 5.3-18 Concentrations of selected sediment quality measurement endpoints in middle reach of the Muskeg River, near the Canterra Road crossing (reach MUR-D-2), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station MUR-2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1	3	4	8	12
Silt	%	-	19	3	13	16	22
Sand	%	-	80	3	72	74	79
Total organic carbon	%	-	3.6	4	2.1	2.75	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<5	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<10	2	<5	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	110	2	<5	-	**160**
Fraction 3 (C16-C34)	mg/kg	400[2]	**1200**	2	**1800**	-	**2900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1100	2	1400	-	1600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0023	4	0.0016	0.0110	0.020
Retene	mg/kg	-	0.146	4	<0.21	0.1635	0.285
Total dibenzothiophenes	mg/kg	-	2.81	4	3.28	5.69	10.63
Total PAHs	mg/kg	-	7.84	4	14.27	18.11	30.44
Total HMW PAHs	mg/kg	-	2.11	4	3.40	4.85	9.63
Total LMW PAHs	mg/kg	-	5.73	4	10.87	13.26	20.81
Predicted PAH toxicity[1]	H.I.	-	0.95	4	1.18	1.53	1.75
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	3	6	7	7
Chironomus growth - 10d	mg/organism	-	2.1	3	0.68	2.5	2.5
Hyalella survival - 14d	# surviving	-	8	3	8	8	8
Hyalella growth - 14d	mg/organism	-	0.2	3	0.11	0.18	0.35

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-19 Concentrations of selected sediment quality measurement endpoints in upper reach of the Muskeg River (reach MUR-D-3), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station MUR-D2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	40	3	5	6	7
Silt	%	-	29	3	10	14	15
Sand	%	-	31	3	79	80	85
Total organic carbon	%	-	24.9	3	1.7	5.5	24.7
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	<5	-	130
Fraction 3 (C16-C34)	mg/kg	400[2]	52	2	**540**	-	**1900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	630	2	210	-	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0065	3	0.0031	0.0039	0.0145
Retene	mg/kg	-	0.339	3	0.156	0.398	0.498
Total dibenzothiophenes	mg/kg	-	0.19	3	0.10	0.12	0.13
Total PAHs	mg/kg	-	1.27	3	0.67	1.12	1.26
Total HMW PAHs	mg/kg	-	0.28	3	0.20	0.31	0.51
Total LMW PAHs	mg/kg	-	0.99	3	0.47	0.75	0.82
Predicted PAH toxicity[1]	H.I.	-	0.72	3	0.15	0.32	0.56
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6	3	3	7	8
Chironomus growth - 10d	mg/organism	-	1.9	3	1.43	1.8	2.2
Hyalella survival - 14d	# surviving	-	8	3	7	7	8
Hyalella growth - 14d	mg/organism	-	0.3	3	0.11	0.2	0.34

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-20 Concentrations of selected sediment quality measurement endpoints in lower reach of the Jackpine River (reach JAC-D-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station JAC-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	2	3	-	18.7
Silt	%	-	1	2	0.3	-	11
Sand	%	-	99	2	81	-	87
Total organic carbon	%	-	0.2	2	1.1	-	2
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	13	1	-	-	17
Fraction 3 (C16-C34)	mg/kg	400[2]	150	1	-	-	**450**
Fraction 4 (C34-C50)	mg/kg	2800[2]	210	1	-	-	530
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0016	2	<0.003	-	<0.0026
Retene	mg/kg	-	0.0072	1	-	-	0.0614
Total dibenzothiophenes	mg/kg	-	0.10	2	0.72	-	1.64
Total PAHs	mg/kg	-	0.41	2	2.13	-	4.49
Total HMW PAHs	mg/kg	-	0.17	2	0.49	-	1.26
Total LMW PAHs	mg/kg	-	0.24	2	1.65	-	3.24
Predicted PAH toxicity[1]	H.I.	-	0.30	2	0.21	-	1.13
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	7
Chironomus growth - 10d	mg/organism	-	2.4	1	-	-	3.2
Hyalella survival - 14d	# surviving	-	9	1	-	-	7
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.14

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-21 Concentrations of selected sediment quality measurement endpoints in upper reach of the Jackpine River (reach JAC-D-2), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	13	-	-	-	-
Silt	%	-	21	-	-	-	-
Sand	%	-	66	-	-	-	-
Total organic carbon	%	-	1.9	-	-	-	-
Total hydrocarbons							
BTEX	mg/kg	-	<10	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<10	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	160	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	89	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0022	-	-	-	-
Retene	mg/kg	-	0.0331	-	-	-	-
Total dibenzothiophenes	mg/kg	-	0.01	-	-	-	-
Total PAHs	mg/kg	-	0.12	-	-	-	-
Total HMW PAHs	mg/kg	-	0.04	-	-	-	-
Total LMW PAHs	mg/kg	-	0.08	-	-	-	-
Predicted PAH toxicity[1]	H.I.	-	0.18	-	-	-	-
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	10	-	-	-	-
Chironomus growth - 10d	mg/organism	-	2.3	-	-	-	-
Hyalella survival - 14d	# surviving	-	8	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.3	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-22 Daily fish counts at the Muskeg River counting fence, spring 2006.

Date (m/d/y)	Downstream Migration							Upstream Migration								Grand Total
	LKWH	LNSC	MNWH	NRPK	WALL	WHSC	Total	ARGR	LKWH	LNSC	MNWH	NRPK	WALL	WHSC	Total	
4/19/2006				1		2	3					5			5	8
4/20/2006						1	1			12		8		1	21	22
4/21/2006		1		1			2			5		1		3	9	11
4/22/2006				1		1	2			1		2			3	5
4/23/2006				1		1	2					3			3	5
4/24/2006										1		4			5	5
4/25/2006				1			1			52		11		7	70	71
4/26/2006										23		9		6	38	38
4/27/2006		1					1			9		5		4	18	19
4/28/2006										59		11		24	94	94
4/29/2006										4		5		1	10	10
4/30/2006												3			3	3
5/1/2006		1		1			2			9		7		1	17	19
5/2/2006										1		1		1	3	3
5/4/2006														11	11	11
5/5/2006				1			1	1		4		2			7	8
5/6/2006										120		7		42	169	169
5/7/2006										200		11		83	294	294
5/8/2006										68		8		48	124	124
5/9/2006										38	1	3		82	124	124
5/10/2006								1		20		3		32	56	56
5/11/2006										6		7		13	26	26
5/12/2006		1					1		1	15		2		23	41	42
5/13/2006	1		1				2		2	6		4		14	26	28
5/14/2006		2		1		2	5		2	7				4	13	18
5/15/2006									2	1				4	7	7
5/16/2006						1	1			3			1	6	10	11
5/17/2006										2		4		7	13	13
5/18/2006						1	1			2	1	1	1	5	10	11
5/19/2006					1		1									1
Grand Total	1	6	1	8	1	9	26	2	7	668	2	127	2	422	1230	**1256**

Table 5.3-23 Summary of mark/recapture data for dominant fish species captured at the Muskeg River fish fence, spring 2006.

Species	Status	Direction of Migration	No. of fish			Total[1]
			Male	Female	Unknown	
Longnose Sucker	Captured		235	251	188	674
	Tagged	Upstream	176	176	113	465
		Downstream	1	0	1	2
		Total Tagged[3]	177	176	114	467
	Recaptured (of Tagged)	Downstream	3	5	6	14
		Upstream	0	0	0	0
		Total	3	5	6	14
		% of Tagged	1.7%	2.8%	5.3%	3.0%
White Sucker	Captured [2]		159	230	42	431
	Tagged	Upstream	137	213	30	380
		Downstream	1	2	4	7
		Total Tagged[3]	138	215	34	387
	Recaptured (of Tagged)	Downstream	5	5	2	12
		Upstream	0	1	1	2
		Total	5	6	3	14
		% of Tagged	3.6%	2.3%	6.7%	3.2%
Northern Pike	Captured		50	36	49	135
	Tagged	Upstream	49	35	33	117
		Downstream	1	1	4	8
		Total Tagged[3]	50	36	37	125
	Recaptured (of Tagged)	Downstream	5	5	6	16
		Upstream	2	0	2	4
		Total	7	5	8	20
		% of Tagged	10.2%	14.3%	18.2%	13.7%

[1] Percent tagged of total fish from three dominant species captured = 79%

[2] All individual fish captured not including recaptures

[3] Represents percent tagged fish released upstream of the fence and recaptured in the downstream box

Figure 5.3-13 Timing of the longnose sucker migration in the Muskeg River, spring 2006.

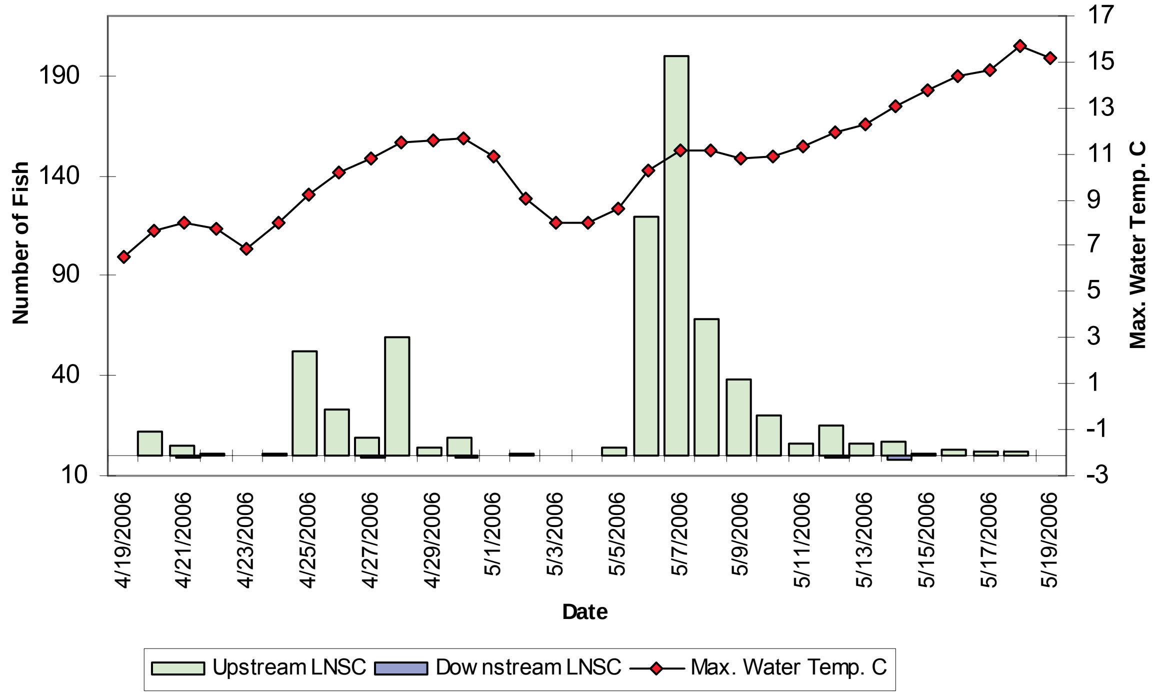


Figure 5.3-14 Timing of white sucker migration in relation to water temperature in the Muskeg River, May 2006.

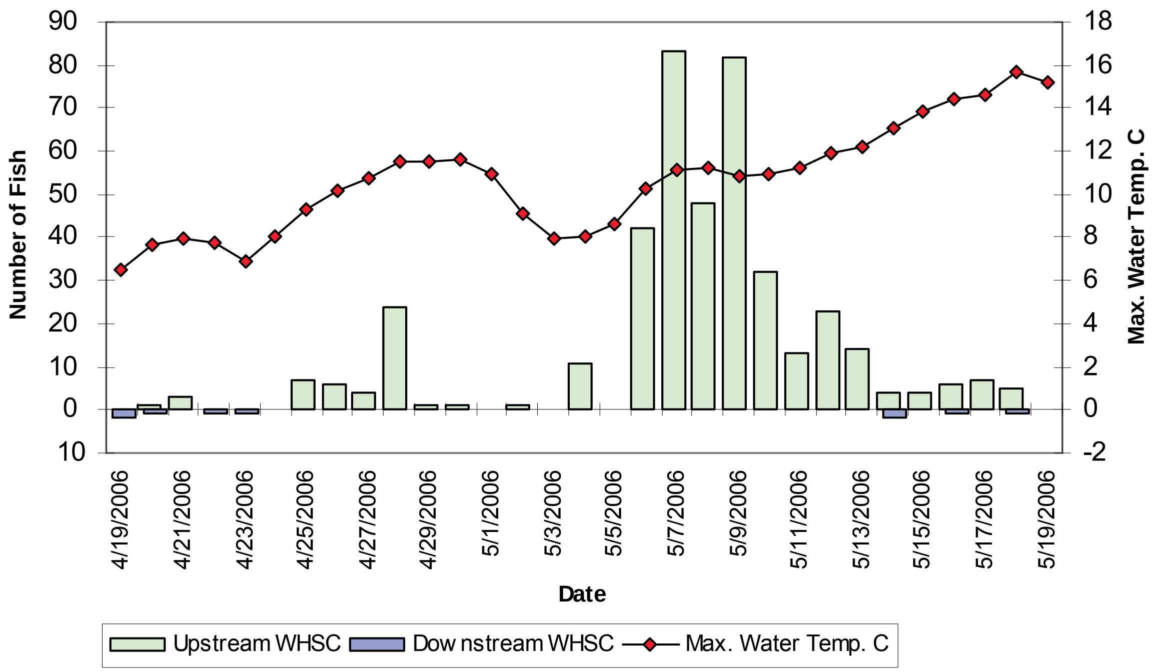


Figure 5.3-15 Timing of the northern pike migration in the Muskeg River fish fence, spring 2006.

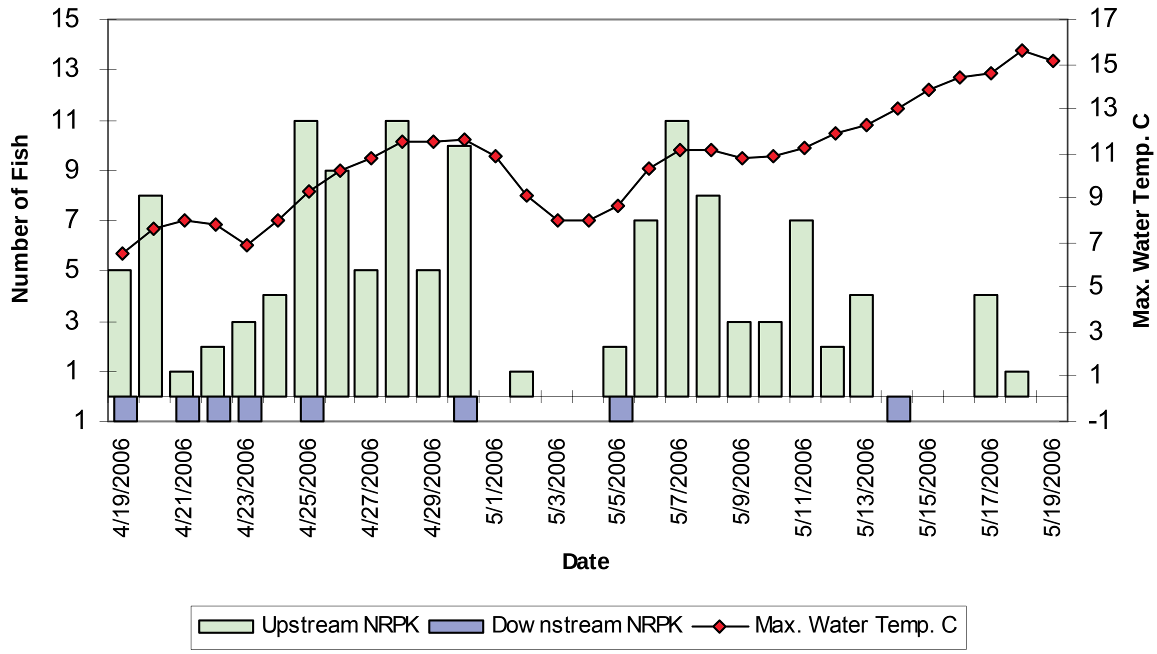


Table 5.3-24 Summary of residency time of fish tagged at the Muskeg River fish fence, spring 2006.

Species	Gender	Residency Time (Number of Days)			
		Migrants[1]		Recaptures[2]	
		Range	Average	Range[3]	Average
White Sucker	Male	1 - 28	10.7	0.5 - 1	0.6
	Female	1 - 29	11.5	0.5 - 21	4
	Unknown	1 - 30	13.4		
Longnose Sucker	Male	2 - 29	15.0	0.5 - 5	2
	Female	2 - 29	13.9	0.5 – 3	1.1
	Unknown	1 - 29	13.6		
Northern Pike	Male	2 – 30	19.7	0.5 - 9	3.1
	Female	2 – 24	14.8	0.5 - 17	3.9
	Unknown	1 – 30	17.2		

[1] Minimum residence time shown. These migrants did not return downstream before the fish fence program finished, therefore minimum residence is the number of days between first capture and the end of the program (May 19 2006).

[2] Actual residence time between first capture and recapture. Note that low residency times may be a reflection of fish fatigue; a small number of fish, after being caught and processed moving upstream, were immediately (less than 12 hrs) caught in the downstream trap.

[3] A residency time of 0.5 days indicates fish being recaptured on the same day.

Figure 5.3-16 Length-frequency distribution of longnose sucker caught at the Muskeg River fish fence, spring 2006.

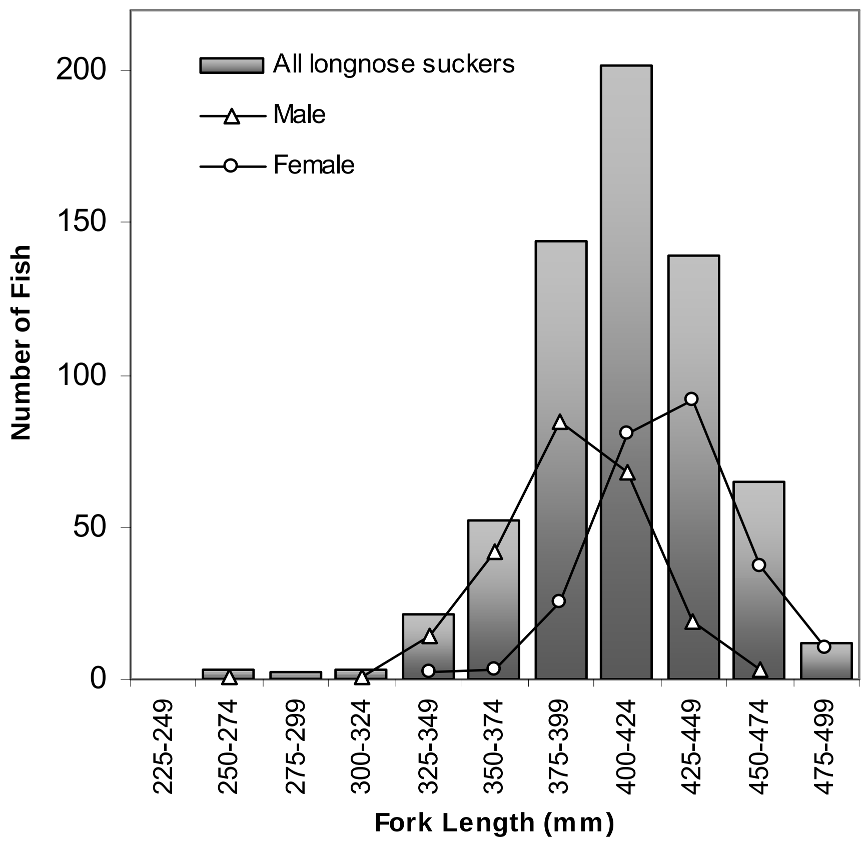


Figure 5.3-17 Weight-length relationship for male and female longnose sucker, Muskeg River fish fence program, spring 2006.

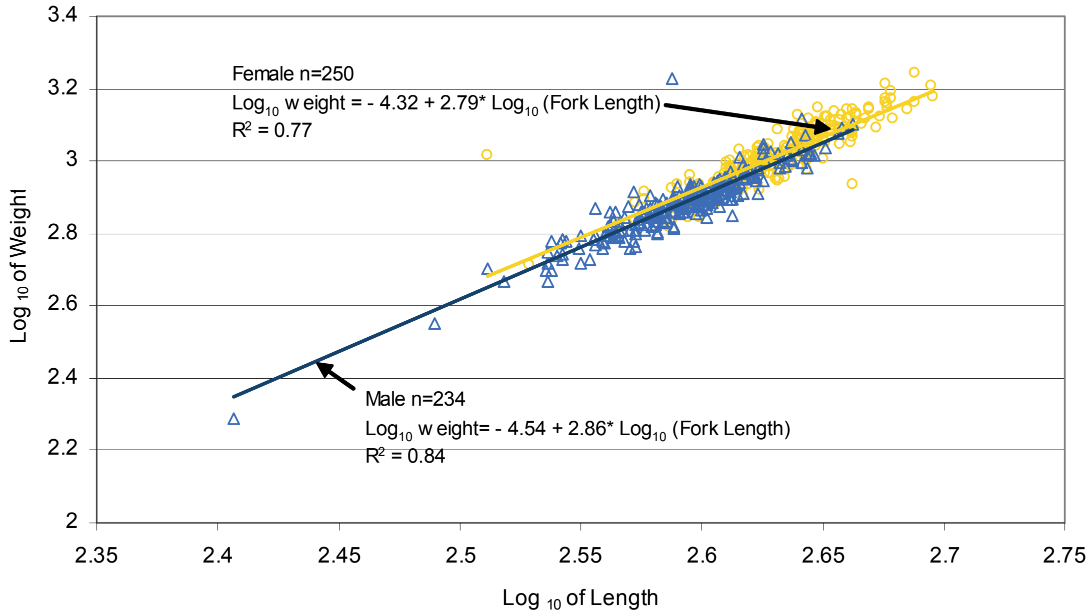


Figure 5.3-18 Age composition for longnose sucker sampled at the Muskeg River fish fence, spring 2006.

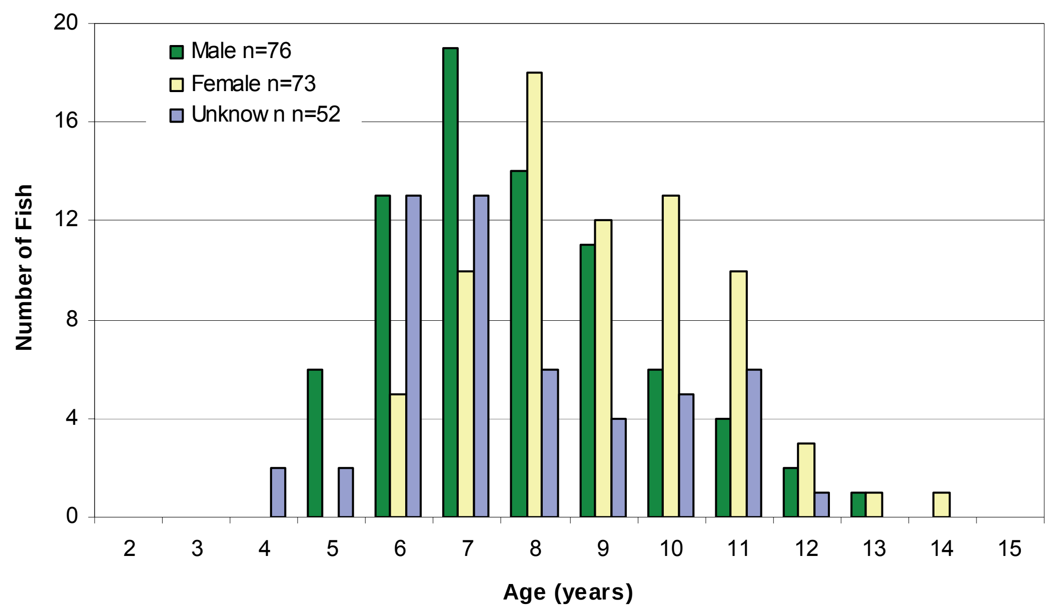


Figure 5.3-19 Length-at-age relationship by gender for longnose sucker sampled at the Muskeg River fish fence, spring 2006.

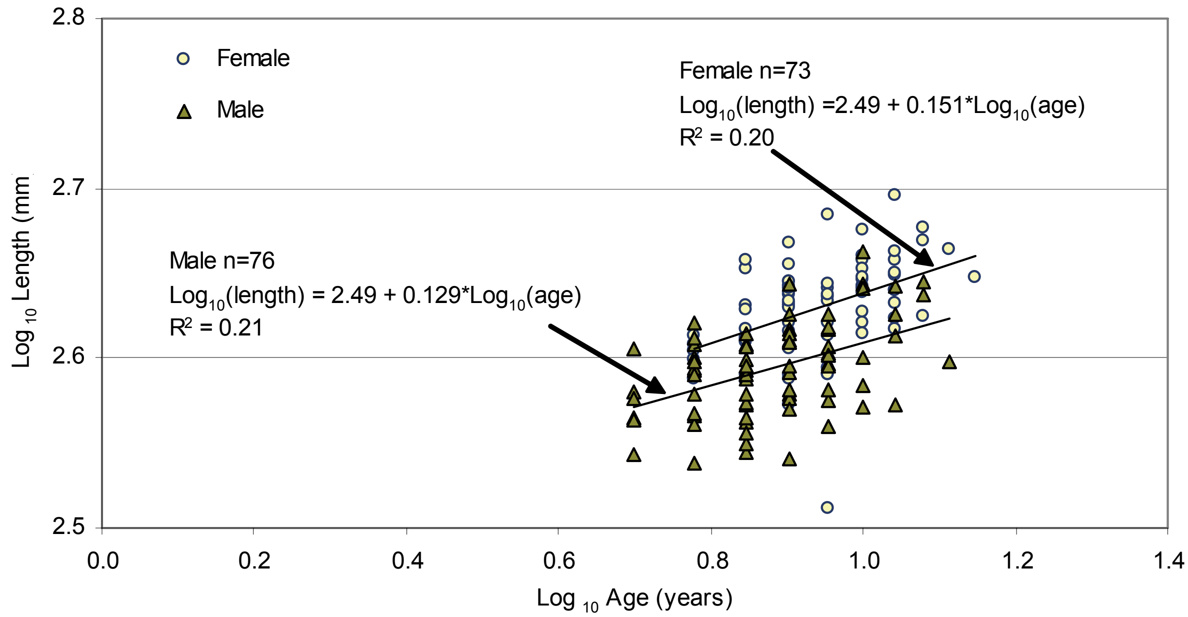


Figure 5.3-20 Length-frequency distribution of white sucker caught at the Muskeg River fish fence, spring 2006.

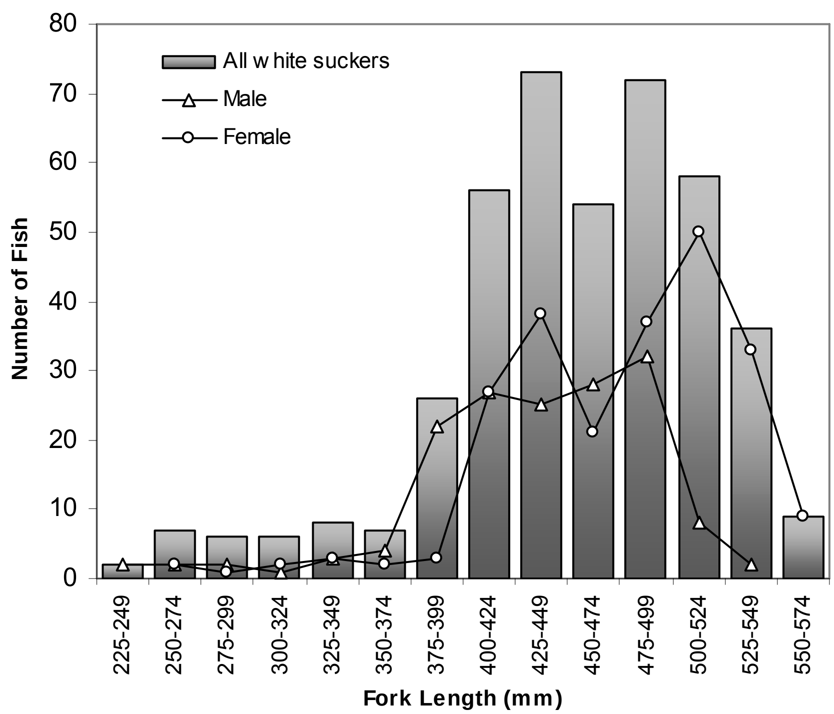


Figure 5.3-21 Weight-length relationships for male and female white sucker, Muskeg River fish fence, spring 2006.

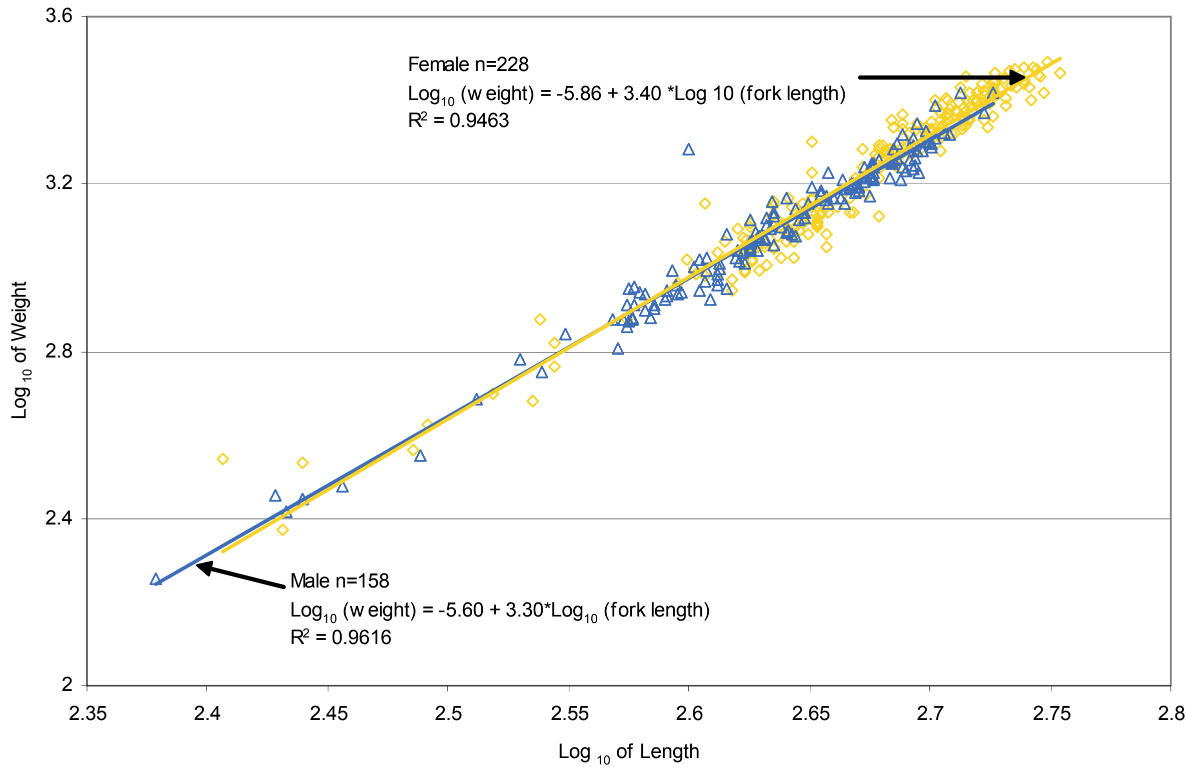


Figure 5.3-22 Age composition of white sucker sampled at the Muskeg River fish fence, spring 2006.

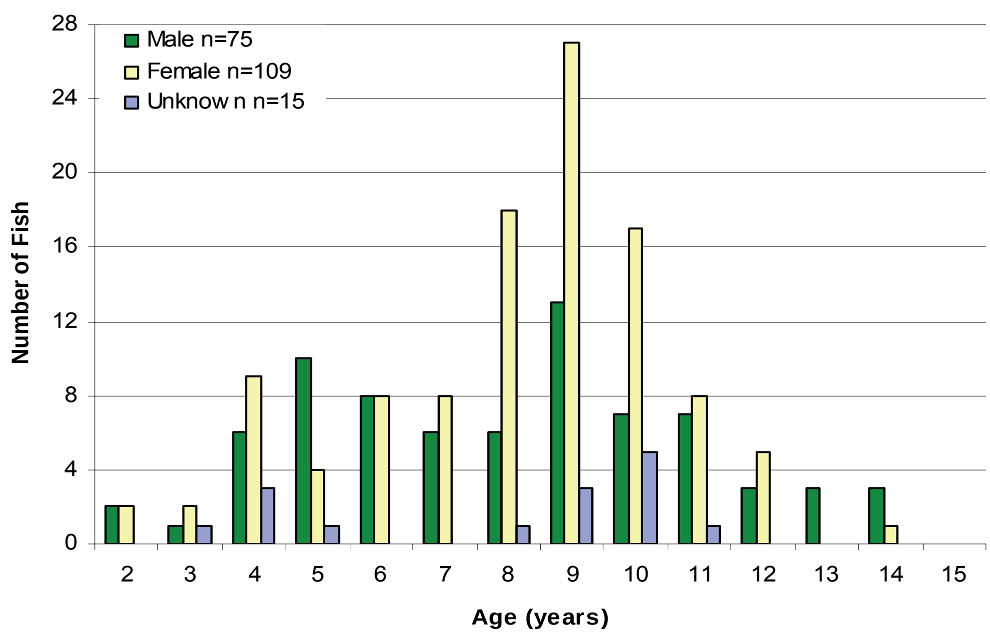


Figure 5.3-23 Length-at-age relationship by gender for white sucker sampled at the Muskeg River fish fence, spring 2006.

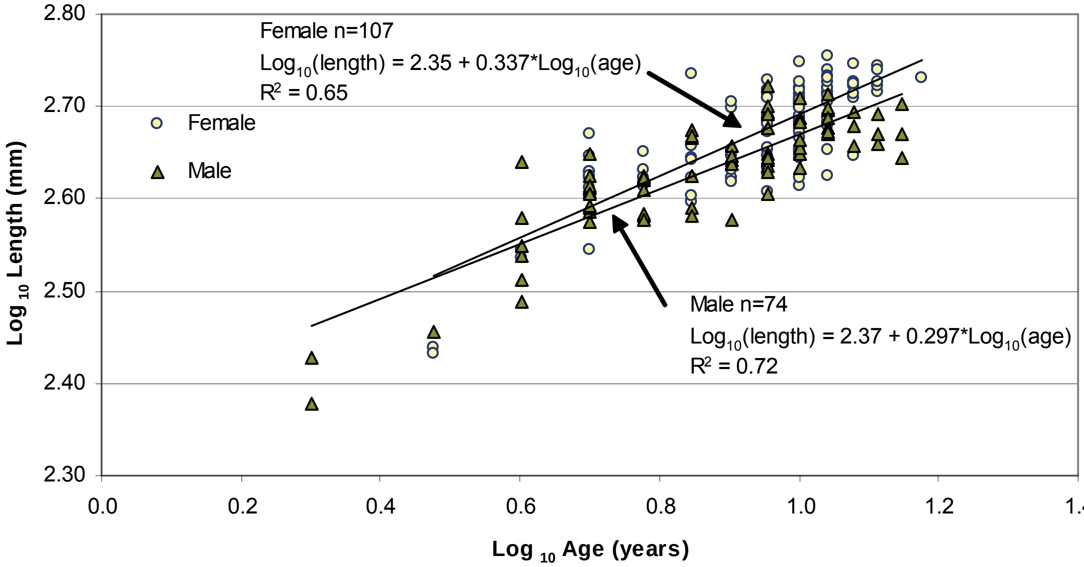


Figure 5.3-24 Length-frequency distribution for northern pike caught at the Muskeg River fish fence, spring 2006.

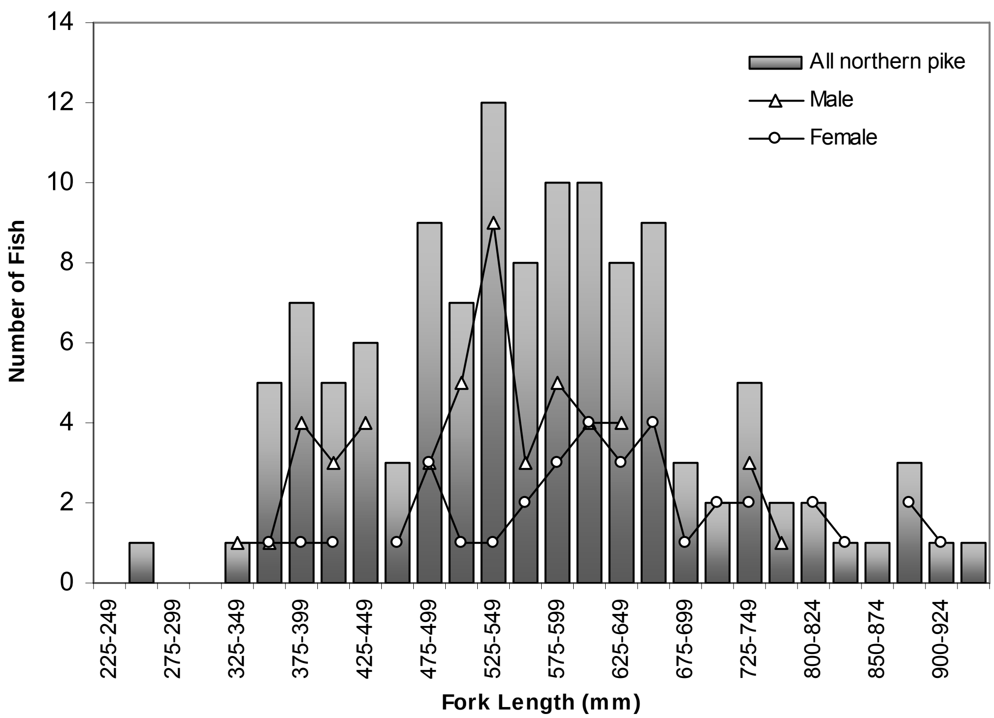


Figure 5.3-25 Weight-length relationships for male and female northern pike, Muskeg River fish fence, spring 2006.

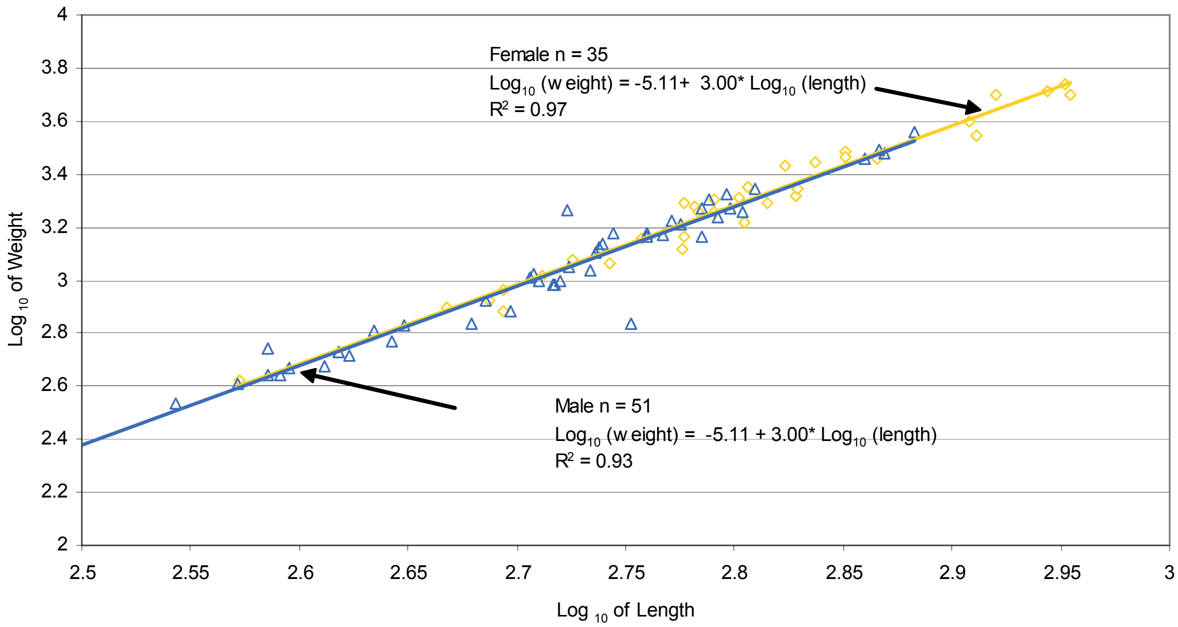


Figure 5.3-26 Age composition for northern pike sampled at the Muskeg River fish fence, spring 2006.

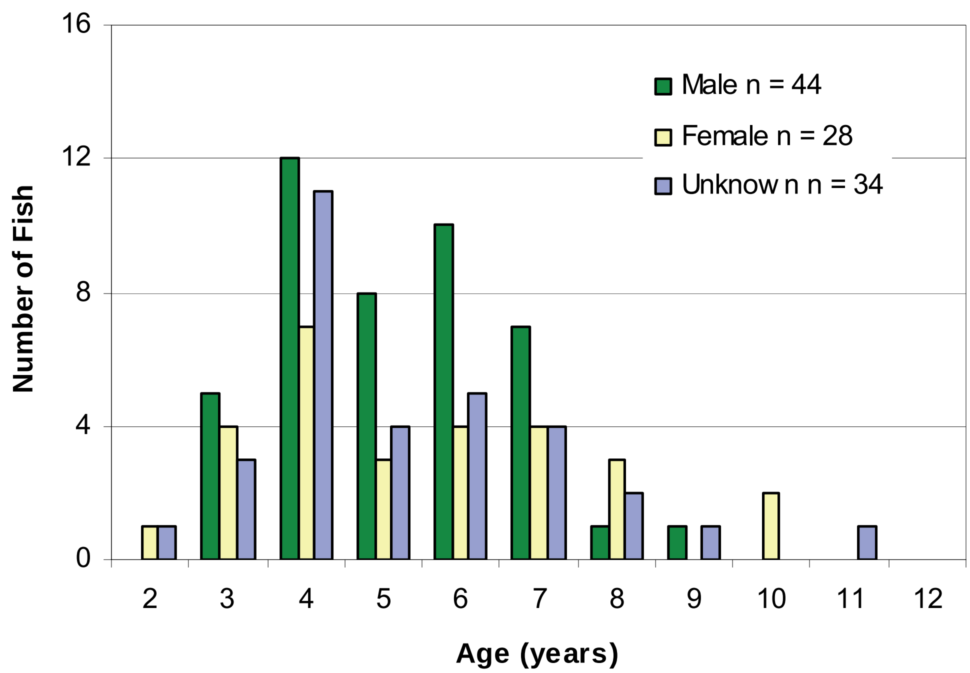


Figure 5.3-27 Length-at-age relationship by gender for northern pike sampled at the Muskeg River fish fence, spring 2006.

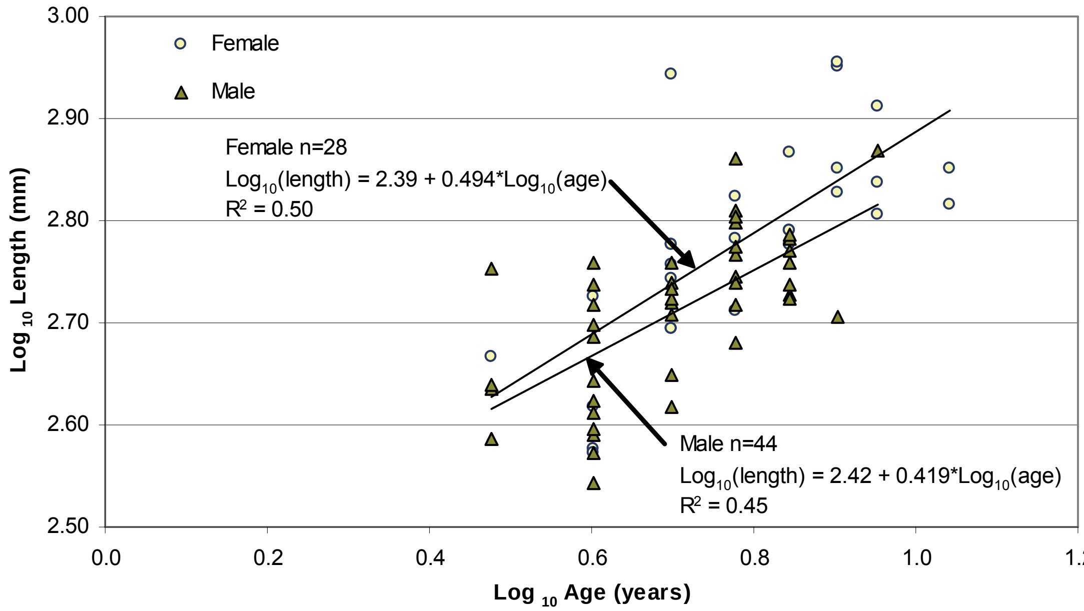


Table 5.3-25 Number of fish with specific external abnormalities for the three dominant fish species captured at the Muskeg River fish fence, spring 2006.

External Examination	Observation and EPI Value	Longnose sucker	White sucker	Northern Pike	Total
Fin Erosion	Light (10)	18	66	8	92
	Moderate (20)	4	15	4	23
	Severe (30)	2	0	1	3
Skin Aberration /Lesion	Mild (10)	26	68	10	104
	Moderate (20)	13	19	1	33
	Severe (30)	3	9	1	12
Eyes	Swollen/Growth (30)	0	2	0	2
Opercles shortening	Mild (30)	1	5	1	7
	Severe (30)	1	1	1	3
Body Deformities	Presence (30)	0	0	0	0
Sample Size		640	419	125	1184
% affected by abnormalities		13.3	52.5	36.0	29.6
EPI Mean Value		1.5	5.9	3.2	
Ectoparasites	Presence[a]	4	19	3	26

Note: An individual fish may exhibit more than one type of abnormality

[a] Incidence of ectoparasite infestation was not included as part of the EPI calculation

Table 5.3-26 Data on incidental fish species caught at the Muskeg River fish fence, spring 2006.

Species	Date	Fork Length (mm)	Weight (g)	Condition Factor	Sex	State of Maturity	Age	Migration Direction
ARGR	5/5/06	302	285	1.03	Unknown	Maturing	4	Up
ARGR	5/10/06	288	260	1.09	Female	Unknown		Up
LKWH	5/13/06	391	850	1.42	Unknown	Mature	6	Down
LKWH	5/12/06	343	560	1.39	Unknown	Unknown		Up
LKWH	5/13/06	394	815	1.33	Unknown	Mature	13	Up
LKWH	5/13/06	344	640	1.57	Unknown	Mature	10	Up
LKWH	5/14/06	346	590	1.42	Unknown	Unknown	7	Up
LKWH	5/14/06	355	615	1.37	Unknown	Unknown	11	Up
LKWH	5/15/06	399	875	1.38	Unknown	Mature	18	Up
LKWH	5/15/06	378	785	1.45	Female	Mature	8	Up
LKWH	5/15/06	385	895	1.57	Unknown	Unknown		Up
MNWH	5/13/06	245	205	1.39	Unknown	Unknown	2	Down
MNWH	5/9/06	226	145	1.26	Unknown	Unknown		Up
MNWH	5/18/06	309	375	1.27	Unknown	Mature	8	Up
WALL	5/19/06	342	390	0.97	Male	Ripe	8	Down
WALL	5/16/06	439	990	1.17	Unknown	Mature	10	Up
WALL	5/18/06	375	635	1.20	Unknown	Mature	9	Up

5.4 STEEPBANK RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions			
Climate and Hydrology				
	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	√			
Mean winter discharge	not measured			
Annual maximum daily discharge	√			
Minimum open-water season discharge	√			

The Steepbank River basin produced 62 mm of runoff in March to October 2006, about 40% below the historical mean runoff. Cumulative, watershed-level changes in hydrologic conditions in the Steepbank River caused by focal project activities in the watershed have been negligible.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]	
Measurement endpoints with guidelines	2006 Potentially Influenced Stations (n=1)	2006 Reference Stations (n=3)
Physical variables (max = 1 for exp, 3 for ref)	0	0
Nutrients (max = 3 for exp, 9 for ref)	0	2
Ions (max = 2 for exp, 6 for ref)	0	0
Selected metals (max=5 for exp, 15 for ref)	0	0

Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2006 Potentially Influenced Stations (n=1 station X 13 endpoints)	2006 Reference Stations (n=3 stations X 13 endpoints)
Greater than 95th percentile	0	1
Between 5th and 95th percentiles	13	36
Less than 5th percentile	0	2

Focal projects in the Steepbank River watershed have had generally no effect on water quality at the lower Steepbank River as of 2006. In 2006 there were few exceedances of water quality guidelines throughout the watershed, concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance in fall 2006 was generally consistent throughout the watershed with ion balance in previous years.

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline					
	2006 Potentially Influenced Stations (n= 1)			2006 Reference Stations (n= 1)		
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above
Abundance		1			1	
Richness		1			1	
Diversity		1			1	
Evenness		1			1	
% EPT		1			1	

Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]	
Measurement endpoints with guidelines	2006 Potentially Influenced Stations (n=0)	2006 Reference Stations (n=0)
Total Hydrocarbons	no sediment quality sampling conducted in Steepbank River watershed in 2006	
PAHs		

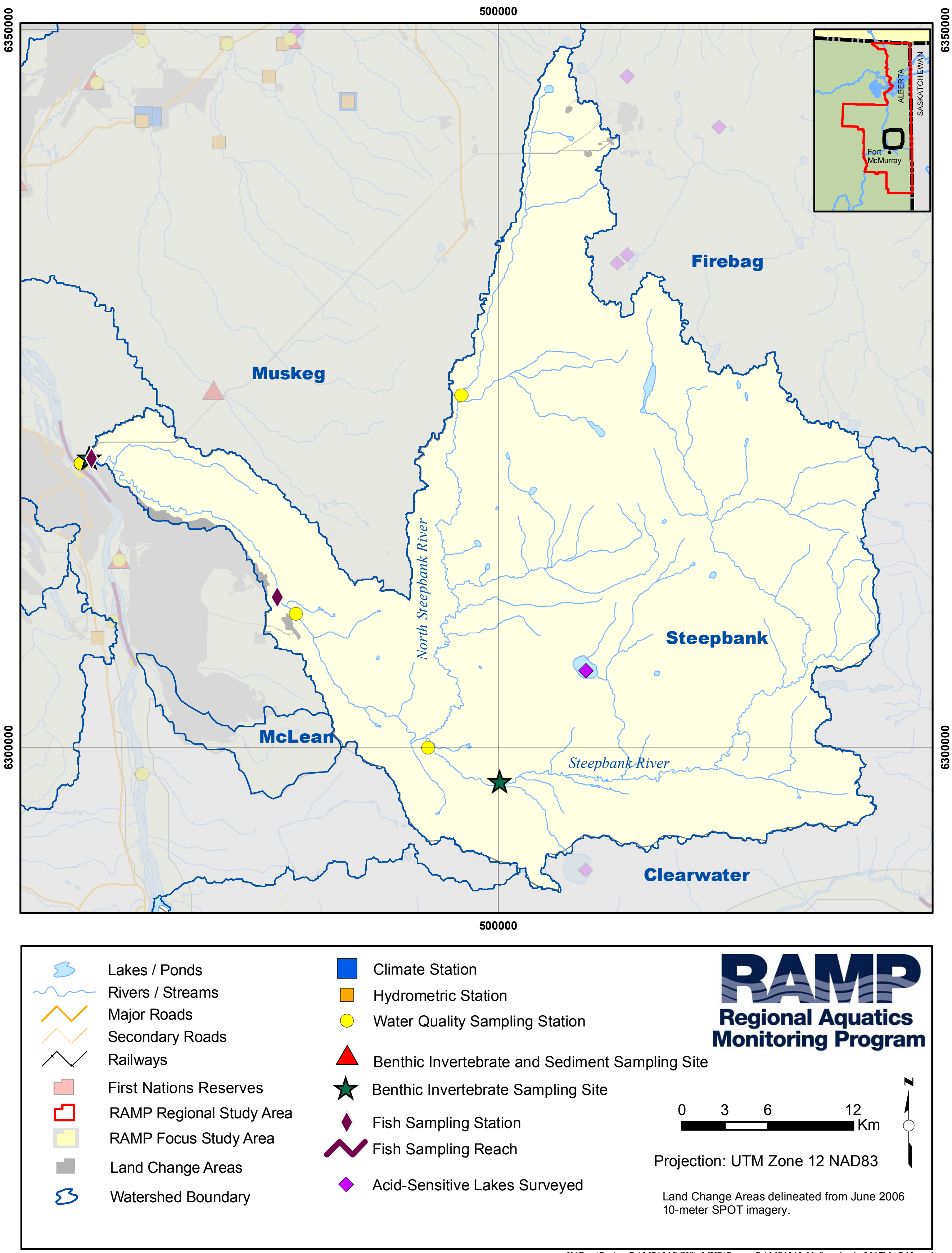
There were some significant, though statistically weak differences in some benthic invertebrate community measurement endpoints between sampled reaches designated as potentially-influenced and reference. Values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled in the Steepbank River watershed were within the normal range of values observed from regional baseline reaches, and there continues to be consistency across years in values of all benthic invertebrate community measurement endpoints with respect to regional baseline reaches.

Fish Populations

Fish Inventory	No fish inventory studies conducted in 2006.
Sentinel Studies	Results of the 2006 sentinel fish species study suggest no clear pattern in differences in sculpin growth, reproduction, and condition that can be readily explained by factors measured in the study itself or the study design. The 2006 results also indicate no clear differences in sculpin population measurement endpoints between *reference* and *potentially influenced* sites that would suggest possible effects of focal project activities on these populations.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.
[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.4-1 Steepbank River watershed.



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5.4.1 Development Status

While only approximately 0.5% of the Steepbank River watershed had undergone land change as of 2006 from focal project activities (Table 2.6-2), much of this land change is concentrated in the lower portion of the watershed. Therefore, the designations of specific areas of the watershed are as follows:

- The Steepbank River watershed downstream of the Suncor Steepbank and Millennium oil sands developments (Figure 2.6-1) is designated as *potentially influenced*. All data gathered from 2006 RAMP sampling locations in this area of the watershed are designated as operational data; and
- The remainder of the watershed is designated as *reference*, and all data gathered from the 2006 RAMP sampling locations in these parts of the watershed are designated as baseline data.

5.4.2 Hydrologic Conditions

2006 Hydrologic Conditions The Steepbank River basin produced 62 mm of runoff in March to October 2006, about 40% below the historical mean runoff of 103 mm (Figure 5.4-2). The spring runoff was early but small. The flow peaked twice in May and again in July in response to rainfall events. During June and September the discharges were well below the historical median flow. The July maximum daily discharge was 14.5 m^3/s, less than half of the mean annual flood. The minimum open-water discharge of 1.43 m^3/s was 25% lower than the historical average minimum discharge of 1.91 m^3/s.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the Steepbank River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.4-1. As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 2.43 km^2 and 3.36 km^2, respectively, in the Steepbank River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1), the estimated net effects of which were to reduce inflows to the Steepbank River by 0.108 million m^3 in 2006.

The baseline hydrograph that would have occurred at WSC Station 07DA006, Steepbank River near Fort McMurray in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have decreased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by 0.1%. The cumulative effect is that all hydrologic measurement endpoints for the Steepbank River watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.4-2, Table 5.4-2). These calculated incremental changes in the hydrologic measurement endpoints (-0.1%) would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information, as well as information available regarding focal project activities in the Steepbank River watershed, cumulative, watershed-level changes in hydrologic conditions in the Steepbank River caused by focal project activities in the watershed as of 2006 have been negligible.

5.4.3 Water Quality

Water quality samples were collected from four stations in the Steepbank watershed in 2006:

- Near the mouth of the Steepbank River in the fall season (station STR-1, *potentially influenced*, operational data available from 1997 to 2006);
- Upstream of Suncor's Millennium/Steepbank oil sands developments in the fall season (station STR-2, *reference*, baseline data available from 2002 to 2006);
- Upper Steepbank River above the confluence with the North Steepbank River in the spring, summer, and fall seasons (STR-3, *reference*, baseline data from 2004 and 2006); and
- North Steepbank River in the fall season (NSR-1, *reference*, baseline data from 2002 to 2006).

All stations were sampled in fall 2006, while spring and summer sampling was also conducted at station STR-3 in 2006.

Water quality was sampled in the winter season in 2002 at station STR-2 and in 2004 at station STR-3; the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration There were 2 (9%) of a possible 22[1] cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values at station STR-1, the only station in the Steepbank River watershed designated as *potentially influenced* that was sampled in fall 2006. This statistic is much less than at the three stations designated as *reference* in fall 2006, at which there were 33 (50%) of a possible 66 cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum values. Station-specific details are provided below.

Water quality at station STR-1 was consistent with historical results, with all water quality measurement endpoints within the range previously observed except pH, slightly higher than the previous maximum, and dissolved organic carbon, slightly lower than the previous minimum (Table 5.4-3).

Concentrations of several water quality measurement endpoints at stations STR-2, STR-3, and NSR-1 were greater or less than historical observations (Table 5.4-4, Table 5.4-5, Table 5.4-6). In general, concentrations of ions (except sulphate) were higher than previously observed or (at station STR-2) close to the previously-measured maximum concentration. Sulphate concentrations were lower than the previously-measured minimum at all three stations. The high number of ions with concentrations that were outside the previously-measured ranges may reflect a proportionately greater contribution of groundwater to instream flows due to low precipitation and surface runoff in fall 2006, although this is not reflected at station STR-1.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were no exceedances of water quality guidelines for any of the water quality measurement endpoints at any of the four water quality stations (Table 5.4-3 to Table 5.4-6), with the exception of total aluminum at station STR-3 in summer 2006 (Table 5.4-5).

[1] There are 22 water quality measurement endpoints (Section 3.2.6.1).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the Steepbank River watershed in 2006 (Table 5.4-3 to Table 5.4-6):

- Sulphide and total iron at the Upper Steepbank River above the confluence with the North Steepbank River (station STR-3) in spring;
- Sulphide, total phosphorus, and dissolved and total iron at station STR-3 in summer;
- Sulphide, dissolved and total iron at all four stations in fall 2006;
- Total phosphorus at station STR-3 and station NSR-1 in fall 2006; and
- Total phenols at stations STR-1, STR-2, and NSR-1 in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station STR-1, the only station in the Steepbank River watershed designated as *potentially influenced* that was sampled in fall 2006, there were no water quality measurement endpoints with fall 2006 concentrations either below the 5th or above the 95th percentile of regional baseline concentrations (Figure 5.4-3). At stations designated as *reference* in fall 2006, the concentration of 3 (8%) out of a possible 39[2] water quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations (Figure 5.4-3). These were total boron at station STR-3, which in fall 2006 exceeded the 95th percentile of regional baseline concentration and sulphate at station STR-2 and station NSR-1 with concentrations in fall 2006 below the 5th percentile of regional baseline concentrations.

In general, several water quality measurement endpoints found completely or predominantly in the dissolved fraction (e.g., total dissolved solids, total boron, total strontium, calcium, magnesium, sodium) were higher at station STR-3 than at station NSR-1 (Figure 5.4-3), possibly indicating a relatively greater contribution of groundwater to total flow at station STR-3. Concentrations of these water quality measurement endpoints at station STR-2 and station STR-1 were generally intermediate between concentrations at the other two stations, indicating a mixing of waters from the two upper sources (Figure 5.4-3).

Ion Balance The ionic composition of water at all stations in the Steepbank River watershed in the fall season is dominated by calcium and bicarbonate ions, and the ionic characteristics of all stations have changed little over the sampling period, including 2006, with the exception of STR-1 in 1998 (Figure 5.4-4).

Summary The results described above suggest that focal projects in the Steepbank River watershed have had generally no effect on water quality at the lower Steepbank River as of 2006. In 2006, there were few exceedances of water quality guidelines throughout the watershed, concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance in fall 2006 was generally consistent throughout the watershed with ion balance in previous years.

[2] Thirteen selected water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4) were sampled at three stations designated as *potentially influenced* in the Steepbank River watershed in fall 2006, making for a total of 39 water quality measurement endpoint- station combinations.

5.4.4 Benthic Invertebrate Communities and Sediment Quality

5.4.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from the following reaches in the Steepbank River watershed:

- An erosional lower reach near the mouth of the Steepbank River (reach STR-E-1, *potentially influenced*, operational data available intermittently from 1998 to 2006); and
- An erosional reach well upstream of the North Steepbank confluence (reach STR-E-2, *reference*, baseline data available for 2004 to 2006).

2006 Habitat Conditions Habitat conditions at both reach STR-E-1 and reach STR-E-2 in fall 2006 were typical of erosional habitats in the RAMP FSA with high flow velocities (0.6 m/s) and coarse substrate consisting of gravel and cobble (Table 5.4-8). Macrophytes were generally absent, while the low periphyton chlorophyll *a* biomass was indicative of oligotrophic conditions (Figure 5.4-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Mayflies and chironomids dominated the benthic invertebrate community of the lower reach of the Steepbank River (reach STR-E-1, Table 5.4-9), with enchytraeid worms, mites, and naidids being sub-dominant. A variety of sensitive taxa were present in reach STR-E-1 including the mayflies *Ephemerella* and *Heptagenia*, as well as chloroperlid stoneflies and the stonefly *Taeniopteryx*, and the empidid *Hemerodromia*. *Rheotanytarsus* and *Cricotopus/Orthocladius* were the dominant chironomids. Overall abundance in reach STR-E-1 was about 2,000 individuals/m^2, which is near the lower limits of the long-term average for that reach. The average number of taxa was 23, up six taxa from last year. Diversity was high, while percent EPT (15%) was the lowest average measured (Table 5.4-9).

Chironomids, naidid worms, caddisflies and mayflies dominated the reach upstream of the North Steepbank confluence (reach STR-E-2, Table 5.4-9), with empidids, stoneflies, mites, and various other flies (e.g., Tipulid craneflies, simuliid blackflies) sub-dominant. A variety of sensitive taxa were present in reach STR-E-2 including the mayflies *Drunella grandis*, the stoneflies *Zapada*, *Skwala*, and *Pteronarcys*, the caddisfly *Brachycentrus*, and the empidid *Hemerodromia*. *Baetis*, a complex genus comprising several species including both tolerant and sensitive forms, was the most common mayfly of both STR-E-1 and STR-E-2. Chironomids in the reach STR-E-2, like reach STR-E-1, were dominated by a variety of groups, but principally *Rheotanytarsus* and members of the *Cricotopus/Orthocladius* complex.

Effects of Focal Project Activities The most relevant ANOVA tests for effects of focal projects on benthic invertebrate communities in the Steepbank River were the *reach* and *reach x time* contrasts between reach STR-E-1 and reach STR-E-2. With three years of data in both reaches, there were indications of minor (subtle) differences in time trends for abundance, diversity and percent EPT (Table 5.4-10). Total numbers, richness and percent EPT were higher in reach STR-E-2 than reach STRE-1, while diversity and evenness were not statistically different in the two reaches. The only *reach x time* contrasts that were significant were those for diversity and evenness, and those were marginal. The levels of significance for these comparisons are considered low in this situation because of available samples sizes and resulting statistical power available for these tests (RAMP 2005b). In addition, values of diversity and evenness, like all benthic invertebrate community measurement endpoints for reach STR-E-1 and reach STR-E-2 in fall 2006, were within the normal range of variation for reference conditions in erosional reaches (Figure 5.4-6). In addition, the ordination of the benthic invertebrate community for reach STR-E-1 indicates considerable similarity across all years with the anticipated reference condition (with the exception of 2002) (Figure 5.4-7). There was, therefore, no evidence in 2006 of effects of focal project activities on the benthic invertebrate community in the Steepbank River.

5.4.4.2 Sediment Quality

As sediment quality in 2006 was only sampled in the depositional reaches in which benthic invertebrate communities were sampled, and as both reaches of the Steepbank River watershed in which benthic invertebrate communities were sampled are erosional, no sediment quality sampling was conducted in the Steepbank River in 2006.

5.4.4.3 Summary

There was no evidence of effects of focal project activities on benthic invertebrate communities in the Steepbank River watershed in 2006. There were some significant, though statistically weak differences in some benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference*. Values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled in the Steepbank River watershed were within the normal range of values observed from regional reference reaches, and there continues to be consistency across years in values of all benthic invertebrate community measurement endpoints with respect to regional reference reaches.

5.4.5 Fish Populations

Fish Population component studies in the Steepbank River in 2006 consisted of a sentinel fish species survey using slimy sculpin. The Steepbank River watershed was one of four watersheds used in the 2006 sentinel fish species survey, and the results of the entire 2006 survey are presented and discussed below. The monitoring sites designated as *potentially influenced* for the 2006 survey were:

- The lower Steepbank River adjacent to the Steepbank Mine/Project Millennium operations (Site SR-E), which was also sampled as part of the 2004 sentinel fish species survey; and
- The lower Muskeg River, approximately 0.2 to 0.6 km upstream of the confluence with the Athabasca River (Site MR-E).

The monitoring sites designated as *reference* for the 2006 survey were:

- An upper reach of the Steepbank River (site SR-R2). The 2006 site is approximately 7.5 km upstream of the 2004 reference site on the Steepbank River, the re-location necessitated by increasing focal project activities in the vicinity of the original location;
- A site on the Horse River (site HR-R) approximately 140 km upstream of the confluence with the Athabasca River, also sampled as part of the 2004 sentinel fish species survey; and
- A site on the Dunkirk River (site DR-R) approximately 25 km upstream of the confluence with the Athabasca River, also sampled as part of the 2004 sentinel fish species survey.

5.4.5.1 Field Sampling Results

A habitat survey was carried out at each sampling site in August 2006. Major habitat characteristics for each site are summarized in Table 5.4-11, and detailed results of habitat assessments provided in Appendix H. Habitat at the five sentinel sampling sites was generally comparable, with similar gradient, average water velocity, channel morphology, and substrate. Field observations suggested an increased amount of compacted material and bitumen deposits in the substrate at the lower Steepbank River site (site SR-E).

Seasonal *in situ* water quality variables measured at the time of fish sampling were similar between potentially influenced and reference sites (Appendix H). In August, water temperature ranged from 14°C to 17.5°C, pH ranged from 8.1 to 8.5, and dissolved oxygen ranged from 7.2 mg/L (Dunkirk River, site DR-R) to 9.4 mg/L (lower Steepbank River, site SR-E). As expected, water temperatures were lower in October, and ranged from 5.4°C to 8.7°C, while the other variables were at similar levels to those found in August.

The number of slimy sculpin collected at each site ranged from 60 to 100 during the summer survey and from 43 to 100 during the fall survey (Table 5.4-12), an overall capture success that was similar to 2004 results. Spoonhead sculpin were also found at three of the five sampling locations. Species composition of captured sculpin varied both seasonally and among sites, with the lower Steepbank River (site SR-E) having the highest percentage of spoonhead sculpin in both summer (9%) and fall (32%).

5.4.5.2 Population Distribution

A "pairwise" statistical analysis was used to compare slimy sculpin length-frequency distributions between all combinations of sampling sites (*reference* and *potentially influenced*). In 2006, all comparisons were significantly different in both August and October ($p < 0.05$) (Table 5.4-13), meaning that the sculpin populations were different in their range and abundance of fish of various body lengths. Differences in range of lengths and number of individuals for each length class among sites sampled in August and October 2006 was most evident at the Steepbank River sites, where young-of-the-year (YOY) individuals represented a smaller relative proportion of the population present than at the three other sites (Figure 5.4-8 and Figure 5.4-9).

5.4.5.3 Growth

Growth was evaluated by measuring the magnitude of change in mean length of the youngest size class (YOY if present) between August and October. As expected, within-site length-frequency distributions between August and October were significantly different ($p < 0.05$), meaning that slimy sculpin at all five sites grew between the August and October sampling events. Both sculpin length and weight increased between the August and October sampling events (Figure 5.4-10, Figure 5.4-11).

There were significant differences in overall mean length and weight in both August and October 2006 ($p < 0.05$). In August 2006, slimy sculpin from the upper Steepbank River (site SR-R2) were on average longer and heavier than the other sites, while those collected from the upper Horse River (site HR-R) were the smallest (Table 5.4-14). In October 2006, the lower Steepbank River (site SR-E) had the longest and heaviest fish, and the upper Horse River (site HR-R), upper Dunkirk River (site DR-R), and the lower Muskeg River (site MR-E) had the smallest fish (Table 5.4-14).

Figure 5.4-12 and Figure 5.4-13 illustrate the shifts in the length size range of the YOY cohort between the August and October sampling campaigns. Shifts in larger-sized (i.e., older) cohorts were also evident, particularly for the two Steepbank River sites (sites SR-E and SR-R2), although they are generally less pronounced than the shifts in YOY growth. With increased age, growth in length may be influenced by shifts in energy allocation to reproductive development (in contrast to YOY fish, which devote their energy to somatic growth). YOY growth was estimated for each site for the period from August to October (standardized at 45 days). The population at the Upper Dunkirk River (site DR-R) had the lowest YOY growth rate (0.11 mm/day), while populations at the other sites exhibited growth rates ranging from 0.14 to 0.30 mm/day (Table 5.4-15).

Reproductive performance and short-term survival for a population can be estimated by examining the proportion of a population composed of YOY individuals. The percentage of YOY in the population at each site, an estimate of reproductive performance and short-term survival of the population, ranged in August 2006 from 5.6% of the population at the upper Steepbank River (site SR-R2) to almost 93% of the population at the lower Muskeg River site (MR-E) (Table 5.4-16). Reasons for the low percentage of YOY collected at site SR-R2 are unknown; sampling methods and amount of effort were comparable to the other sampling sites. The percentage of the populations represented by the YOY cohort in October 2006 declined at four of the five sites in comparison with August 2004, which was not unexpected. The exception to the August to October decline was at site SR-R2 at which the percentage of YOY increased by almost 30% (Table 5.4-16).

5.4.5.4 Energy Storage

Condition factor is a standard measurement endpoint that is calculated for each fish as a ratio of the fish's length and weight (i.e., how fat a fish is), and provides a measure of energy storage. YOY data were excluded from the analysis of differences in condition among sites as the fluctuating number of YOY sculpin captured at the various sites may exert an influence on the ability to detect differences in condition among populations. To minimize this influence, an ANCOVA analysis was conducted using the seasonal data (comparing intercepts of regression lines between length and weight) using only length cohorts judged to include 1+ year or older fish. This analysis found significant differences in condition among sites and between seasons ($p < 0.001$, Table 5.4-17).

5.4.5.5 Discussion

There are numerous differences in measured sculpin size, growth and condition across sites, seasons, and years. Sculpin sampled in the fall of 2001, 2004 and 2006 were longer at the lower Steepbank River site (site SR-E) relative to sculpin from two *reference* sites in the summer and all three *reference* sites in the fall of those years. Unlike 2001 and 2004, sculpin collected from the lower Muskeg River site (site MR-E) in August 2006 were on average shorter relative to the population of the upper Steepbank River site (site SR-R2) (although they were similar in size to the populations in the other two *reference* sites. This can be partially explained by the presence of a larger proportion of YOY at site MR-E in the summer of 2006 relative that present in 2004; this significant difference was no longer present in fall 2006.

Slimy sculpin at the lower Steepbank River site (site SR-E) were also significantly heavier in 2006 and 2004 relative to at least some of the *reference* sites. Similar to 2001 and 2004, captured slimy sculpin from the lower Muskeg River site (site MR-E) were consistently larger than those from the upper Horse River site (site HR-R).

Growth rates calculated for populations of YOY (the most distinct size/age cohort between August and October) varied among both the *reference* and *potentially influenced* sites in 2006, with the lower Steepbank River (site SR-E) having the highest estimated growth (0.42 mm/day). In 2006, growth rates of populations in the Horse River (site HR-R) and the lower Muskeg River (site MR-E) were very similar to 2004 growth rates, while growth rates in the upper Dunkirk River (site DR-R) were lower in 2006 than in 2004.

These observed differences in sculpin size, growth and condition can be interpreted as a collective indication of the environmental conditions present at a particular site over time, including, but not limited to, nutrient enrichment and/or metabolic disruption (Munkittrick *et al.* 2002). Significant differences in population distributions and comparatively low proportions of YOY sculpin captured at the Steepbank River sites in 2006, may be the result of limited reproductive capacity in adults, elevated early life history mortality, limited resource availability, competition or a combination of these factors. As reported in 2004, lethal sampling conducted on the sculpin population of the lower Steepbank River in 2001 reported 15% smaller gonad size relative to the Dunkirk River *reference* population (considered a significant difference). The lower Steepbank River slimy sculpin population also appears to co-exist with the largest spoonhead sculpin population of all five monitoring sites based on 2006 capture results (Table 5.4-12). This suggests the possibility for both intra- and inter-specific competition for resources including food, and/or potentially reduced access to preferred spawning habitat due to elevated substrate compaction. In turn, this could result in an increase in mean age of a population (Gibbons and Munkittrick 1994), as was observed in 2001 for male sculpin from the lower Steepbank River (Golder 2002).

For the lower Muskeg River site, significant seasonal differences in population distributions, smaller mean size, significantly lower condition factors relative to two of the three *reference* sites, and a high proportion of YOY sculpin captured in both 2006 seasons suggest increased early life history recruitment, elevated mortality with increased age, or a combination of these factors. This is in contrast to both the 2004 non-lethal results, when high proportions of larger size classes were present in the population, and to the 2001 lethal results which indicated smaller female gonad size and fecundity from the Muskeg River population relative to the *reference* sites.

5.4.5.6 Impact Analysis

Of the measurement endpoints established for the lethal sentinel species monitoring approach (Environment Canada 2002), only condition factor can be applied as a measurement endpoint when using a non-lethal approach. The impact criterion for condition factor defined by Environment Canada (2002) is a ± 10% difference between *potentially influenced* and *reference* sites; that is, a difference in condition that is greater than 10% indicates a population may be affected by some factor or factors.

Table 5.4-18 and Table 5.4-19 provide a summary of sculpin condition factor in 2006 from the lower Steepbank River (site SR-E) and lower Muskeg River (site MR-E), respectively, (both *potentially influenced* sites) as compared to the three *reference* sites. Only one difference in condition factor met the Environment Canada 10% impact criterion of the possible 12 comparisons[3]:

- Fall condition factor at the lower Steepbank River site was 11.2% lower compared to the Upper Steepbank River site.

[3] two *potentially influenced sites* each compared to three *reference* sites in two seasons

As indicated above, currently condition factor is the only non-lethal sentinel species measurement endpoint that has a numerical criterion for identifying an effect. Below is a modified list of possible indicators associated with non-destructive sampling (Environment Canada 2004):

Growth

- o Length and/or weight of young-of-year at end of growth period;
- o Length and/or weight of 1+ year old fish; and
- o size-at-age (if possible to determine ages of fish captured).

Reproduction

- o Relative abundance of young-of-year (i.e., % composition); and
- o Young-of-year survival.

Survival

- o Length frequency distribution – identification of missing size (age) cohorts.

Unlike 2004, no possible recruitment failure in sculpin populations at either of the *potentially influenced* sites were identified in 2006. In addition, no sharp declines were measured in the YOY proportion of sculpin populations from *potentially influenced* sites in either the August or October sampling campaigns, indicating good survival and seasonal recruitment. However, a low proportion of YOY individuals was measured in August 2006 in population at the upper Steepbank River site (site SR-R2, Table 5.4-16), although, the proportion represented by YOY individuals in this population had increased substantially by October.

The lowest proportions of YOY in October 2006 were at the two Steepbank River sites with less than half the YOY proportion measured at the other three sites (Table 5.4-16). It is possible that the lower YOY proportions at the Steepbank River sites may represent a weak 2006-age class. Chronic or repetitive year class failure within a population would indicate potential effects and or influences from environmental factors, and warrant more detailed study to identify the cause.

5.4.5.7 Summary

RAMP sentinel fish species studies are designed to identify differences in growth, reproduction, and energy storage (condition) among sculpin populations between *reference* and *potentially influenced* sites (Gray *et al*. 2002, Environment Canada 2004). The results of the 2006 sentinel fish species study suggest no clear pattern in measured differences in growth, reproduction, and condition that can be readily explained by factors measured in the study itself or the study design. The 2006 results also indicate no clear differences in sculpin population measurement endpoints between *reference* and *potentially influenced* sites that would suggest possible effects of focal project activities on these populations.

5.4.6 Summary of Conditions

There is little evidence in 2006 of watershed-level effects of focal project activities on RAMP aquatic resources in the Steepbank River watershed. Cumulative, watershed-level changes in hydrologic conditions in the Steepbank River caused by focal project activities in the watershed as of 2006 have been negligible. In 2006 there were few exceedances of water quality guidelines throughout the watershed, concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance in fall 2006 was generally consistent throughout the watershed with ion balance in previous years. There were some significant, though statistically weak differences in some benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference*, but values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled were within the normal range of values observed from regional reference reaches. Finally, there are no clear differences in sculpin population measurement endpoints between *reference* and *potentially influenced* sites that would suggest possible effects of focal project activities on these populations.

Figure 5.4-2 Steepbank River: 2006 hydrograph and historical context.

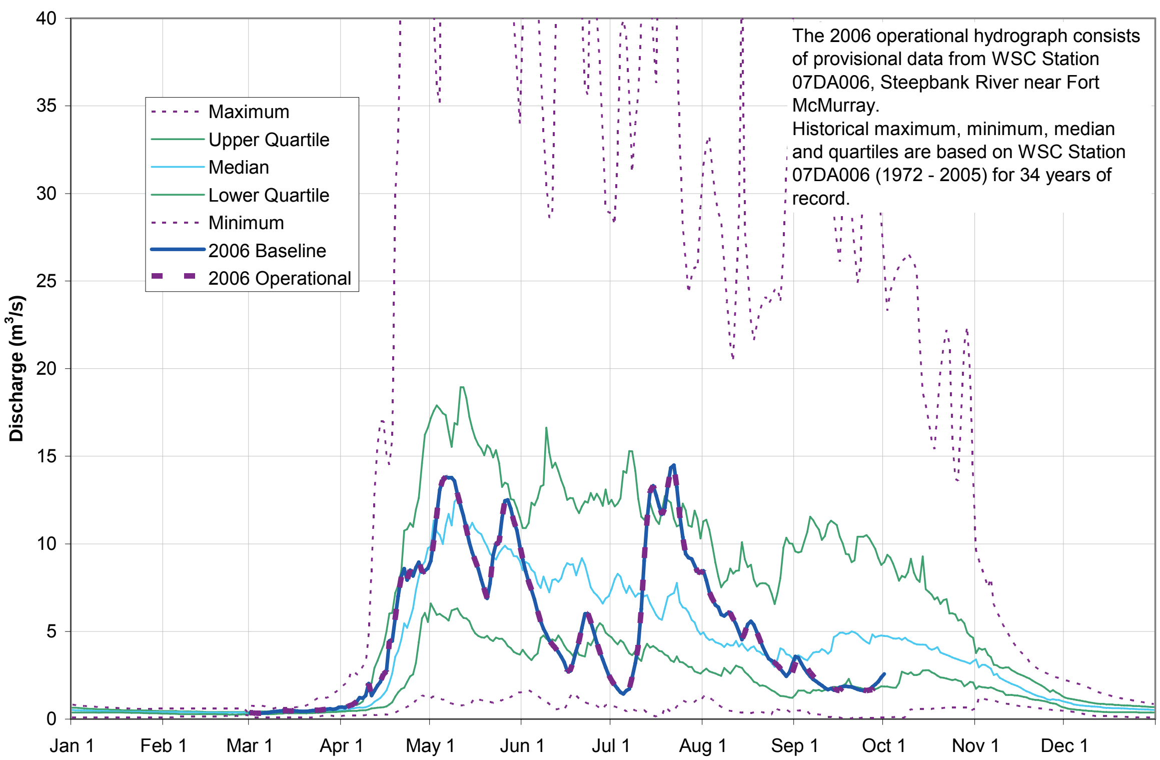


Table 5.4-1 Inputs for calculation of the baseline hydrograph at WSC Station 07DA006, Steepbank River near Fort McMurray.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	94.9	Observed daily discharges, obtained from WSC Station 07DA006, Steepbank River near Fort McMurray
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.156	2.43 km^2 within Steepbank River drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.048	3.36 km^2 within Steepbank River drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Steepbank River for focal project activities	0	Unknown, none reported, assumed to be negligible
Releases to Steepbank River for focal project activities	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Steepbank River not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	95.0	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total annual discharge)	- 0.108	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.11%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.4-2 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed for 2006.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	6.21	6.20	-0.1%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	14.5	14.5	-0.1%
Open-water season minimum daily discharge	1.43	1.43	-0.1%

Note: As measured at WSC Station 07DA006, Steepbank River near Fort McMurray.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.4-3 Concentrations of water quality measurement endpoints in the lower Steepbank River (STR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	8	7.7	8.2	8.4
Total Suspended Solids	mg/L	-[1]	3	8	<3	6.5	60
Conductivity	µS/cm	-	284	8	141	218	516
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.026	8	0.006	0.020	0.032
Total nitrogen*	mg/L	1.0	0.40	8	0.25	0.75	**2.40**
Nitrate+Nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	10	8	11	17.5	26
Ions							
Sodium	mg/L	-	14	8	6	12	38
Calcium	mg/L	-	33.8	8	17.2	27.8	50.3
Magnesium	mg/L	-	10	8	5.4	8.4	16.2
Chloride	mg/L	230, 860[3]	4	8	1.0	2.5	8.4
Sulphate	mg/L	100[4]	4.6	8	4.2	5.1	12.3
Total Dissolved Solids	mg/L	-	190	8	120	200	320
Total Alkalinity	mg/L		141	8	63	107.5	263
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.078	8	0.040	**0.142**	**2.73**
Dissolved aluminum	mg/L	0.1[2]	0.005	8	0.004	0.016	0.099
Total boron	mg/L	1.2[5]	0.083	8	0.025	0.062	0.200
Total molybdenum	mg/L	0.073	0.00027	8	0.00015	0.00020	0.00050
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.135	8	0.064	0.105	0.252

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.4-4 Concentrations of water quality measurement endpoints in the Steepbank River upstream of Steepbank Mine/Project Millennium (STR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.8	8.1	8.3
Total Suspended Solids	mg/L	-[1]	4	4	3	11	28
Conductivity	µS/cm	-	255	4	121	160	274
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.031	4	0.014	0.021	0.038
Total nitrogen*	mg/L	1.0	0.8	4	0.6	0.8	**1.5**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	17	4	14	23.5	29
Ions							
Sodium	mg/L	-	14	4	5	7	16
Calcium	mg/L	-	35.3	4	16.8	21.4	35.9
Magnesium	mg/L	-	10.3	4	5.3	6.4	10.8
Chloride	mg/L	230, 860[3]	2	4	1	2	3
Sulphate	mg/L	100[4]	<0.5	4	3.2	3.5	5.5
Total Dissolved Solids	mg/L	-	190	4	140	155	200
Total Alkalinity	mg/L		142	4	61	81	155
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.036	4	0.086	**0.332**	**0.536**
Dissolved aluminum	mg/L	0.1[2]	0.0049	4	0.0056	0.0162	0.0294
Total boron	mg/L	1.2[5]	0.0859	4	0.0227	0.0374	0.0969
Total molybdenum	mg/L	0.073	0.00030	4	0.00010	0.00015	0.00026
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	2.3
Total strontium	mg/L	-	0.134	4	0.053	0.074	0.167

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.4-5 Concentrations of water quality measurement endpoints in the upper Steepbank River (STR-3), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.0	-	8.3
Total Suspended Solids	mg/L	-[1]	4	2	<3	-	3
Conductivity	µS/cm	-	303	2	196	-	276
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.041	2	0.027	-	0.041
Total nitrogen*	mg/L	1.0	0.7	2	0.6	-	0.8
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	20	2	14	-	25
Ions							
Sodium	mg/L	-	17	2	9	-	15
Calcium	mg/L	-	40.7	2	25.5	-	37.9
Magnesium	mg/L	-	12.4	2	7.7	-	11.1
Chloride	mg/L	230, 860[3]	2	2	2	-	2
Sulphate	mg/L	100[4]	3.1	2	3.2	-	3.4
Total Dissolved Solids	mg/L	-	220	2	140	-	210
Total Alkalinity	mg/L		170	2	100	-	165
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.021	2	0.039	-	0.041
Dissolved aluminum	mg/L	0.1[2]	0.0052	2	0.0040	-	0.0175
Total boron	mg/L	1.2[5]	0.114	2	0.058	-	0.094
Total molybdenum	mg/L	0.073	0.00028	2	0.00015	-	0.00024
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.3	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.149	2	0.0945	-	0.150

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
[2] Guideline is for total analyte (no guideline for dissolved species).
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)
[5] B.C. ambient water quality guideline for boron (B.C. 2003).
[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.4-6 Concentrations of water quality measurement endpoints in the North Steepbank River (NSR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	4	7.5	7.9	8.1
Total Suspended Solids	mg/L	-[1]	<3	4	<3	4.5	8
Conductivity	µS/cm	-	191	4	110	142.5	175
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.042	4	0.015	0.018	0.037
Total nitrogen*	mg/L	1.0	0.8	4	0.4	0.6	0.7
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	4	13	17	20
Ions							
Sodium	mg/L	-	4	4	2	3	3
Calcium	mg/L	-	31	4	16.5	22.05	26.9
Magnesium	mg/L	-	8.8	4	4.9	6.3	7.6
Chloride	mg/L	230, 860[3]	1	4	<1	1.5	2
Sulphate	mg/L	100[4]	<0.5	4	1.2	2	5.2
Total Dissolved Solids	mg/L	-	160	4	120	140	160
Total Alkalinity	mg/L		106	4	55	72.5	98
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.054	4	0.028	0.042	**0.129**
Dissolved aluminum	mg/L	0.1[2]	0.0064	4	0.0050	0.0121	0.0148
Total boron	mg/L	1.2[5]	0.0201	4	0.0109	0.0129	0.0173
Total molybdenum	mg/L	0.073	0.00036	4	0.00015	0.000189	0.000311
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.111	4	0.049	0.069	0.099

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
2 Guideline is for total analyte (no guideline for dissolved species).
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)
5 B.C. ambient water quality guideline for boron (B.C. 2003).
6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
7 B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.4-7 List of water quality guideline exceedances, Steepbank River watershed, 2006.

Variable	Units	Guideline*	STR-1	STR-2	STR-3	NSR-1
Spring						
Sulphide	mg/L	0.002[1]	ns	ns	**0.007**	ns
Total iron	mg/L	0.3	ns	ns	**0.429**	ns
Summer						
Sulphide	mg/L	0.002[1]	ns	ns	**0.006**	ns
Total phosphorus	mg/L	0.05	ns	ns	**0.077**	ns
Total aluminum	mg/L	0.1	ns	ns	**0.283**	ns
Dissolved iron	mg/L	0.3[2]	ns	ns	**0.322**	ns
Total iron	mg/L	0.3	ns	ns	**1**	ns
Fall						
Sulphide	mg/L	0.002[1]	**0.009**	**0.01**	**0.006**	**0.008**
Total phosphorus	mg/L	0.05	-	-	**0.06**	**0.059**
Dissolved iron	mg/L	0.3[2]	**0.406**	**0.515**	**0.717**	**0.77**
Total iron	mg/L	0.3	**0.654**	**0.749**	**0.995**	**1.17**
Total phenols	mg/L	0.004	**0.013**	**0.009**		**0.01**

STR-1, STR-2 and NSR-1 were sampled only in fall 2006. STR-3 was sampled in spring, summer and fall 2006.

ns = not sampled

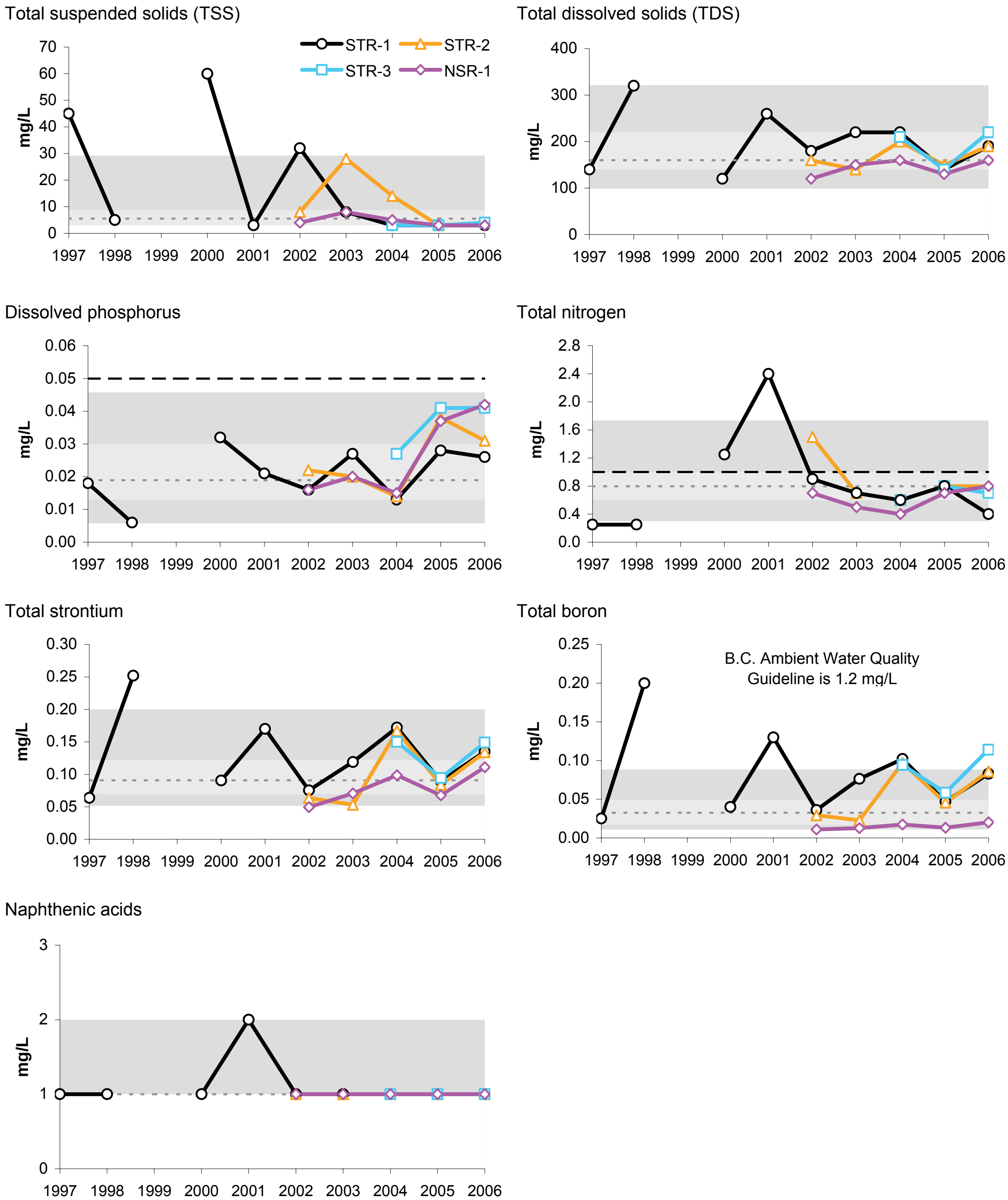
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S.

[2] Guideline is for total metal (no guideline for dissolved species).

[3] B.C. Working Water Quality Guideline (2001).

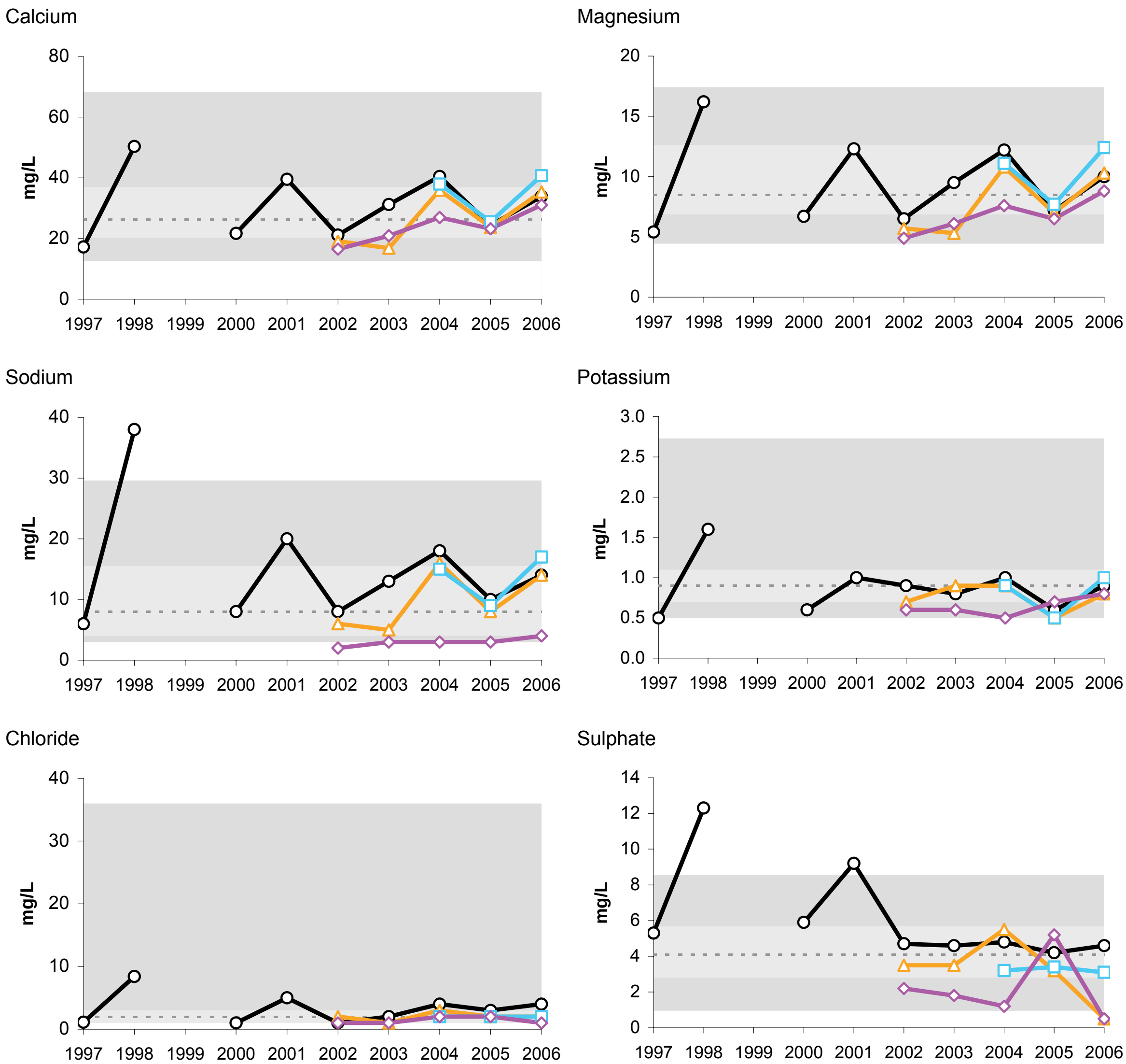
Figure 5.4-3 Selected water quality measurement endpoints in the Steepbank River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.4-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.4-4 Piper diagram of fall concentrations in the Steepbank River watershed, fall 1997-2006.

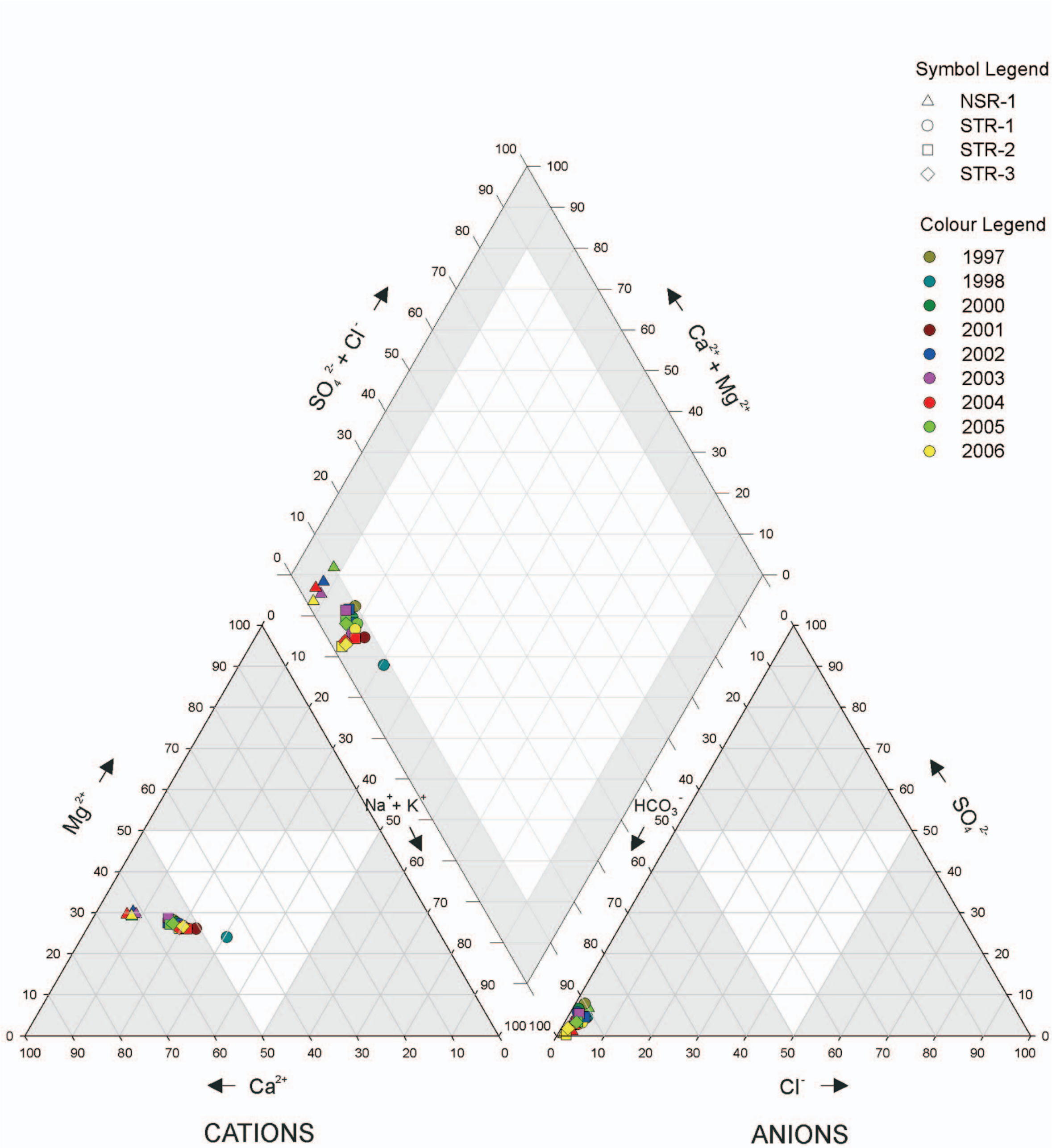


Table 5.4-8 Average habitat characteristics of benthic invertebrate community reaches in the Steepbank River, fall 2006.

Variable	Units	Lower Reach of the Steepbank River (Reach STR-E-1)	Upper Reach of the Steepbank River (Reach STR-E-2)
Sample date	-	Sept 10, 2006	Sept 18, 2006
Habitat	-	Erosional	Erosional
Water depth	m	0.3	0.27
Current velocity	m/s	0.6	0.6
Macrophyte cover	%	0	1
Benthic algae	µg/m^2	41.1	41.5
Sand/Silt/Clay	%	13	12
Field Water Quality			
Dissolved oxygen	mg/L	9.4	9.45
Conductivity	µS/cm	306	335
pH		8.1	8.7
Water temperature	°C	12.7	9.9
Sediment Composition			
Sand/Silt/Clay	%	6	6
Small gravel	%	8	5
Large gravel	%	26	11
Small cobble	%	54	26
Large cobble	%	3	40
Boulder	%	3	12
Bedrock	%	0	0

Figure 5.4-5 Annual variation in periphyton chlorophyll *a* in the lower reach of the Steepbank River (reach STR-E-1) and the upper reach of the Steepbank River (reach STR-E-2).

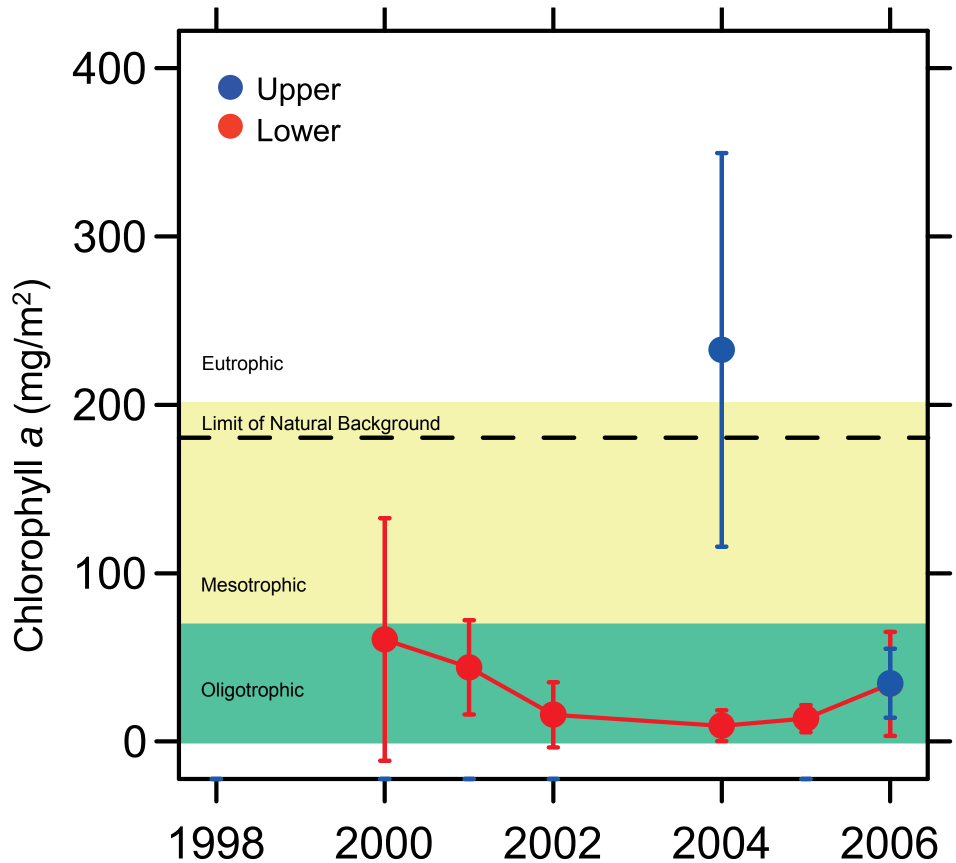
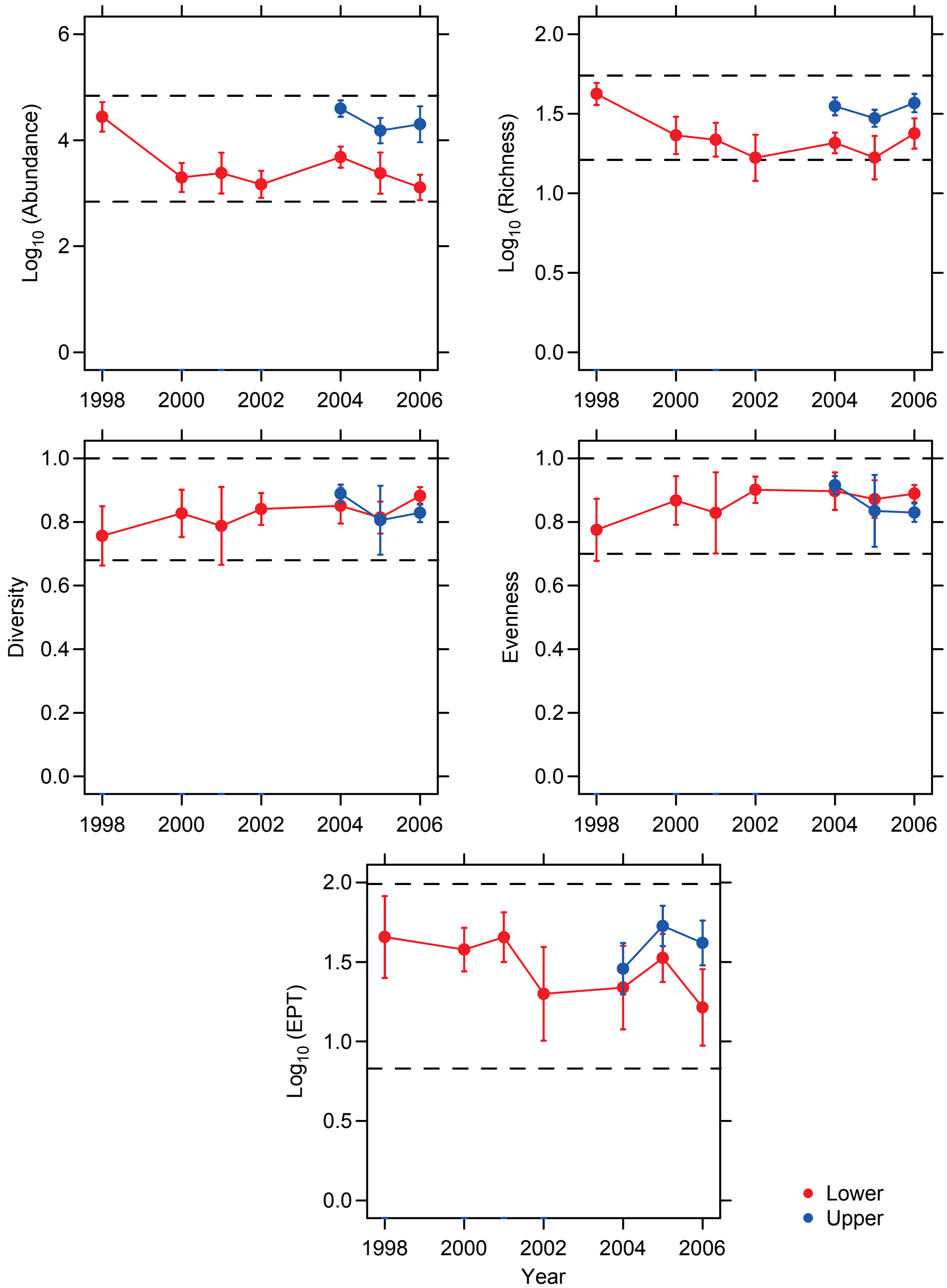


Table 5.4-9 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Steepbank River.

Taxon	% Enumerated Taxa in Each Year									
	Reach STR-E-1							Reach STR-E-2		
	1998	2000	2001	2002	2004	2005	2006	2004	2005	2006
Anisoptera	<1	<1	<1	1	<1	<1	<1	<1	<1	0.3
Athericidae		<1	<1	<1	<1	<1	<1	<1	3	1
Bivalvia				<1					<1	<1
Brachycera		<1								
Ceratopogonidae	<1		<1	<1	<1		<1			
Chironomidae	31	15	25	43	38	25	29	46	32	24
Chydoridae		<1						4		<1
Cladocera	1									
Collembola	<1	<1						<1		
Copepoda	<1	<1	<1	<1		<1		4	<1	1
Dolichopodidae								<1		
Empididae	2	1	2	6	4	9	7	2	6	2
Enchytraeidae	1	11	1	9	6	9	15	<1	1	
Ephemeroptera	51	42	51	19	23	38	15	18	23	17
Gastropoda	<1	<1	<1	<1	<1		1			<1
Heteroptera		<1	<1	<1						
Hydracarina	6	3	6	4	4	9	15	7	3	5
Lepidoptera		<1		<1						
Lumbriculidae		<1			<1					
Naididae	2	21	2	2	21	5	13	2	2	24
Nematoda	1	2	2	2	1	<1	1	3	1	1
Ostracoda	1	<1	<1	<1			<1	1		0
Plecoptera	<1	1	<1	1	1	<1	<1	2	4	2
Psychodidae		<1								
Simuliidae	3	<1	<1	1	<1	3	1	<1	1	1
Tabanidae	<1	<1			<1			<1	<1	0
Tipulidae	<1	<1						1	1	1
Trichoptera	1	<1	<1	1	1	1	<1	9	24	22
Tubificidae	2	1	<1	1	<1	1	1	<1		1
Benthic Invertebrate Community Measurement Endpoints										
Total Abundance ($No./m^2$)	2,987	2,321	3,156	1,725	5,259	3,105	1,453	41,844	17,317	24,764
Richness	41	23	21	17	20	17	23	34	29	36
Simpson's Diversity	0.76	0.83	0.79	0.84	0.85	0.81	0.88	0.89	0.81	0.83
Evenness	0.78	0.87	0.83	0.9	0.9	0.87	0.89	0.92	0.83	0.83
% EPT	47	39	47	23	24	34	15	29	54	40

Figure 5.4-6 Annual variation in benthic invertebrate community measurement endpoints in the lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.

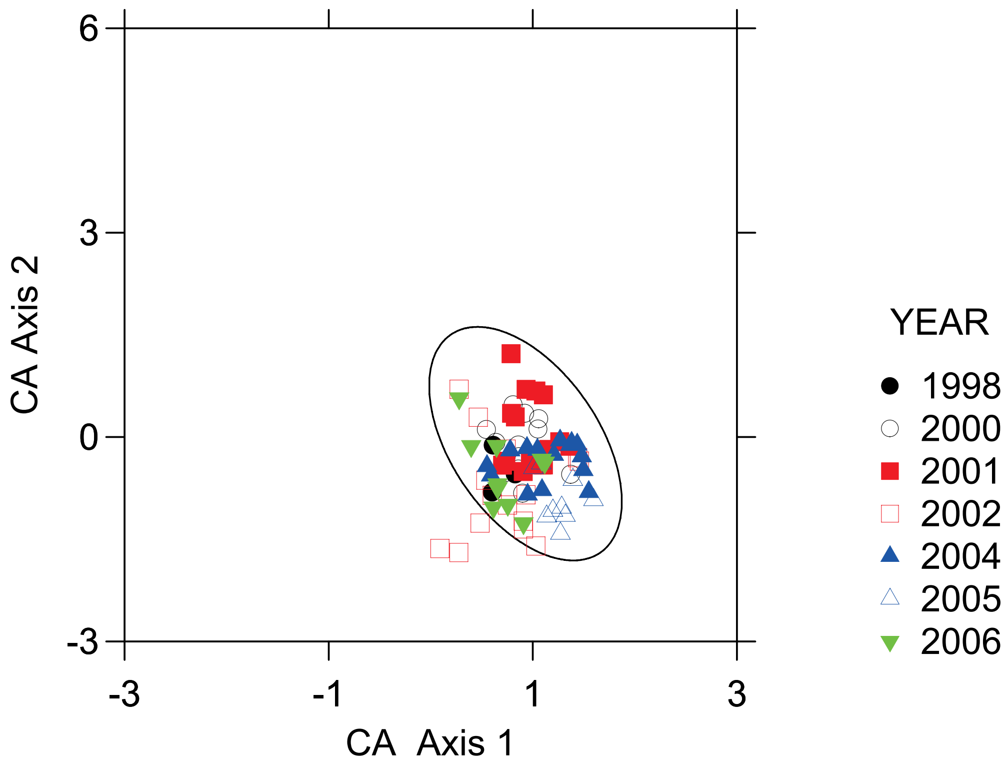


Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional reaches. Lower – reach STR-E-1; upper – reach STR-E-2.

Table 5.4-10 Analysis of variance (ANOVA) between reach STR-E-1 and reach STR-E-2.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	32.40	9	50.49	<0.001
Reach	15.92	1	223.23	<0.001
Time (Linear Trend)	2.27	1	31.81	<0.001
Reach x Time (Linear)	0.23	1	3.22	0.076
Reach (2006)	7.12	1	99.79	<0.001
Error	7.70	108		
Log_{10} Richness				
Reach-Year	1.74	9	21.45	<0.001
Reach	0.84	1	93.31	<0.001
Time (Linear Trend)	0.02	1	2.13	0.147
Reach x Time (Linear)	<0.01	1	0.49	0.484
Reach (2006)	0.18	1	20.39	<0.001
Error	0.97	108		
Simpson's Diversity				
Reach	0.137	9	3.37	0.001
Reach	0.001	1	0.23	0.634
Time (Linear Trend)	0.003	1	0.55	0.458
Reach x Time (Linear)	0.025	1	5.53	0.021
Reach (2006)	0.014	1	3.14	0.079
Error	0.488	108		
Evenness				
Reach	0.142	9	3.27	0.001
Reach	0.011	1	2.35	0.129
Time (Linear Trend)	0.026	1	5.53	0.020
Reach x Time (Linear)	0.019	1	3.86	0.052
Reach (2006)	0.017	1	3.70	0.057
Error	0.520	108		
Log_{10} EPT %				
Reach	3.01	9	9.18	<0.001
Reach	0.99	1	27.05	<0.001
Time (Linear Trend)	<0.01	1	0.11	0.736
Reach x Time (Linear)	0.25	1	6.77	0.011
Reach (2006)	0.82	1	22.54	<0.001
Error	3.94	108		

Figure 5.4-7 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach STR-E-1.



Note: Ellipse is for reference baseline data for erosional reaches.

Table 5.4-11 Summary of habitat characteristics of sentinel species monitoring sites, August 2006.

Parameter	Lower Steepbank River (site SR-E)	Lower Muskeg River (site MR-E)	Upper Steepbank River (site SR-R)[a]	Upper Steepbank River (site SR-R2)[b]	Upper Horse River (site HR-R)	Upper Dunkirk River (site HR-R)
Channel Morphology	Riffle-Pool	Riffle-Pool	Riffle-Pool	Riffle-Pool	Riffle-Pool	Riffle-Pool
Gradient (%)	1.5	1.5	1.5	1.5	1.0	1.0
Avg. Channel Width (m)	23.5	25.3	28.2	30.0	19	29.1
Avg. Wetted Width (m)	18.5	14.8	21.4	26.5	16.9	28.826.5
Avg. Water Velocity (m/s)	Riffle:0.82[C] Run: 1.10	Run: 0.58	Riffle: 1.16 Run: 0.89	Riffle: 1.16 Run: 0.87	Riffle: 0.41	Riffle: 0.52[C] Run: 0.44[C]
Substrate	Cobble / Gravel	Gravel / Cobble	Cobble / Boulder	Angular cobble / Boulder	Cobble / Gravel	Cobble / Gravel
Cover Type	Pool / Boulder	Pool / Boulder	Boulder / Pool	Boulder / Pool / Overhanging vegetation	Boulder / Small woody debris.	Boulder / Pool

[a] Original reference site. The reference site was moved on August 17, 2007 due to increasing focal projects development.

[b] New reference site, located upstream of all current development but still within the Fort McMurray Formation.

[c] Data recorded in October 2006 during fall sampling efforts.

Table 5.4-12 Results of fish sampling efforts during August and October 2004 and 2006 sentinel species monitoring programs.

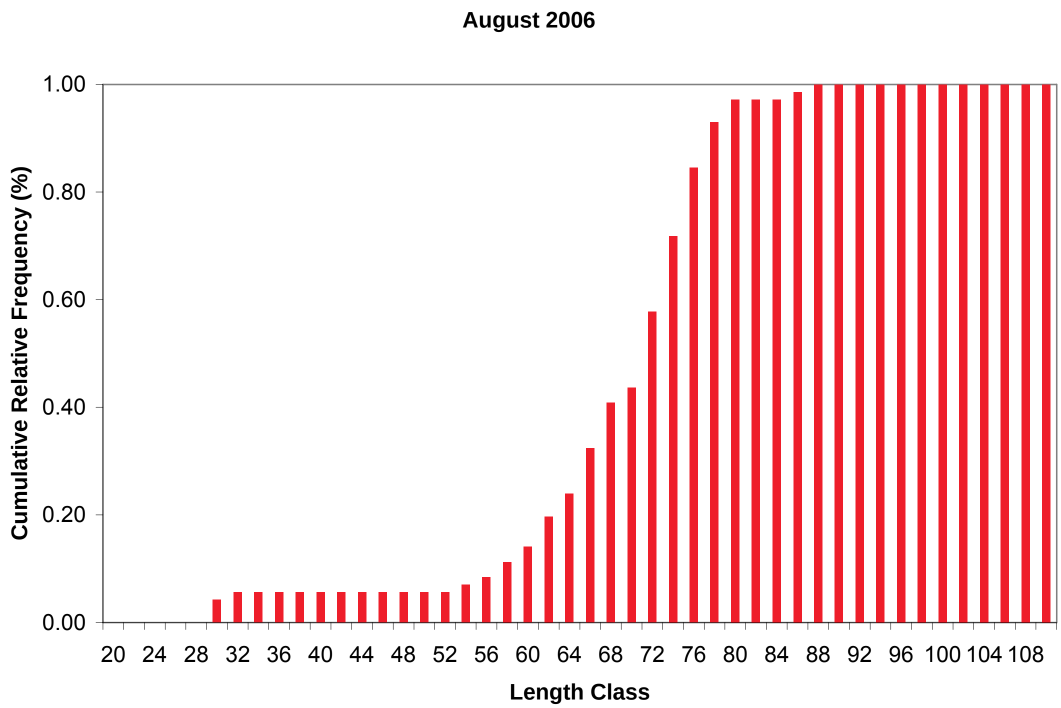
Site	August 2006			October 2006			August 2004	October 2004
	SLSC	SPSC	Total Sculpin	SLSC	SPSC	Total Sculpin	Total[1]	Total[1]
Lower Steepbank River (site SR-E)	60	6	66	43	20	63	103	110
Lower Muskeg River (site MR-E)	97	5	102	79	0	79	102	94
Upper Steepbank River (site SR-E2)	71	0	71	79	9	88	96	102
Upper Horse River (site HR-R)	100	0	100	100	0	100	111	104
Upper Dunkirk River (site DR-R)	98	0	98	98	8	106	108	101

SLSC: slimy sculpin; SPSC – spoonhead sculpin

Table 5.4-13 Statistical comparison of length-frequency distributions between Steepbank River sites and other sentinel species sites, 2006.

Site Comparison	*p* value of Kolmogorov-Smirnov Two-Sample Test			
	2006		2004	
	August	October	August	October
Upper Steepbank River (site SR-R2) versus:				
Lower Steepbank River (site SR-E)	<0.0001	<0.005	<0.0001	<0.0001
Upper Dunkirk River (site DR-R)	<0.0001	<0.0001	<0.0001	<0.0001
Upper Horse River (site HR-R)	<0.0001	<0.0001	<0.0001	0.268
Lower Muskeg River (site MR-E)	<0.0001	<0.0001	<0.0001	<0.0001
Lower Steepbank River (site SR-E) versus:				
Upper Dunkirk River (site DR-R)	<0.005	<0.0001	0.113	0.016
Upper Horse River (site HR-R)	<0.0001	<0.0001	<0.0001	<0.0001
Lower Muskeg River (site MR-E)	<0.0001	<0.0001	<0.0001	<0.0001
Upper Dunkirk River (site DR-R) vs. Upper Horse River (site HR-R)	<0.0001	<0.0001	<0.0001	<0.0001
Upper Dunkirk River (site DR-R) vs. Lower Muskeg River (site MR-E)	<0.05	<0.0001	<0.0001	<0.0001
Upper Horse River (site HR-R) vs. Lower Muskeg River (site MR-E)	<0.0001	<0.0001	<0.0001	<0.0001

Figure 5.4-8 Cumulative length-frequency distributions for slimy sculpin populations at upper Steepbank River (site SR-R2), 2006.



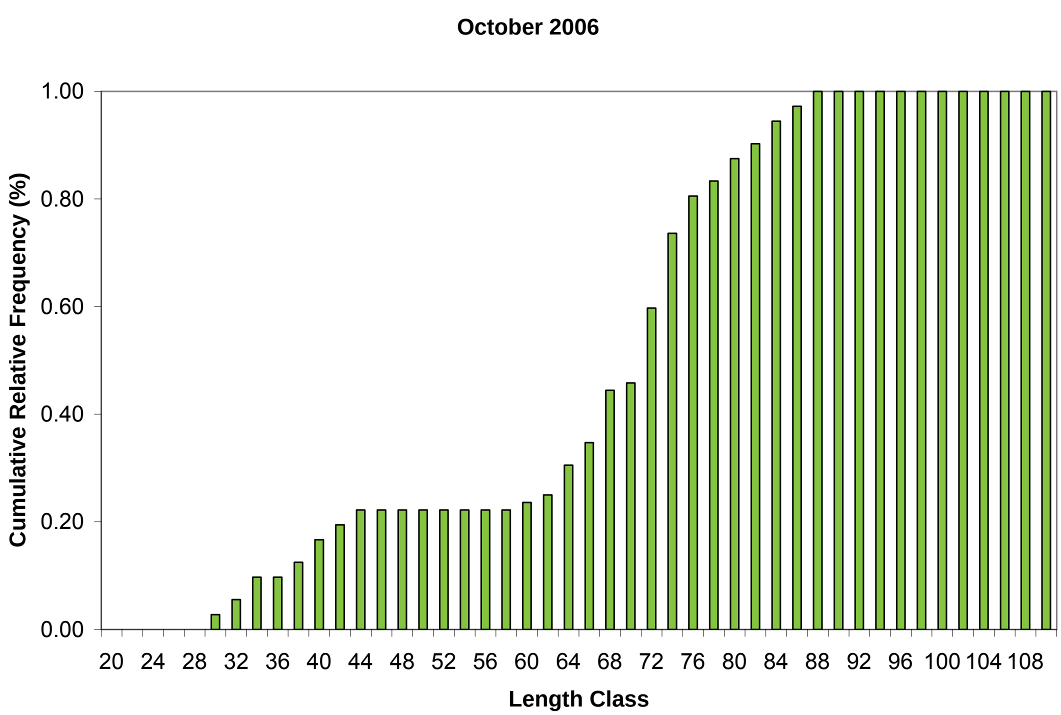
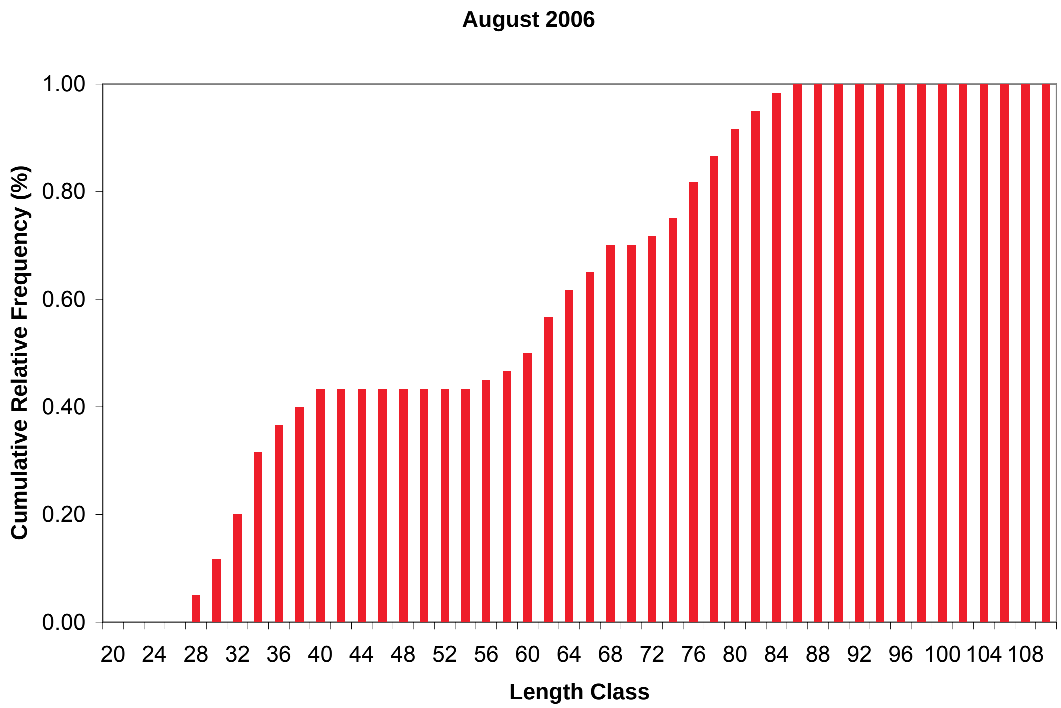


Figure 5.4-9 Cumulative length-frequency distributions for slimy sculpin populations at lower Steepbank River (site SR-E), 2006.



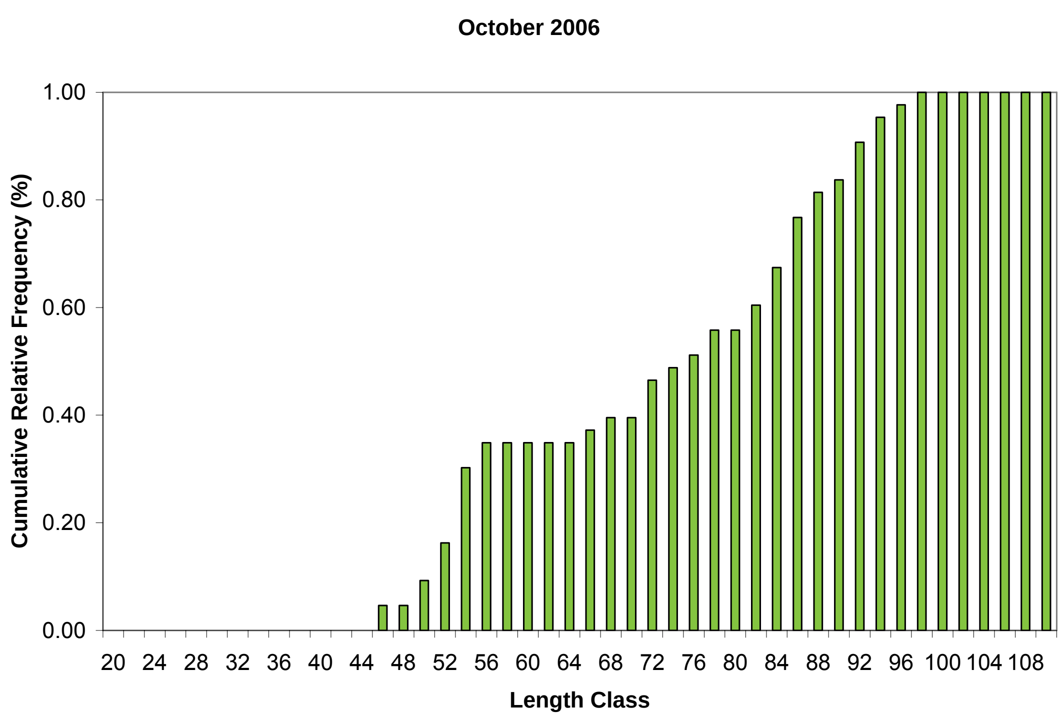


Figure 5.4-10 Mean length of slimy sculpin captured in the 2006 sentinel fish species fish survey.

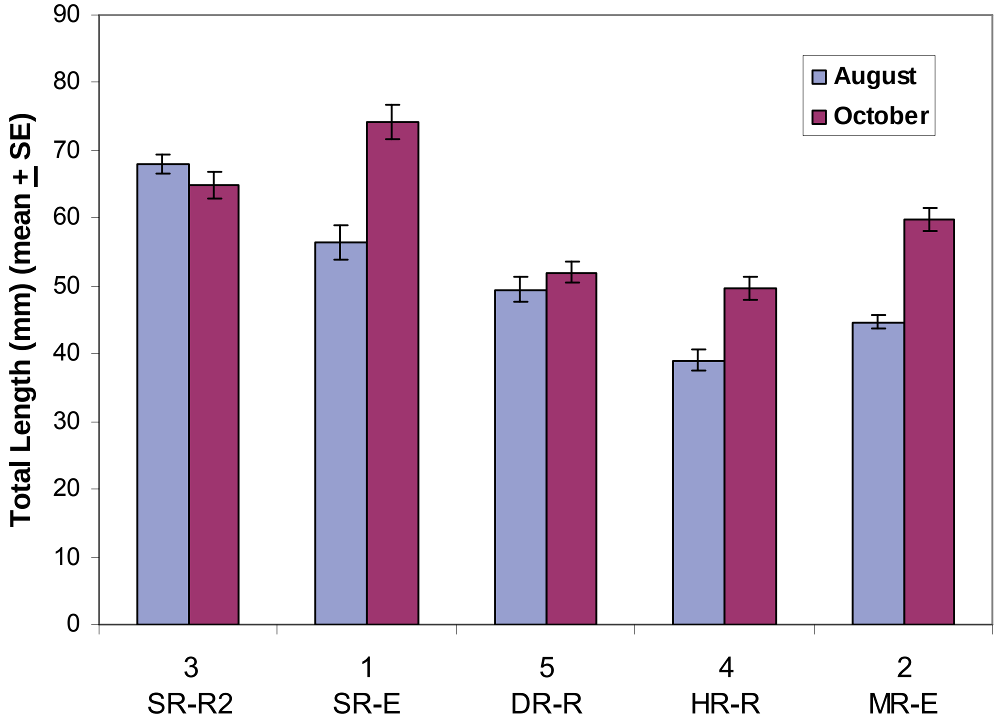


Figure 5.4-11 Mean weight of slimy sculpin captured in the 2006 sentinel fish species survey.

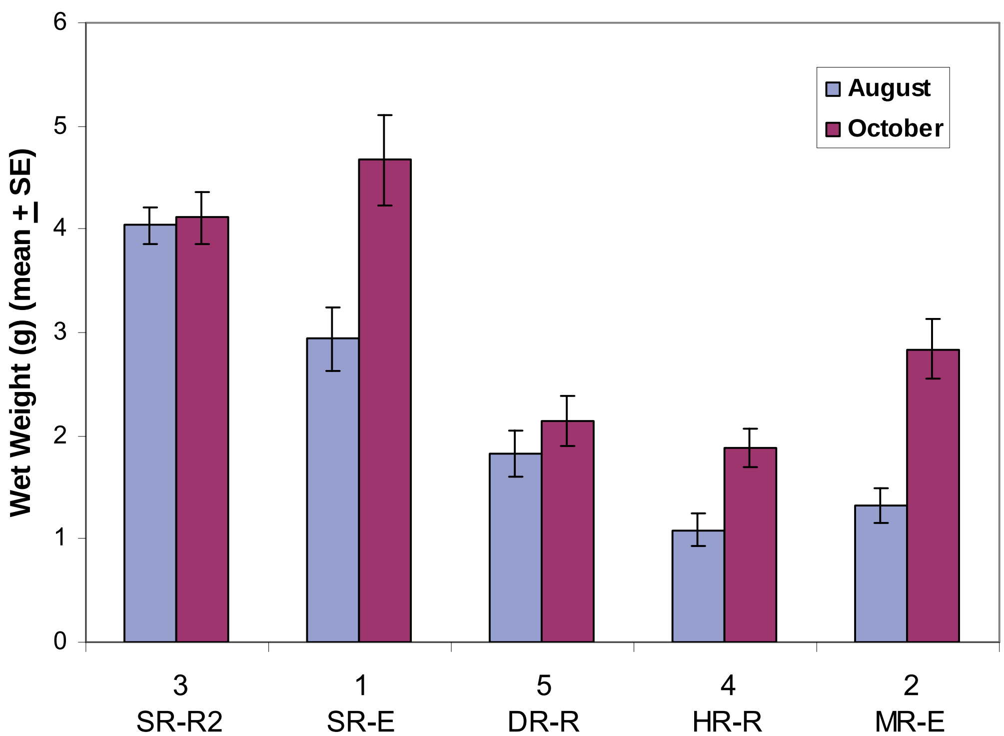
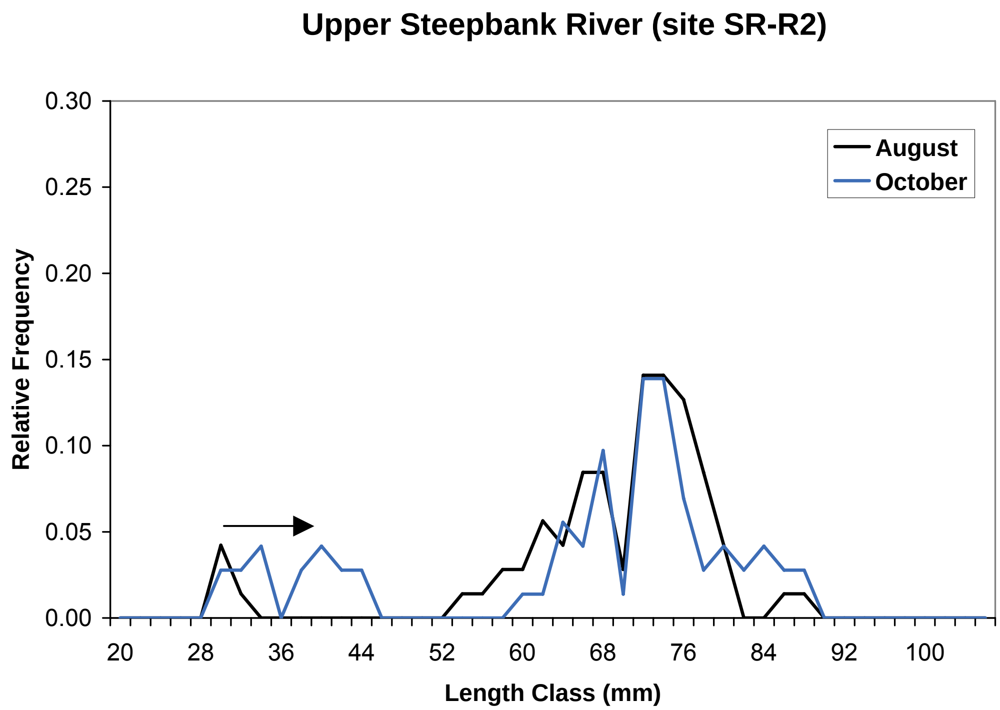


Table 5.4-14 Seasonal comparison of size of captured slimy sculpin, August and October 2006.

		Lower Steepbank River (site SR-E)	Lower Muskeg River (site MR-E)	Lower Steepbank River (site SR-R2)	Upper Horse River (site HR-R)	Upper Dunkirk River (site DR-R)
August	**Sample Size**	60	97	71	100	98
Length (mm)	Mean	56.4 B	44.6 C	68.1 A	39.1 D	49.4 C
	SE	2.60	0.93	1.43	1.45	1.84
	Min	30	33	23	25	31
	Max	87	86	87	92	97
Weight (g)	Mean	2.94 B	1.32 C	4.03 A	1.09 D	1.83 C
	SE	0.31	0.17	0.17	0.17	0.23
	Min	0.37	0.42	0.23	0.16	0.32
	Max	7.72	14.12	7.26	10.30	8.30
October	**Sample Size**	43	79	72	100	92
Length (mm)	Mean	74.1 A	59.9 B	65.0 B	49.6 D	52.0 C
	SE	2.54	1.71	1.95	1.64	1.57
	Minimum	47	45	28	30	35
	Maximum	99	111	87	86	91
Weight (g)	Mean	4.67 A	2.84 C	4.11 B	1.88 C	2.14 C
	SE	0.43	0.29	0.25	0.19	0.23
	Minimum	0.96	1.06	0.29	0.21	0.60
	Maximum	10.48	12.66	8.72	7.41	11.58

Those values bearing different letters indicate significant difference between sites as determined through ANOVA ($p<0.05$) and Bonferroni adjusted multiple comparisons. Sites with the same letter were not significantly different from each other; sites with different letters were significantly different from each other.

Figure 5.4-12 Length-frequency distributions of slimy sculpin from the Steepbank River, August and October 2006.



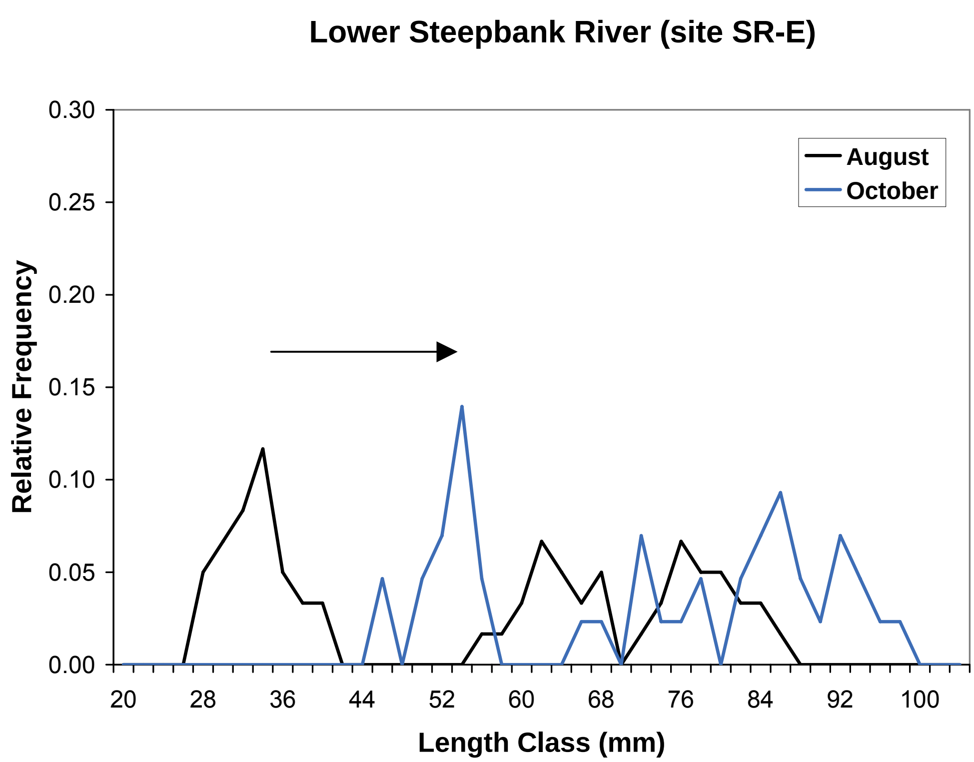
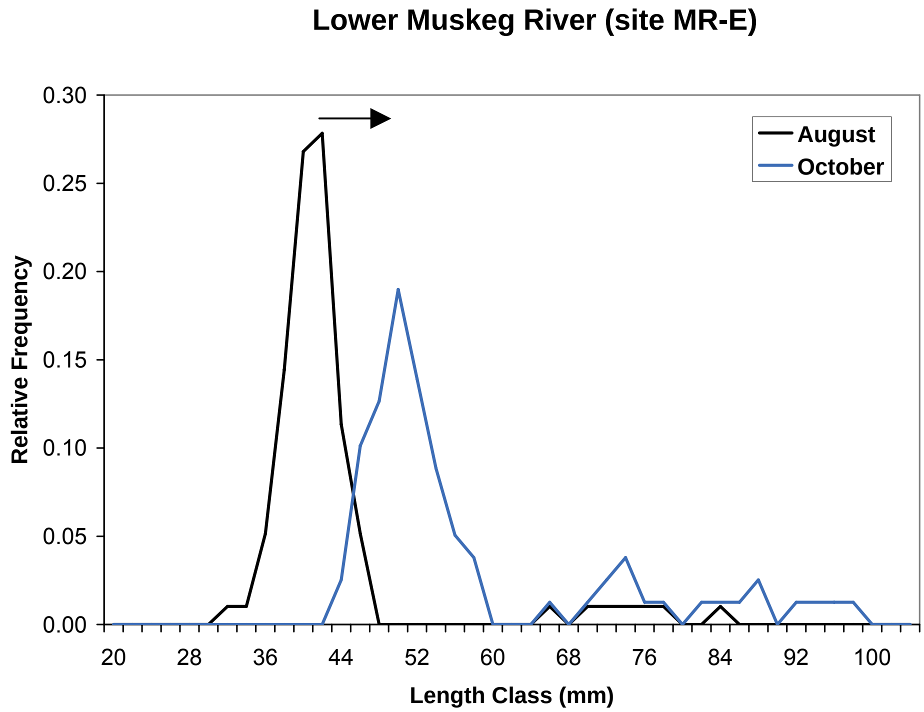


Figure 5.4-13 Length-frequency distributions of slimy sculpin from the Dunkirk, Horse and Muskeg rivers, August and October 2006.



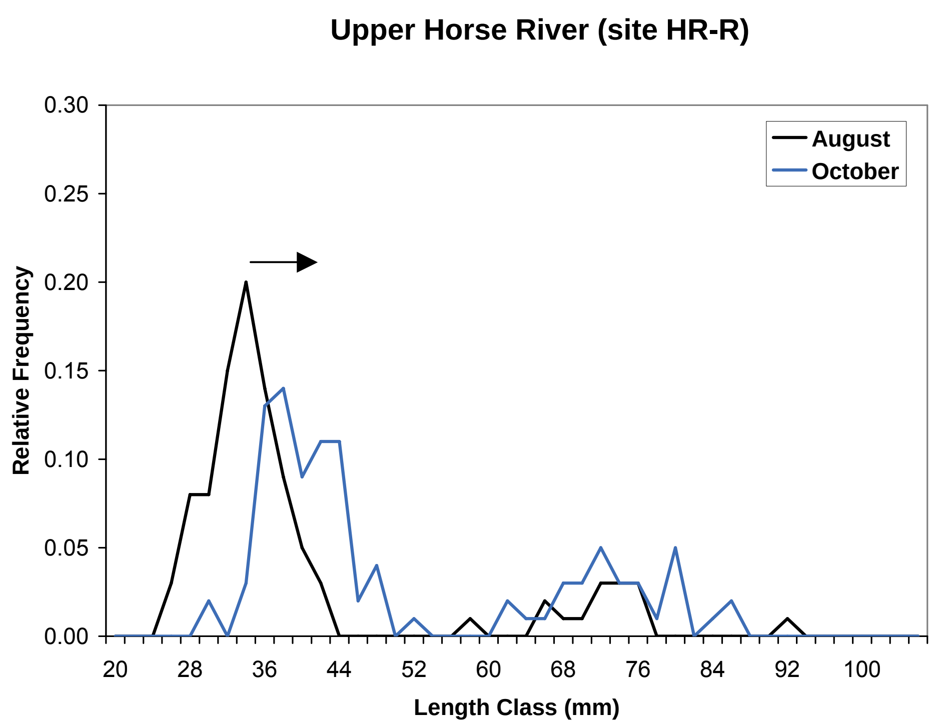


Figure 5.4-13 Cont'd.

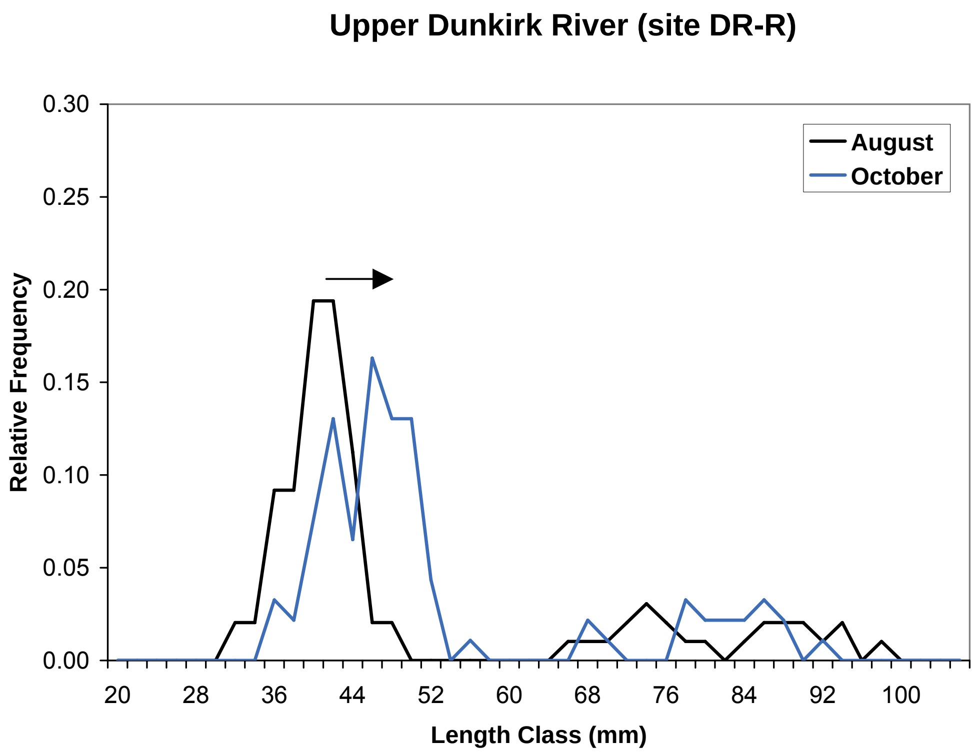


Table 5.4-15 Estimated growth rates of young-of-the-year sculpin, 2006.

Site	Mean Length (mm)			2006 Estimated Growth (mm/day)	2004 Estimated Growth[1] (mm/day)
	August	October	Difference		
Lower Steepbank River (site SR-E)	34.9	53.8	18.9	0.42	n/a[2]
Lower Muskeg River (site MR-E)	42.2	52.2	9.9	0.22	0.22
Upper Steepbank River (site SR-R2)	27.5	36.6	9.1	0.20	0.24
Upper Horse River (site HR-R)	33.3	39.5	6.2	0.14	0.14
Upper Dunkirk River (site DR-R)	39.8	44.9	5.1	0.11	0.21

[1] Combined slimy and spoonhead sculpin

[2] n/a - not applicable–only one YOY captured

Table 5.4-16 Proportion of slimy sculpin populations represented by young-of-year individuals, August and October 2006.

Site	August 2006			October 2006		
	Total	No. YOY	% YOY	Total	No. YOY	% YOY
Lower Steepbank River (site SR-E)	60	26	43.3	43	15	22.2
Lower Muskeg River (site MR-E)	97	90	92.8	79	60	79.6
Upper Steepbank River (site SR-R2)	71	4	5.6	72	16	34.9
Upper Horse River (site HR-R)	100	85	85.0	100	70	75.9
Upper Dunkirk River (site DR-R)	98	75	76.5	93	74	70.0

Table 5.4-17 Mean condition factor of slimy sculpin (excluding YOY fish), 2006.

	Lower Steepbank River (site SR-E)	Lower Muskeg River (site MR-E)	Upper Steepbank River (site SR-R2)	Upper Dunkirk River (site DR-R)	Upper Horse River (site HR-R)
August					
Sample Size	34	7	67	23	15
Mean Condition Factor	1.18 A	1.05 B	1.20 A	1.01B	1.23 A
SE	0.01	0.02	0.01	0.02	0.03
October					
Sample Size	28	19	56	19	30
Mean Condition Factor	1.00 B	1.09 B	1.28 A	1.18 A	1.17 A
SE	0.01	0.03	0.03	0.04	0.04

Condition Factor = (weight)/(length^3) * 10^5

Values with different letters indicate significant differences between sites as determined through ANCOVA ($p < 0.05$) and Bonferroni adjusted multiple comparisons. Sites with the same letter were not significantly different from each other; sites with different letters were significantly different from each other.

Table 5.4-18 Effect summary for condition factor[1] of adult slimy sculpin from the lower Steepbank River (site SR-E *potentially influenced*) relative to each *reference* site, 2006.

Reference Site	Summer 2006		Fall 2006		Fall 2004	
	Effect[2]	% Difference[3]	Effect[2]	% Difference[3]	Effect[2]	% Difference[3]
Upper Steepbank River	No	-0.2 ns	Yes	-11.2	No	-4.0
Upper Dunkirk River	No	+8.7	No	-7.7	No	+6.7
Upper Horse River	No	-2.2 ns	No	-8.6	No	+4.5 ns

[1] Condition Factor = (weight)/(length^3) * 10^5

[2] Effect when condition > ± 10% of reference mean.

[3] Percent difference of potentially influenced site relative to reference site; ns = not significantly different.

Table 5.4-19 Effect summary for condition factor[1] of adult slimy sculpin from the lower Muskeg River (site MR-E, *potentially influenced*) relative to each *reference* site, 2006.

Reference Site	Summer 2006		Fall 2006		Fall 2004	
	Effect[2]	% Difference[3]	Effect[2]	% Difference[3]	Effect[2]	% Difference[3]
Upper Steepbank River	No	-7.8	No	-7.0	Yes	-10.0
Upper Dunkirk River	No	+0.3 ns	No	-3.4	No	0.0 ns
Upper Horse River	No	-9.7	No	-4.4	No	-2.1 ns

[1] Condition Factor = (weight)/(length^3) * 10^5

[2] Effect when condition > ± 10% of reference mean.

[3] Percent difference of potentially influenced site relative to reference site; ns = not significantly different.

5.5 TAR RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge		◄── √	──►		
Mean winter discharge					
Annual maximum daily discharge		◄── √	──►		
Minimum open-water season discharge		◄── √	──►		

The May to October 2006 runoff volume was 6% below the historical average. The estimated effects of focal projects were to reduce inflows to the Tar River by 0.086 million m^3 in May to October 2006. The effects are assessed as Low to Moderate for the hydrologic measurement endpoints.

Water Quality

Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006[1]**	
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Stations (n=1)**	**2006 *Reference* Stations (n=1)**
Physical variables (max=1 for exp, 1 for ref)	0	0
Nutrients (max=3 for exp, 3 for ref)	2	1
Ions (max=2 for exp, 2 for ref)	0	0
Selected metals (max=5 for exp, 5 for ref)	1	1

Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline[2]**	
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* Stations (n=1 station X 13 endpoints)**	**2006 *Reference* Stations (n=1 station X 13 endpoints)**
Greater than 95th percentile	2	0
Between 5th and 95th percentiles	11	13
Less than 5th percentile	0	0

Concentrations of ions and nitrogen were higher than previously observed at TAR-1 and were also relatively high at TAR-2. High ion concentrations may be related to a lower water table and relatively higher contribution of groundwater to instream flows. The high concentration of nitrate+nitrite observed at TAR-1 is attributed to point source discharges of treated wastewater from CNRL's sewage treatment plant.

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**					
	2006 *Potentially Influenced* Stations (n=1)			**2006 *Reference* Stations (n=1)**		
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**
Abundance		1			1	
Richness		1			1	
Diversity		1			1	
Evenness		1			1	
% EPT	1				1	

Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006[1]**	
Measurement endpoints with guidelines	**2006 *Potentially Influenced Stations* (n=1)**	**2006 *Reference* Stations (n=0)**
Total Hydrocarbons(max=12 for exp,0 for ref)	0	No measurement of sediment quality in depostional reference stations in 2006
PAHs (max=3 for exp, 0 for ref)	0	

There is evidence of effects of focal project activities on benthic invertebrate communities in 2006. There were some statistically significant differences in benthic invertebrate community measurement endpoints between sampled reaches designated as potentially-influenced and reference and over time. Effects are not seen in the ordination measures of benthic invertebrate community measurement endpoints. There were no measured sediment quality measurement endpoints with concentrations above sediment quality guidelines in fall 2006. There may be little contribution of sediment quality in to differences in benthic invertebrate communities in the Tar River.

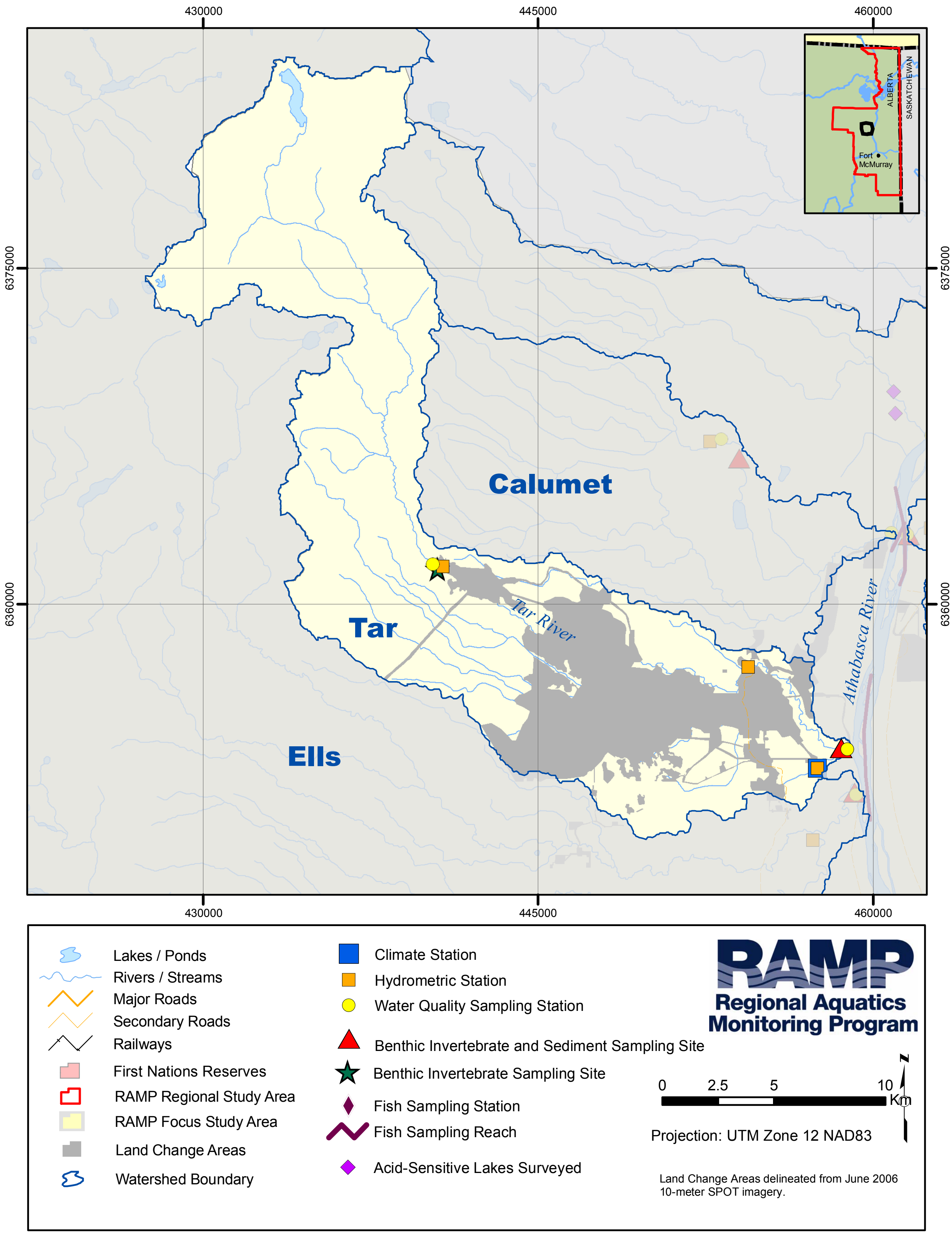
Fish Populations

Fish Inventory	No fish inventory studies conducted in 2006.
Sentinel Studies	No sentinel fish studies conducted in 2006.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.5-1 Tar River watershed.



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5.5.1 Development Status

As of 2006, approximately 21% of the Tar River watershed had undergone land change as a result of focal projects occurring in the watershed (Table 2.6-2). The designations of specific areas of the watershed are as follows:

- The lower Tar River drainage (Figure 5.5-1) is designated as *potentially influenced*. All data gathered from the 2006 RAMP stations located in this area of the watershed are designated as operational data; and
- The westernmost quarter of Oil Sands Lease 18 and all areas of the Tar River drainage upstream of Oil Sands Lease 18 (Figure 5.5-1) are designated as *reference*. (Figure 2.4-1). All data gathered from the 2006 RAMP stations located in this area of the watershed are designated as baseline data.

5.5.2 Hydrologic Conditions

2006 Hydrologic Conditions The observed May to October runoff volume in the Tar River watershed, as measured at RAMP station S15, Tar River near the Mouth (07DA015), was 6% below the historical average in 2006 (Figure 5.5-2). Discharges were below the previously recorded minimum flows for May and the first half of June. Rainfall events in June and July raised the stream levels significantly, and discharges remained above historical median values until late August. During September and October, streamflows receded to lower than previously recorded values for those months. The maximum daily discharge of 4.77 m^3/s was very close to the mean annual flood of 5.0 m^3/s. The minimum observed open-water discharge was 0.12 m^3/s, which is much lower than the average minimum open-water discharge of 0.30 m^3/s.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the Tar River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is as follows (details are provided in Table 5.5-1):

- As of 2006, the area of land change not closed-circuited was 69.6 km^2 in the Tar River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1); and
- Discharges to the Tar River by focal projects in 2006 are estimated at 0.088 million m^3 in the May to October 2006 period that RAMP station S15 was operational. This discharge was released from CNRL's wastewater treatment plant.

The estimated net effect of these focal project activities was to increase flow in the Tar River by an estimated 0.608 million m^3 in the May to October period in 2006. The estimated cumulative effect in 2006 is that mean open-water season discharge was increased by 5.2%, annual maximum daily discharge was increase by 4.4% and open-water season minimum daily discharge was increased by 10% (Figure 5.5-2, Table 5.5-2). The calculated hydrologic effects would have been assessed as Low to Moderate for these hydrologic measurement endpoints in many oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information as well as information available regarding focal project activities in the Tar River watershed, cumulative, watershed-level changes in hydrologic conditions in the Tar River as of 2006 have been low to moderate.

5.5.3 Water Quality

In 2006, water quality samples were collected from:

- The mouth of the Tar River in the fall season (station TAR-1, established in 1998, sampled every year since 2002, designated as *potentially influenced* since summer 2004); and
- Tar River upstream in the spring, summer, and fall seasons (station TAR-2, designated as *reference* since station establishment in 2004).

2006 Results and Historical Ranges of Concentration At station TAR-1, there were 14 (64%) of a possible 22[1] cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum concentrations (Table 5.5-3). This statistic is greater than at station TAR-2, at which there were 5 (23%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum concentrations (Table 5.5-4). In fall 2006:

- pH and conductivity, as well as concentrations of total nitrogen, nitrate plus nitrite, sodium, calcium, magnesium, chloride, sulphate, TDS, and naphthenic acids were above previously measured maximum concentrations at station TAR-1 (Table 5.5-3);
- Concentrations of TSS, total aluminum, and total mercury were below previously measured minimum concentrations at station TAR-1 (Table 5.5-3);
- Conductivity, as well as concentrations of total nitrogen, chloride, and sulphate were above previously measured maximum concentrations at station TAR-2 (Table 5.5-4); and
- Concentration of dissolved organic carbon was below the previously measured minimum concentration at station TAR-2 (Table 5.5-4).

Concentrations of many ions in the lower Tar River (station TAR-1) were greater in fall 2006 than in fall 2005. Similar patterns in concentration over time for calcium, magnesium, sodium, potassium, boron, strontium and, to a lesser degree, chloride and sulphate, indicate that changes in these ion concentrations may be related to changes in the water table and relative contribution of groundwater to river flow.

Concentrations of total nitrogen have increased in the lower Tar River (station TAR-1) between 2003 and 2006. Total nitrogen was also higher in fall 2006 in the upper Tar River (station TAR-2). However, a large proportion of total nitrogen at station TAR-1 was comprised of nitrate+nitrite (Table 5.5-3), which was non-detectable at station TAR-2 (Table 5.5-4). Nitrate and nitrate can be indicators of nutrient enrichment from sewage treatment plants, and it may be that the relatively high concentration of nitrate+nitrite observed at station TAR-1 in fall 2006 resulted from the discharge of CNRL's wastewater treatment plant (Section 2.2.5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were 3 (30%) out of 10[2] possible exceedances in water quality guidelines for the water quality measurement endpoints at station TAR-1 in fall 2006; these were dissolved phosphorus, total nitrogen, and total aluminum (Table 5.5-3). This is similar to the

[1] There are a total of 22 selected water quality measurement endpoints (Section 3.2.6.1).

[2] There are water quality guidelines for ten of the selected water quality measurement endpoints.

2 (18%) out of 11 possible exceedances in water quality guidelines for the water quality measurement endpoints at the reference station TAR-2 in fall 2006, which were dissolved phosphorus and total aluminum (Table 5.5-4).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines for the following water quality variables not designated as water quality measurement endpoints were exceeded in the Tar River watershed in 2006 (Table 5.5-5):

- Concentrations of sulphide, total aluminum, total chromium, dissolved iron, and total iron exceeded water quality guidelines in the upper Tar River (station TAR -2) in spring 2006 (water at station TAR-1 was not sampled in spring 2006);
- Concentrations of sulphide, total phosphorus, total aluminum, dissolved cadmium, total cadmium, total chromium, total iron, and dissolved iron exceeded water quality guidelines in the upper Tar River (station TAR-2) in summer 2006 (water at station TAR-1 was not sampled in summer 2006);
- Concentrations of sulphide, total phosphorus, total aluminum, total iron, dissolved iron, and total phenols exceeded water quality guidelines in the upper Tar River (station TAR-2) in fall 2006; and
- Concentrations of sulphide, total phosphorus, total nitrogen, nitrate+nitrite, total aluminum, total iron, and total phenols exceeded water quality guidelines in the lower Tar River (station TAR-1) in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At the lower Tar River, the concentrations of 2 (15%) out of a possible 13[3] water quality measurement endpoint-station combinations, total boron and sulphate, were below the 5^{th} or above the 95^{th} percentile of regional baseline concentrations (Figure 5.5-3). This is higher than the upper Tar River at which none of a possible 13 water quality measurement endpoint-station combinations were below the 5^{th} or above the 95^{th} percentile of regional baseline concentrations (Figure 5.5-3).

Ion Balance Ion balance at station TAR-1 was generally consistent between 1998 and 2004 (Figure 5.5-4); however, ion balance has been increasingly influenced by sulphate (and decreasingly influenced by bicarbonate) since 2005 and including 2006 (Figure 5.5-4). Ion balance at station TAR-2 in fall 2006 also exhibited slightly more influence of sulphate in 2006 than in 2004 or 2005.

Summary There was some evidence of possible effects of focal project activities on water quality in the lower Tar River in fall 2006, likely as a result of effects of wastewater treatment facility discharge on nutrients in water in the lower Tar River. Concentrations of water quality measurement endpoints in fall 2006 were generally within regional ranges of concentrations for baseline conditions and there were few instances of concentrations of water quality measurement endpoints exceeding water quality guidelines.

[3] Thirteen water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4) were sampled at one station designated as *potentially influenced* in the Tar River watershed in fall 2006, making for a total of 13 water quality measurement endpoint-station combinations.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from:

- A reach near the mouth of the Tar River (reach TAR-D-1, depositional, *potentially influenced*, sampled by RAMP since 2002); and
- A reach in the upper Tar River (reach TAR-E-2, erosional, *reference*, sampled since 2004).

2006 Habitat Conditions The substrate of the reach near the mouth of the Tar River (reach TAR-D-1) was sand, with current velocities averaging 0.3 m/s, and no macrophyte cover (Table 5.5-6). Dissolved oxygen concentrations (near 10 mg/L) and pH (over 8) were relatively high. In contrast, the reach in the upper Tar River (reach TAR-E-2) was a typical erosional habitat with coarse substrate consisting of gravel, cobble and boulder, and higher flow velocities (0.7 m/s). There was some limited macrophyte cover at reach TAR-E-2. Periphyton chlorophyll *a* biomass at reach TAR-E-2 was low in fall 2006 and similar to previous years (Figure 5.5-5), indicating generally oligotrophic, nutrient-poor waters.

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The reach in the upper Tar River (reach TAR-E-2) was dominated numerically by EPT taxa, principally mayflies (48%), of the Baetidae and Heptageniidae families (Table 5.5-7). Stoneflies were diverse including *Nemoura*, *Zapada*, *Isogenoides*, *Skwala*, and *Pteronarcella*, plus several immature forms that could not be confidently identified to genus. In contrast, the reach near the mouth of the Tar River (reach TAR-D-1) was generally devoid of benthic fauna in fall 2006 compared to what had been measured in previous years (Table 5.5-7). The benthic invertebrate community fauna in 2006 in reach TAR-D-1 was dominated by chironomids, principally two genera (*Saetheria*, *Rheosmittia*). Four other genera of Chironomidae were found sporadically, as were miscellaneous dipteran fauna, snails, clams and worms (naidids, tubificids).

Effects of Focal Project Activities An ANOVA was conducted to compare the benthic invertebrate community measurement endpoints for reaches TAR-D-1 (*potentially influenced*) and TAR-E-2 (*reference*). There were significant *reach x time* interactions[4], both the before-after and linear time trends for richness, diversity, evenness and percent EPT (Table 5.5-8) suggesting effects on benthic invertebrate communities have occurred in reach TAR-D-1 as a result of focal project activities. Taxa richness, Simpson's diversity and evenness have always been higher in reach TAR-E-2 than in reach TAR-D-1, but declines in each reach over time have been more pronounced in the reach TAR-D-1 (Figure 5.5-6). The reach near the mouth of the Tar River (reach TAR-D-1) also used to contain low but significant populations of EPT taxa; percent EPT was 0 in reach TAR-D-1 in fall 2005 and fall 2006, which is at or below the normal range of %EPT values observed from regional reference depositional reaches (Figure 5.5-6). The average number of taxa in the reach near the mouth of the Tar River (reach TAR-D-1) has been approximately 4 since it was designated as *potentially influenced* in 2004, which is a 75% reduction from what was measured in the reach when it was designated as *reference* (2002 and 2003). These results indicate some degree of effect of focal project activities in the lower reach of the Tar River

[4] The linear contrast testing for differences in changes from before to after development between reaches (i.e., *reach x time [before to after]*) was the most insightful in terms of showing development-related effects. The *reach x time (linear)* contrast was also somewhat useful because it would show whether time trends differed in the upper and lower reaches, but did not distinguish changes in time trends from before to after development.

(reach TAR-D-1). However, ordination results indicate that the benthic invertebrate community of reach TAR-D-1 continues to lie within expected conditions for *reference* depositional reaches in the RAMP FSA (Figure 5.5-7). Multivariate techniques tend to be more sensitive to disturbance than univariate metrics (Kilgour et al., 2004), but have not detected the apparent effects of focal project activities on benthic invertebrate communities in the lower Tar River.

5.5.4.2 Sediment Quality

Sediment quality was sampled in fall 2006 in reach TAR-D-1 (*potentially influenced*), the depositional reach in which benthic invertebrate communities were sampled in fall 2006.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is, therefore, no historical record of sediment quality at reach TAR-D-1. Therefore, data from the closest sediment quality sampling location prior to 2006 was used as the basis of comparison for 2006 results; this was sediment quality sampling station TAR-1, sampled in 1998 and then from 2002 to 2005. Comparison of 2006 results from reach TAR-D-1 with results from previous years at sediment sampling station TAR-1 is characterized by 2 to 5 years of data in the historical record, depending on the sediment quality measurement endpoint.

Sediments at the lower Tar River reach (reach TAR-D-1) were dominated by sand, with a small proportion of both silt and clay, and total organic carbon content was low (Table 5.5-9). Eight out of 20 (40%) sediment quality measurement endpoints were measured in fall 2006 at reach TAR-D-1 at concentrations at or below the historically measured minimum concentrations: %clay; %silt; total organic carbon; Fraction 2, Fraction 3, and Fraction 4 hydrocarbons naphthalene, and retene (Table 5.5-9). Only one sediment quality measurement endpoint, %sand, was at or above historically measured minimum concentrations (Table 5.5-9). As in previous years, Fraction 1 hydrocarbons, including BTEX, were not detectable at TAR-D-1. Hydrocarbons were dominated by the C16-C34 fraction, and hydrocarbons in fall 2006 were at lower concentrations than previously measured in this reach. Survival of *Chironomus tentans* and *Hyalella azteca* was high despite a hazard index (predicted PAH toxicity) greater than 1 (Table 5.5-9).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines There were no sediment quality measurement endpoints with concentrations above sediment quality guidelines at reach TAR-D-1 in fall 2006 (Table 5.5-9).

Correlations among Sediment Quality Variables and Benthic Invertebrate Community Measurement Endpoints The analysis of the benthic invertebrate community for reach TAR-D-1 and TAR-E-2 indicate statistically significant *time x reach* interactions for benthic richness, diversity evenness, and %EPT. The results of the correlation analysis among sediment quality and benthic invertebrate community measurement endpoints in depositional reaches (Appendix F) reveals no sediment quality measurement endpoints that are significantly correlated with benthic invertebrate community richness, diversity or evenness and significant negative correlations between %EPT and %silt content, *Chironomus* growth, as well as concentrations of F3 hydrocarbons, total PAHs, and high molecular weight (HMW) PAHs. Of these, only *Chironomus* growth was higher at reach TAR-D-1 in fall 2006 than previously recorded (n=2). This suggests that the *time x reach* interactions for benthos diversity and evenness between these reaches may not be due to changes in sediment quality.

5.5.4.3 Summary

There is evidence of effects of focal project activities on benthic invertebrate communities in the Tar River watershed in 2006. There were some statistically significant differences in benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference* and over time. %EPT in fall 2006 at the lower reach sampled in the Tar River watershed was below the normal range of %EPT values observed from regional reference reaches. However, effects are not seen in the ordination measures of benthic invertebrate community measurement endpoints. There may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in the Tar River watershed.

5.5.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in the Tar River watershed.

5.5.6 Summary of Conditions

Monitoring activities in the Tar River watershed in 2006 included hydrology, water quality, benthic invertebrate communities, and sediment quality. The Tar River watershed in 2006 showed some changes in RAMP aquatic resources from previous years. The effects of focal project activities on hydrologic conditions in 2006 was assessed as low to moderate based on effects criteria used in oil sands EIAs for mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge. Concentrations of water quality measurement endpoints in fall 2006 were generally within regional ranges of concentrations for baseline conditions and there were few instances of concentrations of water quality measurement endpoints exceeding water quality guidelines, although there was some evidence of possible effects on water quality in the lower Tar River of wastewater treatment facility discharge. Finally, generally lower values of benthic invertebrate community measurement endpoints in 2006, and recent downward trends in a number of these measurement endpoints in areas of the watershed designated as *potentially influenced* (lower Tar River) indicate possible effects of focal project activities on benthic invertebrate communities in the lower parts of the Tar River watershed.

Figure 5.5-2 Tar River: 2006 hydrograph and historical context.

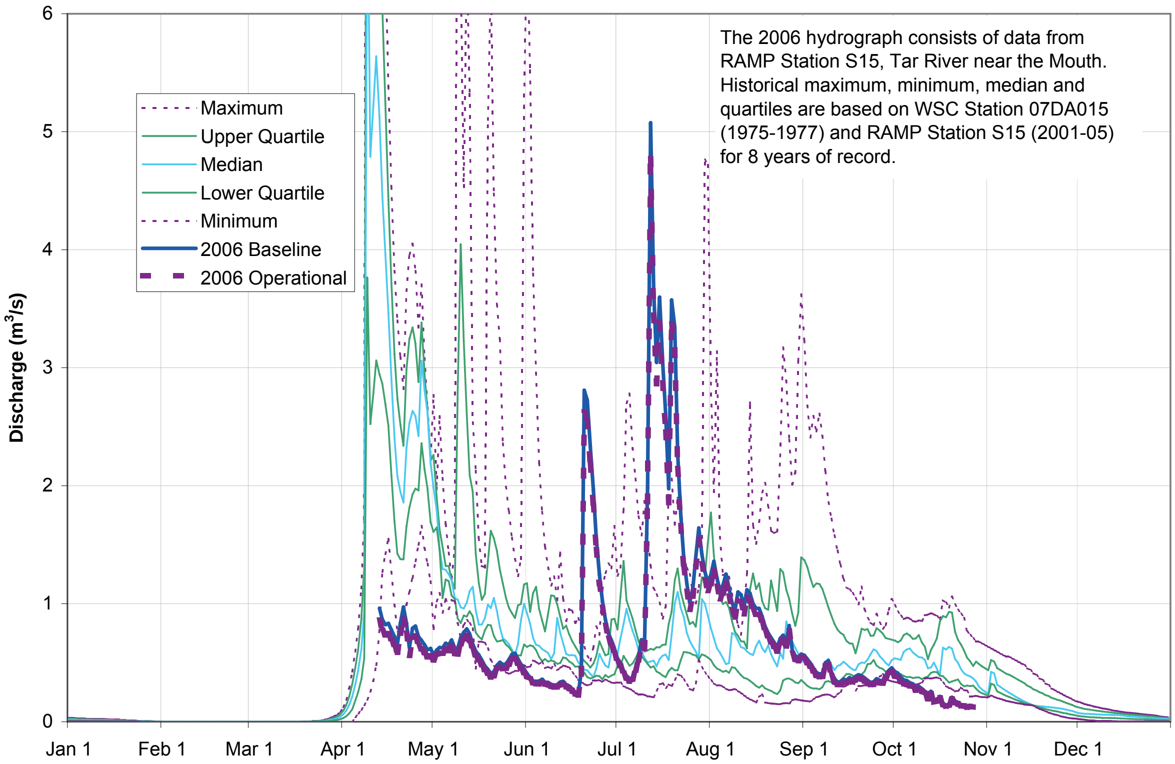


Table 5.5-1 Summary of inputs to the calculation of the Tar River baseline hydrograph at RAMP/WSC Station S15, Tar River near the Mouth (07DA015).

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	12.4	Observed daily discharges obtained from RAMP/WSC Station S15, Tar River near the Mouth (07DA015)
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	0	No land within Tar River drainage closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.520	69.6 km^2 within Tar River drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Tar River for focal project activities	0	Assumed to be negligible
Releases to Tar River from focal project activities	- 0.088	May to October discharge to Tar River from CNRL Horizon wastewater treatment facilities
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Tar River not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	11.9	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total annual discharge)	+ .608	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	+ 5.1%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.5-2 Calculated change in hydrologic measurement endpoints for the Tar River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	0.696	0.732	+5.2%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	4.57	4.77	+4.4%
Open-water season minimum daily discharge	0.109	0.121	+10%

Note: As measured at and calculated for RAMP/WSC Station S15, Tar River near the Mouth (07DA015).

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.5-3 Concentrations of water quality measurement endpoints, lower Tar River (station TAR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.5	5	8.1	8.2	8.2
Total Suspended Solids	mg/L	-[1]	11	5	15	36	214
Conductivity	µS/cm	-	543	5	302	326	493
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.051**	5	0.015	0.017	**0.067**
Total nitrogen*	mg/L	1.0	**2.40**	5	0.5	0.65	1.30
Nitrate+Nitrite	mg/L	-	1.5	5	<0.05	<0.1	0.2
Dissolved organic carbon	mg/L	-	17	5	12	14	21
Ions							
Sodium	mg/L	-	36	5	15	19	32
Calcium	mg/L	-	63.3	5	38	41.7	52.3
Magnesium	mg/L	-	19.3	5	11.3	11.9	16.5
Chloride	mg/L	230, 860[3]	9	5	1.7	4	5
Sulphate	mg/L	100[4]	87.9	5	20.4	31.5	42.0
Total Dissolved Solids	mg/L	-	380	5	170	280	330
Total Alkalinity	mg/L		179	5	121	153	210
Organic compounds							
Naphthenic acids	mg/L	-	1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.36**	5	**0.47**	**0.92**	**3.95**
Dissolved aluminum	mg/L	0.1[2]	0.008	5	0.005	0.015	0.026
Total boron	mg/L	1.2[4]	0.128	5	0.054	0.065	0.145
Total molybdenum	mg/L	0.073	0.00125	5	0.00037	0.00115	0.00200
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	3	0.6	0.9	2.8
Total strontium	mg/L	-	0.228	5	0.143	0.156	0.239

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.5-4 Concentrations of water quality measurement endpoints, upper Tar River (station TAR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.0	-	8.3
Total Suspended Solids	mg/L	-[1]	5	2	6	-	7
Conductivity	µS/cm	-	331	2	233	-	297
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.055**	2	0.024	-	**0.058**
Total nitrogen*	mg/L	1.0	0.60	2	0.5	-	0.50
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.1	-	0.1
Dissolved organic carbon	mg/L	-	8	2	8	-	14
Ions							
Sodium	mg/L	-	13	2	6	-	16
Calcium	mg/L	-	44	2	31.4	-	45.6
Magnesium	mg/L	-	13.2	2	8.8	-	13.7
Chloride	mg/L	230, 860[3]	2	2	2	-	2
Sulphate	mg/L	100[4]	38	2	20	-	29.9
Total Dissolved Solids	mg/L	-	210	2	160	-	280
Total Alkalinity	mg/L		131	2	100	-	159
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	**0.170**	2	0.087	-	**0.708**
Dissolved aluminum	mg/L	0.1[2]	0.016	2	0.008	-	0.017
Total boron	mg/L	1.2[5]	0.056	2	0.035	-	0.066
Total molybdenum	mg/L	0.073	0.00131	2	0.00083	-	0.00140
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	2	0.6	-	1.4
Total strontium	mg/L	-	0.118	2	0.101	-	0.185

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.5-5 List of all 2006 water quality guideline exceedances, Tar River.

Variable	Units	Guideline*	TAR-1	TAR-2
Spring				
Sulphide	mg/L	0.002[1]	ns	**0.004**
Total aluminum	mg/L	0.1	ns	**0.961**
Total chromium	mg/L	0.0010, 0.0089[2]	ns	**0.00116**
Dissolved iron	mg/L	0.3[3]	ns	**0.382**
Total iron	mg/L	0.3	ns	**1.03**
Summer				
Sulphide	mg/L	0.002[1]	ns	**0.008**
Total phosphorus	mg/L	0.05	ns	**0.095**
Total aluminum	mg/L	0.1	ns	**1.67**
Dissolved cadmium	mg/L	-[4]	ns	**0.0000436**
Total cadmium	mg/L	-[4]	ns	**0.0000534**
Total chromium	mg/L	0.0010, 0.0089[2]	ns	**0.00274**
Dissolved iron	mg/L	0.3[3]	ns	**0.602**
Total iron	mg/L	0.3	ns	**2.11**
Fall				
Sulphide	mg/L	0.002[1]	**0.013**	**0.006**
Total phosphorus	mg/L	0.05	**0.135**	**0.074**
Total nitrogen	mg/L	1.0	**2.4**	-
Nitrate+nitrite	mg/L	1.0[5]	**1.5**	-
Total aluminum	mg/L	0.1	**0.36**	**0.17**
Dissolved iron	mg/L	0.3[3]	-	**0.679**
Total iron	mg/L	0.3	**2.04**	**1.14**
Total phenols	mg/L	0.004	**0.005**	**0.006**

TAR-1 was sampled only in fall 2006. TAR-2 was sampled in spring, summer and fall 2006.

ns = not sampled

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2001).

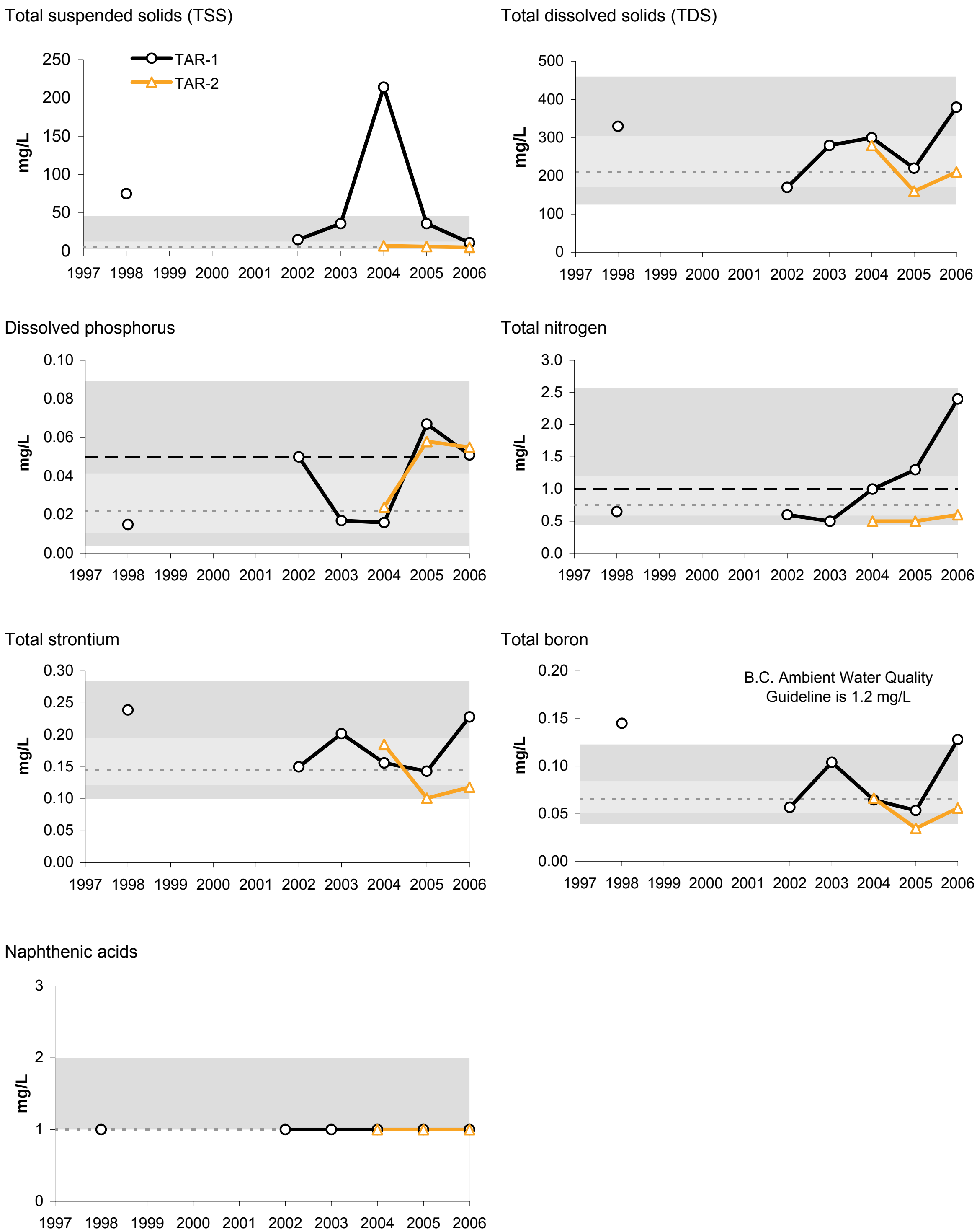
[2] Guidelines for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

[3] Guideline is for total metal (no guideline for dissolved species).

[4] Guideline is hardness-dependent.

[5] Guideline is for total nitrogen.

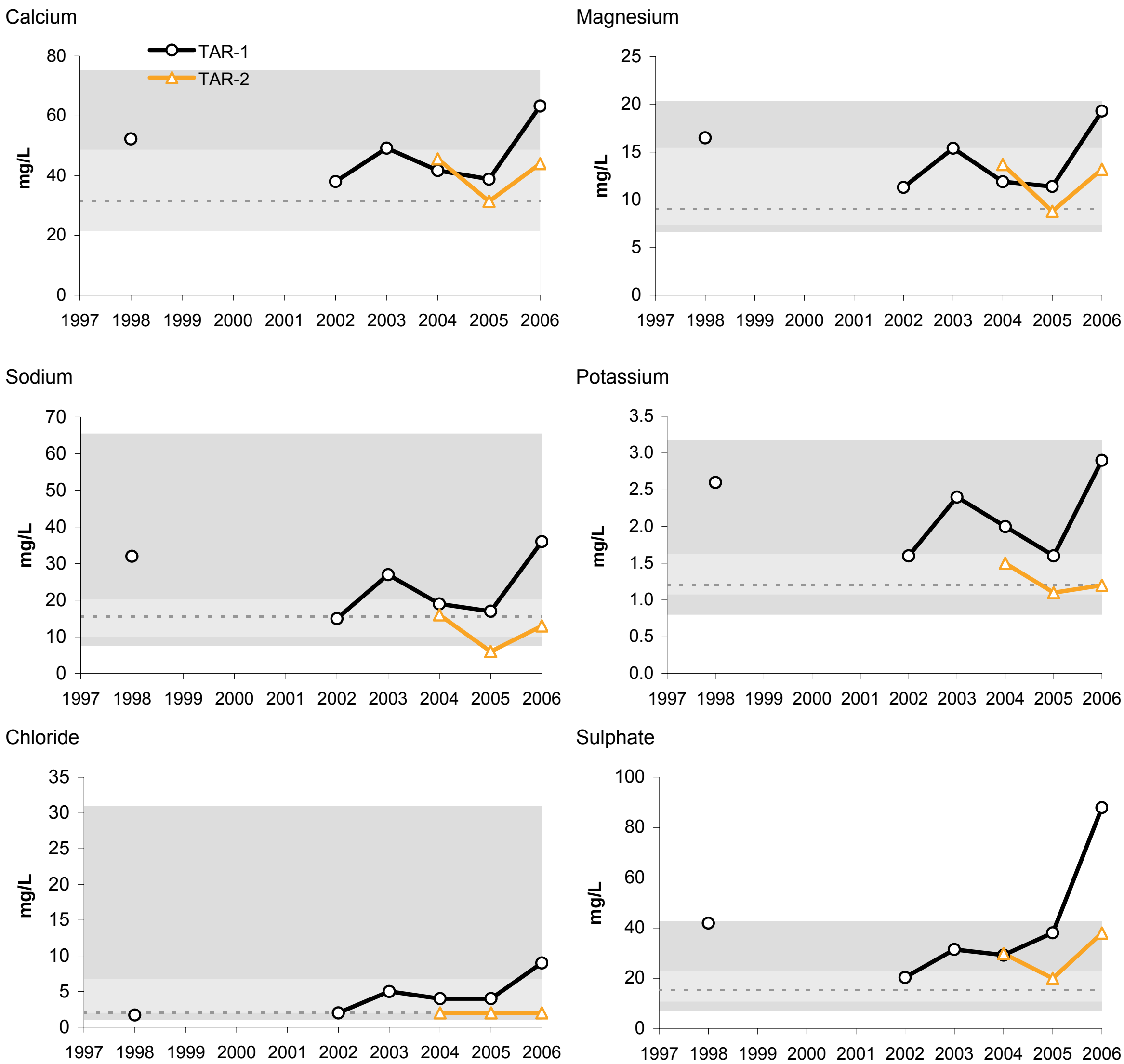
Figure 5.5-3 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.5-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.5-4 Piper diagram of fall ion concentrations in the Tar River watershed.

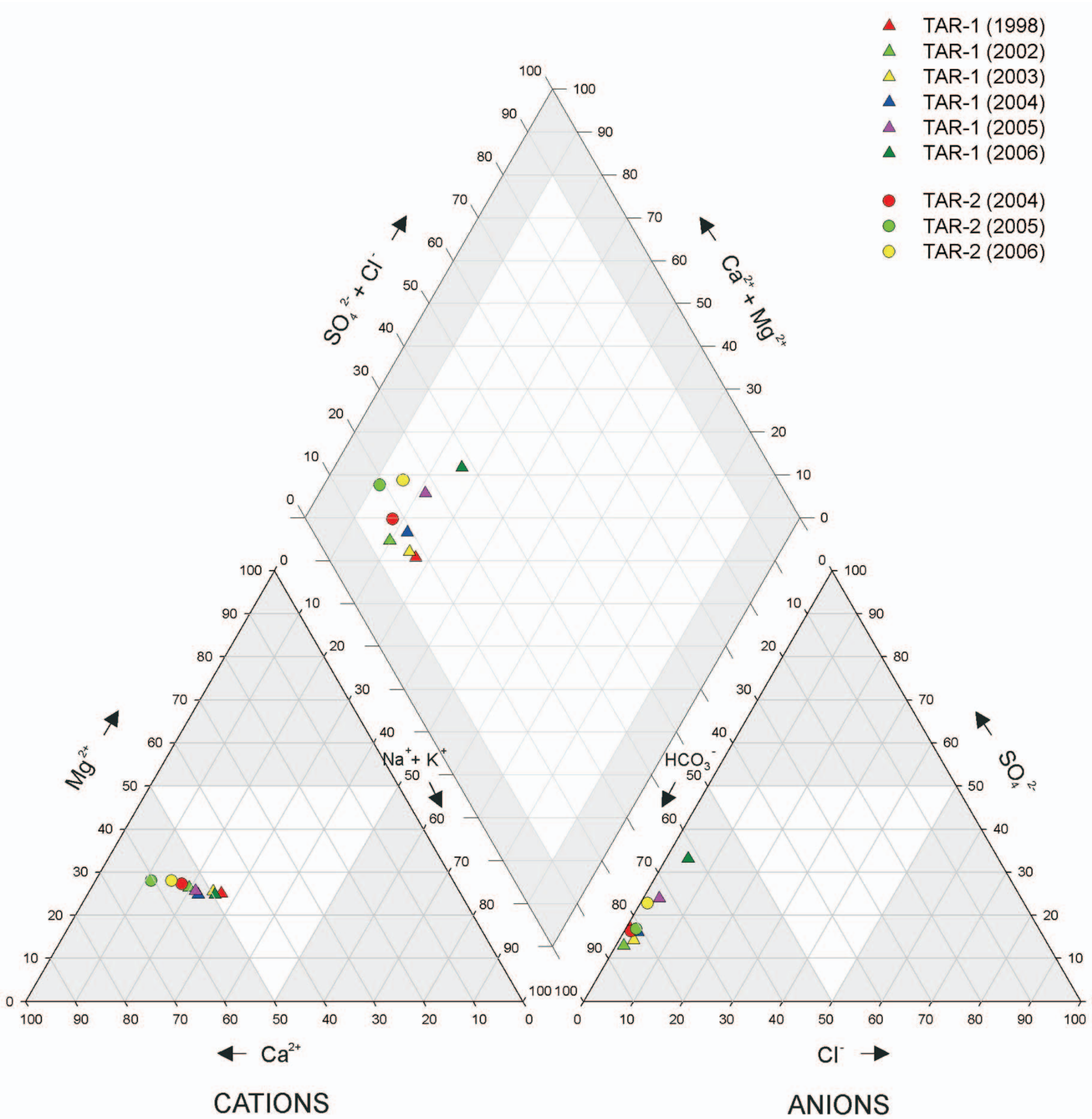


Table 5.5-6 Average habitat characteristics of benthic invertebrate community sampling reaches in the Tar River, fall 2006.

Variable	Units	Lower Reach of the Tar River (reach TAR-D-1)	Upper Reach of the Tar River (reach TAR-E-1)
Sample date	-	Sept 7, 2006	Sept 11, 2006
Habitat	-	Depositional	Erosional
Water depth	m	0.2	0.17
Current velocity	m/s	0.3	0.7
Macrophyte cover	%	0	17.1
Benthic algae	$\mu g/m^2$	n/a	14
Sand/Silt/Clay	%	100	0
Sediment Composition			
Sand	%	95	
Silt	%	2	
Clay	%	3	
Sand/Silt/Clay	%		0
Small gravel	%		1
Large gravel	%		10
Small cobble	%		21
Large cobble	%		38
Boulder	%		30
Bedrock	%		0

Figure 5.5-5 Annual variation in periphyton chlorophyll *a* biomass in the upper reach of the Tar River (reach TAR-E-2).

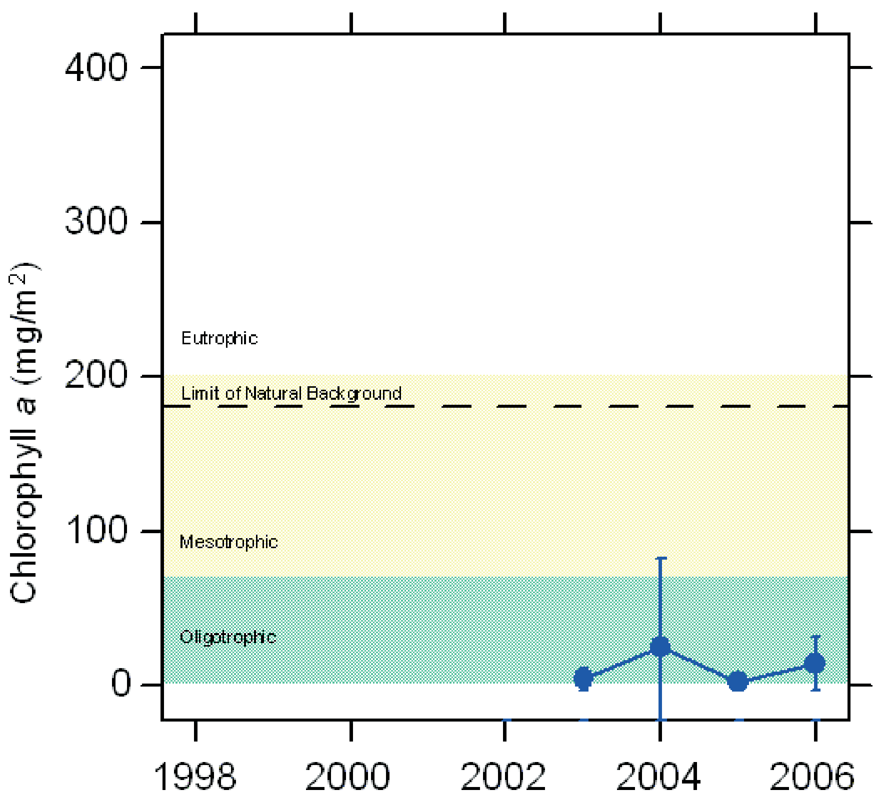


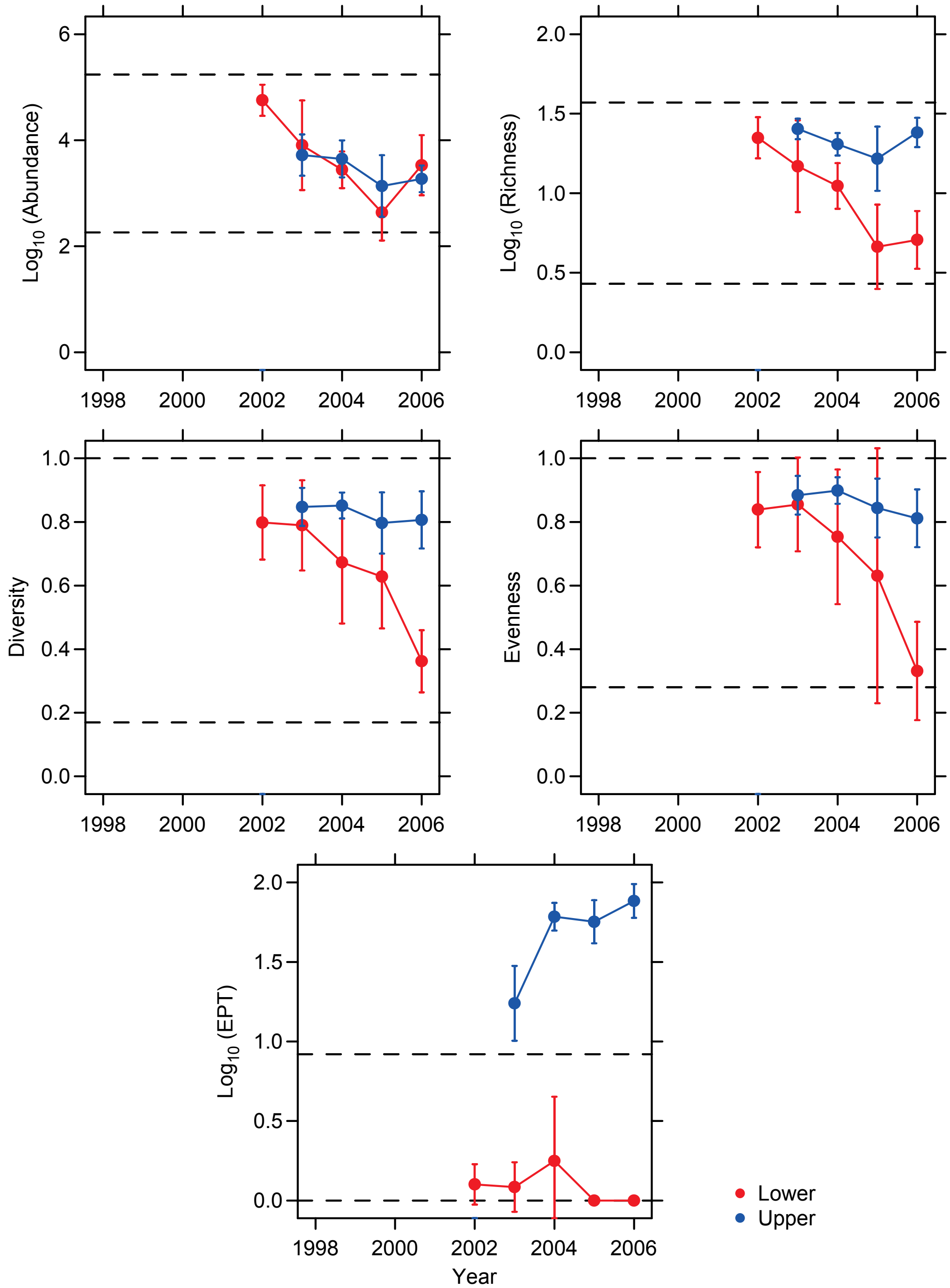
Table 5.5-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Tar River.

Taxon	%Total Taxa Enumerated in Each Year								
	Reach TAR-D-1					Reach TAR-E-2			
	2002	2003	2004	2005	2006	2003	2004	2005	2006
Amphipoda	<1	0	0	0	0	0	0	0	0
Anisoptera	<1	0	0	0	0	0	0	0	0
Bivalvia	1	<1	<1	1	<1	0	0	0	0
Ceratopogonidae	1	1	16	8	0	<1	<1	0	<1
Chironomidae	86	90	33	20	97	67	21	33	8
Chydoridae	<1	<1	<1	0	0	0	0	0	0
Coleoptera	<1	0	<1	0	0	0	<1	0	<1
Collembola	0	<1	0	0	0	0	0	0	0
Copepoda	<1	<1	2	0	0	1	0	<1	0
Dolichopodidae	0	0	1	0	0	0	<1	0	0
Empididae	1	1	1	0	<1	2	1	2	8
Enchytraeidae	0	0	5	2	<1	2	<1	<1	2
Ephemeroptera	<1	<1	1	0	0	5	38	45	48
Ephydridae	0	0	0	0	0	<1	0	0	0
Erpobdellidae	<1	<1	<1	0	0	0	<1	0	0
Gastropoda	<1	0	1	0	<1	0	0	0	0
Heteroptera	0	0	0	0	0	<1	0	0	0
Hydracarina	<1	1	1	0	0	1	2	<1	2
Lepidoptera	0	0	0	0	0	0	0	0	0
Lumbriculidae	0	0	0	0	0	1	0	<1	0
Megaloptera	0	0	0	0	0	0	<1	0	0
Naididae	<1	4	2	0	<1	6	<1	<1	<1
Nematoda	2	<1	4	1	<1	2	<1	<1	<1
Ostracoda	2	<1	25	37	0	0	0	0	0
Plecoptera	<1	<1	<1	0	0	8	13	12	8
Psychodidae	0	0	0	0	0	<1	0	<1	0
Simuliidae	0	0	0	0	0	0	13	2	1
Tabanidae	<1	<1	<1	1	<1	0	0	0	0
Tipulidae	<1	<1	<1	3	0	1	<1	<1	<1
Trichoptera	<1	<1	<1	0	0	2	10	3	19
Tubificidae	7	1	6	28	<1	1	1	1	<1
Zygoptera	0	0	0	0	0	0	0	0	0
Benthic Invertebrate Community Measurement Endpoints									
Total Abundance (No./m^2)	69,759	20,805	3,489	657	5,508	7,166	5,781	2,263	2,110
Richness	22	16	11	4	4	25	20	17	23
Simpson's Diversity	0.8	0.74	0.67	0.50	0.33	0.85	0.85	0.80	0.81
Evenness	0.84	0.85	0.75	0.87	0.33	0.88	0.9	0.86	0.81
% EPT	<1	<1	2	0	0	18	61	58	75

Table 5.5-8 Results of Analysis of Variance (ANOVA) on Tar River, reaches TAR-D-1 and TAR-E-2, with planned comparisons.

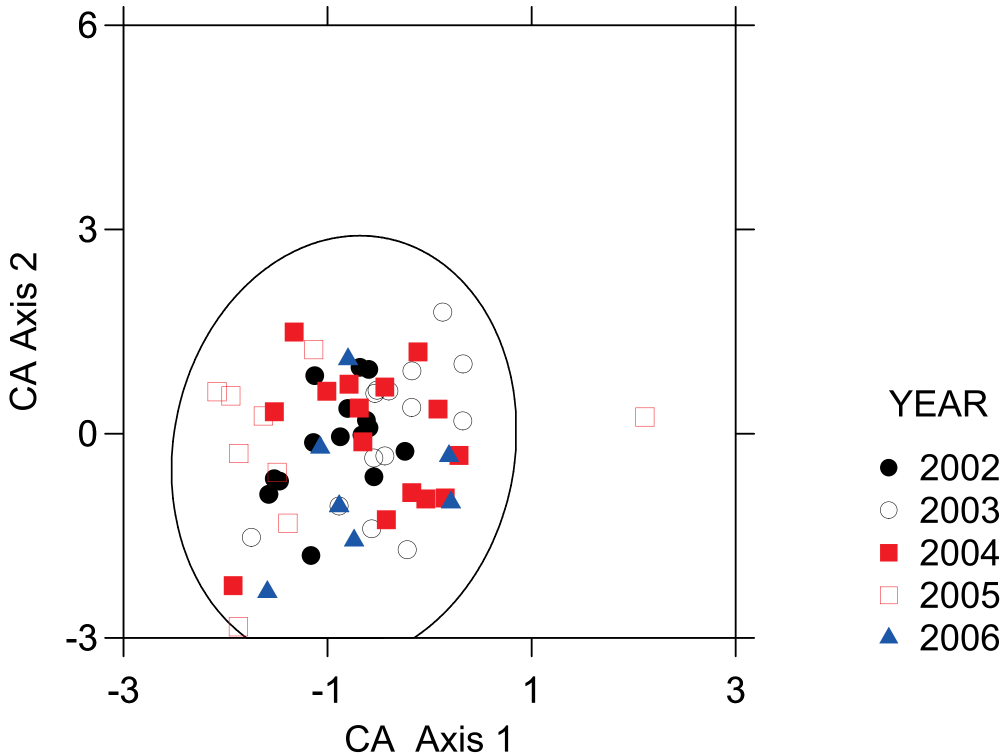
Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	34.41	8	19.31	<0.001
Reach	0.11	1	0.47	0.493
Time (Linear Trend)	5.30	1	23.78	<0.001
Time (Before to After)	5.95	1	26.70	<0.001
Reach x Time (Linear)	0.001	1	0.06	0.803
Reach X Time (B-A)	0.58	1	2.62	0.109
Reach (2006)	0.33	1	1.47	0.228
Error	23.61	106		
Log_{10} Richness				
Reach-Year	7.00	8	31.79	<0.001
Reach	4.47	1	162.42	<0.001
Time (Linear Trend)	1.25	1	45.48	<0.001
Time (Before to After)	1.13	1	41.06	<0.001
Reach x Time (Linear)	0.82	1	29.99	<0.001
Reach X Time (B-A)	0.36	1	12.97	<0.001
Reach (2006)	2.28	1	82.91	<0.001
Error	2.92	106		<0.001
Simpson's Diversity				
Reach-Year	2.79	8	13.87	<0.001
Reach	1.70	1	67.46	<0.001
Time (Linear Trend)	0.76	1	30.41	<0.001
Time (Before to After)	0.36	1	14.54	<0.001
Reach x Time (Linear)	0.44	1	17.45	<0.001
Reach X Time (B-A)	0.22	1	8.86	<0.001
Reach (2006)	1.15	1	45.88	<0.001
Error	2.66	106		
Evenness				
Reach-Year	2.73	8	13.31	<0.001
Reach	1.07	1	41.81	<0.001
Time (Linear Trend)	1.04	1	40.54	<0.001
Time (Before to After)	0.46	1	17.97	<0.001
Reach x Time (Linear)	0.54	1	21.04	<0.001
Reach X Time (B-A)	0.31	1	11.98	<0.001
Reach (2006)	1.15	1	44.97	<0.001
Error	2.72	106		
Log_{10} EPT %				
Reach-Year	70.48	8	252.16	<0.001
Reach	60.04	1	1718	<0.001
Time (Linear Trend)	0.42	1	12.05	<0.001
Time (Before to After)	1.66	1	47.46	<0.001
Reach x Time (Linear)	1.68	1	48.14	<0.001
Reach X Time (B-A)	1.68	1	48.16	<0.001
Reach (2006)	17.73	1	507.6	<0.001
Error	3.70	106		

Figure 5.5-6 Annual variation in benthic invertebrate community measurement endpoints in the lower Tar River, reach TAR-D-1 and the upper Tar River, reach TAR-E-2.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches.
Lower: reach TAR-D-1; Upper: reach TAR-E-2

Figure 5.5-7 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach TAR-D-1 (designated as *potentially influenced* as of summer 2004).



Note: Ellipse is for *reference* depositional reaches.

Table 5.5-9 Sediment quality measurement endpoints, lower reach of Tar River near the mouth (reach TAR-D-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station TAR-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3	5	10	15	26
Silt	%	-	3	5	10	20	50
Sand	%	-	94	5	24	65	80
Total organic carbon	%	-	0.3	5	0.5	1.1	6.3
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	13	2	59	79.5	100
Fraction 3 (C16-C34)	mg/kg	400[2]	220	2	**810**	**835**	**860**
Fraction 4 (C34-C50)	mg/kg	2800[2]	170	2	360	410	460
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0013	5	0.0013	0.0044	0.015
Retene	mg/kg	-	0.0116	4	0.0226	0.0559	0.379
Total dibenzothiophenes	mg/kg	-	0.60	5	0.15	0.94	6.26
Total PAHs	mg/kg	-	1.96	5	0.62	2.76	19.14
Total HMW PAHs	mg/kg	-	0.70	5	0.10	0.64	2.17
Total LMW PAHs	mg/kg	-	1.26	5	0.52	2.14	16.97
Predicted PAH toxicity[1]	H.I.	-	1.40	5	0.21	2.06	5.44
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	2	5	-	7
Chironomus growth - 10d	mg/organism	-	1.9	2	2	-	4
Hyallela survival - 14d	# surviving	-	9	1	-	-	6.6
Hyallela growth - 14d	mg/organism	-	0.2	1	-	-	0.1

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

5.6 MACKAY RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	Cumulative, watershed-level changes in hydrologic conditions in the MacKay River caused by focal project activities in the watershed as of 2006 have been negligible.
Mean open-water season discharge	√				
Mean winter discharge	not measured				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**[1]		There did not appear to be any effects of focal project activities on water quality at the lower MacKay River in fall 2006.
Measurement endpoints with guidelines	**2006 Potentially Influenced Stations (n=1)**	**2006 Reference Stations (n=1)**	
Physical variables (max=1 for exp, 1 for ref)	0	0	
Nutrients (max=3 for exp, 3 for ref)	1	1	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=5 for exp, 5 for ref)	0	1	
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**[2]		
Percentile of Regional Baseline Values	**2006 Potentially Influenced Stations (n=1 station X 13 endpoints)**	**2006 Reference Stations (n=1 station X 13 endpoints)**	
Greater than 95th percentile	0	0	
Between 5th and 95th percentiles	13	13	
Less than 5th percentile	0	0	

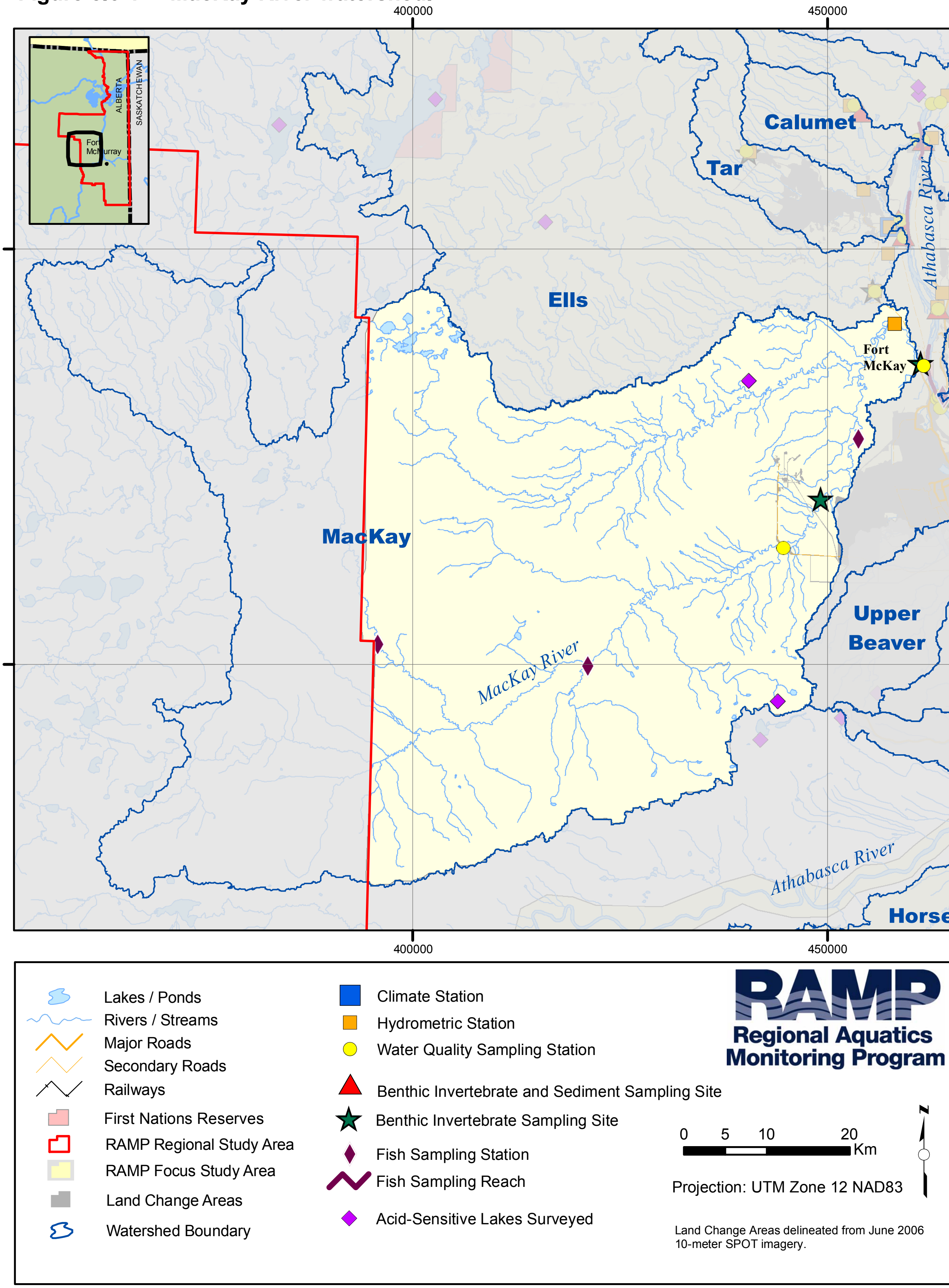
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**						There was some evidence of perhaps subtle watershed-level effects of focal project activities on benthic invertebrate communities in the MacKay River watershed in 2006. There were some statistically significant differences in benthic invertebrate community measurement endpoints between sampled reaches designated as potentially-influenced and reference and over time, but benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats.
	2006 Potentially Influenced Stations (n= 1)			**2006 Reference Stations (n= 1)**			
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance		1			1		
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		
Sediment Quality Guideline Exceedances	**Sample-Endpoint Combinations Exceeding Guidelines in 2006**[1]						
Measurement endpoints with guidelines	**2006 Potentially Influenced Stations (n=0)**			**2006 Reference Stations (n=0)**			
Total Hydrocarbons	No sediment quality sampling conducted in MacKay River watershed in 2006.						
PAHs							

Fish Populations		
Fish Inventory	No fish inventory studies conducted in 2006.	Results of reconnaissance-level field sampling carried out on the MacKay River in fall 2006 suggest suitable conditions for a non-lethal sentinel program do not exist on the MacKay River because of low abundance of candidate sentinel species.
Sentinel Studies	No sentinel fish studies conducted in 2006.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue program was not conducted in 2006.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.6-1 MacKay River watershed.



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5.6.1 Development Status

As of 2006, less than 1% of the MacKay River watershed had undergone land change as a result of focal developments in the watershed (Table 2.6-2). The designations of specific areas of the watershed are therefore as follows:

- All areas and 2006 RAMP stations located downstream of the Petro-Canada MacKay River and Petro-Canada Devon *in situ* operations and that part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 5.6-1) are designated as *potentially influenced*. All data gathered from the 2006 RAMP stations located in this area of the watershed are designated as operational data; and
- The MacKay River drainage upstream of these *in situ* oil sands developments and the 2006 RAMP stations located in this part of the watershed (Figure 5.6-1) are designated as *reference*.

5.6.2 Hydrologic Conditions

2006 Hydrologic Conditions Streamflow in the MacKay River basin, as measured at RAMP Station S26 and WSC Station 07DB001 (designated as *potentially influenced*), was far below normal in 2006 (Figure 5.6-2). The basin produced only 32 mm of runoff, less than half of its normal yield. The spring peak on the MacKay River was earlier and lower than usual, and after the freshet, flows remained near or below the low quartile until the rain in July. The maximum daily discharge of 38.6 m^3/s that occurred in July was only about one third of the mean annual flood of 111 m^3/s. The minimum discharge of 1.14 m^3/s was about one third of the historical average minimum flow.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the MacKay River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.6-1. As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 2.1 km^2 and 6.27 km^2, respectively, in the MacKay River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1), the estimated net effects of which were to reduce inflows to the MacKay River by 0.037 million m^3.

The estimated effect of these reduced flows was a reduction of less than 0.025% in mean open-water season discharge, annual maximum daily discharge, and open-water season minimum daily discharge (Table 5.6-2). The cumulative effect is that all hydrologic measurement endpoints for the MacKay River watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.6-2, Table 5.6-2). The calculated incremental changes in the hydrologic measurement endpoints would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information as well as information available regarding focal project activities in the MacKay River watershed, cumulative, watershed-level changes in hydrologic conditions in the MacKay River caused by focal project activities in the watershed as of 2006 have been negligible.

5.6.3 Water Quality

In fall 2006, water quality samples were collected from:

- The mouth of the MacKay River (station MAR-1, *potentially influenced*, first sampled in 1998, fall sampling every year since 2000); and

- Upstream of the Petro-Canada MacKay River and Petro-Canada Devon *in situ* developments (station MAR-2, *reference*, first sampled in 2002).

Baseline winter water quality data was collected at station MAR-2 in 2002 and 2003, while winter data was collected from the *potentially influenced* station MAR-1 in 2002 and 2004; the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration Water quality at the mouth of the MacKay River (station MAR-1) was generally consistent with historical observations, with fall 2006 concentrations of all water quality measurement endpoints within the ranges previously observed at this station in the fall season, with the exception of conductivity (below lowest previously measured fall concentration) and total mercury (above highest previously-measured fall concentration) (Table 5.6-3). At upstream MacKay River (station MAR-2) in fall 2006, concentrations of dissolved organic carbon, chloride, and total mercury were above the highest previously-measured fall concentrations, while sulphate concentration was below the lowest previously measured-fall concentration; all other water quality measurement endpoints at station MAR-2 were within their historically-measured minimum and maximum fall concentrations (Table 5.6-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total nitrogen was the only water quality measurement endpoint measured at the mouth of the MacKay River (station MAR-1) in fall 2006 with a concentration greater than its water quality guideline (Table 5.6-3). Only two water quality measurement endpoints, total nitrogen and total aluminum, had fall 2006 concentrations that exceeded water quality measurement endpoints at upstream MacKay River (station MAR-2, Table 5.6-4).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the MacKay River watershed in 2006 (Table 5.6-5):

- Sulphide, total nitrogen, total Kjeldahl nitrogen, dissolved iron, and total iron at the mouth of the MacKay River (station MAR-1); and

- Sulphide, total nitrogen, total Kjeldahl nitrogen, total aluminum, dissolved iron, total iron, and total phenols at upstream MacKay River (station MAR-2).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of all selected water quality measurement endpoints at both the mouth of the MacKay River (station MAR-1) and upstream MacKay River (station MAR-2) in fall 2006 were at or between the 5th and 95th percentile regional baseline concentration (Figure 5.6-3).

Ion Balance Ion balance at both the mouth of the lower MacKay River (station MAR-1) in fall 2006 and upstream MacKay River (station MAR-2) were similar, both to each other and to ion balance in previous years (with the exception of 1998) (Figure 5.6-4).

Summary There did not appear to be any effects of focal project activities on water quality at the lower MacKay River in fall 2006.

5.6.4 Benthic Invertebrate Communities and Sediment Quality

5.6.4.1 Benthic Invertebrate Communities

In 2006, benthic invertebrate community samples were collected from:

- An erosional reach near the mouth of the MacKay River (reach MAR-E-1, *potentially influenced*, sampled first in 1998 and from 2000 onwards); and
- An erosional reach in the upstream MacKay River (reach MAR-E-2, *reference*, sampled from 2000 onwards).

2006 Habitat Conditions Both the reach near the mouth of the MacKay River (reach MAR-E-1) and upstream MacKay River reach (reach MAR-E-2) are typical erosional habitats, with moderate current velocities (0.5 to 0.7 m/s) and shallow mid-channel water depths (<0.5 m) (Table 5.6-6). Periphyton chlorophyll *a* biomass was low in reach MAR-E-1 (5 mg/m^2) and higher in reach MAR-E-2 (48 mg/m^2) (Figure 5.6-5), indicating the MacKay River in fall 2006 was oligotrophic. Chlorophyll *a* biomass has tended to be higher in upstream MacKay River (reach MAR-E-2) throughout the data record than the lower MacKay River (reach MAR-E-1) (Figure 5.6-5), indicating higher nutrient concentrations in the upper reach. Macrophytes covered about 10% of the lower MacKay River reach, and substrate composition was similar in the both reaches, consisting of a broad mixture of sand through to boulders (Table 5.6-6).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The lower MacKay River reach (reach MAR-E-1) was dominated numerically by EPT taxa (mayflies, stoneflies and caddisflies) as in previous years, with chironomids, other diptera and worms (naidids, tubificids) sub-dominant (Table 5.6-7). The dominant mayflies included the common forms *Heptagenia*, *Rhithrogena* and *Tricorythodes*, while the most prevalent stoneflies included *Isogenoides*, *Isoperla*, *Skwala* and *Taeniopteryx*. *Hydropsyche* was the dominant caddisfly.

The upstream MacKay River reach (reach MAR-E-2) was dominated numerically by chironomids (over 60%) with mayflies, stoneflies and caddisflies present in relatively low percent abundances (Table 5.6-7). A variety of Diptera were present including simuliid blackflies, tipulid craneflies and ceratopogonids (sand flies). The dominant mayflies were *Baetis*, *Rhithrogena* and *Heptagenia*, the dominant stoneflies were *Isoperla* and *Claassenia sabulosa*, while the dominant caddisflies were *Glossosoma*, *Protoptila*, *Hydropsyche*, *Fabria*/*Ptilostomis* and *Psychomyia*.

Effects of Focal Project Activities Two ANOVA tests were used to examine potential effects of focal project activities on benthic invertebrate communities in the lower MacKay River:

- The *time (before to after in lower)* contrast contained in the ANOVA results (Table 5.6-8) tested for differences in average values of benthic invertebrate community measurement endpoints in the lower MacKay River (reach MAR-E-1) from before 2002 when reach MAR-E-1 was designated as *reference* to 2002 and after when reach MAR-E-1 was designated as *potentially influenced*; and
- The *reach x time (linear)* contrast contained in the ANOVA results (Table 5.6-8) tested for differences in linear time trends between reach MAR-E-1 and reach MAR-E-2 after reach MAR-E-1 had been designated as *potentially influenced*.

There were a variety of significant contrasts (Table 5.6-8):

- Total numbers in the lower MacKay River (reach MAR-E-1) have generally declined over the past three years at a rate which is faster than has been observed in the upstream MacKay River reach (reach MAR-E-1) (Figure 5.6-6);
- Trends in richness have been very subtle, with a minor change in trends in 2006 compared to previous years (Figure 5.6-6); and
- Percent EPT is higher in the lower MacKay River (reach MAR-E-1) since 2002, with the percentages increasing faster over time in reach MAR-E-1 than in the upstream MacKay River reach (Figure 5.6-6).

These suggest some effects of focal project activities on benthic invertebrate communities in the lower MacKay River. However, average values of benthic invertebrate community measurement endpoints in the lower MacKay River (reach MAR-E-1) have been and continue to be within the normal ranges of variability observed in reference erosional reaches in the RAMP FSA (Figure 5.6-6). In addition, ordination results (Table 5.6-8) provide supporting evidence that the benthic invertebrate community of the lower MacKay River (reach MAR-E-1) continues to be similar to benthic invertebrate communities from reference erosional reaches in the RAMP FSA.

5.6.4.2 Sediment Quality

As sediment quality in 2006 was only sampled in the depositional reaches in which benthic invertebrate communities were sampled, and as both reaches of the MacKay River watershed in which benthic invertebrate communities were sampled are erosional, no sediment quality sampling was conducted in the MacKay River in 2006.

5.6.4.3 Summary

There was some evidence of perhaps subtle watershed-level effects of focal project activities on benthic invertebrate communities in the MacKay River watershed in 2006. There were some statistically significant differences in benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference* and over time, but benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats.

5.6.5 Fish Populations

Fish Population component activities in the MacKay River watershed in 2006 consisted of; 1) a sentinel fish reconnaissance study; and 2) the use of the Dunkirk River drainage, lying in the upper MacKay River watershed, was a *reference* location for the sentinel fish monitoring study on select tributaries of the Athabasca River. The sentinel fish study was undertaken in a number of RAMP FSA watersheds; the findings of the Dunkirk River drainage portion of this study are presented in the Fish Population component results for the Steepbank River watershed (Section 5.4.5).

5.6.5.1 Sentinel Fish Reconnaissance

Reconnaissance-level field sampling was carried out on the MacKay River in the fall of 2006 to assess the potential for non-lethal sentinel species monitoring studies to be conducted in the watershed. Sampling was conducted on the lower MacKay River, designated as *potentially influenced* (Figure 5.6-8), and the upper MacKay River, designated as *reference* (Figure 5.6-9).

5.6.5.2 Results

A total of 106 fish of seven different species were caught in the reconnaissance surveys. Slimy sculpin was the most abundant species captured, followed by longnose dace and lake chub (Table 5.6-9). Thirty-eight fish, representing five of the seven species caught during the survey, were caught at the downstream, *potentially influenced* location. However, only two of the three most abundant species were caught at this site; no slimy sculpin were captured. Catch-per-unit-effort (CPUE) was 4.14 per 100 s of electrofishing at the lower, *potentially influenced* site (Table 5.6-10). Sixty-eight fish, representing five of the seven captured species, were captured at the upstream, *reference* location; all three dominant species were caught at this site (Table 5.6-9). CPUE at the upper, *reference*, site was 7.08 fish per 100 s of electrofishing (Table 5.6-10).

5.6.5.3 Discussion

Success of the non-lethal sentinel monitoring program depends greatly on the selection of appropriate fish species. Important criteria for sentinel species selection include: relative abundance and ease of capture; limited mobility and home range to allow for maximum exposure to localized environmental conditions; availability of non-lethal aging structures; and a single annual spawning event as opposed to multiple spawning events. Based on these criteria the slimy sculpin has been selected as the most appropriate species for use in several other RAMP FSA watersheds (RAMP 2005b). Results from the 2006 reconnaissance sampling suggest suitable conditions for a non-lethal sentinel program do not exist on the MacKay River. Slimy sculpin abundance appears to be too low to serve as an appropriate sentinel species because it was captured at only one of two sites. Longnose dace numbers were also relatively low. In addition to the marginal fish sampling results, the possibility of high water levels that often persist until the month of August on the MacKay River (Figure 5.6-2) represents an additional challenge to the successful implementation of sentinel species program on the MacKay River, as reliable/stable field conditions are necessary for maintaining sampling continuity between sampling years.

5.6.6 Summary of Conditions

Data collected in the MacKay River watershed in 2006 indicated negligible changes in hydrological conditions as a result of focal project activities, little measurable change in water quality and possible subtle effects on benthic invertebrate communities. These results indicate that focal project activities have had, to 2006, little effect on RAMP aquatic resources at the watershed level in the MacKay River watershed.

Figure 5.6-2 MacKay River: 2006 hydrograph and historical context.

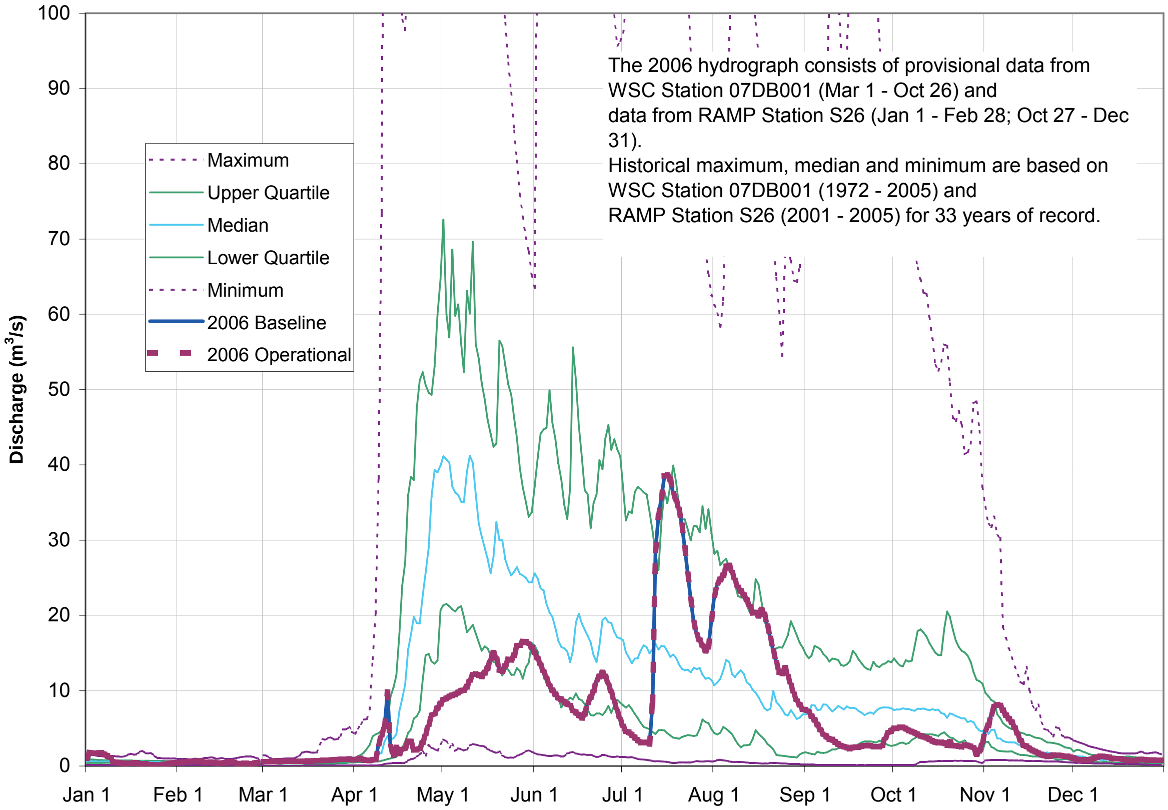


Table 5.6-1 Inputs to calculation of MacKay River baseline hydrograph at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	203	Observed daily discharges obtained from RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001)
Natural runoff that would have occurred from focal project areas that were closed-circuited as of 2006	+ 0.083	2.1 km^2 within MacKay River drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change due to focal project development areas and are not closed-circuited	- 0.046	6.27 km^2 within MacKay River drainage estimated to have undergone land change by focal projects as of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from the MacKay River by focal project activities	0	Water withdrawals are from groundwater
Releases to the Muskeg River by focal project activities	0	Unknown and assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects on tributaries of Muskeg River not accounted for in figures contained in this table
Baseline hydrograph	203	Estimated baseline (“without focal project”) flow for 2006
Incremental flow	- 0.037	Difference in total flow between operational and baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.02%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.6-2 Calculated change in hydrologic measurement endpoints for the MacKay River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	11.3	11.2	< -0.025%
Mean winter discharge	1.15	1.25	< -0.025%
Annual maximum daily discharge	38.6	38.6	< -0.025%
Open-water season minimum daily discharge	2.25	1.14	< -0.025%

Note: as measured at and calculated for RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.6-3 Concentrations of water quality measurement endpoints, mouth of MacKay River (station MAR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	7	7.6	8.1	8.6
Total Suspended Solids	mg/L	-[1]	<3	7	<3	7	26
Conductivity	μS/cm	-	196	7	217	278	576
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.024	7	0.004	0.019	0.047
Total nitrogen*	mg/L	1.0	**1.2**	7	0.4	**1.1**	**3.2**
Nitrate+Nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	7	20	24	33
Ions							
Sodium	mg/L	-	20	7	15	20	60
Calcium	mg/L	-	29.1	7	24.7	27.3	44.7
Magnesium	mg/L	-	9.5	7	8.1	9.0	15.9
Chloride	mg/L	230, 860[3]	7	7	3.0	6.0	41.2
Sulphate	mg/L	100[4]	14.7	7	12.7	20.2	35.5
Total Dissolved Solids	mg/L	-	238	7	170	240	342
Total Alkalinity	mg/L		124	7	96	116	202
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.050	7	0.050	**0.238**	**0.501**
Dissolved aluminum	mg/L	0.1[2]	0.016	7	0.010	0.020	0.030
Total boron	mg/L	1.2[5]	0.080	7	0.063	0.093	0.140
Total molybdenum	mg/L	0.073	0.0004	7	0.0002	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.9	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.168	7	0.133	0.158	0.287

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.6-4 Concentrations of water quality measurement endpoints, upstream MacKay River (station MAR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.8	8.0	8.3
Total Suspended Solids	mg/L	-[1]	<3	4	<3	3	10
Conductivity	µS/cm	-	235	4	182	220	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.038	4	0.008	0.032	0.039
Total nitrogen*	mg/L	1.0	**1.3**	4	0.8	**1.3**	**3.1**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	33	4	22	28	32
Ions							
Sodium	mg/L	-	16	4	11	16	19
Calcium	mg/L	-	27.5	4	21.3	24.4	31.5
Magnesium	mg/L	-	8.6	4	6.9	8.0	10.1
Chloride	mg/L	230, 860[3]	3	4	1	2	2
Sulphate	mg/L	100[4]	8.1	4	11.0	16.5	23.7
Total Dissolved Solids	mg/L	-	190	4	160	195	240
Total Alkalinity	mg/L	-	104	4	81	98.5	128
Organic compounds							
Naphthenic acids	mg/L	-	1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.142**	4	0.020	**0.180**	**0.468**
Dissolved aluminum	mg/L	0.1[2]	0.0223	4	0.0002	0.0241	0.0251
Total boron	mg/L	1.2[5]	0.064	4	0.051	0.066	0.105
Total molybdenum	mg/L	0.073	0.00054	4	0.00023	0.00033	0.00054
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.8	3	<0.6	<0.6	0.7
Total strontium	mg/L	-	0.141	4	0.114	0.139	0.197

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
2 Guideline is for total analyte (no guideline for dissolved species).
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)
5 B.C. ambient water quality guideline for boron (B.C. 2003).
6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
7 B.C. Working Water Quality Guideline for sulphide as H_2S.
8 Guideline is for total nitrogen.

Table 5.6-5 List of water quality guideline exceedances, MacKay River watershed, 2006.

Variable	Units	Guideline*	MAR-1	MAR-2
Fall				
Sulphide	mg/L	0.002[1]	**0.008**	**0.021**
Total nitrogen	mg/L	1.0	**1.2**	**1.3**
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.1**	**1.2**
Total aluminum	mg/L	0.1	-	**0.142**
Dissolved iron	mg/L	0.3[3]	**0.694**	**0.76**
Total iron	mg/L	0.3	**0.878**	**1.04**
Total phenols	mg/L	0.004	-	**0.02**

MAR-1 and MAR-2 were sampled only in fall 2006.

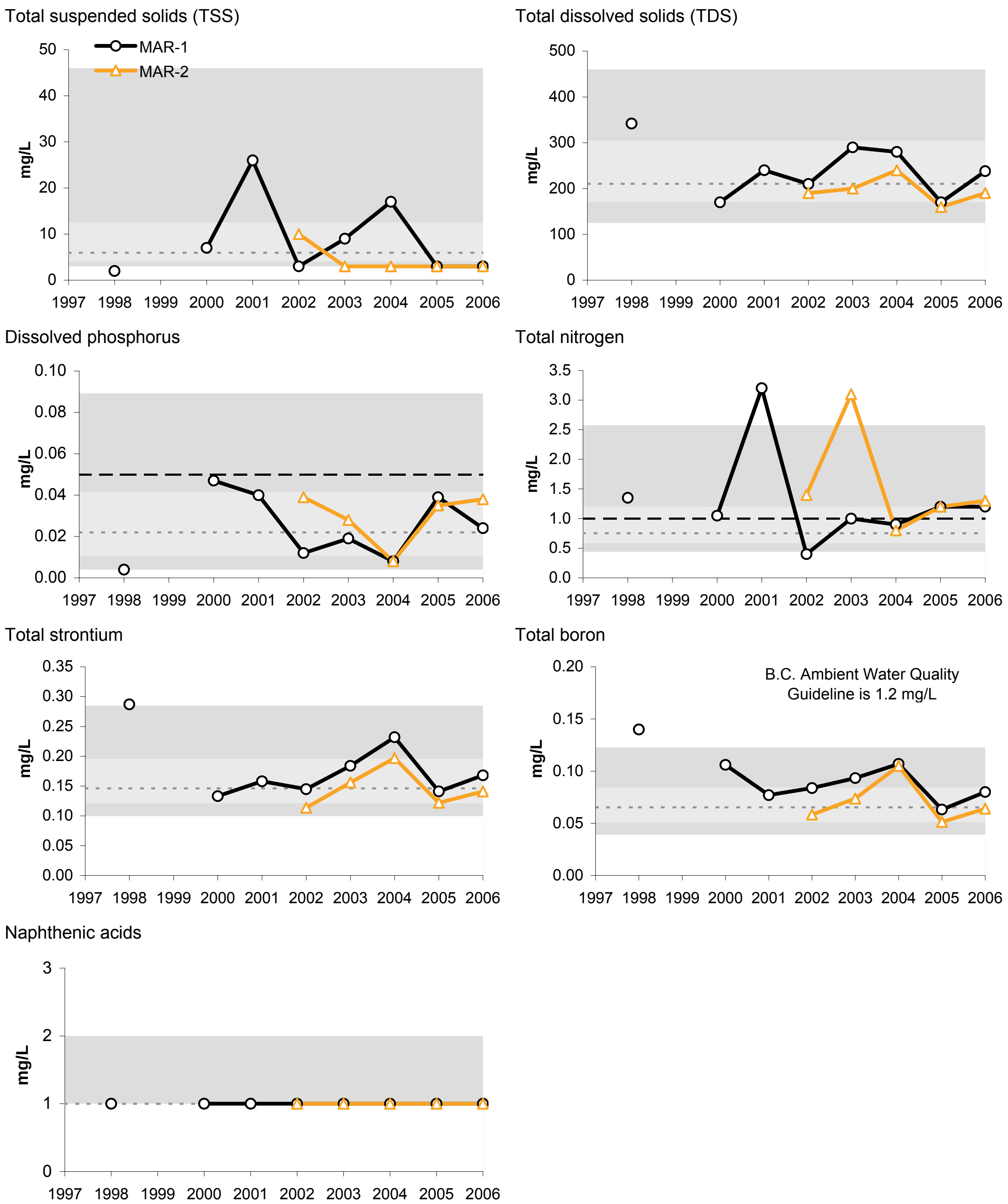
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (2001).

[2] Guideline is for total nitrogen.

[3] Guideline is for total analyte (no guideline for dissolved species).

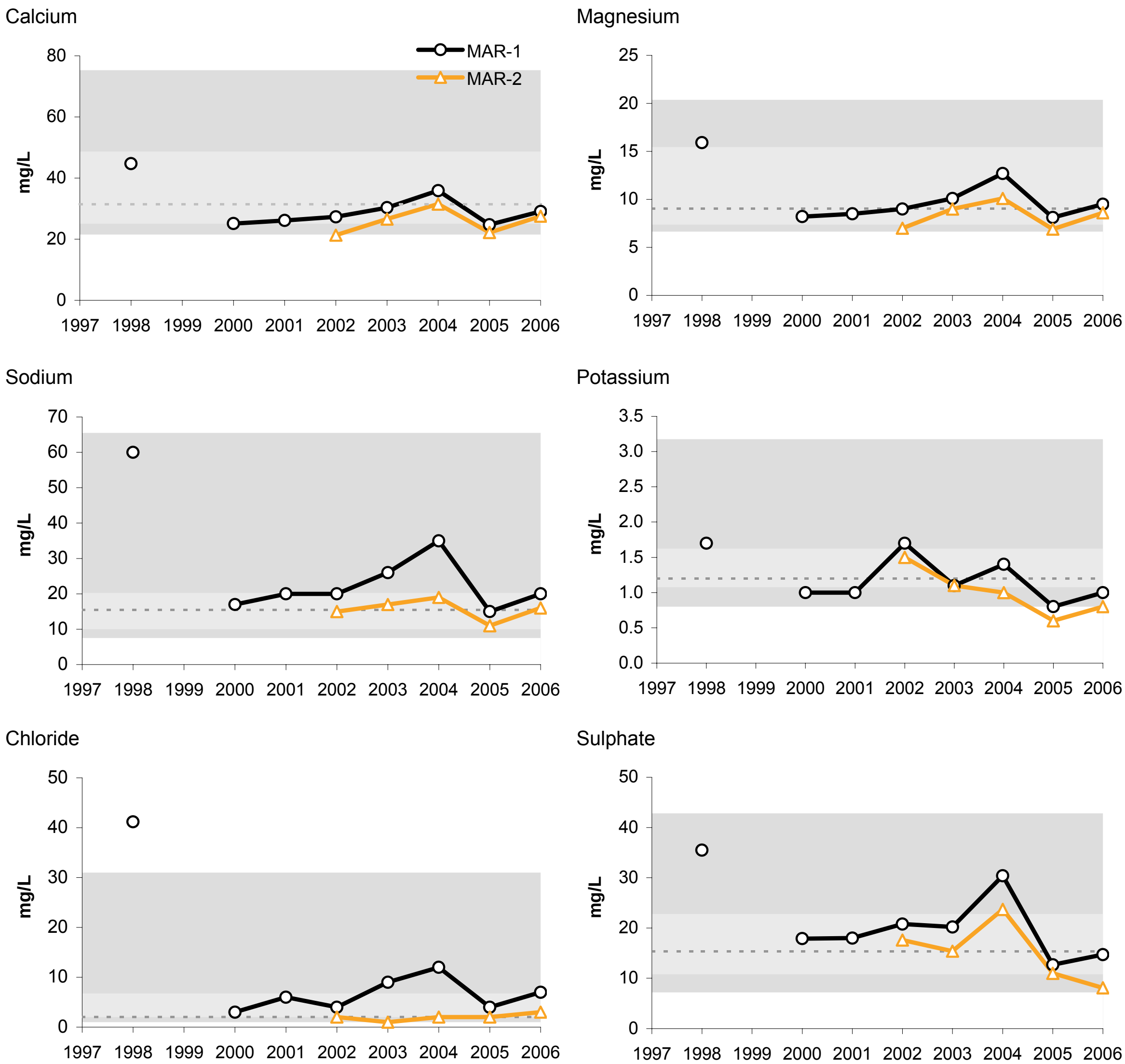
Figure 5.6-3 Concentrations of selected water quality measurement endpoints in the MacKay River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.6-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.6-4 Piper diagram of fall ion concentrations in the MacKay River watershed.

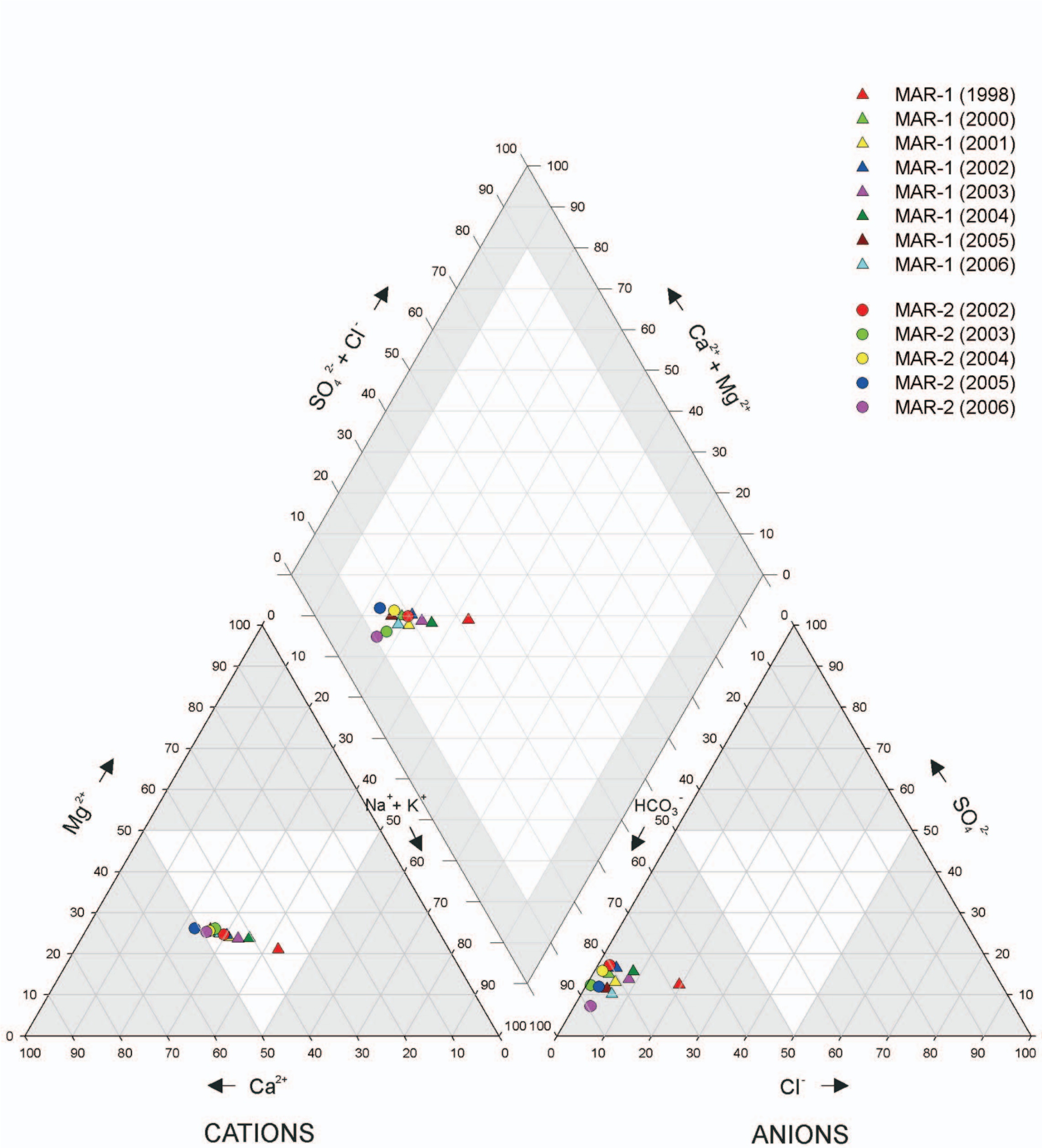
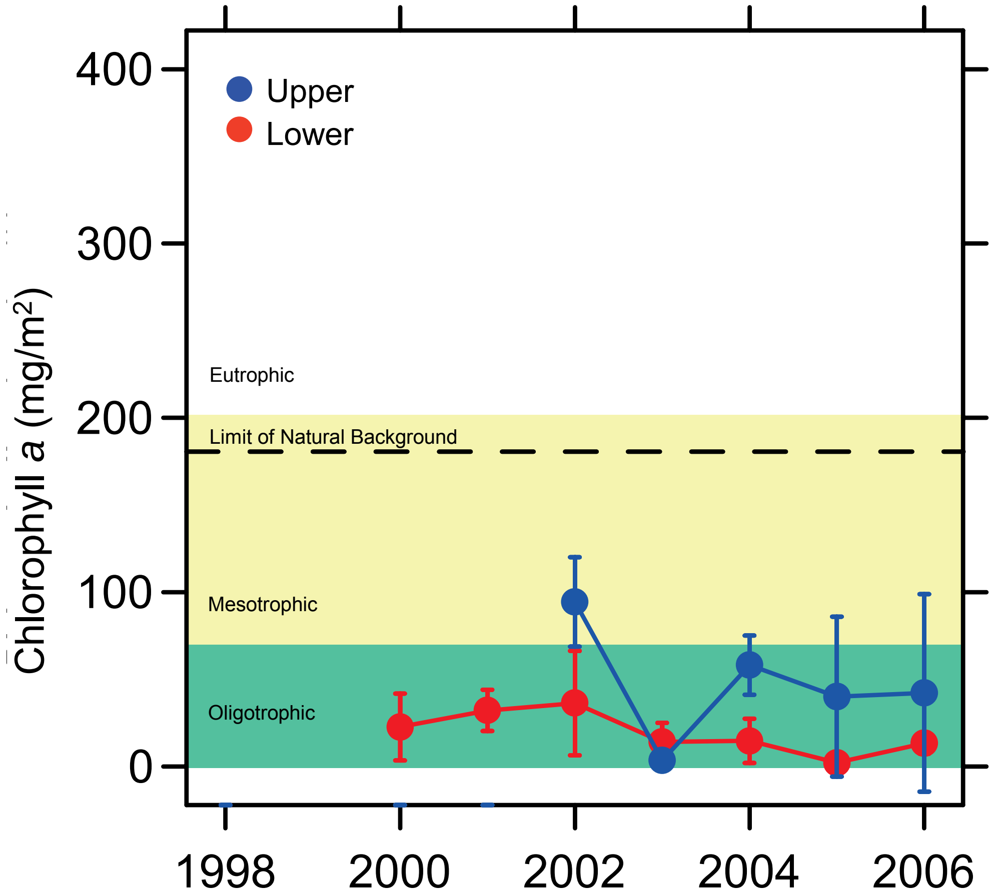


Table 5.6-6 Average habitat characteristics of benthic invertebrate community sampling reaches in the MacKay River, fall 2006.

Variable	Units	Lower Reach of the MacKay River (reach MAR-E-1)	Upstream Reach of the MacKay River (reach MAR-E-2)
Sample date	-	Sept 14, 2006	Sept 8, 2006
Habitat	-	Erosional	Erosional
Water depth	m	0.23	0.27
Current velocity	m/s	0.5	0.8
Macrophyte cover	%	12.5	n/a
Benthic algae	mg/m^2	16.0	50.6
Sand/Silt/Clay	%	10	8
Field Water Quality			
Dissolved oxygen	mg/L	10	8
Conductivity	µS/cm	291	245
pH		8	8
Water temperature	°C	9	14.2
Sediment Composition			
Sand/Silt/Clay	%	4	8
Small gravel	%	39	17
Large gravel	%	30	18
Small cobble	%	13	20
Large cobble	%	10	28
Boulder	%	4	9
Bedrock	%	0	0

Figure 5.6-5 Annual variation in periphyton chlorophyll *a* biomass in the lower MacKay River (reach MAR-E-1) and upstream MacKay River (reach MAR-E-2).

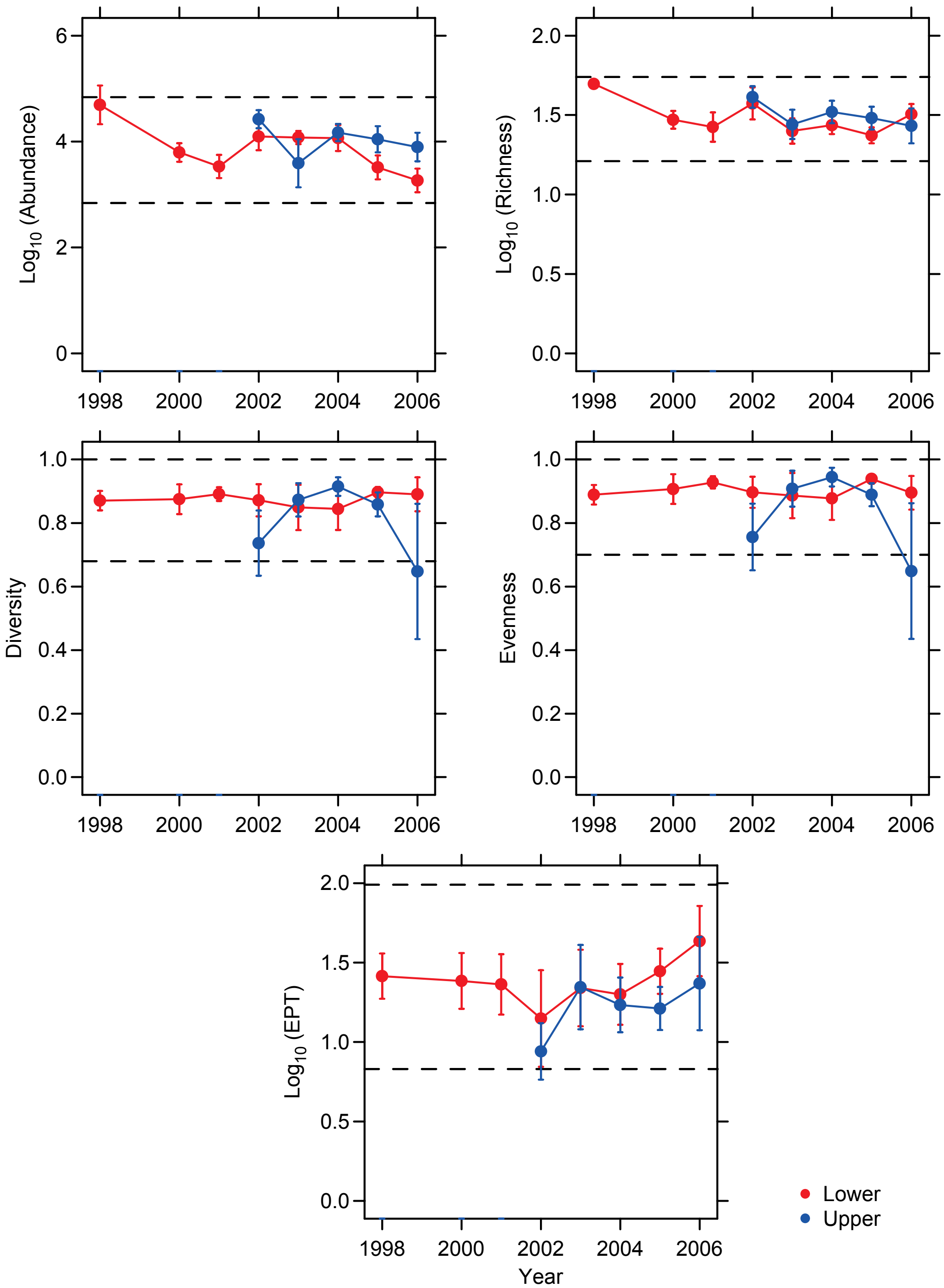


Lower: reach MAR-E-1; Upper: reach MAR-E-2

Table 5.6-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the MacKay River.

Taxon	% Major Taxa Enumerated in Each Year												
	Reach MAR-E-1								Reach MAR-E-2				
	1998	2000	2001	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
Anisoptera	1	1	2	1	1	3	2	2	<1	1	<1	<1	<1
Bivalvia		<1	<1	1	2	2	1	<1	<1	4	1	<1	<1
Ceratopogonidae	1	1	<1	1	<1	1	5	3	<1	<1	1	1	1
Chironomidae	57	34	4	31	4	57	2	3	31	3	59	49	63
Coleoptera	<1	<1			<1	<1		<1		<1	<1	<1	
Copepoda	<1	<1	<1	<1				0.3	<1		<1		
Daphniidae				<1		<1							
Dolichopodidae				<1					<1	<1			
Empididae	1	1	4	3	2	2	12	6	1	2	1	5	<1
Enchytraeidae	4	12	1	5	5	1	1	1	1	4	3	3	1
Ephemeroptera	26	21	18	12	19	13	25	29	2	14	11	1	12
Erpobdellidae						<1				<1			
Gastropoda	<1	<1	1	2	<1	1		1	<1	<1	<1	<1	
Heteroptera	<1		<1										
Hydra	<1			1	<1				<1				
Hydracarina	1	4	6	3	18	6	1	2	7	21	4	9	5
Lumbriculidae					<1					<1		<1	
Macrothricidae		<1		1									
Naididae	2	17	2	24	8	3	11	8	48	15	4	15	2
Nematoda	2	2	8	6	1	3	1	1	3	1	3	1	3
Ostracoda	<1	1	1	6		<1		<1	<1	<1	<1		
Plecoptera	2	5	5	<1	1	3	3	8	<1	3	3	1	2
Simuliidae	1	<1	<1	<1	<1		2	<1		<1		<1	0.2
Tabanidae					<1		1			<1			
Tipulidae	<1	<1			<1				<1	<1	<1		0.9
Trichoptera	<1	<1	3	3	2	5	<1	5	6	4	3	5	1
Tubificidae	2	<1	1	2	<1	1	6	2	<1	<1	8	1	1
	Benthic Invertebrate Community Measurement Endpoints												
Total Abundance (No./m^2)	56,434	6,680	3,745	14,425	12,347	13,290	3,592	2,055	28,222	5,568	15,733	12,332	8,929
Richness	49	29	26	37	24	27	23	30	40	27	32	30	24
Simpson's Diversity	0.87	0.87	0.89	0.87	0.85	0.84	0.90	0.89	0.74	0.87	0.91	0.86	0.65
Evenness	0.89	0.91	0.93	0.90	0.89	0.88	0.94	0.89	0.76	0.91	0.94	0.89	0.65
% EPT	26	25	24	16	23	20	28	42	8	25	17	16	24

Figure 5.6-6 Annual variation in benthic invertebrate community measurement endpoints in the lower MacKay River (reach MAR-E-1) and upstream MacKay River (MAR-E-2).

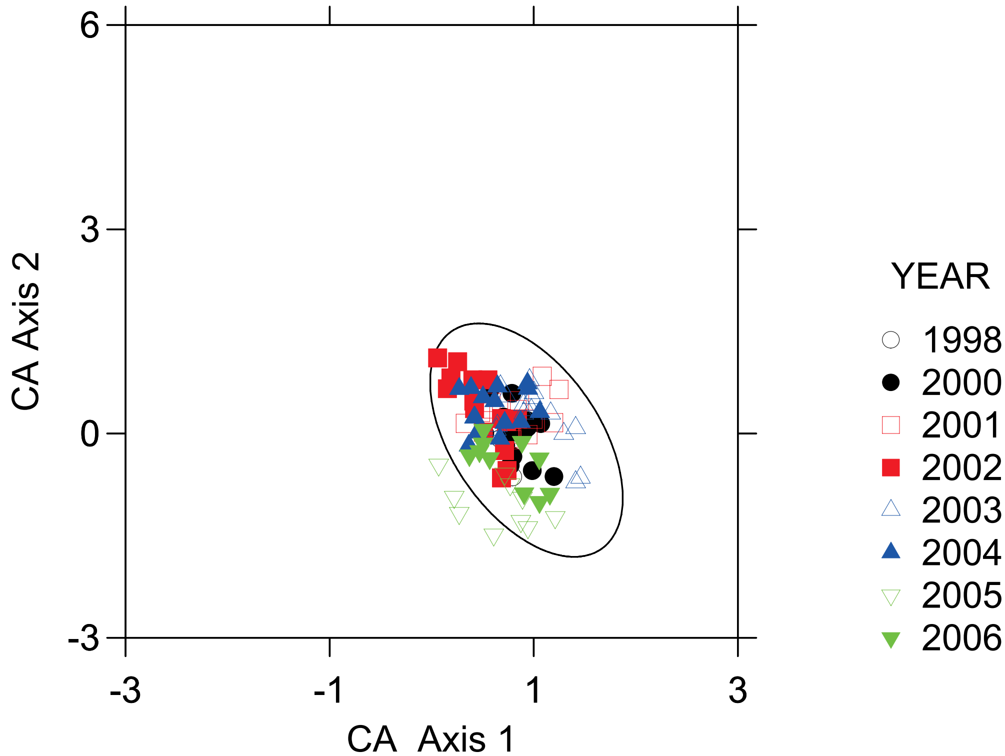


Note:Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for *reference* erosional reaches. Lower reach: reach MAR-E-1; Upper reach: reach MAR-E-2. 1998 figures are for reach MAR-1 (Table 3.3-2).

Table 5.6-8 Results of analysis of variance (ANOVA) on MacKay River, reaches MAR-E-1 and MAR-E-2, with planned comparisons.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	17.76	12	26.62	<0.001
Reach	1.53	1	27.55	<0.001
Time (Before-After in Lower)	0.60	1	10.78	<0.001
Time (Linear Trend)	4.79	1	86.17	<0.001
Reach X Time (Linear)	3.55	1	63.93	<0.001
Reach (2006)	1.98	1	35.76	<0.001
Error	8.28	149		
Log_{10} Richness				
Reach-Year	0.896	12	13.52	<0.001
Reach	0.050	1	9.10	0.003
Time (Before-After in Lower)	0.077	1	14.02	<0.001
Time (Linear Trend)	0.141	1	25.50	<0.001
Reach X Time (Linear)	0.028	1	5.09	0.025
Reach (2006)	0.027	1	4.85	0.029
Error	0.823	149		
Simpson's Diversity				
Reach-Year	0.752	12	12.04	<0.001
Reach	0.129	1	24.86	<0.001
Time (Before-After in Lower)	0.001	1	0.70	0.658
Time (Linear Trend)	0.007	1	1.34	0.250
Reach X Time (Linear)	0.003	1	0.51	0.474
Reach (2006)	0.294	1	56.57	<0.001
Error	0.776	149		
Evenness				
Reach-Year	0.924	12	14.55	<0.001
Reach	0.152	1	28.75	<0.001
Time (Before-After in Lower)	0.001	1	0.22	0.639
Time (Linear Trend)	0.020	1	3.84	0.052
Reach X Time (Linear)	0.006	1	1.10	0.295
Reach (2006)	0.304	1	57.47	<0.001
Error	0.788	149		
Log_{10} EPT %				
Reach-Year	3.81	12	7.53	<0.001
Reach	0.72	1	17.06	<0.001
Time (Before-After in Lower)	<0.01	1	0.15	0.700
Time (Linear Trend)	1.69	1	40.20	<0.001
Reach X Time (Linear)	0.63	1	14.04	<0.001
Reach (2006)	0.33	1	7.82	0.004
Error	6.39	149		

Figure 5.6-7 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for lower MacKay River (reach MAR-E-1), designated as *potentially influenced* as of summer 2002.



Note: Ellipse is for erosional reaches sampled in the RAMP FSA and designated as *reference*. 1998 figures are for reach MAR-1 (Table 3.3-2).

Figure 5.6-8 Location and stream habitat details of lower (*potentially influenced*) sampling location for the 2006 MacKay River non-lethal sentinel reconnaissance study.

Referencing Information	
Project Name:	RAMP Sentinel Sp. Recon.
Project Number:	RAMP 1245-3103
Waterbody Name:	MacKay River
Site Type:	*Potentially Influenced*
Date:	16-September-2006
Time:	9:15
Crew Members:	CD/SE
Site UTM:	453731E 6327177N
Access:	Helicopter
Water Quality	
Temperature (^{0}C):	9
Dissolved Oxygen (mg/L):	9.7
pH:	8.0
Conductivity (uS/cm):	300
Channel Characteristics	
Avg. Channel Width (m):	47
Avg. Wetted Width (m):	25
Gradient (%):	1.0-1.5
Stage:	Moderate
Cover	
Crown Closure (%):	1-20
Total Cover:	Moderate
Dominant Cover Type:	Boulder
Secondary Cover Type:	Deep Pools
Functional Large Woody Debris:	Few
Functional Small Woody Debris:	Few
Bank Shape:	Sloping
Bank Texture:	Fines
Riparian Vegetation:	Mixed forest
Vegetation Stage:	Young/Mature Forest
Instream Vegetation:	Trace
Channel Morphology	
Dominant Bed Material:	Boulder
Sub-Dominant Bed Material:	Cobble
Flood Signs:	None
Pattern:	Irregular Meandering
Islands:	Occasional
Bars:	Side
Confinement:	Confined
Disturbance Indicators:	None
Morphology:	Riffle-pool

Comments

Site was situated upstream of an island.
Minimal algae was present along river margins.
Water depth ranged from 0.25 to 0.60 m.

Fish Inventory	
Total Fishing Effort:	917
No. Fish Caught:	38
CPUE	4.14 fish/100 s

Figure 5.6-9 Location and stream habitat details of upper (*reference*) sampling location for the 2006 MacKay River non-lethal sentinel reconnaissance study.

Referencing Information	
Project Name:	RAMP Sentinel Sp. Recon.
Project Number:	RAMP 1245-3103
Waterbody Name:	MacKay River
Site Type:	*Reference*
Date:	16-September-2006
Time:	13:15
Crew Members:	CD/SE
Site UTM:	421096E 6299844N
Access:	Helicopter
Water Quality	
Temperature (^{0}C):	9.0
Dissolved Oxygen (mg/L):	9.8
pH:	8.0
Conductivity (uS/cm):	260
Channel Characteristics	
Avg. Channel Width (m):	40
Avg. Wetted Width (m):	39
Gradient (%):	-
Stage:	Moderate
Cover	
Crown Closure (%):	1-20
Total Cover:	Moderate
Dominant Cover Type:	Boulder
Secondary Cover Type:	Instream Vegetation
Functional Large Woody Debris:	Few
Functional Small Woody Debris:	Few
Bank Shape:	Sloping
Bank Texture:	Fines
Riparian Vegetation:	Mixed forest
Vegetation Stage:	Young/Mature Forest
Instream Vegetation:	Moderate
Channel Morphology	
Dominant Bed Material:	Boulder
Sub-Dominant Bed Material:	Large cobble
Flood Signs:	None
Pattern:	Irregular Meandering
Islands:	Occasional
Bars:	Side
Confinement:	Confined
Disturbance Indicators:	None
Morphology:	Run-riffle

Comments

Run-riffle transition located upstream of the tributary confluence
Considerable algae was present along river margins.
Water depth ranged from 0.3 to 0.5m.

Fish Inventory	
Total Fishing Effort:	960 s
No. Fish Caught:	68
CPUE	7.08 fish/100 s

Table 5.6-9 Results of the MacKay River sentinel reconnaissance fish sampling program, September 2006.

Species	Parameter	Site Lower	Site Upper	Overall Total
LKCH	N	9	22	31
	mean fork length (mm)	85.7	65.7	
	mean weight (g)	8.3	3.9	
LNDC	N	26	8	34
	mean fork length (mm)	63.0	58.4	
	mean weight (g)	2.8	2.7	
LNSC	N	1	1	2
	mean fork length (mm)	298	88	
	mean weight (g)	142.4	8.8	
SLSC	N		34	34
	mean fork length (mm)		49.9	
	mean weight (g)		2.0	
TRPR	N	1		1
	mean fork length (mm)	41		
	mean weight (g)	1.3		
WHSC	N		3	3
	mean fork length (mm)		64.0	
	mean weight (g)		5.1	
WALL	N	1		1
	mean fork length (mm)	116		
	mean weight (g)	14.0		
Total Number of Fish		38	68	106

LKCH= lake chub, LNDC= longnose dace, LNSC = longnose sucker, SLSC= slimy sculpin, TRPR= trout perch, WHSC= white sucker, WALL= walleye

Table 5.6-10 CPUE for the two electrofishing sites on the MacKay River sentinel reconnaissance, September 2006.

Site	Date	Effort (seconds)	Total Fish Caught	CPUE (#fish/100s)
Lower	Sep. 16, 2006	917	38	4.14
Upper	Sep. 16, 2006	960	68	7.08

5.7 CALUMET RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Hydrologic measurement endpoints are estimated to be 0.8% less than what they would have been in the absence of focal project activities.
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge	√				

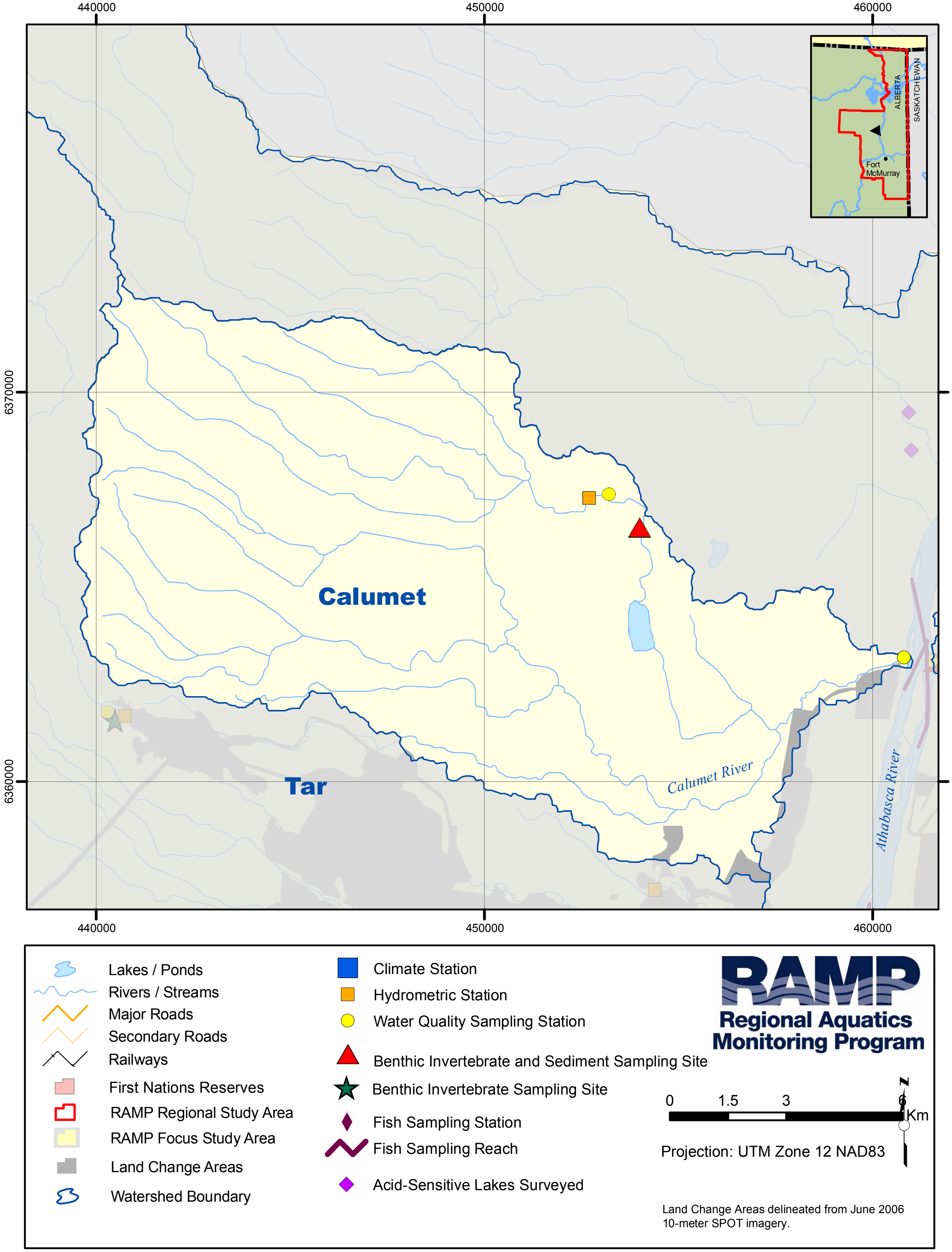
Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]		
Measurement endpoints with guidelines	2006 *Potentially Influenced* Stations (n=1)	2006 *Reference* Stations (n=1)	Focal project activities do not appear to have affected water quality in the Calumet River watershed. Concentrations of nearly all measurement endpoints were within the range of regional baseline values, and have not changed notably since station CAR-1 was designated as *potentially influenced* in 2005. Differences in ionic character between the lower and upper Calumet River are likely related to biogeophysical factors rather than the influence of focal project activities.
Physical variables (max=1 for exp, 1 for ref)	0	0	
Nutrients (max=3 for exp, 3 for ref)	1	2	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=5 for exp, 5 for ref)	0	0	
Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2006 *Potentially Influenced* Stations (n=1 station X 13 endpoints)	2006 *Reference* Stations (n=1 station X 13 endpoints)	
Greater than 95th percentile	2	4	
Between 5th and 95th percentiles	11	9	
Less than 5th percentile	0	0	

Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline						
	2006 *Potentially Influenced* Stations (n= 0)			2006 *Reference* Stations (n= 1)			Dissolved oxygen levels were very low at the time the upper Calumet River (reach CAR-D-1) was sampled. The most dominant chironomids belonged to the genus *Chironomus* , a group known for its tolerance of degraded water quality. Values of benthic invertebrate community measurement endpoints declined in 2006 compared to 2005, including %EPT, which declined to zero. Total organic carbon was high at reach CAR-D-2, likely due a large amount of decaying vegetation. Retene concentration was relatively high; this may result from the large quantities of deposited and decaying organic matter.
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance	Benthic invertebrate communities were not sampled in areas of the Calumet River watershed designated in 2006 as *potentially influenced* .				1		
Richness					1		
Diversity					1		
Evenness					1		
% EPT					1		
Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]						
Measurement endpoints with guidelines	2006 *Potentially Influenced* Stations (n=0)			2006 *Reference* Stations (n=1)			
Total Hydrocarbons(max=3)	Sediments were not sampled in areas of the Calumet River watershed designated in 2006 as *potentially influenced* .			2			
Metals				arsenic			
PAHs (max=1)				0			

Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2006.
Sentinel Studies	No sentinel fish studies conducted in 2006.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.
[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.7-1 Calumet River watershed.



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5.7.1 Development Status

Slightly more than 1% of the Calumet River watershed has undergone land change as a result of focal project activities (Table 2.6-2), and most of this land change has occurred in the lower part of the watershed (Figure 5.7-1). The designations of specific areas of the watershed are therefore as follows:

- The portion of watershed downstream of the last major northerly bend in the Calumet River (Figure 5.7-1) is designated as *potentially influenced* as most of the land changes from focal project activities as of 2006 were in this part of the watershed. All data gathered from RAMP sampling conducted in this part of the watershed in 2006 are designated as operational data; and
- All areas upstream of the last major bend in the Calumet River (Figure 5.7-1) are designated as *reference*; all data gathered from RAMP sampling conducted in this part of the watershed are designated as baseline data.

5.7.2 Hydrologic Conditions

2006 Hydrologic Conditions The 2006 hydrograph for the Calumet River as provided by CNRL for their station CR1 is presented in Figure 5.7-2. The peak flow that occurred in July is missing from the record because the rating curve available for the site is not applicable to overbank discharges (Golder, *pers.comm.*, 2007). The minimum open-water discharge of 0.009 m^3/s was less than half of the mean annual minimum discharge of 0.023 m^3/s.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the Calumet River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.7-1. As of 2006, the area of land change not closed-circuited was 2.00 km^2 in the Calumet River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1), the estimated net effects of which were to increase flow in the Calumet River by 0.008 million m^3.

The baseline hydrograph that would have occurred at CNRL Station CR-1, Calumet River near the Mouth, in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have increased mean open-water season discharge and open-season minimum daily discharge by 0.23%. The cumulative effect is that all hydrologic measurement endpoints for the Firebag River watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.7-2, Table 5.7-2). These calculated incremental changes in the hydrologic measurement endpoints would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information as well as information available regarding focal project activities in the Calumet River watershed, cumulative, watershed-level changes in hydrologic conditions in the Calumet River caused by focal project activities in the watershed as of 2006 have been negligible.

5.7.3 Water Quality

In 2006, water quality samples were collected from:

- The mouth of the Calumet River in the fall season (station CAR-1, established in 2002, designated as *potentially influenced* since 2005); and

- The upper Calumet River in the spring, summer, and fall seasons (station CAR-2, designated as *reference* since station establishment in 2005).

2006 Results and Historical Ranges of Concentration Concentrations of most water quality measurement endpoints were similar at station CAR-1 and station CAR-2, although dissolved phosphorus, total nitrogen, and sulphate were higher at station CAR-2 than at station CAR-1. In fall 2006, concentrations of several water quality measurement endpoints were greater or less than historically observed results (Table 5.7-3, Table 5.7-4). At the mouth of the Calumet River (station CAR-1), concentrations of most water quality measurement endpoints in fall 2006 were within previously recorded ranges, with the exception of total suspended solids, dissolved organic carbon, total aluminum, and total molybdenum (below the previously measured minimum) and calcium, magnesium, sulphate, and total mercury (above the previously measured maximum). As the upper Calumet River (station CAR-2) has only been measured once prior to 2006, historical ranges of concentrations of water quality measurement endpoints can not yet be established.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Overall, concentrations of water quality measurement endpoints exceeded water quality guidelines in 3 (15%) out of 20[1] possible cases for the Calumet River watershed in fall 2006. One of these three cases, total nitrogen, was at the mouth of the Calumet River (station CAR-2, Table 5.7-3), and two of these three cases, dissolved phosphorus and total nitrogen, were in the upper Calumet River (station CAR-2, Table 5.7-4). Total nitrogen also exceed its water quality guideline in spring and summer in the upper Calumet River (station CAR-2) (Table 5.7-5).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the Calumet River watershed in 2006 (Table 5.7-5):

- Sulphide, sulphate, total phosphorus, total Kjeldahl nitrogen, total and dissolved iron, and total phenols in the upper Calumet River (station CAR-2) in spring 2006;
- Sulphide, total phosphorus, total Kjeldahl nitrogen, total and dissolved iron, total phenols, and dissolved oxygen in the upper Calumet River (station CAR-2) in summer 2006; and
- Sulphide, total phosphorus, total Kjeldahl nitrogen, and total and dissolved iron in both the mouth of the Calumet River (station CAR-1) and the upper Calumet River (station CAR-2), as well as total phenols in the upper Calumet River (station CAR-2) in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At the mouth of the Calumet River (station CAR-1), the concentrations of 2 (15%) out of a possible 13[2] water quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations in fall 2006 (Figure 5.7-3). This is fewer than at the upper Calumet River

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[1] There are 22 water quality measurement endpoints, ten of which have water quality guidleines, and water quality was sampled at two locations in the Calumet River watershed in fall 2006, making for a total of 20 possible guideline exceedances.

[2] Thirteen water quality measurement endpoints were selected for comparison against regional baseline concentrations (Section 3.2.7.4).

(station CAR-2), at which concentrations of 4 (30%) out of a possible 13 water quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations in fall 2006 (Figure 5.7-3), although the small sample size, as well as a currently very short time series of water quality data for the upper Calumet River (station CAR-2) means it is not possible to ascertain the significance of these differences in variability that were measured in fall 2006. Dissolved phosphorus and sulphate concentrations were, as in 2005, greater than the 95th percentile of regional baseline concentrations at the upper Calumet River (station CAR-2). Concentrations of magnesium and potassium were greater than the 95th percentile of regional baseline concentrations at both stations in fall 2006 (Figure 5.7-3).

Ion Balance The ion balance of water sampled in the fall at the mouth of the Calumet River (station CAR-1) and the upper Calumet River (station CAR-2) has been relatively consistent over the period of sampling (Figure 5.7-4). Differences in the ionic character between the two stations appear to be related to anion concentrations; the ionic character at station CAR-2 is more highly dominated by sulphate and less dominated by bicarbonate than at station CAR-1.

Summary Based on the available water quality and information regarding focal projects in the Calumet river watershed, watershed-level water quality conditions in the Calumet River watershed do not appear to be affected by focal project activities in the watershed as of 2006. Water quality at the lower Calumet River (station CAR-1) remains generally within the range of regional baseline concentrations, and differences in ionic character between the lower Calumet River (station CAR-1) and the upper Calumet River (station CAR-2) are likely related to biogeophysical factors rather than the influence of focal project activities.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate community samples were collected from a depositional reach in the upper Calumet River (reach CAL-D-2, *reference*, data available beginning in 2003).

2006 Habitat Conditions Benthic invertebrate community samples taken from the upper Calumet River reach (reach CAL-D-2) were collected from sandy substrates in an average of 1.4 m of water (Table 5.7-6). Dissolved oxygen levels were very low (0.8 mg/L) at the time of sampling and the sediments being sampled had a sulfurous odour. Dissolved oxygen levels have been low (~ 4 mg/L) in previous years as well (RAMP 2005a). Water pH was 7.0 and macrophyte cover was measured as 0 (Table 5.7-6).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Copepods were the most dominant taxa sampled, with chironomids, nematodes, naidid worms and ostracods being sub-dominant numerically (Table 5.7-7). There were no mayfly or caddisfly taxa, unlike previous years when these two groups were present, though in low relative abundance. Phantom midges (chaoborids) were somewhat more abundant (4%) than in 2005 (2%). The most dominant chironomids belonged to the genus *Chironomus,* a group known for its tolerance of degraded water quality, specifically low dissolved oxygen concentrations (Bode, 1988).

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions Measures of diversity including number of taxa, Simpson's diversity, and evenness of benthic invertebrate communities all declined in the upper Calumet River (reach CAL-D-2) in fall 2006 compared to 2005, as did the percent

EPT (to zero) (Figure 5.7-5). However, values of all benthic invertebrate community measurement endpoints in reach CAL-D-2 in fall 2006 were within normal range of values observed from regional reference depositional reaches.

Effects of Focal Project Activities An assessment of the effects of focal project activities on benthic invertebrate communities could not be conducted for 2006 because benthic invertebrate communities were not sampled in the lower Calumet River (*potentially influenced*) in 2006.

5.7.4.2 Sediment Quality

Sediment quality was sampled fall 2006 in reach CAL-D-2, the depositional reach where benthic invertebrate communities were sampled in the upper Calumet River.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is, therefore, no historical record of sediment quality at reach CAL-D-2. Therefore, data from the nearest sediment quality sampling location in the Calumet River watershed prior to 2006, station CAR-2, was used as the basis of comparison for 2006 results. However, sediment quality was measured only once at station CAR-2 prior to 2006 and comparisons were therefore limited.

Sediments sampled at the upper Calumet River reach (reach CAL-D-2) were dominated by sand, but also contained a significant quantity of silt and clay. Total organic carbon was relatively high (16.5%), likely due a large amount of decaying vegetation found in this reach, which may have also contributed to the low oxygen levels measured (Table 5.7-5, Table 5.7-6).

Fraction 1 (C6-C10) and fraction 2 (C10-C16) hydrocarbons were non-detectable, while concentrations of fractions 3 (C16-C34) and 4 (C34-C50) were high. The concentration of retene was relatively high, comprising over half of the low molecular weight PAHs. As reach CAL-D-2 contains numerous beaver ponds, the high concentration of retene may result from the large quantities of deposited and decaying organic matter. Survival of *Chironomus tentans* was somewhat lower in fall 2006 than previously observed with sediments from this reach, although growth was similar.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines The concentration of total arsenic in sediment sampled in fall 2006 at reach CAL-D-2 exceeded the CCME interim sediment quality guideline, but not the probable effects level.

5.7.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2006 in the upper Calumet River continued to be within the normal range of regional baseline conditions for similar habitats.

5.7.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in the Calumet River watershed.

5.7.6 Summary of Conditions

RAMP aquatic resources were measured in the Calumet River watershed in 2006 as being similar to previous years. Values of few measurement endpoints in 2006 exceeded existing environmental guidelines, and few selected measurement endpoints were outside the range of expected reference conditions for similar river systems and habitats in the RAMP FSA. Effects of focal project activities in the watershed were negligible in 2006 in the case of hydrologic conditions, and no effects of focal project activities on water quality were detected.

Figure 5.7-2 Calumet River: 2006 hydrograph and historical context.

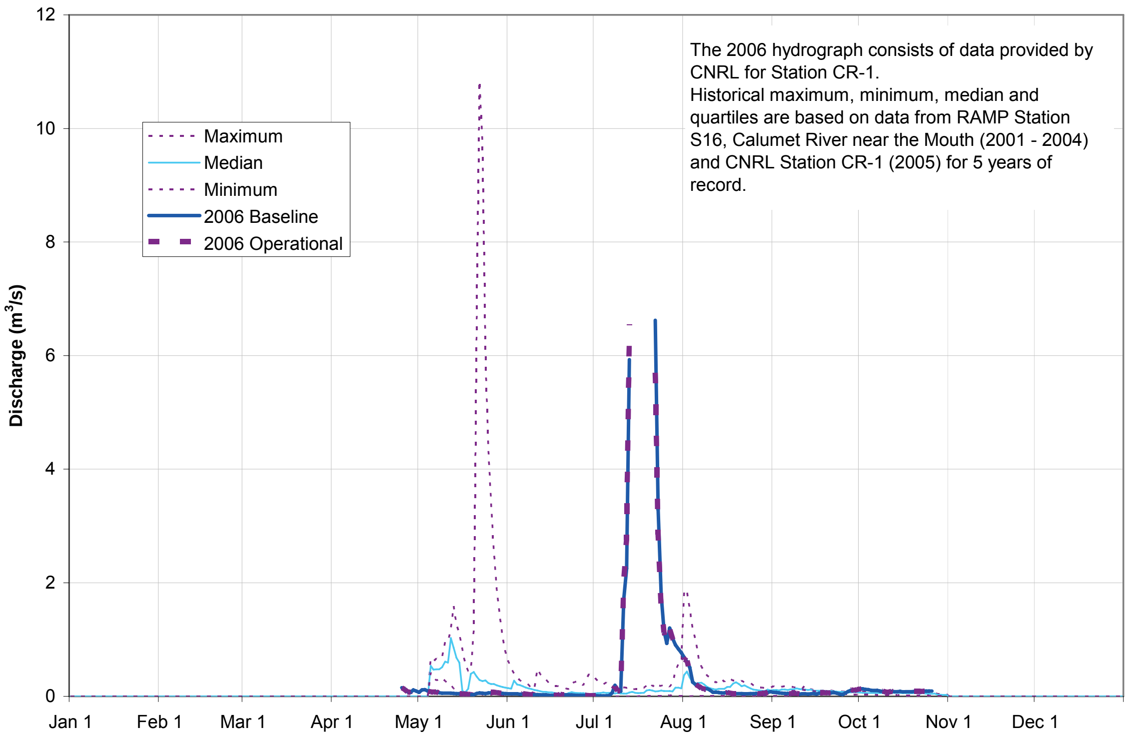


Table 5.7-1 Inputs to calculation of Calumet River baseline hydrograph at CNRL Station CR-1, Calumet River near the Mouth.

Component	Volume During 2006 CR-1 Data Record (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 CR-1 data record)	3.46	Sum of observed daily discharges, obtained from CNRL Station CR-1, Calumet River near the Mouth
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	0	No land within Calumet River drainage closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.008	2.00 km^2 within Calumet River drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Calumet River for focal project activities	0	Unknown, none reported, assumed to be negligible
Releases to Calumet River for focal project activities	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Calumet River not accounted for in figures contained in this table
Baseline hydrograph (total discharge during 2006 CR-1 data record)	3.45	Estimated total baseline discharge during 2006 CR-1 data record (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total discharge during 2006 CR-1 data record)	+ 0.008	Total discharge from operational hydrograph less total discharge of estimated baseline hydrograph for 2006 CR-1 data record
Incremental flow (% of observed total discharge during 2006 CR-1 data record)	+ 0.23%	Incremental flow as a percentage of total discharge of estimated baseline hydrograph during 2006 CR-1 data record

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Peak flows that occurred between July 14 and 21 are missing from the record. Statistics in the table are for a partial year.

Table 5.7-2 Calculated change in hydrologic measurement endpoints for the Calumet River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	0.230	0.230	+0.23%
Mean winter discharge	Not monitored	Not monitored	
Annual maximum daily discharge	Missing	Missing	
Open-water season minimum daily discharge	0.009	0.009	+0.23%

Note: as measured at and calculated for CNRL Station CR-1, Calumet River near the Mouth.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.7-3 Concentrations of water quality measurement endpoints, mouth of Calumet River (station CAR-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	8.1	8.2	8.4
Total suspended solids	mg/L	-[1]	<3	4	4	11.5	41
Conductivity	μS/cm	-	649	4	463	559	702
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.044	4	0.025	0.041	**0.076**
Total nitrogen*	mg/L	1.0	**1.4**	4	1.0	**1.2**	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	4	29	31	34
Ions							
Sodium	mg/L	-	65	4	39	57	71
Calcium	mg/L	-	67.3	4	39.4	57.6	66.0
Magnesium	mg/L	-	22.5	4	13.4	18.3	21.6
Chloride	mg/L	230, 860[3]	23	4	12	22	34
Sulphate	mg/L	100[4]	14.5	4	11.2	12.1	13.5
Total dissolved solids	mg/L	-	469	4	300	390	480
Total alkalinity	mg/L		324	4	216	278	337
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.040	4	0.050	**0.161**	**0.337**
Dissolved aluminum	mg/L	0.1[2]	0.0036	4	0.0026	0.0047	0.0058
Total boron	mg/L	1.2[5]	0.101	4	0.074	0.087	0.117
Total molybdenum	mg/L	0.073	0.00015	4	0.00018	0.00021	0.00030
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.8	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.263	4	0.195	0.253	0.297

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.7-4 Concentrations of water quality measurement endpoints, upper Calumet River (station CAR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	1	-	-	7.8
Total suspended solids	mg/L	-[1]	5	1	-	-	<3
Conductivity	µS/cm	-	577	1	-	-	526
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.31**	1	-	-	**0.13**
Total nitrogen*	mg/L	1.0	**2.4**	1	-	-	**2**
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	40	1	-	-	47
Ions							
Sodium	mg/L	-	65	1	-	-	53
Calcium	mg/L	-	43.1	1	-	-	44
Magnesium	mg/L	-	20.6	1	-	-	18
Chloride	mg/L	230, 860[3]	17	1	-	-	14
Sulphate	mg/L	100[4]	50.6	1	-	-	45.3
Total dissolved solids	mg/L	-	460	1	-	-	370
Total alkalinity	mg/L	-	234	1	-	-	213
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	2
Selected metals							
Total aluminum	mg/L	0.1	0.0245	1	-	-	0.0621
Dissolved aluminum	mg/L	0.1[2]	0.0172	1	-	-	0.0132
Total boron	mg/L	1.2[5]	0.0876	1	-	-	0.0817
Total molybdenum	mg/L	0.073	0.00009	1	-	-	0.00024
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	1	-	-	<0.6
Total strontium	mg/L	-	0.242	1	-	-	0.273

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

8 Guideline is for total nitrogen.

Table 5.7-5 List of all 2006 water quality guideline exceedances, Calumet River.

Variable	Units	Guideline*	CAR-1	CAR-2
Spring				
Sulphide	mg/L	0.002[1]	ns	**0.011**
Sulphate	mg/L	50, 100[2]	ns	**69.8**
Total phosphorus	mg/L	0.05	ns	**0.105**
Total nitrogen	mg/L	1.0	ns	**1.5**
Total Kjeldahl nitrogen	mg/L	1.0[3]	ns	**1.4**
Dissolved iron	mg/L	0.3[4]	ns	**0.396**
Total iron	mg/L	0.3	ns	**0.774**
Total phenols	mg/L	0.004	ns	**0.041**
Summer				
Sulphide	mg/L	0.002[1]	ns	**0.043**
Total phosphorus	mg/L	0.05	ns	**0.398**
Total nitrogen	mg/L	1.0	ns	**2.2**
Total Kjeldahl nitrogen	mg/L	1.0[2]	ns	**2.1**
Dissolved iron	mg/L	0.3[3]	ns	**1.23**
Total iron	mg/L	0.3	ns	**1.76**
Total phenols	mg/L	0.004	ns	**0.043**
Dissolved oxygen	mg/L	5.0[4]	ns	**2.8**
Fall				
Sulphide	mg/L	0.002[1]	**0.011**	**0.095**
Total phosphorus	mg/L	0.05	**0.096**	**0.349**
Total nitrogen	mg/L	1.0	**1.4**	**2.4**
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.3**	**2.3**
Dissolved iron	mg/L	0.3[3]	**0.911**	**0.322**
Total iron	mg/L	0.3	**2.05**	**0.551**
Total phenols	mg/L	0.004	**-**	**0.041**

CAR-1 sampled only in fall 2006. No winter sampling was conducted in this watershed.

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

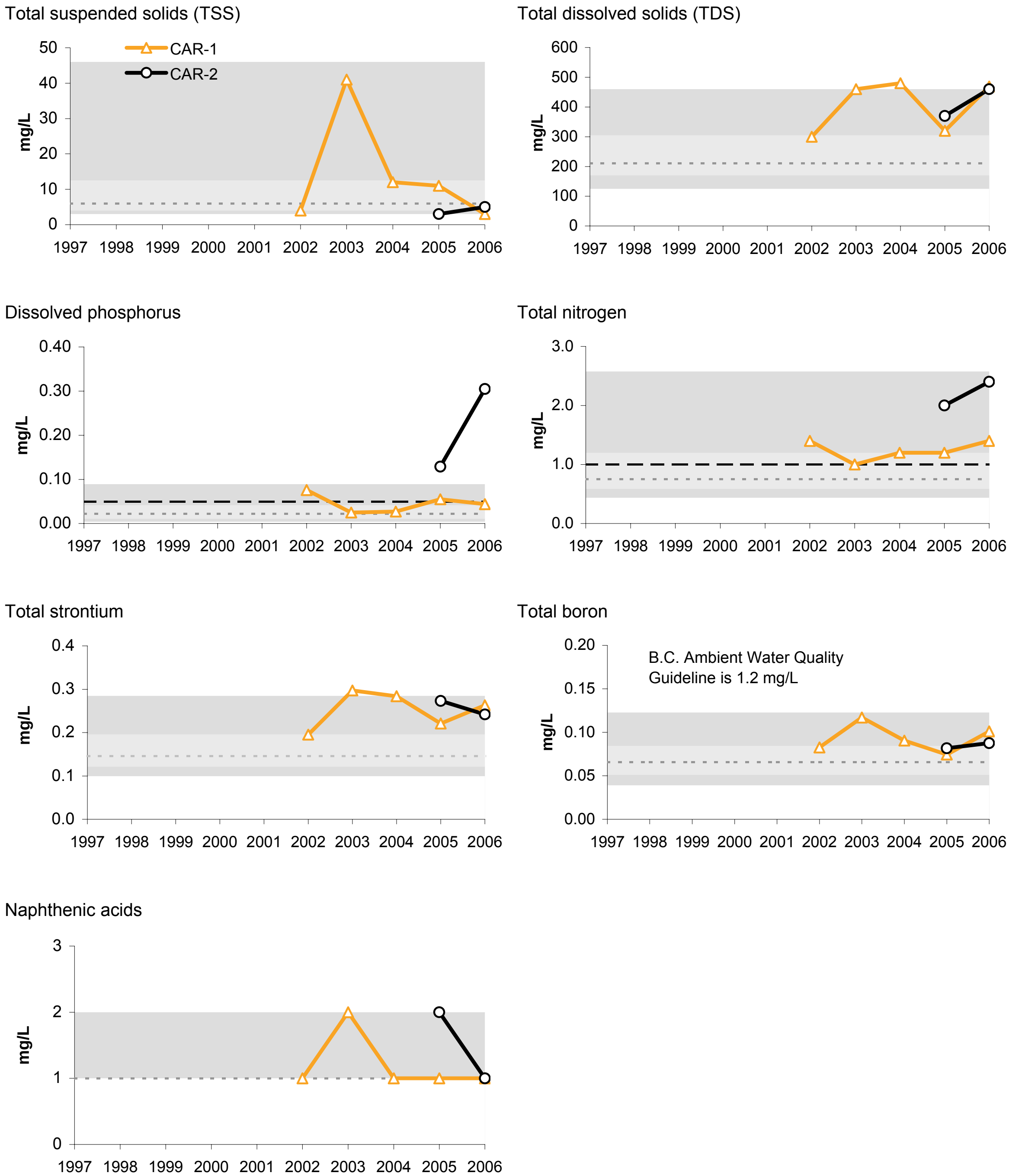
[1] B.C. Working Water Quality Guideline.

[2] Guideline is for total nitrogen (no guideline for TKN).

[3] Guideline is for total metal (no guideline for dissolved analyte).

[4] AENV 1-day minimum dissolved oxygen level. Dissolved oxygen measured by titration in the field.

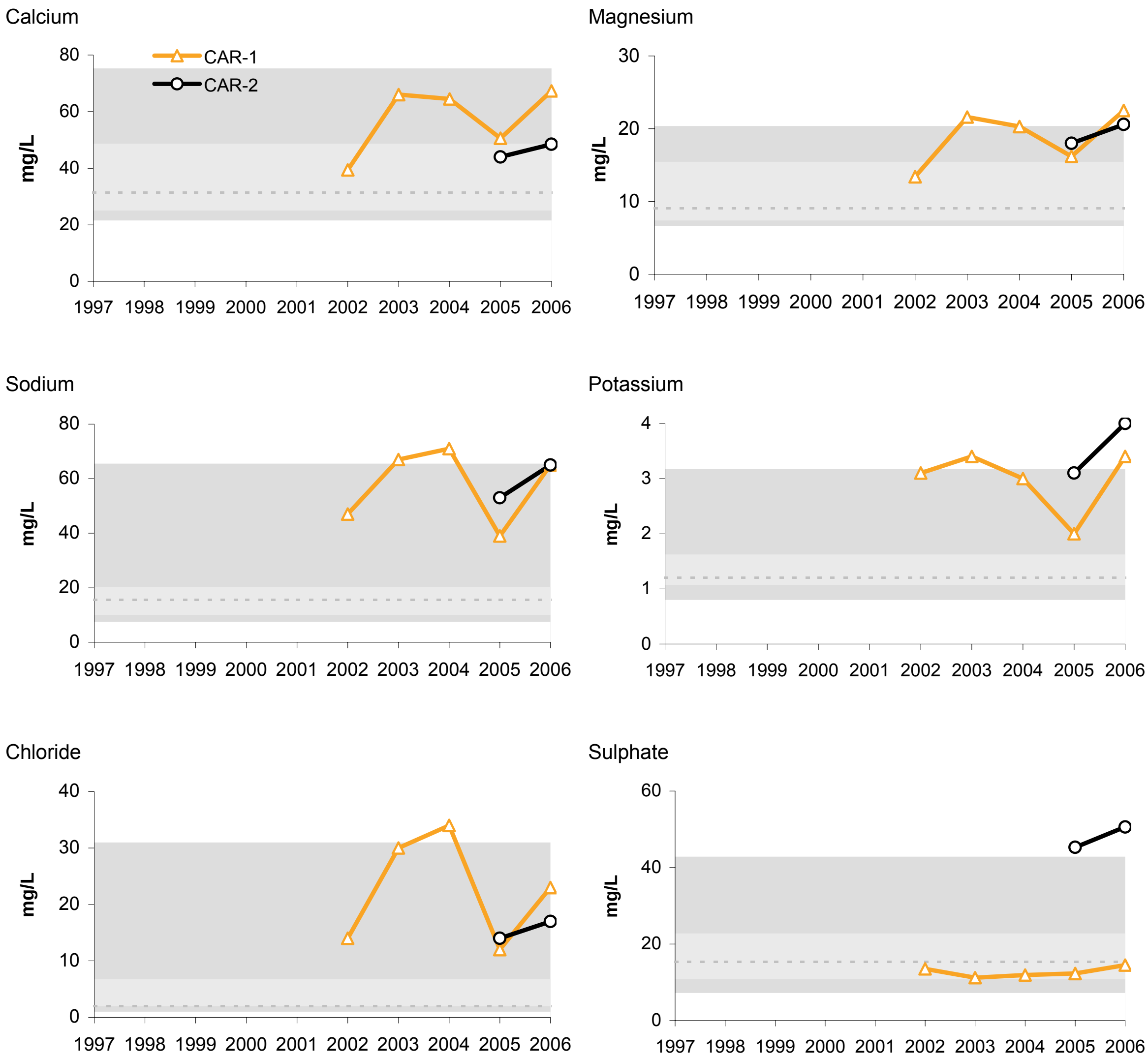
Figure 5.7-3 Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.7-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.7-4 Piper diagram of fall ion concentrations in Calumet River watershed.

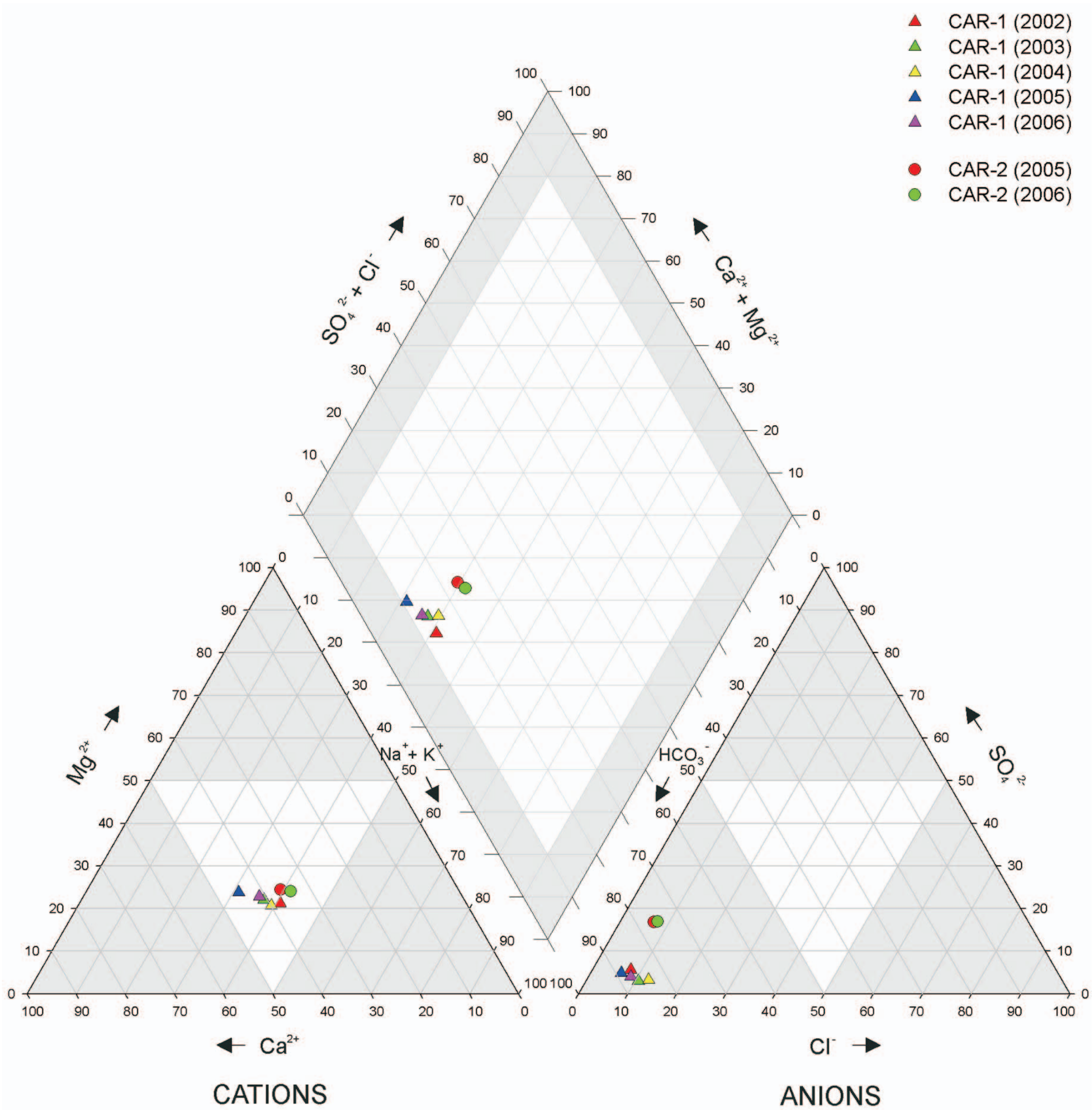


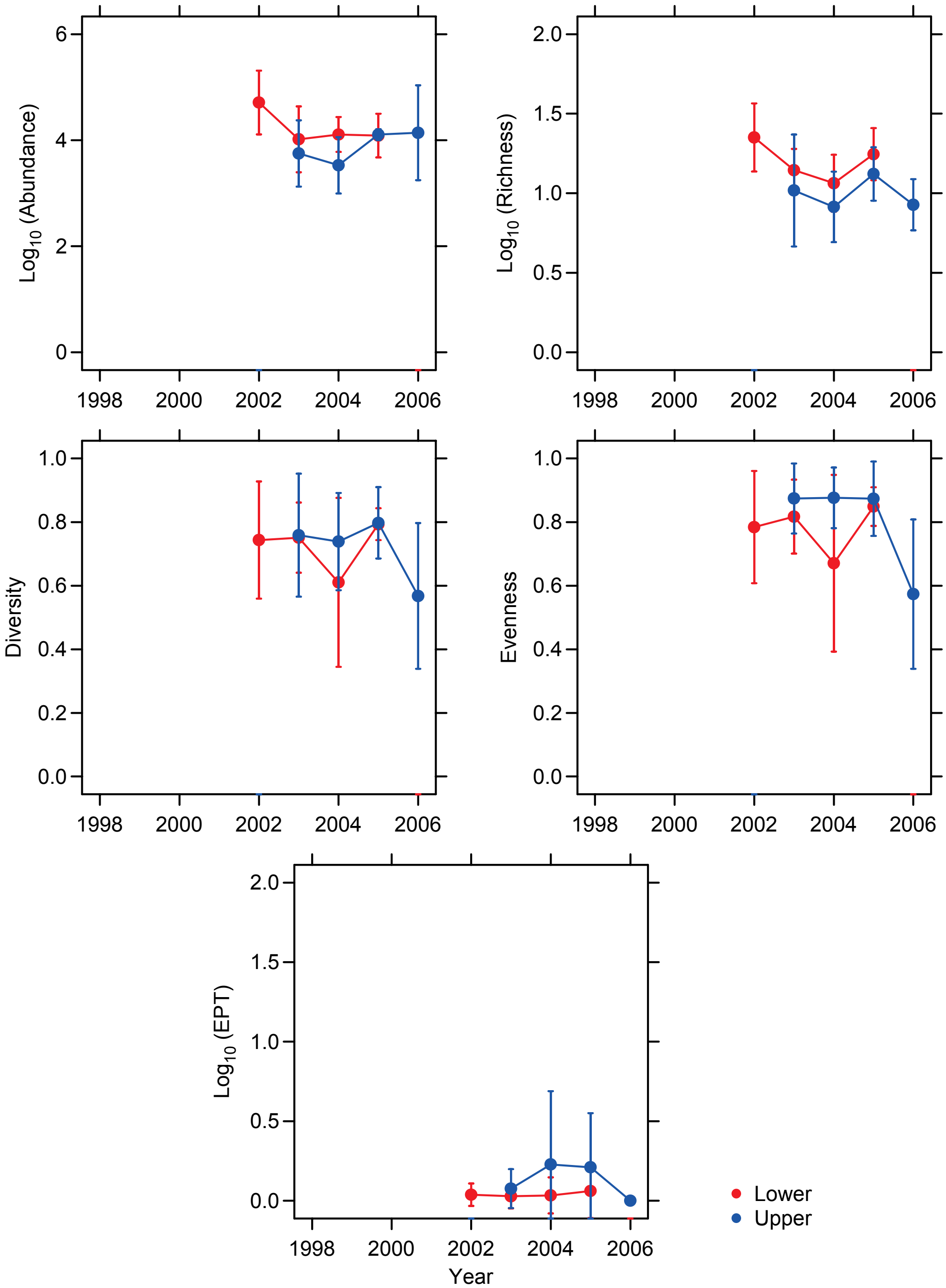
Table 5.7-6 Habitat characteristics of upper Calumet River reach, fall 2006.

Variable	Units	Upper Reach (CAL-D-2)
Sample date	-	n/a
Habitat	-	Depositional
Water depth	m	1.4
Current velocity	m/s	n/a
Macrophyte cover	%	0
Sand/Silt/Clay	%	100
Field Water Quality		
Dissolved oxygen	mg/L	8.0
Conductivity	µS/cm	539
pH	pH units	7.0
Water temperature	°C	13.0
Sediment Composition		
Sand	%	40
Silt	%	38
Clay	%	22

Table 5.7-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Calumet River.

Taxon	% Total Taxa Enumerated in Each Year							
	Reach CAL-D-1				Reach CAL-D-2			
	2002	2003	2004	2005	2003	2004	2005	2006
Amphipoda	<1		<1		3	2		
Anisoptera	<1	<1	<1		<1	<1	1	
Bivalvia	1	2	1	1	1	1	<1	<1
Ceratopogonidae	1	2	2	<1	3		4	
Chaoboridae					3	1	2	4
Chironomidae	91	85	48	86	54	42	67	19
Coleoptera	<1	<1	1	<1				
Copepoda	1	2	<1	1	4	3	4	36
Daphniidae	<1	<1	<1		3			
Dolichopodidae		<1	<1					
Enchytraeidae	<1	<1	<1	<1				
Ephemeroptera	<1	<1	<1	<1	<1	1	1	
Erpobdellidae	<1	<1	<1			<1	<1	
Gastropoda	<1	<1	<1		13	5	1	<1
Heteroptera	<1	<1	<1					
Hydra				1				
Hydracarina	<1	<1	<1	<1	3		2	1
Macrothricidae	<1	<1	<1					
Naididae	<1	4	2	<1	9	6	6	11
Nematoda	1	<1	3	1	4	16	5	19
Ostracoda	3	2	4	3		12	7	7
Plecoptera	<1		<1	1				
Tabanidae	<1	1	1	<1				
Trichoptera	<1	<1			<1	<1	<1	
Tubificidae	1	1	37	6		1		0.9
Benthic Invertebrate Community Measurement Endpoints								
Total Abundance (No./m^2)	73,983	19,664	16,954	1,796	10,302	4,612	12,957	38,621
Richness	23	14	11	18	12	8	13	8
Simpson's Diversity	0.74	0.75	0.61	0.79	0.76	0.74	0.8	0.57
Evenness	0.78	0.82	0.67	0.85	0.87	0.88	0.87	0.57
% EPT	<1	<1	<1	<1	<1	2	1	0

Figure 5.7-5 Annual variation in benthic invertebrate community measurement endpoints in the Calumet River, reach CAL-D-1 and reach CAL-D-2.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.
Lower: reach CAL-D-1; Upper: reach CAL-D-2.

Table 5.7-8 Concentrations of sediment quality measurement endpoints, upper Calumet River (reach CAL-D-2), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, CAR-2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	13	-	-	-	-
Silt	%	-	31	-	-	-	-
Sand	%	-	56	-	-	-	-
Total organic carbon	%	-	16.5	1	-	-	20.5
Total hydrocarbons							
BTEX	mg/kg	-	<80	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<80	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	1	-	-	**230**
Fraction 3 (C16-C34)	mg/kg	400[2]	**4100**	1	-	-	**6100**
Fraction 4 (C34-C50)	mg/kg	2800[2]	**4300**	1	-	-	**3000**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0147	1	-	-	0.020
Retene	mg/kg	-	0.745	1	-	-	0.353
Total dibenzothiophenes	mg/kg	-	0.02	1	-	-	0.04
Total PAHs	mg/kg	-	2.68	1	-	-	1.93
Total HMW PAHs	mg/kg	-	1.23	1	-	-	0.12
Total LMW PAHs	mg/kg	-	1.45	1	-	-	1.81
Predicted PAH toxicity[1]	H.I.	-	0.14	1	-	-	0.07
Metals that exceed CCME guidelines in 2005							
Arsenic	mg/kg	5.9, 17[4]	**7.6**	1	-	-	**12.6**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	5	1	-	-	8
Chironomus growth - 10d	mg/organism	-	2.5	1	-	-	2.24
Hyalella survival - 14d	# surviving	-	6	1	-	-	6
Hyalella growth - 14d	mg/organism	-	0.4	1	-	-	0.44

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

[4] CCME interim sediment quality guideline and probable effects level, respectively.

5.8 FIREBAG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Total runoff in 2006 was almost exactly equal to the long-term average. Cumulative, watershed-level changes in hydrologic conditions in the Firebag River caused by focal project activities in the watershed as of 2006 have been negligible.
Mean winter discharge	√				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]		
Measurement endpoints with guidelines	2006 *Potentially Influenced* Stations (n=0)	2006 *Reference* Stations (n=2)	
Physical variables (max=2)	No water quality sampling stations were designated as *potentially influenced* in 2006.	0	Concentrations of water quality measurement endpoints were generally consistent with results from previous years. Sulphate concentrations were greater than the 95th percentile of regional baseline concentrations at both sampled stations, while dissolved phosphorus was greater than the 95th percentile at the upper Firebag, upstream of the Suncor Firebag project.
Nutrients (max=6)		3	
Ions (max=4)		0	
Selected metals (max=10)		0	
Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2006 *Potentially Influenced* Stations (n=0 stations X 13 endpoints)	2006 *Reference* Stations (n=2 stations X 13 endpoints)	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced* in 2006.	3	
Between 5th and 95th percentiles		23	
Less than 5th percentile		0	

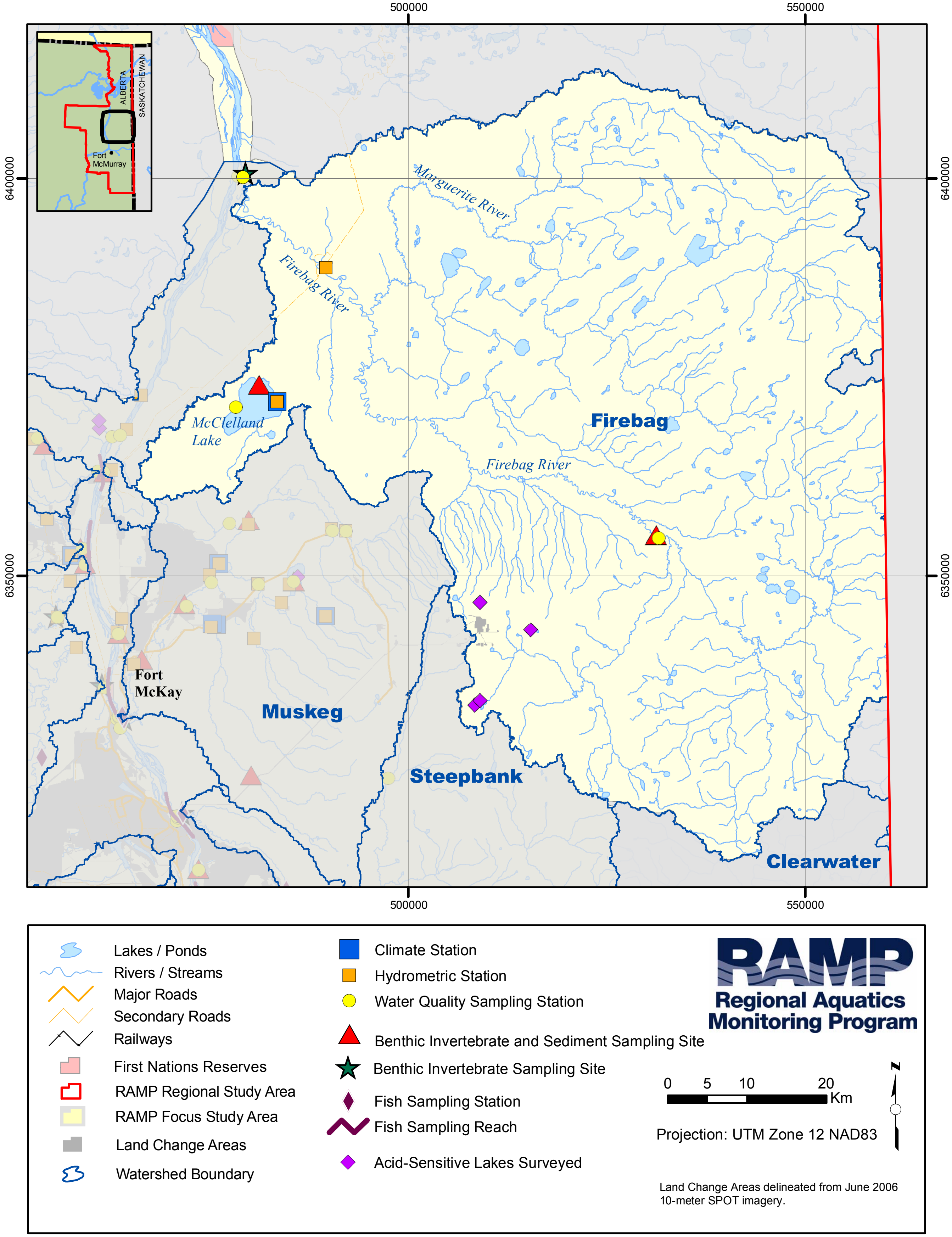
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline						
Values in Relation to Regional Baseline Mean	2006 *Potentially Influenced* Sites (n=0)			2006 *Reference* Sites (n=2)			
	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance	No benthic invertebrate community sampling locations were designated as *potentially influenced* in 2006.				2		Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats, and sediment quality measurement endpoints were all within historical ranges.
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		
Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006						
Measurement endpoints with guidelines	2006 *Potentially Influenced* Sites (n=0)			2006 *Reference* Sites (n=1)			
Total Hydrocarbons (max=4)	No sediment quality sampling locations were designated as *potentially influenced* in 2006.			0			
PAHs (max=1)				0			

Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2006.
Sentinel Studies	No sentinel fish studies conducted in 2006.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.8-1 Firebag River watershed.



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5.8.1 Development Status

As of 2006, 0.06% of the area of the Firebag River watershed had undergone land change from focal project activities (Table 2.6-2). Given this small land change area, all parts of the Firebag River watershed are designated as *reference* for 2006. Therefore, all RAMP stations in the Firebag River watershed in 2006 are designated as *reference* stations and all data gathered at these stations in 2006 are designated as baseline data.

5.8.2 Hydrologic Conditions

2006 Hydrologic Conditions Total runoff in the Firebag River watershed in 2006 was almost exactly equal to the long-term average, with a May to October runoff depth of 100 mm. During the year, flows fluctuated from well below to well above average (Figure 5.8-2). The maximum daily discharge of 127 m^3/s, amounting to 120% of the mean annual flood, occurred in July in response to a large rainfall event. The minimum open-water discharge was 7.54 m^3/s, only about half as much as the mean annual minimum discharge of 15.3 m^3/s.

Estimation of Hydrologic Effects An assessment was made of the hydrologic effects of the existing land change area in the Firebag River watershed even though the entire watershed is designated as *reference* for 2006. As indicated in Section 3.1.7.2, the methodology of the hydrologic assessment, unlike the methodology of the other RAMP components (with the exception of the Acid-Sensitive Lakes component), does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted even in watersheds whose entire area is designated as *reference*.

A summary of the inputs to the water balance model for the Firebag River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.8-1. As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 3.07 km^2 and 0.45 km^2, respectively, in the Firebag River drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1), the estimated net effects of which were to reduce inflows to the Firebag River by 0.052 million m^3 in 2006.

The baseline hydrograph that would have occurred at RAMP/WSC Station S27, Firebag River near the Mouth (07DC001) in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have decreased mean open-water season discharge, mean winter discharge, annual maximum daily discharge, and open-season minimum daily discharge by 0.06%. The cumulative effect is that all hydrologic measurement endpoints for the Firebag River watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.8-2, Table 5.8-2). These calculated incremental changes in the hydrologic measurement endpoints (-0.06%) would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information as well as information available regarding focal project activities in the Firebag River watershed, cumulative, watershed-level changes in hydrologic conditions in the Firebag River caused by focal project activities in the watershed as of 2006 have been negligible.

5.8.3 Water Quality

In 2006, fall water quality samples were collected from:

- The mouth of the Firebag River (station FIR-1, *reference*, first sampled in 2002); and
- Upstream of the Suncor Firebag project (station FIR-2, *reference*, first sampled in 2002).

Water quality was sampled in the winter season from 2002 to 2005 at station FIR-1 and station FIR-2; the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration Concentrations of water quality measurement endpoints in fall 2006 at both station FIR-1 and station FIR-2 were within the range of previously measured concentrations at these stations (Table 5.8-3, Table 5.8-4), with the exception of:

- Total suspended solids, lower concentration in fall 2006 than the previously measured minimum fall concentration at station FIR-1;
- Calcium and sulphate, higher concentrations in fall 2006 than the previously measured maximum fall concentrations at both stations;
- Total strontium, lower concentration in fall 2006 than the previously measured minimum fall concentration at station FIR-2; and
- Total aluminum, higher concentration in fall 2006 at station FIR-2 than the previously measured maximum fall concentration.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines In fall 2006, there were no cases in which concentrations of water quality measurement endpoints exceeded water quality guidelines at either the mouth of the Firebag River (station FIR-1, Table 5.8-3) or the Firebag River upstream of the Suncor Firebag project (station FIR-2, Table 5.8-4).

Comparison of Other Water Quality Variables to Water Quality Guidelines In fall 2006, concentrations of sulphide, total phosphorus, total iron, and dissolved iron, all water quality variables not designated as water quality measurement endpoints, exceeded water quality guidelines at both station FIR-1 and station FIR-2 in the Firebag River watershed (Table 5.8-5).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions The concentrations of 3 (12%) out of a possible 26[1] water quality measurement endpoint-station combinations were below the 5th or above the 95th percentile of regional baseline concentrations in fall 2006 (Figure 5.8-3). The concentration of dissolved phosphorus at station FIR-2 was greater than the 95th percentile of regional baseline concentrations while concentrations of sulphate were greater than the 95th percentile of regional baseline concentrations at both stations. The trend in concentrations of all water quality measurement endpoints has been the same in both station FIR-1 and station FIR-2 throughout the data record (Figure 5.8-3).

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[1] Thirteen water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4) were sampled at two stations designated as *reference* in the Firebag River watershed in fall 2006, making for a total of 26 water quality measurement endpoint-station combinations.

Ion Balance Ionic characteristics of water measured at station FIR-1 and station FIR-2 were consistent from 2002 to 2005, but differed slightly in 2006 (Figure 5.8-4). This shift in ion balance was driven by the anion balance and was related to the slightly higher sulphate concentrations observed in 2006 relative to previous years.

Summary Water quality conditions in the Firebag River, as measured at stations FIR-1 and FIR-2 in fall 2006, were similar to water quality conditions at these stations in previous years.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from:

- A depositional reach near the mouth of the Firebag River (reach FIR-D-1, *reference*, first sampled in 2003); and
- An erosional reach upstream of the Suncor Firebag Project (reach FIR-E-2, *reference*, first sampled in 2003).

2006 Habitat Conditions The lower reach near the mouth of the Firebag River (reach FIR-D-1) was characterized in fall 2006 by moderate depths, slow current, and minor macrophyte coverage (Table 5.8-6). Velocities at reach upstream of the Suncor Firebag Project (reach FIR-E-2), averaged just over 1 m/s in fall 2006 (Table 5.8-6). Macrophytes were generally present at all the individual stations in reach FIR-E-2 and comprised of typically long strands of flat-stemmed pondweed (*Potamogeton zosteriformis*) and tape grass (*Valisneria americana*). Periphyton chlorophyll *a* biomass was at moderate levels at reach FIR-E-2 in fall 2006 (Figure 5.8-5) and has averaged 44 mg/m² during the historical sampling period, indicating water at this reach has been oligotrophic.

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Tubificid worms and chironomids dominated the lower reach near the mouth of the Firebag River (reach FIR-D-1) in fall 2006, with some additional types of fly larvae (ceratopogonids, tipulids), and sphaeriid clams (Table 5.8-7). Stoneflies were absent from the samples, unlike previous years. Chironomids, mayflies, caddisflies and beetles dominated the benthic invertebrate communities of the reach upstream of the Suncor Firebag Project (reach FIR-E-2, Table 5.8-7), while mites, nematodes and naidids worms were sub-dominant. Several of the taxa found at reach FIR-E-2 are indicative of high quality benthic invertebrate community habitat including the mayflies *Acentralla*, *Paraleptophlebia* and *Siphloplecton*, the stoneflies *Isoperla* and *Taeniopteryx*, and the caddisflies *Brachcentrus*, *Glossosoma*, *Lepidostoma* and *Psychomyia*. The dominant chironomids included *Thiennemannimyia*, *Polypedilum*, various *Tanytarsini*, and the orthoclad *Cricotopus*/*Othorcladius.*

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions Values of all benthic invertebrate community endpoints at the reach upstream of the Suncor Firebag Project (reach FIR-E-2) have remained relatively constant from year to year, in contrast with diversity, evenness, and %EPT at the reach near the mouth of the Firebag River (reach FIR-D-1), which have steadily declined since 2004 (Figure 5.8-6).

5.8.4.2 Sediment Quality

Sediment quality was sampled in fall 2006 in reach FIR-D-1, the depositional reach where benthic invertebrate communities were sampled near the mouth of the Firebag River.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is therefore no historical record of sediment quality at reach FIR-D-1. Therefore, data from the nearest sediment quality sampling location in the Firebag River watershed prior to 2006 was used as the basis of comparison for 2006 results; this was sediment quality sampling station FIR-1. Comparison of 2006 results from reach FIR-D-1 with results from previous years at station FIR-1 is characterized by small sample sizes of the historical record ($n \leq 3$).

Sediments at the lower Firebag River (reach FIR-D-1) in fall 2006 were dominated by sand, with a small proportion of clay and silt. Total organic carbon content in these sediments was low (0.5%).

Concentrations of all sediment quality measurement endpoints in fall 2006 at reach FIR-D-1 were within historical ranges (Table 5.8-8). Fraction 1 hydrocarbons and BTEX were not detectable at reach FIR-D-1 in fall 2006, while concentrations of other (i.e., C10-C50) PAH concentrations were generally less than the median historical concentration observed in this reach. Survival of both *Chironomus tentans* and *Hyalella azteca* were higher than previously measured.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines There were no sediment quality measurement endpoints in fall 2006 at reach FIR-D-1 with measured concentrations that exceeded sediment quality guidelines.

5.8.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats, and sediment quality measurement endpoints were all within historical ranges.

5.8.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in the Firebag River watershed.

5.8.6 Summary of Conditions

At a watershed level, the conditions of RAMP aquatic resources of the Firebag River watershed were similar in 2006 relative to previous years. There were few exceedances of water quality environmental guidelines in 2006, and almost all water quality and benthic invertebrate community measurement endpoints for RAMP aquatic resources that were sampled in 2006 were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Figure 5.8-2 Firebag River: 2006 hydrograph and historical context.

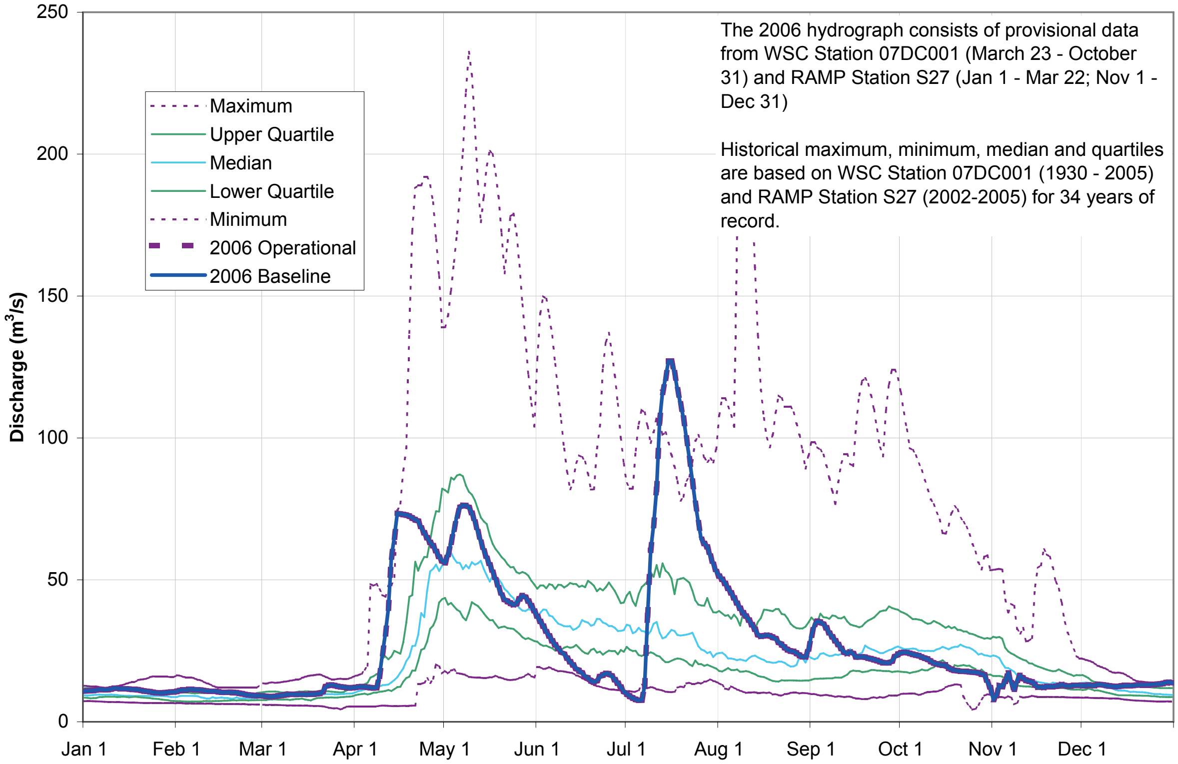


Table 5.8-1 Inputs to calculation of Firebag River baseline hydrograph at RAMP/WSC Station S27, Firebag River near the Mouth (07DC001).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	871	Observed daily discharges obtained from RAMP/WSC Station S27, Firebag River near the Mouth (07DC001)
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.530	3.07 km^2 within Firebag River drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.0131	0.45 km^2 within Firebag River drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Firebag River for focal project activities	0	Unknown, none reported, assumed to be negligible
Releases to Firebag River for focal project activities	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Firebag River not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	871	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total annual discharge)	- 0.0517	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.06%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.8-2 Calculated change in hydrologic measurement endpoints for the Firebag River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	37.6	37.6	-0.06%
Mean winter discharge	11.6	11.6	-0.06%
Annual maximum daily discharge	127	127	-0.06%
Open-water season minimum daily discharge	7.54	7.54	-0.06%

Note: as measured at and calculated for RAMP/WSC Station S27, Firebag River near the Mouth (07DC001).

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.8-3 Concentrations of water quality measurement endpoints, mouth of Firebag River (station FIR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	7.9	8.2	8.2
Total suspended solids	mg/L	-[1]	4	4	5	9.5	17
Conductivity	µS/cm	-	219	4	178	193	227
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.04	4	0.016	0.033	**0.057**
Total nitrogen*	mg/L	1.0	0.6	4	0.4	0.6	**1.7**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	4	8	10.5	16
Ions							
Sodium	mg/L	-	4	4	3	4	4
Calcium	mg/L	-	33.2	4	25.2	28.8	31.3
Magnesium	mg/L	-	9.5	4	8.2	8.9	9.5
Chloride	mg/L	230, 860[3]	3	4	2	2.5	3
Sulphate	mg/L	100[4]	10.3	4	2.8	3.3	4.1
Total dissolved solids	mg/L	-	160	4	60	135	170
Total alkalinity	mg/L		110	4	87	104	112
Organic compounds							
Naphthenic acids	mg/L	-	-	4	<1	1	1
Selected metals							
Total aluminum	mg/L	0.1	0.069	4	0.033	**0.219**	**0.292**
Dissolved aluminum	mg/L	0.1[2]	0.0035	4	0.0028	0.0071	0.0089
Total boron	mg/L	1.2[5]	0.0162	4	0.0140	0.0159	0.0190
Total molybdenum	mg/L	0.073	0.00016	3	0.00011	0.00013	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.069	3	0.053	0.065	0.073

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.8-4 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (station FIR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.9	8.1	8.1
Total suspended solids	mg/L	-[1]	3	3	<3	3	8
Conductivity	μS/cm	-	169	3	160	162	174
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.087**	3	0.039	**0.060**	**0.096**
Total nitrogen*	mg/L	1.0	0.7	3	0.5	0.5	0.7
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	3	8	12	16
Ions							
Sodium	mg/L	-	4	3	3	4	4
Calcium	mg/L	-	26.2	3	22.9	25	25.7
Magnesium	mg/L	-	7.3	3	6.4	7.2	7.4
Chloride	mg/L	230, 860[3]	2	3	<1	2	2
Sulphate	mg/L	100[4]	8.8	3	1.9	2.8	2.9
Total dissolved solids	mg/L	-	140	3	110	120	150
Total alkalinity	mg/L		86	3	81	91	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0369	3	0.0232	0.0289	0.0359
Dissolved aluminum	mg/L	0.1[2]	0.0043	3	0.0031	0.0063	0.0066
Total boron	mg/L	1.2[5]	0.0122	3	0.0107	0.0134	0.0153
Total molybdenum	mg/L	0.073	0.00018	3	0.00015	0.00016	0.00020
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.8	3	<0.6	<0.6	1.1
Total strontium	mg/L	-	0.046	3	0.048	0.050	0.068

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.8-5 List of all 2006 water quality guideline exceedances, Firebag River.

Variable	Units	Guideline*	FIR-1	FIR-2
Fall				
Sulphide	mg/L	0.002[1]	**0.004**	**0.003**
Total phosphorus	mg/L	0.05	**0.063**	**0.119**
Dissolved iron	mg/L	0.3[2]	**0.448**	**0.528**
Total iron	mg/L	0.3	**0.785**	**0.917**

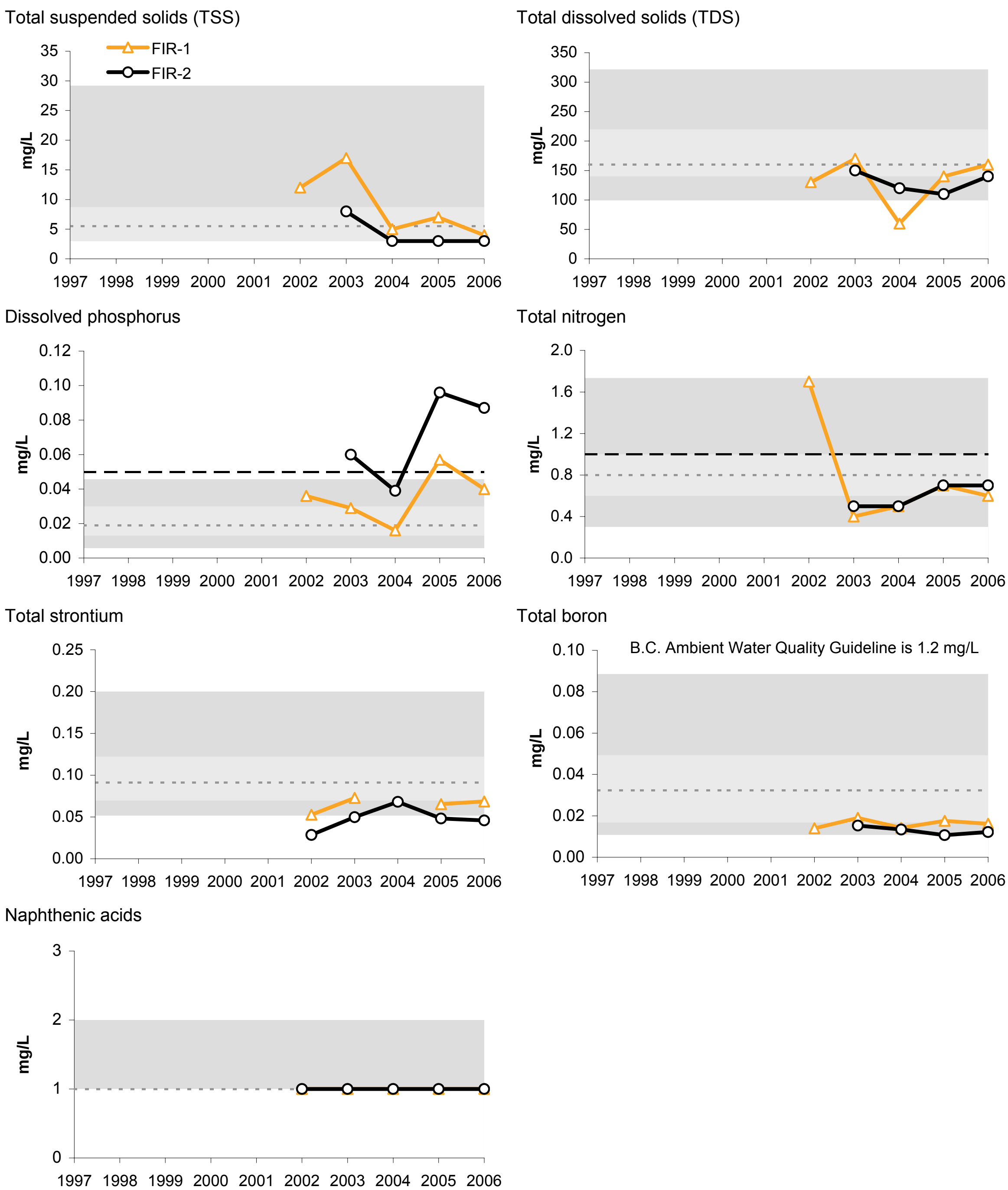
FIR-1 and FIR-2 sampled only in fall 2006.

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

1 B.C. Working Water Quality Guideline for sulphide as H_2S.

2 Guideline is for total metal (no guideline for dissolved analyte).

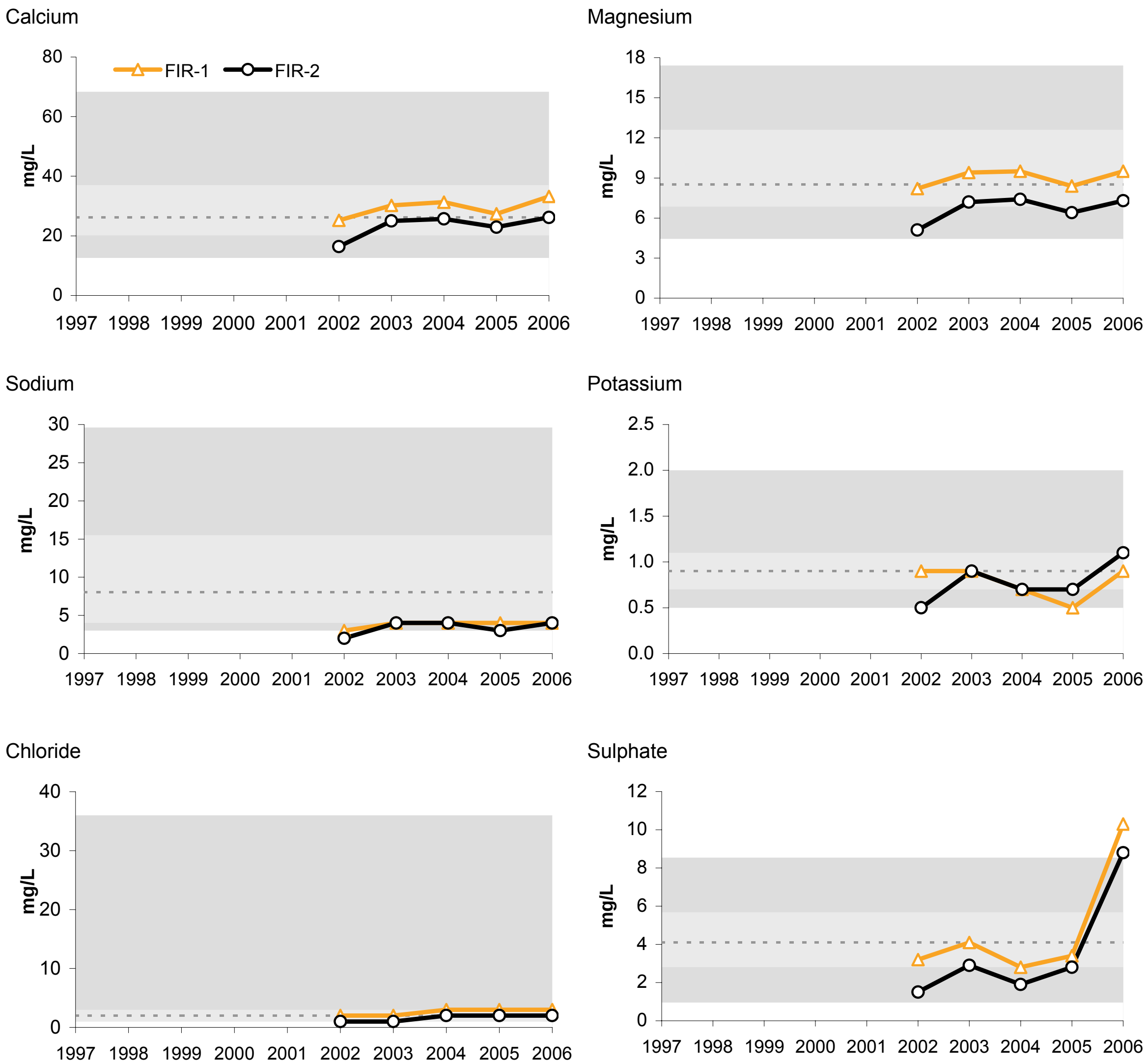
Figure 5.8-3 Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2006) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.8-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.8-4 Piper diagram of fall ion concentrations in the Firebag River watershed.

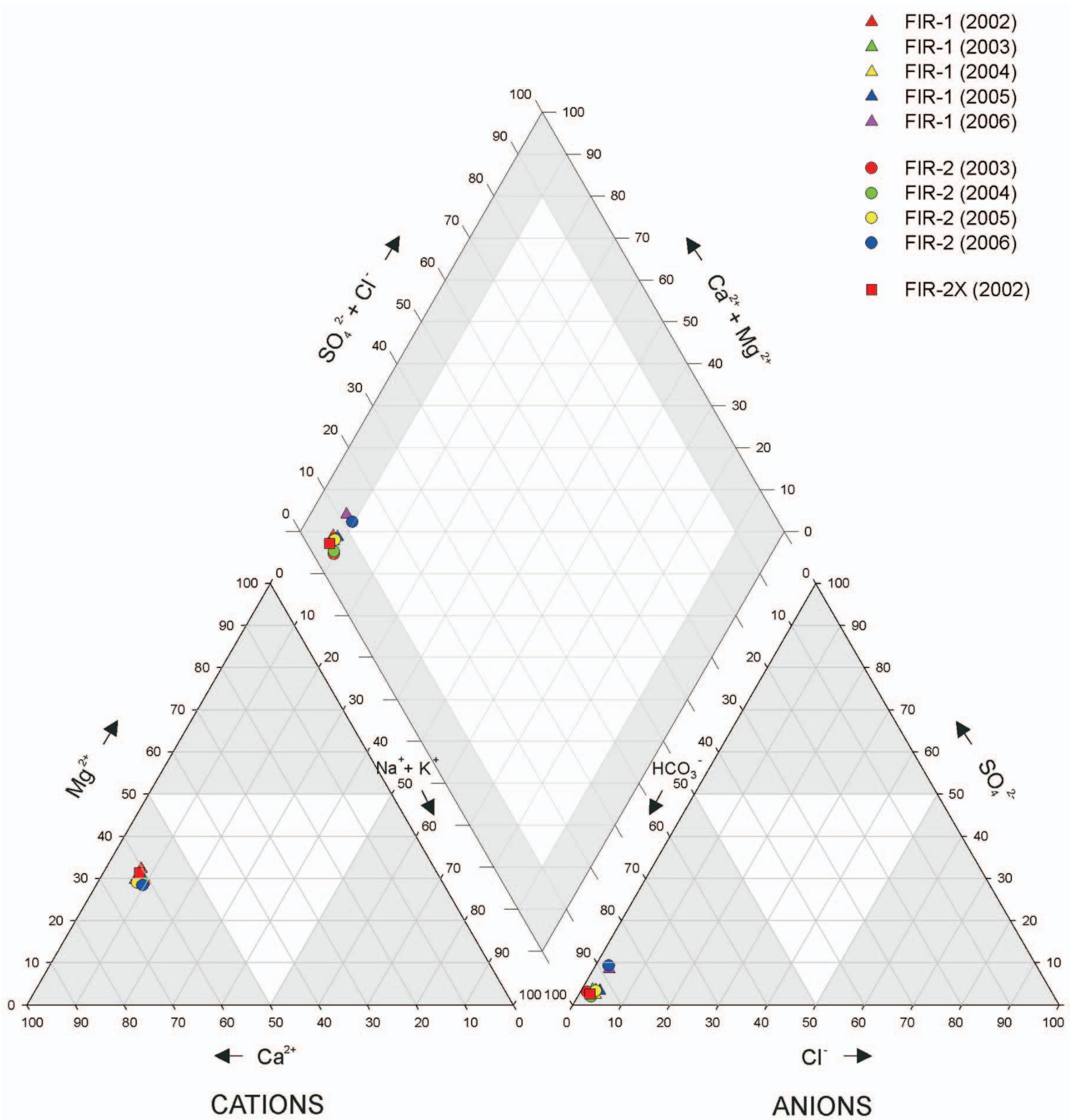


Table 5.8-6 Average habitat characteristics of benthic invertebrate community sampling reaches in the Firebag River, fall 2006.

Variable	Units	Lower Reach of the Firebag River (reach FIR-D-1)	Upper Reach of the Firebag River (reach FIR-E-2)
Sample date	-	Sept. 12, 2006	Sept. 12, 2006
Habitat	-	Depositional	Erosional
Water depth	m	0.4	0.26
Current velocity	m/s	0.3	1.2
Macrophyte cover	%	9	26
Benthic algae	mg/m^2	n/a	44
Sand/Silt/Clay	%	98	25
Field Water Quality			
Dissolved oxygen	mg/L	7.9	n/a
Conductivity	µS/cm	202	175
pH	pH units	7.8	7.8
Water temperature	°C	13.4	12.2
Sediment Composition[1]			
Sand	%	80	
Silt	%	17	
Clay	%	4	
Sand/Silt/Clay	%		3
Small gravel	%		39
Large gravel	%		30
Small cobble	%		13
Large cobble	%		10
Boulder	%		4
Bedrock	%		0

[1] Sediment composition for a given reach may not total 100% due to rounding.

Figure 5.8-5 Annual variation in periphyton chlorophyll *a* in the upper reach of the Firebag River (reach FIR-E-2).

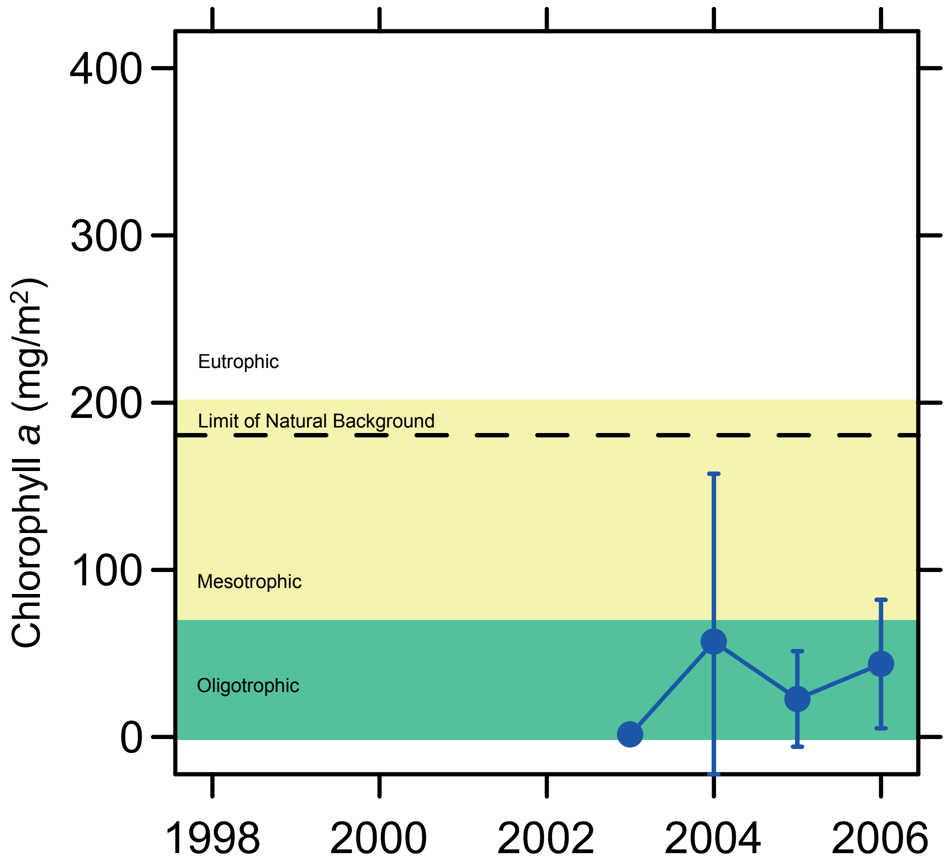
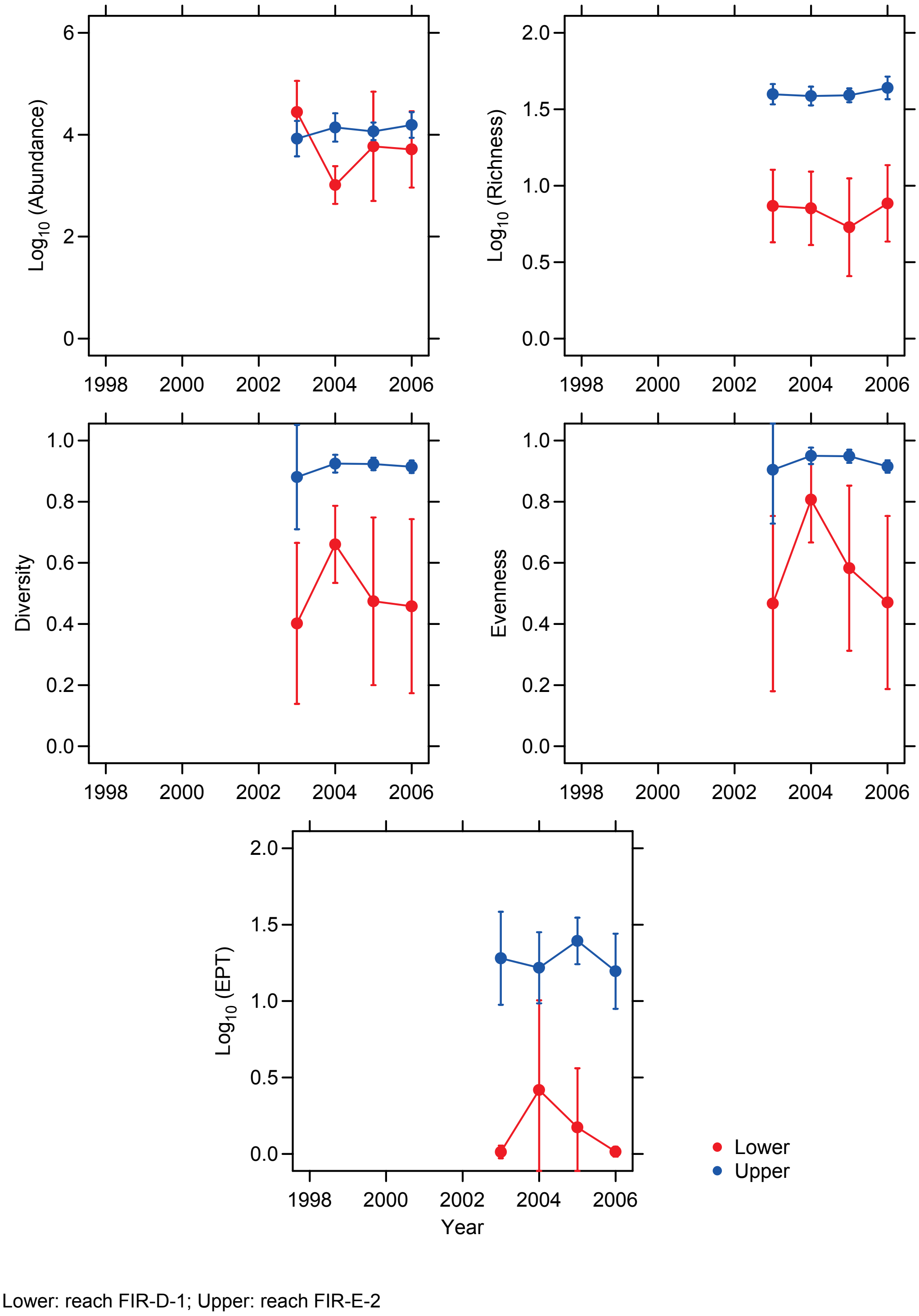


Table 5.8-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Firebag River.

Taxon	% Total Taxa Enumerated in Each Year							
	Reach FIR-D-1				Reach FIR-E-2			
	2003	2004	2005	2006	2003	2004	2005	2006
Amphipoda					<1	<1		
Anisoptera	<1		<1	1	<1	<1	<1	<1
Bivalvia		4	1	<1	3	3	2	<1
Ceratopogonidae	<1	2	1	<1		<1	<1	1
Chironomidae	96	33	36	52	63	48	35	65
Chydoridae						<1	<1	
Coleoptera					2	4	5	6
Collembola						<1	<1	
Copepoda					1	1	<1	
Empididae	<1	2						1
Enchytraeidae					1	<1	<1	<1
Ephemeroptera	<1	3			9	12	15	9
Ephydridae		3						
Erpobdellidae						<1		
Gastropoda			<1	<1	1	<1		<1
Glossiphoniidae					<1	<1	<1	
Heteroptera	1	<1			<1	<1		
Hydra					<1	<1		
Hydracarina		<1			5	1	11	6
Lumbriculidae		<1			<1			
Megaloptera						<1		
Naididae	1	1			2	5	4	6
Nematoda	<1	4	1	<1	2	4	3	2
Ostracoda		9		<1	<1	<1	<1	<1
Piscicolidae					<1			
Plecoptera	<1		<1		2	1	1	1
Simuliidae					<1	<1	<1	<1
Tabanidae	<1			<1	<1	<1	<1	1
Tipulidae		9	<1		1	<1	<1	1
Trichoptera			1	<1	5	7	1	8
Tubificidae	1	28	6	47	1	1	1	<1
Benthic Invertebrate Community Measurement Endpoints								
Total Abundance (No./m^2)	62,517	1,391	19,722	12,168	11,930	16,024	12,335	18,871
Richness	7	7	6	8	39	38	38	43
Simpson's Diversity	0.4	0.62	0.38	0.46	0.88	0.92	0.92	0.91
Evenness	0.47	0.81	0.67	0.47	0.9	0.95	0.95	0.91
% EPT	<1	5	1	<1	22	17	25	17

Figure 5.8-6 Annual variation in benthic invertebrate community measurement endpoints in the Firebag River, reach FIR-D-1 and reach FIR-E-2.



Lower: reach FIR-D-1; Upper: reach FIR-E-2

Table 5.8-8 Sediment quality measurement endpoints, lower reach near mouth of Firebag River (reach FIR-D-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station FIR-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5	3	<1	<1	6
Silt	%	-	2	3	<1	9	21
Sand	%	-	93	3	74	91	100
Total organic carbon	%	-	0.5	3	<0.1	0.8	2.2
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	14	1	-	-	32
Fraction 3 (C16-C34)	mg/kg	400[2]	140	1	-	-	330
Fraction 4 (C34-C50)	mg/kg	2800[2]	150	1	-	-	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0011	3	0.0010	0.0016	0.01
Retene	mg/kg	-	0.0606	3	0.0019	0.0349	0.125
Total dibenzothiophenes	mg/kg	-	0.16	3	0.02	0.39	0.70
Total PAHs	mg/kg	-	0.69	3	0.17	1.46	3.36
Total HMW PAHs	mg/kg	-	0.28	3	0.10	0.59	1.52
Total LMW PAHs	mg/kg	-	0.40	3	0.07	0.88	1.84
Predicted PAH toxicity[1]	H.I.	-	0.67	3	0.35	0.87	0.92
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	2	7	-	8
Chironomus growth - 10d	mg/organism	-	1.9	2	1.9	-	2.6
Hyalella survival - 14d	# surviving	-	9	1	-	-	5
Hyalella growth - 14d	mg/organism	-	0.2	1	-	-	0.06

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

5.9 ELLS RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions					
Climate and Hydrology						
	Assessment of Change					Total 2006 runoff volume was about 25% less than normal. All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of focal project activities. The estimated effect in the measurement endpoints are assessed as Negligible.
	Negligible	**Low**		**Moderate**	**High**	
Mean open-water season discharge	√					
Mean winter discharge	not measured					
Annual maximum daily discharge	√					
Minimum open-water season discharge	√					

Measurement Endpoint	Summary of 2006 Conditions		
Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**[1]		Water quality conditions in the Ells River in 2006 were similar to water quality conditions at these stations in previous years. All selected water quality measurement endpoints were at or between the 5th and 95th percentile of regional baseline observations in fall 2006. In fall 2006, total aluminum was the only water quality measurement endpoint with a measured concentration that exceeded water quality guidelines.
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Stations (n=0)**	**2006 *Reference* Stations (n=2)**	
Physical variables (max=2)	No water quality sampling stations were designated as *potentially influenced* in 2006.	0	
Nutrients (max=6)		0	
Ions (max=4)		0	
Selected metals (max=10)		2	
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**[2]		
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* (n=0 stations X 13 endpoints)**	**2006 *Reference* Stations (n=2 stations X 13 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced* in 2006.	0	
Between 5th and 95th percentiles		26	
Less than 5th percentile		0	

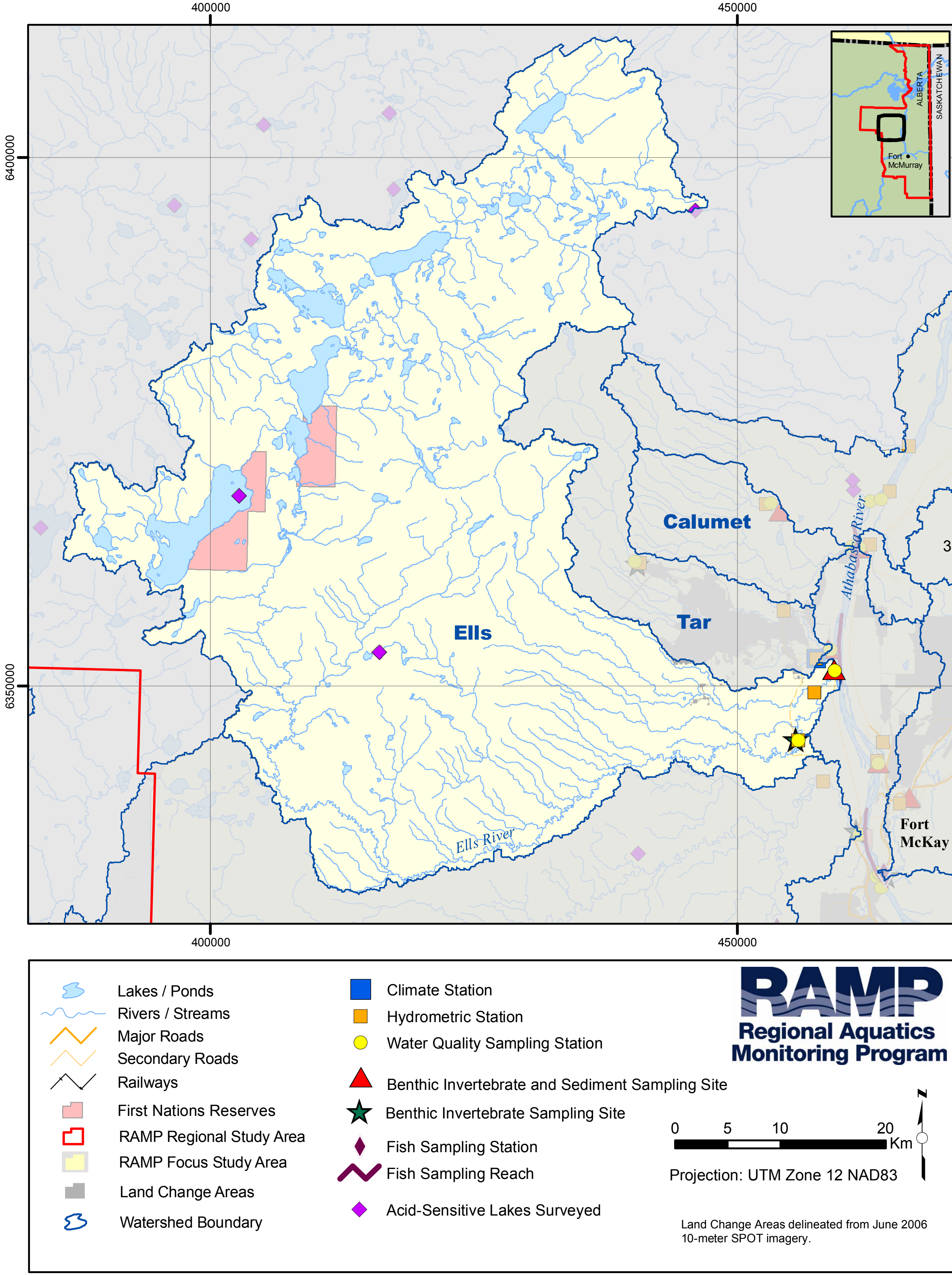
Measurement Endpoint	Summary of 2006 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**						Conditions in the two reaches sampled in fall 2006, one depositional and one erosional, were representative and typical of depositional and erosional reaches in the RAMP FSA. Values of all benthic invertebrate community measurement endpoints were similar in fall 2006 to values measured in previous years. Values of most sediment quality measurement endpoints were within the range of previously-measured values for the watershed with the exception of some sediment quality measurement endpoints related to chronic toxicity of sediments.
Values in Relation to Regional Baseline Mean	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=2)**			
	>2 SD below	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling locations were designated as *potentially influenced* in 2006.				2		
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		
Sediment Quality Guideline Exceedances	**Reach-Endpoint Combinations Exceeding Guidelines in 2006**						
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=1)**			
Total Hydrocarbons	No sediment quality sampling locations were designated as *potentially influenced* in 2006.				0		
PAHs					2		

Measurement Endpoint	Summary of 2006 Conditions
Fish Populations	
Fish Inventory	No fish inventory studies conducted in Ells River watershed in 2006.
Sentinel Studies	No sentinel fish studies conducted in Ells River watershed in 2006.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in Ells River watershed 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; dissolved phosphorous; total nitrogen; total strontium, total boron; naphthenic acids; calcium, magnesium, sodium, potassium, chloride, sulphate

Figure 5.9-1 Ells River watershed.



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5.9.1 Development Status

As of 2006, 0.07% of the area of the Ells River watershed had undergone land change from focal project activities (Table 2.6-2). Given this small land change area, all parts of the Ells River watershed are designated as *reference* for 2006. Therefore, all RAMP stations in the Ells River watershed in 2006 are designated as *reference* stations and all data gathered at these stations in 2006 are designated as baseline data.

5.9.2 Hydrologic Conditions

2006 Hydrologic Conditions Runoff volume in the Ells River basin, as measured at RAMP Station S14A, was 25% below average in 2006 (Figure 5.9-2), with a May to October runoff depth of 45 mm compared to the long-term average of 60 mm. The snowmelt runoff was relatively minor, peaking at 12.2 m^3/s. The highest flow measured during the year occurred in July in response to a rainfall event. Except for July and early August, discharges were below historical average values throughout the open-water season (Figure 5.9-2). The maximum daily discharge of 28.4 m^3/s was almost exactly equal to the mean annual flood, and the minimum open-water discharge of 2.30 m^3/s was significantly lower than the mean open-water minimum discharge of 3.53 m^3/s.

Estimation of Hydrologic Effects An assessment was made of the hydrologic effects of the existing land change area in the Ells River watershed even though the entire watershed is designated as *reference* for 2006. As indicated in Section 3.1.7.2, the methodology of the other RAMP components (with the exception of the Acid-Sensitive Lakes component), does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted even in watersheds whose entire area is designated as *reference*. A summary of the inputs to the water balance model for the Ells River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.9-1. As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) were 1.33 km^2 and 0.6 km^2, respectively. As a result of cumulative development of focal projects in the Ells River watershed (Table 2.6-1), the estimated net effects were to reduce inflows to the Ells River by 0.059 million m^3 in 2006.

The baseline hydrograph that would have occurred at RAMP Station S14, Ells River above Joslyn Creek in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have decreased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by 0.05%. The cumulative effect is that all hydrologic measurement endpoints for the Ells River watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.9-2, Table 5.9-2). These calculated incremental changes in the hydrologic measurement endpoints (-0.05%) would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic information as well as information available regarding focal project activities in the Ells River watershed, cumulative, watershed-level changes in hydrologic conditions in the Ells River caused by focal project activities in the watershed as of 2006 have been negligible.

5.9.3 Water Quality

In 2006, water quality samples were collected in spring, summer, and fall from:

- The mouth of the Ells River in the fall season (station ELR-1, *reference*, established in 1998, sampled every year since 2002); and
- Upstream Ells River in the spring, summer, and fall seasons (ELR-2, *reference*, established in 2000, sampled every year since 2004).

Water quality was sampled in the winter season from 2002 to 2005 at the lower Ells River (station ELR-1); the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration Concentrations of all water quality measurement endpoints in fall 2006 were within the range of previously observed concentrations at both stations (Table 5.9-3, Table 5.9-4) with the exception of sulphate at station ELR-1 and total nitrogen at station ELR-2 (slightly below the previously measured minimum), and pH and dissolved aluminum at ELR-2 (slightly above the previously measured maximum). Water quality was similar at both stations in fall 2006, with a notable decrease in naphthenic acids in 2006 relative to 2005 at station ELR-1.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines In fall 2006, total aluminum was the only water quality measurement endpoint with a measured concentration that exceeded water quality guidelines (Table 5.9-3, Table 5.9-4); total aluminum guideline exceedance was measured at both station ELR-1 and station ELR-2.

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the Ells River watershed in 2006 (Table 5.9-5):

- Sulphide, total phosphorus, total aluminum, total iron, total copper, and total phenols at upstream Ells River (station ELR-2) in spring 2006;
- Sulphide, total phosphorus, total aluminum, total cadmium, total copper, total iron, total lead, and total phenols at upstream Ells River (station ELR-2) in summer 2006; and
- Sulphide, total aluminum, and total iron at both the mouth of the Ells River (station ELR-1) and upstream Ells River (station ELR-2) in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of all selected water quality measurement endpoints were at or between the 5th and 95th percentile of regional baseline concentrations in fall 2006, although ion concentrations were within the lower end of the range of regional baseline concentrations (Figure 5.9-3).

Ion Balance Ion balance at both the mouth of the Ells River (station ELR-1) and upstream Ells River (station ELR-2) was similar in fall 2006 to previous years, and continues to be dominated by calcium bicarbonate (Figure 5.9-4).

Summary Water quality conditions in the Ells River, as measured at the mouth of the Ells River (station ELR-1) and upstream Ells River (station ELR-2) in 2006, were similar to water quality conditions at these stations in previous years.

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from:

- A depositional reach near the mouth of the Ells River (reach ELR-D-1, *reference*, sampled every year since 2003); and
- An erosional upstream reach of the Ells River (reach ELR-E-2, *reference*, sampled every year since 2003).

2006 Habitat Conditions The reach near the mouth of the Ells River (reach ELR-D-1) in fall 2006 was typical of depositional habitats in the RAMP FSA with fine-grained sediments, shallow water and high dissolved oxygen concentrations (Table 5.9-6). The upstream reach of the Ells River (reach ELR-E-2) was typical of erosional habitats in the RAMP FSA with substrate consisting of cobble and sand (Table 5.9-6). Periphyton chlorophyll *a* biomass in reach ELR-E-2 in fall 2006 (57 mg/m^2) is indicative of oligotrophic status for these waters, and is similar to what has been measured in previous years (Figure 5.9-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The reach near the mouth of the Ells River (reach ELR-D-1) was dominated in fall 2006 by chironomids (57%) and tubificid worms (29%), with ceratopogonids (sand flies), naidid worms, nematodes and empidids sub-dominant (Table 5.9-7). Mayflies (*Tricorythodes*) and stoneflies (*Taeniopteryx*) were present, but in low percent abundances, as were fingernail clams (*Pisidium* sp.).

The upstream reach of the Ells River (reach ELR-E-2) was dominated in fall 2006 by chironomids (46%), naidid worms (25%), and mayflies (13%), with Trichoptera being sub-dominant (3%) (Table 5.9-7). A number of taxa were present in very low percent abundances including stoneflies (principally *Isoperla* and *Pteronarcys*), ceratopogonids, snails and clams, etc. The mayfly fauna was dominated by *Acentrella*, *Baetis*, *Heptagenia* and *Tricorythodes*, while the stoneflies consisted principally of *Isoperla* and *Pteronarcys*. The chironomids were diverse, but were dominated by *Polypedilum*, *Rheotanytarsus*, *Tanytarsus* and *Tventenia*.

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions Benthic invertebrate community abundance, number of taxa and the various measures of diversity have been relatively consistent since the first benthic invertebrate survey of reaches ELR-D-1 and ELR-E-2 in 2003 to 2006 (Figure 5.9-6).

5.9.4.2 Sediment Quality

Sediment quality was sampled in reach ELR-D-1 in fall 2006, the reach where benthic invertebrate communities were sampled near the mouth of the Ells River.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is, therefore, no historical record of sediment quality at reach ELR-D-1. Therefore, data from the nearest sediment quality sampling location in the Ells River watershed prior to 2006 was used as the basis of comparison for 2006 results; this was sediment quality sampling station ELR-1. Comparison of 2006 results from reach ELR-D-1 with results from previous years at sediment sampling station ELR-1 is characterized by 2 to 5 years of data in the historical record, depending on the sediment quality measurement endpoint.

Sediments in the lower Ells River (reach ELR-D1) were dominated by sand, with a relatively small proportion of fines and low total organic carbon (Table 5.9-8). Concentrations of most sediment quality measurement endpoints in fall 2006 at reach ELR-D-1 were within historical ranges with the exception of some endpoints related to chronic toxicity of sediments (Table 5.9-8). While survival of *Chironomus tentans* was similar to previously observed results, growth of this organism was lower than previously observed, and both survival and growth of *Hyalella azteca* in 2006 were lower than historical values (Table 5.9-8).

Hydrocarbons were dominated by fraction 3 (C16-C34) and fraction 4 (C34-C50), with lower concentrations of fraction 2 (C10-C16) and non-detectable concentrations of fraction 1 and BTEX. The total PAH concentration was the highest observed in any reach in the RAMP FSA in fall 2006 (20.19 mg/kg), but was within the historical range previously measured in this reach. PAHs were dominated by low molecular weight species; dibenzothiophenes comprised over half of the low molecular weight fraction, indicating that a substantial proportion of PAHs in this system originate from a petrogenic source.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines The concentrations of both Fraction 2 (C10-C16) and Fraction 3 (C16-C34) hydrocarbons were above sediment quality guidelines at reach ELR-D-1 in fall 2006.

5.9.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats, and sediment quality measurement endpoints were generally within historical ranges.

5.9.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in the Ells River watershed.

5.9.6 Summary of Conditions

Conditions in the Ells River in 2006 were generally similar to previous years. Cumulative, watershed-level changes in hydrologic conditions caused by focal project activities in the Ells River watershed as of 2006 have been negligible. Water quality conditions were similar in 2006 to water quality conditions in previous years. Conditions in the two reaches at which benthic invertebrate communities were sampled in fall 2006, one depositional and one erosional, were representative and typical of depositional and erosional reaches in the RAMP FSA, and values of benthic invertebrate community measurement endpoints were generally consistent with values measured in previous years in the watershed. Values of most sediment quality measurement endpoints were within the range of previously-measured values for the watershed.

Figure 5.9-2 Ells River: 2006 hydrograph and historical context.

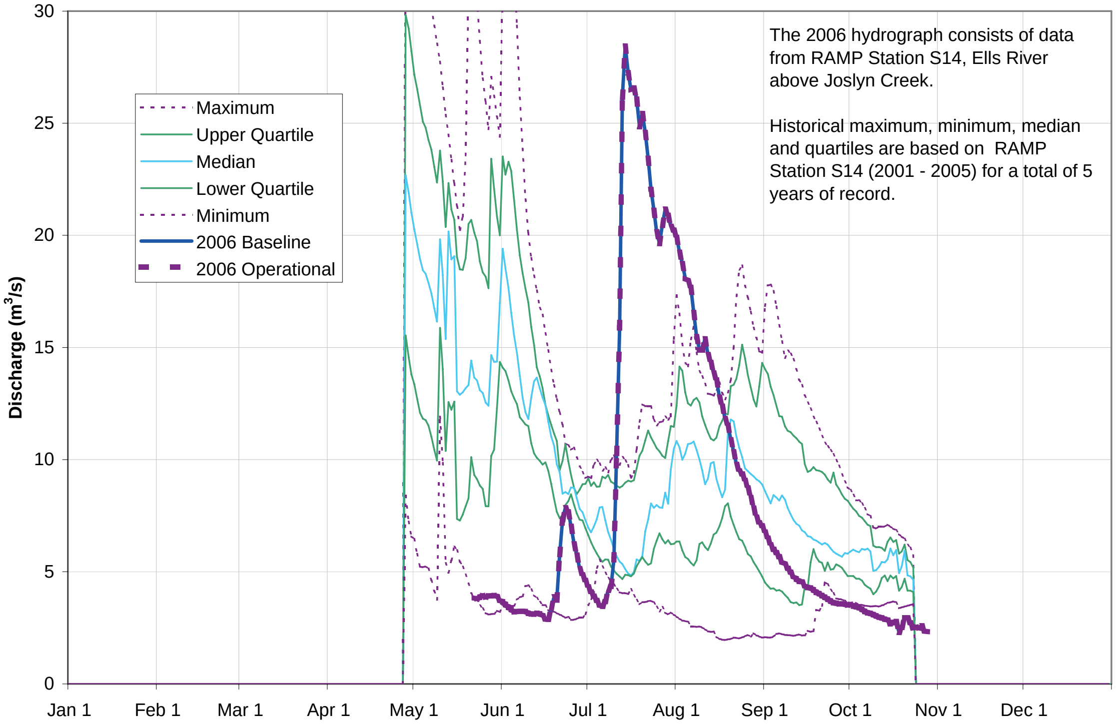


Table 5.9-1 Summary of inputs to the calculation of the Ells River baseline hydrograph at RAMP Station S14, Ells River above Joslyn Creek.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	112	Observed daily discharges obtained from RAMP Station S14, Ells River above Joslyn Creek
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.065	1.33 km^2 within Ells River drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.0055	0.60 km^2 within Ells River drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Ells River for focal project activities	0	Unknown and assumed to be negligible
Releases to Ells River for focal project activities	0	Unknown and assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Ells River not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	112	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total annual discharge)	- 0.059	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.053%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.9-2 Calculated change in hydrologic measurement endpoints for the Ells River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	8.08	8.07	-0.05%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	28.5	28.4	-0.05%
Open-water season minimum daily discharge	2.30	2.30	-0.05%

Note: As measured at and calculated for RAMP Station S14, Ells River above Joslyn Creek.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.9-3 Concentrations of water quality measurement endpoints, mouth of Ells River (ELR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	5	7.8	8.2	8.4
Total suspended solids	mg/L	-[1]	6	5	5	7	16
Conductivity	µS/cm	-	187	5	175	236	258
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.008	5	0.003	0.008	0.020
Total nitrogen*	mg/L	1.0	0.6	5	0.3	0.6	0.9
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	5	11	12	15
Ions							
Sodium	mg/L	-	8	5	8	12	18
Calcium	mg/L	-	22.8	5	21.6	25.1	30.4
Magnesium	mg/L	-	6.7	5	6.5	7.8	9.1
Chloride	mg/L	230, 860[3]	2	5	<1	2	4
Sulphate	mg/L	100[4]	10.5	5	12.3	17.7	27.9
Total dissolved solids	mg/L	-	134	5	110	160	220
Total alkalinity	mg/L	-	86	5	76	97	111
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	3
Selected metals							
Total aluminum	mg/L	0.1	**0.195**	5	0.060	**0.324**	**0.673**
Dissolved aluminum	mg/L	0.1[2]	0.0139	5	0.0077	0.0171	0.078
Total boron	mg/L	1.2[5]	0.0472	5	0.0410	0.0649	0.0784
Total molybdenum	mg/L	0.073	0.00077	5	0.00064	0.00071	0.00084
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.105	5	0.095	0.124	0.136

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

Table 5.9-4 Concentrations of water quality measurement endpoints, upper Ells River (ELR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	2	7.7	-	7.8
Total suspended solids	mg/L	-[1]	4	2	<3.0	-	4
Conductivity	µS/cm	-	185	2	164	-	195
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.009	2	0.004	-	0.017
Total nitrogen*	mg/L	1.0	0.6	2	0.7	-	0.8
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	13	2	10	-	16
Ions							
Sodium	mg/L	-	8	2	6	-	13
Calcium	mg/L	-	22.3	2	20.5	-	24.8
Magnesium	mg/L	-	6.9	2	6.2	-	7.2
Chloride	mg/L	230, 860[3]	2	2	2	-	3
Sulphate	mg/L	100[4]	10.8	2	10.8	-	18.9
Total dissolved solids	mg/L	-	130	2	110	-	190
Total alkalinity	mg/L	-	84	2	73	-	110
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	**0.271**	2	0.052	-	**0.735**
Dissolved aluminum	mg/L	0.1[2]	0.0153	2	<0.0002	-	0.0133
Total boron	mg/L	1.2[5]	0.0457	2	0.0405	-	0.0836
Total molybdenum	mg/L	0.073	0.00074	2	0.00065	-	0.00082
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.102	2	0.094	-	0.110

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.9-5 Water quality guideline exceedances, Ells River watershed, 2006.

Variable	Units	Guideline*	ELR-1	ELR-2
Spring				
Sulphide	mg/L	0.002[1]	ns	**0.008**
Total phosphorus	mg/L	0.05	ns	**0.051**
Total aluminum	mg/L	0.1	ns	**2.86**
Total iron	mg/L	0.3	ns	**1.97**
Total copper	mg/L	-[2]	ns	**0.00216**
Total phenols	mg/L	0.004	ns	**0.005**
Summer				
Sulphide	mg/L	0.002[1]	ns	**0.011**
Total phosphorus	mg/L	0.05	ns	**0.104**
Total aluminum	mg/L	0.1	ns	**3.4**
Total cadmium	mg/L	-[2]	ns	**0.000030**
Total copper	mg/L	-[2]	ns	**0.0033**
Total iron	mg/L	0.3	ns	**4.03**
Total lead	mg/L	-[2]	ns	**0.0021**
Total phenols	mg/L	0.004	ns	**0.011**
Fall				
Sulphide	mg/L	0.002[1]	**0.005**	**0.004**
Total aluminum	mg/L	0.1	**0.195**	**0.271**
Total iron	mg/L	0.3	**0.498**	**0.48**

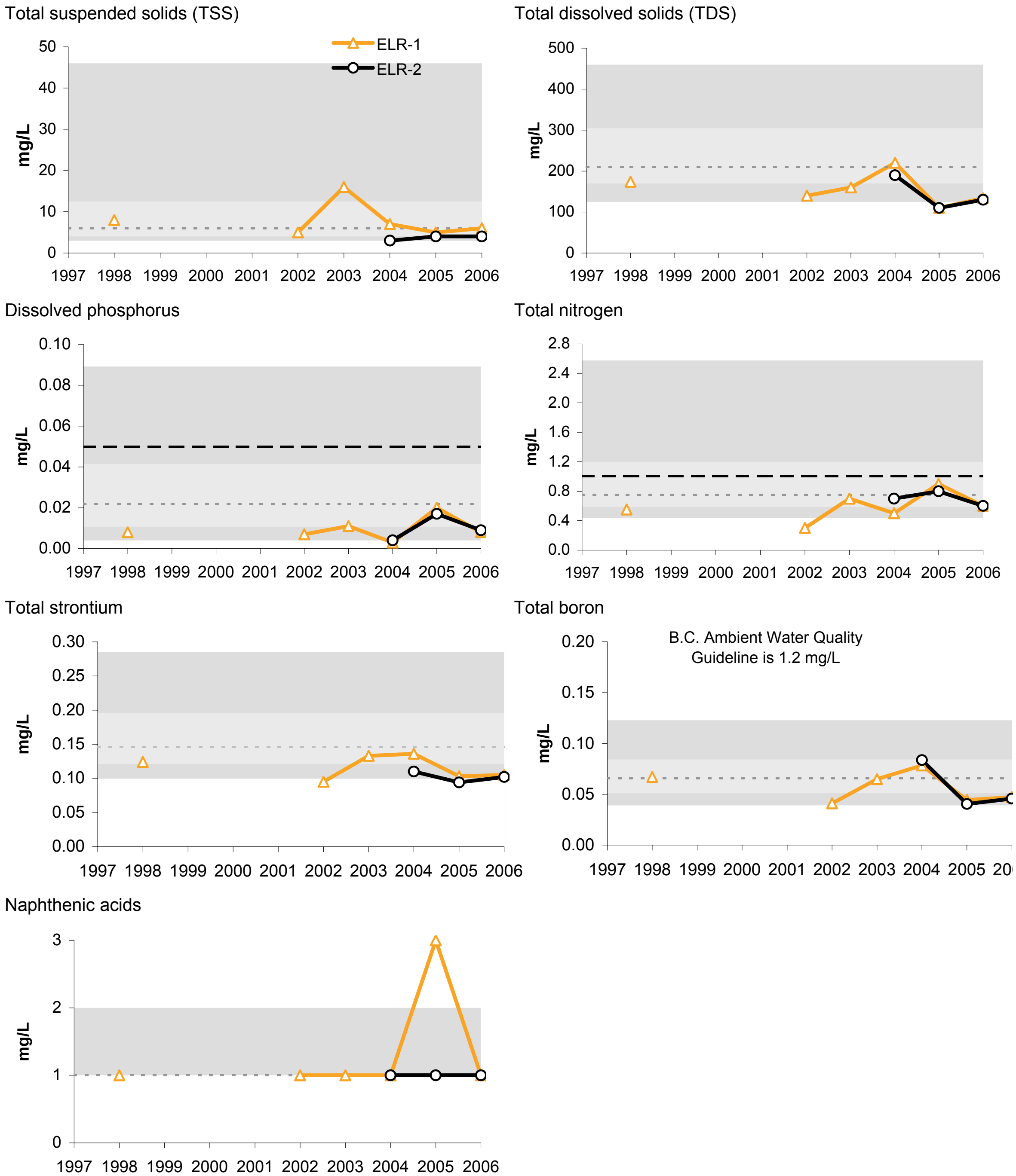
ELR-1 sampled only in fall 2006. No winter sampling was conducted in this watershed.

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S.

[2] Guideline is hardness-dependent.

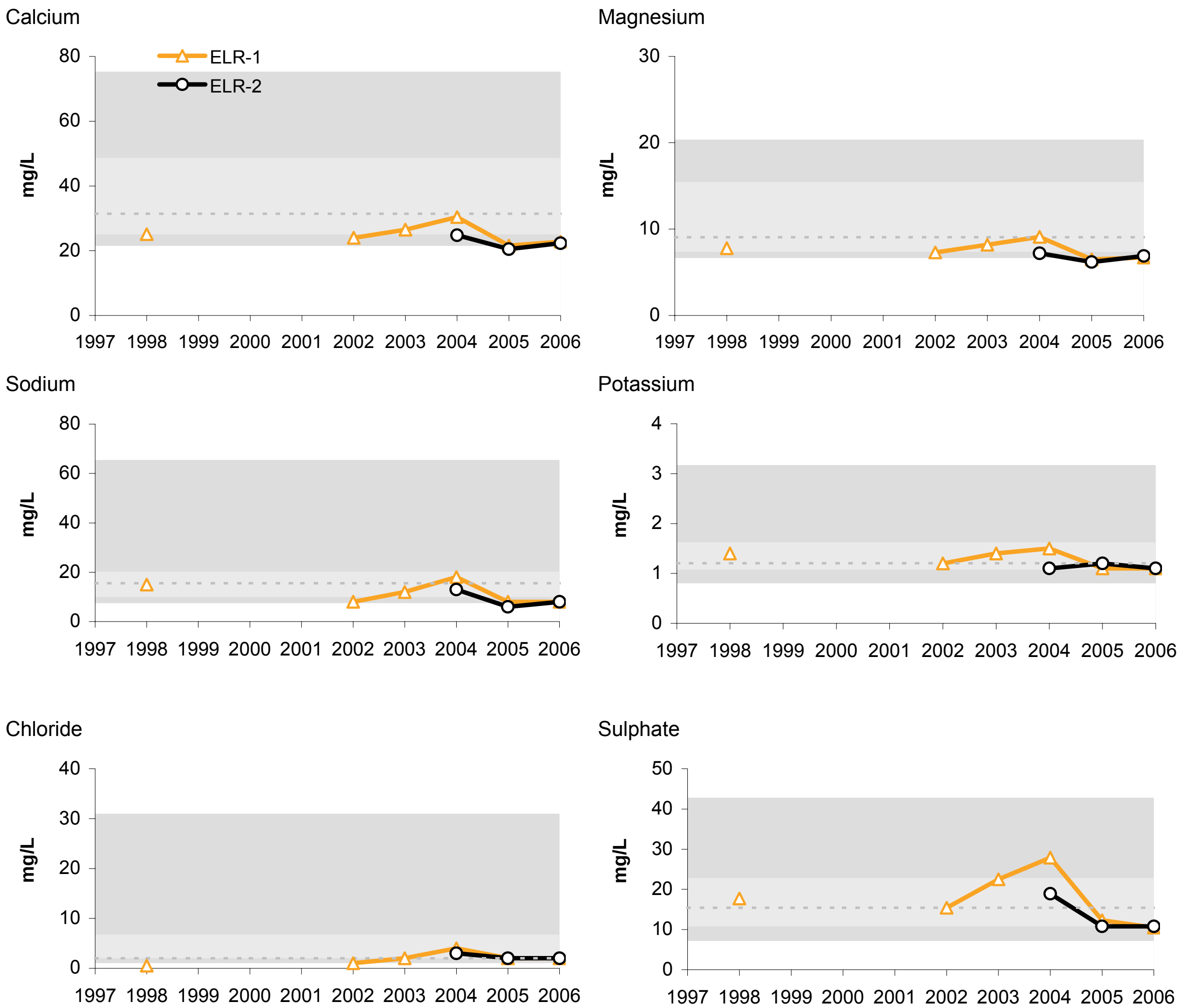
Figure 5.9-3 Selected water quality measurement endpoints in the Ells River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.9-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.9-4 Piper diagram of fall ion concentrations in the Ells River watershed.

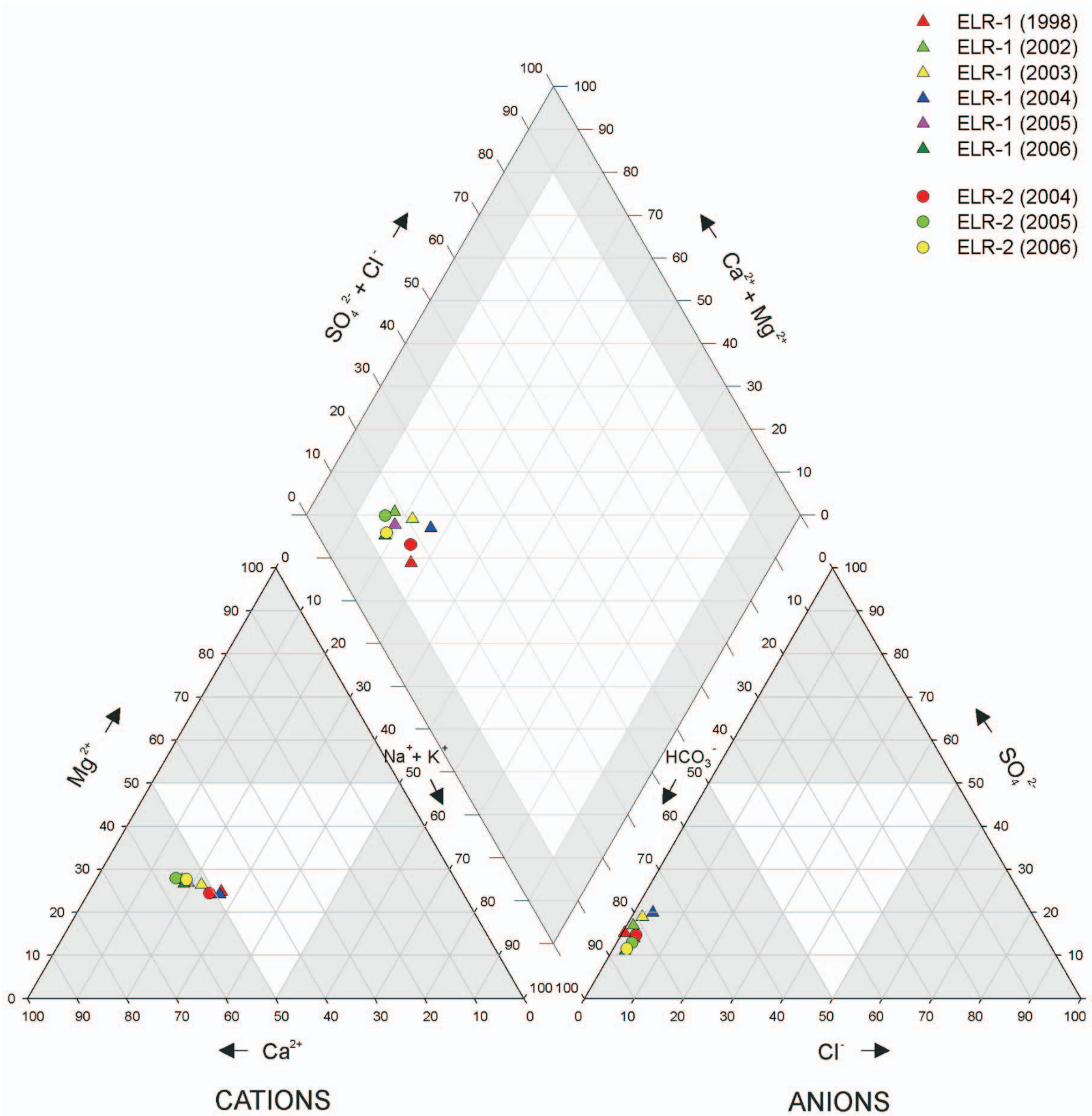


Table 5.9-6 Average habitat characteristics of benthic invertebrate sampling reaches in the Ells River, fall 2006.

Variable	Units	Lower Reach of the Ells River (reach ELR-D-1)	Upper Reach of the Ells River (Reach ELR-E-2)
Sample date	-	Sept 13, 2006	Sept 16, 2006
Habitat	-	Depositional	Erosional
Water depth	m	0.3	0.22
Current velocity	m/s	0.6	0.9
Macrophyte cover	%	0	0
Benthic algae	mg/m^2	n/a	68.9
Sand/Silt/Clay	%	100	10
Field Water Quality			
Dissolved oxygen	mg/L	9.6	11.2
Conductivity	µS/cm	189	186
pH	pH units	7.6	7.9
Water temperature	°C	12.9	7.7
Sediment Composition			
Sand	%	76	
Silt	%	16	
Clay	%	8	
Sand/Silt/Clay	%		2
Small gravel	%		7
Large gravel	%		2
Small cobble	%		49
Large cobble	%		40
Boulder	%		0
Bedrock	%		0

Figure 5.9-5 Annual variation in periphyton chlorophyll *a* in the upper reach of the Ells River (reach ELR-E-2).

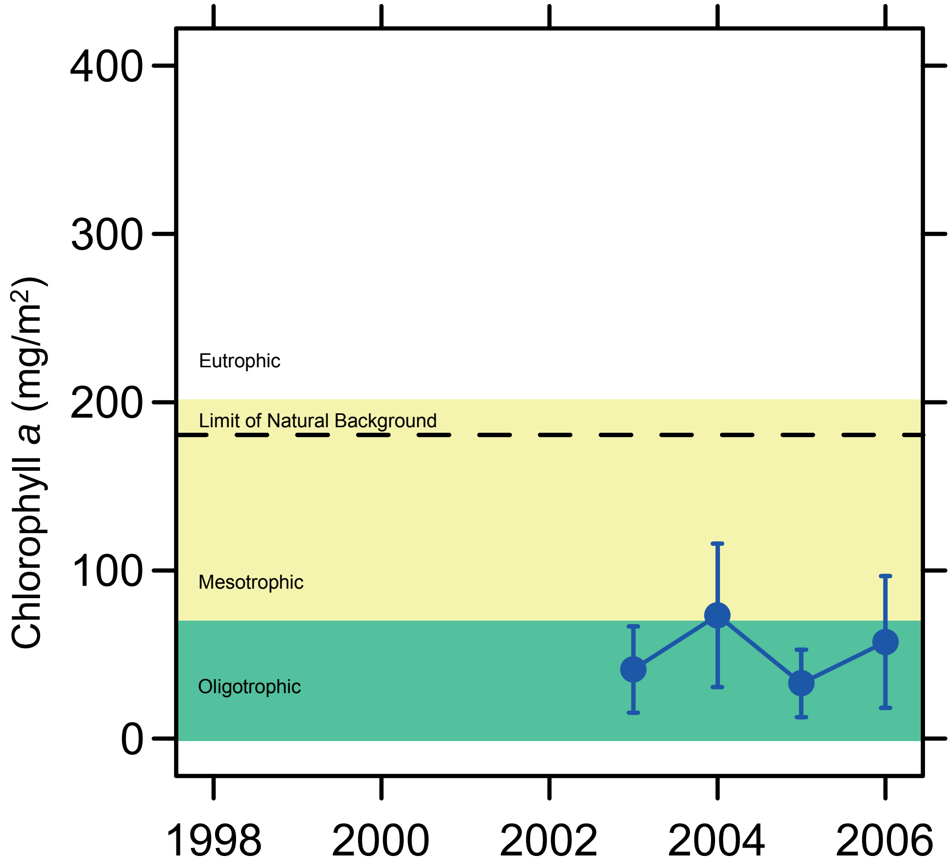
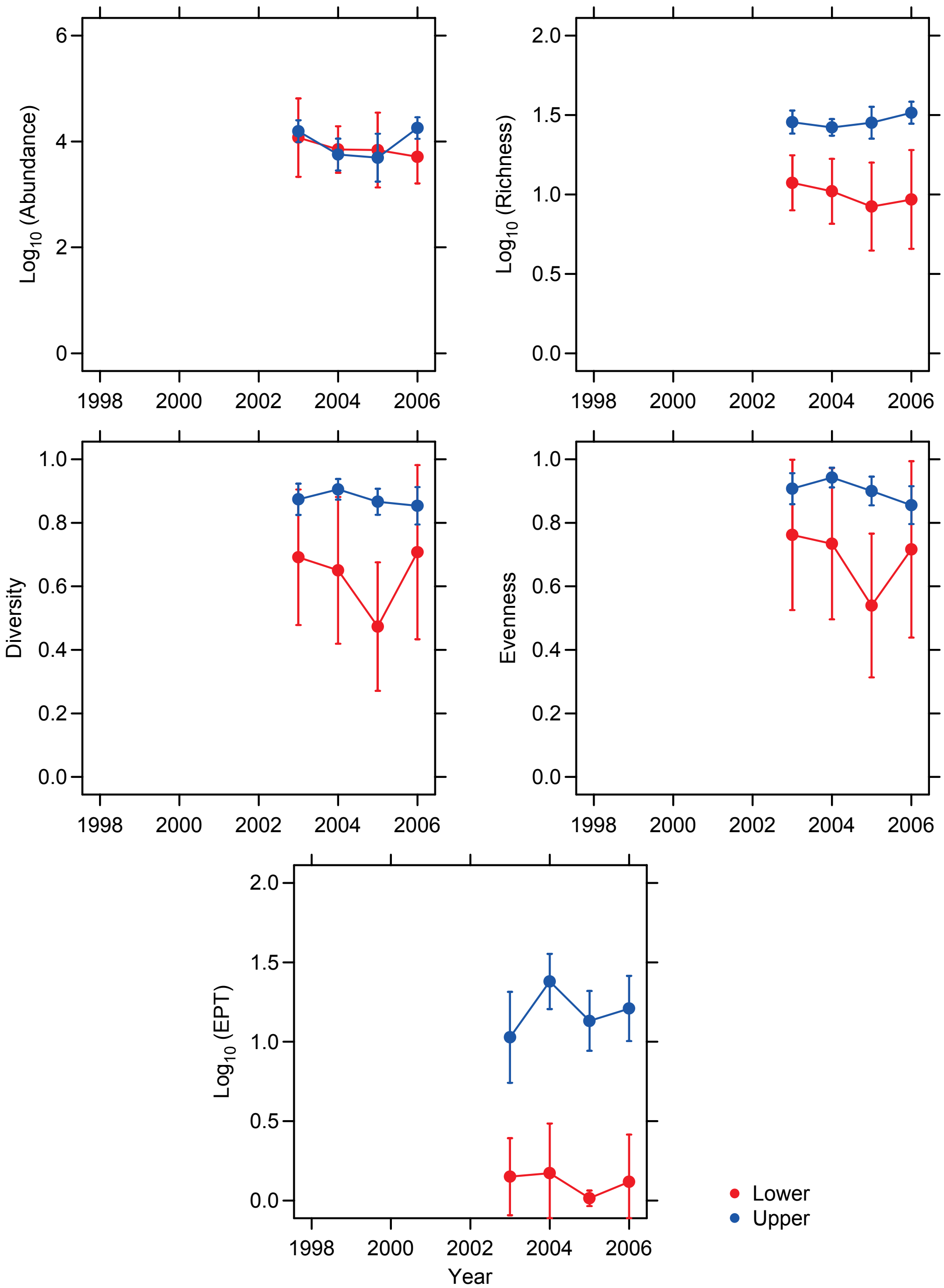


Table 5.9-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Ells River, fall 2006.

Taxon	% Total Taxa Enumerated in Each Year							
	Lower Reach (ELR-D-1)				Upper Reach (ELR-E-2)			
	2003	2004	2005	2006	2003	2004	2005	2006
Anisoptera	<1	<1	<1	<1	<1	2	<1	<1
Bivalvia	<1	<1		<1	<1	1	<1	<1
Ceratopogonidae	3	5	1	5	1	2	<1	2
Chironomidae	19	32	17	57	6	49	35	46
Coleoptera		<1		<1		<1	<1	<1
Copepoda	<1					<1		2
Empididae	<1	<1	<1	2	2	3	1	2
Enchytraeidae		<1			1	1	<1	<1
Ephemeroptera	<1	<1	<1	1	7	15	7	1
Gastropoda	<1	<1			1	<1	<1	<1
Heteroptera	<1							
Hydracarina	<1	<1		1	11	8	19	12
Lepidoptera								
Megaloptera								
Naididae	24	2	17	4	13	5	28	21
Nematoda	<1	2	<1	3	1	4	<1	2
Ostracoda		<1	5		<1	<1	<1	1.0
Plecoptera				0.3	1	6	3	<1
Simuliidae			2		<1	<1	1	1
Tabanidae	<1	1	<1	<1	<1		<1	
Tipulidae		<1			<1		<1	0.1
Trichoptera	<1	<1			2	4	2	3
Tubificidae	52	55	57	29	<1	<1	1	1
Zygoptera		<1						0.2
Benthic Invertebrate Community Measurement Endpoints								
Total Abundance (No./m^2)	30,917	11,129	12,939	8,517	17,207	6,779	7,592	19,659
Richness	12	10	9	10	28	26	28	32
Simpson's Diversity	0.69	0.65	0.47	0.71	0.87	0.91	0.87	0.85
Evenness	0.76	0.73	0.64	0.72	0.91	0.94	0.9	0.86
% EPT	1	1	<1	<1	12	24	14	17

Figure 5.9-6 Annual variation in benthic invertebrate community measurement endpoints in the lower Ells River (reach ELR-D-1) and upstream Ells River (reach ELR-E2-2).



Lower: reach ELR-D-1; Upper: reach ELR-E-2

Table 5.9-8 Sediment quality measurement endpoints, lower reach of Ells River near the mouth (reach ELR-D-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station ELR-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6	5	5	7	26
Silt	%	-	9	5	8	14	51
Sand	%	-	85	5	23	81	85
Total organic carbon	%	-	0.7	5	0.7	1.7	2.8
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	**310**	2	150	-	**320**
Fraction 3 (C16-C34)	mg/kg	400[2]	**2300**	2	1500	-	**3000**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1300	2	790	-	1600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0022	5	<0.0061	0.00356	0.00939
Retene	mg/kg	-	0.265	4	0.067	0.201	0.293
Total dibenzothiophenes	mg/kg	-	8.57	5	1.28	5.43	9.88
Total PAHs	mg/kg	-	20.19	5	4.81	16.16	25.10
Total HMW PAHs	mg/kg	-	4.23	5	0.40	4.26	5.46
Total LMW PAHs	mg/kg	-	15.95	5	4.20	11.86	19.63
Predicted PAH toxicity[1]	H.I.	-	1.51	5	1.18	1.53	2.87
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	2	5	-	7
Chironomus growth - 10d	mg/organism	-	0.7	2	2.1	-	2.8
Hyalella survival - 14d	# surviving	-	8	2	9	-	10
Hyalella growth - 14d	mg/organism	-	0.1	2	0.13	-	1.6

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

5.10 CLEARWATER-CHRISTINA RIVER SYSTEM

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	Open-water season runoff in 2006 was very close to normal in the Clearwater River basin as a whole at 79 mm, but 25% above average in the Christina River catchment.
Mean open-water season discharge	The absence of a hydrometric station at the mouth of either the Clearwater or Christina rivers makes it not possible to calculate hydrologic effects of focal projects in those watersheds.				
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Measurement Endpoint	Summary of 2006 Conditions		
Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**[1]		Water quality conditions in the Clearwater and Christina Rivers, as measured at stations CLR-1, CLR-2, CHR-1, and CHR-2 in fall 2006, were similar to water quality conditions in previous years.
Measurement endpoints with guidelines	**2006 Potentially Influenced Stations (n=0)**	**2006 Reference Stations (n=4)**	
Physical variables (max=4)	No water quality sampling stations were designated as *potentially influenced* in 2006.	0	
Nutrients (max=12)		4	
Ions (max=8)		0	
Selected metals (max=20)		4	
Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**[2]		
Percentile of Regional Baseline Values	**2006 *Potentially Influenced* Stations (n=0 stations X 13 endpoints)**	**2005 Reference Stations (n=4 stations X 13 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced* in 2006.	0	
Between 5th and 95th percentiles		49	
Less than 5th percentile		3	

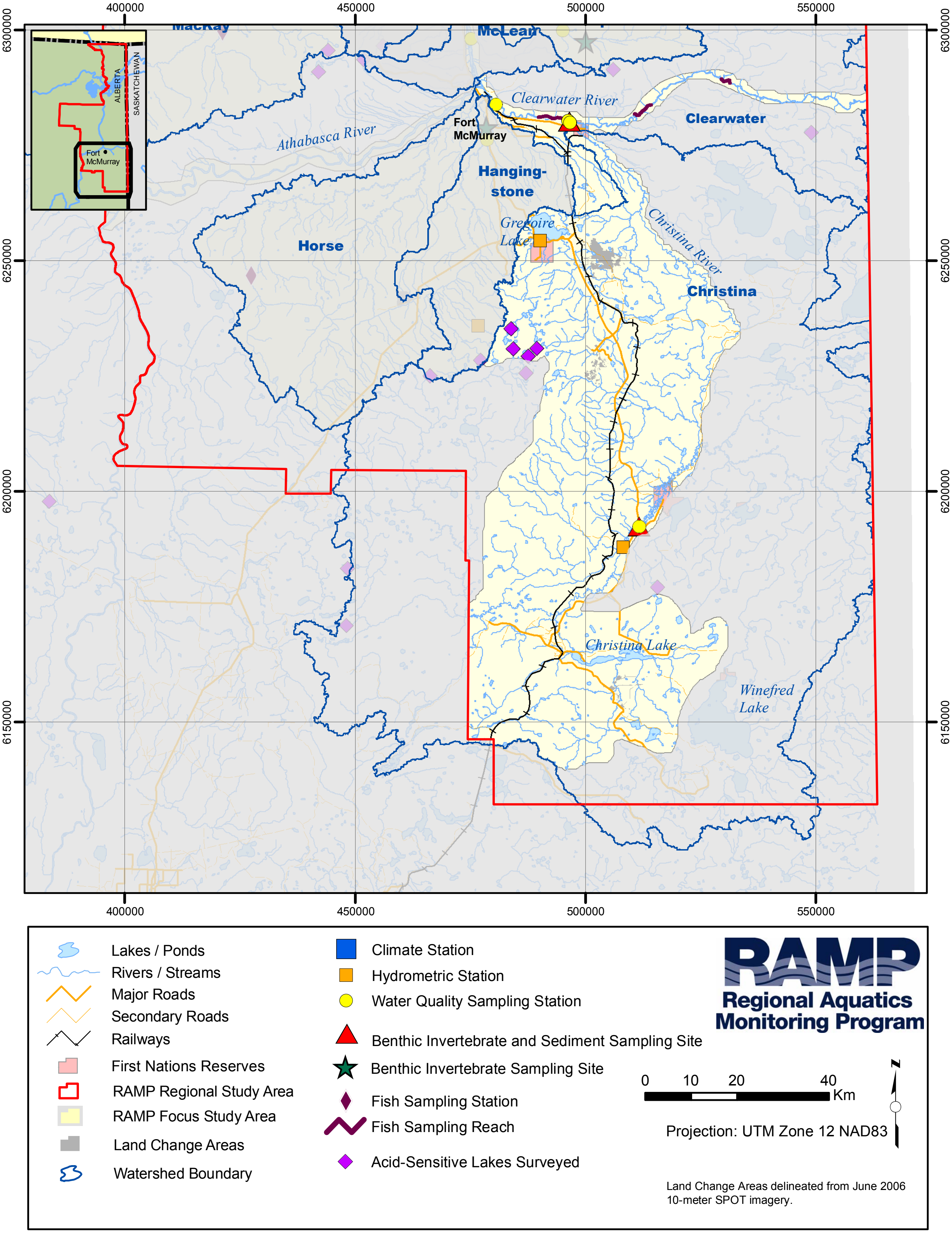
Measurement Endpoint	Summary of 2006 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2006 Compared to Regional Baseline**						Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats in the Christina River watershed, and most PAH sediment quality measurement endpoints were below previously-measured minimum concentrations. All sediment quality measurement endpoints were below sediment quality guidelines.
Values in Relation to Regional Baseline Mean	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=2)**			
	>2 SD below	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced* in 2006.				2		
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2006**						
Measurement endpoints with guidelines	**2006 *Potentially Influenced* Sites (n=0)**			**2006 *Reference* Sites (n=1)**			
Total Hydrocarbons	No sediment quality sampling locations were designated as *potentially influenced* in 2006.				0		
PAHs					0		

Measurement Endpoint	Summary of 2006 Conditions	
Fish Populations		
Fish Inventory	2006 results were generally similar to recent results with respect to length-frequency indicators, condition, external health.	Current and historical fish inventory data from the Clearwater River indicate some level of species-specific variability in relative abundance, length-frequency distribution, and condition factor. Although mercury concentrations in Clearwater River northern pike tissues exceeded some guidelines, comparison with historical regional data indicates these concentrations fall within natural range of concentrations.
Sentinel Studies	No sentinel fish studies conducted in 2005.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence Fishers	Overall mean mercury concentration in northern pike exceeded criteria for subsistence fishers. Arsenic concentrations for northern pike exceeded screening criteria for subsistence fishers.	
Human Health: Recreational Fishers	None of the sampled northern pike exceeded mercury criteria for recreational fishers. Arsenic concentrations for northern pike exceeded screening criteria for recreational fishers.	
Human Health: Subsistence Consumers	One sampled northern pike exceeded mercury criteria for subsistence consumers.	
Human Health: General Consumers	None of the sampled northern pike exceeded mercury criteria for general consumers.	
Human Health: Tainting	All tainting compounds in fish tissue were present at concentrations well below 1 mg/kg.	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.10-1 Clearwater-Christina River watershed.



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5.10.1 Development Status

As of 2006, less than 1% of the Christina River watershed had undergone land change as a result of focal project activities (Table 2.6-2). In addition, none of the part of the Clearwater River basin that is in the RAMP FSA contains any active focal project activities. Therefore, all RAMP stations in the Christina-Clearwater River watersheds in 2006 are designated as *reference* stations and all data gathered at these stations in 2006 are designated as baseline data.

5.10.2 Hydrologic Conditions

2006 Hydrologic Conditions Open-water season runoff in 2006 was very close to normal in the Clearwater River basin as a whole at 79 mm, but 25% above average in the Christina River catchment, where the runoff depth was 94 mm. The May-October runoff depth in the Clearwater River basin was 123 mm, 38% above average. The Christina River basin was even wetter, with a May – October runoff depth of 137 mm, nearly double its long-term average of 70 mm.

The snowmelt runoff peak in mid-April was approximately equaled by a second peak discharge that occurred in late May (Figure 5.10-2). The May peak of 276 m^3/s was 25% lower than the mean annual flood. The minimum open-water discharge on the Clearwater River was 56.4 m^3/s compared to the mean annual minimum discharge of 46.4 m^3/s.

In the Christina River basin, the highest discharge of the year occurred in late May in response to rainfall, and the snowmelt peak was the second highest event of the year (Figure 5.10-3). The May maximum daily discharge of 63.5 m^3/s was 18% lower than the mean annual flood. The minimum open-water season discharge was 9.83 m^3/s, 54% higher than average.

Estimation of Hydrologic Effects An assessment was made of the hydrologic effects of the existing land change area in the Christina River watershed even though the entire watershed is designated as *reference* for 2006. As indicated in Section 3.1.7.2, the methodology of the hydrologic assessment, unlike the methodology of the other RAMP components (with the exception of the Acid-Sensitive Lakes component), does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted even in watersheds whose entire area is designated as *reference*. However, there is no hydrometric station at the mouth of the Christina River and it is, therefore, not possible to estimate changes in hydrologic measurement endpoints as a result of the effects of focal projects in the watershed. However, it is possible to estimate the overall changes in discharge from focal project activities; these were used in the calculation of hydrologic effects in the Athabasca River (Section 5.1.2) and are therefore reported in detail here.

Changes in discharge in 2006 in the Christina River were estimated for two cases. The first case considered only 2006 focal projects; that is, those projects owned by 2006 RAMP funders which were under construction or operational in 2006 in the Christina River watershed. The second case considered all 2006 focal projects plus oil sands projects in the Christina River watershed that were under construction or operation in 2006, but were not owned by 2006 RAMP funders. This latter case can be considered a type of cumulative assessment of hydrologic effects of all significant oil sands activities in the Christina River watershed as of 2006.

The results of the two cases are presented in Table 5.10-1. In the first case, focal projects only, it is estimated that a baseline hydrograph for 2006 for the Christina River would have 1.00 million m^3 more flow than a 2006 operational hydrograph; this is equivalent to 0.075 mm of additional runoff depth for the entire Christina River watershed. In the second case, focal projects plus all active oil sands projects in the Christina River watershed, it is estimated that a baseline hydrograph for 2006 for the Christina River would have 1.66 million m^3 more flow than a 2006 operational hydrograph; this is equivalent to 0.128 mm of additional runoff depth for the entire Christina River watershed.

5.10.3 Water Quality

In 2006, water quality samples were collected from the following stations:

- The Clearwater River upstream of Fort McMurray in all four seasons (station CLR-1, *reference*, baseline data available from 2001);
- The Clearwater River upstream of the Christina River confluence in the fall season (station CLR-2, *reference*, baseline data available from 2001);
- The Christina River at the mouth in the fall season (station CHR-1, *reference*, baseline data available from 2002); and
- The Christina River upstream of Janvier in the fall season (station CHR-2, *reference*, baseline data available from 2002).

Water quality was sampled in the winter from 2001 to 2006 at station CLR-1, from 2001 to 2005 at station CLR-2, and from 2002 to 2005 at stations CHR-1 and CHR-2; the results of the winter water quality analyses are presented in Appendix D.

2006 Results and Historical Ranges of Concentration On the Clearwater River in fall 2006, concentrations of all water quality measurement endpoints were within historically measured values (Table 5.10-2, Table 5.10-3), with the exception of sulphate at both station CLR-1 and station CLR-2, which was below the previously-measured minimum concentration, and dissolved phosphorus at station CLR-2, which was above the previously-measured maximum concentration.

At the Christina River mouth in the fall season (station CHR-1), concentrations of all water quality measurement endpoints were within the range of previously-measured concentrations with the exceptions of sulphate, which was lower than the previously measured minimum concentration and dissolved phosphorus, mercury, and total and dissolved aluminum, all of which were above their previously measured maximum concentrations (Table 5.10-4). There were many water quality measurement endpoints at station CHR-2 in fall 2006 that were measured to be outside historical ranges of concentration. Concentrations of naphthenic acids and total aluminum were both above their previously measured maximum concentrations, while concentrations of total suspended solids, conductivity, dissolved organic carbon, sodium, calcium, sulphate, alkalinity, and total molybdenum were all below their previously measured minimum concentrations (Table 5.10-5).

Concentrations of several measurement endpoints differed notably between CHR-1 and CHR-2 (Table 5.10-5). Both total suspended solids and total dissolved solids were higher at CHR-1 than at CHR-2, while dissolved phosphorus was higher at CHR-2. While concentrations of calcium and magnesium were similar, concentrations of sodium and chloride were substantially lower at CHR-2.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint whose concentration in fall 2006 exceeded water quality guidelines (Table 5.10-2 to Table 5.10-5), and this occurred at all four stations (station CLR-1, station CLR-2, station CHR-1, and station CHR-2).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded in the Clearwater and Christina Rivers in 2006 (Table 5.10-6):

- Total iron at station CLR-1 in winter, spring, and summer and at all stations in the fall season;
- Sulphide and total phosphorus at station CLR-1 in spring and summer and at all stations in the fall season;
- Chromium at station CLR-1 in spring and summer and at station CHR-1 in the fall season; and
- Total phenols at all stations in the fall season.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of all water quality measurement endpoints at all four stations in fall 2006, with the exception of calcium, magnesium, and sulphate at station CLR-2, were at or within regional baseline 5th and 95th percentile concentrations.

Ion Balance The ionic composition of water samples collected in fall 2006 was similar to previous years for all stations (Figure 5.10-5). At CHR-1, CLR-1 and CLR-2, slightly lower sulphate concentrations occurred in 2006 than in previous years. Relative ion concentrations at the upper Christina River station (CHR-2) differ from the other stations, with higher concentrations of calcium and magnesium and lower concentrations of chloride.

Summary Water quality conditions in the Clearwater and Christina Rivers, as measured at stations CLR-1, CLR-2, CHR-1, and CHR-2 in fall 2006, were similar to water quality conditions in previous years.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from:

- A depositional lower reach on the Christina River located near the mouth (reach CHR-D-1, *reference*, baseline data from 2002); and
- A depositional upstream reach of the Christina River, upstream of Janvier (reach CHR-D-2, *reference*, baseline data from 2002).

2006 Habitat Conditions Substrate in reach CHR-D-1 consisted of a mixture of coarse materials including boulders and cobble, intermixed with fine-grained sands. Water depths in reach CHR-D-1 averaged about 0.2 m, and water velocities were slow (~ 0.1 m/s) (Table 5.10-7). Macrophytes were present, but covered a small amount of the river bottom. The substrate in the reach CHR-D-2 was more typically fine-grained dominated and by sand with some small gravel. Water depth averaged 0.4 m, and velocities were higher (0.4 m/s) than reach CHR-D-1 (Table 5.10-7).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The lower reach on the Christina River located near the mouth (reach CHR-D-1) was dominated by chironomids (70%), principally *Chironomus*, *Cryptochironomus*, *Paralauterbourniella* and *Polypedilum* (Table 5.10-8). All of those taxa are relatively common, while *Chironomus* tends to be highly tolerant of degraded conditions, and numerous in the presence of degraded habitat quality. Other more sensitive organisms were present including stoneflies (*Taeniopteryx*), mayflies (*Ephemerella*) and caddisflies (*Brachycentrus*, *Hydropsyche*), as well as a variety of dipteran flies, clams and snails. Both taxa richness (14) and diversity (0.77) were somewhat higher in 2006 relative to previous years (Table 5.10-8).

The upstream reach of the Christina River, upstream of Janvier (reach CHR-D-2) was dominated by chironomids, principally Paracladopelma, Robackia and Lopesocladius (Table 5.10-8). Caddisflies and tubificid worms were sub-dominant, with *Brachycentrus* being an important caddis. Mayflies were present in low percent abundances, as were fingernail clams (Bivalvia).

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions There have been no unusual trends in values of benthic invertebrate community measurement endpoints at either reach CHR-D-1 or CHR-D-2 since 2002 (Figure 5.10-6).

5.10.4.2 Sediment Quality

Sediment quality was sampled in fall 2006 in reach CHR-D-1, the depositional reach where benthic invertebrate communities were sampled near the mouth of the Christina River and in reach CHR-D-2, the depositional reach where benthic invertebrate communities were sampled upstream on the Christina River.

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is, therefore, no historical record of sediment quality at either reach CHR-D-1 or CHR-D-2. Therefore, data from the nearest sediment quality sampling locations in the Christina River watershed prior to 2006 was used as the basis of comparison for 2006 results; this was sediment quality sampling station CHR-1 for reach CHR-D-1 and sediment quality sampling station CHR-2 for reach CHR-D-2. Comparison of reaches sampled in 2006 with results from previous years at sediment-sampling stations is characterized by small sample sizes of the historical record (n = 1 to 3 depending on the sediment quality measurement endpoint).

Sediments at both stations were dominated by sand, although silt and clay comprised a notable proportion of sediments at reach CHR-D-1 (Table 5.10-9, Table 5.10-10). Total organic carbon was low (<1%) at both reaches. All hydrocarbon fractions (C6-C50) were non-detectable at reach CHR-D-2. Hydrocarbons at reach CHR-D-1 were dominated by fraction 3 (C16-C34), but were lower than previously observed at this reach. PAH concentrations at both reaches were relatively low and dominated by low molecular weight PAH species (Table 5.10-9, Table 5.10-10).

Concentrations of all sediment quality measurement endpoints in fall 2006 at both reaches were within historical ranges with the following exceptions (Table 5.10-9, Table 5.10-10):

- %clay, %sand and %total organic carbon at both reach CHR-D-1 and reach CHR-D-2 were below previously-measured minimum levels (conversely, %silt at both reach CHR-D-1 and reach CHR-D-2 in fall 2006 was below previously-measured maximum levels); and

- Retene, total dibenzothiophenes, total PAHs, total HMW PAHs, total LMW PAHs, and predicted PAH toxicity were below previously-measured minimum levels at both reach CHR-D-1 and reach CHR-D-2.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines There were no sediment quality measurement endpoints in fall 2006 at either reach CHR-D-1 or reach CHR-D-2 with measured concentrations that exceeded sediment quality guidelines (Table 5.10-9, Table 5.10-10).

5.10.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats in the Christina River watershed, and most PAH sediment quality measurement endpoints were below previously-measured minimum concentrations.

5.10.5 Fish Populations

Fish population monitoring for 2006 in the Clearwater River/Christina River watersheds consisted of a spring and fall fish inventory on the Clearwater River, as well as a fish tissue analysis of northern pike captured during the inventory.

5.10.5.1 Fish Inventory Results

Species Composition

A total of 1,423 fish were captured during the spring and fall fish inventory within the three reaches (Figure 3.5-1) of the Clearwater River, of which:

- 703 fish comprised of 14 species were captured in the spring sampling (Table 5.10-11); and
- 720 fish comprised of 12 species were recorded in the fall sampling (Table 5.10-12).

A total of 17 fish species were recorded during the 2006 Clearwater River fish inventory. The species richness in 2006 was equal to that reported in 2005 and 2004, but less than 2003 when 21 fish species were captured/observed. Although only 17 species of fish were identified during the 2006 Clearwater fish inventory, collectively over recent years and combined seasons, a total of 22 different species have been captured and/or observed in the Clearwater River. This is the same total species richness reported in Golder (2003a), which listed eight sport species, two sucker species and twelve small-bodied forage species.

White sucker and lake chub were the two dominant fish species captured in the spring, with each representing 24.8% of the total spring catch (Table 5.10-11), while white sucker (27.5%) followed by northern pike (19.7%) were the dominant large-bodied species captured in the fall; spottail shiner (9.0%) was the most common small-bodied species captured during the fall inventory (Table 5.10-12).

Once again, no lake whitefish were captured during 2006 fall inventory activities on the Clearwater River, an identical result to 2005, 2004 and 2003. The absence of lake whitefish during the fall period in four consecutive years supports the likelihood that the Clearwater River is not used by this species for the annual spawning migration. Jones et al. (1978) found neither lake whitefish spawning, nor lake whitefish in spawning condition present in a fall study on the Clearwater River.

The overall catch per unit effort (CPUE) of the 2006 Clearwater River fish inventory was higher in both seasons in 2006 than in past years (Table 5.10-13). Species-specific seasonal catch per unit effort for northern pike and walleye are presented in Figure 5.10-7. In 2004 low, turbid water conditions and technical difficulties reduced the effectiveness of the fall inventory. Catch results for 2006 fell within the historical range, which consists of both annual and seasonal variability.

Length-Frequency Analysis

Length-frequency distributions (2003 to 2006) for five Key Indicator Resource (KIR) species are presented in Figure 5.10-8 to Figure 5.10-11; data have been pooled to include fish captured in both spring and fall. Key features with respect to each KIR fish species are as follows:

- The dominant length class for walleye in 2006 was 351 to 400 mm (29.7% of all walleye captured in 2006 Clearwater inventory), followed by two sub-dominant size classes of 401 to 450 mm and 451 to 500 mm (Figure 5.10-8). The 2006 adult walleye length distribution is similar to 2004 and 2005 distributions, with an increase in the relative abundance of juvenile walleye in the 101-150 mm size class for 2006. The dominant length class is similar to length-frequency distributions for walleye measured in the Athabasca River from 1997 to 2006 which, for 2006, also contained an increase in the relative abundance of juvenile walleye in the 101-150 mm length class (Figure 5.1-15);

- The dominant length class for goldeye in 2006 was 376 to 400 mm, which is the same dominant length class as in 2005 (Figure 5.10-9). A co-dominant size class, 351 to 375 mm, was present in 2006, which corresponds to the dominant size class in both 2003 and 2004;

- Longnose sucker captured in the 2006 Clearwater River inventory were primarily small to mid-size individuals, similar to 2004 and 2005, with a dominant size class of 201 to 250 mm (Figure 5.10-10). A juvenile size class of 51-100 mm, represented 20% of the longnose sucker captured in 2006. This is similar to the 2006 results for longnose sucker in the Athabasca River, which had a dominant size class of 100-150 mm (Figure 5.1-17);

- The co-dominant length classes for white sucker in the 2006 Clearwater River fish inventory were 351 to 400 mm and 401 to 450 mm (Figure 5.10-11). This is the same pattern as 2005 and 2003, and are in contrast to 2004 when the dominant size class was 51 to 100 mm; and

- The dominant length class for northern pike in 2006 was 501 to 550 mm and there was a fairly even and wide distribution of individuals across multiple length classes in 2006 (Figure 5.10-12). This wide length distribution is also present in the capture for the Athabasca River in 2006 (Figure 5.1-19).

Condition Factor

Mean condition factors for KIR fish species captured in the spring of the 2006 Clearwater River inventory are shown in Figure 5.10-13. Analysis of variance determined significant differences in the spring condition factor among years for northern pike (2005 and 2006 spring condition factors greater than 2004 spring condition factor) and walleye (2006 spring condition factor greater than both 2003 and 2005 spring condition factors)

($p < 0.05$). No significant difference in longnose sucker, white sucker, or goldeye spring condition factor were determined, although small sample sizes of longnose sucker may influence the ability to detect significant differences.

External Fish Health

In 2006, 56 of the 703 fish (7.97%) in the spring and 28 of 720 fish (3.89%) were found to have some type of external abnormality. Observed abnormalities were primarily associated with minor skin or body surface aberrations (e.g., raised or missing scales), or old wounds/scars. A few fish had external parasites present (e.g. black spot). The 2006 external pathology index scores for KIR indicator fish species collected from the Clearwater River were within the range of index scores previously measured for both the Athabasca River and Clearwater River inventories (Table 5.10-14).

5.10.5.2 Summary Assessment for Fish Inventory

As outlined in RAMP (2005b), the Clearwater and Athabasca River fish inventories are generally considered to be community-driven activities, which are primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than detailed fish community structure. Current and historical fish inventory data from the Clearwater River indicate some level of species-specific variability in relative abundance, length-frequency distribution, and condition factor. However, statistical analysis of the inventory data collected to date has demonstrated limited significant differences among years with no clear trends.

Currently, only condition factor can be applied as a measurement endpoint for the large-bodied fish in the Clearwater River inventory. The impact criterion for condition factor defined by Environment Canada (2002) is a ± 10% difference between *potentially influenced* and *reference* sites. A difference in condition that is greater than 10% indicates a population may be affected by some factor or factors. This threshold was not exceeded when this criteria was applied to the temporal analysis of spring condition factor for either walleye or northern pike.

5.10.5.3 Fish Tissue Analysis Results

Whole-Organism Metrics

A total of 26 northern pike (10 females, 8 males and 8 unsexed) from the Clearwater River were sampled for fish tissue analysis in conjunction with the 2006 fall inventory. The size of the sampled fish ranged from a 254 mm immature fish to an 810 mm adult female, and age ranged from 1 to 7 years (Table 5.10-15). Mean length and age were 481 mm and 3.8 years, respectively, with females slightly larger than males.

External and or internal fish health assessments were conducted on the eleven fish that were sacrificed plus an additional female fish that was determined to be too large for composite analyses. Two males had a slightly inflamed hindgut and one of these also had increased mesenteric fat (<50%); one female had a fatty liver. No other internal abnormalities were observed, excluding gall bladder colour, which relates to food availability and storage. For fish from which tissue was sampled non-lethally, the most common external abnormality was the presence of minor skin aberration consisting of scale loss or re-growth (7 out of 27); plus one male that had minor fin erosion on the top of its tail. The presence of black spot was also observed on a few of the northern pike examined.

Mercury

Total mercury concentrations in muscle of individual non-lethally sampled northern pike collected from the Clearwater River in 2006 are presented in Table 5.10-15. Concentrations ranged from a high of 0.402 mg/kg in an 800 mm, 7-year old adult male to a low of 0.083 mg/kg in a 289 mm, immature 2-year old fish.

Overall, mean northern pike mercury concentration in 2006 was 0.202 mg/kg; this was not substantially different from the 2004 mean northern pike mercury concentration of 0.201 mg/kg. The mean concentration of mercury in adult female northern pike (0.223 mg/kg) was slightly higher than for adult males (0.200 mg/kg); this is opposite to 2004 results in which the mean concentration of mercury in adult male northern pike was greater than for adult females.

Mercury concentrations had strong positive correlations with length (r_s=0.84) and age (r_s=0.80) (Table 5.10-16). The correlations were stronger for male northern pike than for females. Scatterplots of fork length and age against mercury concentrations in muscle of individual northern pike (Figure 5.10-14, Figure 5.10-15) indicate a positive relationship between fish length and age with mercury concentration for northern pike. Regressions between mercury concentration and fork length and age were significant ($p < 0.001$; fork length adjusted R^2= 0.71 and age adjusted R^2= 0.57) (Figure 5.10-16).

Other Chemicals

Concentrations of other chemicals in sex-specific composite muscle samples of northern pike from the Clearwater River are presented in Table 5.10-17. Concentrations for 17 of 25 metals analyzed, plus the analyzed tainting compounds, were below analytical detection limits. The analyses for arsenic in 2006 utilized a lower detection limit than 2004 (0.01 mg/kg), which allowed the determination of tissue concentrations that was not possible in past years. Concentrations of the detectable chemicals in the composite muscle samples were consistent for both sexes of northern pike.

5.10.5.4 Screening of Potential Effects on Human Health

Mercury

2006 northern pike tissue mercury concentration data were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.10-18). The overall mean mercury concentration (0.202 mg/kg) in northern pike exceeded the Health Canada criteria for subsistence fishers (0.20 mg/kg), USEPA criteria for subsistence fishers (0.049 mg/kg), and USEPA Region III risk-based criteria (0.14 mg/kg) (Figure 5.10-15). One of the sampled northern pike exceeded the USEPA criteria for subsistence consumers (0.4 mg/kg). None of the sampled northern pike from the Clearwater River in 2006 exceeded the Health Canada criteria for general consumers (0.50 mg/kg). Northern pike sex-specific mercury concentrations in 2006 were not significantly different from 2004 results, and have exceeded the Health Canada subsistence consumer criteria in both years (Figure 5.10-17).

Mercury tissue concentrations in northern pike from the Clearwater River are consistent with the natural range of concentrations observed in this region of northern Alberta (RAMP 2003, 2004, 2005 and Grey *et al.* 1995).

Other Chemicals

Arsenic was the only other chemical in 2006 with exceedance of human health criteria (Table 5.10-17). The arsenic concentrations for the 2006 northern pike composite samples (both male and female) exceeded Health Canada and USEPA screening criteria for both recreational and subsistence fishers.

5.10.5.5 Screening of Potential Effects on Fish and Fish Health

Mercury

Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish and fish health (Table 5.10-19)

Other Chemicals

Concentrations of other contaminants in northern pike composite tissue samples from the Clearwater River were screened against the lowest thresholds for effects (and absence of effects) in fish (Table 5.10-20). Concentrations of selenium and vanadium exceeded the no effects thresholds for fish, but were only slightly above the lowest reported no effects level for sublethal effects. While aluminum and silver concentrations were below their analytical detection limits aluminum and silver detection limits are also above the lowest no-effects threshold, and so the results for these metals are inconclusive.

5.10.5.6 Screening of Potential Effects on Palatability of Fish

All tainting compounds in Clearwater River fish tissue were present at concentrations well below the 1 mg/kg threshold for effects on palatability as outlined in Jardine and Hrudey (1988) (Table 5.10-17).

5.10.5.7 Summary Assessment for Fish Tissue

Endpoints used in the impact assessment for the Clearwater River fish tissue program are the range of metals and tainting compounds included in the tissue analysis for both individual and composite samples. Potential effects on human health were predicted from the individual and composite fish tissue analyses. Results for northern pike analyzed from the Clearwater River indicate a potential risk for subsistence consumers due to exceedance of mercury relative to the corresponding guideline. Arsenic concentrations were also in exceedance relative to Health Canada and US EPA guidelines for recreational and subsistence consumers, while other metals and tainting compounds do not appear to pose any human health risks.

Although mercury concentrations in Clearwater River northern pike tissues exceeded some Health Canada and USEPA guidelines, comparison with historical regional data illustrates that these concentrations fall within the natural range of concentrations observed in this region of Alberta.

Fish tissue results for 2006 also suggest that there is a low potential risk to fish health, with only two metals, selenium and vanadium, exceeding sublethal no effects threshold.

5.10.6 Summary of Conditions

Monitoring activities in the Clearwater River and Christina River watersheds in 2006 focused on expanding baseline datasets for hydrology, water quality, benthic invertebrate communities and fish populations.

While hydrologic measurement endpoints for the Christina River watershed could not be estimated because there is no hydrometric station at the mouth of the Christina River, estimated effects of focal project activities in 2006 were to remove 0.075 mm of runoff depth from the watershed. Estimated effects of focal project activities plus oil sands projects in the Christina River watershed that were under construction or operation in 2006 but which were not owned by 2006 RAMP funders were to remove 0.128 mm of runoff depth from the watershed. Water quality measurement endpoints were generally within historical ranges and within the range for regional reference stations. Guideline exceedance of selected water quality measurement endpoints was restricted to nutrients and metals. Values of benthic invertebrate community measurement endpoints were similar to previous years and there have been no unusual trends in these measurement endpoints since sampling began in 2002.

A fourth year of fish inventory work on the Clearwater River was conducted to expand the baseline dataset for this river. Fish community composition, length-frequency relationships external fish health indices, and condition factors were similar to what was found in previous years. Mercury tissue concentrations in northern pike from the Clearwater River measured in 2006 are consistent with the natural range of concentrations observed in this region of northern Alberta and, as in previous years, mercury and arsenic levels in sampled northern pike fish tissue exceeded USEPA screening criteria. No fish tissues effects thresholds for fish and fish health were exceeded and all potential tainting compounds in sampled Clearwater River fish tissue were present at concentrations well below the 1 mg/kg threshold for palatability.

Figure 5.10-2 Clearwater River: 2006 hydrograph and historical context.

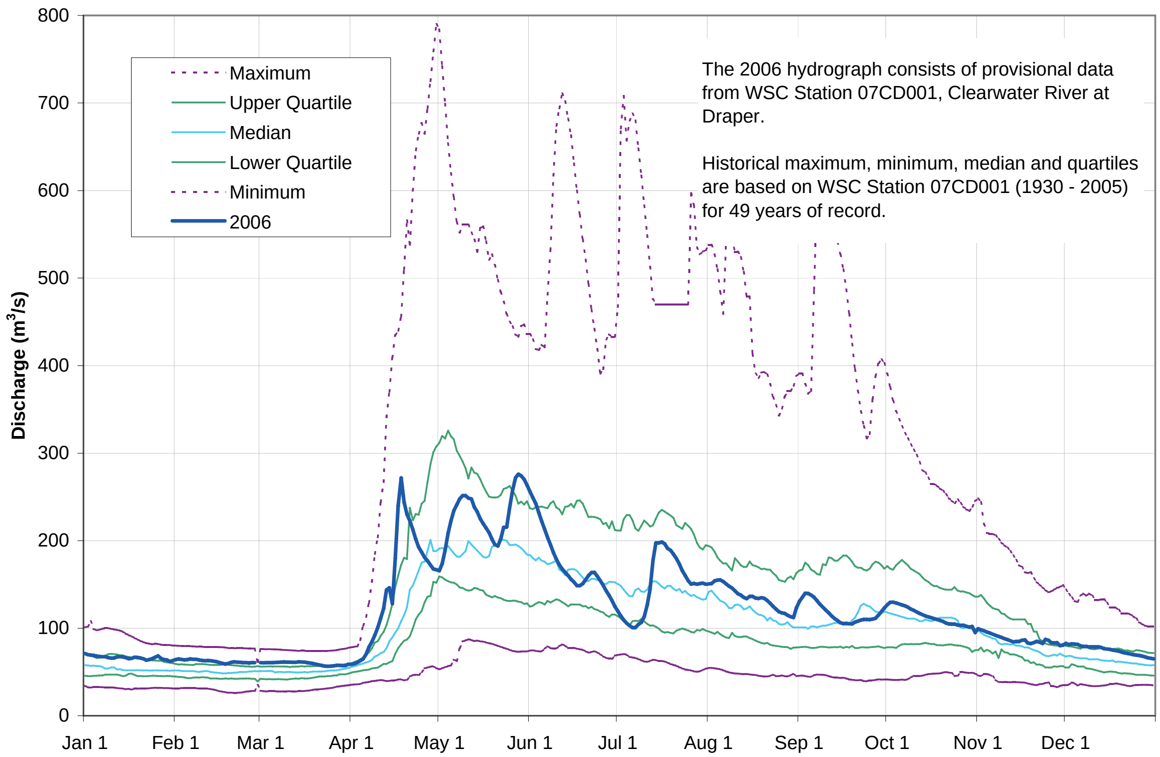


Figure 5.10-3 Christina River: 2006 hydrograph and historical context.

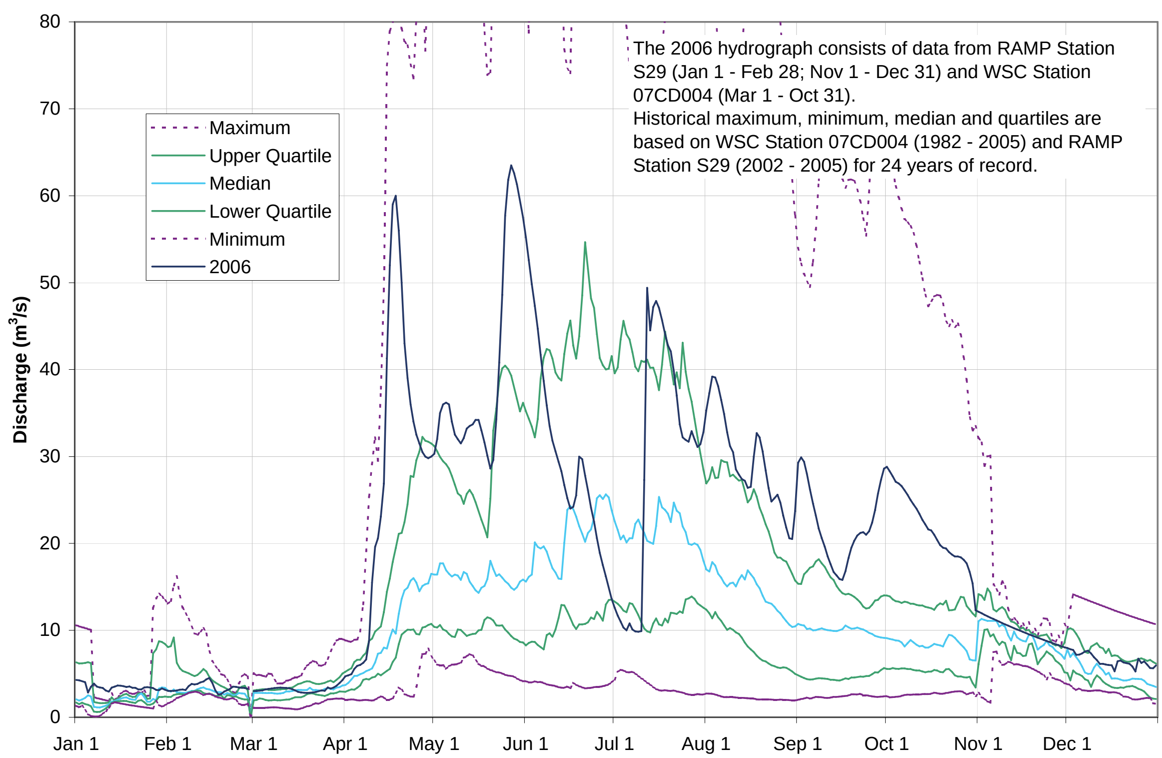


Table 5.10-1 Estimated changes in annual discharge in the Christina River watershed as a result of focal projects and other active oil sands projects in the watershed.

Component	Annual Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus All Other Active Oil Sands Projects in Christina River Watershed	
Natural runoff that would have occurred land area that was closed-circuited as of 2006	+ 1.42	+ 2.3	9.35 km^2 and 15.0 km^2 estimated to have been closed-circuited from focal projects and from focal projects plus other active oil sands projects, respectively, within Christina River watershed as of 2006 (Table 2.6-1).
Incremental runoff from areas of land change that are not closed-circuited	- 0.43	- 0.62	17.4 km^2 and 25.5 km^2 estimated to have undergone land change as of 2006, but are not closed-circuited, from focal projects and from focal projects plus other active oil sands projects, respectively, within Christina River watershed as of 2006 (Table 2.6-1).
Withdrawals from the Christina River	0	0	None reported, assumed to be negligible
Releases to the Christina River	0	0	None reported, assumed to be negligible
Diversions into or out of the watershed	0	0	None reported
The difference between operational and baseline hydrographs on tributary streams	0	0	No focal projects or other oil sands projects on tributaries of Christina River not accounted for in figures contained in this table
Incremental flow (change in total annual discharge)	+ 1.00	+ 1.66	Estimated difference in annual discharge that would have occurred in the baseline case

Table 5.10-2 Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	5	7.5	7.9	8.2
Total Suspended Solids	mg/L	-[1]	19	5	<3	8	38
Conductivity	µS/cm	-	214	5	177	233	291
Nutrients							
Total phosphorus	mg/L	0.05	**0.067**	5	0.033	**0.051**	**0.063**
Total dissolved phosphorus	mg/L	0.05[2]	0.024	5	0.012	0.021	0.028
Total nitrogen*	mg/L	1.0	0.6	5	0.3	0.4	0.7
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	11	5	8	10	14
Ions							
Sodium	mg/L	-	21	5	16	25	31
Calcium	mg/L	-	17.1	5	14.7	17.4	18
Magnesium	mg/L	-	5.5	5	5.1	5.7	5.9
Chloride	mg/L	230, 860[3]	25	5	17	34	43
Sulphate	mg/L	100[4]	1.4	5	5.2	6.8	7.7
Total Dissolved Solids	mg/L	-	150	5	60	150	200
Total Alkalinity	mg/L	-	62	5	59	66	71
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.58**	5	**0.14**	**0.54**	**1.46**
Dissolved aluminum	mg/L	0.1[2]	0.0090	5	0.0060	0.0096	0.0148
Total boron	mg/L	1.2[5]	0.0323	5	0.0275	0.0377	0.0548
Total molybdenum	mg/L	0.073	0.00027	5	0.00016	0.00020	0.00036
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.091	5	0.079	0.106	0.118
Other variables that exceeded CCME/AENV guidelines in fall 2006							
Sulphide	mg/L	0.002[7]	**0.005**	5	<0.003	**0.003**	**0.005**
Dissolved iron	mg/L	0.3[2]	**0.377**	5	0.161	0.277	**0.756**
Total phenols	mg/L	0.004	**0.009**	5	<0.001	0.001	**0.006**
Total iron	mg/L	0.3	**1.24**	5	**0.51**	**1.02**	**2.43**

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.10-3 Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	5	7.2	7.6	8.0
Total Suspended Solids	mg/L	-[1]	14	5	7	7	36
Conductivity	µS/cm	-	177	5	138	205	249
Nutrients							
Total phosphorus	mg/L	0.05	**0.054**	5	0.032	0.036	**0.074**
Total dissolved phosphorus	mg/L	0.05[2]	0.026	5	0.010	0.020	0.026
Total nitrogen*	mg/L	1.0	0.6	5	0.3	0.4	**1.2**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	7	5	6	7	9
Ions							
Sodium	mg/L	-	18	5	13	18	29
Calcium	mg/L	-	11.9	5	10.0	11.7	12.8
Magnesium	mg/L	-	4.2	5	3.7	4.2	4.5
Chloride	mg/L	230, 860[3]	24	5	16	28	43
Sulphate	mg/L	100[4]	<0.5	5	4.4	6.4	7.6
Total Dissolved Solids	mg/L	-	114	5	40	130	160
Total Alkalinity	mg/L	-	44	5	39	44	49
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.33**	5	**0.13**	**0.21**	**0.70**
Dissolved aluminum	mg/L	0.1[2]	0.0065	5	0.0051	0.0093	0.0400
Total boron	mg/L	1.2[5]	0.022	5	0.014	0.024	0.030
Total molybdenum	mg/L	0.073	0.00014	5	0.00009	0.000117	0.00020
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.074	5	0.061	0.084	0.094
Other variables that exceeded CCME/AENV guidelines in fall 2006							
Sulphide	mg/L	0.002[7]	**0.013**	5	<0.003	**0.004**	**0.007**
Total iron	mg/L	0.3	**0.84**	5	**0.56**	**0.79**	**2.07**
Total phenols	mg/L	0.004	**0.007**	5	<0.001	0.001	**0.005**

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.10-4 Concentrations of water quality measurement endpoints, mouth of Christina River (CHR-1), fall 2006.

Analyte	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	8.1	8.3	8.4
Total Suspended Solids	mg/L	-[1]	26	4	<3	18	38
Conductivity	µS/cm	-	301	4	269	293	375
Nutrients							
Total phosphorus	mg/L	0.05	**0.094**	4	0.049	**0.061**	**0.108**
Total dissolved phosphorus	mg/L	0.05[2]	0.033	4	0.021	0.024	0.030
Total nitrogen*	mg/L	1.0	1.0	4	0.6	0.9	**1.6**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	4	14	16	22
Ions							
Sodium	mg/L	-	26	4	20	26	34
Calcium	mg/L	-	27.8	4	25.9	28.15	29.7
Magnesium	mg/L	-	8.4	4	7.8	8.6	9.1
Chloride	mg/L	230, 860[3]	28	4	21	27	41
Sulphate	mg/L	100[4]	2.2	4	6.8	7.2	7.9
Total Dissolved Solids	mg/L	-	190	4	140	200	250
Total Alkalinity	mg/L	-	103	4	101	112.5	118
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.77**	4	**0.24**	**0.51**	**0.73**
Dissolved aluminum	mg/L	0.1[2]	0.0144	4	0.0066	0.0086	0.0099
Total boron	mg/L	1.2[5]	0.054	4	0.027	0.052	0.066
Total molybdenum	mg/L	0.073	0.00038	4	0.00016	0.00037	0.00040
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.129	4	0.078	0.128	0.145
Other variables that exceeded CCME/AENV guidelines in fall 2006							
Sulphide	mg/L	0.002[7]	**0.011**	4	**0.021**	**0.024**	**0.030**
Total chromium	mg/L	0.0010, 0.0089[8]	**0.0011**	4	0.0007	0.0008	**0.0014**
Dissolved iron	mg/L	0.3[2]	**0.586**	4	0.255	**0.417**	**0.711**
Total iron	mg/L	0.3	**1.69**	4	**0.778**	**1.3015**	**1.6**
Total phenols	mg/L	0.004	**0.014**	4	<0.001	<0.001	**0.006**

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

Table 5.10-5 Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	8	8.2	8.3
Total Suspended Solids	mg/L	-[1]	6	4	8	8.5	13
Conductivity	µS/cm	-	187	4	197	218.5	266
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.044	4	0.026	0.036	**0.051**
Total nitrogen*	mg/L	1.0	0.8	4	0.6	**1.1**	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	4	14	16.5	20
Ions							
Sodium	mg/L	-	6	4	6	7.5	10
Calcium	mg/L	-	25.5	4	26.2	28.7	35.1
Magnesium	mg/L	-	8	4	7.7	8.55	10.6
Chloride	mg/L	230, 860[3]	2	4	<1	2	2
Sulphate	mg/L	100[4]	4.1	4	4.4	6.1	9.6
Total Dissolved Solids	mg/L	-	140	4	130	165	240
Total Alkalinity	mg/L	-	92	4	97	109.5	138
Organic compounds							
Naphthenic acids	mg/L	-	1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.304**	3	0.049	0.093	**0.237**
Dissolved aluminum	mg/L	0.1[2]	0.0114	3	0.0041	0.0078	0.0129
Total boron	mg/L	1.2[5]	0.0309	3	0.0316	0.0367	0.0459
Total molybdenum	mg/L	0.073	0.0004	3	0.00042	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	0.9
Total strontium	mg/L	-	0.099	3	0.098	0.117	0.147

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.10-6 Water quality guideline exceedances, Clearwater-Christina River watersheds, 2006.

Variable	Units	Guideline*	CLR-1	CLR-2	CHR-1	CHR-2
Winter						
Total aluminum	mg/L	0.1	**0.173**	ns	ns	ns
Dissolved iron	mg/L	0.3[1]	**0.341**	ns	ns	ns
Total iron	mg/L	0.3	**0.97**	ns	ns	ns
Spring						
Sulphide	mg/L	0.002[2]	**0.006**	ns	ns	ns
Total phosphorus	mg/L	0.05	**0.067**	ns	ns	ns
Total aluminum	mg/L	0.1	**1.68**	ns	ns	ns
Total chromium	mg/L	0.0010, 0.0089[3]	**0.00213**	ns	ns	ns
Total iron	mg/L	0.3	**1.84**	ns	ns	ns
Summer						
Sulphide	mg/L	0.002[2]	**0.007**	ns	ns	ns
Total phosphorus	mg/L	0.05	**0.075**	ns	ns	ns
Total aluminum	mg/L	0.1	**0.81**	ns	ns	ns
Total chromium	mg/L	0.0010, 0.0089[3]	**0.00135**	ns	ns	ns
Total iron	mg/L	0.3	**1.39**	ns	ns	ns
Fall						
Sulphide	mg/L	0.002[2]	**0.005**	**0.013**	**0.011**	**0.007**
Total phosphorus	mg/L	0.05	**0.067**	**0.054**	**0.094**	**0.074**
Total aluminum	mg/L	0.1	**0.579**	**0.328**	**0.765**	**0.304**
Total chromium	mg/L	0.0010, 0.0089[3]	-	-	**0.00111**	-
Dissolved iron	mg/L	0.3[1]	**0.377**	-	**0.586**	**0.816**
Total iron	mg/L	0.3	**1.24**	**0.835**	**1.69**	**1.64**
Total phenols	mg/L	0.004	**0.009**	**0.007**	**0.014**	**0.012**

CHR-1, CHR-2 and CLR-2 were sampled only in fall 2006.

ns = not sampled

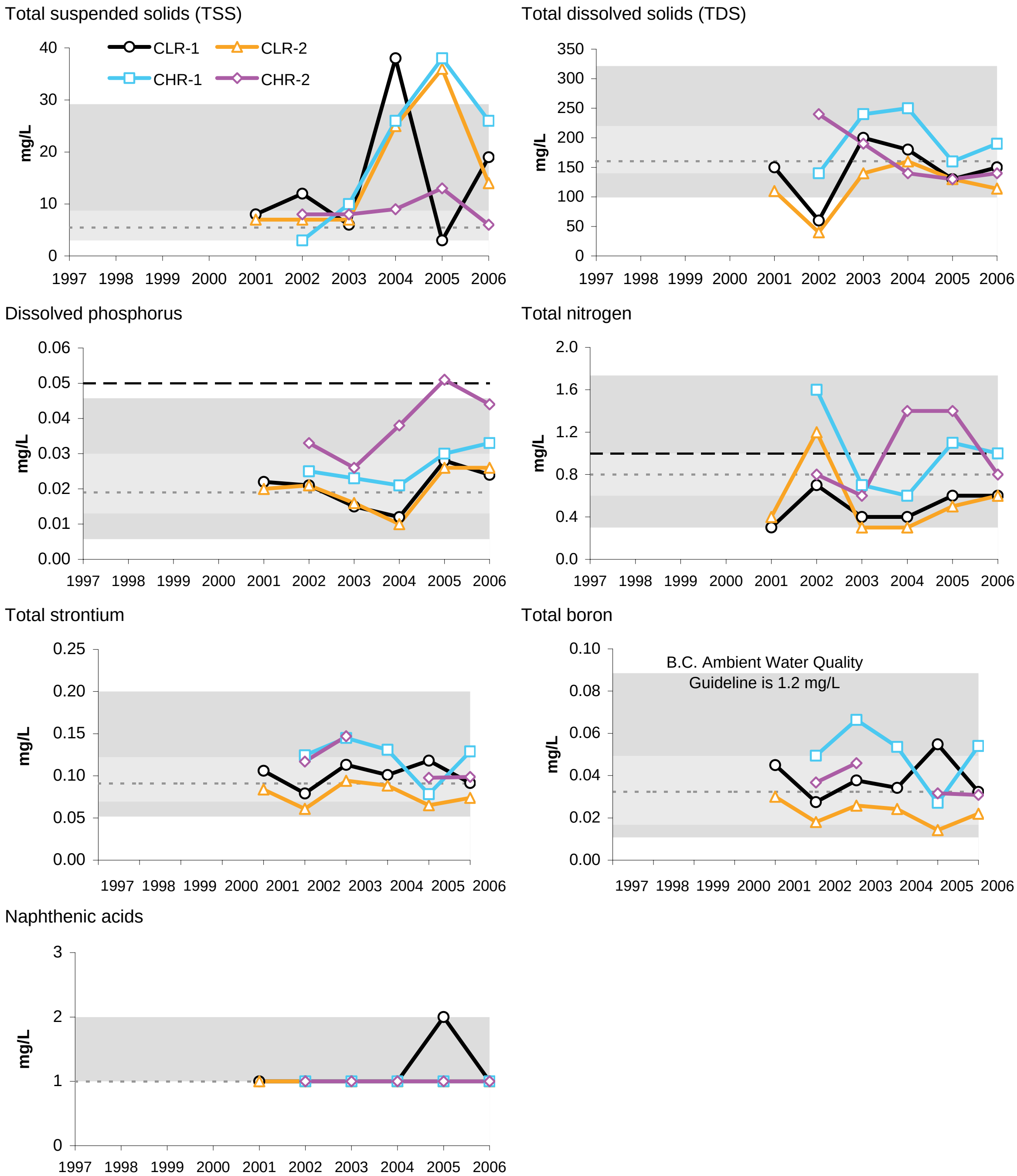
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] Guideline is for total analyte (no guideline for dissolved species).

[2] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2001).

[3] Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

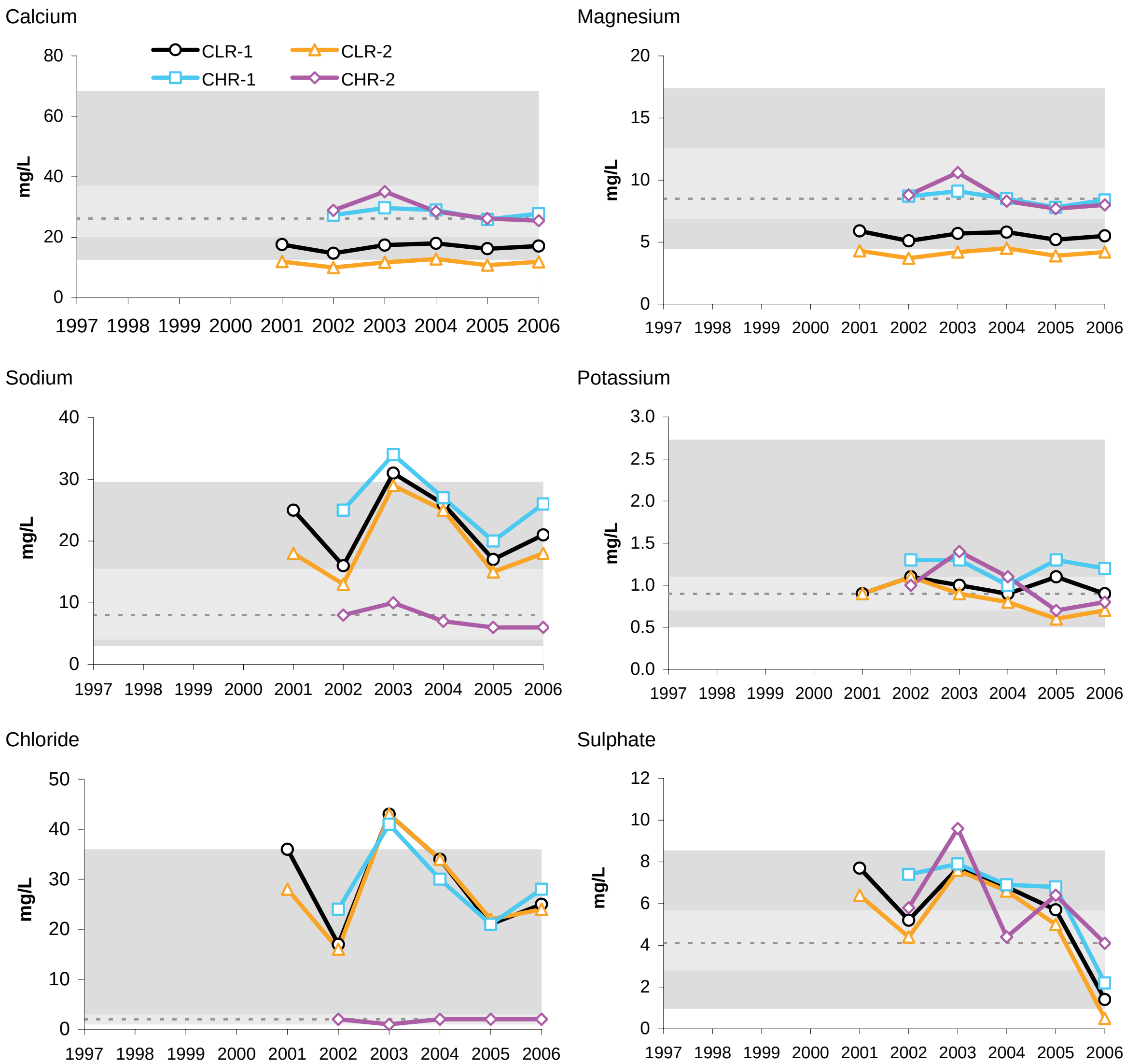
Figure 5.10-4 Concentrations of selected water quality measurement endpoints in the Clearwater and Christina watersheds (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.10-4 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.10-5 Piper diagram of fall ion concentrations in the Clearwater-Christina River system.

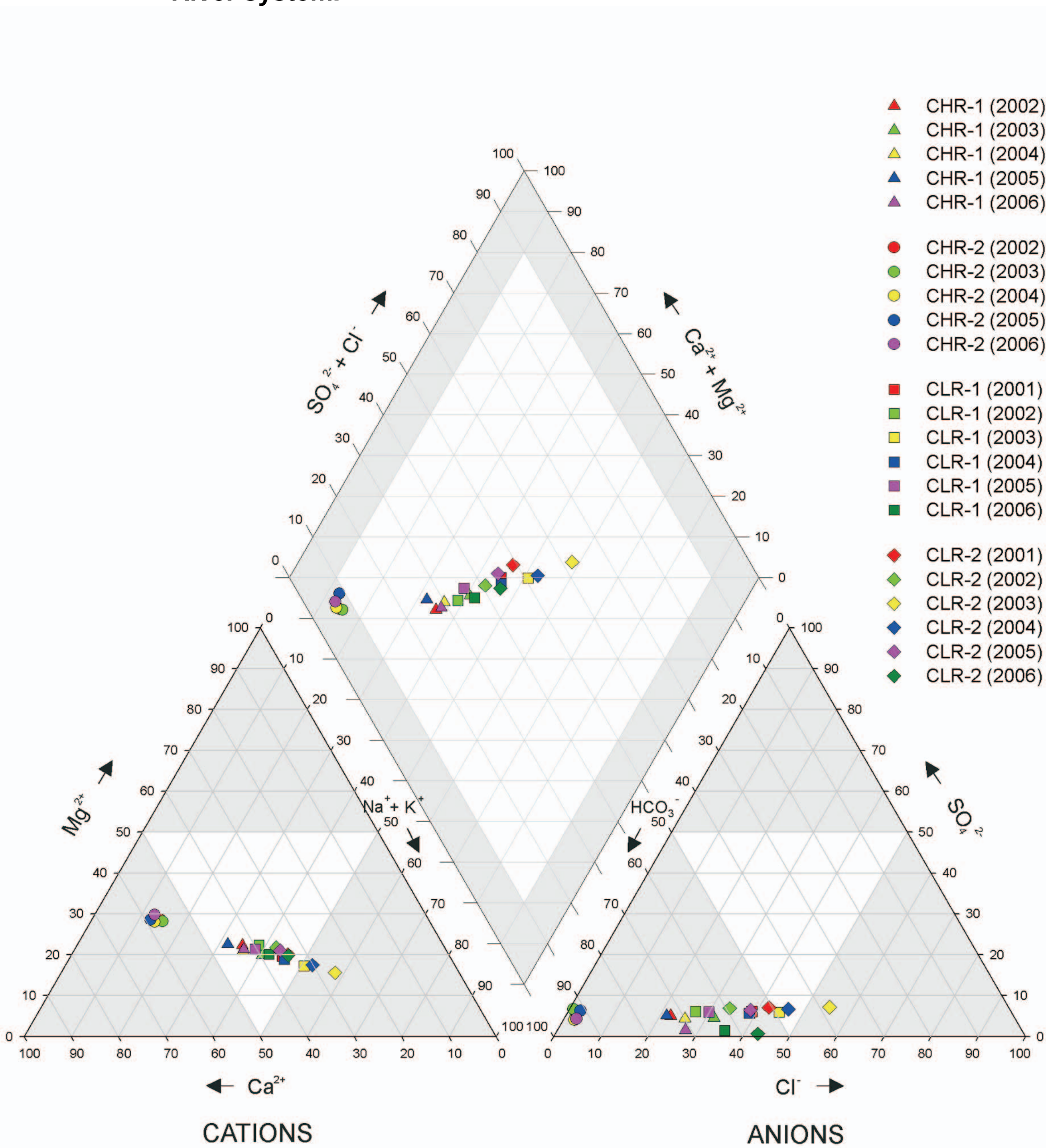


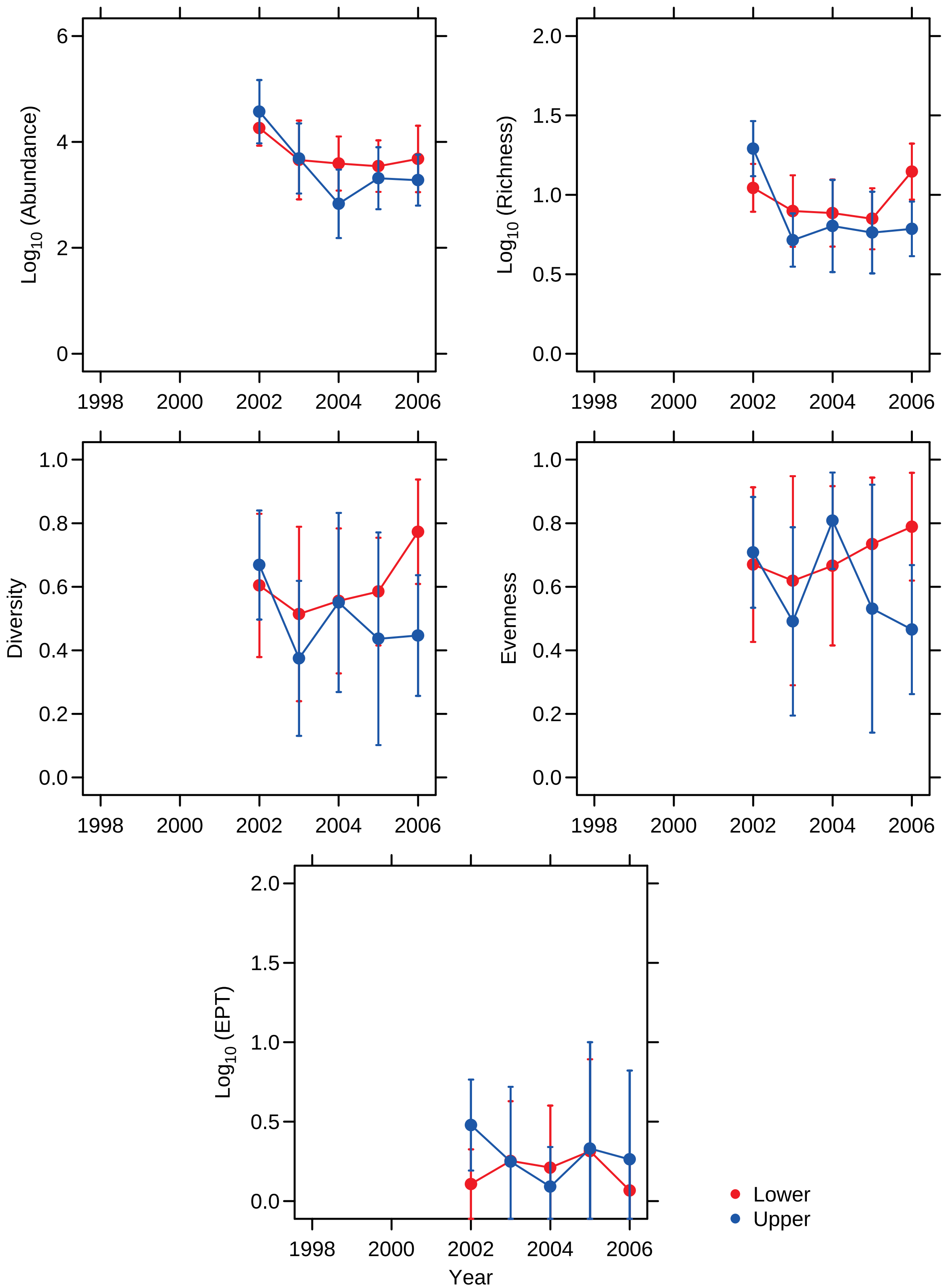
Table 5.10-7 Average habitat characteristics of benthic invertebrate community sampling reaches in the Christina River, fall 2006.

Variable	Units	Lower Reach of the Christina River (reach CHR-D-1)	Upper Reach of the Christina River (reach CHR-D-2)
Sample date	-	Sept. 9, 2006	Sept. 10, 2006
Habitat	-	Depositional	Depositional
Water depth	m	0.23	0.4
Current velocity	m/s	0.1	0.4
Macrophyte cover	%	1.1	0
Field Water Quality			
Dissolved oxygen	mg/L	8.7	8.8
Conductivity	µS/cm	279	193
pH	pH units	7.9	7.6
Water temperature	°C	14.9	16.5
Sediment Composition			
Sand	%	64	98
Silt	%	27	0
Clay	%	9	2

Table 5.10-8 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Christina River, fall 2006.

Taxon	% Total Taxa Enumerated in Each Year									
	Reach CHR-D-1					Reach CHR-D-2				
	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
Anisoptera	<1	<1	<1	<1	<1	<1	<1		<1	<1
Bivalvia	11	1	1	<1	<1	3	<1	7		<1
Ceratopogonidae	<1	1	7	3	7	2		2	1	<1
Chironomidae	39	23	29	46	70	44	99	28	89	91
Chydoridae						<1				
Coleoptera								<1		<1
Copepoda	<1	<1				<1		<1		
Dolichopodidae			<1					4		
Empididae		<1	1	1	3	<1			1	<1
Enchytraeidae				<1				3	<1	
Ephemeroptera		1	1	1	<1	2	<1	<1	<1	<1
Ephydridae			<1					4		
Erpobdellidae		<1	<1							
Gastropoda	2	<1			<1	<1				
Glossiphoniidae	<1					<1				
Heteroptera		<1				<1				
Hydracarina							<1			
Lumbriculidae		<1	<1							
Macrothricidae						<1				
Naididae	<1	5	1	2	<1		<1	4		
Nematoda	1	1	2	1	1	1	<1	11	<1	
Ostracoda	2	<1	9		1	24	<1	2		
Plecoptera	<1	<1	<1	<1	<1				<1	
Tabanidae	<1	<1		<1	0<1	<1		<1	1	
Tipulidae			<1			<1		2		
Trichoptera	<1	<1		<1	<1	<1	<1		4	4
Tubificidae	44	66	5	45	16	23	<1	33	4	3
Benthic Invertebrate Community Measurement Endpoints										
Total Abundance (No./m^2)	22,928	10,178	6,405	5,052	9,788	63,968	12,963	1,305	3,848	3,090
Richness	11	8	8	7	14	20	5	6	6	6
Simpson's Diversity	0.6	0.51	0.56	0.59	0.77	0.67	0.37	0.55	0.44	0.45
Evenness	0.67	0.62	0.67	0.73	0.79	0.71	0.49	0.81	0.63	0.47
% EPT	<1	2	2	6	<1	3	3	1	7	5

Figure 5.10-6 Annual variation in benthic invertebrate community measurement endpoints in the Christina River, reach CHR-D-1 and reach CHR-D-2.



Lower reach: reach CHR-D-1; Upper reach: reach CHR-D-2.

Table 5.10-9 Sediment quality measurement endpoints, lower reach near mouth of Christina River (reach CHR-D-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station CHR-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8	3	10	13	17
Silt	%	-	38	3	16	22	25
Sand	%	-	54	3	58	70	74
Total organic carbon	%	-	0.7	3	0.8	1.8	2
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	-5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	-5
Fraction 2 (C10-C16)	mg/kg	150[2]	81	1	-	-	100
Fraction 3 (C16-C34)	mg/kg	400[2]	200	1	-	-	**970**
Fraction 4 (C34-C50)	mg/kg	2800[2]	130	1	-	-	480
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0019	3	0.0012	0.0022	0.0080
Retene	mg/kg	-	0.0198	3	0.0286	0.0957	0.1490
Total dibenzothiophenes	mg/kg	-	0.25	3	0.65	1.66	3.32
Total PAHs	mg/kg	-	1.00	3	3.13	7.53	11.75
Total HMW PAHs	mg/kg	-	0.35	3	1.37	2.70	4.10
Total LMW PAHs	mg/kg	-	0.65	3	1.76	4.83	7.65
Predicted PAH toxicity[1]	H.I.	-	0.70	3	1.28	2.08	2.78
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	9
Chironomus growth - 10d	mg/organism	-	2.7	1	-	-	2.1
Hyalella survival - 14d	# surviving	-	8	1	-	-	6
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.1

Values in **bold** indicate concentrations exceeding guidelines.

1 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

2 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.10-10 Sediment quality measurement endpoints, upper Christina River (reach CHR-D-2), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station CHR-D2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2	3	4	8	13
Silt	%	-	1	3	19	22	30
Sand	%	-	97	3	57	69	79
Total organic carbon	%	-	0.1	3	1	1.1	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	1	-	-	13
Fraction 3 (C16-C34)	mg/kg	400[2]	<5	1	-	-	47
Fraction 4 (C34-C50)	mg/kg	2800[2]	<5	1	-	-	32
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00189	3	0.0014	0.0018	0.003
Retene	mg/kg	-	0.00122	3	0.011	0.0778	0.092
Total dibenzothiophenes	mg/kg	-	0.001	3	0.02	0.02	0.02
Total PAHs	mg/kg	-	0.024	3	0.15	0.27	0.32
Total HMW PAHs	mg/kg	-	0.003	3	0.08	0.11	0.12
Total LMW PAHs	mg/kg	-	0.022	3	0.07	0.16	0.20
Predicted PAH toxicity[1]	H.I.	-	0.49	3	0.69	0.77	0.97
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	2	5	-	9
Chironomus growth - 10d	mg/organism	-	1.8	2	2.5	-	4.3
Hyalella survival - 14d	# surviving	-	10	2	8	-	10
Hyalella growth - 14d	mg/organism	-	0.4	2	0.11	-	0.2

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.10-11 Clearwater River fish inventory results, spring 2006.

Species	Total Captured	Species Composition (% of seasonal total)	CPUE (No./100 s) (mean ± SE)
Arctic grayling	5	0.7	0.031 ± 0.002
Burbot	2	0.3	0.014 ± 0.008
Flathead chub	7	1.0	0.039 ± 0.039
Fathead minnow	2	0.3	0.011 ± 0.011
Goldeye	47	6.7	0.261 ± 0.229
Lake chub	174	24.8	0.986 ± 0.742
Lake whitefish	1	0.1	0.006 ± 0.006
Longnose sucker	17	2.4	0.101 ± 0.058
Northern pike	54	7.7	0.3336 ± 0.057
Spoonhead sculpin	4	0.6	0.022 ± 0.022
Spottail shiner	73	10.4	0.471 ± 0.256
Trout-perch	67	9.5	0.372 ± 0.187
Walleye	76	10.8	0.425 ± 0.396
White sucker	174	24.8	1.108 ± 0.399
TOTAL	**703**	**100**	**4.18 ± 1.086**

Total spring electrofishing effort = 15,774 s

Table 5.10-12 Clearwater River fish inventory results, fall 2006.

Species	Total Captured	Species Composition (% of seasonal total)	CPUE (No./100 s) (mean ± SE)
Arctic grayling	12	1.7	0.071 ± 0.015
Lake chub	36	5.0	0.208 ± 0.005
Longnose dace	3	0.4	0.020 ± 0.016
Longnose sucker	31	4.3	0.186 ± 0.027
Mountain whitefish	8	1.1	0.050 ± 0.048
Northern pike	142	19.7	0.871 ± 0.238
Spoonhead sculpin	11	1.5	0.066 ± 0.016
Spottail shiner	65	9.0	0.383 ± 0.085
Trout-perch	144	20.0	0.869 ± 0.214
Walleye	62	8.6	0.388 ± 0.088
White sucker	198	27.5	1.160 ± 0.349
Yellow perch	8	1.1	0.051 ± 0.033
TOTAL	**720**	**100**	**4.32 ± 0.294**

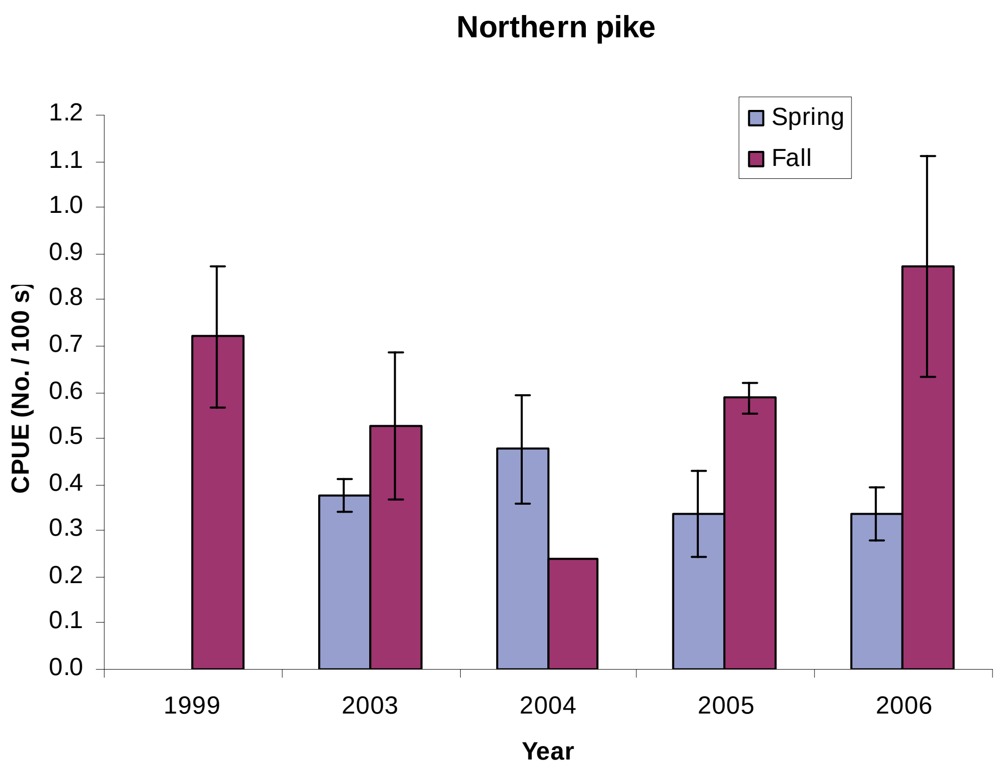
Total fall electrofishing effort = 16,476 s

Table 5.10-13 Seasonal comparison of total catch per unit effort (captured fish only) in the Clearwater River, 2003 to 2006.

Year	Catch per unit effort (No. fish/100 s)	
	Spring (mean ± SE)	Fall (mean ± SE)
1999	N/A	1.38 ± 0.094
2003	1.71 ± 0.158	2.55 ± 0.322
2004	2.34 ± 0.225	1.22
2005	3.53 ± 1.177	3.34 ± 0.335
2006	4.18 ± 1.086	4.32 ± 0.294

Note: Only one reach was sampled in fall 2004.

Figure 5.10-7 Comparison of seasonal northern pike and walleye CPUE, 1999 to 2006.



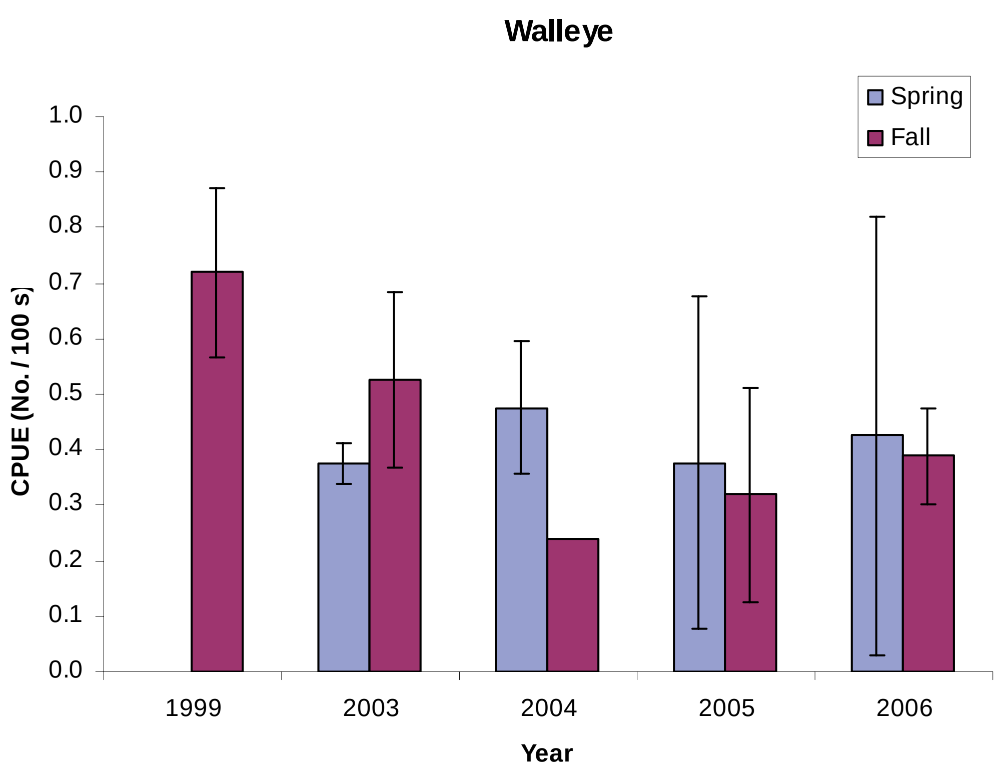


Figure 5.10-8 Relative length-frequency distribution for walleye captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.

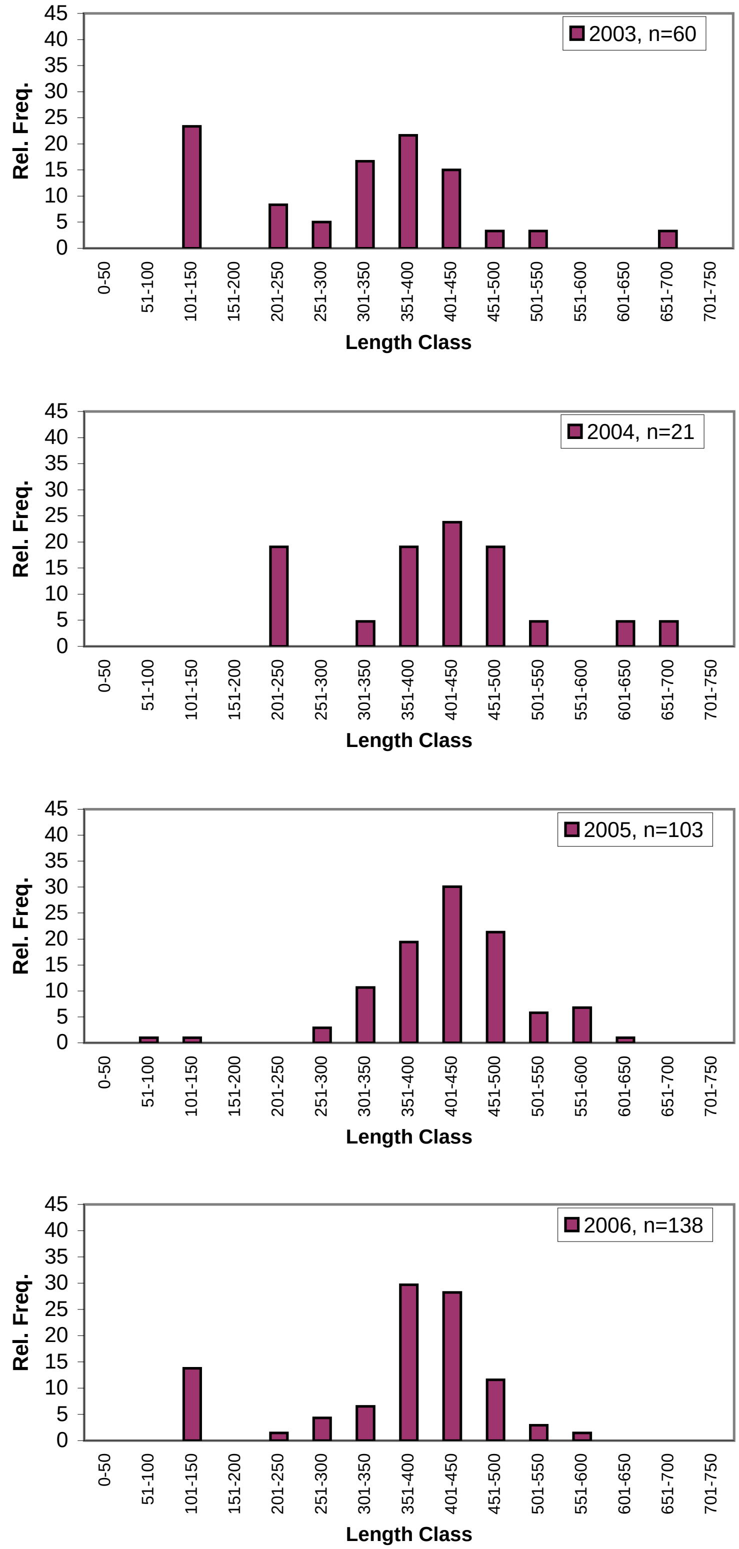


Figure 5.10-9 Relative length-frequency distribution for goldeye captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.

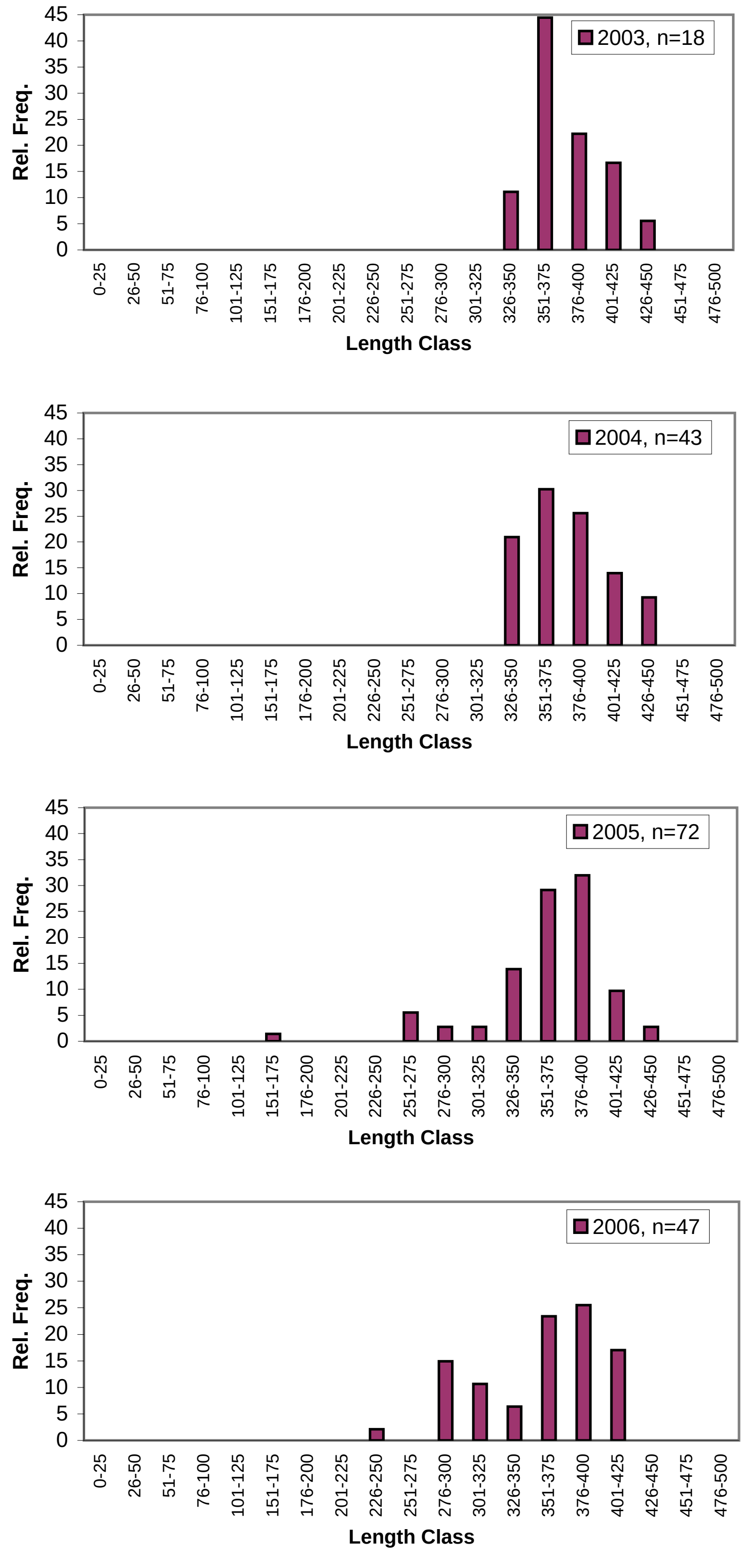


Figure 5.10-10 Relative length-frequency distribution for longnose sucker captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.

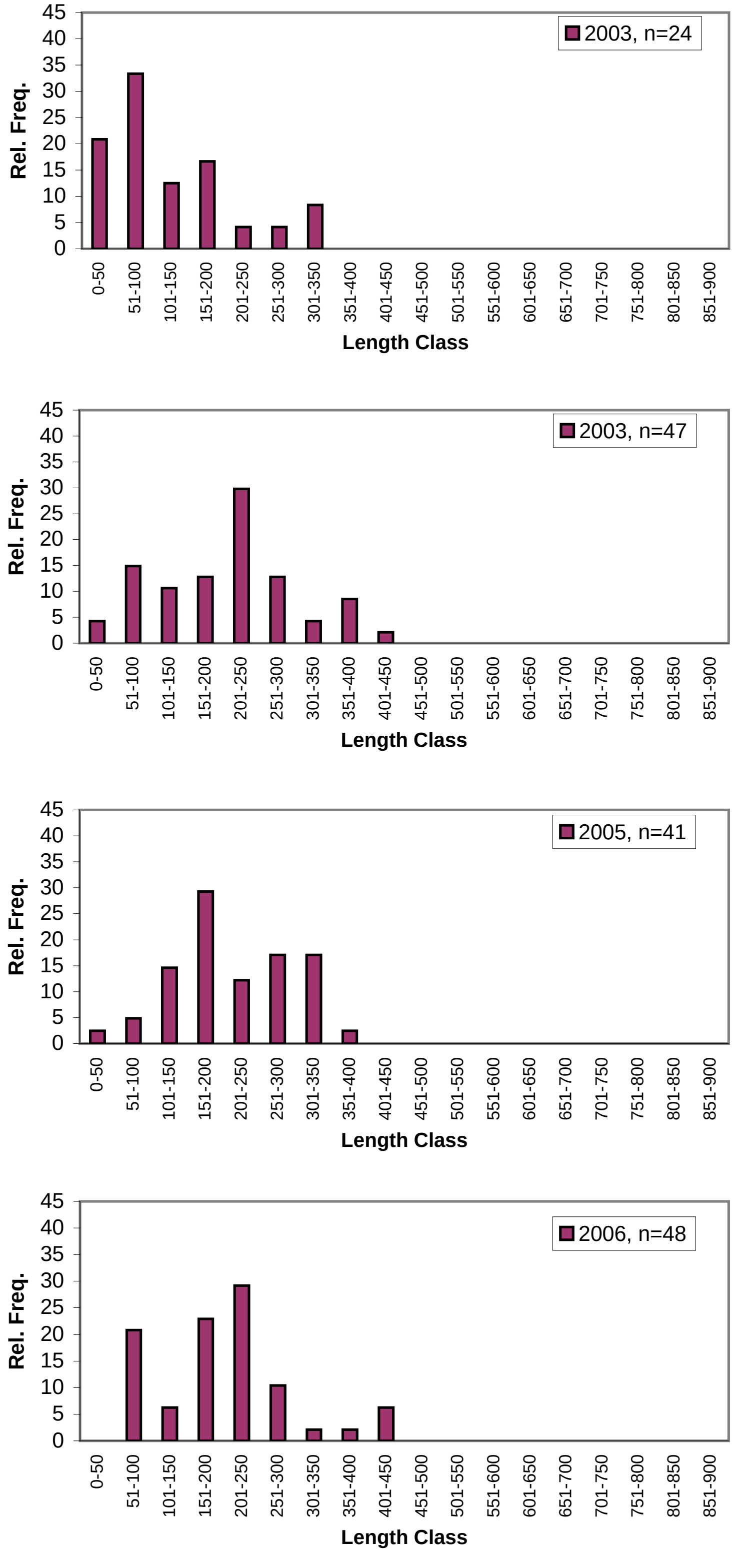


Figure 5.10-11 Relative length-frequency distributions for white sucker captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.

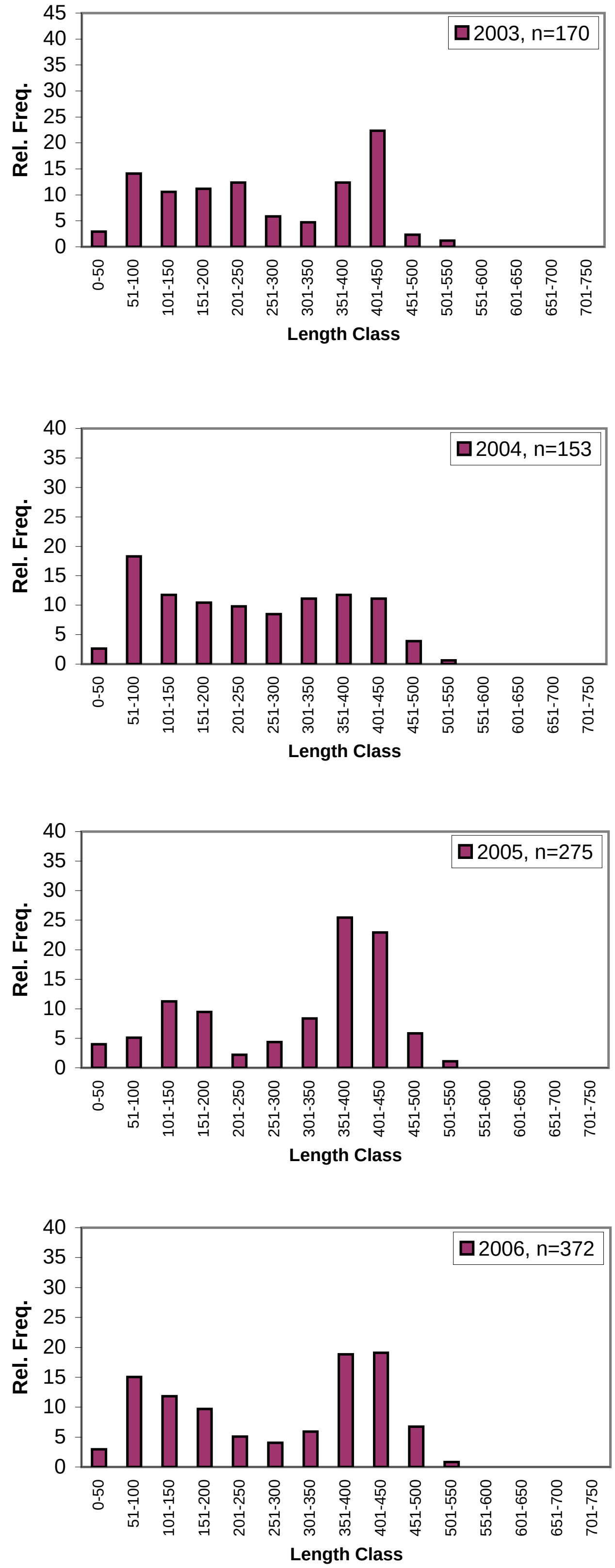


Figure 5.10-12 Relative length-frequency distribution for northern pike captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.

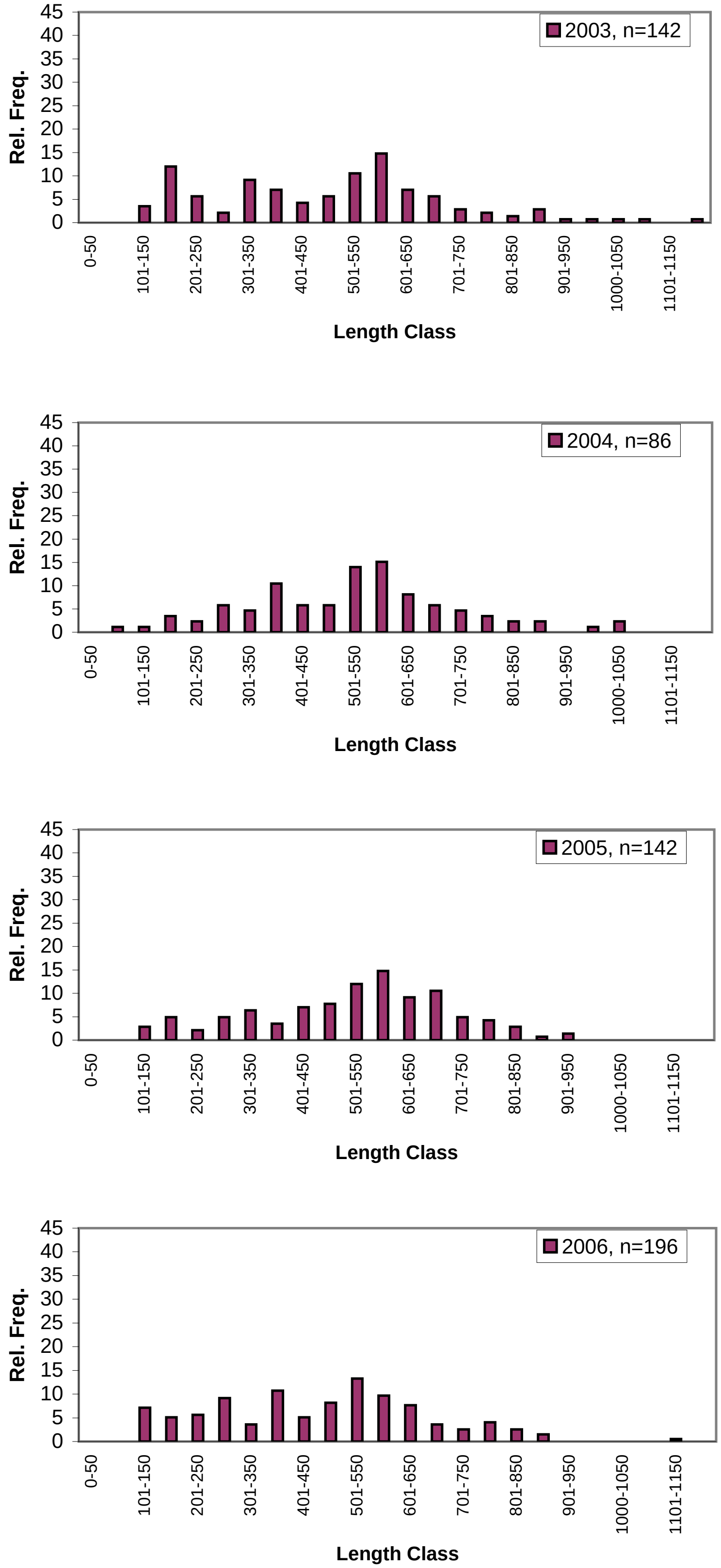


Figure 5.10-13 Mean condition factor (± 1 SE) for key indicator fish species in the Clearwater River, spring 2003 to 2006.

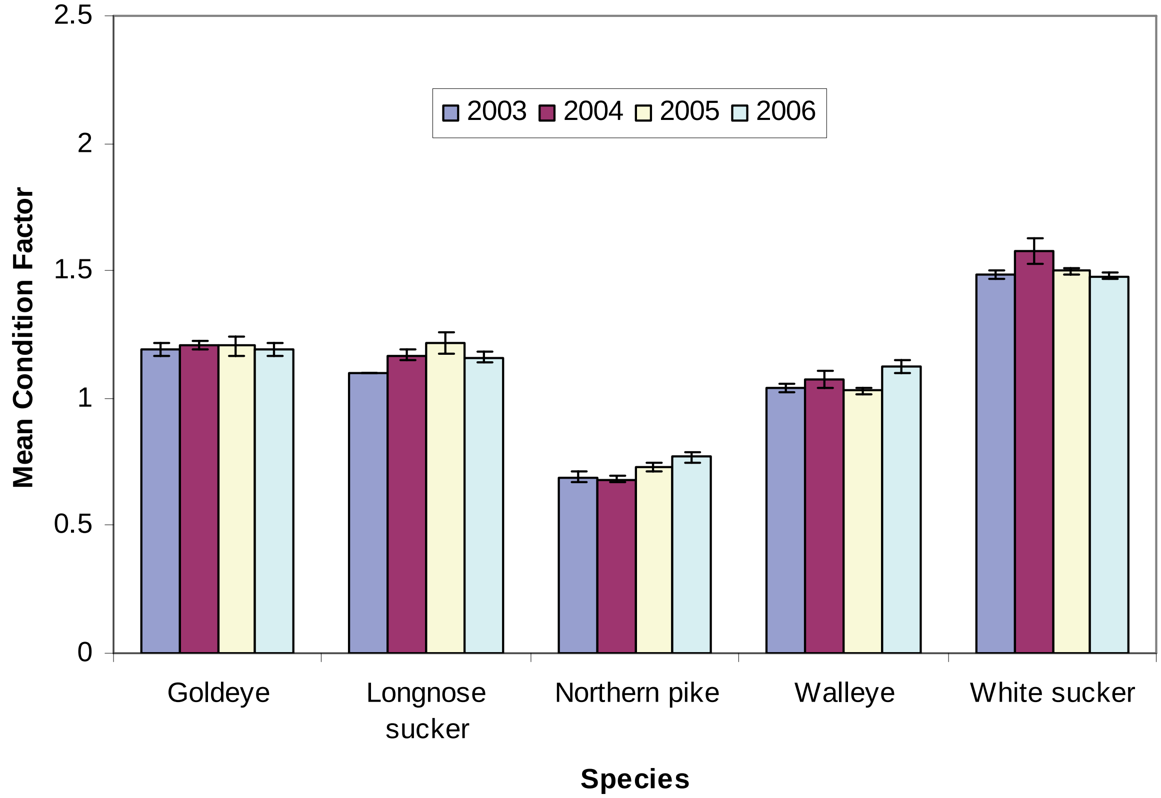


Table 5.10-14 Comparison of external pathology indices for fish captured during the Clearwater River (2004 to 2006) and Athabasca River (1995 to 2006) inventories.

	External Pathology Index, Athabasca River									External Pathology Index, Clearwater River		
	1995	**1997**	**1998**	**1999**	**2002**	**2003**	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
Goldeye	9.6	4.3	0.5	3.7	0.4	1.9	0.7	0.8	0.6	0.2	0.4	1.9
Longnose sucker	11	5.8	3.5	4.1	0.9	0.5	1.3	1.1	0.7	0.3	1.1	1.0
Walleye	2.8	1.5	2.1	18.3	1.4	1.1	2.4	1.5	1.2	0.5	0.2	0.7
White sucker	18.6	3.2	9.6	5.7	0.6	7.1	3.4	2.5	1.6	0.7	0.8	1.4
Northern pike	nc	nc	nc	nc	nc	nc	1.2	2.5	0.8	2.3	2.5	1.7

nc – none caught

Table 5.10-15 Metrics and mercury concentrations in northern pike collected from the Clearwater River, fall 2006.

Species	Sex	FishID	Stage	Fork Length (mm)	Age	Mercury Concentration (mg/kg)
NRPK	F	06CR01	A	630	5	101
NRPK	M	06CR02	A	503	6	143
NRPK	M	06CR03	A	432	3	114
NRPK	M	06CR04	A	497	4	170
NRPK	M	06CR05	A	443	4	187
NRPK	M	06CR06	A	459	4	152
NRPK	F	06CR07	A	494	3	130
NRPK	F	06CR08	A	495	5	281
NRPK	F	06CR09	A	564	4	174
NRPK	F	06CR10	A	585	5	347
NRPK	U	06CR11	I	330	3	111
NRPK	U	06CR12	I	425	3	102
NRPK	F	06CR13	A	810	7	317
NRPK	F	06CR14	A	730	5	298
NRPK	M	06CR15	A	800	7	402
NRPK	M	06CR16	A	660	5	269
NRPK	F	06CR17	A	720	7	298
NRPK	M	06CR18	A	397	4	161
NRPK	U	06CR23	I	315	2	92.3
NRPK	U	06CR24	I	289	2	83.4
NRPK	U	06CR25	I	259	1	91.8
NRPK	U	06CR26	I	264	2	90.8
NRPK	U	06CR27	I	261	1	93.1
NRPK	U	06CR28	I	254	3	92.2
NRPK	F	06CR29	A	504	2	169
NRPK	F	06CR30	A	392	2	119

F – female; M – male; U – undetermined; A – adult; I – immature

Table 5.10-16 Correlations between mercury concentration in northern pike muscle from Clearwater River versus length, and age, fall 2006.

Organism Metric	Correlation with Mercury Concentrations (r_s)		
	Male n=8	Female n=10	Combined n=26
Fork length	0.94	0.59	0.84
Age	0.76	0.70	0.80

Figure 5.10-14 Scatterplot of mercury concentration in northern pike muscle versus length, Clearwater River, 2006.

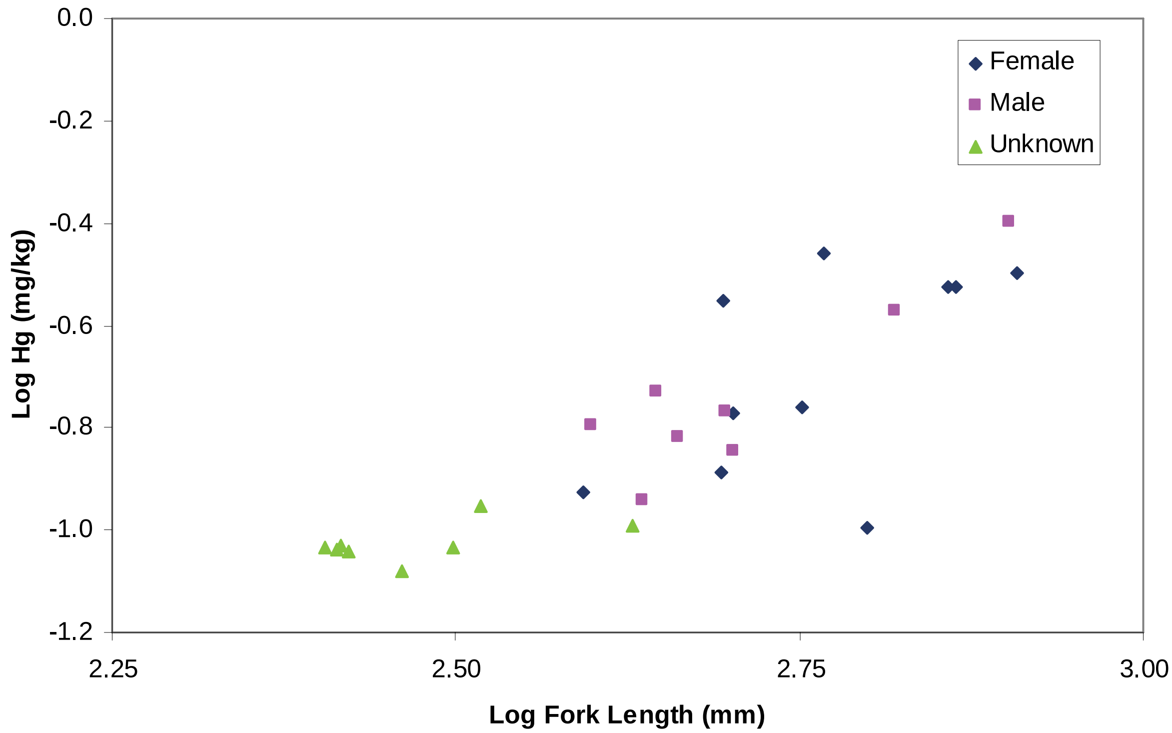


Figure 5.10-15 Scatterplot of mercury concentration in northern pike muscle versus age, Clearwater River, 2006.

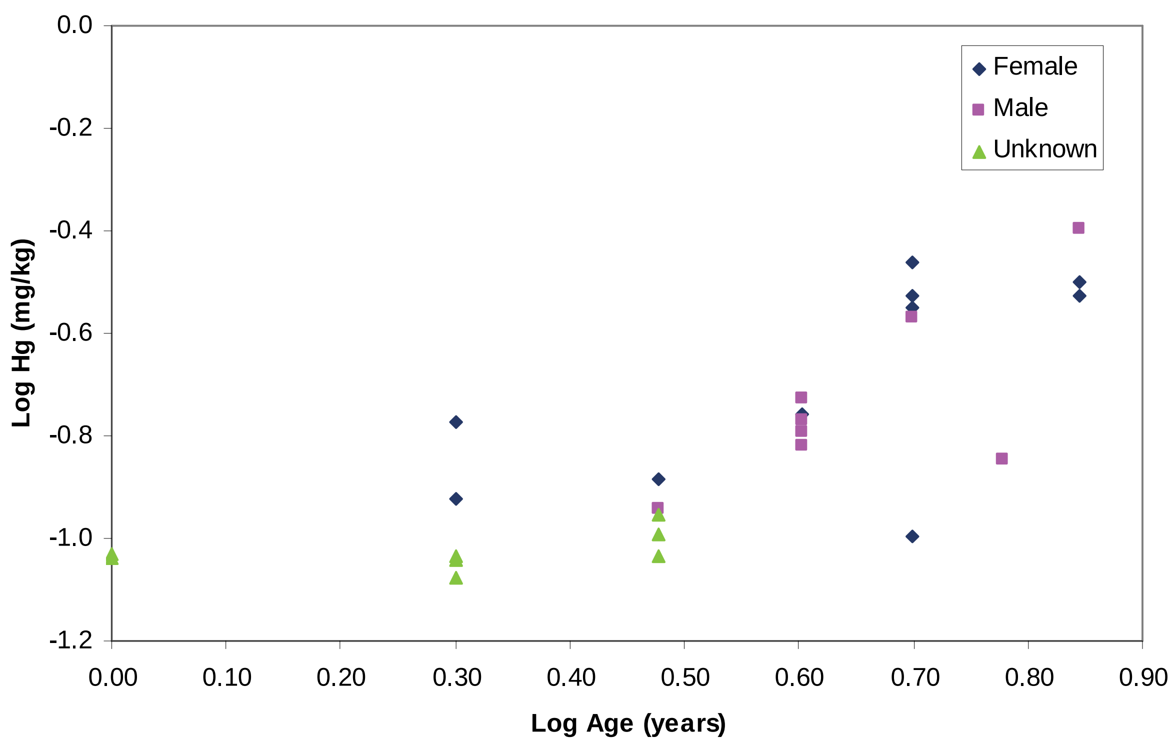
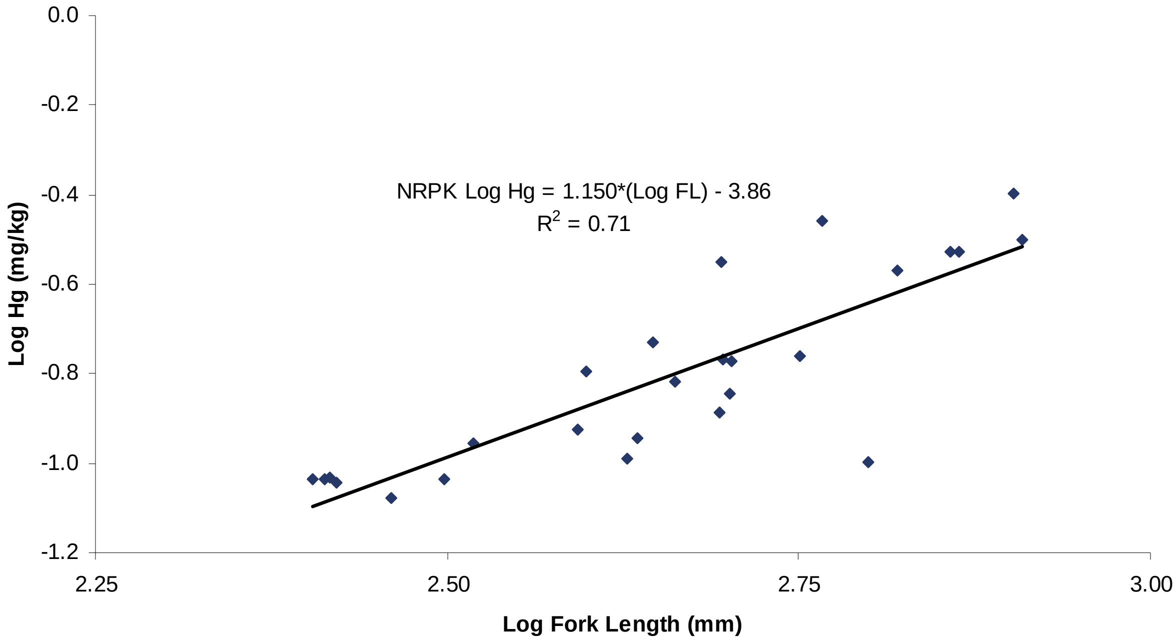


Figure 5.10-16 Regression analysis of mercury concentration in fish muscle versus length and age for northern pike from the Clearwater River, fall 2006.



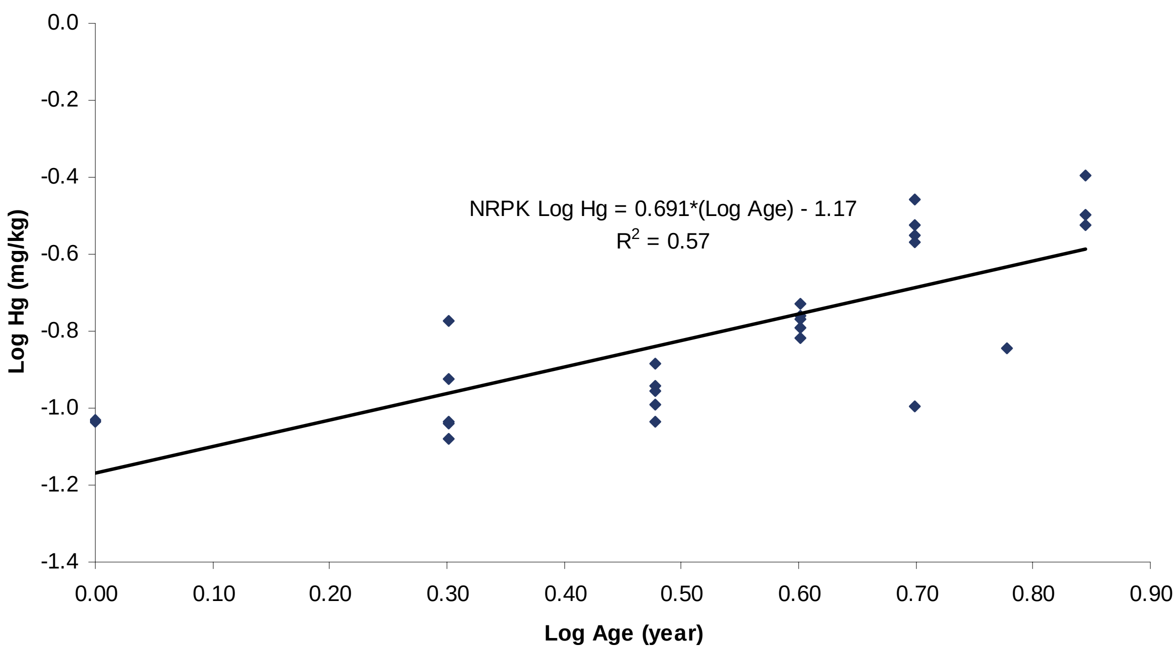


Table 5.10-17 Screening of metals and tainting compounds in northern pike composite samples collected in 2006 from the Clearwater River against criteria fish consumption for the protection of human health.

	UNITS	DL	Composite NRPK		Health Canada Criteria[1]		National USEPA		Region III USEPA[2]
			Female	Male	General	Subsistence	Recreational	Subsistence	Risk-based Criteria
Total Metals									
Aluminum (Al)	mg/kg	2	<2	<2	nc	nc	nc	nc	nc
Antimony (Sb)	mg/kg	0.05	<0.05	<0.05	nc	nc	nc	nc	0.54
Arsenic (As)	mg/kg	0.01	***0.03***	***0.04***	nc	nc	0.026	0.00327	0.0021
Barium (Ba)	mg/kg	0.1	<0.1	0.1	nc	nc	nc	nc	270
Beryllium (Be)	mg/kg	0.2	<0.2	<0.2	nc	nc	nc	nc	2.7
Boron (B)	mg/kg	2	<2	<2	nc	nc	nc	nc	120
Cadmium (Cd)	mg/kg	0.01	<0.01	<0.01	nc	nc	nc	nc	1.4
Calcium (Ca)	mg/kg	20	230	380	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	<0.1	<0.1	nc	nc	nc	nc	4.1
Cobalt (Co)	mg/kg	0.1	<0.1	<0.1	nc	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.20	0.32	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	5	<5	5	nc	nc	nc	nc	410
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	nc	nc	nc	nc	nc
Lithium (Li)	mg/kg	0.5	<0.5	<0.5	nc	nc	nc	nc	27
Manganese (Mn)	mg/kg	0.5	<0.5	<0.5	nc	nc	nc	nc	190
Molybdenum (Mo)	mg/kg	0.05	<0.05	<0.05	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	0.02	<0.02	<0.02	nc	nc	nc	nc	27

value = exceeds USEPA screening value for subsistence fishers; ***value*** = exceeds Region III risk-based criteria

value = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] last updated 15 December 2005; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] last updated 31 October 2006; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

[3] Naphthalene was tested for three target analytes: 1-Methylnapthalene, 2,6-Dimethylnaphthalene, and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg and the have the heath criteria guideline

Table 5.10-17 Cont'd.

	UNITS	DL	Composite NRPK		Health Canada Criteria[1]		National USEPA		Region III USEPA[2]
			Female	Male	General	Subsistence	Recreational	Subsistence	Risk-based Criteria
Total Metals Cont'd.									
Selenium (Se)	mg/kg	0.002	0.144	0.110	nc	nc	20	2.457	6.8
Silver (Ag)	mg/kg	0.02	<0.02	<0.02	nc	nc	nc	nc	6.8
Strontium (Sr)	mg/kg	0.05	0.24	0.59	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	0.05	<0.05	<0.05	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	0.1	<0.1	<0.1	nc	nc	nc	nc	810
Titanium (Ti)	mg/kg	0.05	0.35	<0.05	nc	nc	nc	nc	nc
Vanadium (V)	mg/kg	0.006	0.019	0.028	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	0.5	4.5	6.7	nc	nc	nc	nc	410
Tainting Compounds									
Thiophene	mg/kg	0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	nc	nc	nc	nc	110
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	nc	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Naphthalene[3]	mg/kg	0.05	<0.05	<0.05	nc	nc	nc	nc	nc

value = exceeds USEPA screening value for subsistence fishers; ***value*** = exceeds Region III risk-based criteria

value = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] last updated 15 December 2005; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] last updated 31 October 2006; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

[3] Naphthalene was tested for three target analytes: 1-Methylnapthalene, 2,6-Dimethylnaphthalene, and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg and the have the heath criteria guideline

Table 5.10-18 Screening of mercury concentrations in northern pike from the Clearwater River against criteria for fish consumption for the protection of human health, fall 2006.

Mercury Screening Criteria		**Mercury Concentration (mg/kg)**
Health Canada	*General Consumer*	0.50
	Subsistence Fishers	0.20
Region III USEPA Risk-Based Criterion[1]		0.14
National USEPA Criteria[2]	Recreational Fishers	0.40
	Subsistence Fishers	0.049
Mercury Concentrations in Clearwater River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Northern pike	Female	0.101
		0.130
		0.281
		0.174
		0.347
		0.317
		0.298
		0.298
		0.169
		0.119
		0.101
	Male	0.143
		0.114
		0.170
		0.187
		0.152
		0.402
		0.269
		0.161
	Immature	0.111
		0.102
		0.0923
		0.0834
		0.0918
		0.0908
		0.0931
		0.0922

[1] Region III USEPA risk-based criteria for fish consumption are based on a 70 kg individual consuming 54 g of fish per day over a 30-year period (USEPA 2003). Criterion is for methyl mercury. Criteria last updated April 2006.

[2] National USEPA screening values for recreational fishers are based on a 70 kg individual consuming 17.5 g of fish per day over a 70-year period; screening values for subsistence fishers are based on a 142.4 kg individual consuming 17.5 g of fish per day over a 70-year period (USEPA 2000). Criterion is for methyl mercury.

Table 5.10-19 Screening of mercury concentrations in northern pike from the Clearwater River against criteria for the protection of fish, fall 2006.

Effects Thresholds for Fish[1]		Mercury Concentration (mg/kg)
No effects – lethal		1.91
No effects – sublethal		2.28
Effects - lethal		6.2
Effects - sublethal		8.6
Mercury Concentrations in Clearwater River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Northern pike	Female	0.101
		0.130
		0.281
		0.174
		0.347
		0.317
		0.298
		0.298
		0.169
		0.119
		0.101
	Male	0.143
		0.114
		0.170
		0.187
		0.152
		0.402
		0.269
		0.161
	Immature	0.111
		0.102
		0.0923
		0.0834
		0.0918
		0.0908
		0.0931

[1] Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.10-20 Screening of metals and tainting compounds in northern pike composite samples collected in 2006 from the Clearwater River against criteria for the protection of fish.

Analyte	UNITS	DL	Composite NRPK		Thresholds for the Protection of Fish			
					Lowest no-effects Thresholds		Lowest Effects Thresholds	
			Female	Male	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Total Metals								
Aluminum (Al)	mg/kg	2	*<2*	*<2*	1.0	nc	20	nc
Antimony (Sb)	mg/kg	0.05	<0.05	<0.05	5	nc	9	nc
Arsenic (As)	mg/kg	0.01	0.03	0.04	2.6	0.9	11.2	3.1
Cadmium (Cd)	mg/kg	0.01	<0.01	<0.01	0.02	0.09	0.14	0.12
Copper (Cu)	mg/kg	0.05	0.20	0.32	0.5	3.4	0.5	nc
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	4.0	nc	nc	nc
Nickel (Ni)	mg/kg	0.02	<0.02	<0.02	0.82	nc	118.1	nc
Selenium (Se)	mg/kg	0.002	*0.144*	*0.110*	0.28	0.08	0.92	0.32
Silver (Ag)	mg/kg	0.02	*<0.02*	*<0.02*	0.003	0.003	nc	nc
Vanadium (V)	mg/kg	0.006	0.019	*0.028*	5.33	0.02	nc	0.41
Zinc (Zn)	mg/kg	0.5	4.5	6.7	60	60	nc	nc

Note: Only analytes with a at least one criteria concentration are reported. None of the tainting compounds had any criteria for the protection of fish.

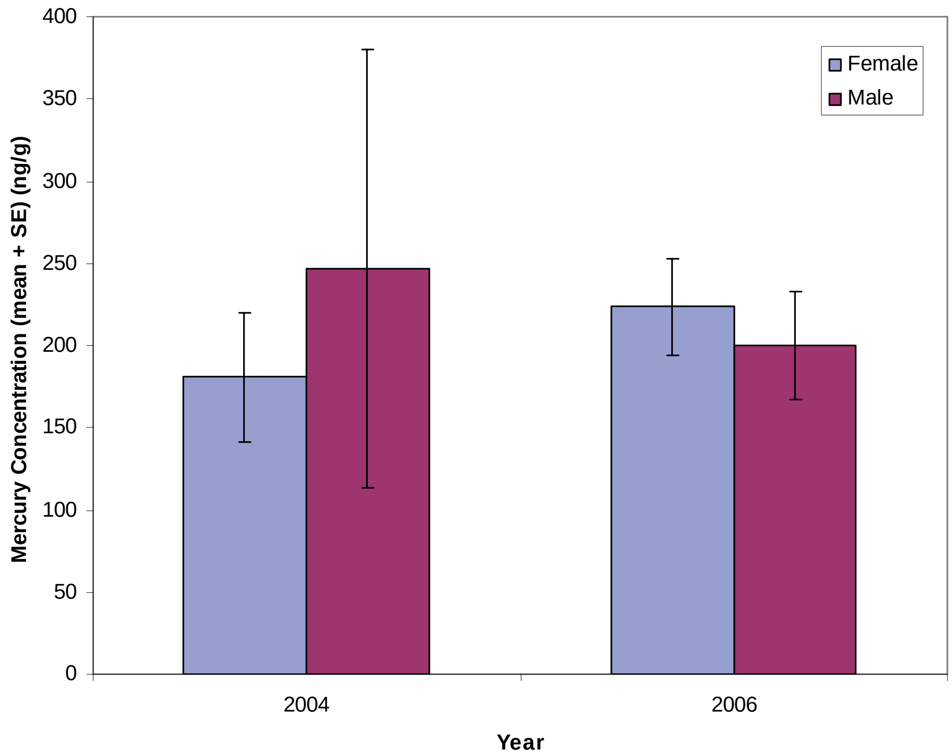
value = exceeds lethal or sublethal no effects threshold; effects have not been observed at this concentration.

value = exceeds lethal or sublethal effects threshold; effects have been observed at this concentration.

nc = no criteria; DL – detection limit

[1] Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Figure 5.10-17 Temporal comparison of mercury concentration in northern pike from the Clearwater River, 2004 and 2006.



5.11 HANGINGSTONE RIVER WATERSHED

Summary of Results

Measurement Endpoint — **Summary of 2006 Conditions**

Climate and Hydrology

	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	√			
Mean winter discharge	not measured			
Annual maximum daily discharge	√			
Minimum open-water season discharge	√			

Total 2006 runoff volume was about half of normal. All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of oil sands development. The estimated effect in the measurement endpoints are assessed as Negligible.

Water Quality

Guideline Exceedances

Measurement endpoints with guidelines	Station-Endpoint Combinations Exceeding Guidelines in Fall 2006[1]: 2006 *Potentially Influenced* Stations (n=0)	2006 Reference Stations (n=1)
Physical variables (max=1)	No water quality sampling stations were designated as *potentially influenced* in 2006.	0
Nutrients (max=3)		0
Ions (max=2)		0
Selected metals (max=5)		1

Comparison to Regional Baselines

Percentile of Regional Baseline Values	Endpoints in 2006 Compared to Regional Baseline[2]: 2006 *Potentially Influenced* Stations (n=0 stations X 13 endpoints)	2006 *Reference* Stations (n=1 station X 13 endpoints)
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced* in 2006.	0
Between 5th and 95th percentiles		13
Less than 5th percentile		0

Based on the available water quality and oils sands development information there have been no water quality effects of focal projects in the Hangingstone River, and no cumulative, watershed-level changes in water quality conditions in the Hangingstone River watershed caused by all approved and operational oil sands development activities in the watershed have been detected.

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines

Values in Relation to Regional Baseline Mean	Endpoints in 2006 Compared to Regional Baseline: 2006 *Potentially Influenced* Sites (n=0)			2006 *Reference* Sites (n=1)		
	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above
Abundance					1	
Richness					1	
Diversity					1	
Evenness					1	
% EPT					1	

Sediment Quality Guideline Exceedances

Measurement endpoints with guidelines	Station-Endpoint Combinations Exceeding Guidelines in 2006: 2006 *Potentially Influenced* Sites (n=0)	2006 *Reference* Sites (n=0)
Total Hydrocarbons	No sediment quality sampling was conducted in Hangingtsone River watershed in 2006.	
PAHs		

Similar to previous years, chironomids, mayflies, stoneflies, caddisflies and mites dominated the benthic invertebrate community in reach HAR-E-1 in fall 2006. Values of all benthic invertebrate community measurement endpoints were similar in fall 2006 to values measured in previous years.

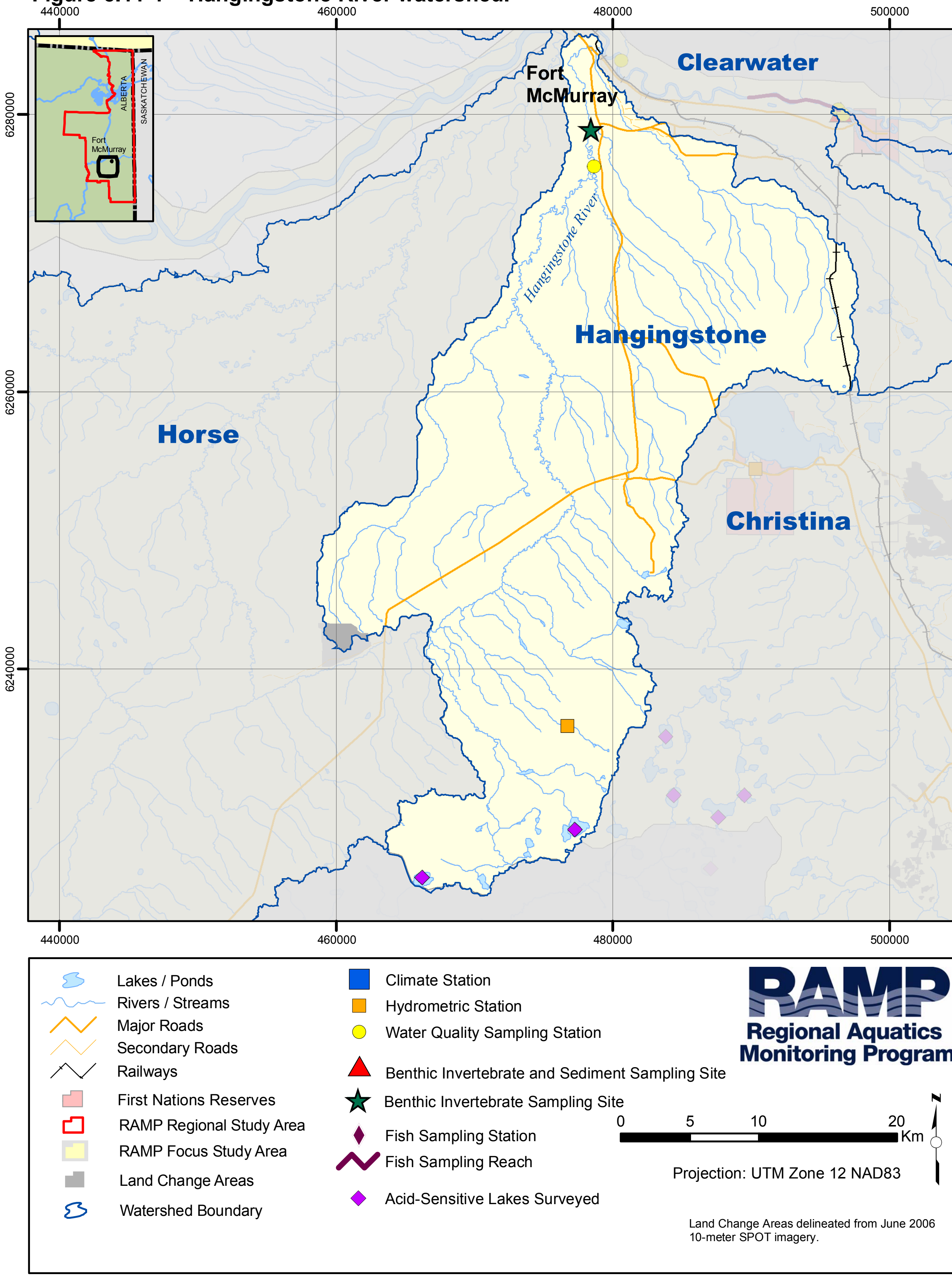
Fish Populations

Fish Inventory	No fish inventory studies conducted in Hangingstone River watershed in 2006.
Sentinel Studies	No sentinel fish studies conducted in Hangingstone River watershed in 2006.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

Figure 5.11-1 Hangingstone River watershed.



5.11.1 Development Status

All parts of the Hangingstone River watershed are designated as *reference* for 2006. As of 2006, none of the 2006 focal projects were located in the watershed and, approximately 0.4% of the watershed area had undergone land change from oil sands activities from non-RAMP-member companies. Therefore, all RAMP stations in the Hangingstone River watershed in 2006 are designated as *reference* stations and all data gathered at these stations up to and including 2006 are designated as baseline data.

5.11.2 Hydrologic Conditions

2006 Hydrologic Conditions Total runoff volume in the Hangingstone River watershed, as measured at WSC Station 07CD004, Hangingstone River at Fort McMurray, was only about half of normal in 2006, with a May to October runoff depth of 53 mm compared to the long-term average of 100 mm (Figure 5.11-2). Most of the runoff occurred in April and May. By early June, streamflow subsided to below median levels and remained low for the summer and fall, reaching record low levels (for the time of year) in August and September. The July rainfall event that produced a large runoff response elsewhere in the Fort McMurray region was relatively insignificant in the Hangingstone River watershed. The highest maximum daily discharge of 16 m^3/s, which occurred in mid-May, was less than half of the mean annual flood of 40.0 m^3/s. The lowest discharge of the open-water season was 0.13 m^3/s; the mean annual minimum open-water discharge is 0.96 m^3/s.

Estimation of Hydrologic Effects An assessment was made of the hydrologic effects of the land change area in the Hangingstone River watershed even though the watershed is designated as *reference* for 2006. As indicated in Section 3.1.7.2, the methodology of the hydrologic assessment, unlike the methodology of the other RAMP components (with the exception of the Acid-Sensitive Lakes component), does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted even in watersheds whose entire area is designated as *reference*.

Because there were no focal projects operating within the Hangingstone River watershed, there have been to date no effects of RAMP-funder projects on hydrologic measurement endpoints in the Hangingstone River watershed. As indicated above, however, there were oil sands activities from non-RAMP-member companies operating within the watershed as of 2006. A summary of the inputs to the water balance model for the Hangingstone River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.11-1. As of 2006, areas of closed-circuited land change was 3.86 km^2 in the Hangingstone River watershed as a result of non-RAMP-member company oil sands projects in the watershed (Table 2.6-1), the estimated net effects of which were to reduce inflows to the Hangingstone River by 0.216 million m^3 in 2006. The estimated cumulative effect in 2006 is that mean open-water season discharge was reduced by 0.2%, annual maximum daily discharge was decreased by 0.3% and open-water season minimum daily discharge was reduced by 0.2%. All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of these oil sands development activities (Figure 5.11-2, Table 5.11-2). This calculated incremental change in the hydrologic measurement endpoints would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic and oils sands development information:

- As of 2006, there have been no hydrologic effects of focal projects in the Hangingstone River watershed; and

- Cumulative, watershed-level changes in hydrologic conditions in the Hangingstone River watershed caused by land change from all approved and operational oil sands development activities in the watershed as of 2006 have been negligible.

5.11.3 Water Quality

In 2006, water quality sampling was conducted at the mouth of the Hangingstone River (station HAR-1) in spring, summer, and fall. Station HAR-1 has been designated as a *reference* station up to and including 2006.

2006 Results and Historical Ranges of Concentration In fall 2006, concentrations of several water quality measurement endpoints were greater or less than previously-measured results (Table 5.11-3). All ions, as well as pH, conductivity, total dissolved solids, dissolved phosphorus, total boron, and total molybdenum were equal to or greater than the previously-measured maximum, while total suspended solids, total nitrogen, dissolved organic carbon, and dissolved aluminum were lower than the previously-measured minimum.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with concentrations that exceeded water quality guidelines at the mouth of the Hangingstone River (station HAR-1) in 2006 (Table 5.11-4); the total aluminum water quality guideline was exceeded in 2006 in spring, summer, and fall.

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines of the following water quality variables not designated as water quality measurement endpoints were exceeded at the mouth of the Hangingstone River (station HAR-1) in 2006 (Table 5.11-4):

- Sulphide, total phosphorus, total cadmium, total chromium, total iron, and total phenols in spring 2006;
- Sulphide, dissolved iron, total iron, and total phenols in summer 2006; and
- Sulphide, total phosphorus, dissolved iron, total iron, and total phenols in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions All selected water quality measurement endpoints measured at mouth of the Hangingstone River (station HAR-1) in fall 2006 were at or between the 5th and 95th percentile of regional baseline concentrations (Figure 5.11-3). In addition, there are no apparent trends in the selected water quality measurement endpoints in the three years that water quality has been measured at the mouth of the Hangingstone River (station HAR-1).

Ion Balance Ionic composition at the mouth of the Hangingstone River (station HAR-1) in 2006 was similar to that observed in 2004 and 2005, and continues to be dominated by calcium bicarbonate (Figure 5.11-4).

Summary Based on the available water quality and oils sands development information there have been no water quality effects of focal projects in the Hangingstone River, and no cumulative, watershed-level changes in water quality conditions in the Hangingstone River watershed caused by all approved and operational oil sands development activities in the watershed have been detected.

5.11.4 Benthic Invertebrate Communities and Sediment Quality

5.11.4.1 Benthic Invertebrate Communities

In 2006, benthic invertebrate community samples were collected from a lower erosional reach in the Hangingstone River (reach HAR-E-1, *reference*, first sampled in 2004).

2006 Habitat Conditions The substrate in 2006 at reach HAR-E-1 was dominated by cobble and boulder, with finer particles in the interstices (Table 5.11-5). Current velocities were relatively high (0.5 m/s), while measured periphyton chlorophyll *a* biomass in fall 2006 was similar to previous years and indicative of oligotrophic status for the lower Hangingstone River (Figure 5.11-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Similar to previous years, chironomids, mayflies, stoneflies, caddisflies and mites dominated the benthic invertebrate community in reach HAR-E-1 in fall 2006 (Table 5.11-6). Diversity has been relatively high with 29 taxa (average) in 2006, and Simpson's diversity and evenness near 0.9. A number of sensitive benthic taxa were found in 2006 including the mayfly *Ephemerella*, the stoneflies, *Isoperla*, and *Taeniopteryx*, the caddisfly *Psychomyia*, and the empidid *Hemerodromia*. Other mayflies included the large group *Baetis*, *Heptagenia* and *Rithrogena*. Chironomids were diverse, with *Rheotanytarsus* and *Cricotopus*/*Orthocladius* about the most common.

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions Values of all benthic invertebrate community measurement endpoints were similar in fall 2006 to values measured in previous years (Figure 5.11-6).

5.11.4.2 Sediment Quality

Because the lower reach in the Hangingstone River sampled for benthic invertebrate communities (reach HAR-E-1) is an erosional reach, no sediment quality sampling was conducted in the Hangingstone River watershed in 2006.

5.11.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2006 continued to be within the normal range of regional baseline conditions for similar habitats in the RAMP FSA.

5.11.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in the Hangingstone River watershed.

5.11.6 Summary of Conditions

2006 results confirm that the Hangingstone River is a typical Athabasca River basin watershed, with RAMP aquatic resources in 2006 within the range of regional baseline conditions for similar watersheds and habitat types. As of 2006, there have been no detectable effects of focal projects or cumulative, watershed-level changes in the Hangingstone River watershed.

Figure 5.11-2 Hangingstone River: 2006 hydrograph and historical context.

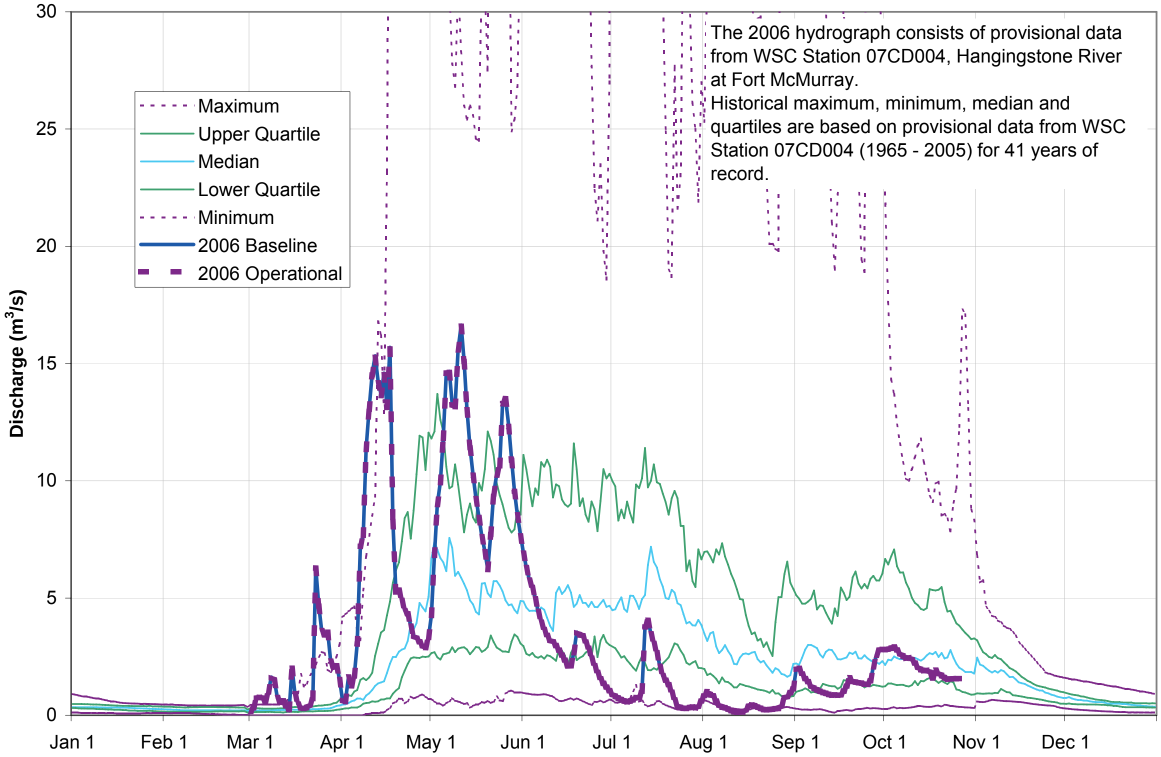


Table 5.11-1 Inputs for calculation of the baseline hydrograph at WSC Station 07CD004, Hangingstone River at Fort McMurray.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total annual discharge)	71.4	Sum of observed daily discharges, obtained from WSC Station 07CD004, Hangingstone River at Fort McMurray
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.216	3.86 km^2 within Hangingstone River drainage estimated to have been closed-circuited by focal projects and other oil sands projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	0	0 km^2 within Hangingstone River drainage estimated to have undergone land change by focal projects and other oil sands projects as of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Hangingstone River for focal project activities and other oil sands development projects	0	None reported, assumed to be negligible
Releases to Hangingstone River for focal project activities and other oil sands development projects	0	None reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Hangingstone River not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	71.6	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2006
Incremental flow (change in total annual discharge)	- 0.216	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.3%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.11-2 Calculated change in hydrologic measurement endpoints for the Hangingstone River watershed for 2006.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	3.23	3.22	-0.2%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	16.6	16.6	-0.3%
Open-water season minimum daily discharge	0.126	0.126	-0.2%

Note: As measured at WSC Station 07CD004, Hangingstone River at Fort McMurray.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.11-3 Concentrations of water quality measurement endpoints, mouth of Hangingstone River (station HAR-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	2	8.0	-	8.2
Total Suspended Solids	mg/L	-[1]	<3	2	5	-	12
Conductivity	µS/cm	-	278	2	231	-	233
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.049	2	0.038	-	0.046
Total nitrogen*	mg/L	1.0	0.7	2	0.9	-	0.9
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	17	2	21	-	28
Ions							
Sodium	mg/L	-	21	2	17	-	17
Calcium	mg/L	-	31.5	2	23.2	-	25.7
Magnesium	mg/L	-	8.3	2	7.2	-	7.4
Chloride	mg/L	230, 860[3]	13	2	9	-	13
Sulphate	mg/L	100[4]	11.8	2	10	-	10.4
Total Dissolved Solids	mg/L	-	210	2	170	-	190
Total Alkalinity	mg/L	-	119	2	88	-	99
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	**0.18**	2	**0.17**	-	**0.42**
Dissolved aluminum	mg/L	0.1[2]	0.0113	2	0.0138	-	0.0296
Total boron	mg/L	1.2[5]	0.087	2	0.061	-	0.066
Total molybdenum	mg/L	0.073	0.00156	2	0.000746	-	0.000988
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.1	2	<0.6	-	1.2
Total strontium	mg/L	-	0.179	2	0.123	-	0.128

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.11-4 List of all 2006 water quality guideline exceedances, Hangingstone River (station HAR-1).

Variable	Units	Guideline*	HAR-1
Spring			
Sulphide	mg/L	0.002[1]	**0.011**
Total phosphorus	mg/L	0.05	**0.061**
Total aluminum	mg/L	0.1	**1.51**
Total cadmium	mg/L	-[2]	**0.0000283**
Total chromium	mg/L	0.0010, 0.0089[3]	**0.00179**
Total iron	mg/L	0.3	**1.46**
Total phenols	mg/L	0.004	**0.006**
Summer			
Sulphide	mg/L	0.002[1]	**0.014**
Total aluminum	mg/L	0.1	**0.41**
Dissolved iron	mg/L	0.3[4]	**0.62**
Total iron	mg/L	0.3	**1.3**
Total phenols	mg/L	0.004	**0.018**
Fall			
Sulphide	mg/L	0.002[1]	**0.008**
Total phosphorus	mg/L	0.05	**0.068**
Total aluminum	mg/L	0.1	**0.18**
Dissolved iron	mg/L	0.3[4]	**0.772**
Total iron	mg/L	0.3	**1.42**
Total phenols	mg/L	0.004	**0.011**

No winter sampling was conducted in this watershed.

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

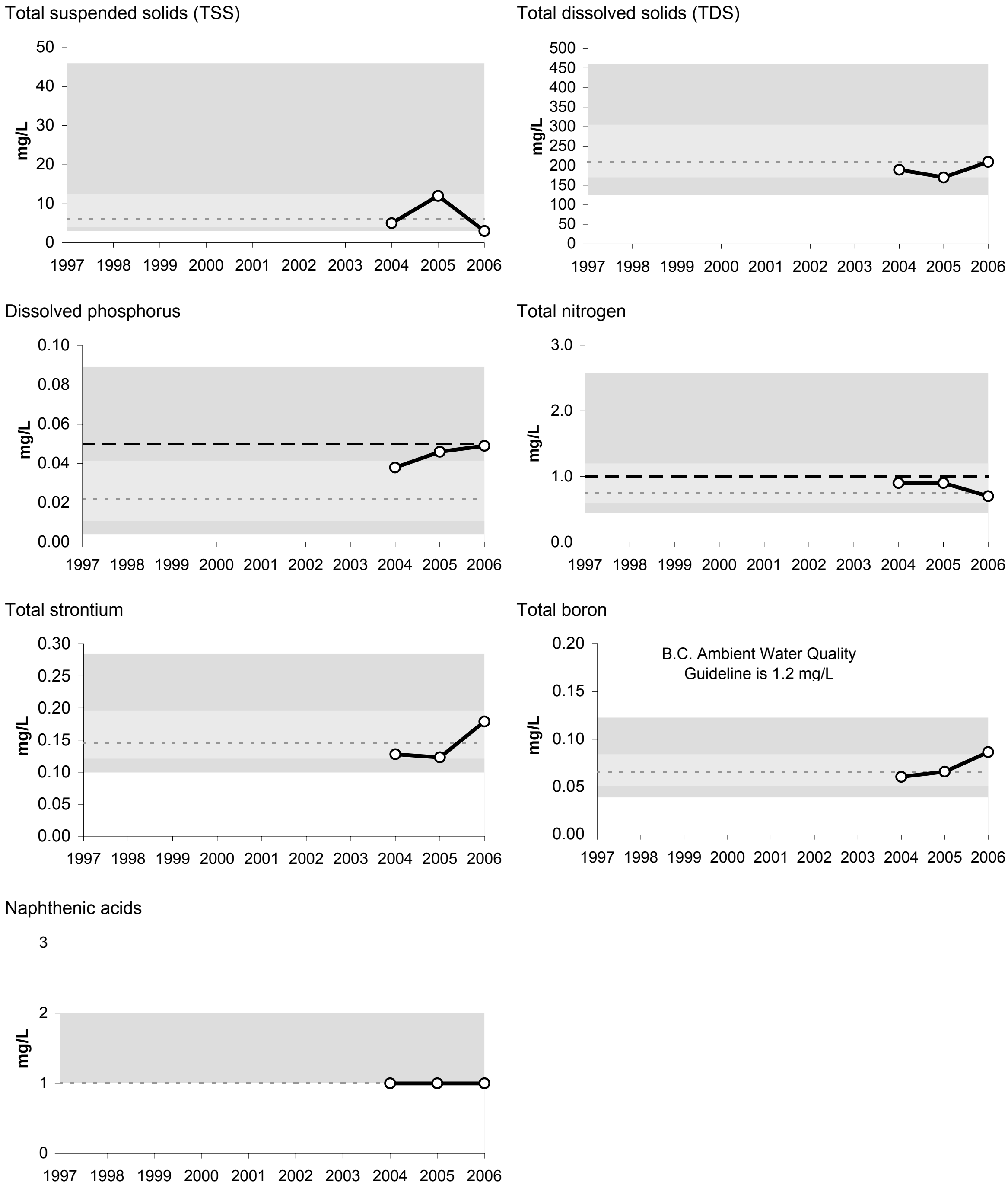
[1] B.C. Working Water Quality Guideline for sulphide as H_2S (2001).

[2] Guideline is hardness-dependent.

[3] Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

[4] Guideline is for total analyte (no guideline for dissolved species).

Figure 5.11-3 Concentrations of selected water quality measurement endpoints at the mouth of Hangingstone River (station HAR-1) (fall 2006) relative to regional baseline fall concentrations.

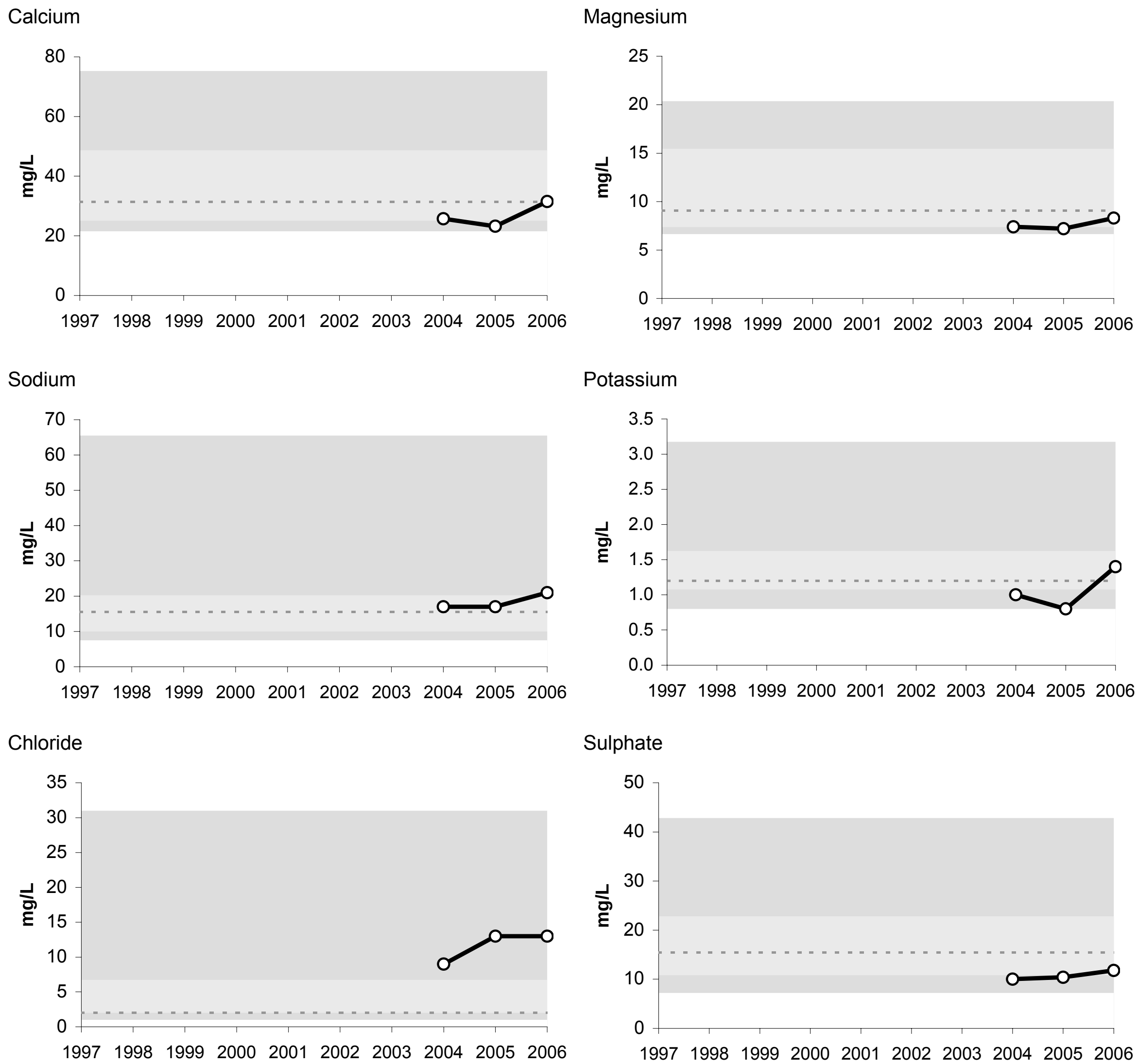


Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.

See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.11-3 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.

See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.11-4 Piper diagram of fall ion concentrations, mouth of Hangingstone River (station HAR-1).

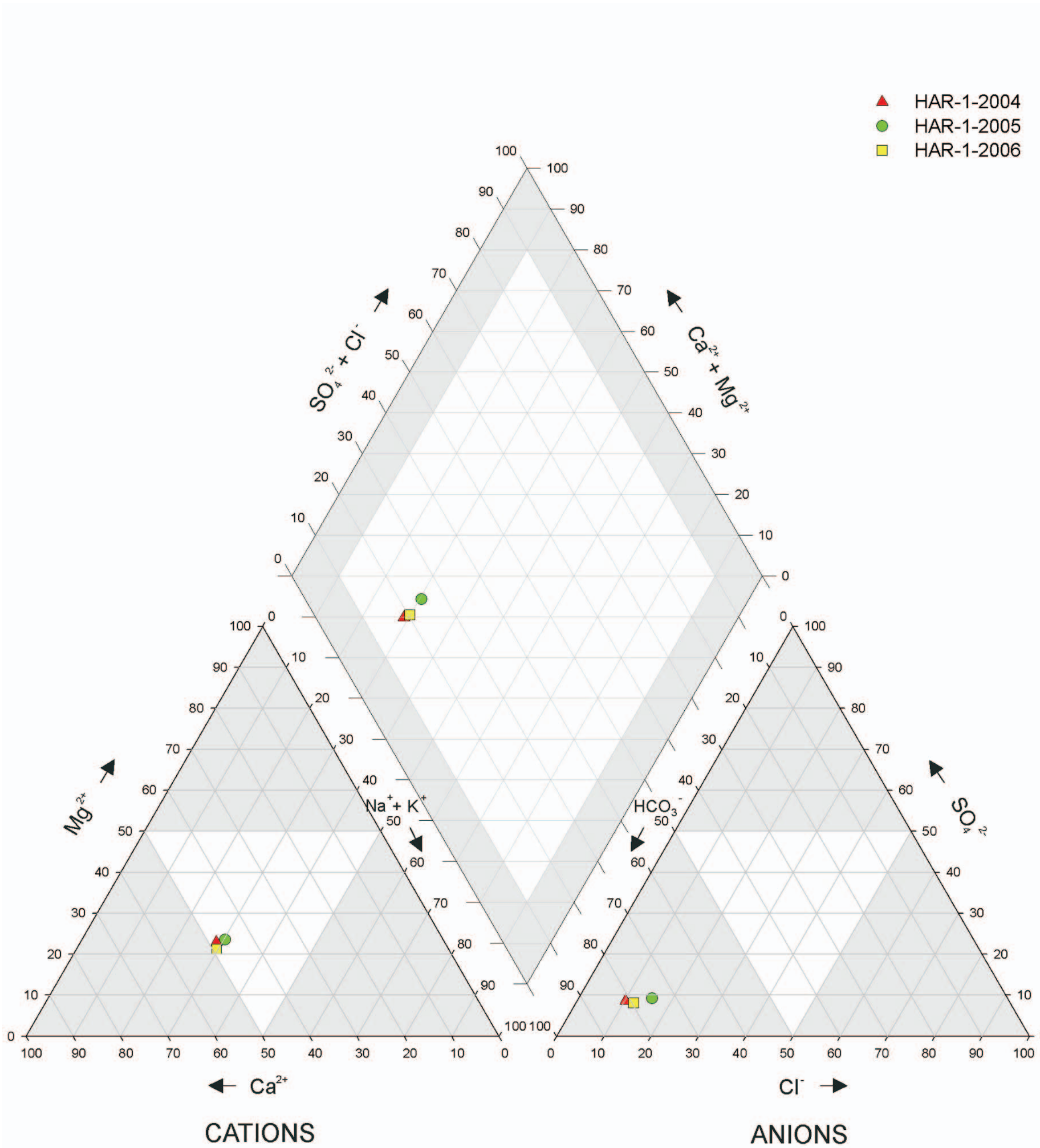


Table 5.11-5 Average habitat characteristics of benthic invertebrate community sampling reaches in the Hangingstone River, fall 2006.

Variable	Units	Lower Reach of Hangingstone River (Reach HAR-E-1)
Sample date	-	Sept 6, 2006
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	0.5
Macrophyte cover	%	0
Benthic algae	mg/m^2	67.5
Sand/Silt/Clay	%	10
Field Water Quality		
Dissolved oxygen	mg/L	8.2
Conductivity	µS/cm	333
pH	pH units	8.3
Water temperature	°C	17.7
Sediment Composition[1]		
Sand/Silt/Clay	%	8
Small gravel	%	6
Large gravel	%	5
Small cobble	%	17
Large cobble	%	24
Boulder	%	41
Bedrock	%	0

[1] Sediment composition may not total 100% due to rounding.

Figure 5.11-5 Annual variation in chlorophyll *a* in the lower reach of the Hangingstone River (reach HAR-E-1).

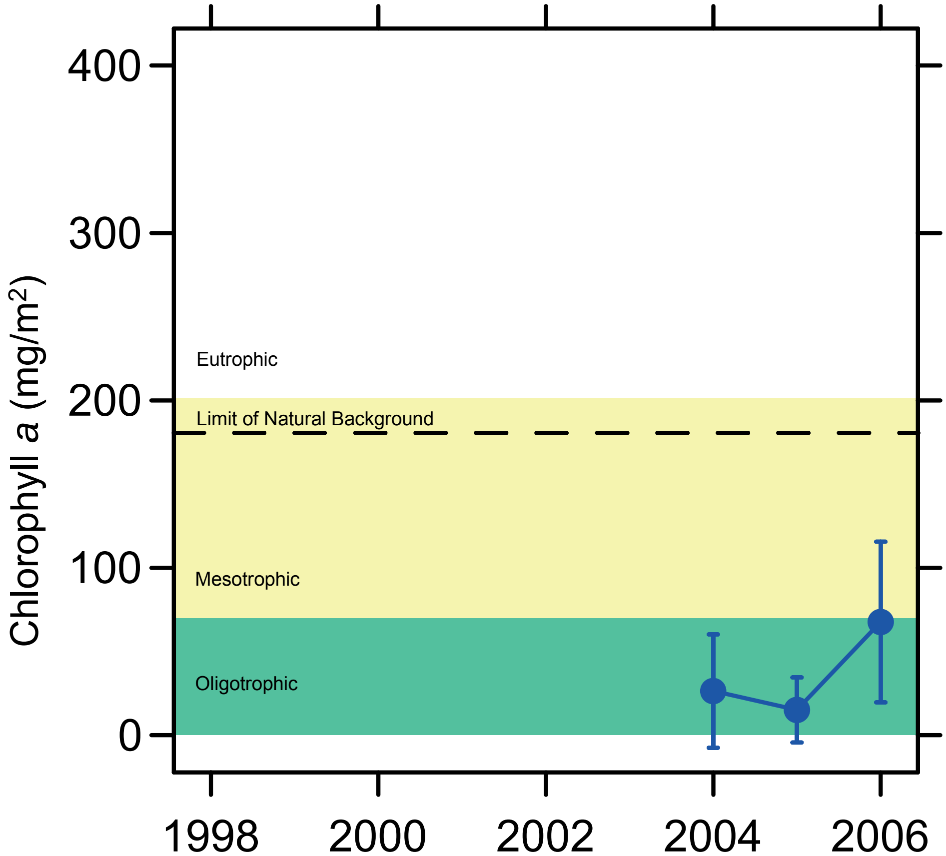
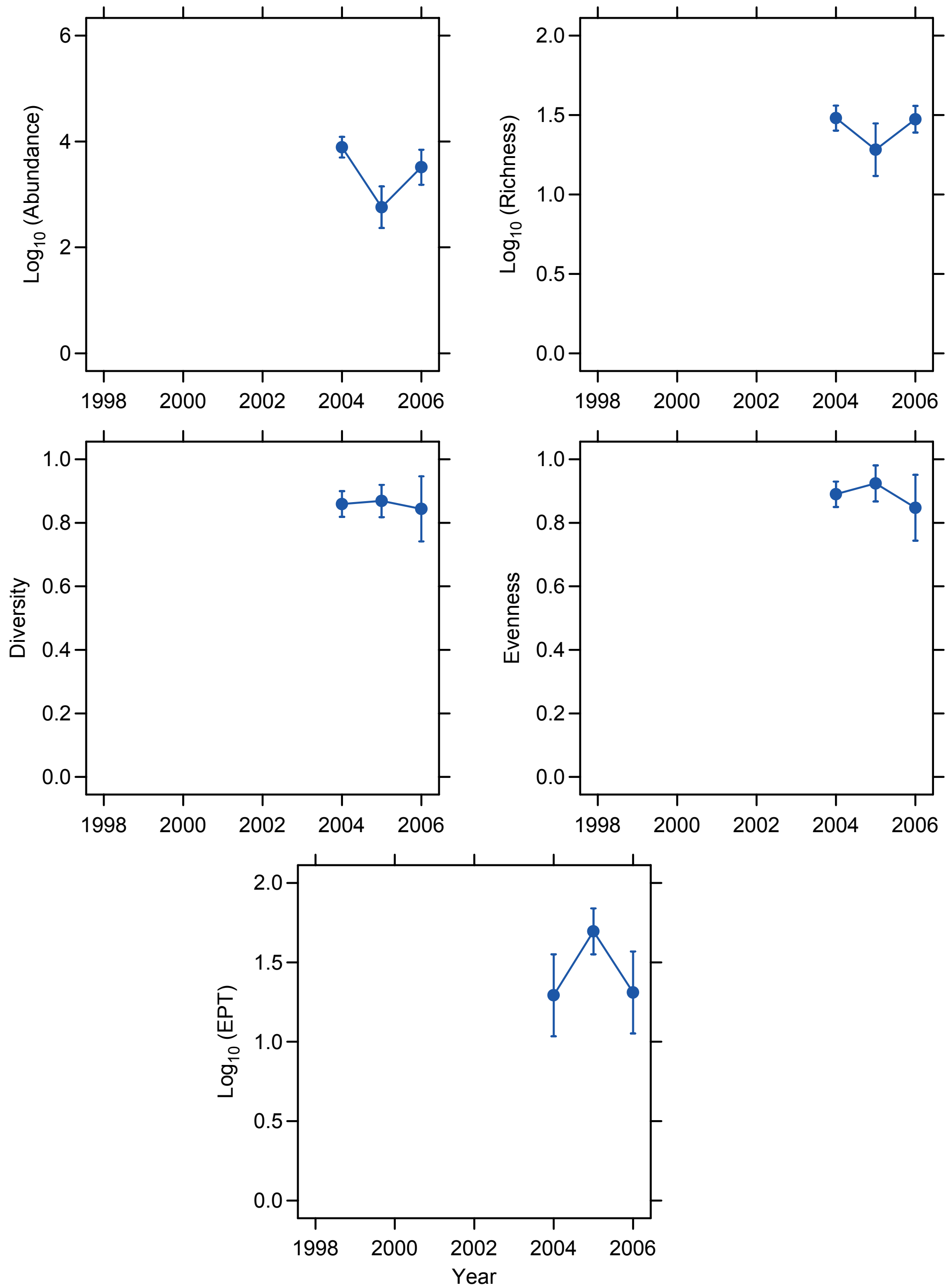


Table 5.11-6 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).

Taxon	% Major Taxa Enumerated in Each Year		
	Reach HAR-E-1		
	2004	2005	2006
Anisoptera	<1	1	<1
Athericidae	<1	3	1
Bivalvia	<1		
Ceratopogonidae	<1	<1	<1
Chironomidae	33	14	40
Coleoptera	<1	<1	<1
Collembola		<1	
Copepoda	<1	<1	
Dolichopodidae			
Empididae	2	2	4
Enchytraeidae	1	2	1
Ephemeroptera	16	34	11
Gastropoda	<1		
Hydra		1	
Hydracarina	6	13	5
Naididae	24	3	25
Nematoda	6	2	2
Ostracoda	5		<1
Plecoptera	3	10	2
Simuliidae		3	
Tabanidae	<1		
Tipulidae		<1	
Trichoptera	4	12	8
Tubificidae	<1	<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	8,560	773	4,255
Richness	30	19	29
Simpson's Diversity	0.86	0.87	0.84
Evenness	0.89	0.92	0.85
% EPT	21	50	21

Figure 5.11-6 Annual variation in benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).



5.12 MISCELLANEOUS AQUATIC SYSTEMS

Summary of Results

Measurement Endpoint	Summary of 2006 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√ (FC)			√ (PC)	Poplar Creek spillway is largest influence of focal project activities in miscellaneous aquatic systems. The 14 million m^3 spillway discharge in 2006 represents 92% of total 2006 flow at mouth of Poplar Creek. Minimum open-water season discharge could not be estimated for Poplar Creek.
Mean winter discharge	could not be assessed for Poplar Creek or Fort Creek				
Annual maximum daily discharge	√ (FC)			√ (PC)	
Minimum open-water season discharge	√ (FC)				

Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]		
Measurement endpoints with guidelines	2006 *Potentially Influenced* Stations (n=6)	2006 Reference Stations (n=2)	There was little to distinguish 2006 water quality conditions in the miscellaneous aquatic systems from previous years, with the exception of possible increased influence of groundwater on water quality due low precipitation in the RAMP FSA and reduced surface runoff north of Fort McMurray in 2006. There was little evidence of effects on focal project activities on water quality conditions in these aquatic systems in 2006. This section also summarizes fall 2006 sampling in the OPTI lakes (results not presented in this table).
Physical variables (max=6 for exp,2 for ref)	0	0	
Nutrients max=12 for exp,4 for ref)	2	1	
Ions (max=12 for exp,4 for ref)	0	0	
Selected metals max=30 for exp,10 for ref)	3	0	
Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2006 Potentially-Influenced Stations (n=6 stations X 13 endpoints)	2006 *Reference* Stations (n=2 stations X 13 endpoints)	
Greater than 95th percentile	19	1	
Between 5th and 95th percentiles	58	23	
Less than 5th percentile	1	2	

Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2006 Compared to Regional Baseline						
	2006 *Potentially Influenced* Stations (n=3)			2006 *Reference* Stations (n=2)			Benthic invertebrate communities that were sampled in 2006 were generally within the normal range of variation observed in reference lakes or regional reference conditions for watercourses of similar habitats. The exception is Isadore's Lake, sampled for the first time in 2006, with showed evidence of degraded benthic invertebrate community conditions. There was nothing in the results of sediment quality sampling in the potentially influenced system that would suggest effects of focal project activities, and there may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in Isadore's Lake
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance		3			2		
Richness		3			2		
Diversity		3			2		
Evenness	1	2			2		
% EPT	1	2			2		

Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2006[1]	
Measurement endpoints with guidelines	2006 *Potentially Influenced Stations* (n=3)	2006 *Reference* Stations (n=2)
Total Hydrocarbons(max=12 for exp,0 for ref)	2	1
PAHs (max=3 for exp, 0 for ref)	0	1
Metals	Arsenic: 2 lakes, Fort Creek	

Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2006.
Sentinel Studies	No sentinel fish studies conducted in 2006.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2006.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Water Quality Guidelines.

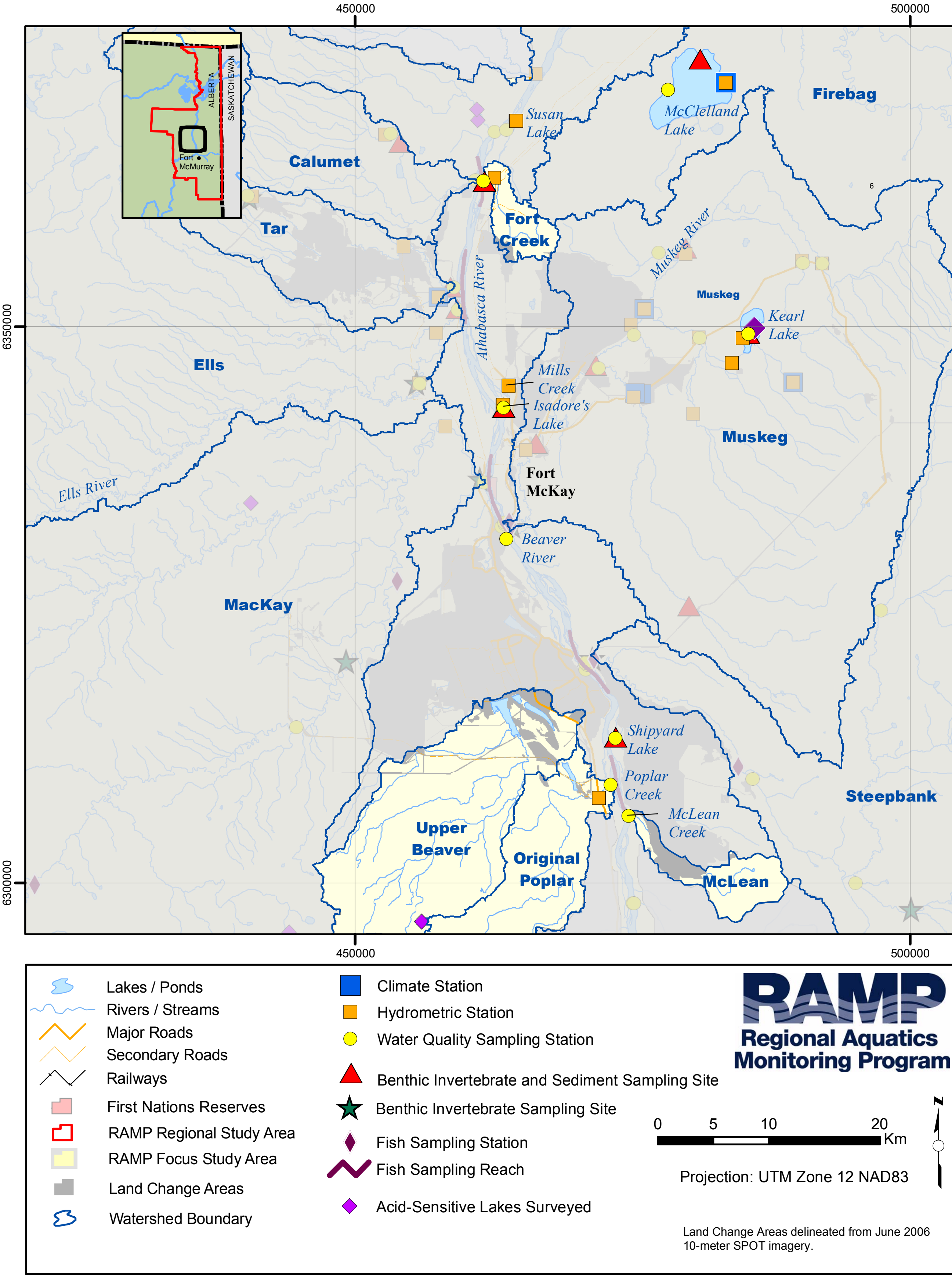
[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

FC: Fort Creek; PC: Poplar Creek

Water quality stations designated as *potentially influenced:* Beaver River; Poplar Creek; McLean Creek; Isadore's Lake, Shipyard Lake; and Fort Creek

Water quality stations designated as *reference:* Kearl Lake and McClelland Lake

Figure 5.12-1 Miscellaneous aquatic systems.



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5.12.1 Development Status

This section includes 2006 results from the following aquatic systems, each with a specific status:

- Mills Creek, Poplar Creek, McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake are designated as *potentially influenced*, and all data gathered at these stations in 2006 are designated as operational data. To date, land changes from focal project activities has covered slightly more than 1% of the Poplar Creek watershed, slightly more than 6% of the Fort Creek watershed, and almost 24% of the McLean Creek watershed (Table 2.6-2). None of the watersheds of these aquatic systems contain oil sands projects that were under construction or operation in 2006 but not owned by 2006 RAMP funders;
- Kearl Lake, McClelland Lake, and the Susan Lake outlet are designated as *reference* for 2006, and all data gathered at these stations in 2006 are designated as baseline data; and
- Water quality results presented below include 2006 results for the OPTI lakes sampling.

5.12.2 Hydrologic Conditions

5.12.2.1 Potentially-Influenced Aquatic Systems

In 2006, hydrologic monitoring was undertaken on the following miscellaneous aquatic systems designated as *potentially-influenced*: Isadore's Lake, Mills Creek, Poplar Creek, and Fort Creek.

2006 Hydrologic Conditions: Isadore's Lake Isadore's Lake water level fluctuated very little in 2006 (Figure 5.12-2). Lake levels were higher than the average levels observed over the previous six years of monitoring, but were within historical ranges except in January 2006. The lake level rose slightly in April and May in response to snowmelt runoff, and in July in response to the large regional rainfall event in that month.

2006 Hydrologic Conditions: Mills Creek The Mills Creek drainage produced 22 mm of runoff in May to October 2006, about two thirds of the historical mean runoff of 33 mm (Figure 5.12-3). The highest discharge occurred in July in response to rainfall runoff, and several other relatively high flow events occurred during May, August and September. The July maximum daily discharge was 0.095 m^3/s, roughly half of the mean annual flood. The minimum open-water discharge of 0.011 m^3/s was significantly lower than the historical average minimum discharge of 0.019 m^3/s.

2006 Hydrologic Conditions: Poplar Creek Flow in Poplar Creek, including releases from the Poplar Creek spillway, amounted to a volume of 14.2 million m^3 in May – October 2006. The 2006 volume was below normal, at about 58% of the historical mean flow of 24.4 million m^3 (Figure 5.12-4). The May maximum daily discharge was 2.44 m^3/s, less than half of the mean annual flood of 8.2 m^3/s. The minimum open-water discharge of 0.05 m^3/s was about one third of the historical average minimum discharge of 0.14 m^3/s.

2006 Hydrologic Conditions: Fort Creek The Fort Creek basin produced 16 mm of runoff in May to October 2006, about 65% of the historical mean runoff of 25 mm (Figure 5.12-5). Flows were well below normal all year, except for the rainfall runoff that occurred in July. The July maximum daily discharge was 0.33 m^3/s, 40% lower than the mean annual flood. The minimum open-water discharge of 0.005 m^3/s was only 20% of the historical average minimum discharge of 0.025 m^3/s.

Estimation of Hydrologic Effects: Poplar Creek A summary of the inputs to the water balance model for Poplar Creek used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is as follows (details are provided in Table 5.12-1):

- As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) were 0.07 km^2 and 1.78 km^2, respectively, in the Poplar Creek drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1); and
- Discharges to Poplar Creek by focal projects in 2006 are estimated at 14.02 million m^3 2006 from the Poplar Creek spillway. This is the largest hydrologic influence on the flows of Poplar Creek and exists as a result of the Beaver Diversion. The 14.02 million m^3 discharge from the Poplar Creek spillway represents 92% of the total flow measured at RAMP Station S11 (Table 5.12-1), and removal of this diversion from Poplar Creek flows from the calculation of the baseline hydrograph has a major influence on the values of the hydrologic measurement endpoints.

The baseline hydrograph that would have occurred at RAMP station S11, Poplar Creek at Highway 63 (07DA007) in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the operational hydrograph recorded at RAMP station S11. The estimated net effect of focal project activities was to increase inflows to Poplar Creek by an estimated 14.06 million m^3 in 2006.

The estimated cumulative effect in 2006 is that mean open-water season discharge was reduced by 0.45%, mean winter discharge was increased by 300%, annual maximum daily discharge was increased by 50%, and open-water season minimum daily discharge was created (i.e., the open-water season minimum daily discharge for the estimate baseline hydrograph is 0 m^3/s, Figure 5.12-4, Table 5.12-2). These differences would have been assessed as High in many oil sands EIAS (RAMP 2005b).

Estimation of Hydrologic Effects: Fort Creek A summary of the inputs to the water balance model for Fort Creek used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.12-3. As of 2006, areas of closed-circuited land change and other land change (not closed-circuited) was 0.24 km^2 and 1.77 km^2, respectively, in the Fort Creek drainage as a result of cumulative development of focal projects in the watershed (Table 2.6-1), the estimated net effects of which were to increase flows in Fort Creek by 0.003 million m^3 in 2006.

The baseline hydrograph that would have occurred at RAMP Station S12, Fort Creek at Highway 63 in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2006. These estimated influences are predicted to have increased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by 0.4%. The cumulative effect is that all hydrologic measurement endpoints for the Fort Creek watershed are estimated to be essentially identical to what they would have been in the absence of focal project activities (Figure 5.12-5, Table 5.12-4). These calculated incremental changes in the hydrologic measurement endpoints (-0.4%) would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b).

5.12.2.2 Reference Aquatic Systems

In 2006, hydrologic monitoring was undertaken on the following miscellaneous aquatic systems designated as *reference*: Kearl Lake, McClelland Lake, and the Susan Lake outlet.

2006 Hydrologic Conditions: Kearl Lake Kearl Lake began the year almost 0.2 m lower than the lowest January level observed over the past seven years of monitoring, and the lake level continued to fall until early April (Figure 5.12-6). The level recovered slightly during the spring and again in July, but remained well below normal levels all year. The level was so low that outflow from the lake stopped entirely in July (Figure 5.12-7).

2006 Hydrologic Conditions: McClelland Lake McClelland Lake water levels were slightly higher than the 1997 – 2005 average in 2006 (Figure 5.12-8). The levels fluctuated only slightly within the year, with a total range between the highest and lowest observed levels of 0.16 m. The only significant rise in lake level occurred in July in response to the regional rainfall event.

2006 Hydrologic Conditions: Susan Lake Outlet Flow in the Susan Lake Outlet peaked three times in 2006; in May, June and July (Figure 5.12-9). The period of record available for flow in the stream before 2006 consists of only a partial year of monitoring in 2002, which is insufficient to provide a useful historical context for the 2006 observations.

5.12.2.3 Summary

Based on the available hydrologic information as well as information available regarding focal project activities in the watersheds of the miscellaneous aquatic systems monitored by RAMP in 2006:

- cumulative, watershed-level effects on hydrologic conditions in Poplar Creek caused by focal project activities in the current watershed as of 2006 have been high; and
- cumulative, watershed-level effects on hydrologic conditions in Fort Creek caused by focal project activities in the watershed as of 2006 have been negligible.

5.12.3 Water Quality

5.12.3.1 Potentially-Influenced Aquatic Systems

In 2006, water quality monitoring was undertaken on the following miscellaneous aquatic systems designated as *potentially-influenced*: Beaver River; Poplar Creek; McLean Creek; Isadore's Lake, Shipyard Lake; and Fort Creek, all of which were sampled in the fall season only with the exception of Isadore's Lake and Shipyard Lake which were sampled in the summer and fall seasons.

Beaver River

2006 Results and Historical Ranges of Concentration At station BER-1 there were 6 (27%) of a possible 22[1] cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum fall concentrations (Table 5.12-5): concentrations of calcium, magnesium, and sulphate were higher than their previously-measured maximum concentrations; while concentrations of

1 There are a total of 22 selected water quality measurement endpoints (Section 3.2.6.1).

total nitrogen, dissolved organic carbon, and total aluminum were below their previously-measured minimum concentrations.

Sampling in 2003 indicated high concentrations of ions and high conductivity relative to other RAMP stations, suggesting a potential effect of tailings pond seepage on water quality (RAMP 2004). Ion concentrations and conductivity were nearly as high in 2006, while concentrations in 2004 and 2005 were somewhat lower. This variability in water quality may be related to water flows that attenuate potential effects of seepage on Beaver River water quality (RAMP 2006), or may be due to variability in the water table and relative contribution of groundwater to river flows.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Sulphate was the only water quality measurement endpoint with a fall 2006 concentration at station BER-1 that exceeded water quality guidelines (Table 5.12-5).

Comparison of Other Water Quality Variables to Water Quality Guidelines Concentrations of sulphide and total iron, water quality variables not designated as water quality measurement endpoints, exceeded water quality guidelines at station BER-1 in fall 2006 (Table 5.12-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At the lower Beaver River (station BER-1) in fall 2006, the concentrations of eight (62%) out of a possible 13[2] water quality measurement endpoint-station combinations, total dissolved solids, total strontium, total boron, calcium, magnesium, sodium, chloride, and sulphate, were above the 95th percentile of regional fall baseline concentrations (Figure 5.12-10); no water quality measurement endpoints at station BER-1 in fall 2006 had concentrations that were below the 5th percentile of regional fall baseline concentrations.

Ion Balance Ion balance at station BER-1 has remained relatively consistent over the period of sampling (Figure 5.12-11).

Poplar Creek

2006 Results and Historical Ranges of Concentration At station POC-1 there were 5 (23%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum fall concentrations (Table 5.12-7): pH was lower than its previously-measured maximum level; while concentrations of total suspended solids, dissolved organic carbon, sulphate, and dissolved aluminum were above their previously-measured maximum concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a fall 2006 concentration at station POC-1 that exceeded water quality guidelines (Table 5.12-7). Fall concentrations of total aluminum have exceeded water quality guidelines at station POC-1 in every year of sampling.

Comparison of Other Water Quality Variables to Water Quality Guidelines Concentrations of sulphide, total iron, and total phenols, water quality variables not designated as water quality measurement endpoints, exceeded water quality guidelines

[2] Thirteen water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4).

at station POC-1 in fall 2006 (Table 5.12-6). Fall concentrations of total iron have exceeded water quality guidelines at station POC-1 in every year of sampling.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station POC-1 in fall 2006, total boron was the only water quality measurement endpoint above the 95th percentile of regional baseline concentrations (Figure 5.12-10); no water quality measurement endpoints at station POC-1 in fall 2006 had concentrations that were below the 5th percentile of regional fall baseline concentrations. Elevated concentrations of total boron relative to regional baseline concentrations also occurred at Beaver Creek and McLean Creek, suggesting similar biophysical factors or processes such as greater relative contribution of groundwater to surface flow were related to the boron concentrations in these waterbodies.

Ion Balance Ion balance at station POC-1 has been relatively consistent over all years of sampling except in 2001, when higher sodium, potassium, and chloride concentrations led to a shift in ionic composition (Figure 5.12-11).

McLean Creek

2006 Results and Historical Ranges of Concentration At station MCC-1 there were 6 (27%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations either above or below previously measured minimum or maximum fall concentrations (Table 5.12-8): concentrations of total nitrogen and dissolved aluminum were lower than their previously-measured maximum concentrations; pH and alkalinity, and well as concentrations of magnesium and strontium were above their previously measured maximum levels or concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a fall 2006 concentration at station MCC-1 that exceeded water quality guidelines (Table 5.12-8).

Comparison of Other Water Quality Variables to Water Quality Guidelines Total iron was the only water quality variables not designated as water quality measurement endpoints with a concentration that exceeded water quality guidelines at station MCC-1 in fall 2006 (Table 5.12-8).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station MCC-1 in fall 2006, the concentrations of six (46%) out of a possible 13 water quality measurement endpoint-station combinations, total dissolved solids, total strontium, total boron, magnesium, sodium and chloride, were above the 95th percentile of regional fall baseline concentrations (Figure 5.12-10); no water quality measurement endpoints at station MCC-1 in fall 2006 had concentrations that were below the 5th percentile of regional fall baseline concentrations.

Ion Balance Ion balance at station MCC-1 has varied over the years of sampling (Figure 5.12-11); however ionic character in fall 2006 was within the range previously observed at this station.

Isadore's Lake

2006 Results and Historical Ranges of Concentration At station ISL-1 there were 14 (64%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations at, above, or below previously measured minimum or maximum fall concentrations (Table 5.12-9). Concentrations of total suspended solids and dissolved aluminum were at or below their previously-measured minimum concentrations; while pH and conductivity, as well as concentrations of nitrate-nitrite, dissolved organic carbon, sodium, magnesium, chloride, sulphate, total dissolved solids, total boron, total mercury, and total strontium were at or above their previously-measured maximum levels or concentrations. The concentration of several ions, total dissolved solids, total strontium, and total boron has increased every year at station ISL-1 since 2004 or earlier.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Sulphate was the only water quality measurement endpoint with a fall 2006 concentration at station ISL-1 that exceeded water quality guidelines (Table 5.12-9). Sulphate concentrations also exceeded water quality guidelines at station ISL-1 in summer 2006 (Table 5.12-8).

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines for the following water quality variables not designated as water quality measurement endpoints were exceeded at station ISL-1 in 2006 (Table 5.12-6):

- Concentrations of sulphate, sulphide, and total phenols exceeded water quality guidelines at station ISL-1 in summer 2006; and
- Concentrations of sulphide, and total nitrogen exceeded water quality guidelines at station ISL-1 in fall 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station ISL-1 in fall 2006, the concentrations of two (15%) out of a possible 13 water quality measurement endpoint-station combinations, magnesium and sulphate, were above the 95^{th} percentile of regional fall baseline concentrations (Figure 5.12-12); no water quality measurement endpoints at station ISL-1 in fall 2006 had concentrations that were below the 5^{th} percentile of regional fall baseline concentrations.

Ion Balance Ion balance in 2006 was similar to that observed in 2004 and 2005 (Figure 5.12-13). Anionic character in these years was more heavily dominated by sulphate than in 2000 and 2001.

Shipyard Lake

2006 Results and Historical Ranges of Concentration At station SHL-1 there were 9 (41%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations that were at or above below previously measured maximum fall levels or concentrations (Table 5.12-10): pH; conductivity; sodium; calcium; magnesium; total dissolved solids; alkalinity; total boron; and total strontium. There were no water quality measurement endpoints with concentrations at station SHL-1 in fall 2006 that were at or below previously measured minimum fall concentrations. Several of these water quality measurement endpoints have increased since 2004 or earlier.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were no water quality measurement endpoints with a fall 2006 concentration at station SHL-1 that exceeded water quality guidelines (Table 5.12-10).

Comparison of Other Water Quality Variables to Water Quality Guidelines Total phenols in summer and sulphide and total iron in fall were water quality variables not designated as water quality measurement endpoints with concentrations that exceeded water quality guidelines at station SHL-1 in 2006 (Table 5.12-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station SHL-1 in fall 2006, sulphate was the only water quality measurement endpoint with a concentration that was below the 5th percentile of regional fall baseline concentrations (Figure 5.12-12); no water quality measurement endpoints at station SHL-1 in fall 2006 had concentrations that were above the 95th percentile of regional fall baseline concentrations.

Ion Balance Ionic character of Shipyard Lake water in fall 2006 was consistent with all previous years of sampling (Figure 5.12-13).

Fort Creek

2006 Results and Historical Ranges of Concentration At station FOC-1 there were 16 (73%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations at, above, or below previously measured minimum or maximum fall concentrations (Table 5.12-11). Concentrations of sulphate and dissolved aluminum were at or lower than their previously-measured maximum concentrations. pH and conductivity, as well as concentrations of dissolved organic carbon, sodium, calcium, magnesium, chloride, total dissolved solids, alkalinity, total aluminum, total boron, total molybdenum, and total strontium were at or above their previously-measured maximum concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a fall 2006 concentration at station FOC-1 that exceeded water quality guidelines (Table 5.12-11).

Comparison of Other Water Quality Variables to Water Quality Guidelines Sulphide, total phosphorus, total chromium, total iron, and total phenols were water quality variables not designated as water quality measurement endpoints with concentrations that exceeded water quality guidelines at station FOC-1 in fall 2006 (Table 5.12-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station FOC-1 in fall 2006, the concentrations of two (15%) out of a possible 13 water quality measurement endpoint-station combinations were below the 5th (sulphate) or above the 95th (calcium) percentile of regional fall baseline concentrations (Figure 5.12-14).

Ion Balance Ionic character of Shipyard Lake water in fall 2006 was consistent with all previous years of sampling (Figure 5.12-15).

5.12.3.2 Reference Aquatic Systems

In 2006, water quality monitoring was undertaken on Kearl Lake and McClelland Lake, both of which are designated as *reference* for 2006. Both lakes were sampled in fall 2006.

Kearl Lake

2006 Results and Historical Ranges of Concentration At station KEL-1 there were 4 (18%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations that were at, above, or below previously measured minimum or maximum fall concentrations (Table 5.12-12). Conductivity and concentration of dissolved aluminum were at or below than their previously-measured minimum concentrations, while total suspended solids and chloride were at or above their previously-measured maximum concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total nitrogen was the only water quality measurement endpoint with a fall 2006 concentration at station KEL-1 that exceeded water quality guidelines (Table 5.12-12).

Comparison of Other Water Quality Variables to Water Quality Guidelines Sulphide and total Kjeldahl nitrogen were water quality variables not designated as water quality measurement endpoints with concentrations that exceeded water quality guidelines at station KEL-1 in 2006 (Table 5.12-13).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station KEL-1 in fall 2006, no water quality measurement endpoints had a concentration that was below the 5^{th} or above the 95^{th} percentile of regional fall baseline concentrations (Figure 5.12-16).

Ion Balance The ion balance at station KEL-1 in fall 2006 was consistent with historic ionic characteristics of Kearl Lake (Figure 5.12-17), and is dominated by calcium bicarbonate.

McClelland Lake

2006 Results and Historical Ranges of Concentration At station MCL-1 there were 11 (50%) of a possible 22 cases of water quality measurement endpoints with fall 2006 concentrations that were at, above, or below previously measured minimum or maximum fall concentrations (Table 5.12-14). Concentrations of total suspended solids, dissolved organic carbon, and dissolved aluminum were at or below their previously measured minimum concentrations, while conductivity as well as sodium, magnesium, chloride, sulphate, total dissolved solids, alkalinity, and total strontium were at or above their previously-measured maximum levels or concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were no only water quality measurement endpoints with a fall 2006 concentration measured at station MCL-1 that exceeded water quality guidelines (Table 5.12-14).

Comparison of Other Water Quality Variables to Water Quality Guidelines There were no other water quality variables measured at station MCL-1 with a fall 2006 concentration measured at station MCL-1 that exceeded water quality guidelines at station MCL-1 in 2006 (Table 5.12-13).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station MCL-1 in fall 2006, the concentrations of three (23%) out of a possible 13 water quality measurement endpoint-station combinations were below the 5^{th} (dissolved phosphorus and chloride) or above the 95^{th} (potassium) percentile of regional fall baseline concentrations (Figure 5.12-18).

Ion Balance Ion balance in McClelland Lake in fall 2006 was consistent with that of previous years, with a high relative concentration of calcium and magnesium bicarbonate and low concentrations of sodium and potassium chloride (Figure 5.12-17).

5.12.3.3 OPTI Lakes

In 2006, water quality samples were collected from the following OPTI lakes in spring and fall 2006: Birch Lake (BIL-1), Long Lake (LOL-1), Poison Lake (POL-1), Pushup Lake (PUL-1), Rat Lake (RAL-1), Reference Lake 2 (REF-2), Reference Lake 4 (REF-4), Unnamed Lake 3 (UNL-3), Canoe Lake (CANL-1), Caribou Horn Lake (CARL-1), Frog Lake (FRL-1), Gregoire Lake (GRL-1), Kiskatinaw Lake (KIL-1), Sucker Lake (SUL-1), and Unnamed Lake 2 (UNL-2). Results from the 2006 sampling for the water quality measurement endpoints are shown in Table 5.12-15 to Table 5.12-28. Results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.12-19 to Figure 5.12-22, while all exceedances of CCME/AENV water quality guidelines measured in the OPTI lakes in 2006 are shown in Table 5.12-29.

2006 Results and Historical Ranges of Concentration In the OPTI lakes in fall 2006 there were 130 (42%) of a possible 308[3] cases of water quality measurement endpoints with fall 2006 concentrations that were at, above, or below previously measured minimum or maximum fall concentrations (Table 5.12-15 to Table 5.12-28).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were 15 (11%) out of a 140[4] possible exceedances in water quality guidelines for the water quality measurement endpoints in the OPTI lakes in fall 2006 (Table 5.12-15 to Table 5.12-28). Total nitrogen comprised ten of these water quality guideline exceedances. Water quality guidelines for dissolved phosphorus, total aluminum , and dissolved aluminum (all at Unnamed Lake 2) were exceeded once in fall 2006, and pH in Unnamed Lake 1 and Unnamed Lake 2 was lower than the guideline range of 6.5 to 9.0 in fall 2006.

Comparison of Other Water Quality Variables to Water Quality Guidelines Water quality guidelines for a number of water quality variables not designated as water quality measurement endpoints were exceeded in the OPTI lakes in both spring and fall 2006 (Table 5.12-29). The guideline for total phenols was exceeded at nearly every lake in spring 2006 (exceptions were Frog Lake and Gregoire Lake), while phenols were non-detectable at all lakes in fall 2006. Sulphide concentrations exceeded the British Columbia water quality guideline at most lakes in both fall and spring 2006.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions By definition, most measurement endpoints in fall 2006 were at or between the 5th and 95th percentile of pooled observations for these lakes (Figure 5.12-19 to Figure 5.12-22); water quality measurement endpoints with concentrations outside this range in fall 2006 were:

- Chloride in lake BIL-1, lake CANL-1, and lake FRL-1 (greater than the 95th percentile);
- Sulphate in lake LOL-1 (greater than the 95th percentile) and lake REF-4 (lower than the 5th percentile);
- Total nitrogen in lake GRL-1 and lake REF-4 (lower than the 5th percentile);
- Dissolved phosphorus in lake UNL-2 (greater than the 95th percentile); and
- Total strontium, total alkalinity, calcium, magnesium, and sodium in lake REF-4 (greater than the 95th percentile concentrations).

[3] There are a total of 22 selected water quality measurement endpoints (Section 3.2.6.1) and a total of fourteen OPTI lakes were sampled in fall 2006, making for a total of 308 water quality measurement endpoints to be considered.

[4] There are water quality guidelines for ten of the selected water quality measurement endpoints and a total of 14 OPTI lakes sampled.

In general, concentrations of water quality measurement endpoints in fall 2006 were similar to previously observed results. Several water quality measurement endpoints appear to vary similarly across all lakes (e.g., total dissolved solids increased between 2001 and 2002 in all lakes sampled in both years), while other measurement endpoints (e.g., total suspended solids) vary differently over time among lakes (Figure 5.12-19 to Figure 5.12-22). In fall 2006, concentrations of sulphate in Long Lake were higher than in any other lake and similar to concentrations observed in 2005, while concentrations in other lakes (e.g., Birch, Poison, Pushup, Unnamed Lake 3) decreased between 2005 and 2006.

Arsenic concentrations in all lakes have been below the water quality guideline in all years of sampling. The evidently high concentrations shown for 2001 (Figure 5.12-19 to Figure 5.12-22) were actually non-detectable (shown at the detection limit), as the detection limit for total arsenic in that year was up to 5,000 times higher than the detection limit in other years.

Ion Balance The ionic composition of water samples collected at all OPTI lakes over all seasons from 2000 to 2006 was dominated primarily by calcium bicarbonate (Figure 5.12-23 to Figure 5.12-26). For several lakes (e.g., Gregoire Lake, Kiskatinaw Lake, Sucker Lake), the ionic composition of samples from all years and seasons was very similar (Figure 5.12-25), with inter-lake variability in ionic balance greater than the variability attributable to season or year. In Long Lake (Figure 5.12-23), variable relative concentrations of bicarbonate and sulphate were observed; spring and fall 2005 and 2006 samples exhibited higher relative sulphate and lower relative bicarbonate concentrations than in other years and seasons. In Pushup Lake, the ionic composition in fall 2001 and spring 2006 exhibited higher relative concentrations of chloride relative to other years and seasons (Figure 5.12-23). Canoe Lake exhibited a trend of decreasing relative calcium concentrations and increasing relative sodium/potassium concentrations from 2000 to 2006 (Figure 5.12-24). In Reference Lake 2 and Reference Lake 4, ion balance was grouped tightly by lake (i.e., little variability between seasons) in 2006 (Figure 5.12-26). In contrast, ion balance in Unnamed Lake 1 was more variable between seasons than between years.

Water Sources and Recharge Pathways for OPTI Lakes The results of the Principal Components Analysis (PCA) described in Appendix D indicate differences between metal concentrations among the lakes and, therefore, provide information on possible water sources and recharge pathways. Positive values of principal component 1 (PC1), which was strongly correlated with calcium, barium, and boron, were observed in all years and seasons in Sucker Lake, Poison Lake, Frog Lake, and Reference Lake 4, indicating that these lakes consistently exhibit relatively high concentrations of calcium, barium, and boron. These findings may indicate a higher relative contribution of groundwater to lake volume. In contrast, Unnamed Lake 1 and Reference Lake 2 exhibited negative values of PC1, indicating consistently low concentrations of calcium, barium, and boron and, likely, a limited role of groundwater recharge to these lakes.

Principal component 2 (PC2) was strongly or moderately positively correlated with iron, manganese, and zinc. Positive values of PC2 were observed for nearly all season-year combinations in Canoe Lake, Long Lake, Birch Lake, and Pushup Lake, indicating that these lakes generally exhibit relatively high concentrations of these metals. As iron and manganese are typically elevated in surface waters due to the weathering of surficial material (Corkum 1985) and are associated with muskeg drainage waters, the positive PC2 values associated with these lakes may indicate that surface water inputs are relatively important sources of recharge in these lakes. PC3, strongly correlated with aluminum and vanadium, was negative for all years and seasons in Reference Lake 2, Reference Lake 4, and Gregoire Lake, and negative for most season-year combinations in Pushup Lake and Unnamed Lake 3, indicating relatively low concentrations of aluminum and vanadium in these waterbodies.

Concentrations of ions (calcium, magnesium, and sodium), total dissolved solids, total alkalinity, total nitrogen, total strontium and total boron generally have been high in Poison Lake (POL-1) relative to concentrations observed in other lakes over the period of sampling. These findings are consistent with the results of the principal components analysis, which indicated that relatively high concentrations of constituents normally associated with groundwater (e.g., calcium, boron) are found in Poison Lake (see above).

5.12.3.4 Summary

There was little to distinguish 2006 water quality conditions in the miscellaneous aquatic systems from previous years, with the exception of possible increased influence of groundwater on water quality due low precipitation in the RAMP FSA and reduced surface runoff north of Fort McMurray in 2006. There was little evidence of effects on focal project activities on water quality conditions in these aquatic systems in 2006.

5.12.4 Benthic Invertebrate Communities and Sediment Quality

5.12.4.1 Benthic Invertebrate Communities

In fall 2006, benthic invertebrate community samples were collected from:

- Shipyard Lake (station SHL-1, *potentially influenced*, operational data available since 2000);
- Isadore's Lake (station ISL-1, *potentially influenced*, first sampled in 2006);
- A depositional reach at lower Fort Creek (reach FOC-D-1, *potentially influenced*, data available from 2001 with the exception of 2004);
- Kearl Lake (station KEL-1, *reference*, baseline data since 2001); and
- McClelland Lake (station MCL-1, *reference*, baseline data available for 2002, 2003, and 2006).

Lakes

2006 Habitat Conditions Sampling locations in the four lakes had similar water depths (1 to 2 m, Table 5.12-30). pH among the lakes varied from 7.5 to 8.8, there was generally no macrophyte cover with the exception of Shipyard Lake (20% cover), and dissolved oxygen was high, again with the exception of Shipyard Lake (3.06 mg/L).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 Shipyard Lake benthic invertebrate communities were dominated by chironomids (37%), ostracods (22%) and naidid worms (16%), with amphipods, clams, snails, caddisflies and mayflies present in the lake (Table 5.12-31).

Isadore's Lake had a low-diversity benthic fauna being dominated by nematodes (72%), and with chironomids comprising only 3% of the fauna (Table 5.12-31). There were no clams, snails, caddisflies or mayflies in Isadore's Lake.

Kearl Lake benthic invertebrate communities were dominated by chironomids (42%), clams (23%) and amphipods (23%), with mayflies and caddisflies present, but in relatively low abundance (Table 5.12-31). There was a variety of non-amphipod Crustacea also present, but in low percent abundance. All of the taxa found in Kearl Lake are relatively common forms of benthic biota in the RAMP FSA. The dominant chironomids were *Pagastiella*, *Polypedilum*, *Cladotanytarsus* and *Procladius*. The genus *Pisidium* represented the clams (bivalves), and *Hyalella azteca* and *Gammarus lacustris* represented the amphipods, with *Hyalella* being relatively more abundant.

McClelland Lake benthic invertebrate communities were dominated by chironomids (91%), though caddisflies, mayflies, amphipods and clams were also present (Table 5.12-31). The dominant chironomids included *Chironomus*, *Dicrotendipes*, *Paratanytarsus*, *Cricotopus*/*Othrocladius*, and *Ablabesmyia*, all of which are relatively common.

Effects of Focal Project Activities ANOVA was used to test for differences in benthic invertebrate community measurement endpoints between Shipyard Lake and Isadore's Lake, the two lakes designated as *potentially influenced*, and Kearl Lake and McClelland Lake, the two lakes designated as *reference*. For Shipyard Lake, the contrasts were between average conditions to the average conditions in the two reference lakes (*reference vs exposed* contrast), and for differences in time trends in the *reference* lakes and *potentially influenced* lake (*time* contrast and *lakes vs time* contrast). For Isadore's Lake, the only possible contrast was between the benthic invertebrate community measurement endpoints of Isadore's Lake in 2006 to the measurement endpoints for the two *reference* lakes in 2006 (*reference vs exposed* contrast).

There were a number of significant contrasts (Table 5.12-32), particularly with respect to abundance, diversity, and evenness. Abundance of benthic organisms has been slightly higher in Shipyard Lake than the two *reference* lakes, while diversity, evenness and percent EPT have been slightly lower. Average values of the benthic invertebrate community measurement endpoints have, however, been within the normal range of variation for the *reference* lakes for the past two years (Figure 5.12-27). The presence of sensitive taxa such as mayflies and caddisflies, and a generally diverse fauna, in addition to benthic invertebrate community measurement endpoints falling within normal ranges, indicates a benthic community that is in relatively good condition in Shipyard Lake.

Isadore's Lake had significantly fewer taxa, and less diversity than the two *reference* lakes (Table 5.12-33). Diversity and evenness in Isadore's Lake in fall 2006 were also more than 2 standard deviations less than mean values for the two *reference* lakes (Figure 5.12-27). Isadore's Lake in fall 2006 was also missing important and sensitive taxa including snails, clams, mayflies and caddisflies. The lower diversity, and absence of sensitive fauna is indicative of a stressed benthic community in Isadore's Lake.

Fort Creek

2006 Habitat Conditions Reach FOC-D-1 is depositional, dominated by fine-grained sand and silt. Total organic carbon content was relatively high (4%; Table 5.12-34) reflecting high wood debris associated with beaver dams upstream. At low flow the creek is shallow with depths of about 0.2 m, while the channel is quite wide (bankfull width of about 7 m and wetted width of about 4 m).

Relative Abundance of Benthic Invertebrate Community Taxa in 2006 The dominant taxa in 2006 included Chironomids (55%, principally *Polypedilum* and *Cryptochironomus*) and tubificid worms (29%) (Table 5.12-35). The benthic invertebrate community at reach

FOC-D-1 has been dominated by Chironomidae, with a large variety of additional taxa including bivalves (fingernail clams, Sphaeriidae), nematodes, worms, ostracods, and miscellaneous Diptera. Like 2005, the benthic invertebrate community of the lower reach of Fort Creek (reach FOC-D-1) had lower diversity than in previous years, but demonstrated some recovery. Abundance and richness, which had declined in 2005, demonstrated some recovery in fall 2006 inventory.

Effects of Focal Project Activities ANOVA was used to contrast years in which reach FOC-D-1 was designated as *potentially influenced* with years in which it was designated as *reference*. There were significant differences in diversity and evenness among years (Table 5.12-36). However, both time trends of all benthic invertebrate community measurement endpoints and ordination scores for reach FOC-D-1 have always been within the regional baseline ranges for depositional reaches (Figure 5.12-28). These results indicate that the benthic community of lower Fort Creek has had a composition representative of reference depositional reaches throughout the period of sampling and that it has experienced limited effects of focal project activities.

5.12.4.2 Sediment Quality

Sediment quality in fall 2006 was sampled in Shipyard Lake (SHL-1, *potentially influenced*), Isadore's Lake (ISL-1, *potentially influenced*), Kearl Lake (KEL-1, *reference*), McClelland Lake (MCL-1, *reference*), and the lower reach of Fort Creek (reach FOC-D-1, *potentially influenced)* at the same locations at which benthic invertebrate community sampling was undertaken in fall 2006.

Lakes

2006 Results and Historical Ranges of Concentration Sediment composition in Kearl and McClelland lakes (KEL-1, MCL-1) dominated by sand (Table 5.12-39, Table 5.12-40), while sediment composition in Shipyard Lake and Isadore's Lake (ISL-1, SHL-1) was more evenly distributed among sand, silt and clay (Table 5.12-37, Table 5.12-38). Total organic carbon was relatively high in Kearl, McClelland, and Shipyard lakes (>25%), but was lower (5.7%) in Isadore's Lake.

Concentrations of seven out of 20 (35%) sediment quality measurement endpoints were at or above previously recorded maximum levels or concentrations in Shipyard lake (sediment quality at Isadore's Lake was sampled only once before 2006 and there is no historical record for Isadore's Lake against which 2006 sediment quality results can be compared): %sand; naphthalene; total PAHs; total HMW PAHs; predicted PAH toxicity; and *Chironomus* survival and growth (Table 5.12-37).

The historical record of sediment quality for Kearl and McClelland lakes is such that comparisons of 2006 results with previous results are impossible except for PAHs in McClelland Lake (Table 5.12-40). Concentrations of total dibenzothiophenes, total PAHs, and total LMW PAHs at MCL-1 in fall 2006 were above previously measured maximum concentrations, and total HMW PAHs and predicted PAH toxicity were below previously measured minimum concentrations (Table 5.12-40).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines There were five cases in which concentrations of sediment quality measurement endpoints were above sediment quality guidelines in fall 2006: Fraction 3 hydrocarbons in Shipyard Lake (SHL-1, Table 5.12-37) and McClelland Lake (MCL-1, Table 5.12-40); naphthalene in Kearl Lake (KEL-1, Table 5.12-39); and arsenic in Shipyard Lake (SHL-1, Table 5.12-37) and Isadore's Lake (ISL-1, Table 5.12-38).

Correlations among Sediment Quality Variables and Benthic Invertebrate Community Measurement Endpoints The analysis of benthic invertebrate community measurement endpoints above for Isadore's Lake (ISL-1) indicate significant *reference vs exposed* differences for benthic invertebrate community richness, diversity, and evenness. The results of the correlation analysis among sediment quality measurement endpoints and benthic invertebrate community measurement endpoints in depositional reaches (Appendix F) reveals no sediment quality measurement endpoints that are significantly correlated with benthic invertebrate community richness, diversity or evenness. This suggests that the statistically significant *reference vs exposed* interactions for benthic invertebrate community richness, diversity and evenness between Isadore's Lake and the two *reference* lakes (Kearl and McClelland lakes) that are described above may not be due to changes in sediment quality.

Fort Creek

2006 Results and Historical Ranges of Concentration 2006 was the first year in which the Sediment Quality component was integrated with the Benthic Invertebrate Community component and there is therefore no historical record of sediment quality at reach FOC-D-1. Therefore, data from the nearest sediment quality sampling location prior to 2006 was used as the basis of comparison for 2006 results; this was sediment quality sampling station FOC-1. Comparison of 2006 results from reach FOC-D-1 with results from previous years at sediment sampling station FOC-1 is characterized by 1 to 2 years of data in the historical record, depending on the sediment quality measurement endpoint.

Sediments at reach FOC-D1 were dominated by sand and silt, with a smaller proportion of clay (Table 5.12-41). Hydrocarbons at FOC-D1 were dominated by fraction 4 (C34-C50) and fraction 3 (C16-C34). BTEX and fraction 1 hydrocarbons (C6-C10) were non-detectable. Concentrations of five out of 20 (25%) sediment quality measurement endpoints were at or below previously recorded minimum concentrations: %sand; total organic carbon; total dibenzothiophenes; total PAHs; total HMW PAHs; and total LMW PAHs (Table 5.12-41), while %clay and %silt were above previously recorded maximum levels.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines Concentrations of Fraction 3 hydrocarbons and arsenic were above sediment quality guidelines at reach FOC-D-1 in fall 2006 (Table 5.12-41).

5.12.4.3 Summary

Benthic invertebrate communities that were sampled in 2006 were generally within the normal range of variation observed in reference lakes or regional reference conditions for watercourses of similar habitats. The exception is Isadore's Lake, sampled for the first time in 2006, with showed evidence of degraded benthic invertebrate community conditions. There was nothing in the results of sediment quality sampling in the *potentially influenced* system that would suggest effects of focal project activities, and there may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in Isadore's Lake.

5.12.5 Fish Populations

The 2006 RAMP Fish Population component did not include any activities in any of the miscellaneous aquatic systems.

5.12.6 Summary of Conditions

Miscellaneous aquatic systems designated as *potentially influenced* in 2006 included Mills Creek, Fort Creek, Poplar Creek, McLean Creek, Isadore's Lake, and Shipyard Lake, while miscellaneous aquatic systems designated as *reference* in 2006 included Kearl Lake and McClelland Lake. The OPTI lakes were also sampled in 2006. The effect of focal project activities on the hydrology of Poplar Creek is assessed as High, due to the hydrologic effects of the Poplar Creek spillway, while the effect of focal project activities on the hydrology of Fort Creek is assessed as Negligible. There was little to distinguish 2006 water quality conditions in these aquatic systems from previous years, with the exception of possible increased influence of groundwater on water quality due low precipitation in the RAMP FSA and reduced surface runoff north of Fort McMurray in 2006. There was little evidence of effects on focal project activities on water quality conditions in these aquatic systems in 2006. Benthic invertebrate communities in miscellaneous aquatic systems that were sampled in 2006 had values of benthic invertebrate measurement endpoints that were in the range of regional baseline conditions. The exception was Isadore's Lake, in which lower diversity and the absence of sensitive faunal species in 2006 is indicative of a stressed benthic community.

Figure 5.12-2 Isadore's Lake: 2006 hydrograph and historical context.

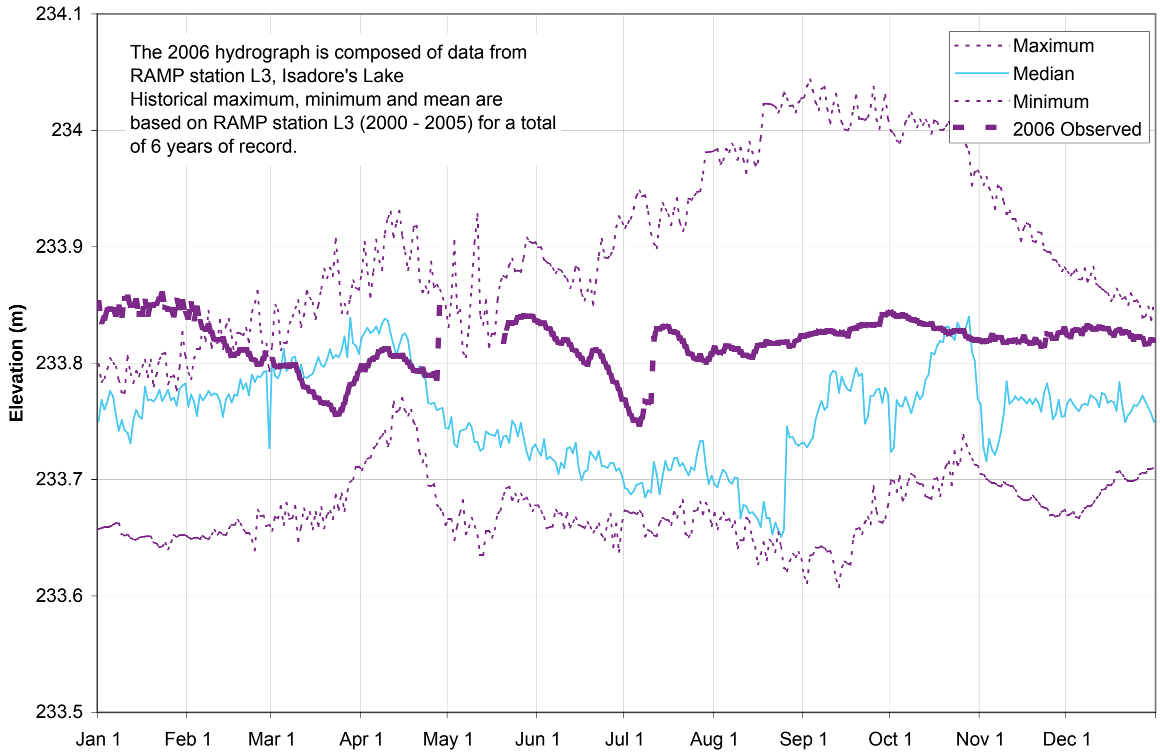


Figure 5.12-3 Mills Creek: 2006 hydrograph and historical context.

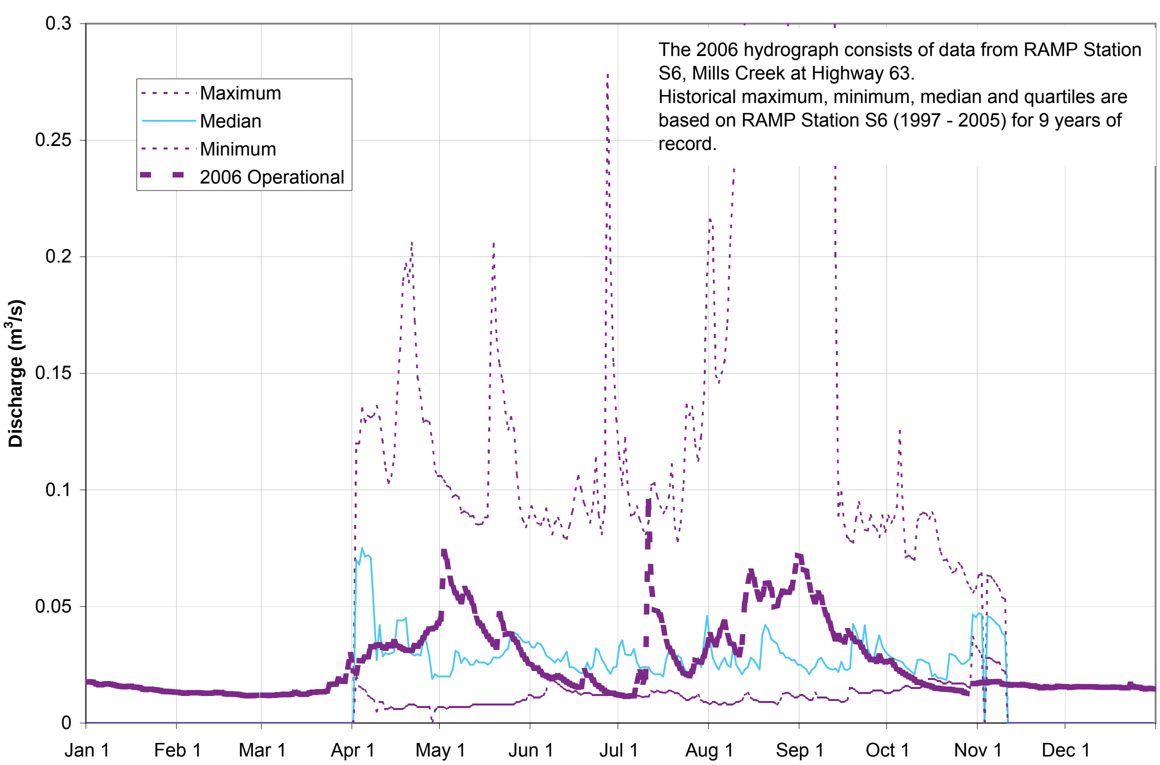


Figure 5.12-4 Poplar Creek: 2006 hydrograph and historical context.

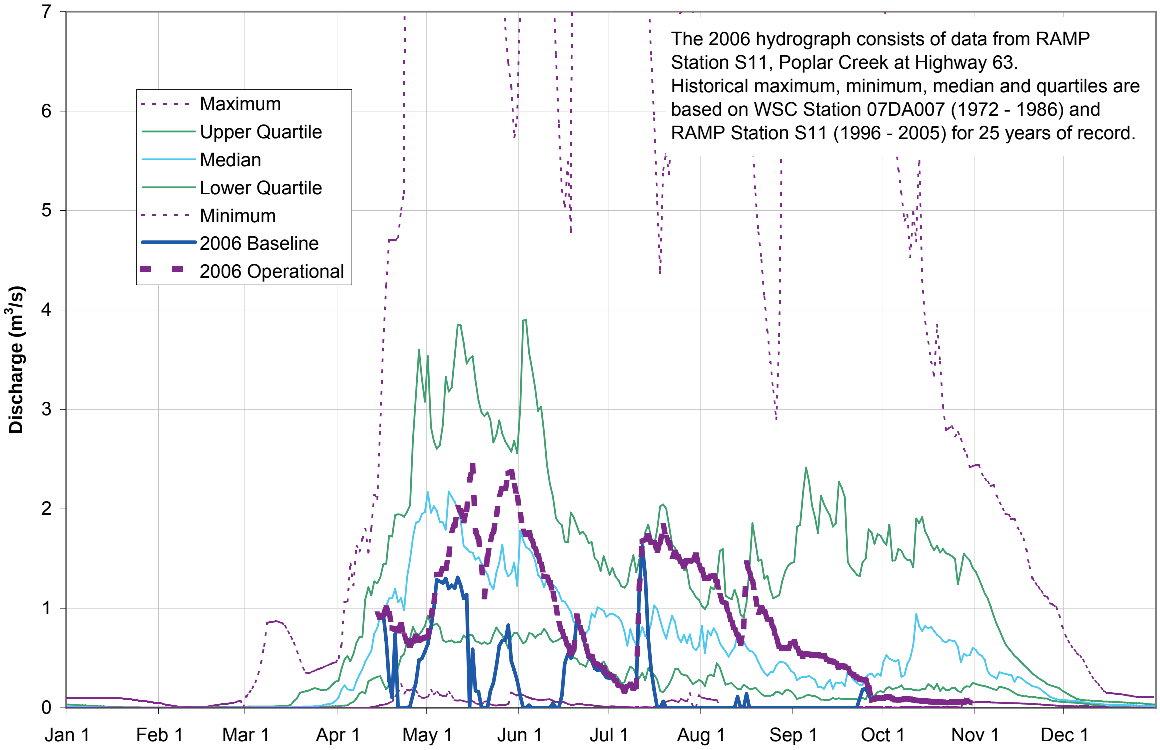


Figure 5.12-5 Fort Creek: 2006 hydrograph and historical context.

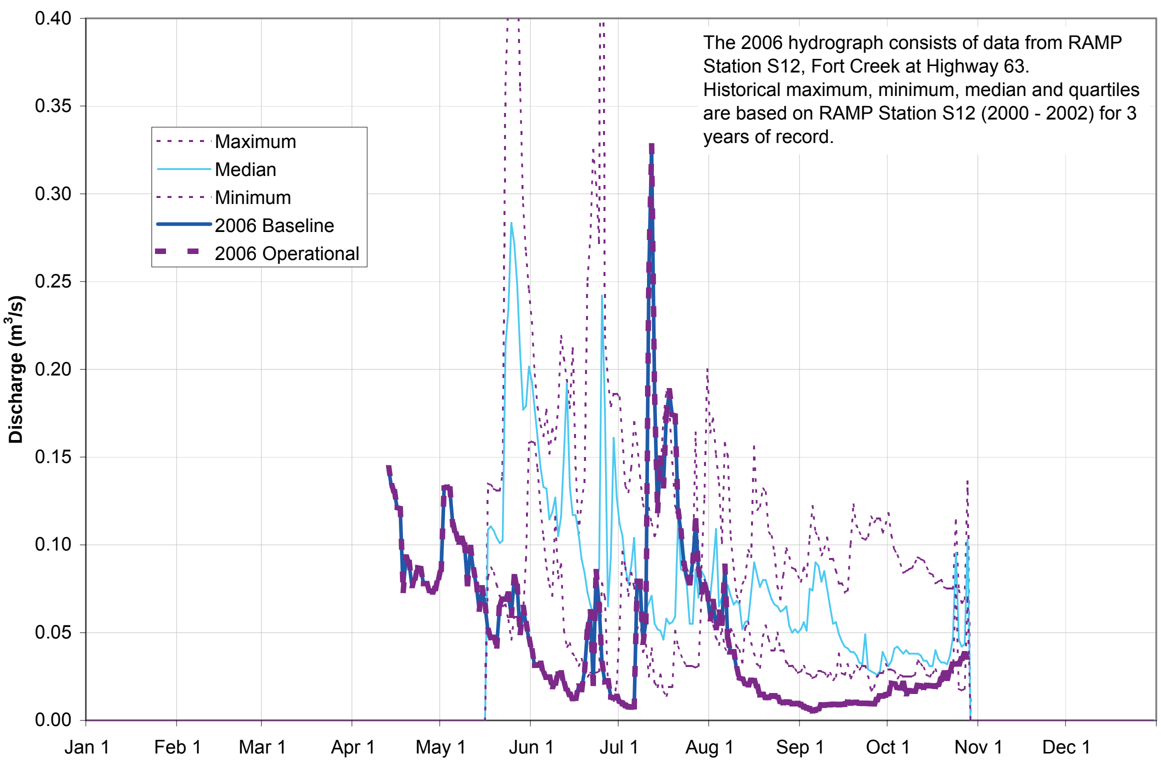


Table 5.12-1 Inputs for calculation of the baseline hydrograph at RAMP Station S11, Poplar Creek at Highway 63 (07DA007).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	15.3	Observed daily discharges, obtained from RAMP Station S11, Poplar Creek at Highway 63 (07DA007)
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.007	0.07 km^2 within Poplar Creek drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.036	1.78 km^2 within Poplar Creek drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Poplar Creek for focal project activities	0	None reported, assumed to be negligible
Releases to Poplar Creek from focal project activities	0	None reported, assumed to be negligible
Diversions into or out of the watershed	- 14.0	Diversion from original upper Beaver River catchment area into Poplar Creek; daily discharges for the Poplar Creek Spillway reported by Syncrude
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects on tributaries of Poplar Creek not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	1.24	Estimated total annual baseline discharge (i.e., without focal projects) for 2006
Incremental flow (change in total annual discharge)	+ 14.1	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of baseline total annual discharge)	+ 1233%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.12-2 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed for 2006.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	0.224	0.896	300%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	1.63	2.44	50%
Open-water season minimum daily discharge	0.000	0.048	-

Note: As measured at RAMP Station S11, Poplar Creek at Highway 63.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.12-3 Inputs for calculation of the baseline hydrograph at RAMP Station S12, Fort Creek at Highway 63.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2006 data record)	0.861	Observed daily discharges, obtained from RAMP station S12, Fort Creek at Highway 63
Natural runoff that would have occurred from areas that were closed-circuited as of 2006	+ 0.006	0.24 km^2 within Poplar Creek drainage estimated to have been closed-circuited by focal projects as of 2006 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2006	- 0.010	1.77 km^2 within Fort Creek drainage estimated to have undergone land change by focal projects of 2006, but are not closed-circuited (Table 2.6-1)
Withdrawals from Fort Creek for focal project activities	0	None reported, assumed to be negligible
Releases to Fort Creek from focal project activities	0	None reported, assumed to be negligible
Diversions into or out of the watershed	0	No diversions reported
The difference between operational and baseline hydrographs on tributary streams	0	No focal projects on tributaries of Fort Creek not accounted for in figures contained in this table
Baseline hydrograph (total annual discharge)	0.858	Estimated total annual baseline discharge (i.e., without focal projects) for 2006
Incremental flow (change in total annual discharge)	+ 0.003	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	+ 0.34%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.12-4 Calculated change in hydrologic measurement endpoints for the Fort Creek watershed for 2006.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	0.046	0.046	0.4%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	0.326	0.327	0.4%
Open-water season minimum daily discharge	0.005	0.005	0.4%

Note: As measured at RAMP Station S12, Fort Creek at Highway 63.

Note: rounding of results occurs due to the use of a maximum of three significant digits.

Figure 5.12-6 Kearl Lake: 2006 hydrograph and historical context.

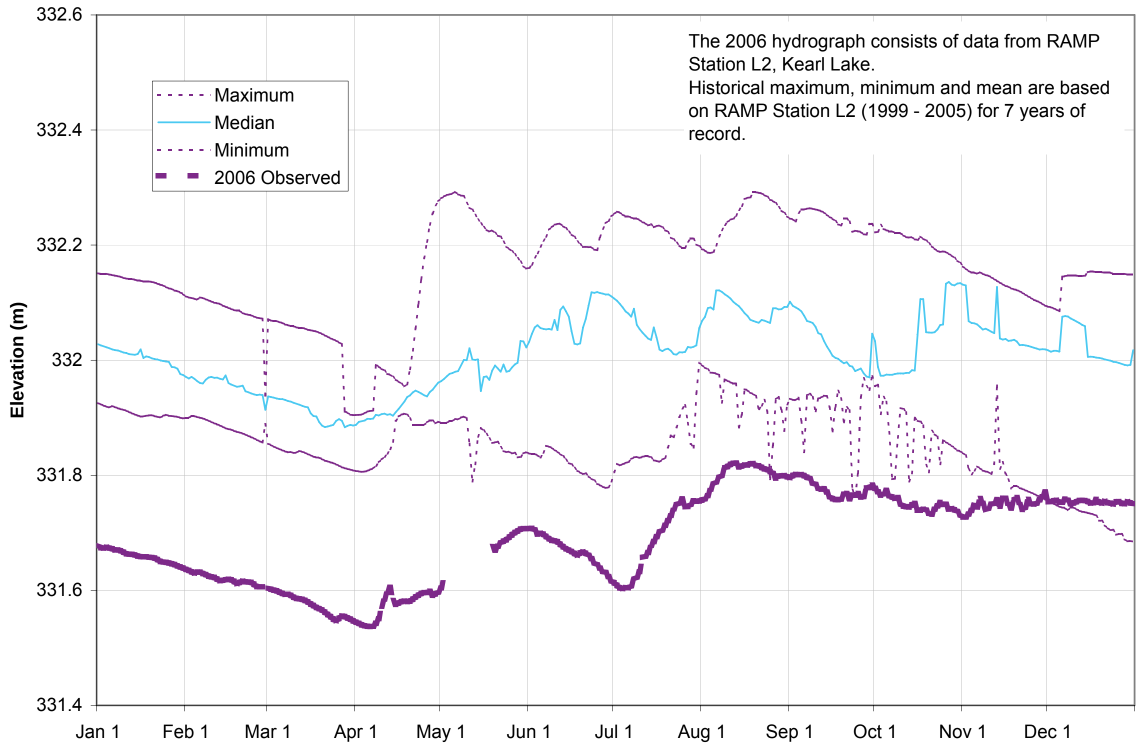


Figure 5.12-7 Kearl Lake outlet: 2006 hydrograph and historical context.

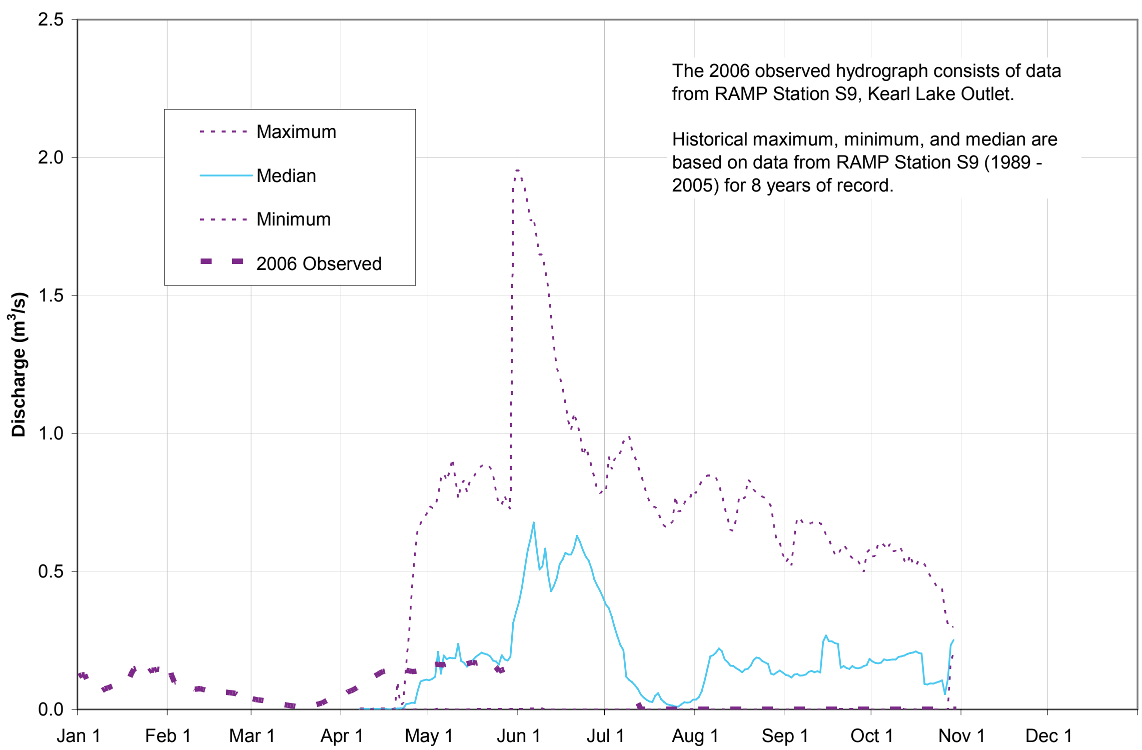


Figure 5.12-8 McClelland Lake: 2006 hydrograph and historical context.

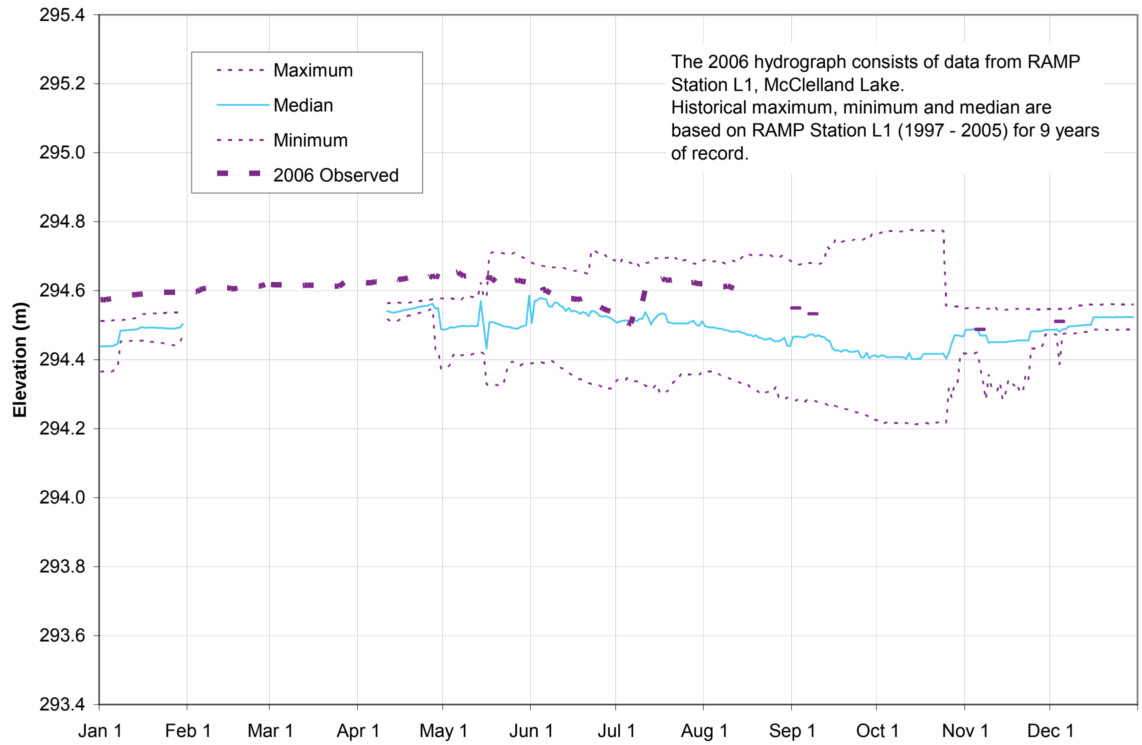


Figure 5.12-9 Susan Lake Outlet: 2006 hydrograph.

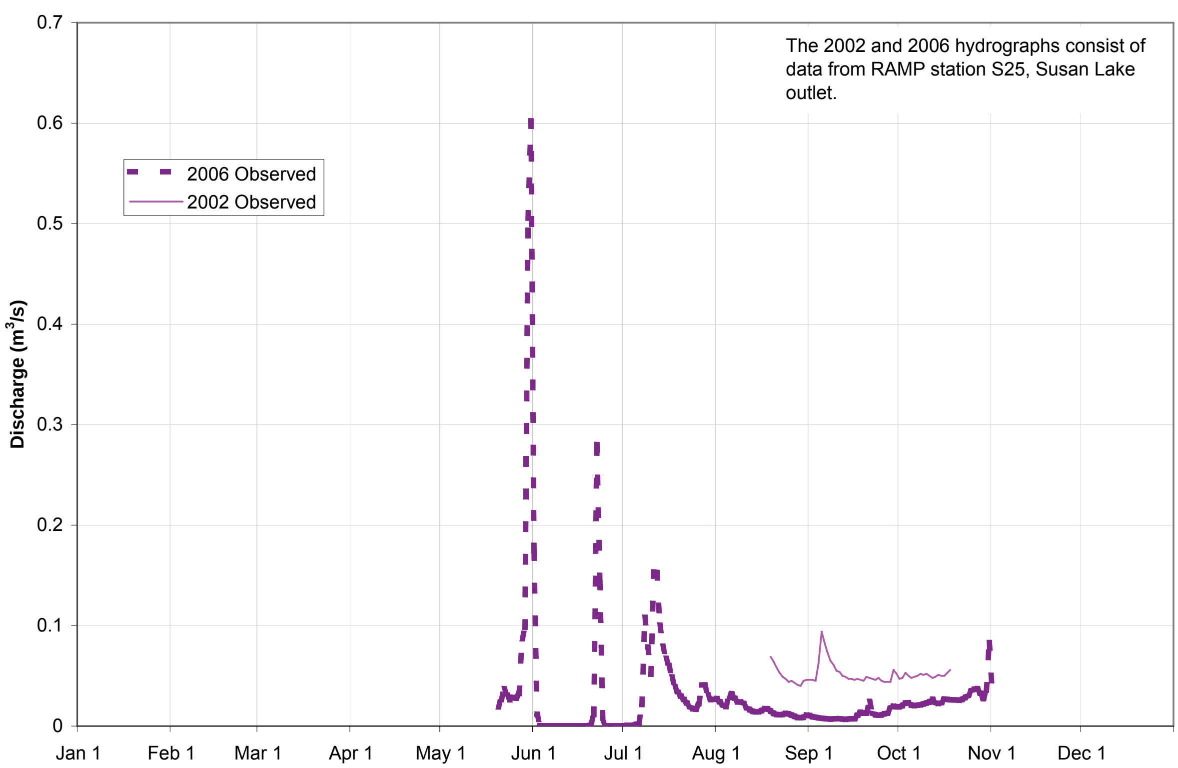


Table 5.12-5 Concentrations of water quality measurement endpoints, lower Beaver River, (BER-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	8.0	8.0	8.2
Total Suspended Solids	mg/L	-[1]	3	3	<3	11	26
Conductivity	µS/cm	-	1120	3	566	605	1430
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.005	3	0.004	0.008	0.022
Total nitrogen*	mg/L	1.0	0.8	3	0.9	0.9	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	3	21	31	52
Ions							
Sodium	mg/L	-	128	3	53	67	181
Calcium	mg/L	-	91.4	3	49.1	52.4	89.6
Magnesium	mg/L	-	27.9	3	15.5	16	26.3
Chloride	mg/L	230, 860[3]	146	3	55	56	221
Sulphate	mg/L	100[4]	**117**	3	54	72	79
Total Dissolved Solids	mg/L	-	731	3	450	460	830
Total Alkalinity	mg/L	-	266	3	158	169	294
Organic compounds							
Naphthenic acids	mg/L	-	2	3	<1	1	3
Selected metals							
Total aluminum	mg/L	0.1	0.098	3	**0.238**	**0.265**	**0.318**
Dissolved aluminum	mg/L	0.1[2]	0.0031	3	0.0017	0.0141	0.0445
Total boron	mg/L	1.2[5]	0.149	3	0.088	0.136	0.169
Total molybdenum	mg/L	0.073	0.00025	3	0.00019	0.000377	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	1.3
Total strontium	mg/L	-	0.330	3	0.233	0.245	0.425

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-6 Water quality guideline exceedances in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1), 2006.

Variable	Units	Guideline*	POC-1	BER-1	MCC-1	ISL-1	SHL-1	FOC-1
Summer								
Sulphate	mg/L	100[1]	ns	ns	ns	**101**	-	-
Sulphide	mg/L	0.002[2]	ns	ns	ns	**0.005**	-	-
Total phenols	mg/L	0.004	ns	ns	ns	**0.013**	**0.014**	-
Fall								
Sulphate	mg/L	100[1]	-	**117**	-	**109**	-	-
Sulphide	mg/L	0.002[2]	**0.007**	**0.014**	-	**0.004**	**0.006**	**0.005**
Total phosphorus	mg/L	0.05	-	-	-	-	-	**0.059**
Total nitrogen	mg/L	1.0	-	-	-	**1.2**	-	-
Total aluminum	mg/L	0.1	**0.437**	-	**0.148**	-	-	**0.85**
Total chromium	mg/L	0.0010, 0.0089[5]	-	-	-	-	-	**0.00122**
Dissolved iron	mg/L	0.3[4]	**0.304**	-	-	-	-	-
Total iron	mg/L	0.3	**0.929**	**3.49**	**0.579**	-	**0.6**	**1.94**
Total phenols	mg/L	0.004	**0.014**	-	-	-	-	**0.005**

BER-1, MCC-1 and POC-1 were sampled only in fall 2006. ISL-1 and SHL-1 were sampled in summer and fall 2006.

ns = not sampled

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[1] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

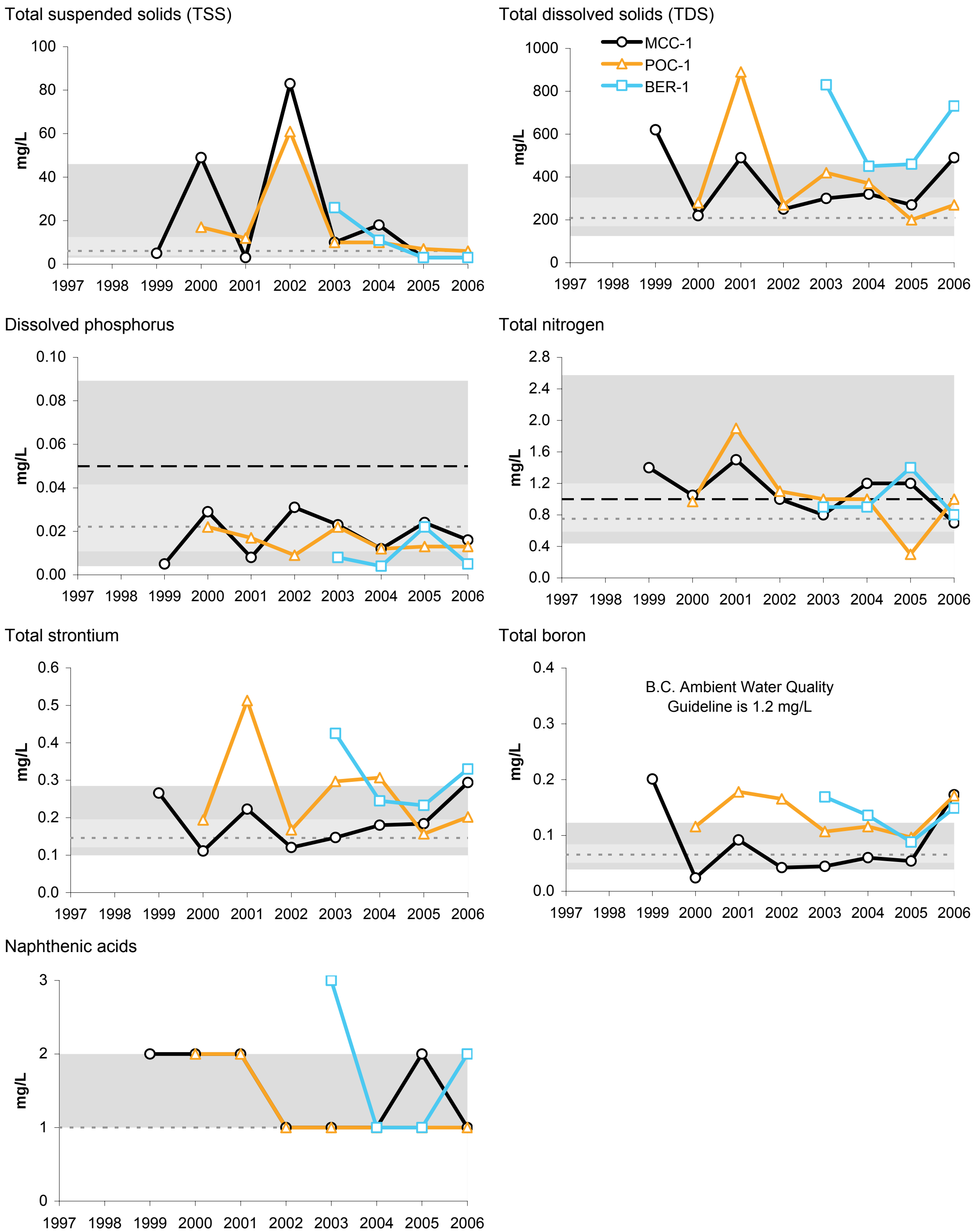
[2] B.C. Working Water Quality Guideline for sulphide as H_2S (2001).

[3] Guideline is hardness-dependent.

[4] Guideline is for total metal (no guideline for dissolved species).

[5] Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

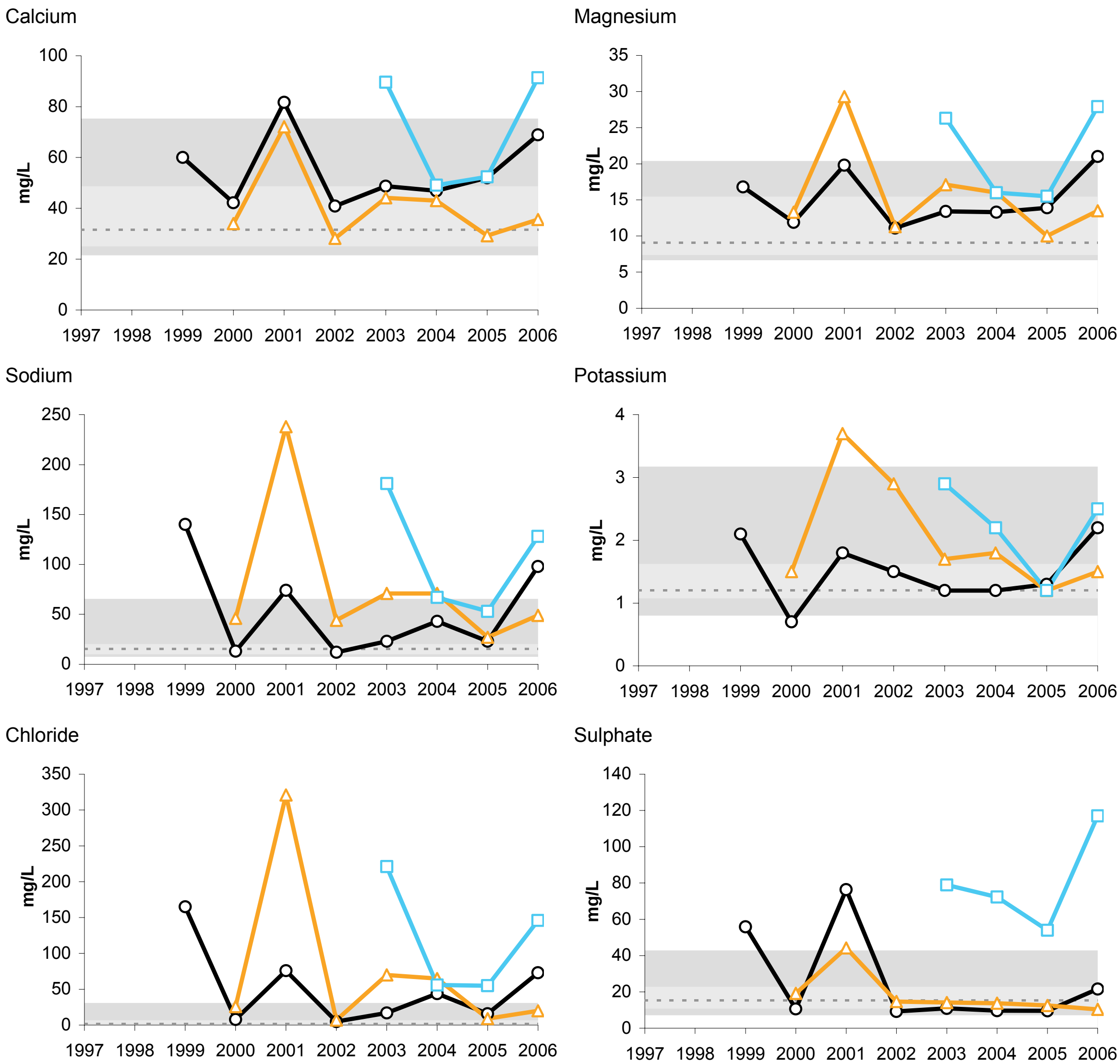
Figure 5.12-10 Concentrations of selected water quality measurement endpoints in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1) (fall 2006) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-10 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-11 Piper diagram of ion balance in McLean Creek, Beaver River and Poplar Creek, 1999-2006.

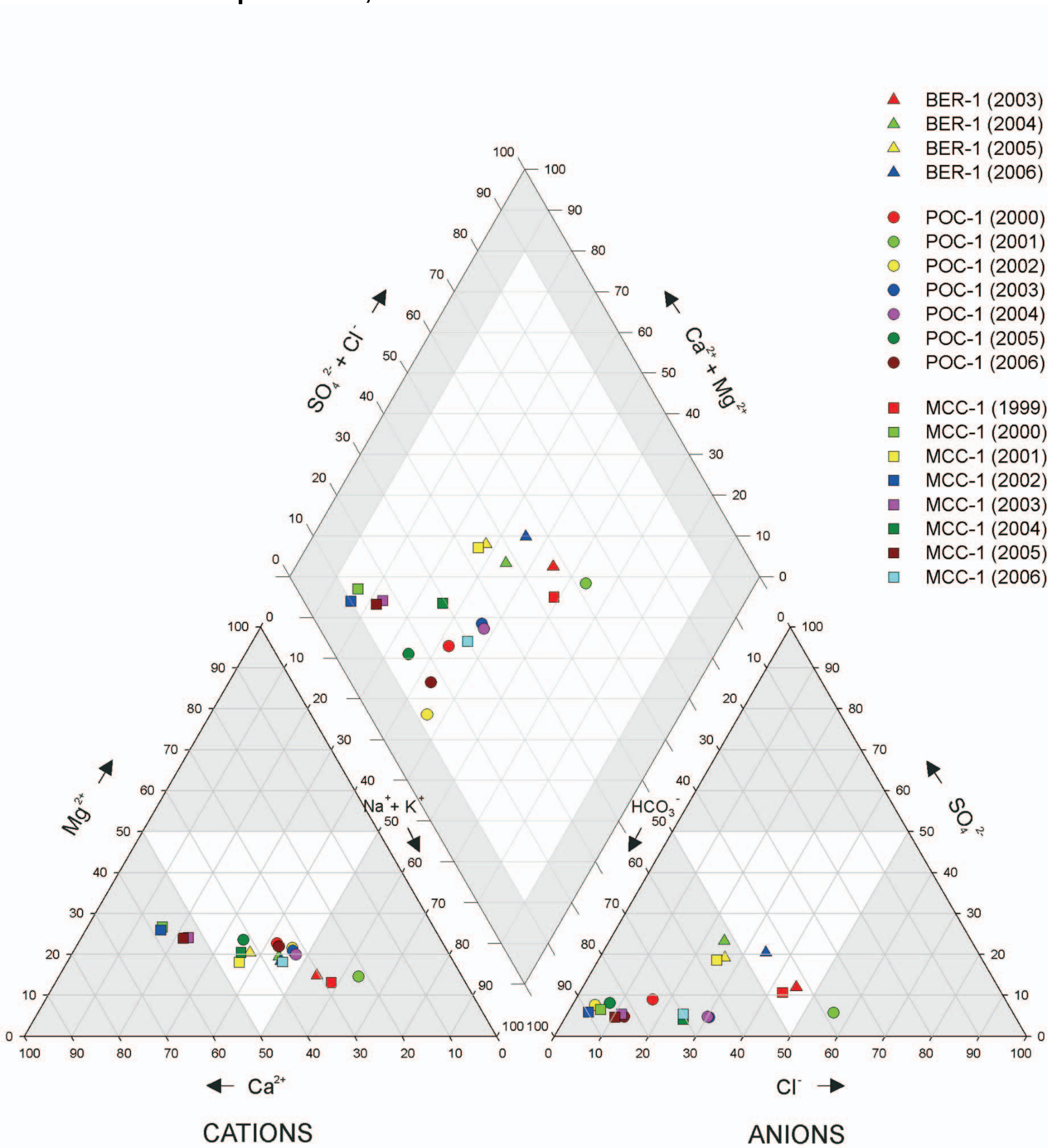


Table 5.12-7 Concentrations of water quality measurement endpoints, Poplar Creek (POC-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	6	7.9	8.2	8.3
Total Suspended Solids	mg/L	-[1]	6	6	7	11	61
Conductivity	µS/cm	-	428	6	308	486	1590
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	6	0.009	0.015	0.022
Total nitrogen*	mg/L	1.0	1	6	0.3	1	**1.9**
Nitrate+Nitrite	mg/L	-	<0.1	6	<0.1	0.09	0.1
Dissolved organic carbon	mg/L	-	18	6	21	24	32
Ions							
Sodium	mg/L	-	49	6	27	58.5	238
Calcium	mg/L	-	35.6	6	28.2	38.5	72.1
Magnesium	mg/L	-	13.5	6	10	14.7	29.3
Chloride	mg/L	230, 860[3]	20	6	7	46	**321**
Sulphate	mg/L	100[4]	10.4	6	12.5	14.4	44.2
Total Dissolved Solids	mg/L	-	270	6	200	325	890
Total Alkalinity	mg/L	-	191	6	135	187	304
Organic compounds							
Naphthenic acids	mg/L	-	1	6	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.437**	6	**0.207**	**0.291**	**1.44**
Dissolved aluminum	mg/L	0.1[2]	0.0039	6	0.00542	0.0093	<0.01
Total boron	mg/L	1.2[5]	0.171	6	0.096	0.116	0.178
Total molybdenum	mg/L	0.073	0.00025	6	0.0002	0.00029	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	0.9
Total strontium	mg/L	-	0.202	6	0.157	0.246	0.513

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-8 Concentrations of water quality measurement endpoints, McLean Creek (MCC-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.6	7	8.0	8.3	8.4
Total Suspended Solids	mg/L	-[1]	3	7	<3	10	83
Conductivity	µS/cm	-	829	7	300	402	1000
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.016	7	0.005	0.023	0.031
Total nitrogen*	mg/L	1.0	0.7	7	0.8	**1.2**	**1.5**
Nitrate+Nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<1
Dissolved organic carbon	mg/L	-	18	7	14	22	34
Ions							
Sodium	mg/L	-	98	7	12	23	140
Calcium	mg/L	-	68.9	7	40.9	48.7	81.7
Magnesium	mg/L	-	21	7	11.1	13.4	19.8
Chloride	mg/L	230, 860[3]	73	7	5	17	165
Sulphate	mg/L	100[4]	21.6	7	9.2	10.6	76.4
Total Dissolved Solids	mg/L	-	490	7	220	300	620
Total Alkalinity	mg/L	-	319	7	144	176	251
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	2	2
Selected metals							
Total aluminum	mg/L	0.1	**0.15**	7	0.07	**0.35**	**2.58**
Dissolved aluminum	mg/L	0.1[2]	0.0025	7	0.0080	0.0100	0.0157
Total boron	mg/L	1.2[5]	0.173	7	0.024	0.054	0.201
Total molybdenum	mg/L	0.073	0.0002	7	0.00014	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	0.9
Total strontium	mg/L	-	0.294	7	0.111	0.180	0.266

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

Table 5.12-9 Concentrations of water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.7	8.1	8.2
Total Suspended Solids	mg/L	-[1]	<3	4	5	8	10
Conductivity	µS/cm	-	588	4	353	494	551
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.006	4	0.004	0.024	**0.067**
Total nitrogen*	mg/L	1.0	**1.2**	4	0.3	0.75	**1.25**
Nitrate+Nitrite	mg/L	-	0.3	4	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	12	4	8	9.5	11
Ions							
Sodium	mg/L	-	13	4	6	7.5	10
Calcium	mg/L	-	69	4	37	54.35	72.2
Magnesium	mg/L	-	33.2	4	25.6	28.4	29.2
Chloride	mg/L	230, 860[3]	16	4	4	6	12
Sulphate	mg/L	100[4]	**109**	4	63.9	81.9	**109**
Total Dissolved Solids	mg/L	-	380	4	250	310	340
Total Alkalinity	mg/L	-	170	4	122	159.5	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.016	4	<0.02	0.052	**0.182**
Dissolved aluminum	mg/L	0.1[2]	0.0003	3	0.000589	0.0060	0.020
Total boron	mg/L	1.2[5]	0.0491	4	0.0350	0.0391	0.0439
Total molybdenum	mg/L	0.073	0.000019	4	0.000018	0.00010	0.000125
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.4	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.238	4	0.162	0.208	0.237

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

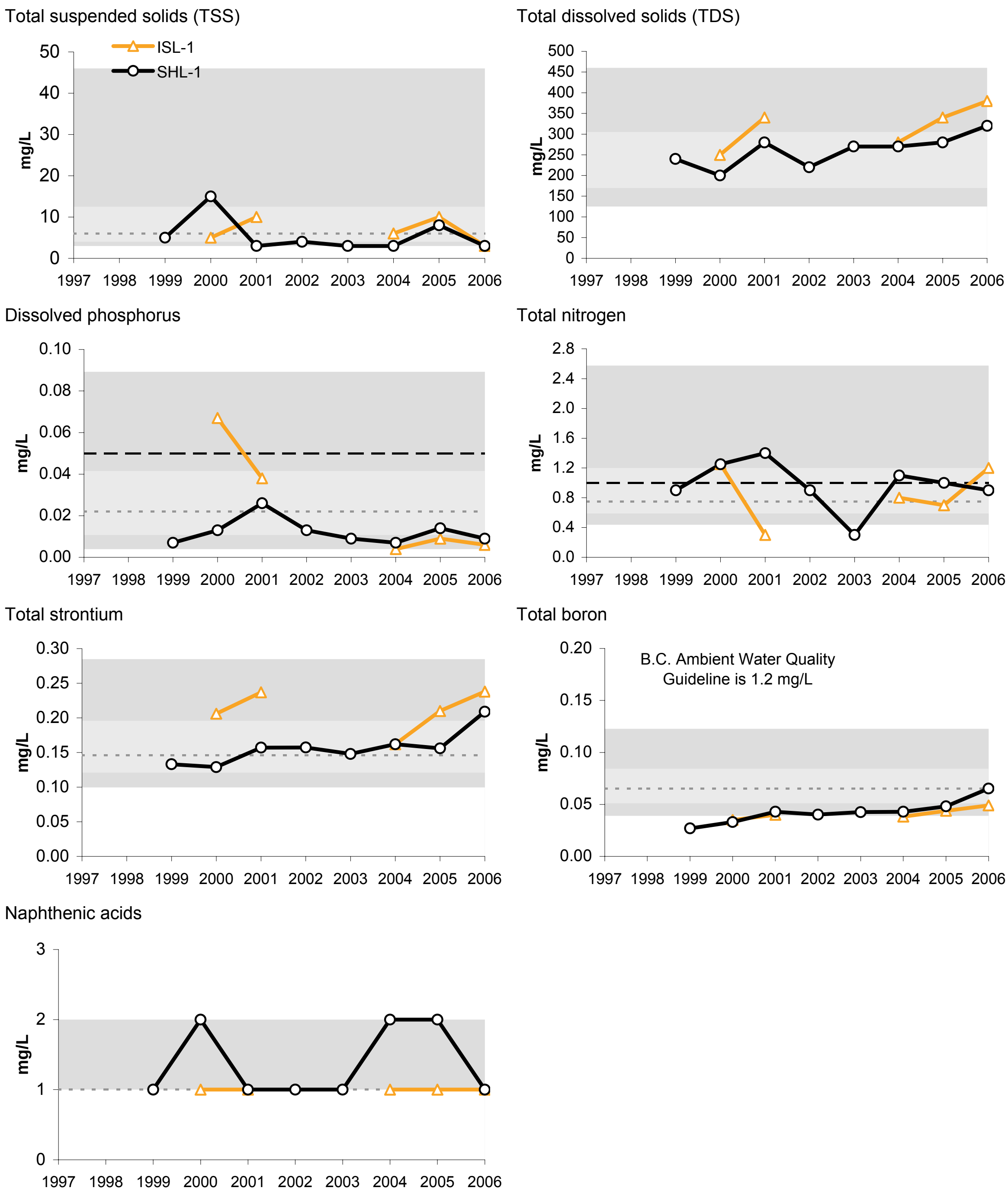
4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

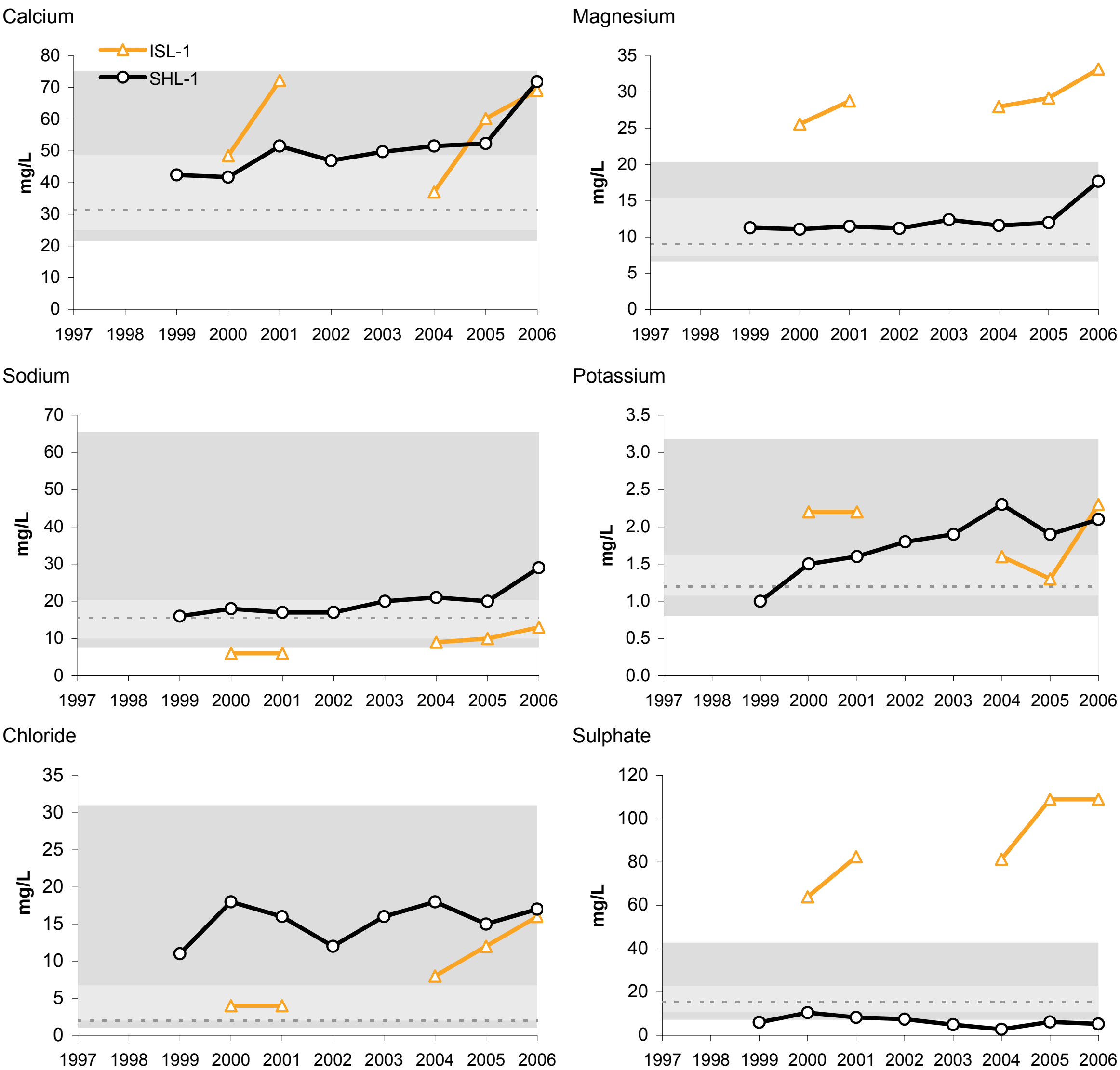
Figure 5.12-12 Concentrations of selected fall water quality measurement endpoints, Shipyard Lake (SHL-1) and Isadore's Lake (ISL-1) (fall 2006), relative to regional fall baseline concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-12 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-13 Piper diagram of ion balance in Shipyard Lake and Isadore's Lake, 1999-2006.

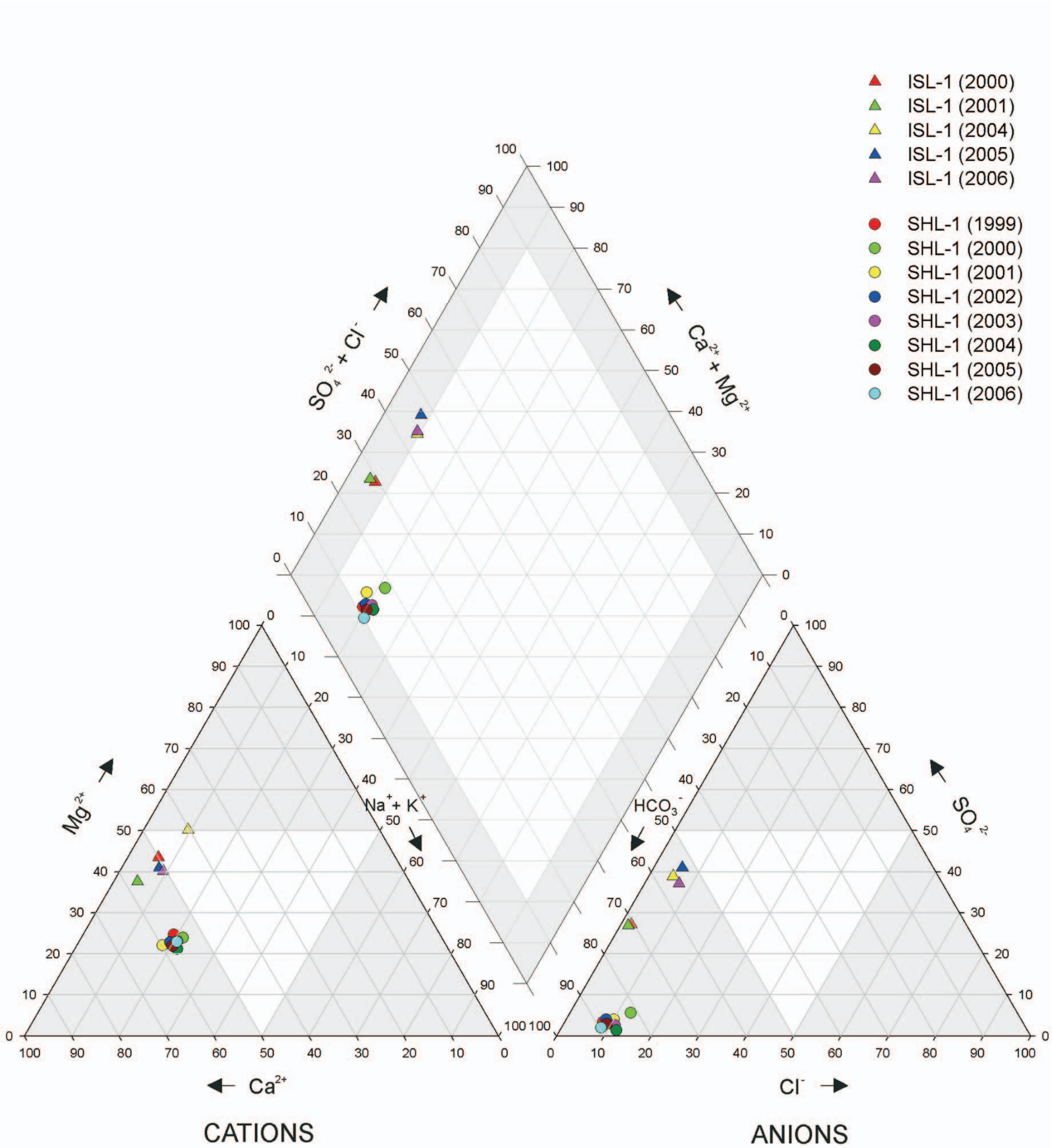


Table 5.12-10 Concentrations of water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	7	7.7	8.1	8.1
Total Suspended Solids	mg/L	-[1]	<3	7	<3	4	15
Conductivity	µS/cm	-	509	7	358	379	421
Nutrients							
Total nitrogen*	mg/L	1.0	0.9	7	0.3	1.0	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	18	7	17	20	24
Ions							
Sodium	mg/L	-	29	7	16	18	21
Calcium	mg/L	-	71.8	7	41.7	49.7	52.3
Magnesium	mg/L	-	17.7	7	11.1	11.5	12.4
Chloride	mg/L	230, 860[3]	17	7	11	16	18
Sulphate	mg/L	100[4]	5.3	7	2.8	6.2	10.5
Total Dissolved Solids	mg/L	-	320	7	200	255	280
Total Alkalinity	mg/L	-	251	7	159	175	201
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.010	7	0.004	0.023	**0.140**
Dissolved aluminum	mg/L	0.1[2]	0.00090	7	0.00049	0.00280	<0.01
Total boron	mg/L	1.2[5]	0.0653	7	0.0270	0.0426	0.0481
Total molybdenum	mg/L	0.073	0.000061	7	0.000046	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	0.7	1.0
Total strontium	mg/L	-	0.209	7	0.129	0.156	0.162

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-11 Concentrations of water quality measurement endpoints, lower Fort Creek (FOC-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n[9]	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	5	8.1	8.2	8.3
Total Suspended Solids	mg/L	-[1]	25	5	5	14	61
Conductivity	µS/cm	-	562	5	432	482	546
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	5	0.01	0.016	0.02
Total nitrogen*	mg/L	1.0	0.9	5	0.4	0.5	1.0
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	5	11	13	14
Ions							
Sodium	mg/L	-	18	5	8	10	12
Calcium	mg/L	-	89.6	5	69.4	74.4	82.2
Magnesium	mg/L	-	20.1	5	14.3	15.6	19.7
Chloride	mg/L	230, 860[3]	7	5	2	2	4
Sulphate	mg/L	100[4]	3.7	5	4.7	7.8	11.2
Total Dissolved Solids	mg/L	-	360	5	260	320	360
Total Alkalinity	mg/L	-	304	5	231	260	289
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.85**	5	0.04	0.050	**0.30**
Dissolved aluminum	mg/L	0.1[2]	0.0011	5	0.0015	0.003	0.090
Total boron	mg/L	1.2[5]	0.0731	5	0.0260	0.0500	0.053
Total molybdenum	mg/L	0.073	0.00010	5	<0.0001	0.0001	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	1	-	-	1.1
Total strontium	mg/L	-	0.224	5	0.142	0.172	0.206
Other variables that exceeded CCME/AENV guidelines in fall 2006							
Sulphide	mg/L	0.002[7]	**0.005**	5	<0.003	<0.003	**0.004**
Total chromium	mg/L	0.0010, 0.0089[8]	**0.0012**	5	0.00012	<0.0008	0.0006
Total iron	mg/L	0.3	**1.94**	5	0.07	**0.60**	**1.29**
Total phenols	mg/L	0.004	**0.005**	5	<0.001	0.002	**0.027**

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

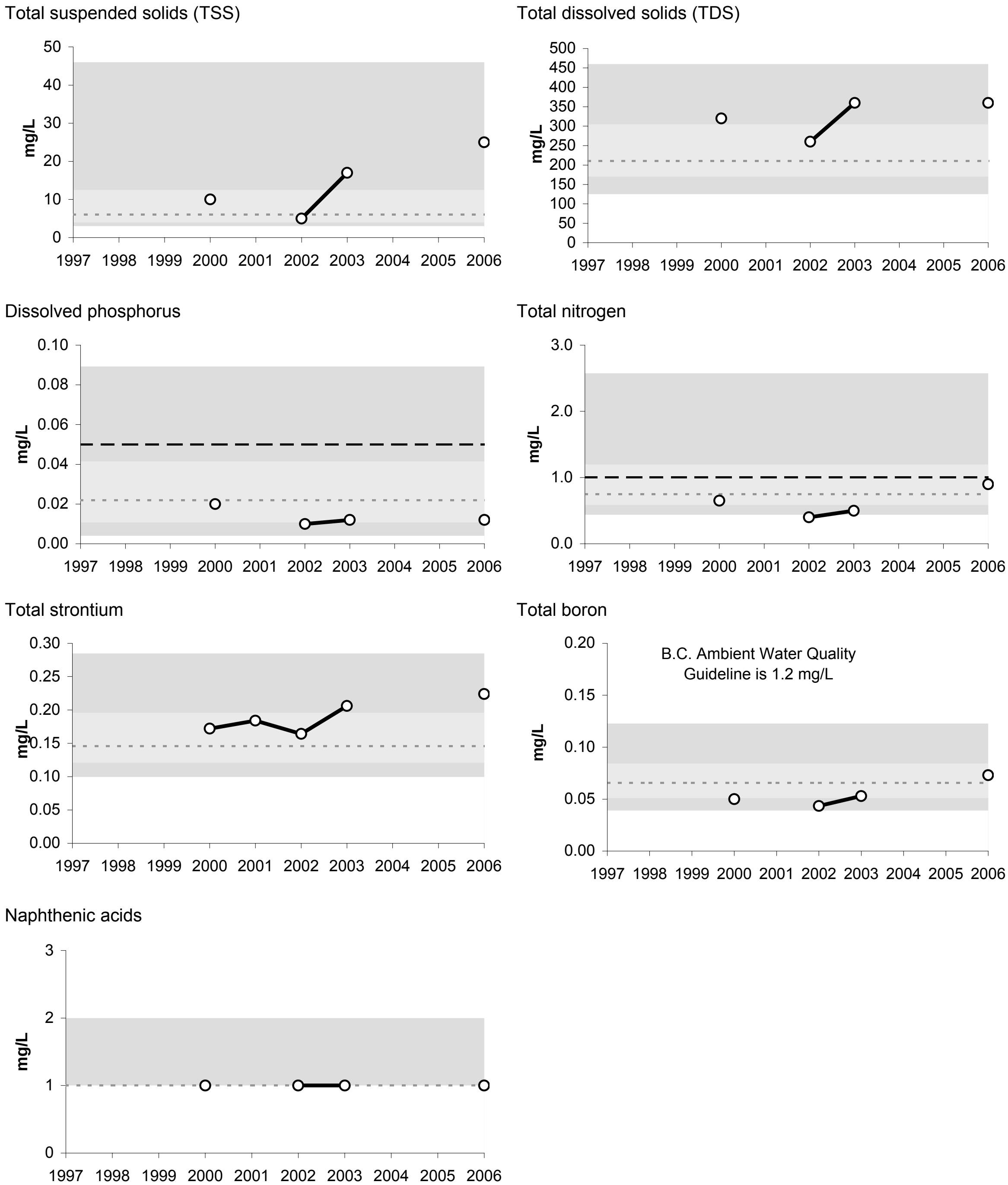
6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

8 Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

9 FOC-1 was sampled in both September and October 2000.

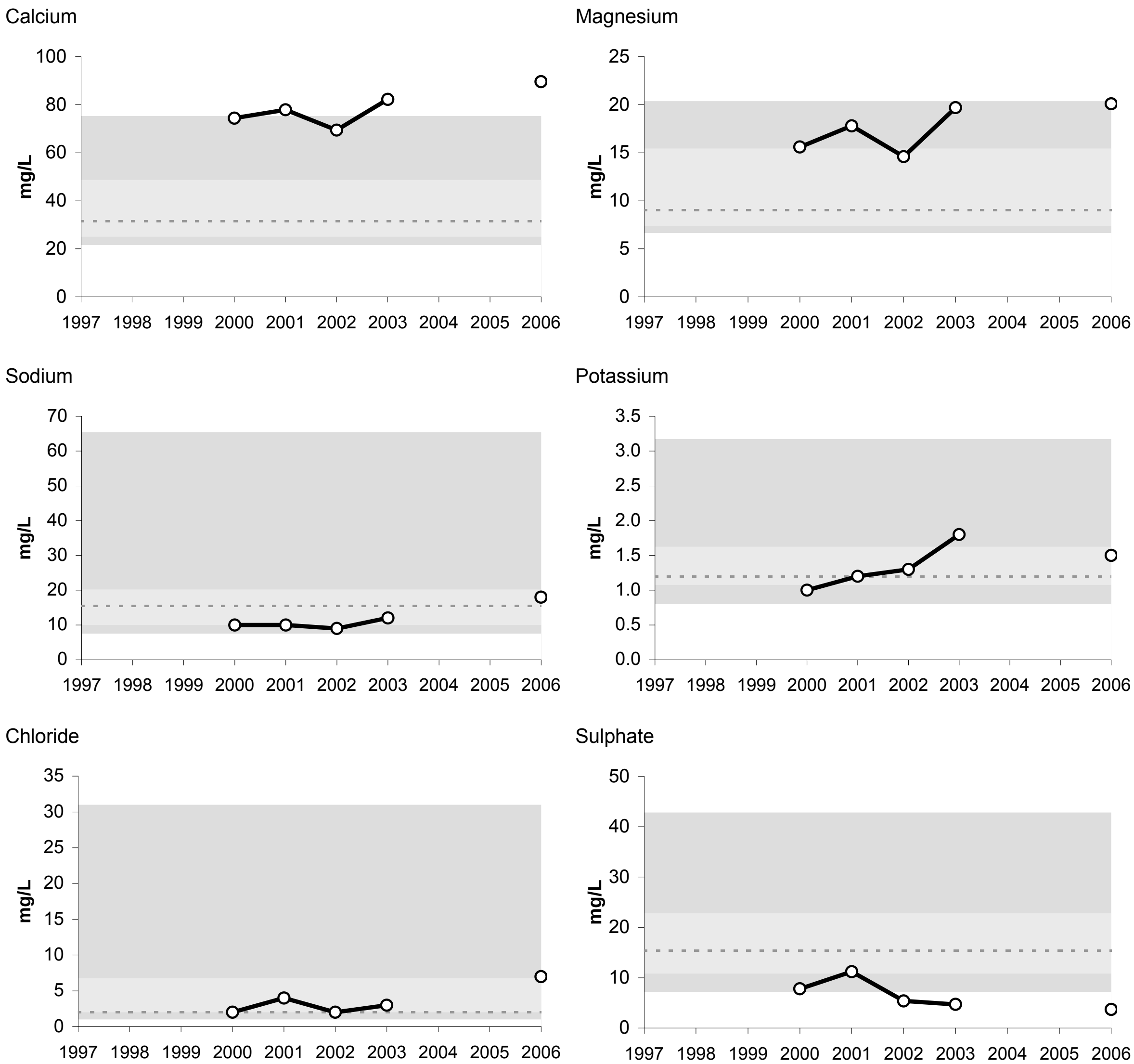
Figure 5.12-14 Concentrations of selected water quality measurement endpoints in Fort Creek (fall 2006) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-14 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-15 Piper diagram of fall ion balance in Fort Creek, 2000 to 2006.

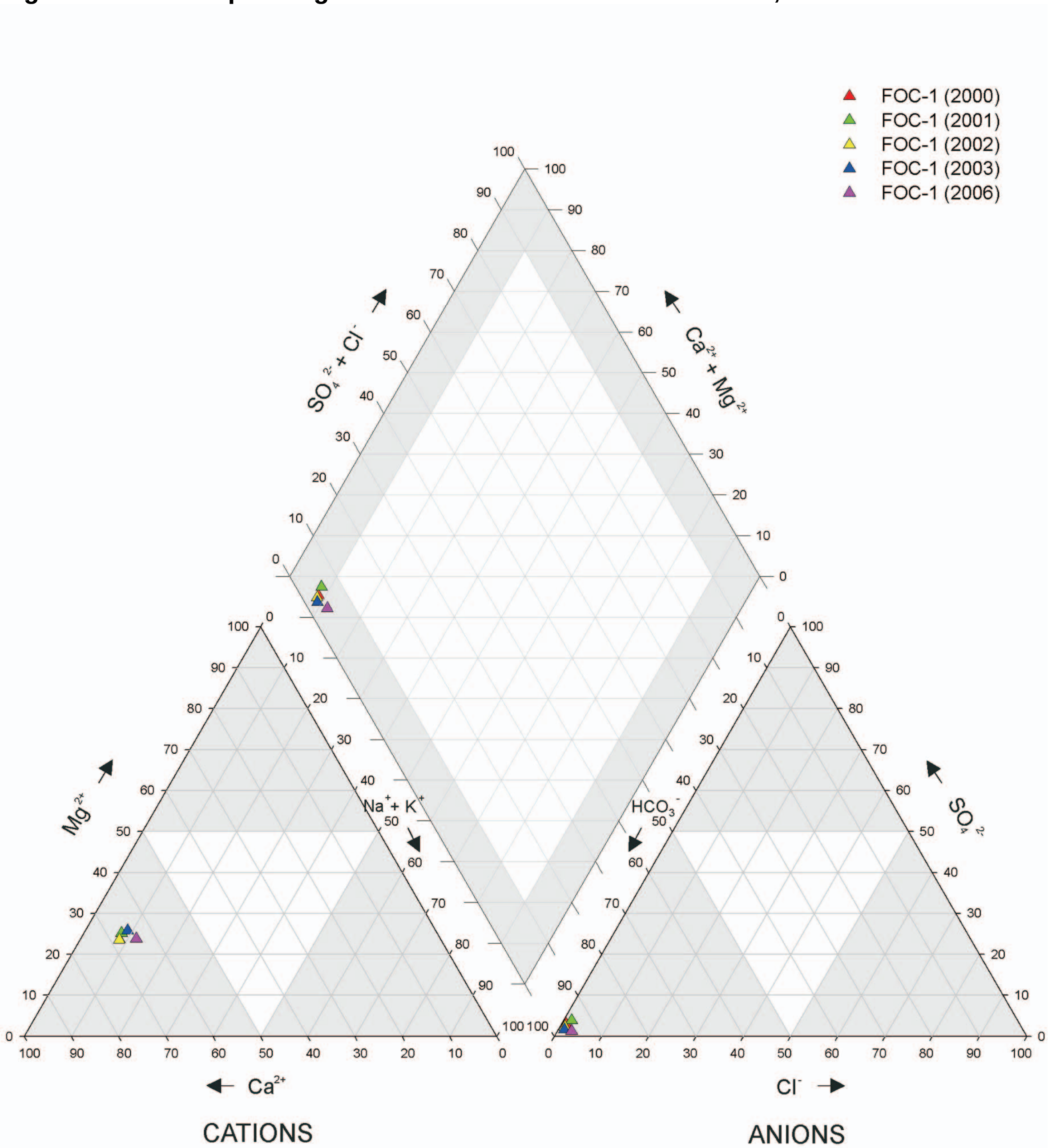


Table 5.12-12 Concentrations of water quality measurement endpoints, Kearl Lake (station KEL-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	7	7.6	8.0	8.1
Total suspended solids	mg/L	-[1]	19	7	<3	4	15
Conductivity	µS/cm	-	133	7	150	179	183
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.008	7	0.002	0.008	0.013
Total nitrogen*	mg/L	1.0	**1.5**	7	0.45	0.95	**1.8**
Nitrate+nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	7	15	21	24
Ions							
Sodium	mg/L	-	10	7	8	10	11
Calcium	mg/L	-	20	7	16.5	19.6	20.6
Magnesium	mg/L	-	7.5	7	6	6.9	7.6
Chloride	mg/L	230, 860[3]	2	7	<0.5	<1.0	2
Sulphate	mg/L	100[4]	5.6	7	2.7	4.8	5.7
Total dissolved solids	mg/L	-	154	7	94	140	220
Total alkalinity	mg/L		84	7	72	88	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.057	7	0.011	0.030	**0.13**
Dissolved aluminum	mg/L	0.1[2]	0.0014	7	0.0014	0.0050	0.030
Total boron	mg/L	1.2[5]	0.0473	7	0.012	0.047	0.0493
Total molybdenum	mg/L	0.073	0.00012	7	<0.0001	0.00010	0.0009
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	3	<0.6	<0.6	<0.6
Total strontium	mg/L	-	0.068	7	0.056	0.061	0.215

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-13 Water quality guideline exceedances, Kearl Lake (station KEL-1) and McLelland Lake (station MCL-1), fall 2006.

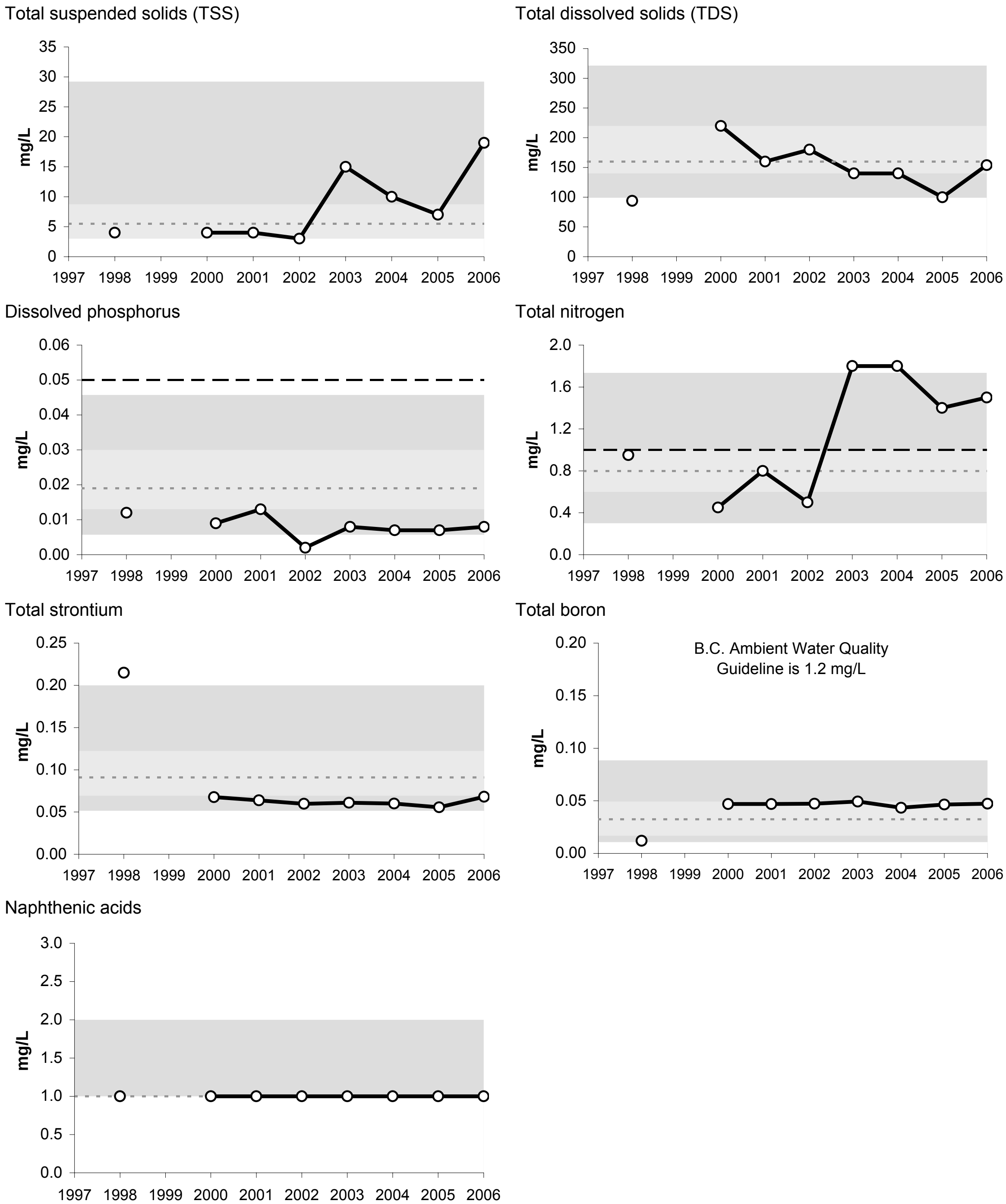
Variable	Units	Guideline	KEL-1	MCL-1
Fall				
Sulphide	mg/L	0.002[1]	**0.007**	-
Total nitrogen	mg/L	1.0	**1.5**	-
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.4**	-

KEL-1 and MCL-1 not sampled in winter, spring, or summer 2006.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S.

[2] Guideline is for total nitrogen.

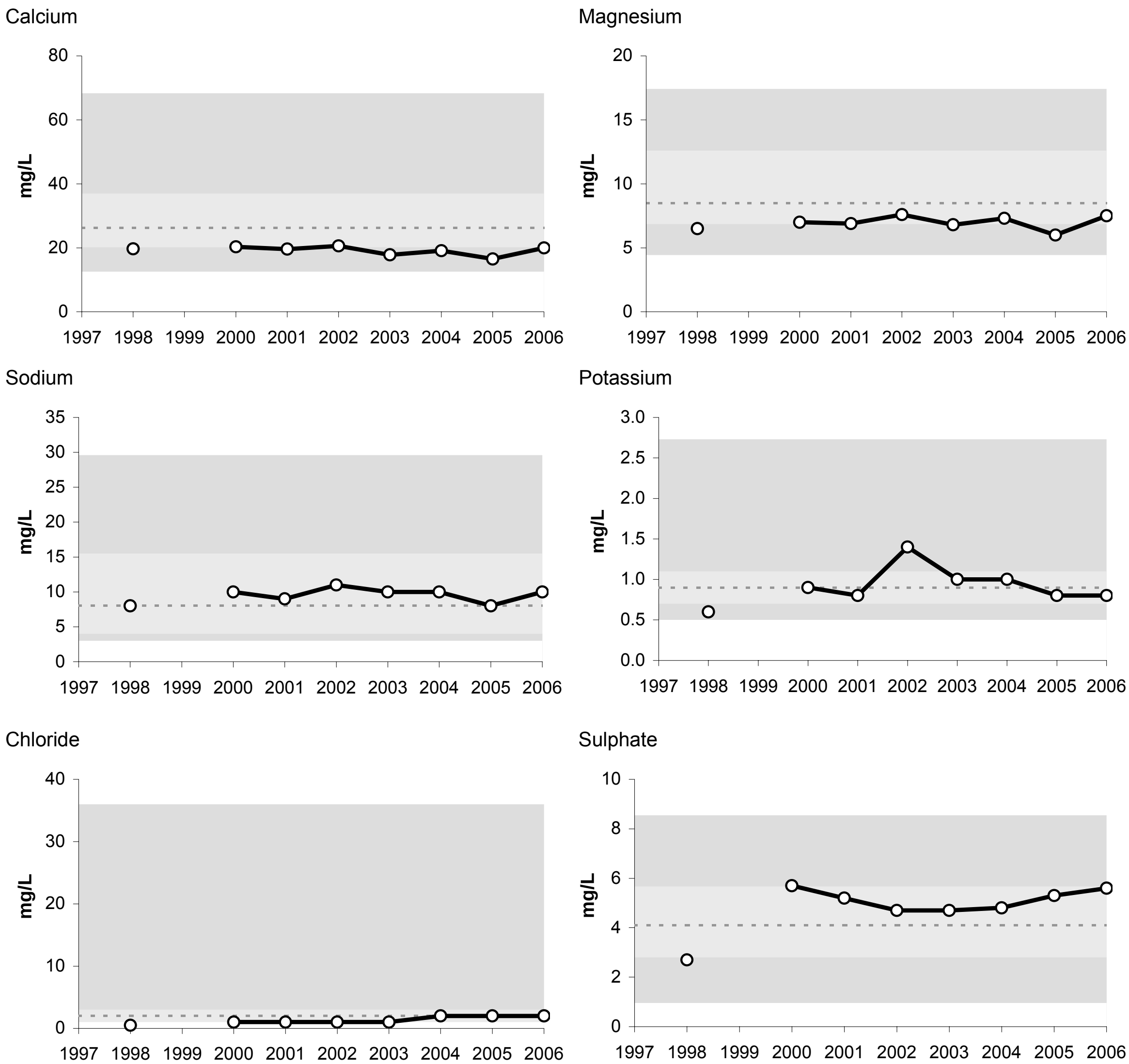
Figure 5.12-16 Concentrations of selected water quality measurement endpoints in Kearl Lake (station KEL-1, fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-16 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-17 Piper diagram of fall concentrations in Kearl Lake (station KEL-1) and McClelland Lake (station (MCL-1).

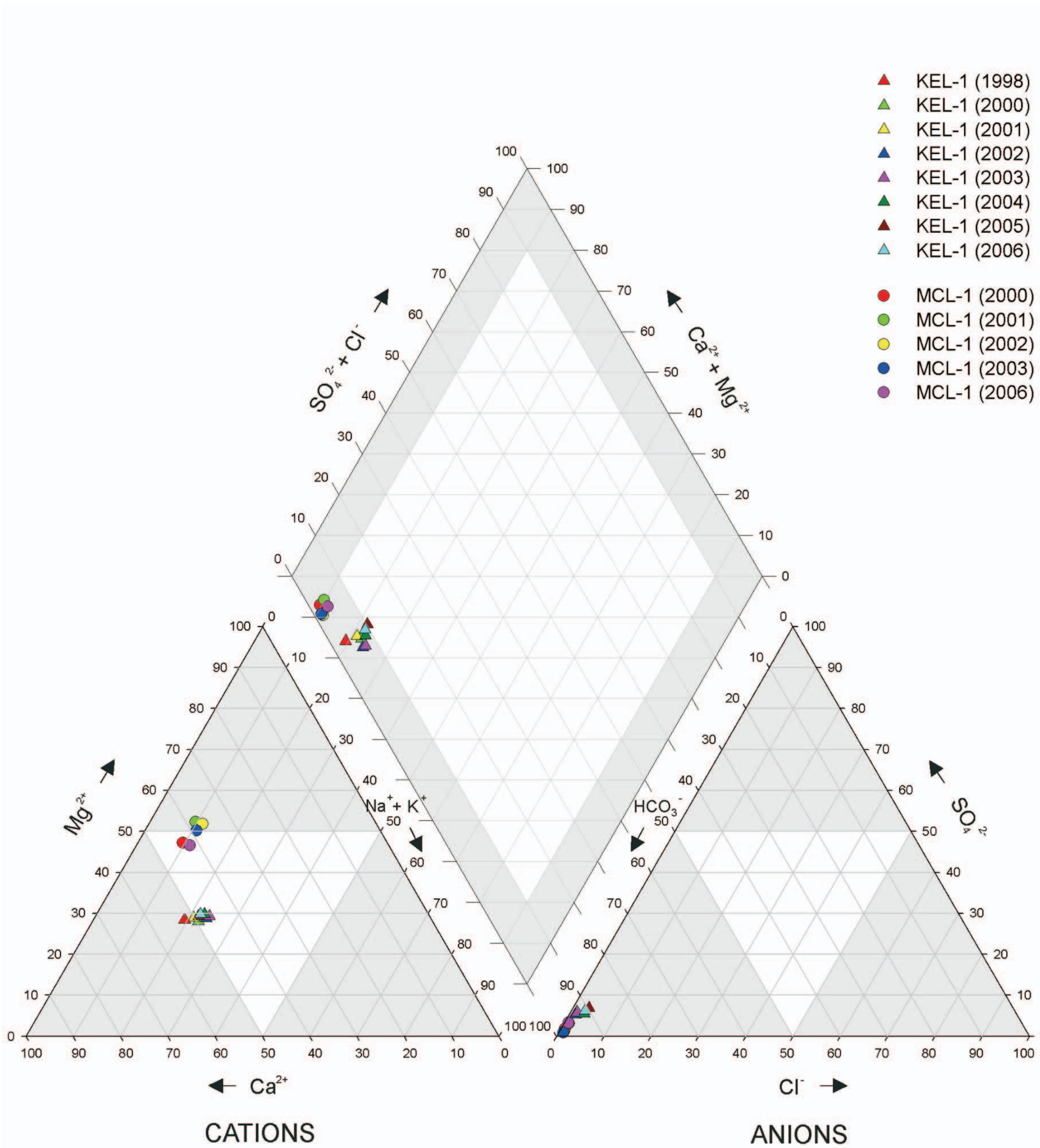


Table 5.12-14 Concentrations of water quality measurement endpoints, McClelland Lake (station MCL-1), fall 2006.

Endpoint	Units	Guideline	September 2006	1997-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	8.1	8.4	8.5
Total suspended solids	mg/L	-[1]	<3	4	<3	4	5
Conductivity	µS/cm	-	245	4	150	179	183
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.004	4	0.002	0.005	0.013
Total nitrogen*	mg/L	1.0	0.9	4	0.6	1.0	**2.0**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	11	4	11	12.5	17
Ions							
Sodium	mg/L	-	6	4	4	4.5	5
Calcium	mg/L	-	25.8	4	19.3	20.3	22
Magnesium	mg/L	-	17.3	4	14.6	16.3	16.7
Chloride	mg/L	230, 860[3]	1	4	<1	<1	<1
Sulphate	mg/L	100[4]	4.3	4	1.0	1.8	3.6
Total dissolved solids	mg/L	-	167	4	80	145	160
Total alkalinity	mg/L		135	4	122	123	129
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.009	4	0.005	0.020	0.026
Dissolved aluminum	mg/L	0.1[2]	0.0004	4	0.0012	0.0061	0.010
Total boron	mg/L	1.2[5]	0.0656	4	0.0513	0.0629	0.0670
Total molybdenum	mg/L	0.073	0.000004	4	<0.00002	0.00007	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<0.6	1	-	-	<0.6
Total strontium	mg/L	-	0.145	4	0.112	0.124	0.142

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

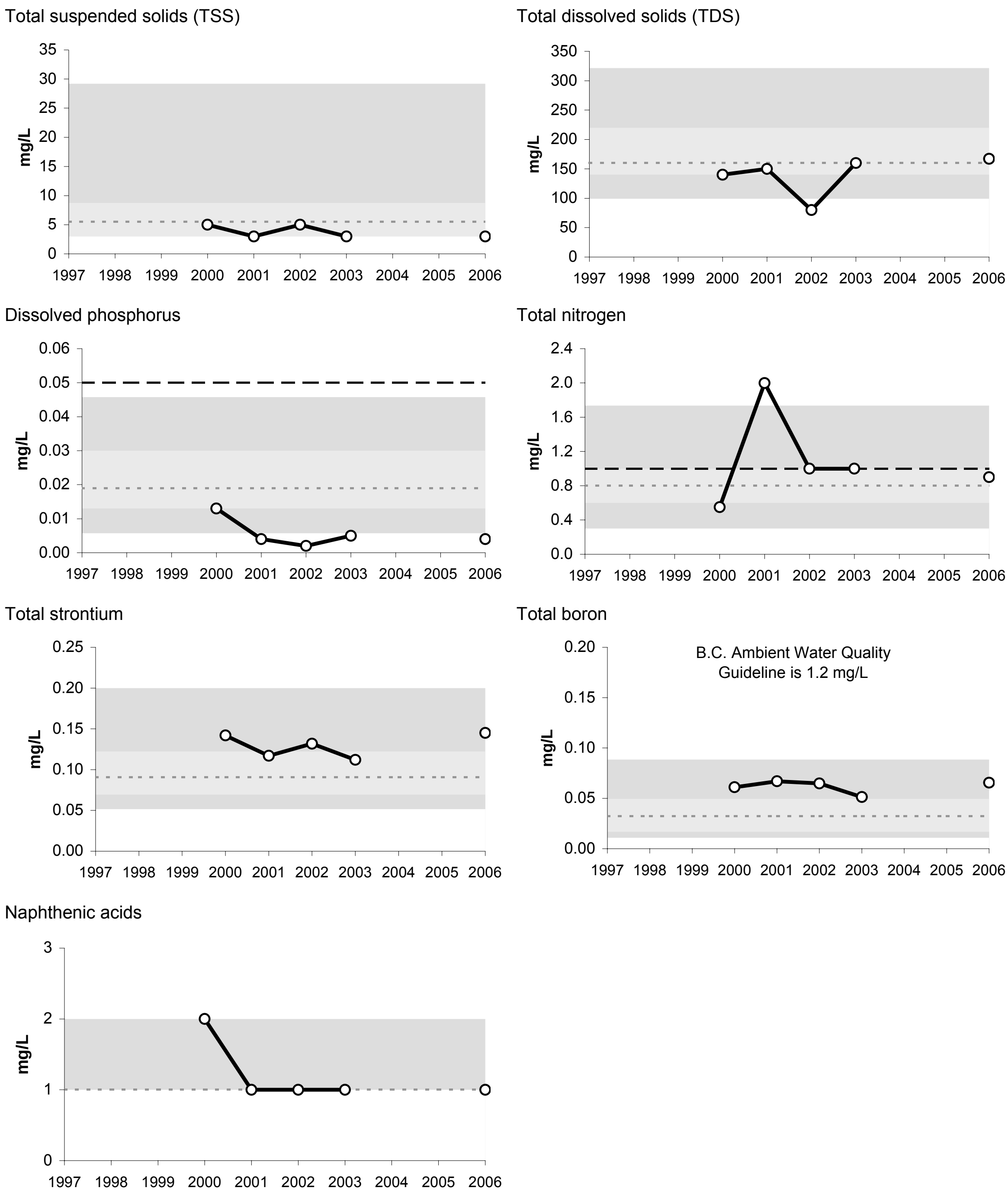
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

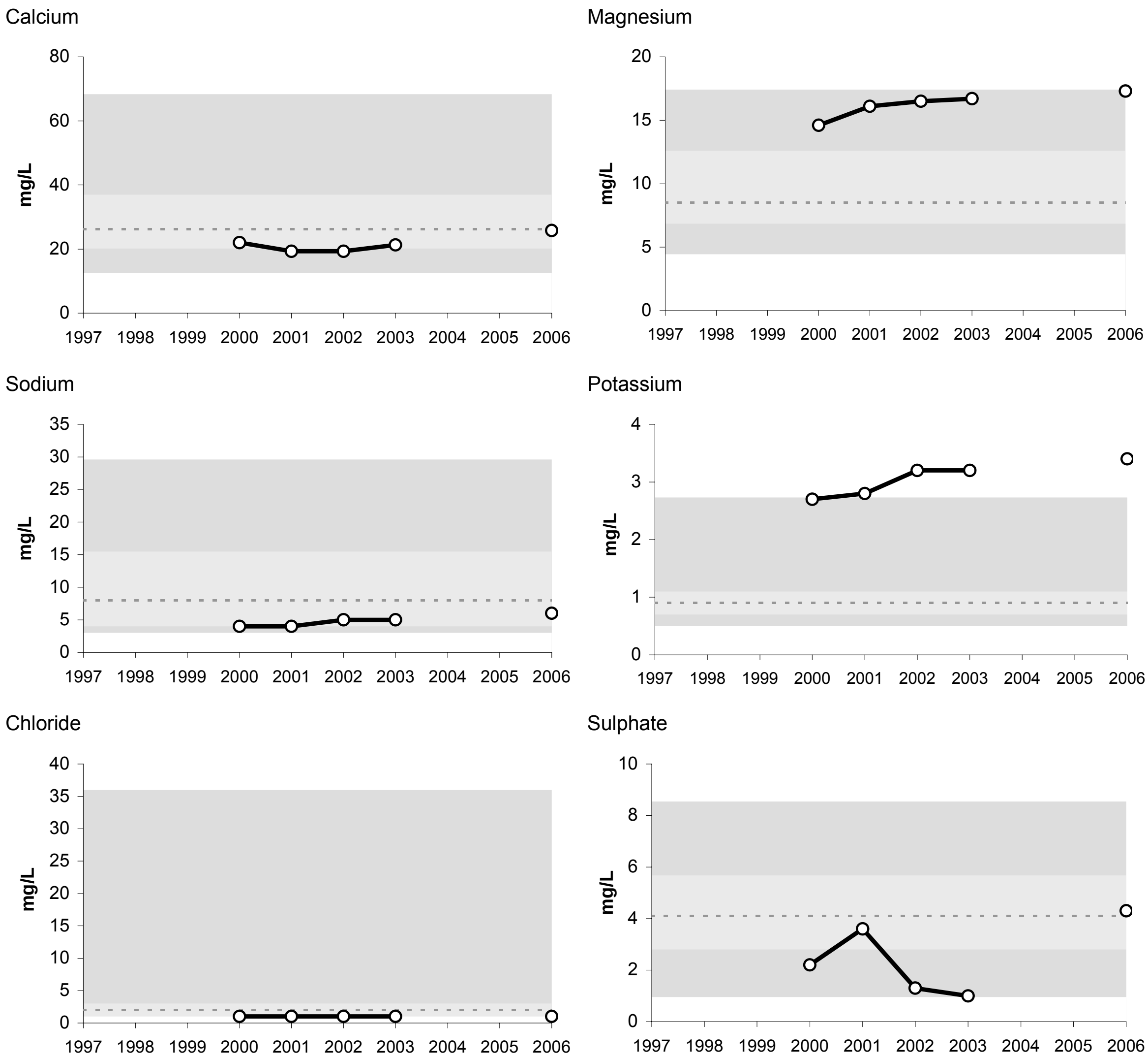
Figure 5.12-18 Concentrations of selected water quality measurement endpoints in McClelland Lake (station MCL-1, fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.12-18 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Table 5.12-15 Concentrations of water quality measurement endpoints (fall data), Birch Lake (BIL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.1	5	6.8	7.1	7.6
Total Suspended Solids	mg/L	-[1]	4	4	<3	3	8
Conductivity	µS/cm	-	107	5	90	93	101
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.032	3	0.009	0.02	0.033
Total nitrogen*	mg/L	1.0	**1.3**	5	0.1	**1.2**	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.006
Dissolved organic carbon	mg/L	-	30	4	23	28	32
Ions							
Sodium	mg/L	-	6	5	3	4	4
Calcium	mg/L	-	14.6	5	12	12.4	12.6
Magnesium	mg/L	-	4.1	5	3.21	3.3	3.4
Chloride	mg/L	230, 860[3]	4	5	<1	2	2
Sulphate	mg/L	100[4]	1.7	5	1.73	2	3.5
Total Dissolved Solids	mg/L	-	133	4	50	125	140
Total Alkalinity	mg/L	-	48	5	40	43	47
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	2
Selected metals							
Total aluminum	mg/L	0.1	0.0574	4	0.03	0.0469	0.07
Dissolved aluminum	mg/L	0.1[2]	0.0376	2	0.0195	-	0.0475
Total boron	mg/L	1.2[5]	0.0207	4	0.011	0.0216	0.0223
Total molybdenum	mg/L	0.073	0.000066	4	<0.001	0.0000	6.53E-05
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.058	4	0.049	0.050	0.053

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-16 Concentrations of water quality measurement endpoints (fall data), Long Lake (LOL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.2	5	7.0	7.1	7.6
Total Suspended Solids	mg/L	-[1]	<3	5	1	6	9
Conductivity	µS/cm	-	123	5	73	87	113
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.014	4	0.006	0.018	0.044
Total nitrogen*	mg/L	1.0	**1.1**	5	0.826	**1.3**	**2.2**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.006	<0.1	<0.1
Dissolved organic carbon	mg/L	-	29	5	22	29	33
Ions							
Sodium	mg/L	-	7	5	4	5	5
Calcium	mg/L	-	14.4	5	8.2	9.8	13
Magnesium	mg/L	-	5.1	5	2.6	3.4	4.4
Chloride	mg/L	230, 860[3]	3	5	<1	1.2	3
Sulphate	mg/L	100[4]	13.4	5	5	6.1	13.4
Total Dissolved Solids	mg/L	-	130	5	47	120	140
Total Alkalinity	mg/L	-	44	5	27	37	39
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.023	5	0.025	0.057	0.090
Dissolved aluminum	mg/L	0.1[2]	0.0058	2	0.0147	-	0.0192
Total boron	mg/L	1.2[5]	0.0187	5	0.011	0.0190	0.0232
Total molybdenum	mg/L	0.073	0.000083	5	0.00002	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.7	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.070	5	0.010	0.051	0.063

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-17 Concentrations of water quality measurement endpoints (fall data), Poison Lake (POL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.6	4	7.6	8.0	8.1
Total Suspended Solids	mg/L	-[1]	<3	4	7	9	12
Conductivity	µS/cm	-	182	4	186	194	320
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.011	3	0.007	0.014	0.014
Total nitrogen*	mg/L	1.0	**1.8**	4	**2.2**	**2.7**	**3.3**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.053	0.2
Dissolved organic carbon	mg/L	-	33	4	26	33.5	49
Ions							
Sodium	mg/L	-	11	4	8	9.6	14
Calcium	mg/L	-	21.6	4	23.5	24.15	38.7
Magnesium	mg/L	-	7.7	4	6.82	7.6	10.8
Chloride	mg/L	230, 860[3]	2	4	<1	1.1	2.0
Sulphate	mg/L	100[4]	0.8	4	2.0	2.6	3.3
Total Dissolved Solids	mg/L	-	169	4	104	175	310
Total Alkalinity	mg/L	-	90	4	96	100.5	168
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	3
Selected metals							
Total aluminum	mg/L	0.1	0.053	4	0.013	0.040	**0.120**
Dissolved aluminum	mg/L	0.1[2]	0.0015	2	0.002	-	0.006
Total boron	mg/L	1.2[5]	0.0529	4	0.0512	0.0696	0.0833
Total molybdenum	mg/L	0.073	0.000057	4	0.000052	0.0001	0.00021
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.098	4	0.104	0.122	0.195

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S.

8 Guideline is for total nitrogen.

Table 5.12-18 Concentrations of water quality measurement endpoints (fall data), Pushup Lake, 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.2	5	7.2	7.7	**9.2**
Total Suspended Solids	mg/L	-[1]	5	5	<3	3	13
Conductivity	μS/cm	-	84.2	5	82	90	101
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	4	0.003	0.006	0.034
Total nitrogen*	mg/L	1.0	**1.9**	5	**1.3**	**1.4**	**1.9**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.006
Dissolved organic carbon	mg/L	-	27	5	16	21	33
Ions							
Sodium	mg/L	-	2	5	1.6	2	2
Calcium	mg/L	-	11.3	5	9.8	10.6	12.4
Magnesium	mg/L	-	2.7	5	2.4	2.7	3
Chloride	mg/L	230, 860[3]	2	5	<1	1	2
Sulphate	mg/L	100[4]	<0.5	5	0.8	1.4	2.6
Total Dissolved Solids	mg/L	-	88	5	44	110	140
Total Alkalinity	mg/L	-	38	5	38	40	48
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.032	5	0.017	0.027	0.070
Dissolved aluminum	mg/L	0.1[2]	0.0062	2	0.0021	-	0.0030
Total boron	mg/L	1.2[5]	0.0168	5	0.003	0.0156	0.0266
Total molybdenum	mg/L	0.073	0.000013	5	0.000007	0.00002	0.00003
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.040	5	0.030	0.034	0.045

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] Guideline is for total nitrogen.

Table 5.12-19 Concentrations of water quality measurement endpoints (fall data), Rat Lake (RAL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	2	7.7	-	7.7
Total Suspended Solids	mg/L	-[1]	6	2	<1	-	4
Conductivity	µS/cm	-	204	2	206	-	208
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	1	-	-	0.009
Total nitrogen*	mg/L	1.0	**1.4**	2	0.8	**1.1**	**1.3**
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.006	-	<0.1
Dissolved organic carbon	mg/L	-	26	2	18	-	18
Ions							
Sodium	mg/L	-	8	2	6.5	-	8
Calcium	mg/L	-	27	2	26.6	-	26.6
Magnesium	mg/L	-	8	2	7.83	-	8.3
Chloride	mg/L	230, 860[3]	2	2	<1	-	1
Sulphate	mg/L	100[4]	2.7	2	4.4	-	4.6
Total Dissolved Solids	mg/L	-	167	2	113	-	180
Total Alkalinity	mg/L	-	100	2	103	-	109
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.016	2	0.016	-	0.033
Dissolved aluminum	mg/L	0.1[2]	0.0004	-	-	-	-
Total boron	mg/L	1.2[5]	0.033	2	0.023	-	0.034
Total molybdenum	mg/L	0.073	0.00007	2	0.00007	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.094	2	0.097	0.099	0.100

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-20 Concentrations of water quality measurement endpoints, (fall data) Canoe Lake (CANL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.4	3	6.8	7.2	7.3
Total Suspended Solids	mg/L	-[1]	4	3	<3	1.0	19
Conductivity	µS/cm	-	102	3	83	84.0	93.6
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.02	2	0.013	-	**0.065**
Total nitrogen*	mg/L	1.0	**1.4**	3	**1.1**	**1.2**	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	3	0.06	<0.1	<0.1
Dissolved organic carbon	mg/L	-	23	3	20	21	22
Ions							
Sodium	mg/L	-	7	3	3	4.1	5
Calcium	mg/L	-	10.8	3	9.2	9.6	10.2
Magnesium	mg/L	-	3.5	3	3.1	3.2	3.2
Chloride	mg/L	230, 860[3]	5	3	<1	1	1.8
Sulphate	mg/L	100[4]	0.8	3	2.2	2.3	2.5
Total Dissolved Solids	mg/L	-	109	3	46	100	110
Total Alkalinity	mg/L	-	43	3	36	41	43
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.028	3	0.014	0.072	**0.110**
Dissolved aluminum	mg/L	0.1[2]	0.0063	-	-	-	-
Total boron	mg/L	1.2[5]	0.0193	3	0.015	0.018	0.018
Total molybdenum	mg/L	0.073	0.000042	3	<0.00002	<0.0001	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.036	3	0.037	0.037	0.040

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-21 Concentrations of water quality measurement endpoints (fall data), Caribou Horn Lake (CARL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.7	2	7.2	-	7.8
Total Suspended Solids	mg/L	-[1]	5	2	<3	-	2
Conductivity	µS/cm	-	160	2	176	-	182
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.017	1	-	-	0.009
Total nitrogen*	mg/L	1.0	1.1	2	0.6	-	**1.2**
Nitrate+Nitrite	mg/L	-	0.2	2	<0.006	-	<0.1
Dissolved organic carbon	mg/L	-	26	2	18	-	22
Ions							
Sodium	mg/L	-	6	2	5.2	-	6
Calcium	mg/L	-	21.6	2	22	-	23.1
Magnesium	mg/L	-	7	2	7.4	-	7.56
Chloride	mg/L	230, 860[3]	2	2	<1	-	1.1
Sulphate	mg/L	100[4]	1.3	2	3.4	-	16.1
Total Dissolved Solids	mg/L	-	138	2	97	-	180
Total Alkalinity	mg/L	-	77	2	74	-	94
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.0343	2	0.047	-	**0.116**
Dissolved aluminum	mg/L	0.1[2]	0.00803	-	-	-	-
Total boron	mg/L	1.2[5]	0.0311	2	0.0113	-	0.032
Total molybdenum	mg/L	0.073	0.00007	2	0.00002	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.053	2	0.017	0.042	0.067

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-22 Concentrations of water quality measurement endpoints (fall data), Frog Lake (FRL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	2	7.5	-	7.6
Total Suspended Solids	mg/L	-[1]	3	2	3	-	5
Conductivity	µS/cm	-	180	2	178	-	181
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.015	1	-	-	0.015
Total nitrogen*	mg/L	1.0	**1.6**	2	**1.3**	-	**1.3**
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.006	-	<0.1
Dissolved organic carbon	mg/L	-	39	2	28	-	30
Ions							
Sodium	mg/L	-	8	2	7.5	-	9
Calcium	mg/L	-	24.5	2	24.2	-	24.3
Magnesium	mg/L	-	7.6	2	7.2	-	7.5
Chloride	mg/L	230, 860[3]	5	2	<1	-	1
Sulphate	mg/L	100[4]	1.9	2	2.9	-	3.4
Total Dissolved Solids	mg/L	-	183	2	100	-	200
Total Alkalinity	mg/L	-	83	2	88	-	95
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.0162	2	0.035	-	0.043
Dissolved aluminum	mg/L	0.1[2]	0.00365	-	-	-	-
Total boron	mg/L	1.2[5]	0.038	2	0.052	-	0.070
Total molybdenum	mg/L	0.073	0.000074	2	0.00006	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.087	2	0.099	0.101	0.102

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-23 Concentrations of water quality measurement endpoints (fall data), Gregoire Lake (GRL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.6	1	-	-	7.6
Total Suspended Solids	mg/L	-[1]	6	1	-	-	<3
Conductivity	µS/cm	-	127	1	-	-	146
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.007	1	-	-	0.006
Total nitrogen*	mg/L	1.0	0.6	1	-	-	0.9
Nitrate+Nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	11	1	-	-	11
Ions							
Sodium	mg/L	-	4	1	-	-	4
Calcium	mg/L	-	16.9	1	-	-	18.3
Magnesium	mg/L	-	4.5	1	-	-	4.9
Chloride	mg/L	230, 860[3]	3	1	-	-	<1
Sulphate	mg/L	100[4]	6.4	1	-	-	6.7
Total Dissolved Solids	mg/L	-	96	1	-	-	120
Total Alkalinity	mg/L	-	53	1	-	-	64
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.0548	1	-	-	0.021
Dissolved aluminum	mg/L	0.1[2]	0.00279	-	-	-	-
Total boron	mg/L	1.2[5]	0.0174	1	-	-	0.019
Total molybdenum	mg/L	0.073	0.00056	1	-	-	0.00074
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.061	1	0.079	0.079	0.079

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

Table 5.12-24 Concentrations of water quality measurement endpoints (fall data), Kiskatinaw Lake (KIL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	2	7.7	-	7.8
Total Suspended Solids	mg/L	-[1]	4	2	<3	-	1
Conductivity	µS/cm	-	164	2	183.0	-	185
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.011	1	-	-	0.008
Total nitrogen*	mg/L	1.0	**1.1**	2	0.78	-	**1.1**
Nitrate+Nitrite	mg/L	-	0.1	2	<0.1	-	<0.006
Dissolved organic carbon	mg/L	-	24	2	20.0	-	40
Ions							
Sodium	mg/L	-	7	2	6.2	-	7
Calcium	mg/L	-	21.2	2	22.7	-	24.1
Magnesium	mg/L	-	6.6	2	6.9	-	7.31
Chloride	mg/L	230, 860[3]	2	2	<1	-	1.1
Sulphate	mg/L	100[4]	1.1	2	2.8	-	3.8
Total Dissolved Solids	mg/L	-	146	2	102.0	-	160
Total Alkalinity	mg/L	-	80	2	92.0	-	99
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.034	2	0.002	-	0.047
Dissolved aluminum	mg/L	0.1[2]	0.00293	-	-	-	-
Total boron	mg/L	1.2[5]	0.0445	2	<0.00008	-	0.040
Total molybdenum	mg/L	0.073	0.0000852	2	<0.00002	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.057	2	0.00001	-	0.074

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-25 Concentrations of water quality measurement endpoints (fall data), Sucker Lake (SUL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	3	7.7	7.8	7.9
Total Suspended Solids	mg/L	-[1]	4	2	<1	-	8
Conductivity	µS/cm	-	187	3	211	218	219
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.019	1	-	-	0.013
Total nitrogen*	mg/L	1.0	**1.9**	3	0.1	0.8	**1.5**
Nitrate+Nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.006
Dissolved organic carbon	mg/L	-	25	2	19	-	20
Ions							
Sodium	mg/L	-	10	3	9.8	10	11
Calcium	mg/L	-	23	3	24	25	27
Magnesium	mg/L	-	6.8	3	7.4	7.7	8.3
Chloride	mg/L	230, 860[3]	2	3	0.8	<1	2
Sulphate	mg/L	100[4]	2.5	3	3.4	4.0	6
Total Dissolved Solids	mg/L	-	157	2	117	-	190
Total Alkalinity	mg/L	-	91	3	106	113	115
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.0164	2	0.010	-	0.032
Dissolved aluminum	mg/L	0.1[2]	0.00046	-	-	-	-
Total boron	mg/L	1.2[5]	0.044	2	0.050	-	0.069
Total molybdenum	mg/L	0.073	0.000039	2	0.00006	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.087	3	0.044	0.114	0.120

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-26 Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 1 (UNL-1), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	**5.3**	3	**5.6**	**6.0**	**6.4**
Total Suspended Solids	mg/L	-[1]	<3	3	<1	5.0	22
Conductivity	µS/cm	-	24.3	3	23.2	26.1	39.2
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.03	1	-	-	0.023
Total nitrogen*	mg/L	1.0	1.0	2	0.7	-	**1.3**
Nitrate+Nitrite	mg/L	-	<0.1	2	<0.1	-	<0.006
Dissolved organic carbon	mg/L	-	28	3	21	22	22
Ions							
Sodium	mg/L	-	<1	3	0.6	<1	<1
Calcium	mg/L	-	3.3	3	2.6	3.0	3.1
Magnesium	mg/L	-	0.8	3	0.7	0.8	0.9
Chloride	mg/L	230, 860[3]	2	3	0.8	<1	<1
Sulphate	mg/L	100[4]	0.8	3	2.0	2.4	2.7
Total Dissolved Solids	mg/L	-	74	3	13	90	100
Total Alkalinity	mg/L	-	6	3	8	10	15
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	0.097	2	0.058	-	0.081
Dissolved aluminum	mg/L	0.1[2]	0.0749	-	-	-	-
Total boron	mg/L	1.2[5]	0.00836	2	<0.002	-	0.025
Total molybdenum	mg/L	0.073	0.000046	2	0.00011	-	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.009	2	0.010	0.026	0.042

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

Table 5.12-27 Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 2 (UNL-2), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	**5.7**	3	**5.6**	**6.1**	**6.2**
Total Suspended Solids	mg/L	-[1]	<3	2	<1	-	<3
Conductivity	µS/cm	-	35.9	3	33.7	35.4	41.5
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.11**	1	-	-	0.014
Total nitrogen*	mg/L	1.0	**1.1**	3	0.1	0.7	**1.2**
Nitrate+Nitrite	mg/L	-	0.1	3	<0.006	<0.1	<0.1
Dissolved organic carbon	mg/L	-	39	3	25	26	33
Ions							
Sodium	mg/L	-	2	4	<1	1.5	8.5
Calcium	mg/L	-	5.3	4	4.0	4.9	32
Magnesium	mg/L	-	1.5	4	1.2	1.4	8.1
Chloride	mg/L	230, 860[3]	3	3	1	1.5	2.0
Sulphate	mg/L	100[4]	1.2	3	2.6	3.2	6.2
Total Dissolved Solids	mg/L	-	109	2	17	-	100
Total Alkalinity	mg/L	-	11	3	7	9	10
Organic compounds							
Naphthenic acids	mg/L	-	<1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	**0.148**	3	0.021	**0.146**	**0.230**
Dissolved aluminum	mg/L	0.1[2]	**0.144**	-	-	-	-
Total boron	mg/L	1.2[5]	0.0077	3	0.018	0.030	0.039
Total molybdenum	mg/L	0.073	0.000033	3	0.00009	0.0009	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	-	-	-	-
Total strontium	mg/L	-	0.017	3	0.017	0.063	0.135

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is hardness-dependent. See guidelines for details.

Table 5.12-28 Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 3 (UNL-3), 2000 to 2006.

Endpoint	Units	Guideline	September 2006	2000-2005 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.6	4	7.7	7.9	8.0
Total Suspended Solids	mg/L	-[1]	9	4	<3	5	17
Conductivity	µS/cm	-	180	4	172	199	263
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.016	3	0.015	0.016	0.018
Total nitrogen*	mg/L	1.0					
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.006	<0.1	<0.1
Dissolved organic carbon	mg/L	-	31	4	32	40	47
Ions							
Sodium	mg/L	-	9	4	8	11	14
Calcium	mg/L	-	25	4	23	24	30
Magnesium	mg/L	-	6.4	4	5.6	6.7	8.5
Chloride	mg/L	230, 860[3]	2	4	<1	1	2
Sulphate	mg/L	100[4]	3.1	4	3.9	4.4	5.1
Total Dissolved Solids	mg/L	-	157	4	109	170	260
Total Alkalinity	mg/L	-	90	4	87	102	134
Organic compounds							
Naphthenic acids	mg/L	-	1	2	<1	-	3
Selected metals							
Total aluminum	mg/L	0.1	0.020	4	0.010	0.025	0.042
Dissolved aluminum	mg/L	0.1[2]	0.00086	2	0.00101	-	0.00196
Total boron	mg/L	1.2[5]	0.031	4	0.022	0.026	0.044
Total molybdenum	mg/L	0.073	0.000063	4	0.000040	0.000050	<0.001
Total mercury (ultra-trace)	ng/L	5, 13[6]	0.6	2	<0.6	-	<0.6
Total strontium	mg/L	-	0.082	4	0.037	0.082	0.111

Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S.

[8] Guideline is for total nitrogen.

Table 5.12-29 Water quality guideline exceedances, OPTI lakes, spring and fall 2006.

Variable	Units	Guideline*	BIL-1	CANL-1	CARL-1	FRL-1	GRL-1	KIL-1	LOL-1	POL-1	PUL-1	RAL-1	SUL-1	UNL-1	UNL-2	UNL-3	REF-2	REF-4
Spring																		
pH	pH units	6.5-9.0	-	-	-	-	-	-	-	-	-	-	-	5.2	5.9	-	-	-
Sulphide	mg/L	0.002[1]	0.01	0.005	0.008	0.009	-	0.005	0.005	0.004	-	0.004	0.004	-	0.01	0.006	-	-
Dissolved phosphorus	mg/L	0.05[4]	-	-	-	-	-	-	-	-	-	-	-	0.054	0.087	-	-	-
Total phosphorus	mg/L	0.05	-	-	-	-	-	-	-	-	-	-	-	0.064	0.101	-	-	-
Total Kjeldahl nitrogen	mg/L	1.0[3]	-	-	-	-	-	-	-	1.6	1.1	-	-	-	1.2	1.3	-	-
Total nitrogen	mg/L	1.0	1.1	1.2	-	1.1	-	-	-	1.7	1.2	1.1	1.1	-	1.3	1.4	-	1.1
Total aluminum	mg/L	0.1	-	0.756	-	0.842	-	-	-	-	-	-	-	-	-	-	-	-
Total cadmium	mg/L	-[2]	-	0.0000212	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved iron	mg/L	0.3[4]	-	-	-	-	-	0.468	-	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	-	0.842	-	0.961	-	0.716	-	-	-	-	-	-	-	-	-	-
Total phenols	mg/L	0.004	0.016	0.013	0.014	-	-	0.014	0.015	0.017	0.017	0.015	0.013	0.009	0.026	0.01	0.007	0.014
Fall																		
pH	pH units	6.5-9.0	-	-	-	-	-	-	-	-	-	-	-	5.3	5.7	-	-	-
Sulphide	mg/L	0.002[1]	0.008	0.005	0.007	0.01	-	0.006	0.015	0.003	-	0.008	0.007	0.004	0.009	0.004	0.004	0.004
Dissolved phosphorus	mg/L	0.05[4]	-	-	-	-	-	-	-	-	-	-	-	-	0.11	-	-	-
Total phosphorus	mg/L	0.05	0.052	0.053	-	-	-	-	-	-	-	-	0.054	-	0.112	-	-	-
Total Kjeldahl nitrogen	mg/L	1.0[3]	1.2	1.3	-	1.5	-	-	-	1.7	1.8	1.3	1.8	-	-	1.9	1.1	-
Total nitrogen	mg/L	1.0	1.3	1.4	1.1	1.6	-	1.1	1.1	1.8	1.9	1.4	1.9	-	1.1	-	1.3	-
Dissolved aluminum	mg/L	0.1[4]	-	-	-	-	-	-	-	-	-	-	-	-	0.144	-	-	-
Total aluminum	mg/L	0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.148	-	-	-
Dissolved cadmium	mg/L	-[2, 4]	-	-	-	-	-	-	-	-	-	-	-	-	0.0000099	-	-	-
Total cadmium	mg/L	-[2]	-	-	-	-	-	-	-	-	-	-	-	-	0.0000099	-	-	-
Dissolved iron	mg/L	0.3[4]	1.17	-	-	-	-	-	-	-	0.307	-	-	-	0.484	-	-	-
Total iron	mg/L	0.3	1.52	0.383	0.407	-	-	-	-	-	0.646	-	-	0.321	0.516	-	-	-

No winter sampling was conducted in this watershed.

* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

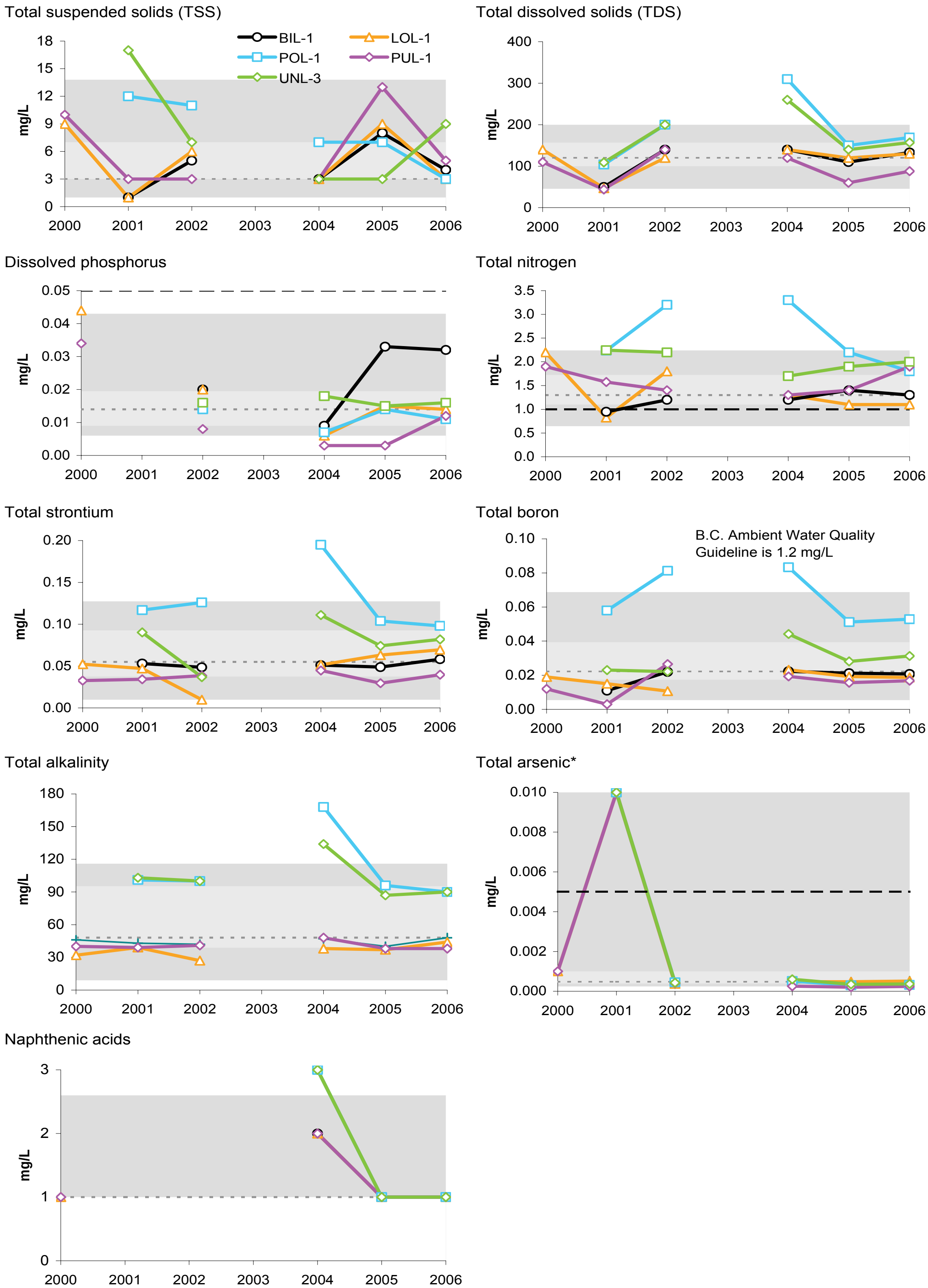
[1] B.C. Working Water Quality Guideline for sulphide as H_2S (2001).

[2] Guideline is hardness-dependent.

[3] Guideline is for total nitrogen.

[4] Guideline is for total analyte (no guideline for dissolved species).

Figure 5.12-19 Concentrations of selected water quality measurement endpoints in Birch (BIL-1), Long (LOL-1), Poison (POL-1), Pushup (PUL-1), and Unnamed Lake 3 (UNL-3) (fall data) relative to regional baseline fall concentrations.

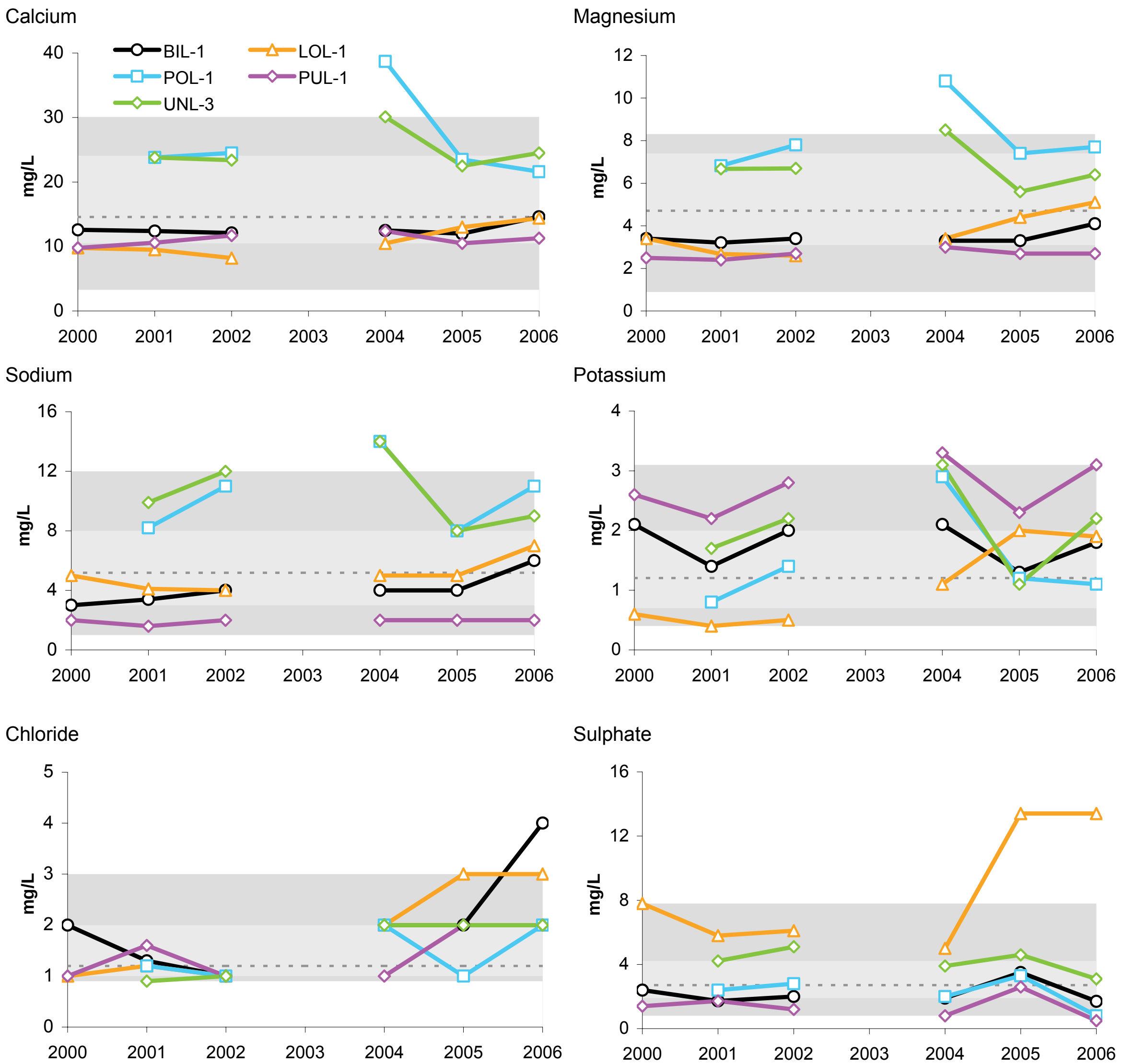


Non-detectable values are shown at the detection limit.

* Detection limit for arsenic in 2001 was 0.01 (higher than in other years); result is shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

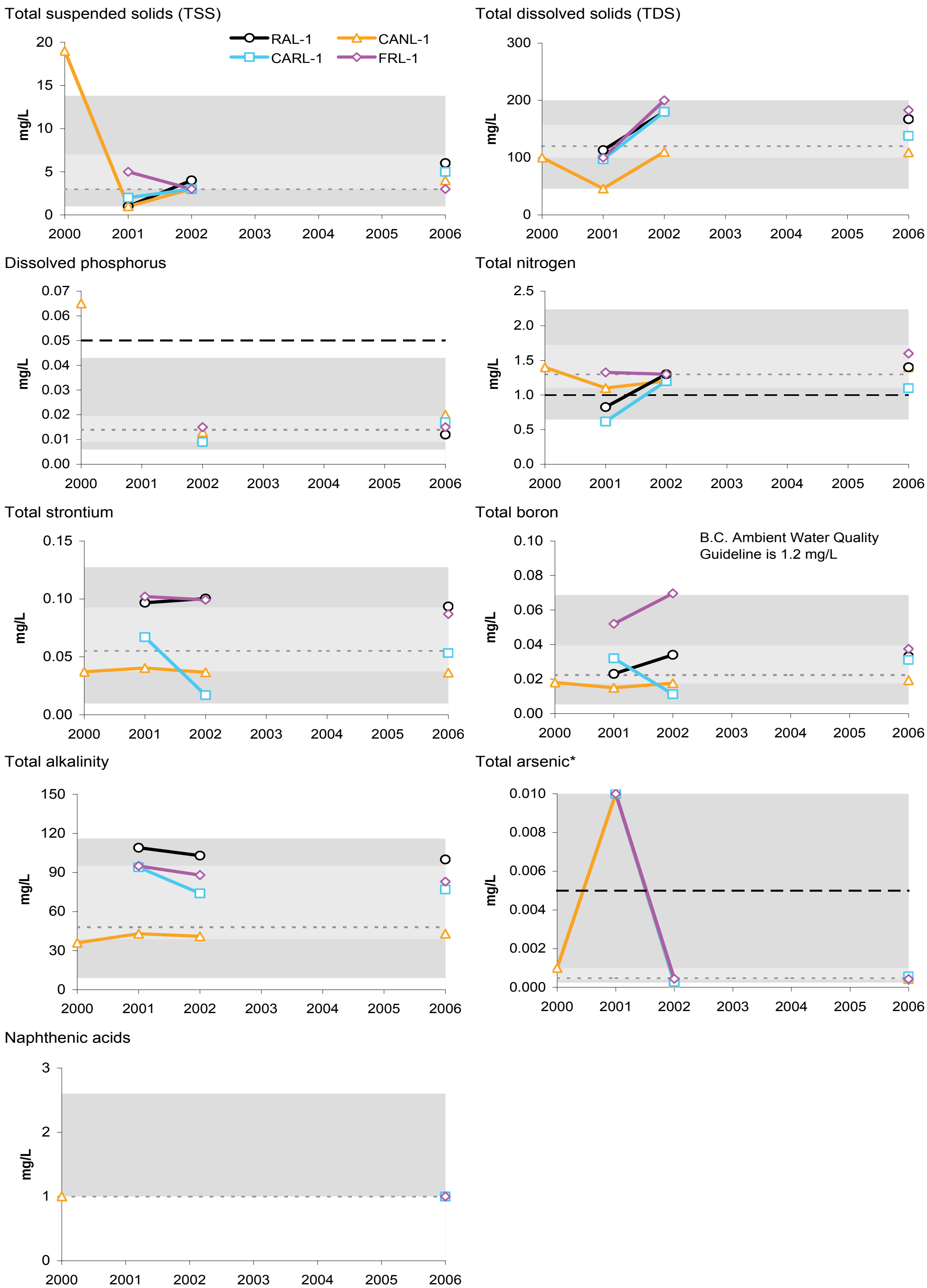
Figure 5.12-19 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-20 Concentrations of selected water quality measurement endpoints in Rat (RAL-1), Canoe (CANL-1), Caribou Horn (CARL-1), and Frog (FRL-1) lakes (fall data) relative to regional baseline fall concentrations.

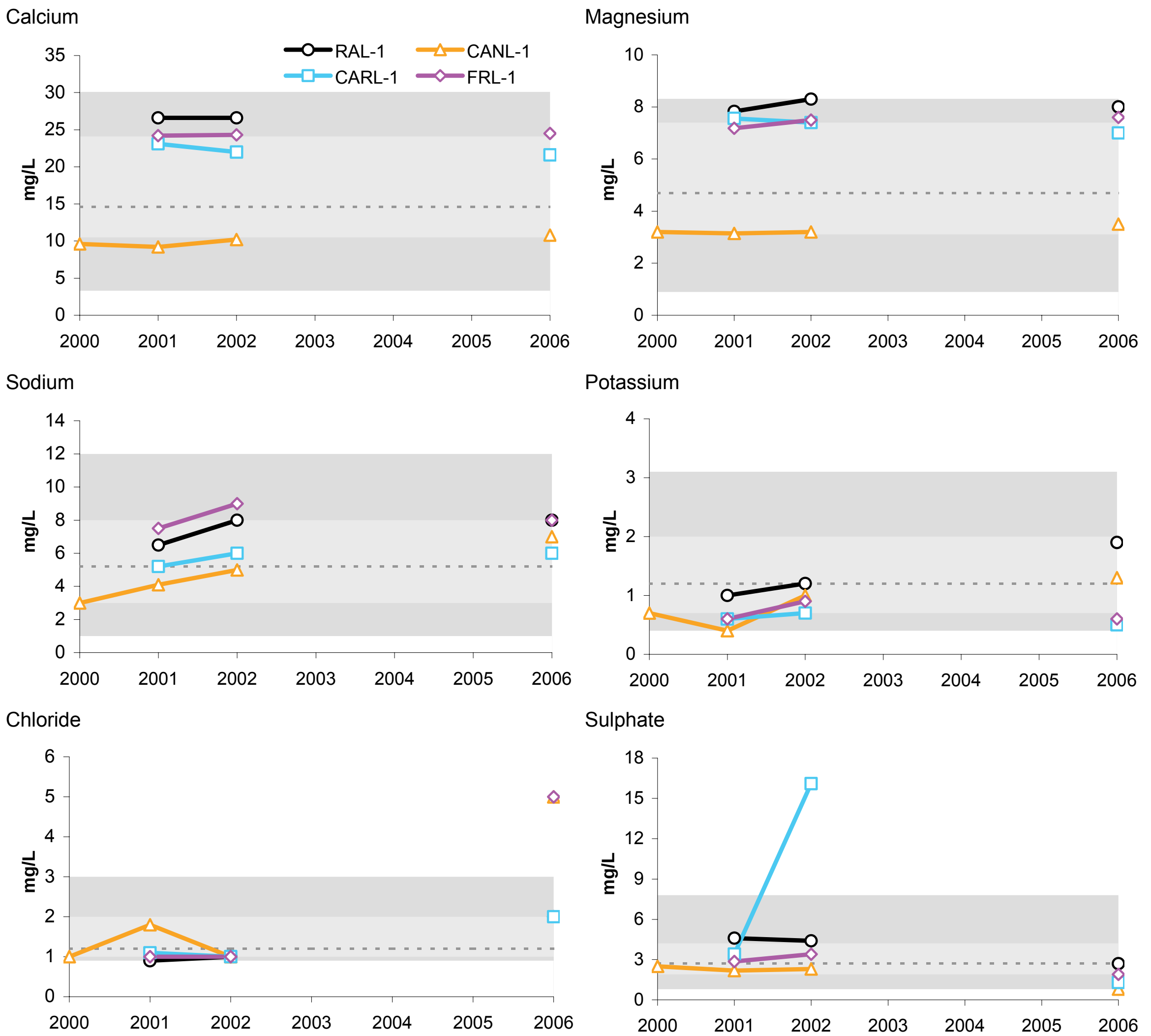


Non-detectable values are shown at the detection limit.

* Detection limit for arsenic in 2001 was 0.01 (higher than in other years); result is shown at the detection limit.

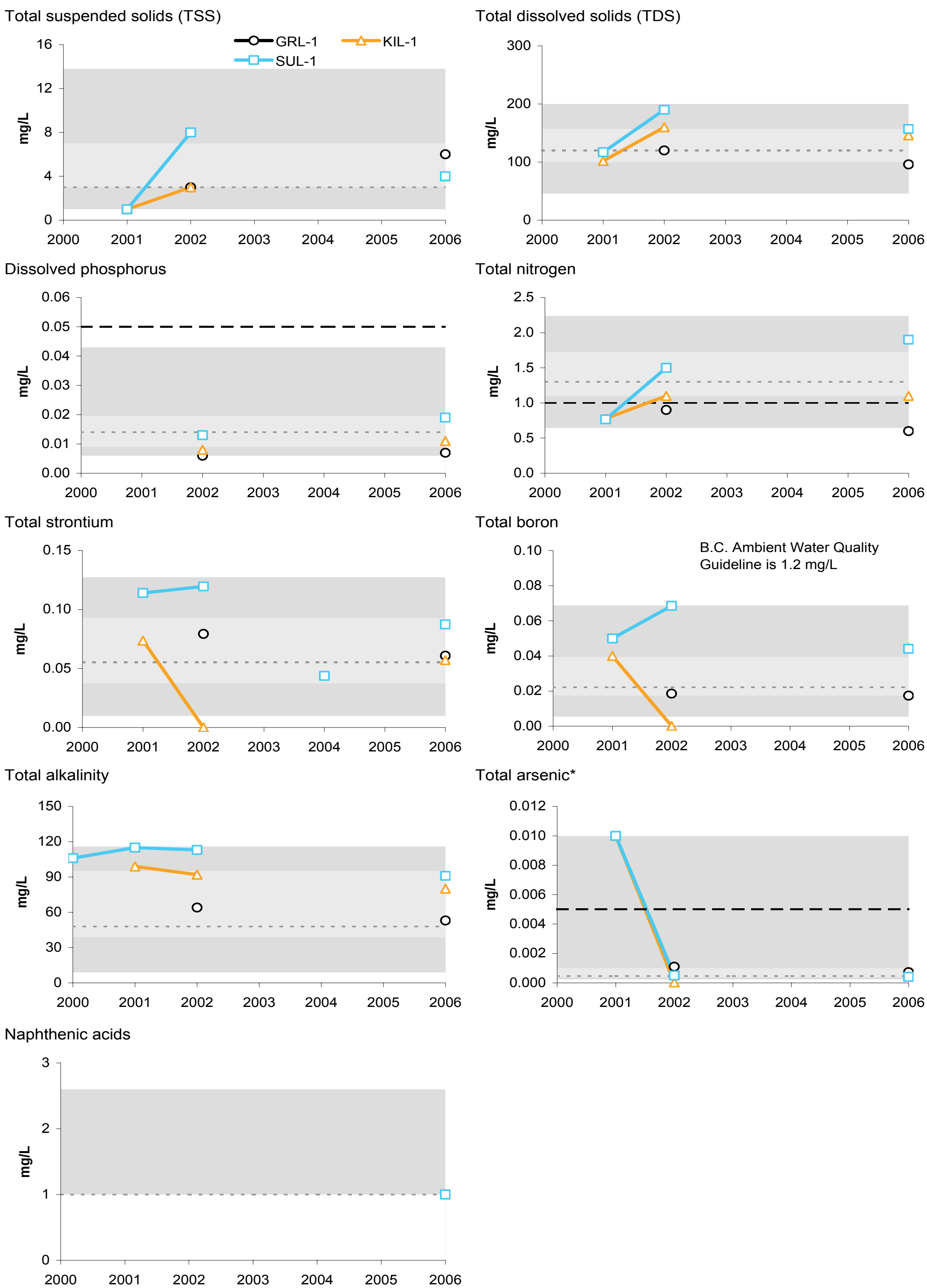
Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-20 Cont'd.



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-21 Concentrations of selected water quality measurement endpoints in Gregoire (GRL-1), Kiskatinaw (KIL-1), and Sucker (SUL-1) lakes (fall data) relative to regional baseline fall concentrations.

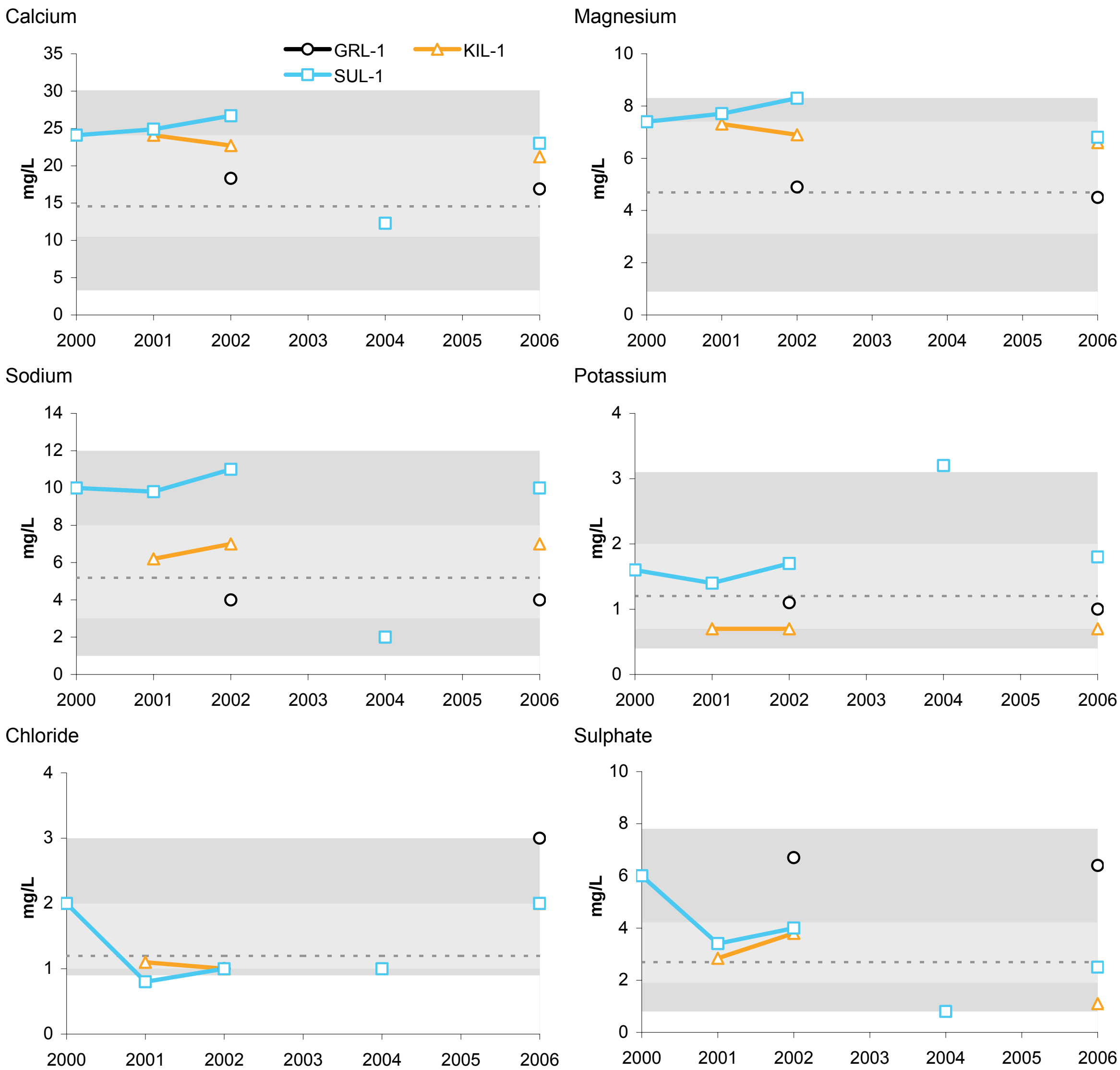


Non-detectable values are shown at the detection limit.

* Detection limit for arsenic in 2001 was 0.01 (higher than in other years); result is shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

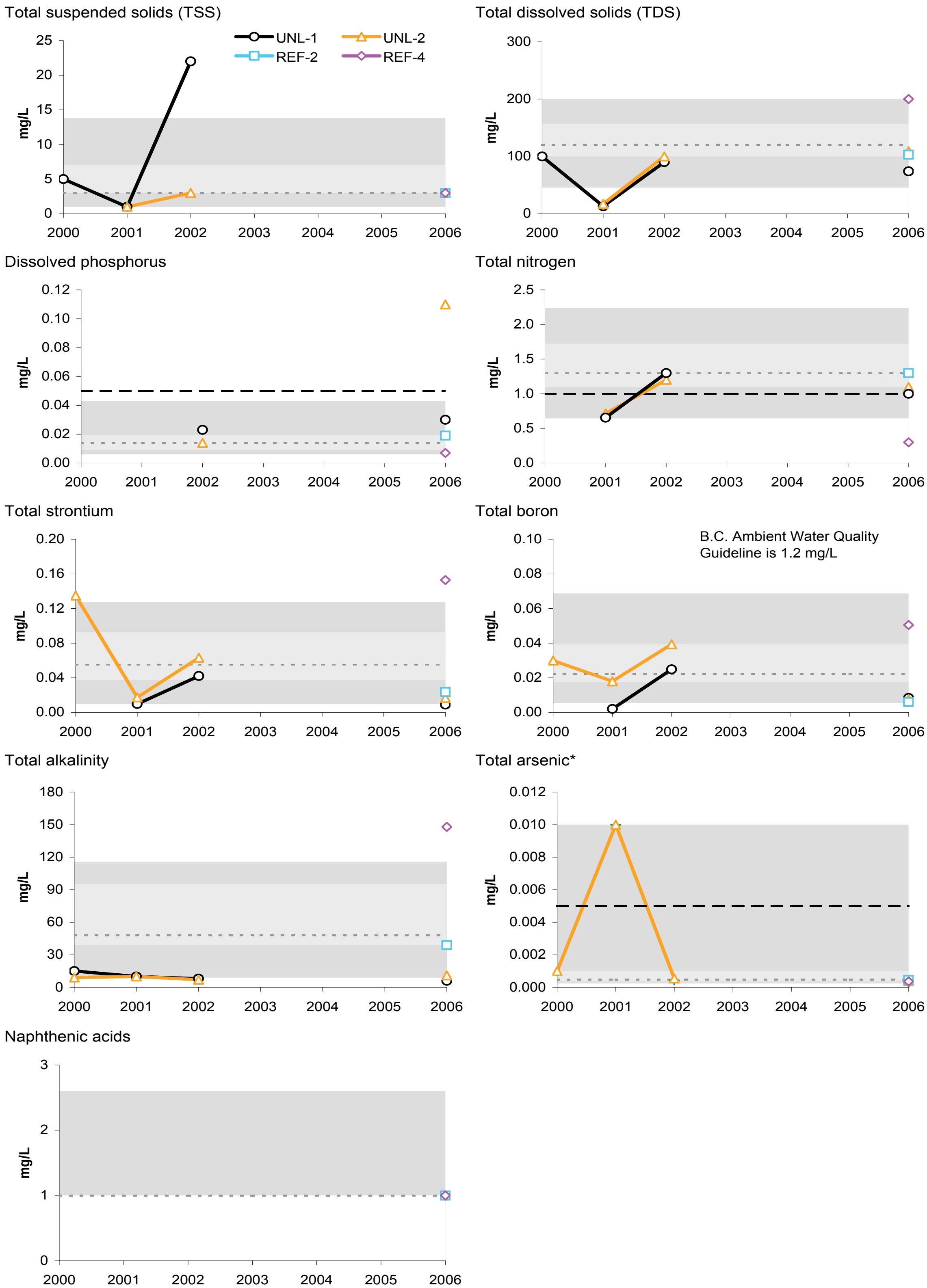
Figure 5.12-21 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-22 Concentrations of selected water quality measurement endpoints in Unnamed Lake 1 (UNL-1), Unnamed Lake 2 (UNL-2), Reference Lake 2 (REF-2), and Reference Lake 4 (REF-4) (fall data) relative to regional baseline fall concentrations.

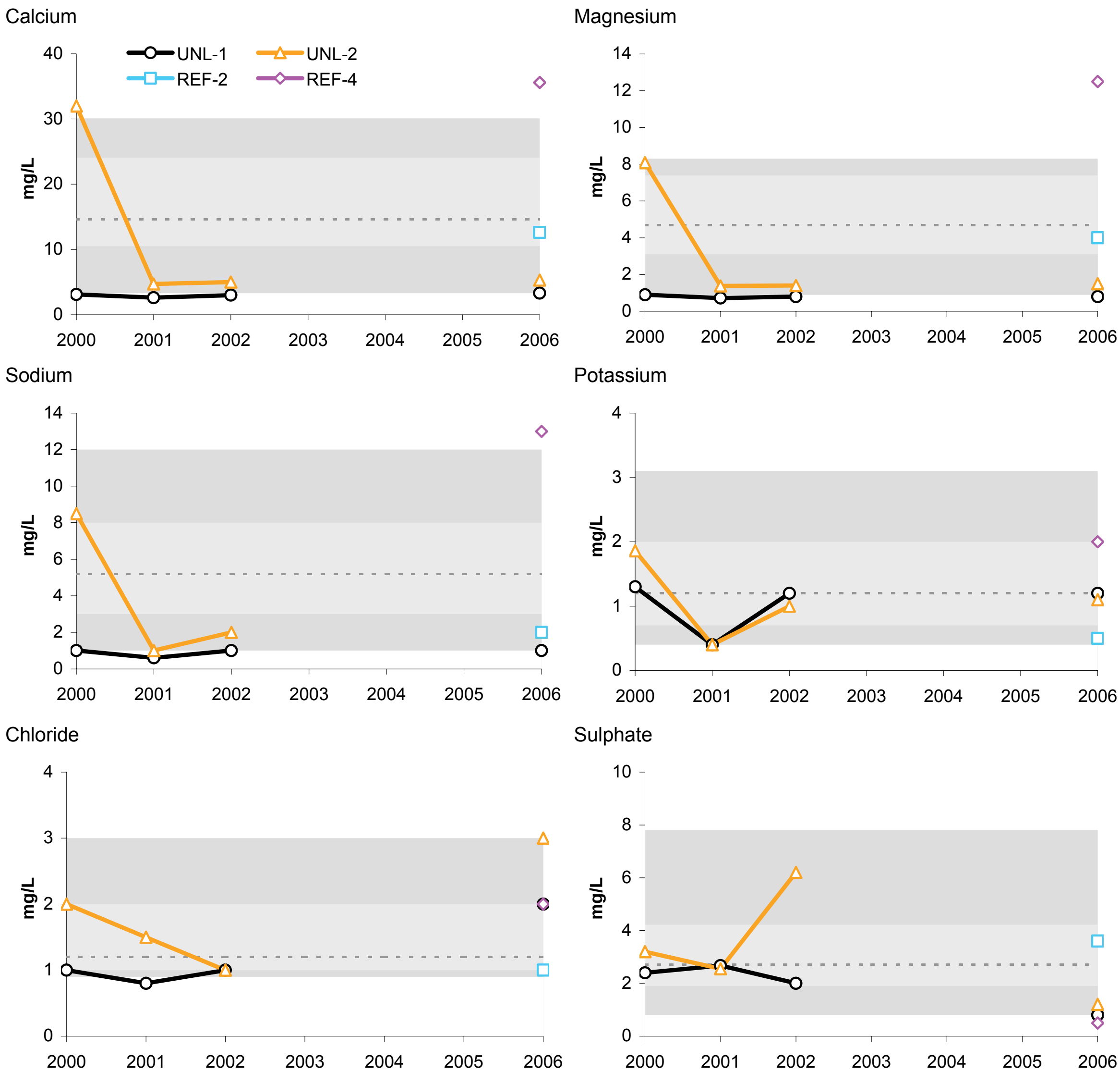


Non-detectable values are shown at the detection limit.

* Detection limit for arsenic in 2001 was 0.01 (higher than in other years); result is shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-22 Cont'd.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all OPTI baseline stations from all years of fall sampling.

Figure 5.12-23 Piper diagram of spring, summer and fall ion concentrations in Birch, Long, Poison, Pushup lakes and Unnamed Lake 3.

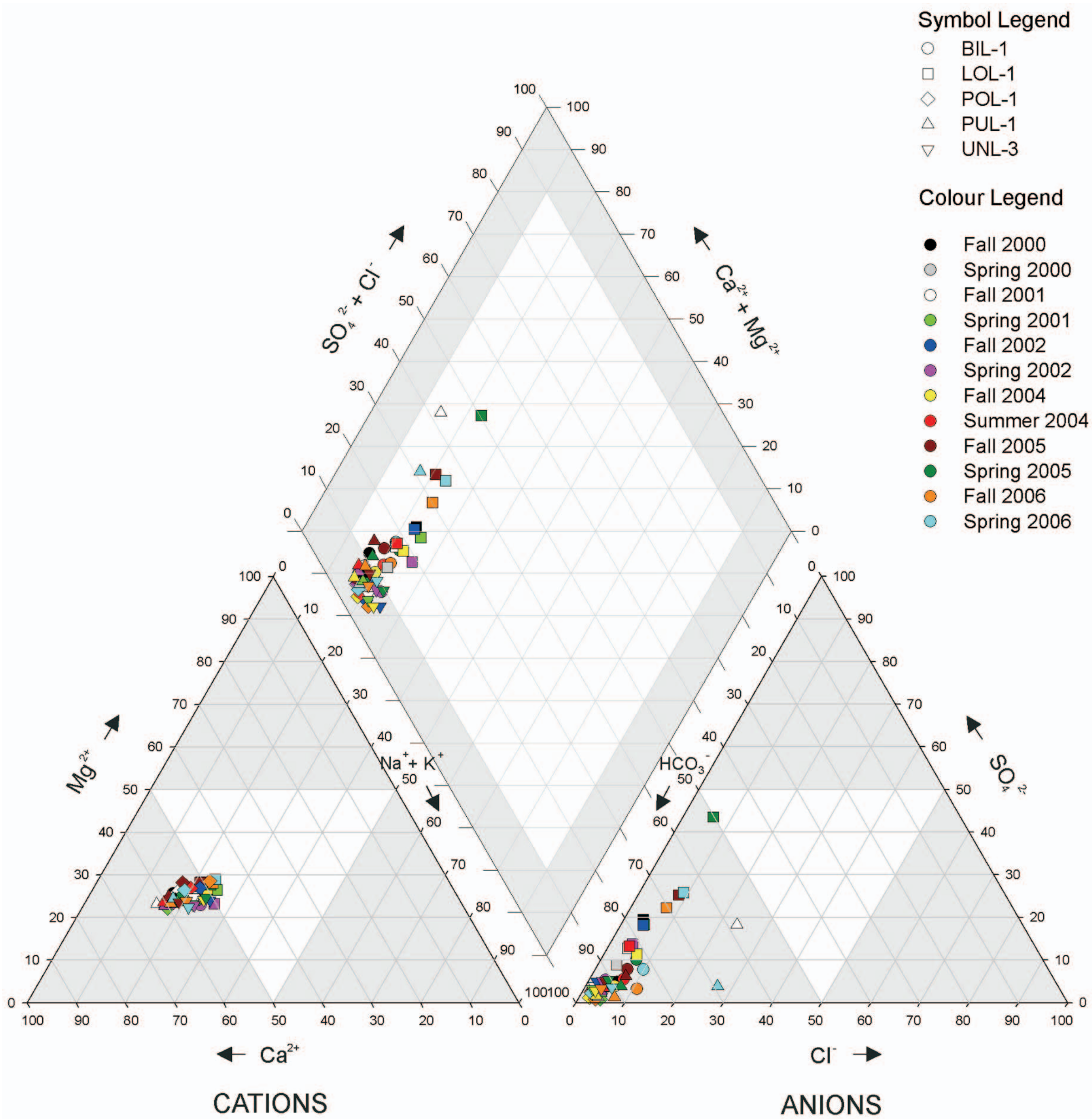


Figure 5.12-24 Piper diagram of spring, summer and fall ion concentrations in Rat, Canoe, Caribou Horn and Frog lakes.

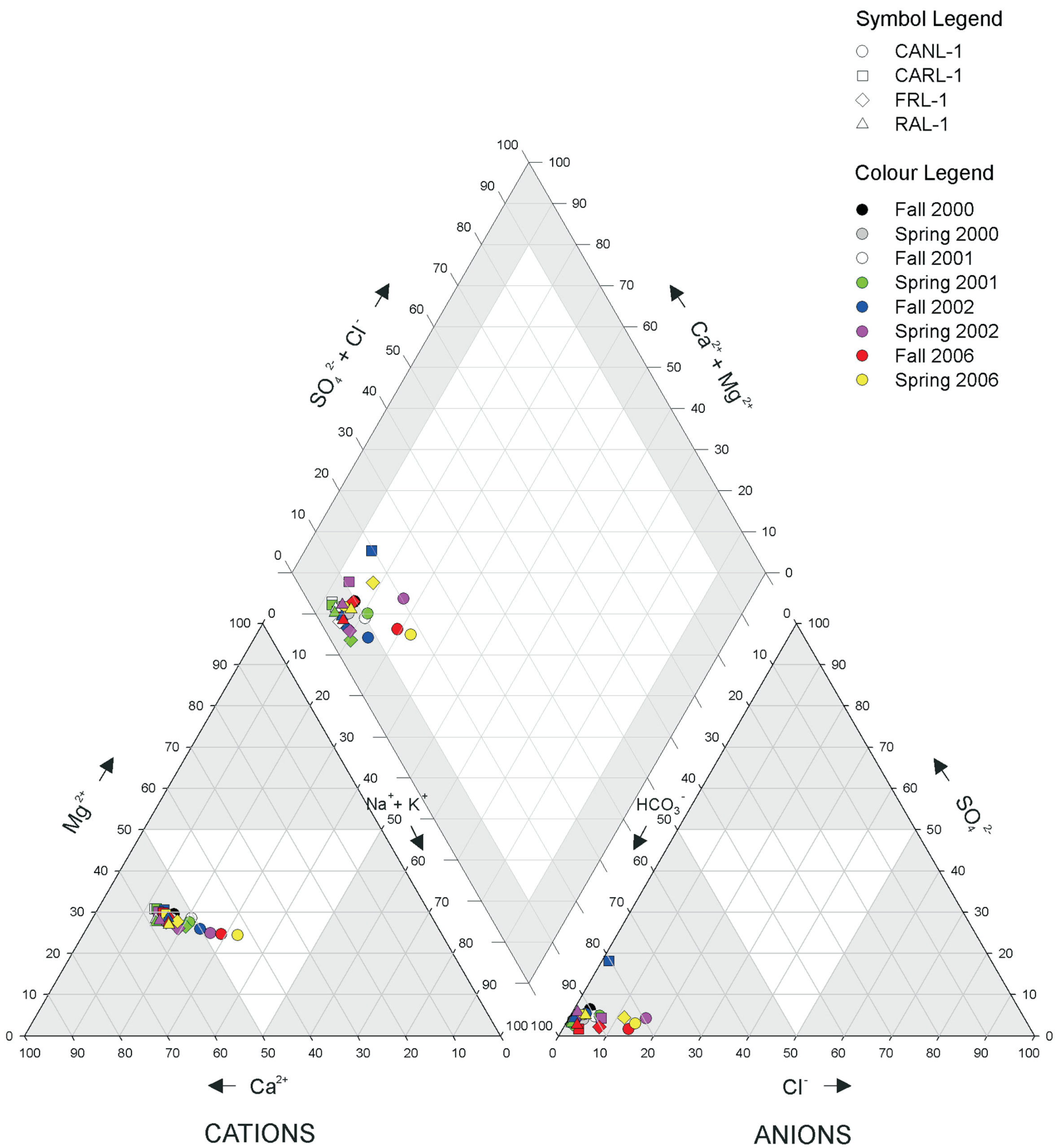


Figure 5.12-25 Piper diagram of spring, summer and fall ion concentrations in Gregoire, Kiskatinaw and Sucker lakes.

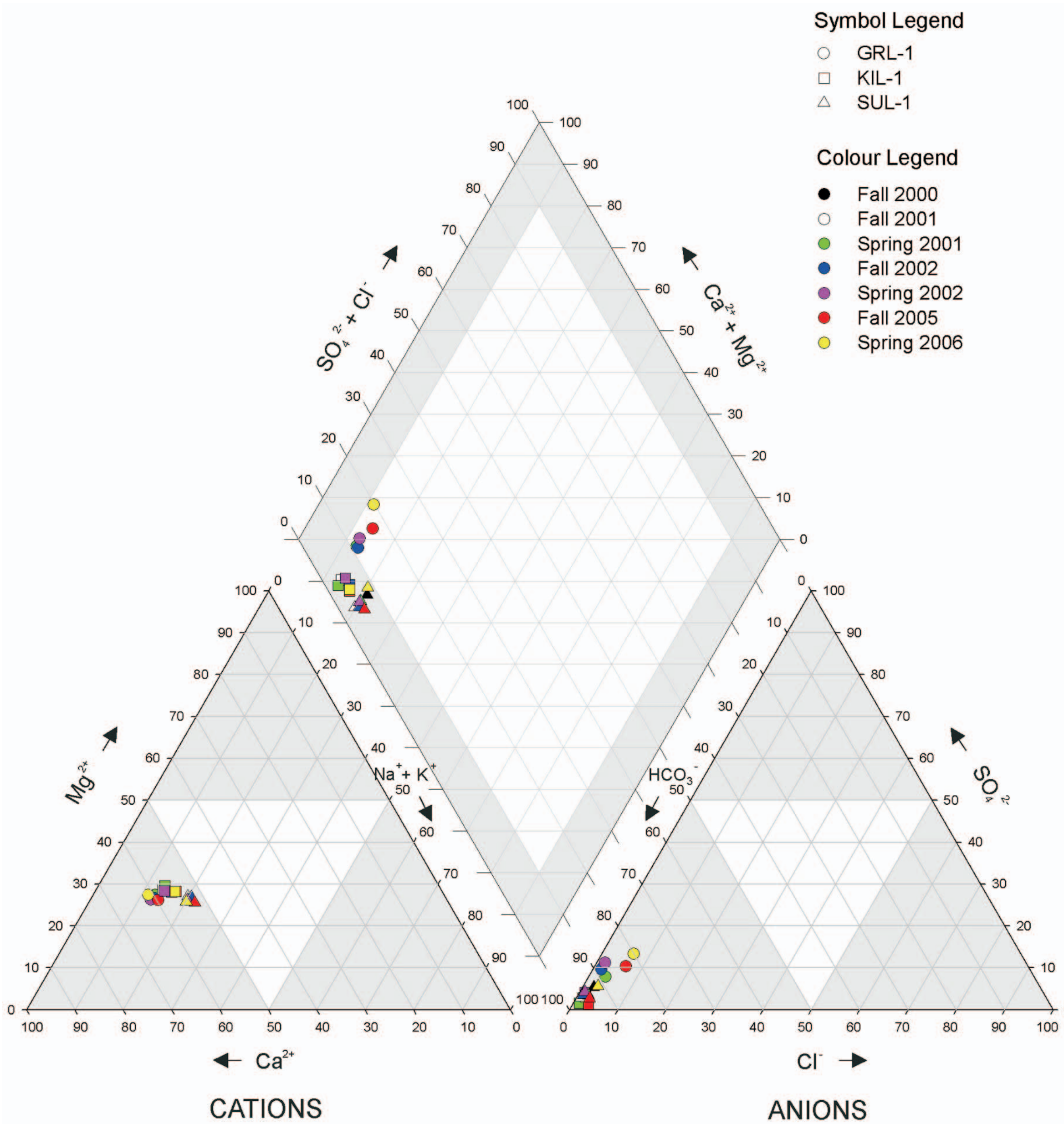


Figure 5.12-26 Piper diagram of spring, summer and fall ion concentrations in Unnamed 1, Unnamed 2, Reference 2 and Reference 4 lakes.

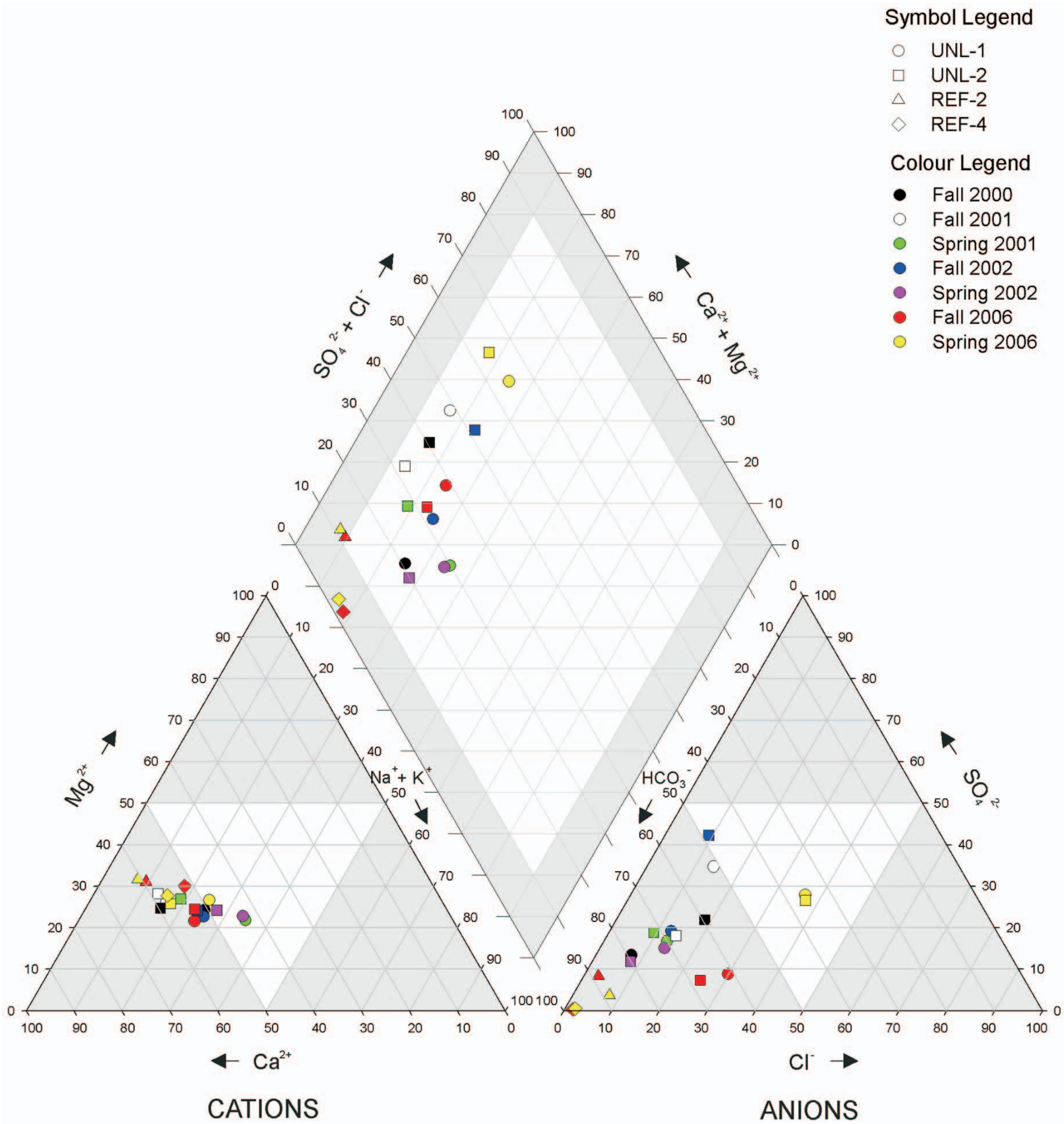


Table 5.12-30 Average habitat characteristics of benthic invertebrate sampling locations in Kearl, McClelland, and Shipyard lakes, fall 2006.

Variable	Units	Shipyard Lake (SHL-1)	Isadore's Lake (ISL-1)	Kearl Lake (KEL-1)	McClelland Lake (MCL-1)
Sample date	-	Sept 24, 2006	Sept 23, 2006	Sept 14, 2006	Sept 15, 2006
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	1.9	2.0	0.9	2.0
Macrophyte cover	%	20	0	0	0
Field Water Quality					
Dissolved oxygen	mg/L	3.05	8.2	n/a	7.8
Conductivity	µS/cm	382	640	200	257
pH	-	7.5	7.8	8.8	8.3
Water temperature	°C	12.9	10.0	12.5	10.0
Sediment Composition					
Sand	%	42	16	90	64
Silt	%	33	55	9	24
Clay	%	25	29	1	12

Table 5.12-31 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in Kearl, Shipyard, McClelland, and Isadore's lakes.

Taxon	% Total Taxa Enumerated in Each Year																		
	Kearl						McClelland					Shipyard							Isadore's
	2001	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006	2000	2001	2002	2003	2004	2005	2006	2006
Amphipoda	13	46	36	58	25	23	11	22	21	7	<1	7		2	3		2	2	<1
Anisoptera						<1			<1	1	<1	<1	1	<1			<1		
Bivalvia	4	4	6	9	4	23	2	8	6	9	<1	7	<1	8	6	1	<1	2	
Ceratopogonidae		1	1			<1				1	<1		1	<1	1			6	<1
Chaoboridae	1											3	53	1	32	1	<1	6	<1
Chironomidae	6	42	46	20	45	42	58	39	24	27	91	25	40	48	32	3	30	37	2
Chydoridae	1		<1	1	3	<1	<1		2	2	<1	3					<1		
Copepoda	<1	<1		2	15	<1			2	1	1	1	<1		9	1	3	1	3
Daphniidae			<1	<1	4	<1				<1	<1					<1	2		
Ephemeroptera	<1	1				2	1	2	8	7	1	16	1	2			<1	<1	
Erpobdellidae					<1	<1	1	<1	<1									1	
Gastropoda	1	<1				<1	<1	1		2	<1	18	1	7	5	1	2	<1	
Glossiphoniidae	<1	1	1	<1									<1	<1	<1				
Hydracarina	<1		<1				1	<1		1			1	<1		<1	1		
Lumbriculidae						<1		<1	<1	<1							<1		
Naididae		<1	6	5	1	3	14	13	7	12	2	8	<1	3		4	9	16	4
Nematoda					1	1	1	<1	4	<1	1			3	2	2	1	1	72
Ostracoda	7	7	4	4	1	<1	10	8	15	29	1	6	2	25	8	87	5	22	1
Trichoptera	2	1	1	<1	<1	1	1		3	1	<1	2	1	<1		<1	1	1	
Tubificidae					1	2		6	<1		1	1		1	3	1	7		
Zygoptera								<1			1	3		1		<1			
Benthic Invertebrate Community Measurement Endpoints																			
Abundance (No./m^2)	891	8,706	5,366	5,690	12,691	17,405	6,352	4,823	3,504	8,874	40,526	4,552	3,284	19,780	1,530	30,867	27,930	10,647	33,987
Number of Taxa	7	9	8	7	12	17	11	11	6	11	23	13	6	13	4	9	15	12	10
Simpsons Diversity	0.73	0.64	0.63	0.60	0.76	0.76	0.71	0.71	0.66	0.72	0.76	0.84	0.43	0.77	0.61	0.21	0.63	0.72	0.41
Evenness	0.92	0.72	0.79	0.71	0.83	0.76	0.84	0.81	0.91	0.85	0.76	0.92	0.55	0.84	0.83	0.24	0.69	0.72	0.42
%EPT	3	2	1	<1	<1	2	2	2	10	7	2	19	1	2	<1	<1	1	<1	<1

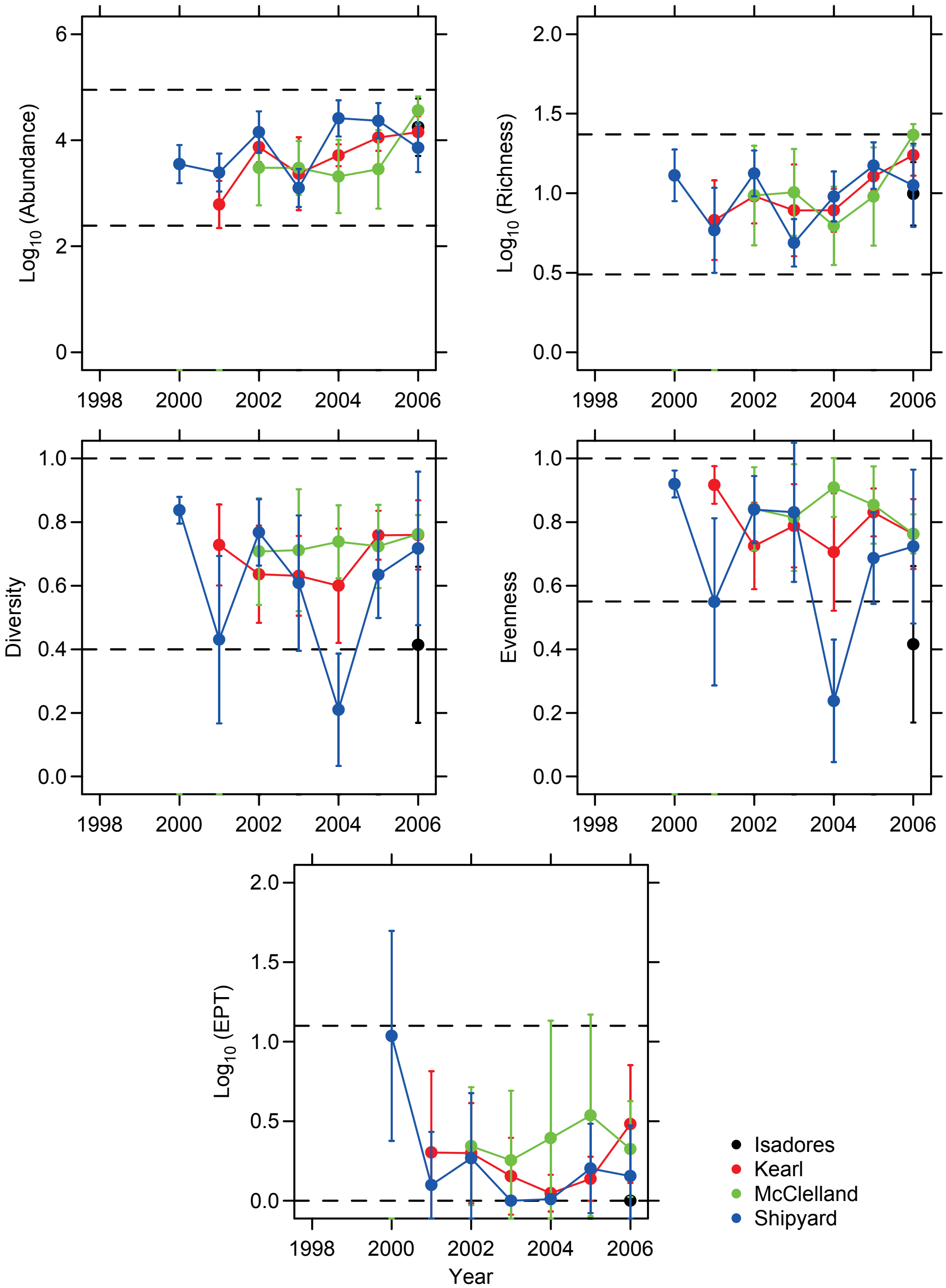
Table 5.12-32 Results of analysis of variance (ANOVA) testing for effects in Shipyard Lake (SHL-1) relative to Kearl and McClelland lakes.

Source	SS	df	F	p
Log_{10} Abundance				
Lake-Year	38.18	17	11.93	<0.001
Lakes (Ref vs Exp)	2.81	1	14.91	<0.001
Time (linear trend)	7.12	1	37.84	<0.001
Lakes x Time (linear)	0.65	1	3.46	0.064
Error	29.93	159		
Log_{10} Richness				
Lakes-Year	5.07	17	7.46	<0.001
Lakes (Ref vs Exp)	0.03	1	0.80	0.374
Time (linear trend)	0.44	1	10.91	0.001
Lakes x Time (linear)	0.12	1	2.99	0.086
Error	6.36	159		
Simpson's Diversity				
Lake-Year	3.12	17	7.43	<0.001
Lakes (Ref vs Exp)	0.80	1	32.52	<0.001
Time (linear trend)	0.04	1	1.73	0.019
Lakes x Time (linear)	<0.01	1	0.05	0.819
Error	3.92	159		
Evenness				
Lake-Year	3.78	17	11.02	<0.001
Lakes (Ref vs Exp)	0.99	1	48.99	<0.001
Time (linear trend)	0.12	1	6.02	0.015
Lakes x Time (linear)	0.02	1	1.13	0.289
Error	3.21	159		
Log_{10} EPT %				
Lake-Year	9.74	17	4.11	<0.001
Lakes (Ref vs Exp)	0.80	1	5.75	0.018
Time (linear trend)	<0.01	1	<0.01	0.969
Lakes x Time (linear)	<0.01	1	0.02	0.893
Error	22.17	159		

Table 5.12-33 Results of analysis of variance (ANOVA) testing for effects in Isadore's Lake (SHL-1) relative to Kearl and McClelland lakes.

Source	SS	df	F	p
Log_{10} Abundance				
Lake-Year	25.61	11	10.11	<0.001
Lakes (Ref vs Exp)	0.08	1	0.37	0.547
Error	24.64	107		
Log_{10} Richness				
Lake-Year	2.94	11	6.11	<0.001
Lakes (Ref vs Exp)	0.63	1	14.33	<0.001
Error	4.68	107		
Simpson's Diversity				
Lake-Year	1.06	11	4.00	<0.001
Lakes (Ref vs Exp)	0.80	1	33.16	<0.001
Error	2.58	107		
Evenness				
Lake-Year	1.88	11	10.20	<0.001
Lakes (Ref vs Exp)	0.80	1	47.89	<0.001
Error	1.79	107		
Log_{10} EPT %				
Lake-Year	2.63	11	1.66	0.092
Lakes (Ref vs Exp)	0.84	1	5.86	0.017
Error	15.40	107		

Figure 5.12-27 Annual variation in benthic invertebrate community measurement endpoints in Kearl, McClelland, Shipyard and Isadore's lakes.



Note: Error bars are ± 2 standard deviations for observations from Kearl and McClelland lakes, designated as *reference.*

Table 5.12-34 Average habitat characteristics of lower Fort Creek, reach FOC-D-1, fall 2006.

Variable	Units	Fort Creek
Sample date	-	Sept 7, 2006
Habitat	-	Depositional
Water depth	m	0.1
Current velocity	m/s	0.5
Macrophyte cover	%	0
Benthic algae	mg/m^2	n/a
Sand/Silt/Clay	%	100
Field Water Quality		
Dissolved oxygen	mg/L	5.7
Conductivity	µS/cm	565
pH	pH units	8.1
Water temperature	°C	16.8
Sediment Composition		
Sand	%	57
Silt	%	31
Clay	%	12
Total Organic Carbon	%	4.1

Table 5.12-35 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in lower Fort Creek, 2001 to 2006.

Taxon	% Total Taxa Enumerated in Each Year				
	Lower Fort Creek (reach FOC-D-1)				
	2001	**2002**	**2003**	**2005**	**2006**
Bivalvia	5	1	<1	8	1
Ceratopogonidae	<1	<1	1		2
Chironomidae	80	95	95	56	55
Copepoda	<1	1	1		
Empididae	1		<1		
Enchytraeidae	1	<1	1		<1
Ephemeroptera	<1				
Erpobdellidae		<1			
Gastropoda	<1		<1		
Glossiphoniidae		<1			
Heteroptera			<1		
Hydracarina	<1		<1		
Macrothricidae		<1	<1		
Naididae	1	1	<1		1
Nematoda	2	1	1	24	4
Ostracoda	1		<1	6	1
Simuliidae			<1		
Tabanidae		<1			1
Tipulidae	8	<1	<1		3
Trichoptera			<1		
Tubificidae		1	<1	6	29
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	4,069	41,905	69,802	913	2,870
Richness	15	13	13	4	10
Simpson's Diversity	0.84	0.69	0.57	0.65	0.76
Evenness	0.91	0.79	0.68	0.90	0.77
% EPT	<1	0	2	0	0

Table 5.12-36 Analysis of variance (ANOVA) of benthic invertebrate community measurement endpoints in reach FOC-D-1 between *reference* and *potentially influenced* years.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	3.74	4	1.26	0.320
Pre-Post	0.18	1	0.24	0.627
Error	13.32	18		
Log_{10} Richness				
Reach-Year	0.48	4	1.81	0.171
Pre-Post	0.01	1	0.11	0.743
Error	1.20	18		
Simpson's Diversity				
Reach	0.199	4	3.97	0.018
Pre-Post	0.021	1	1.66	0.213
Error	0.226	18		
Evenness				
Reach	0.157	4	4.64	0.009
Pre-Post	0.007	1	0.87	0.364
Error	0.151	18		
Log_{10} EPT %				
Reach	0.148	4	0.71	0.593
Pre-Post	0.019	1	0.37	0.552
Error	0.932	18		

Figure 5.12-28 Annual variation in benthic invertebrate community measurement endpoints in lower Fort Creek, reach FOC-D-1.

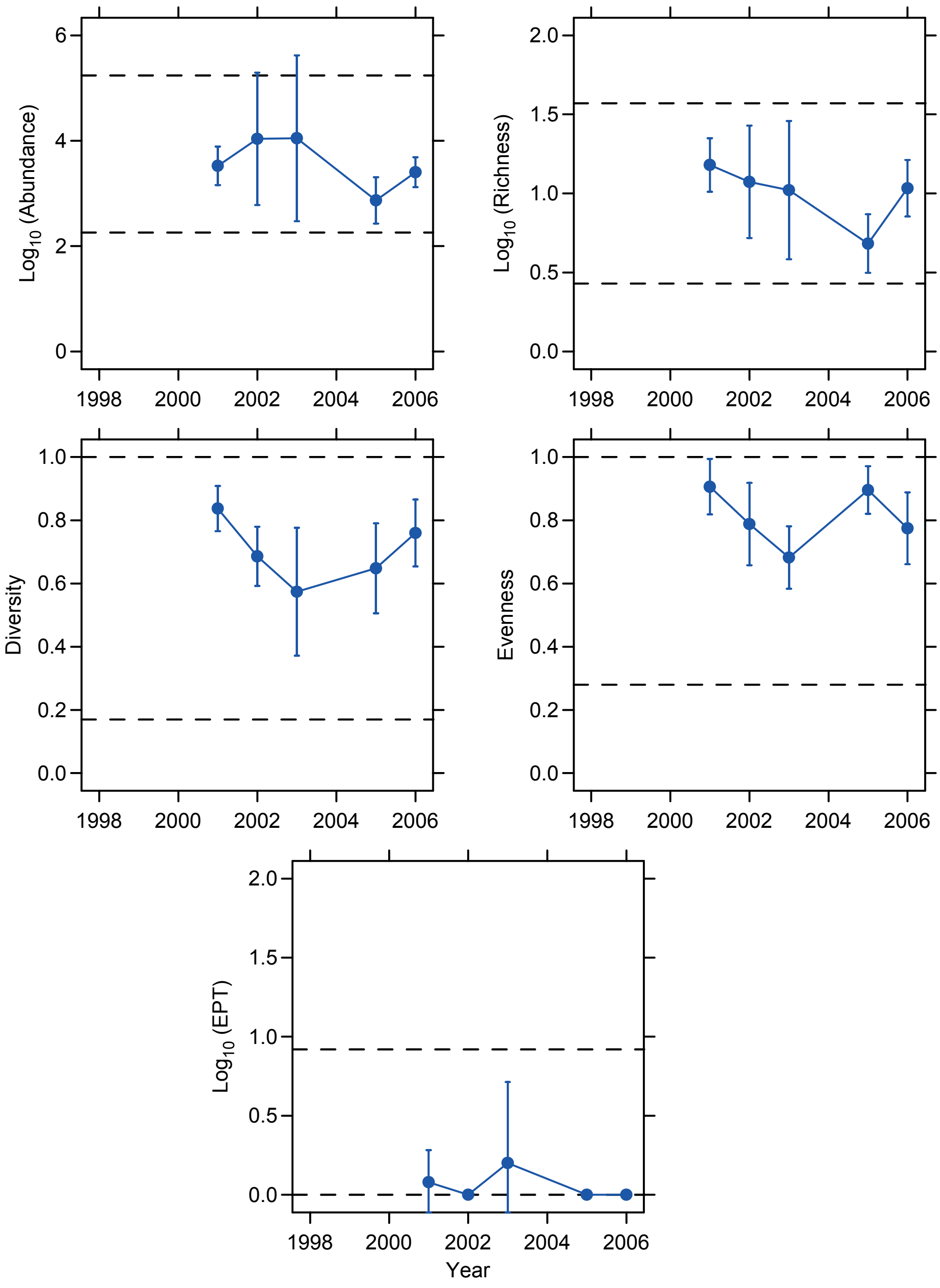
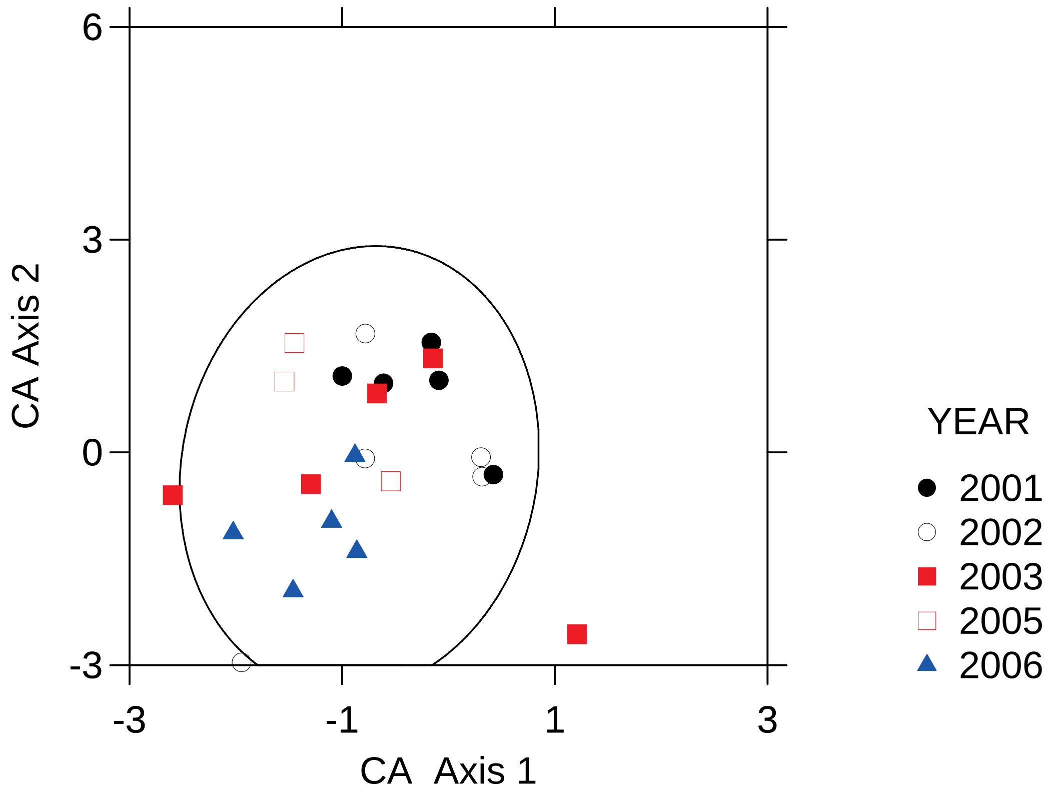


Figure 5.12-29 Ordination biplot for the lower reach (FOC-D-1) of Fort Creek.



Note: Ellipse is for *reference* depositional reaches.

Table 5.12-37 Concentrations of sediment quality measurement endpoints, Shipyard Lake (SHL-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station SHL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	38	4	3	56	60
Silt	%	-	39	4	36	42.5	59
Sand	%	-	64	4	2	3	39
Total organic carbon	%	-	28.9	4	5.5	12.4	15.5
Total hydrocarbons							
BTEX	mg/kg	-	<60	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<60	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	1	-	-	69
Fraction 3 (C16-C34)	mg/kg	400[2]	**550**	1	-	-	290
Fraction 4 (C34-C50)	mg/kg	2800[2]	230	1	-	-	130
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0224	3	0.011	0.0151	0.0186
Retene	mg/kg	-	0.0601	4	0.046	0.0881	0.103
Total dibenzothiophenes	mg/kg	-	0.43	4	0.26	0.44	0.68
Total PAHs	mg/kg	-	8.32	4	2.28	3.35	4.07
Total HMW PAHs	mg/kg	-	6.05	4	0.96	1.19	1.88
Total LMW PAHs	mg/kg	-	2.27	4	0.98	1.87	3.10
Predicted PAH toxicity[1]	H.I.	-	3.61	4	0.10	0.57	2.48
Metals that exceed CCME guidelines in 2005							
Arsenic	mg/kg	-	6.7	4	6.2	7.4	7.8
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	2	7	-	8
Chironomus growth - 10d	mg/organism	-	2.3	2	1.5	-	2
Hyalella survival - 14d	# surviving	-	8	1	-	-	6
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.2

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

[4] CCME interim sediment quality guideline and probable effects level, respectively.

Table 5.12-38 Concentrations of sediment quality measurement endpoints, Kearl Lake (KEL-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station KEL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	1	-	-	58
Silt	%	-	7	1	-	-	33
Sand	%	-	93	1	-	-	9
Total organic carbon	%	-	38.4	2	33.5	-	34.4
Total hydrocarbons							
BTEX	mg/kg	-	<80	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<80	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	320	1	-	-	230
Fraction 4 (C34-C50)	mg/kg	2800[2]	130	1	-	-	81
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	**0.0361**	1	-	-	0.012
Retene	mg/kg	-	0.113	2	0.037	-	0.065
Total dibenzothiophenes	mg/kg	-	0.03	2	0.03	-	0.07
Total PAHs	mg/kg	-	0.86	2	1.05	-	1.10
Total HMW PAHs	mg/kg	-	0.11	2	0.18	-	0.47
Total LMW PAHs	mg/kg	-	0.75	2	0.58	-	0.92
Predicted PAH toxicity[1]	H.I.	-	0.61	2	0.43	-	0.97
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	-	-	-	-
Chironomus growth - 10d	mg/organism	-	1.3	-	-	-	-
Hyalella survival - 14d	# surviving	-	8	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.2	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.12-39 Concentrations of sediment quality measurement endpoints, Isadore's Lake (ISL-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station ISL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	19	1	-	-	26
Silt	%	-	46	1	-	-	54
Sand	%	-	35	1	-	-	20
Total organic carbon	%	-	5.7	1	-	-	1.3
Total hydrocarbons							
BTEX	mg/kg	-	<10	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<10	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	23	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	150	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	89	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0093	1	-	-	0.006
Retene	mg/kg	-	0.0659	1	-	-	0.071
Total dibenzothiophenes	mg/kg	-	0.14	1	-	-	0.15
Total PAHs	mg/kg	-	1.28	1	-	-	1.28
Total HMW PAHs	mg/kg	-	0.52	1	-	-	0.74
Total LMW PAHs	mg/kg	-	0.76	1	-	-	0.54
Predicted PAH toxicity[1]	H.I.	-	1.38	1	-	-	0.56
Metals that exceed CCME guidelines in 2005							
Arsenic	mg/kg	5.9, 17[4]	7.1	1	-	-	7.4
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	-	-	-	-
Chironomus growth - 10d	mg/organism	-	1.9	-	-	-	-
Hyalella survival - 14d	# surviving	-	10	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.3	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

[4] CCME interim sediment quality guideline and probable effects level, respectively.

Table 5.12-40 Concentrations of sediment quality measurement endpoints, McClelland Lake (MCL-1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station MCL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5	2	39	-	49
Silt	%	-	14	2	34	-	37
Sand	%	-	81	2	14	-	27
Total organic carbon	%	-	25	2	27.6	-	30
Total hydrocarbons							
BTEX	mg/kg	-	<100	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<100	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**1200**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	580	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0241	1	-	-	0.011
Retene	mg/kg	-	0.0861	2	0.019	-	0.119
Total dibenzothiophenes	mg/kg	-	0.08	2	0.03	-	0.03
Total PAHs	mg/kg	-	0.73	2	0.36	-	0.56
Total HMW PAHs	mg/kg	-	0.09	2	0.12	-	0.14
Total LMW PAHs	mg/kg	-	0.64	2	0.24	-	0.42
Predicted PAH toxicity[1]	H.I.	-	0.13	2	0.19	-	0.20
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	-	-	-	-
Chironomus growth - 10d	mg/organism	-	1.4	-	-	-	-
Hyalella survival - 14d	# surviving	-	7	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.3	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.12-41 Concentrations of sediment quality measurement endpoints, lower Fort Creek (reach FOC-D1), fall 2006.

Variables	Units	Guideline	September 2006	1997-2005 (fall data only, station FOC-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	17	2	4	-	15
Silt	%	-	43	2	12	-	29
Sand	%	-	40	2	56	-	84
Total organic carbon	%	-	7.1	2	3.2	-	4.7
Total hydrocarbons							
BTEX	mg/kg	-	<10	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<10	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	16	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**440**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	450	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0087	2	0.008	-	0.017
Retene	mg/kg	-	0.0325	2	<0.38	-	0.055
Total dibenzothiophenes	mg/kg	-	0.16	2	1.33	-	3.10
Total PAHs	mg/kg	-	1.85	2	4.76	-	14.26
Total HMW PAHs	mg/kg	-	1.11	2	1.84	-	8.19
Total LMW PAHs	mg/kg	-	0.75	2	2.92	-	6.07
Predicted PAH toxicity[1]	H.I.	-	0.45	2	0.43	-	1.05
Metals that exceed CCME guidelines in 2005							
Arsenic	mg/kg	5.9, 17[4]	**6.1**	2	2.8	-	5.9
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	9
Chironomus growth - 10d	mg/organism	-	3.0	1	-	-	1.5
Hyalella survival - 14d	# surviving	-	6	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.3	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

[4] CCME interim sediment quality guideline and probable effects level, respectively.

5.13 ACID-SENSITIVE LAKES

This section presents the results of the Acid-Sensitive Lakes (ASL) component of RAMP for 2006. Three primary analyses of the RAMP ASL lake dataset were conducted:

- **Between-Year Comparison of ASL Measurement Endpoints** An Analysis of Variance (ANOVA) to determine whether there have been any significant changes in the ASL measurement endpoints over the five years of data available for the 50 lakes;
- **Calculation of Critical Loads of Acidity and Critical Load Exceedances** A Calculation of the Critical Load of acidity (CL) for each RAMP ASL lake and a comparison of the CL values to recent estimates of Potential Acid Input (PAI) for each ASL lake; and
- **Trends in ASL Measurement Endpoints** An analysis of potential trends in ASL measurement endpoints in individual lakes.

These primary analyses are supported by the additional data analysis, the results of which are presented in Appendix H:

- The chemical characteristics of the RAMP ASL lakes were reviewed with the addition of the 2006 data. Summary statistics were calculated on the updated dataset that now includes five years of data on all 50 lakes;
- Trace metal concentrations in the RAMP ASL lakes were summarized and relationships between metal concentrations, lake location and chemistry were noted; and
- Estimates of the seasonal variability in water quality variables in ten of the ASL lakes were updated with the 2006 data and summary statistics were calculated.

5.13.1 Between-Year Comparison of ASL Measurement Endpoints

An Analysis of Variance (ANOVA) was performed in order to determine whether there have been any significant changes in ASL measurement endpoints over the five years of data available for the 50 lakes (2002-2006). No significant changes in ASL measurement endpoints were observed over the five years. However, significant changes were observed in 2005 for two variables (potassium and calcium) that affect the sum of base cations. These changes were related to high rates of precipitation and surface runoff in 2005. Conditions appear to have returned to normal in 2006 (Table 5.13-1).

Lakes having “unusual” chemistry were identified in the 2006 monitoring data as those falling below or above the 5^{th} and 95^{th} percentile for pH, Gran alkalinity, and DOC (Table 5.13-2). These lakes were essentially the same lakes identified in 2005 (RAMP 2005a). Three lakes (168, 287 and 471) had very low (negative) levels of Gran alkalinity. Two of these lakes were found in the Stony Mountains upland region. The highest values of Gran alkalinity and buffering capacities in the RAMP ASL lakes were found in Lakes 270, 271 and Kearl Lake, located N-E of Fort McMurray. Lakes having the lowest pH were Lakes 168 and 172 in the Stony Mountains and Clayton Lake (448) in the Birch Mountains. Lakes 270, 271 and Kearl Lake had the highest pH. The lowest levels of DOC were found in Namur Lake (436) in the Birch Mountains while the highest concentrations were found in Lake 223, a small pond in the West of Fort Mc Murray sub-region and Lake 175, a pond in the Birch Mountains. As indicated in previous RAMP reports, lakes with low levels of Gran alkalinity were generally the same lakes having low pH, high DOC and low conductivity. These were often fairly small, shallow lakes found in the upland regions.

5.13.2 Critical Loads of Acidity and Critical Load Exceedances

The critical loads of acidity (CL) were calculated for each RAMP lake for the years 1999 to 2006 using the Henriksen steady state water chemistry model modified to include the contribution of organic anions as both strong acids and weak organic buffers (WRS 2006; RAMP 2005a).

In 2006, 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. Table 5.13-3 presents the two estimates of runoff and critical loads of acidity between 2002 and 2006. The isotopically derived runoff values were greater than the hydrometrically derived values in 23 lakes and less in 27 lakes. The greatest discrepancies were observed for lakes having the highest rates of runoff.

Using the hydrometrically derived runoff, the critical loads in 2006 ranged from -0.177 keq H^+/ha/y to 1.192 keq H^+/ha/y with a median of 0.202 keq H^+/ha/y (Table 5.13-3). With the isotopically derived runoff, critical loads ranged from -0.136 keq H^+/ha/y to 1.484 keq H^+/ha/y with a median CL of 0.299 keq H^+/ha/y. Individual CL values often differed significantly although the mean and median critical loads for the two methods were quite similar (Table 5.13-4).

Low critical loads observed in the upland regions (the Birch Mountains, the Caribou Mountains and the Stony Mountains) and in the Canadian Shield are consistent with findings of previous RAMP reports (RAMP 2004, 2005a, 2006). Mean critical loads in 2006 for the two methods (hydrometric/isotopic) in the six sub-regions were calculated as follows:

- Stony Mountains: 0.024/0.016 keq H^+/ha/y
- West of Fort McMurray: 0.534/0.235 keq H^+/ha/y
- North-East of Fort McMurray: 0.481/0.537 keq H^+/ha/y
- Birch Mountains: 0.250/0.224 keq H^+/ha/y
- Canadian Shield: 0.234/0.365 keq H^+/ha/y
- Caribou Mountains: 0.166/0.541 keq H^+/ha/y.

Negative critical loads were observed in many of the lakes, especially in the Stony Mountains sub-region. These lakes may be the most acid-sensitive of the 50 RAMP lakes.

The critical loads of acidity were compared to modeled rates of acid deposition (potential development case) for each lake published in the Kearl Lake EIA (Imperial Oil 2005). The PAI for lakes in the Caribou Mountains and the Canadian Shield regions were estimated from the air modeling study reported for the OPTI 2002 EIA and were equivalent to background PAI values (no industrial input).

Lakes having critical load exceedances are identified in Table 5.13-3 and Figure 5.13-1. Rates of critical load exceedance ranged from a low of 30.5% (15 of 49 lakes) in 2006 to a high of 36.7 (18 of 49 lakes) in 2002 (Table 5.13-4). The use of the isotopically derived runoff resulted in 4 additional lake exceedances in 2006.

The rates of exceedance in Table 5.13-4 are considerably higher than the rate of 8% reported for 399 regional lakes in a 2006 NSMWG lake sensitivity report (WRS 2006). The higher rates of exceedance in the RAMP lakes reflect the bias mentioned above in selecting the RAMP lakes where the most poorly buffered lakes in the region were preferentially selected. For comparison to other regions, Henriksen et al. (2002) reported rates of PAI exceedance in four sensitive regions of Ontario ranging from 11% to 26%. Their study did not include modifications to the model for organic anions. Had these modifications been included, exceedance rates in the Ontario study would have been much closer to the values obtained in this study.

Table 5.13-5 summarizes the key chemical characteristics of the lakes having PAI exceedances. As expected, these are small lakes of low pH, low conductivity, low ANC, and high in DOC. A large proportion of these exceeded lakes are found in the Stony and Birch Mountain regions.

In summary, using the critical load as a criterion, a large number of the RAMP lakes are quite sensitive to acidification and high rates of exceedance by the PAI are observed. Both the high acid-sensitivity in the RAMP lakes and high rates of CL exceedance are partially the result of a biased lake selection process favoring the most poorly buffered lakes. The high rates of CL exceedance do not indicate imminent acidification for these lakes. Use of the isotopically derived runoff values resulted in only a minor change to the number of CL exceedances.

5.13.3 Trends in ASL Measurement Endpoints

Potential trends in the ASL measurement endpoints in 31 individual lakes were examined using the Mann-Kendall non-parametric test (Gilbert 1987). As the Mann-Kendall test deals only with differences (rather than their magnitude) small insignificant differences, well within analytical error and natural variability, can result in conclusions of a trend being present, when none really exists (false positives). To reduce the number of false positive effects, estimates of analytical error obtained from the laboratory (Appendix H) were incorporated in the trend analysis by eliminating, as statistically insignificant, all difference-pairs in the Mann-Kendall calculations that were less than one standard deviation.

The results of the Mann Kendall trend analysis (Table 5.13-6) were very similar to those results observed in 2005. Almost the same significant trends were evident in both years. As in 2005, these trends were often inconsistent with any conceivable acidification scenario:

- All significant changes in pH were positive (6 lakes) rather than negative (if acidification were evident);
- All significant changes in sulphate in the lakes, the primary acidifying agent, were decreases;
- Gran alkalinity decreased significantly in three lakes and increased in one; two of the significant decreases in Gran alkalinity were associated with decreases (rather than increases) in sulphate;
- Total alkalinity decreased significantly in two lakes and increased in six lakes;
- Base cations decreased significantly in six lakes and increased in four lakes. Both decreases and increases in base cations occurred under the highest levels of potential acid input; and
- Dissolved organic carbon increased significantly in five lakes, the opposite of the trend expected in acidifying lakes (Schindler et al. 1992).

The conclusions of the trend analysis are essentially those drawn in 2005. It is obvious from the results of the seasonal sampling (Appendix H) that very significant changes in lake chemistry occur naturally over a year. Trying to detect minor trends in ASL measurement endpoints on this highly variable background is extremely difficult without considerably more information on the natural variability in these parameters.

5.13.4 Summary of Conditions

These results of the analysis of 2006 RAMP ASL lake data in conjunction with historical RAMP ASL lake data suggest that there has been no significant change in the overall chemistry of the 50 RAMP ASL lakes in 2006 compared to previous years. Based on the inconsistent results of the trend analysis, there is no evidence to conclude that there have been any significant changes in lake chemistry in the RAMP ASL lakes over the period of the ASL component.

Table 5.13-1 Summary Statistics for RAMP ASL lakes, 2002 to 2006.

Parameter	Minimum		Maximum		Mean		Median		5th Percentile 2006	95th Percentile 2006
	2002 to 2006	2006	2002 to 2006	2006	2002 to 2006	2006	2002 to 2006	2006		
Lab pH	4.17	4.22	9.46	8.04	6.64	6.58	6.79	6.84	4.79	7.79
Gran Alkalinity (µeq/L)	-57.2	-23.2	1687	1545.20	316.86	314	199.60	9.98	-4.39	1148.48
Sulphate (mg/L)	0.18	0.21	16.7	10.30	2.13	2.13	1.18	1.05	0.28	8.36
Nitrate + Nitrite (µg/L)	0.02	1.81	733	190.00	21.67	12.9	3.42	2.78	1.92	42.37
Dissolved Organic Carbon (mg/L)	7.47	7.47	58.5	56.59	23.99	22.9	21.54	22.44	10.93	40.21
Sum base cations (µeq/L)	0.00	38	2291	1642.88	563.22	515.	417.98	430.46	107.78	1465.61

Note: Shaded parameters represent significant differences

Table 5.13-2 RAMP ASL lakes with chemical characteristics either below 5th or above 95th percentile of 2006 values, 2006 data.

Lake	Region	pH	Gran Alkalinity (µeq/L)	DOC (mg/L)
5th percentile, 2006		4.79	-4.4	10.93
95th percentile, 2006		7.79	1148.5	40.21
169 (A24)	Stony Mountains	**4.59**	**-23.2**	17.4
172 A59	Stony Mountains	**4.76**	27.0	33.2
287 (25)	Stony Mountains	4.91	**-7.0**	14.3
448 (L29) Clayton	Birch Mountains	**4.22**	0.00	15.3
444 L25 Legend	Birch Mountains	6.96	198	**8.21**
175 (P13)	Birch Mountains	7.20	998	*47.9*
447 (L28)	Birch Mountains	5.18	31.8	26.3
436 (L18) Namur	Birch Mountains	7.21	406	**7.47**
471(L8)	Northeast of Fort McMurray	4.82	**-7.2**	20.5
270	Northeast of Fort McMurray	*8.44*	*1271*	24.1
271	Northeast of Fort McMurray	*8.20*	*1328*	21.0
418 Kearl	Northeast of Fort McMurray	*8.00*	*1545*	25.2
118 L107	Canadian Shield	7.38	436	**9.70**
223 P94	West of Fort McMurray	7.23	827	*56.6*
165 (A42)	West of Fort McMurray	7.14	369	*44.6*

Note: Bold entries indicate concentrations below the 5th percentile; italicized entries indicate levels above the 95th percentile

Figure 5.13-1 RAMP acid-sensitive lakes with calculated Potential Acid Input exceeding calculated Critical Load, 2006.

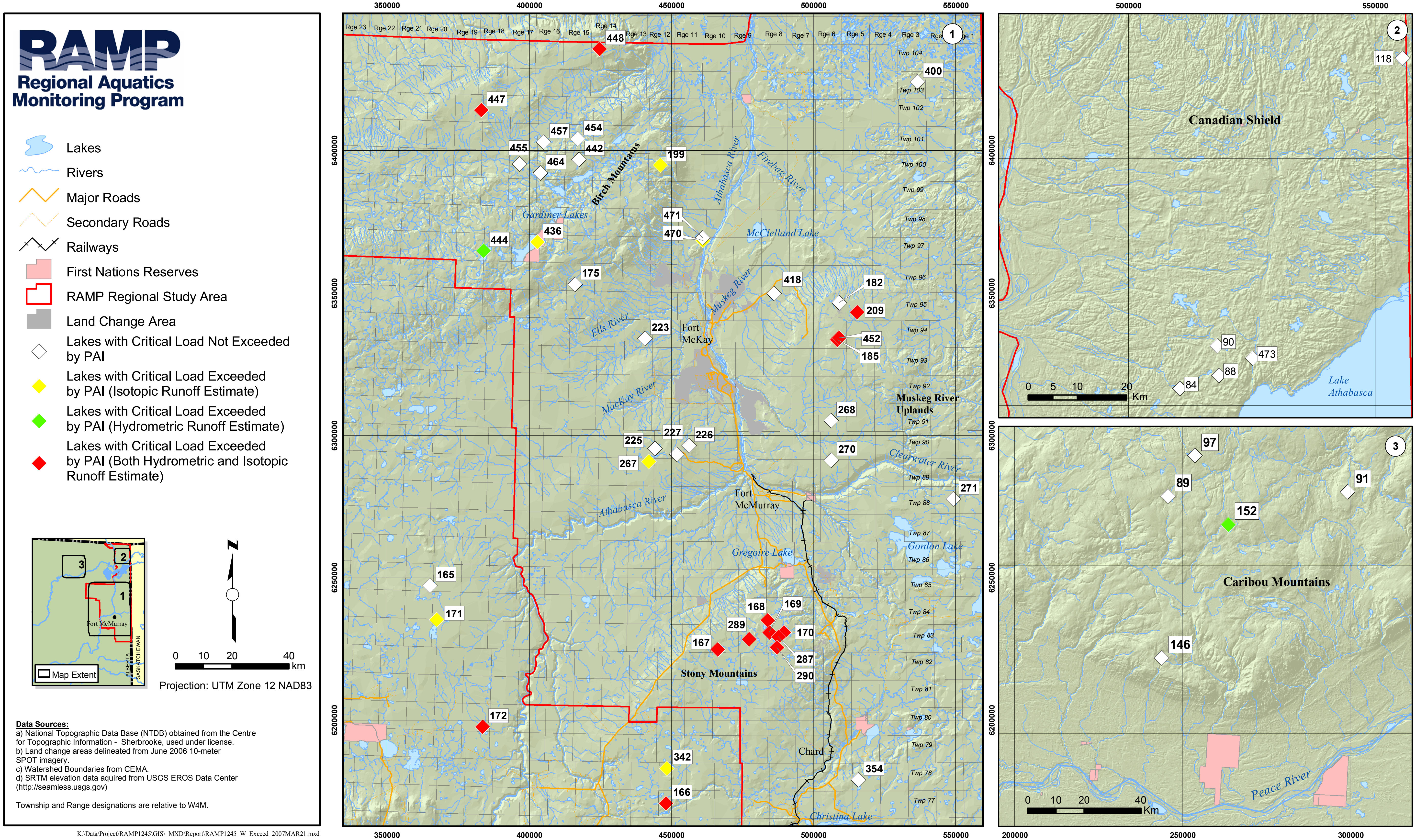


Table 5.13-3 Critical loads of acidity in the RAMP ASL lakes, 2002 to 2006.

ID No.	Original RAMP Designation	Runoff (Hydro) (m^3/s)	Runoff (Isotopic) (m^3/s)	Mean pH	Mean Gran Alk. (μeq/L)	Mean DOC (mg/L)	Mean SBC (μeq/L)	Critical Load of Acidity (keq H+/ha/y)						
								2002	2003	2004	2005	2006 (Hydro)	2006 (Isotopic)	PAI[1]
Stony Mountains Sub-Region														
168	A21	0.0404	0.0474	4.94	43.94	20.54	146.6	-0.089	-0.079	-0.087	-0.118	-0.081	-0.090	0.148
169	A24	0.0264	0.0323	4.64	-4.94	21.24	111.7	-0.124	-0.071	-0.205	-0.132	-0.104	-0.136	0.143
170	A26	0.0238	0.0140	5.42	-6.23	15.14	157.5	-0.030	-0.028	-0.036	-0.047	-0.045	-0.008	0.144
167	A29	0.0131	0.0150	5.74	15.49	15.33	166.5	-0.028	-0.019	-0.002	0.004	0.033	-0.006	0.143
166	A86	0.0147	0.0093	6.55	115.40	17.36	276.4	0.094	0.101	0.109	0.110	0.100	0.058	0.117
287	25	0.0223	0.0335	5.03	-11.64	17.05	116.2	-0.056	-0.055	-0.075	-0.077	-0.068	-0.099	0.142
289	27	0.0216	0.0275	6.45	62.08	12.44	177.0	0.019	0.029	0.035	0.035	0.030	0.038	0.144
290	28	0.0124	0.0130	5.68	31.96	21.24	208.0	0.004	0.033	-0.008	-0.007	0.012	0.007	0.139
342	82	0.0291	0.0085	6.69	166.12	26.84	363.8	0.208	0.181	0.165	0.125	0.182	0.050	0.120
354	94	0.0162	0.0240	7.17	357.68	24.42	539.1	0.322	0.225	0.213	0.226	0.179	0.345	0.141
West of Fort McMurray Sub-Region														
165	A42	0.0639	0.0245	6.94	320.09	46.46	663.0	0.388	0.373	0.553	0.706	0.455	0.163	0.121
171	A47	0.0115	0.0044	6.35	139.69	20.03	329.6	0.217	0.167	0.152	0.253	0.207	0.053	0.120
172	A59	0.1781	0.0339	5.29	43.09	33.48	272.7	0.038	0.001	0.002	-0.023	-0.075	0.000	0.120
223	P94	0.0019	0.0003	7.34	794.16	48.74	1489.7	1.120	1.031	1.054	1.399	1.004	0.171	0.164
225	P96	0.0034	0.0027	7.34	637.32	32.77	967.5	0.745	0.595	0.666	0.825	0.669	0.564	0.142
226	P97	0.0057	0.0056	6.87	344.60	31.06	701.4	0.328	0.346	0.266	1.377	0.238	0.501	0.180
227	P98	0.0070	0.0025	7.23	621.16	32.32	912.8	0.969	0.956	0.917	0.462	1.042	0.313	0.156
267	1	0.1182	0.0138	7.78	770.00	23.70	989.2	1.055	1.024	0.994	1.091	0.732	0.114	0.134
Northeast of Fort McMurray Sub-Region														
452	L4	0.0920	0.0675	5.81	74.40	25.07	286.0	0.070	0.070	0.078	0.143	0.073	0.069	0.164
470	L7	0.1010	0.0376	6.43	159.81	29.27	416.7	0.170	0.190	0.141	0.307	0.707	0.111	0.148
471	L8	0.0450	0.0257	6.79	330.60	21.37	580.5	0.528	0.622	0.527	0.659	0.340	0.317	0.152
400	L39	0.0501	0.0855	6.78	172.03	15.63	378.3	0.157	0.157	0.144	0.073	0.316	0.323	0.104
268	E15	0.0809	0.0472	7.05	379.20	41.08	639.0	0.520	0.465	0.400	0.505	0.092	0.259	
182	P23	0.0296	0.0254	7.73	664.32	17.49	937.4	0.294	1.084	2.017	2.008	0.443	0.923	0.259
185	P27	0.0172	0.0175	5.40	64.52	30.05	277.9	0.035	0.017	-0.095	0.233	-0.030	0.033	0.168
209	P7	0.0072	0.0095	6.07	127.16	25.42	313.3	0.141	0.163	0.112	0.089	0.109	0.156	0.161
270	4	0.0411	0.0371	8.32	1,414.48	34.22	1823.1	1.382	1.318	1.408	1.705	1.037	1.219	0.171
271	6	0.0485	0.0388	8.61	1,369.44	29.33	1689.2	1.293	1.449	1.931	1.369	1.009	1.009	0.145
418	Kearl L.	0.1690	0.2329	7.98	1,503.85	22.53	1493.7	NA	1.280	1.290	1.664	1.192	1.484	0.367

Shaded values represent critical loads exceeded by the Potential Acid Input obtained from the 2005 Kearl Lake EIA (Potential Development Case), Imperial Oil (2005).

[1] Estimate of PAI was based on SO2 deposition alone except for lakes receiving Nitrogen deposition above a threshold value of 9 kg/ha/y;

[2] PAI obtained from OPTI 2002 EIA

Hydro – runoff estimated using traditional hydrometric methods; Isotopic – runoff estimated using analysis of heavy isotopes of oxygen and hydrogen

Table 5.13-3 Cont'd.

ID No.	Original RAMP Designation	Runoff (Hydro) (m^3/s)	Runoff (Isotopic) (m^3/s)	Mean pH	Mean Gran Alk. (µeq/L)	Mean DOC (mg/L)	Mean SBC (µeq/L)	Critical Load of Acidity (keq H+/ha/y)						
								2002	2003	2004	2005	2006 (Hydro)	2006 (Isotopic)	PAI[1]
Birch Mountains Sub-Region														
436	L18	0.3250	0.1485	7.19	388.60	8.57	641.0	0.235	0.239	0.226	0.313	0.225	0.110	0.127
442	L23	0.0430	0.1848	6.77	140.06	13.89	271.7	0.087	0.074	0.065	0.074	0.059	0.321	0.117
444	L25	0.1765	0.6413	6.83	161.97	9.05	304.8	0.088	0.097	0.099	0.134	0.109	0.390	0.112
447	L28	0.0448	0.1130	5.18	22.26	28.06	223.2	-0.016	-0.025	0.002	-0.025	-0.039	-0.045	0.105
448	L29	0.0330	0.0461	4.21	-6.33	16.23	71.8	-0.127	-0.090	-0.073	-0.111	-0.117	-0.131	0.113
454	L46	0.1690	0.1026	6.77	206.20	24.07	631.1	0.394	0.375	0.365	0.374	0.303	0.257	0.114
455	L47	0.1016	0.1422	6.81	224.29	22.88	757.0	0.282	0.241	0.958	0.324	0.272	0.534	0.120
457	L49	0.0666	0.1164	6.56	148.23	22.74	589.2	0.301	0.260	0.283	0.234	0.210	0.479	0.109
464	L60	0.1630	0.0730	7.08	274.69	19.92	612.0	0.408	0.420	0.501	0.422	0.319	0.178	0.115
175	P13	0.0120	0.0028	8.03	926.04	47.15	1460.3	1.198	1.235	2.149	1.449	1.099	0.301	0.133
199	P49	0.0044	0.0013	6.64	160.00	19.19	317.0	0.245	0.215	0.237	0.247	0.305	0.075	0.135
Canadian Shield Sub-Region														
473	A301	0.175586	0.0581	7.26	402.37	15.22	593.1	0.210	0.194	0.189	0.264	0.197	0.070	0.014
118	L107	0.0092	0.0806	7.29	434.40	10.71	639.4	0.118	0.116	0.114	0.168	0.109	1.092	0.007[2]
84	L109	0.3537	0.0974	7.06	362.43	19.36	580.6	0.409	0.394	0.341	0.496	0.386	0.115	0.014[2]
88	O-10	0.0118	0.0094	6.85	212.20	22.88	435.2	0.178	0.189	0.138	NA	0.166	0.155	0.014[2]
90	R1	0.0788	0.0974	7.04	278.63	18.40	455.9	0.318	0.311	0.279	0.408	0.311	0.393	0.014[2]
Caribou Mountains Sub-Region														
146	E52	0.0439	0.1510	7.07	366.23	23.52	633.1	0.377	0.365	0.350	0.531	0.349	1.290	0.027[2]
152	E59	0.0124	0.3079	6.81	170.40	13.19	328.0	0.023	0.025	0.026	0.031	0.021	0.610	0.027[2]
89	E68	0.1576	0.1072	6.87	235.13	22.74	494.8	0.258	0.274	0.223	0.395	0.262	0.205	0.027[2]
91	O-1/E55	0.0044	0.0122	6.26	84.91	21.54	407.5	0.020	0.029	0.038	0.536	0.064	0.255	0.027[2]
97	O-2 E67	0.1109	0.2180	6.64	173.14	23.36	373.8	0.201	0.187	0.149	0.081	0.134	0.345	0.027[2]

Shaded values represent critical loads exceeded by the Potential Acid Input obtained from the 2005 Kearl Lake EIA (Potential Development Case), Imperial Oil (2005).

[1] Estimate of PAI was based on SO_2 deposition alone except for lakes receiving Nitrogen deposition above a threshold value of 9 kg/ha/y;

[2] PAI obtained from OPTI 2002 EIA

Hydro – runoff estimated using traditional hydrometric methods; Isotopic – runoff estimated using analysis of heavy isotopes

Table 5.13-4 Summary of critical loads and exceedance rates (2002-2006).

	2002	2003	2004	2005	2006 (Hydro)	2006 (Isotope)
No.of Lakes	49	50	50	49	50	50
Minimum CL	-0.127	-0.090	-0.205	-0.132	-0.117	-0.136
Maximum CL	1.382	1.449	2.149	2.008	1.192	1.484
Average CL	0.306	0.335	0.387	0.435	0.291	0.299
Median CL	0.210	0.192	0.177	0.253	0.202	0.175
No. of Exceedances	18	16	18	15	16	20
Exceedance Rate (%)	36.7	32.0	36.0	30.6	32.0	40.0

All Critical Loads in keq H^+/ha/yr

Hydro – runoff estimated using traditional hydrometric methods,

Isotopic – runoff estimated using analysis of heavy isotopes

Table 5.13-5 Characteristics of lakes with predicted critical load exceedances, 2006.

Lake	Original Name	pH	Gran Alkalinity (µeq/L)	Conductivity (µS/cm)	DOC (mg/L)	Lake Area (km^2)
168	A21	4.88	-5.53	15.41	20.85	1.38
169	A24	4.66	-1.9	14.91	21.79	1.45
170	A26	5.45	-7.07	13.56	15.10	2.78
167	A29	5.76	10.97	12.70	15.24	1.05
166	A86	6.55	114.32	25.35	17.64	2.17
287	25	5.07	-12.8	13.20	17.73	2.18
289	27	6.42	57.15	15.10	12.44	1.83
290	28	5.72	30.35	17.70	22.08	0.544
342	82	6.71	168.90	30.70	26.32	
171	A47	6.31	127.80	30.60	19.99	
172	A59	5.39	45.77	24.31	33.52	108
452	L4	5.84	76.07	22.31	24.70	0.610
470	L7	6.36	146.88	28.67	29.12	0.330
185	P27	5.51	69.25	21.73	29.06	3.94
209	P7	6.00	125.50	23.93	25.71	
442	L23	6.76	140.30	24.67	14.01	3.44
444	L25	6.81	156.03	28.83	9.17	
447	L28	5.19	20.67	19.69	28.32	1.30
448	L29 Clayton	4.24	-7.6	17.32	16.39	0.650
152	E59	6.81	168.07	28.00	12.98	9.53
91	O-1	6.20	79.40	20.96	21.41	0.800
97	O-2	6.70	172.10	29.00	23.31	3.10

These are lakes with CL exceeded by PAI, irrespective of method of calculating CL.

Table 5.13-6 Results of Mann-Kendall trend analyses on ASL measurement endpoints.

Lake ID	Original RAMP Designation	pH	Total Alkalinity	Gran Alkalinity	Sulphate	Nitrates and Nitrites	Dissolved Organic Carbon	Sum Base Cations	Potential Acid Input (keq/Ha/y)
168	A21	6	-3	-5	-20	-8	-12	-22	0.148
169	A24	3	3	-7	-10	-6	12	-6	0.143
170	A26	-10	-10	-1	-18	10	-1	-14	0.144
167	A29	6	4	9	-2	0	6	18	0.143
166	A86	-1	9	1	7	8	14	20	0.117
165	A42	19	14	9	0	2	6	10	0.121
171	A47	16	18	7	8	0	6	16	0.120
172	A59	-8	-10	-15	-6	-2	-10	-10	0.120
452	L4	-7	-10	-9	-12	8	4	-6	0.164
470	L7	2	-6	8	-6	-5	2	2	0.148
471	L8	2	-16	-8	-10	6	-4	-12	0.152
400	L39	3	-10	-5	-6	8	16	-14	0.104
268	E15 (L15b)	-2	-11	-17	9	1	3	-13	NA
436	L18	21	23	15	-2	-7	0	8	0.127
442	L23	14	8	-3	-16	6	-6	-24	0.117
444	L25	16	17	7	-16	-1	10	4	0.112
447	L28	6	12	3	-11	-12	8	-10	0.105
448	L29	1	0	1	-13	1	-3	-9	0.113
454	L46	-8	-22	-15	-14	-2	10	-22	0.114
455	L47	11	-8	-1	-10	2	14	-8	0.120
457	L49	0	4	-7	-16	0	16	-20	0.109
464	L60	8	8	3	-16	1	16	-10	0.115
118	L107	15	-5	3	6	-3	6	-7	0.007
84	L109	10	-8	-10	-12	-4	8	-12	0.014
88	O-10	11	3	1	-2	-3	-1	-21	0.014
90	R1	8	-6	-5	2	0	0	0	0.014
146	E52	10	18	9	-12	-6	16	8	0.027
152	E59	12	14	9	-10	0	14	6	0.027
89	E68	-3	-3	-5	-11	-3	5	-3	0.027
91	O-1/E55	-3	-2	-11	-4	-10	-4	-17	0.027
97	O-2 E67	22	20	9	-6	-12	14	18	0.027

Numbers represent the S statistic used in the analysis. Negative values represent overall decreases in a variable and positive values represent increases. Shaded values are statistically significant.